A Feasibility Study Guide for an Agricultural Biomass Pellet Company

Produced by

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Request for Comments

This feasibility study guide has not been subjected to any kind of "peer review" process, and it has not been critically reviewed or edited by academic, government and industry experts. If any readers would like to offer corrections or comments, they are invited to send them directly to the author, Ken Campbell at campbell.ken@comcast.net.

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1. Introduction

The Agricultural Utilization Research Institute (AURI) is a unique and innovative nonprofit corporation working to enhance Minnesota's economy through the development of new uses and new markets for the state's agricultural products. Created and supported by the State of Minnesota, AURI is the "research and development arm of Minnesota agriculture."

By providing feasibility analysis, product development assistance and technical support, AURI helps Minnesota companies capture more value and move agricultural products into new places. With knowledgeable and expert staff, unique facilities, and innovative programs designed to move value-added products into the marketplace, AURI is helping to add value to Minnesota agriculture.

In recent months, AURI has received numerous inquiries from farmers and entrepreneurs who are interested in producing and selling agricultural biomass fuel pellets. (To clarify, their interest is in using agricultural feedstock rather than wood feedstock to produce fuel pellets.) Several have asked AURI for technical assistance in appraising the feasibility of such business ventures. This feasibility study guide is provided by AURI to respond to these requests for assistance.

AURI contracted with Cooperative Development Services (CDS) to produce this feasibility study guide. CDS is a nonprofit organization created and governed by the cooperative community of the Upper Midwest for the purpose of developing cooperative businesses in all sectors of the economy.

AURI also engaged a company called "Relevant ideas…LLC" to assess the market for agricultural biomass pellets and write a report. This feasibility study guide does not contain a market assessment chapter because AURI originally intended that the report by "Relevant ideas…LLC" would be included in or attached to this feasibility study guide. Instead, AURI is making this market assessment available separately.

It is important to understand what this document is and what it is not. This document is a feasibility study guide for an enterprise whose primary business would be producing and marketing agricultural biomass fuel pellets. It is ***not*** a feasibility study for a specific business. It is intended to be used as a reference document and a guide for entrepreneurs and organizers of biomass pellet fuel companies who want to produce a feasibility study or a business plan for their proposed enterprise.

This feasibility study guide describes general business models; and it contains technical and financial information, cost estimates, industry data, and references to analyses and other information relevant to the subject. To the extent possible, and within budget and time constraints, efforts were made to verify information and qualify sources by some means, but all information has not necessarily been verified or subjected to due diligence. Furthermore, most of the information contained in this document is general and not specific to a particular business enterprise. If organizers of agricultural biomass pellet companies are seeking equity investments and debt financing, they will probably need their own feasibility studies with verified (or verifiable) and specific information related to their proposed business organization, location, facilities, equipment, feedstock, product, markets, finances, etc.

The reader may look for an executive summary, but there is not one because this feasibility study guide is like an instruction manual. This feasibility study guide offers information, illustrations and some opinions to provide meaningful instruction and guidance, but it does not reach conclusions or justify recommendations about an enterprise of any particular description. Thus, there are no conclusions or recommendations to summarize in an executive summary.

Nevertheless, an author's comment about the viability of agricultural biomass pellet enterprises is appropriate. After working on this feasibility study guide for six months, the author is doubtful about the immediate prospects for development and operation of profitable agricultural biomass pellet companies. There does not appear to be an existing market where large volumes of agricultural biomass pellets may be sold at prices that will afford cost recovery and a satisfactory profit to numerous agricultural biomass pellet companies with their production facilities in Minnesota.

This is not to say, however, that ***all*** agricultural biomass pellet companies are likely to fail. In fact, it seems likely that one or some may be successful. Thus, any negative observations contained in this feasibility study guide are not intended to discourage entrepreneurs and organizers of agricultural biomass pellet companies, but only to show them some challenges and competitive disadvantages they may have to overcome.

Furthermore, market dynamics could change quickly. Enactment of a carbon tax or any other government measure that has the effect of increasing the cost of fossil fuels could immediately improve the economic prospects for an agricultural biomass pellet company.

2. Business Concept

A feasibility study is sometimes called a "proof of concept" study. Thus, a good way to start a feasibility study is to provide a description of the business concept. This feasibility study guide is for a new, stand-alone agricultural biomass fuel pellet company which would be developed and operated to generate profits. The business of the agricultural biomass pellet enterprise would be to:

- Procure agricultural residues, by-products and other feedstock;
- Produce and package agricultural biomass fuel pellets; and
- Market, sell and deliver pellets to customers.

The business entity could be one of several different forms. It could be a sole proprietorship, partnership, cooperative, investor-owned corporation, limited liability company, or a subsidiary of a larger business organization.

Around the upper Midwest, there is some interest in small-scale ("farm-scale") pellet mills that could be set up in farm buildings and operated by farm families and hired hands. Some small pellet mills are even mobile – they can be brought out to a field and run with a tractor's power take-off. Generally, the idea is for a farmer to purchase such a pellet mill, use the farm's crops or crop residues for feedstock, produce enough fuel pellets to meet the farm's heating requirements, and sell some fuel pellets in a local market. This may be an attractive idea, but it is not the business concept that is the primary subject of this feasibility study guide. Farmers interested in pursuing this option may find some useful information in this feasibility study guide nevertheless. (A sketchy capital and operating budget for a farm-scale pellet plant is provided in this feasibility study guide just to get farmers started on their own analyses.)

Another business concept that is ***not*** the focus of this feasibility study guide is to expand an existing agricultural processing enterprise to add fuel pellet production and sales. This model is common in the wood pellet industry where sawmill owners have built pellet plants next to a reliable feedstock supply – their own sawdust and shavings. Some agricultural processing plants already have pellet mills (such as those used to produce feed pellets from oat and soybean hulls), and some ethanol companies are considering installing pellet mills for their DDGS, which the ethanol companies would sell as feed or fuel.

Other worthy business concepts are:

- Integrating the marketing and distribution functions of an agricultural biomass pellet business with a company that has route delivery of another product, such as water softener salt (as at least one Minnesota company has considered).

- A grain elevator company building an agricultural biomass pellet plant adjacent to its existing facilities to use excess capacity (receiving, drying, storage, wheeled equipment, personnel, etc.)

- An agricultural biomass pellet company financed or underwritten by a utility (or other large boiler operator) that wants to be the pellet company's exclusive or semi-exclusive customer.

These might be good ideas with high business potential, but they are ***not*** the subject of this feasibility study guide.

This feasibility study guide is for a commercially viable agricultural biomass fuel pellet enterprise with a stand-alone pellet plant. The company would purchase all of its feedstock at market prices, pay all personnel market wages, and attempt to sell 100% of its product at profitable prices in a competitive market. The facility and its equipment would be sized to achieve economies of scale in capital, labor and fixed operating costs. The operating plan would be to maximize the use of equipment – the schedule would be as near to 24 hours per day, 365 days per year as can be practically achieved in light of equipment maintenance requirements and holidays.

The equipment of a commercial pellet plant are wheel loaders, forklifts, tub grinders, hammermills, dryers, pellet mills and bagging systems. All of the equipment of a pellet plant can be purchased used, but the subject of this feasibility study guide is a business whose purpose is to achieve and sustain long-term profitable operations. In this context, purchasing used equipment, which may be ill-fitting and unreliable, would likely provide false savings. The capital budget estimates offered in this feasibility study guide assume that all equipment and facilities would be new and appropriately sized for their intended purposes.

The product of an agricultural biomass pellet company would be an energy product to be burned (or gasified and then burned) to produce heat. It could be used alone or blended with other fuels (wood pellets, corn or coal) for co-firing. The product probably would be treated in the market as a graded commodity, regardless of any efforts to create distinguishing "brand" characteristics.

The business concept of this feasibility study guide is not one that is necessarily reliant on a single customer or market niche of any sort, but if an agricultural biomass pellet company were to have the certainty of a firm sales contract for a high percentage of its pellet production, this would certainly enhance the viability of the enterprise. Immediately, the market for agricultural biomass fuel pellets is limited. There is some number of residential/small commercial pellet stoves and other appliances in which agricultural biomass pellets could be used as fuel instead of wood pellets or corn. There are also industrial, institutional and utility boilers in which agricultural biomass pellets could be burned with or instead of fuels now being used. However, no companies are presently selling large quantities of agricultural biomass pellets into these markets, and there is no evidence of unmet demand.

Broadly and long-term, it is expected that a company that produces and markets agricultural biomass pellets at a commercial scale would compete against suppliers of unprocessed agricultural biomass, other agricultural biomass pellets, other densified agricultural biomass products, wood pellets, cord wood, propane, electricity, natural gas, coal, and other fuels. The market for agricultural biomass pellets, as for other fuels, would be domestic and international; and the viability of agricultural biomass pellets may depend on tax and energy policy at the state and federal levels in the United States and in other countries as well.

3. Company

A feasibility study for a proposed business enterprise will ordinarily indicate the intended form of business entity and explain why that form would be most advantageous. There are a number of options for a business organization, including sole proprietorship, partnership, corporation, limited liability company and cooperative. Each has its own advantages and disadvantages regarding ownership, governance, management, liability, taxes, equity and debt financing, profit distribution, and other important factors.

The Minnesota Department of Employment and Economic Development (DEED) offers a number of excellent publications for new and existing businesses in Minnesota. A very useful book is A Guide to Starting a Business in Minnesota (25th Edition, January 2007), which contains a thorough presentation of alterative business organizations. DEED's publications are available at www.deed.state.mn.us/publications.

A cooperative business organization could be a good choice for an agricultural biomass pellet enterprise, particularly if there is a desire among the organizers to establish broad community investment and long-term ownership, organize a feedstock supply system of many committed suppliers, and adhere to cooperative business principles.

4. Leadership and Management

It is often said that a bank's commitment to provide debt financing for a new business depends on the banker's confidence in that business' organizers, investors and managers. No banker believes he can look in his perfect crystal ball to see the future of an upstart company in an emerging industry, but he can make judgments about the caliber of individuals (and businesses) who are investing their funds, talents, time and reputations in a new enterprise.

An important section of a feasibility study is a description of the leadership and management of the new business enterprise. This section should include information about the experience, capabilities and responsibilities of active owners (not passive investors) and key management personnel. This section may also include information about any attorneys, accountants, or contractors who will play key roles in project and business development.

More often than not, a chief executive officer or general manager has not yet been selected when a feasibility study for a new business is produced. Even if company officers cannot be named, their intended roles and responsibilities can be described. Bankers and investors will want to see evidence that critical capabilities are not overlooked and that the business organization is well designed to meet the challenges of development, operational and financial management, purchasing (feedstock), plant operations, marketing and sales.

Two challenges warrant highlighting. The first is organizing and managing a feedstock supply system. If an agricultural biomass pellet company is going to rely on numerous producers and harvesters of agricultural residues, managing this may be somebody's most time-consuming and sensitive challenge. The second area worth highlighting is management of operations and maintenance. Individuals with pellet plant experience say that running a pellet plant well, with minimal unscheduled downtime, high production rates, and consistent product quality, takes a lot of talent and know-how gained through experience. Knowledgeable bankers and investors will look in this section of a feasibility study to whether an agricultural biomass pellet company intends to assign these challenges to qualified managers with the authority and time to handle them well.

5. Industry Economics

The fuel pellet industry could be described as an emerging (or developing) industry, but future growth of the industry in the upper Midwest is not a certainty. The future economics of fuel pellets – long-term supply and demand – will be determined by a lot of unpredictable factors. The most important unknown factors relate to federal and state energy and environmental policies. Specifically, one would expect demand in the U.S. for biomass fuel pellets to increase if a carbon tax (or a Btu tax) significantly increases the cost of using fossil fuels, or if renewable energy standards compel industries and utilities to burn biomass instead of coal or natural gas. Absent such market interventions, it is not clear that new demand for biomass fuel pellets will justify the development of additional production capacity in Minnesota.

The Pellet Fuels Institute reports there are more than 80 pellet plants across North America which produce greater than 1.1 million tons of fuel pellets annually. Wood pellets – "premium" wood pellets – are the predominant fuel pellet product. According to the Pellet Fuels Institute, 95% of all fuel pellets produced are premium wood pellets.[1]

This feasibility study guide is for an enterprise that would ***not*** produce premium wood pellets, however. The enterprise would produce agricultural biomass pellets – a product that has no significant industry presence at this time. There are not numerous suppliers of agricultural biomass pellets, and there are no developed markets for this product. Thus, it would be a challenge to credibly explain in a feasibility study (to the satisfaction of prospective investors and lenders) how an agricultural biomass pellet enterprise will fit in the fuel pellet industry and markets.

A market assessment by "Relevant ideas…LLC" (another 2007 publication of AURI) addresses the demand for agricultural biomass pellets. This chapter of the feasibility study guide focuses on the economics of supply. First, however, there is a discussion of energy products, prices and customers. This discussion is placed here so that the reader can then consider economic issues (economies of scale, transportation costs, capital and operating requirements, etc.) in terms of potential impact on price and demand.

5.1 Energy Products and Prices

Comparison to Coal

In Europe, tax policies and regulations have already "tilted" the economics in favor of biomass over coal to accomplish energy and environmental objectives. As a result, wood

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[1] Pellet Fuels Institute, Arlington, Virginia. Statistics reported on the Pellet Fuels Institute website at www.pelletheat.org in the section titled "Industry." October 2007.

pellets (wood chips and ground wood, too) are commonly burned alone or co-fired with coal in heating and electric generation systems, and wood pellets are shipped from North America to Europe for this purpose. For an entrepreneur in Minnesota who wants to develop an agricultural biomass pellet company, this may be heartening, but it probably does not have direct bearing on the entrepreneur's immediate prospects for success.

The cost of coal versus agricultural biomass pellets may become relevant in Minnesota someday, but not until the cost of coal is more than doubled. Coal is an abundant fuel which can be purchased by utilities and large industrial boiler operators at a price of less than $75.00/ton (delivered), or $3.00/million Btu. The more coal a customer uses, the further below $3.00/million Btu the price will be.

It is highly unlikely that the cost of producing agricultural biomass pellets is ever going to be less than the cost of mining and transporting coal, but a $50/ton carbon tax, which would raise the price of coal by roughly $5.00/million Btu, could be an "equalizer." Furthermore, agricultural biomass pellets may not have to be cheaper than coal to justify replacing coal in industrial and utility boilers. Conceivably, co-firing agricultural biomass pellets could increase the costs of production at a power plant but still be the least-cost option for meeting a renewable energy requirement. Thus, the justification for co-firing agricultural biomass pellets in the future may have more to do with the price of wind power than the price of coal.

As explained in a European Commission report,

> In general, the energy systems which co-fire biomass with coal are more expensive than dedicated coal systems. Therefore, reasons for co-firing are primarily connected with environmental benefits rather than cost-savings. Thus a more appropriate approach is a comparison of the costs of co-firing systems with other renewable energy options, among which co-firing is usually the cheapest, in most situations where biomass resources and coal-based power plants are available in the same region. [2]

There has been a higher level of interest in co-firing biomass with coal than there has been interest in using biomass as a substitute for natural gas in the utility, industrial and institutional sectors, but opportunities to replace natural gas should not be ignored. Natural gas is more expensive than coal, which makes replacing natural gas more attractive economically; and a carbon tax (and a Btu tax more so) would increase the effective price of natural gas. Then, solid fuel-fired energy conversion systems may be installed where natural gas is now used in utility, industrial and institutional facilities, thereby creating a market for agricultural biomass pellets (but also other biomass energy products).

An energy tax (carbon or Btu tax) would increase the value of agricultural biomass pellets relative to coal and natural gas, but there would also be an impact on a pellet company's costs of production which should not be overlooked. The costs of feedstock procurement,

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[2] Maciejewska, A., H. Veringa, J. Sanders and S.D. Peteves, Co-firing of Biomass with Coal: Constraints and Role of Biomass Pre-Treatment. Directorate-General Joint Research Centre, European Commission, Luxembourg, 2006. p. 56.

pellet production, and transportation may all be higher as a result of an energy tax (but the net effect of an energy tax would most likely be positive for an agricultural biomass pellet company).

Comparison to Retail Energy Products

Presently, some agricultural biomass pellets are packaged and marketed as a retail product for sale to small commercial and residential customers. As such, agricultural biomass pellets must compete against all other retail energy products.

In Minnesota, energy prices generally vary on a seasonal basis, but they are also volatile – they can rise and fall quickly in response to unforeseen events. Electricity prices can be quite different from one utility's service territory to another; and in some parts of the state, natural gas service is not available at all. The following table (titled "Approximate Retail Energy Prices") offers a comparison of energy prices, but they may not correspond to prices at the time this table is reviewed by a reader. The table is offered merely so that readers may gain a general sense of relative prices.

APPROXIMATE RETAIL ENERGY PRICES
(Minnesota, 2007)

Energy Product	Price/Unit	Btu/Unit	Price/ Million Btu
Electricity	$0.10/kWh	3,412	$29.31
Propane	$1.65/gallon	91,333	$18.07
Fuel Oil	$2.40/gallon	138,690	$17.30
Corn (#2, clean, 12% MC)	$5.00/bushel	406,560	$12.30
Wood Pellets	$180/ton	16,500,000	$10.91
Natural Gas	$1.00/therm	100,000	$10.00
Corn (#2, fines, 15.5% MC)	$3.00/bushel	390,320	$ 7.69
Agricultural Pellets	$180/ton	15,800,000	$11.39
Agricultural Pellets	$172/ton	15,800,000	$10.91
Agricultural Pellets	$150/ton	15,800,000	$ 9.49
Agricultural Pellets	$120/ton	15,800,000	$ 7.59

Note that values provided in the "Btu/Unit" column are estimates of the British thermal units contained in the energy product. This is not "delivered" Btu which readers may have seen in similar tables elsewhere. "Delivered" Btu are based on assumptions regarding the efficiency of conversion technologies. Propane and natural gas appliances are usually shown to have higher efficiency, but appliances that use solid and liquid fuels can now be nearly as efficient, so the differences in delivered Btu are no longer as meaningful. Regarding electricity, however, it appears in the table to be more expensive than it actually is because electricity's delivered Btu approaches 100%, while the delivered efficiencies of other fuels usually fall in a range of 80% to 92%. (Nevertheless, electricity would still be the most expensive, just not as much more expensive.)

The above prices are illustrative of those faced by residential and small commercial customers. (Larger customers generally pay lower prices for electricity and fossil fuels.) The following discussion focuses on residential heating, but the conclusions can be generalized to commercial thermal energy requirements of all kinds.

The Minnesota Department of Commerce estimates that an average Minnesota home uses about 100 million Btu for heat during a typical year. Using natural gas, this would cost about $1,000, based on the price shown above.

Heating with propane would cost about $1,807 during a typical year; heating with fuel oil would cost about $1,730. The Minnesota Department of Commerce and the Minnesota Propane Gas Association estimate that about 200,000 Minnesota homes are heated with propane, and about 90,000 homes are heated with fuel oil. This represents a sizable potential market for pellet appliances.

With a high-efficiency wood pellet furnace, heating a home with wood pellets at $180/ton would cost about $1,091 annually. This would be about $716 less than the cost to heat with propane, and $639 less than with fuel oil.

Agricultural biomass pellets are likely to have a lower energy content than wood pellets due in large part to the non-combustible ash content. Agricultural biomass pellets priced at $172/ton would be comparable to wood pellets priced at $180/ton on a dollars per Btu basis, thus resulting in annual home heating costs of about $1,091. Thus, the fuel cost to heat a house with agricultural biomass pellets priced at $172/ton would be considerably less than the cost to heat that house with propane or fuel oil.

5.2 Price-Motivated Customers

Energy customers, whether they are buying for a household or an electric utility, are price-motivated. The long-term viability of an agricultural biomass pellet company depends on the price of its product relative to the price of substitutable products.

Of course, you can't burn wood pellets in a natural gas furnace; but it is also true that burning agricultural biomass pellets in most existing wood pellet appliances may not work well, either, depending on the composition of the agricultural biomass pellets and the design of the pellet appliance. Today, premium wood pellets are the only recommended fuel for most pellet stoves and furnaces in homes and small commercial buildings. This may change in the future if "multi-fuel" pellet appliances become popular.

"Multi-fuel" pellet appliances are being designed to use agricultural biomass pellets, but their flexibility means that consumers can freely switch from corn to wood pellets to any brand of agricultural biomass pellets. If the business model for an agricultural biomass pellet company depends on selling pellets to residential and small commercial customers, then a plausible case must be made in the feasibility study that:

- A sufficient number of consumers will purchase appliances in which agricultural biomass pellets can be burned;

- Consumers will actually use that appliance instead of their conventional furnace; and

- Consumers will burn *that company's* agricultural biomass pellets instead of corn, wood pellets, or *another company's* agricultural biomass pellets.

Survey results attributed to the Hearth, Patio & Barbeque Association indicate that the most common reason for consumers to purchase supplemental heating appliances is "Looking to save on heating costs." Presumably, this motivation would drive consumers' decisions whether to use their supplemental heating appliance or their conventional furnace on any given day. Particularly if they don't enjoy operating and maintaining their pellet appliance, consumers may choose to leave their pellet appliance cold except when the cost savings are "worth it."

Consumers' price sensitivity can be expected to affect their decisions regarding which fuel to burn in their multi-fuel pellet appliance. If agricultural biomass pellets are perceived to be a better value than wood pellets or corn, then consumers are more likely to purchase agricultural biomass pellets; and, all other factors being equal, consumers would prefer the lowest price agricultural biomass pellets.

Owners of multi-fuel pellet appliances may choose to use corn rather than agricultural biomass pellets even if clean corn is slightly more expensive than pellets. One reason might be that consumers prefer the smell of burning corn. Another reason is that consumers may be more comfortable knowing for sure what they are handling and burning when they fill the hopper with corn. When they fill a hopper with agricultural biomass pellets, they may wonder if they using pellets made from animal parts, feathers, or poultry litter. In this case, corn would be more expensive but perceived as a better value nevertheless. (Of course, consumers don't have to pay a premium price for fuel corn that is cleaned and dried to 12% moisture content. Many consumers in rural regions are probably more inclined to use ordinary USDA Grade # 2 Yellow Dent Corn, which they may purchase from a local farmer or at the elevator by the pick-up truck load.

The above discussion ignores the role of the retailer in shaping demand for a particular product, but the valid point is this: Because consumers are price sensitive with regard to energy products, being able to compete on the basis of price may be essential to the viability of an agricultural biomass pellet company.

Returning briefly to coal, price competitiveness will matter here, too. Depending largely on cost differences, the customer (perhaps a utility, a manufacturer or a college) will decide whether or not to co-fire biomass fuel with coal in its boiler. Then the customer will decide whether to co-fire agricultural biomass pellets or to co-fire another biomass fuel (wood pellets, hogged waste wood or loose chopped agricultural residue). And then the customer will decide which company's agricultural biomass fuel pellets to burn. In short, being able to sell its energy product at a lower price (per million Btu) than the competition will be critical to the long-term viability of an agricultural biomass pellet company whether the target customers are rural households or utilities.

5.3 Industry Research and Economic Analyses

The fuel pellet industry has not been the subject of much research and analysis, but there has been enough economic analysis to confirm reasonable assumptions, such as these:

- Significant economies of scale are achievable in the pellet production process.

- Economies of scale would enable larger producers to offer their pellets at lower prices than smaller producers.

- But a pellet plant could be oversized relative to its economical feedstock supply and accessible markets – economies of scale could be negated if transportation costs for feedstock and finished product are too high.

These topics will be addressed shortly, but first a comment on available documents is appropriate. Investors or lenders are likely to expect authoritative information that validates the conclusions of a feasibility study. Documents should be reviewed critically and used cautiously – just because it is in writing doesn't mean it's true! (This applies to information in this feasibility study guide, too.)

Two of the most highly regarded and often referenced analyses of fuel pellet production were produced by Sudhagar Mani (2006) and Ernie Urbanowski (2005). Their work is some of the most useful that can be found, and their general conclusions are probably sound. Nevertheless, one must be careful about relying on the dollar amounts contained in their financial analyses because they both used cost data that may not be entirely applicable to the economics of an agricultural biomass pellet company in Minnesota.

Sudhagar Mani, now on the University of Georgia faculty, collaborated with personnel of the Oak Ridge National Laboratory to analyze the economics of producing biomass fuel pellets. To develop a capital cost estimate, Mani used equipment purchase and installation cost information contained in general reference documents published in 1990 and 1999, which he adjusted to 2004 U.S. dollar values with Consumer Price Index inflation factors. He also obtained estimates for a hammermill and a pellet mill from a manufacturer.

Based on recent budget estimates from equipment manufacturers and contractors, it seems that Mani's capital budget understates current costs for engineering, project management, installation, controls, and other specific costs (which is not surprising, given equipment and construction cost increases since 2004); and his capital budget does not include the costs of a receiving station, pellet plant building, feedstock storage facilities or a warehouse for finished product. His operating costs include only direct production costs plus some allowance for administrative and marketing personnel costs. Thus, Mani does not present a complete business operating budget (which is not a criticism of Mani's work, only an observation about the limits of his analysis).[3]

Urbanowski analyzed a specific business opportunity for development and operation of a wood pellet plant in British Columbia. Much of his analysis is not relevant to opportunities to develop agricultural biomass pellet companies in Minnesota. Urbanowski bases his capital cost estimates for a wood pellet plant in British Columbia on the reported costs of a 10-tonne/hour pellet plant built in Sweden and a 3-tonne/hour pellet plant built in Austria. This method of estimating a capital budget limits the usefulness of Urbanowski's work.[4] (Where the term "tonne" is used in this feasibility study guide, it refers to a metric ton; this term is only used for consistency with source documents.)

Jeremy Karwandy (Forintek Canada Corp.) is the author of a report prepared for the Saskatchewan Forest Centre titled Pellet Production from Sawmill Residue: a Saskatchewan Perspective. In this report, attempts to reconcile the capital cost estimates of Mani and Urbanowski to a "rule of thumb" that every 10,000 tonnes of annual production capacity costs about $1.0 million.[5] This is not a particularly useful rule of thumb at all because it does not take into account economies of scale or whether a grinder, dryer, bagging/palleting system or enclosed storage are required. Aside from this odd approach, Karwandy's report is a readable document with interesting information and insights about the viability of pellet enterprises.

Finally, there are numerous documents about the economics of pelleting that rely on information produced by and for the Pellet Fuels Institute (PFI) in the mid 1990s. This information pertains to equipment requirements, capital costs, business operations, and operating expenses. It is important to realize that much of the cost data reported in these documents are derived from the results of a survey conducted by PFI in 1994. To be clear, the cost data commonly attributed to the Pellet Fuels Institute are the answers PFI members marked on a survey questionnaire. Readers may find some of this information useful – perhaps the more cross-checks and benchmarks, the better – but budget assumptions should not be based on survey results.

In short, the pellet fuels industry is a small one that has not attracted much academic attention; and good industry data has not reached the public domain – pellet producers are not inclined to tell their secrets about costs and margins.

The pellet fuels industry is nothing like the ethanol industry which has been led by a few design/build companies. There are no real leaders in the pellet fuels industry that are

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[3] Mani, Sudhagar, Shahab Sokhansanj, Xiaotao Bi, and Anthony Turhollow, "Economics of Producing Fuel Pellets from Biomass." Applied Engineering in Agriculture, Volume 22(3): 421-426, 2006. p. 423.

[4] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005.

[5] Karwandy, Jeremy, Pellet Production from Sawmill Residue: a Saskatchewan Perspective, Forintek Canada Corp., March 2007. p. 17.

establishing "industry standards" for design, construction and operation of pellet plants. Likewise, no banks have become the primary debt financing sources for pellet plants (as a handful of banks did for the ethanol industry), thereby establishing lenders' threshold requirements. Thus, there are no readily available templates for pellet plants and their operating business entities, which makes business planning and feasibility analysis for an agricultural biomass pellet enterprise more challenging.

Economies of Scale

According to Karwandy, the average production capacity of pellet plants in the United States in 2005 was only 12,430 tons per year, which corresponds to considerably less than four tons per hour capacity.[6] This might cause some entrepreneurs to think that a small agricultural biomass pellet plant could be viable, but most industry observers probably would disagree. Most existing pellet plants in the United States were sized to use a specific small-volume feedstock stream (the sawdust from an adjacent sawmill, for example) and to supply pellets to a small local market. Now pellet plants are being sited in the vicinity of large feedstock supplies, and they are being sized to compete in a global market.

Karwandy writes, "Remember that a four tonne per hour mill is considered to be on the low end of economically viable. In contrast, a world class mill producing 20 tonne per hour has an annual capacity of around 150,000 tonne per year and consumes between 200,000 tonnes (dry feedstock) and 360,000 tonnes (wet feedstock).[7] If a fuel pellet market matures in the United States, these will be the likely dimensions of competitive pellet plants.

There is little doubt that a commercial pellet plant with a production rate of eight tons/hour or more would have significant economic advantages over a pellet plant with a production rate of four tons/hour or less. There are one-time economies of scale for engineering, equipment purchasing and construction, and there are on-going operating economies of scale. The following graph (titled "Pelleting Cost Versus Plant Size") by Dr. Sudhagar Mani illustrates the effect of these economies of scale. Perhaps the absolute values shown are not accurate for agricultural biomass pellet plants in Minnesota, but the shape of the curve – the phenomenon of declining costs per ton as the production capacity increases – is certainly real. And it is important, too. If a four-ton/hour pellet plant becomes profitable in Minnesota, its profitability might last only as long as it takes for someone to build an eight-ton/hour plant.

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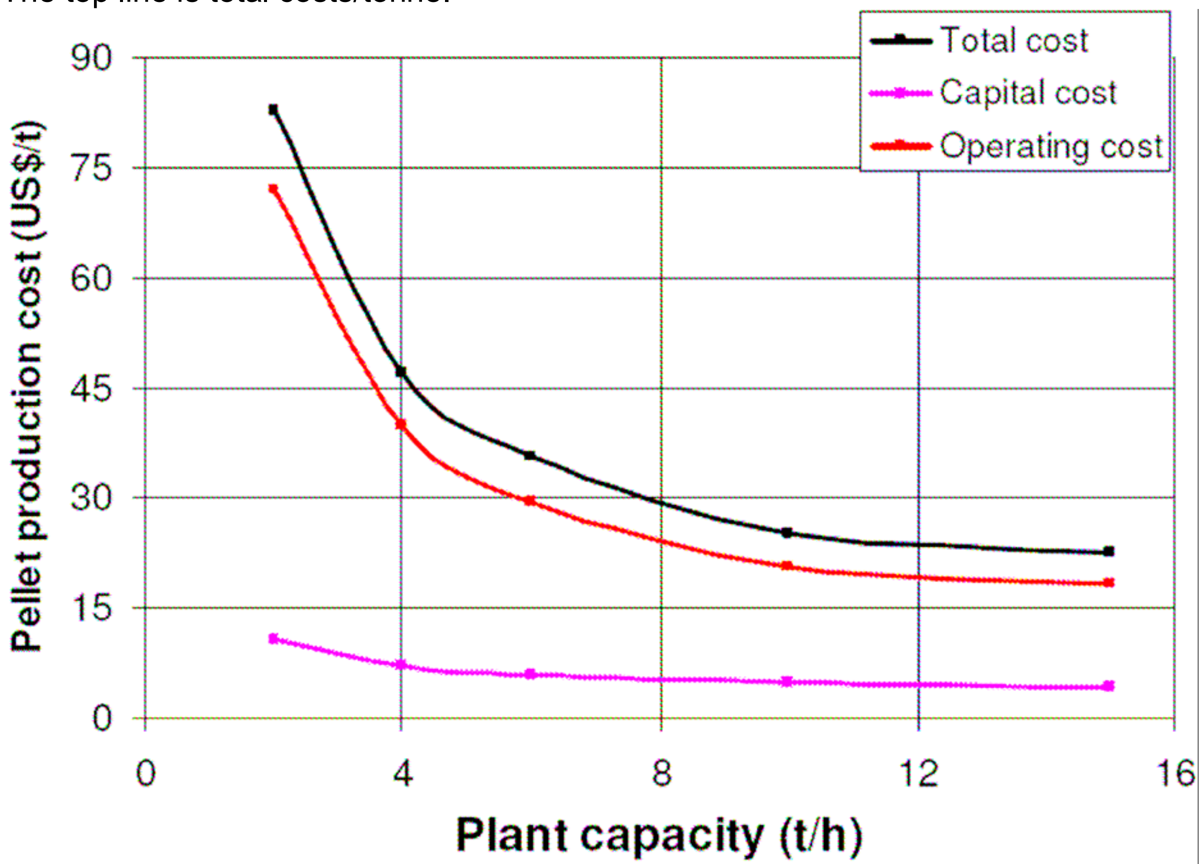
[6] Karwandy, Jeremy, Pellet Production from Sawmill Residue: a Saskatchewan Perspective, Forintek Canada Corp., March 2007. p. 16

[7] Karwandy, Jeremy, p. 16

Pelleting Cost Versus Plant Size

The bottom line is capital costs/tonne.
The middle line is operating costs/tonne.
The top line is total costs/tonne.



Graph presented by Sudhagar Mani, Ph.D., University of British Columbia, in a presentation titled "Simulation of Biomass Pelleting Operation" at the Bioenergy Conference & Exhibition 2006, Prince George, May 31, 2006.

Mani and Urbanowski both show that capital costs/ton for smaller pellet plants are higher than for larger plants; and their findings are generally consistent those of the NEOS Corporation which produced a capital cost comparison of wood pellet plants of different sizes (under contract to the Pellet Fuels Institute in 1995). NEOS's analysis indicates that it would cost only about 50% more to build a 3 to 4-ton/hour pellet plant than a 1-ton/hour plant, and it would cost only about 50% more to build a 7 to 8 ton/hour plant than a 3 to 4 ton/hour plant.[8]

Economies of scale are achieved in all aspects of development – engineering and project management, building construction, and equipment purchasing and installation. The capital

[8] Wood Pelletization Sourcebook: A Sample Business Plan for the Potential Pellet Manufacturer. NEOS Corporation, Lakewood, Colorado, March 1995.

cost line on the graph above is rather deceptive – it looks flatter than it should because it is so long. It actually shows that capital costs/ton fall significantly until plant size of about 6-tons/hour is reached; then the decline is more gradual. However, these economies of scale in plant engineering, procurement and construction are not as consequential as operating economies because capital costs are incurred only once and spread over the life of the facility.

To illustrate, assume that a 5-ton per hour pellet plant would cost $5 million, and this plant would be operated 6,000 hours per year for 15 years. Then it would produce 30,000 tons per year and 450,000 tons of pellets over its fifteen-year life, and the capital cost per ton would be $11.11/ton. Now, let's assume that the additional capital cost to double the production capacity from 5 tons/hour to 10 tons/hour is only $1.0 million (which is, of course, unrealistically low to prove a point). Then the capital cost per ton would fall from $8.33 to $6.66/ton ($6.0 million divided by 900,000 tons). Thus, even with exaggerated economies of scale, capital economies result in savings of only $4.45/ton of pellets produced over the life of the pellet plant.

This should not be interpreted to mean that capital costs are a lower-level concern. If the pellet industry matures, pellets likely will be sold as a graded commodity, and every dollar saved counts towards a competitive advantage and economic viability.

In business management and plant operations, the greatest economies of scale are achieved in personnel costs. A commercial-scale pellet plant and stand-alone business entity would probably require a chief executive officer, a finance officer, a plant mechanic/maintenance worker, and a receiving clerk/bookkeeper whether the plant produces 30,000 tons/year or 60,000 tons/year. The need for a marketer depends on the customer base (whether it several large customers or numerous small customers) more so than the annual production. And whether a plant produces 5 tons/hour or 10 tons/hour, the same number of production employees would be required.

Mani estimated that the personnel costs for a 10-tonne/hour pellet plant would be $4.00/tonne, and the personnel costs for a 2 tonne/hour plant would be $16.00/tonne.[9] Again, the absolute values may not be close to correct for a Minnesota agricultural biomass pellet plant, but the conclusion is probably true – personnel costs/ton for a large pellet plant would be a fraction of personnel costs/ton for a small one.

Even if there were no economies of scale to be realized in pellet production, large customers may be conscious of economies of scale in procurement. For a utility or national retailer (e.g., Wal-Mart), the transaction costs of purchasing a small quantity of fuel pellets would be about the same as the transaction costs of purchasing a large quantity, and the logistical challenges of managing deliveries and inventory multiply as the number of suppliers increases. Therefore, a pellet company with one small pellet plant may not be viable simply

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[9] Mani, Sudhagar, Shahab Sokhansanj, Xiaotao Bi, and Anthony Turhollow, "Economics of Producing Fuel Pellets from Biomass." Applied Engineering in Agriculture, Volume 22(3): 421-426, 2006. p. 424.

because large customers want to achieve economies of scale by purchasing fuel pellets from only large-quantity suppliers.

Feedstock Hauling Costs

Feedstock hauling costs must be considered at the same time as economies of scale because, theoretically at least, there is a trade-off. In his feasibility analysis of a wood pellet plant in British Columbia, Urbanowski recognizes that "plant size must optimize the balance of feedstock trucking costs and economies of scale." He finds, however, that "an 8-tonne/hour plant is more profitable than a 4-tonne/hour plant because economies of scale outweigh additional feedstock (and transportation) costs, resulting in a significantly higher return on equity."[10]

Karwandy also asserts that "balance must be struck between capturing economies of scale and aggregating larger volumes of feedstock." Karwandy uses Urbanowski's and Mani's findings to illustrate how capital and operating costs/ton (excluding feedstock costs) fall as production scale increases from 4 tonnes/hour to 10 tonnes/hour; but feedstock costs increase as the least cost and nearest feedstock is used up and then more expensive and distant feedstock must be procured.[11] This is certainly a real dynamic to consider in locating and sizing a pellet plant, but it may or may not impose constraints on the size of a pellet plant, depending on the intended feedstock and its near-by availability.

An important distinction is whether the intended feedstock may only be procured from a few widely scattered sources (like oats and soybean processing plants, for example). If a pellet plant would be designed only to use agricultural processing co-products such as soybean hulls or dried distiller's grains, then higher production capacity may require planning to procure feedstock from additional sources that may be 100 miles away or more. In this scenario, more pellet production would likely mean significantly higher feedstock hauling costs ($12/ton per 100 miles or more depending on bulk density), which would offset plant capital and production economies of scale to some extent.

Urbanowski confirms the above discussion in his feasibility study for a wood pellet plant that would rely on the sawdust and other by-products from several sawmills. When Urbanowski increased the plant size from 4 tonnes/hour to 8 tonnes/hour, estimated feedstock costs rose from $21/tonne to $29/tonne because the additional feedstock had to come from distant sawmills.[12]

On the other hand, if the feedstock is agricultural residues like corn stover and soybean straw, and the plant location is in a strong crop production region, then it is unlikely capital and operating economies of scale would be negated by higher feedstock hauling costs. An

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[10] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 1.

[11] Karwandy, Jeremy, Pellet Production from Sawmill Residue: a Saskatchewan Perspective, Forintek Canada Corp., March 2007. p. 18.

[12] Urbanowski, Ernie, p. 62.

analysis in the "Biomass Feedstock" chapter of this feasibility study guide will show that to increase the tonnage of corn stover available from 50,000 tons to 100,000 tons, the land required would double (of course) from 737 sections to 1,474 sections, but the increase in the radius of the production region around the plant would be only 6.4 miles, from 15.3 miles to 21.7 miles. Hauling an additional 50,000 tons from this extended feedstock production region would be expected to increase the total cost of finished pellets by less than $3.00/ton.

(The economic viability of a larger-scale pellet plant may be more sensitive to the cost of transporting a larger quantity of finished products to more distant markets. This suggests an important sensitivity analysis to be performed in a project-specific feasibility study – delivery costs could be a significant factor for a Minnesota agricultural biomass pellet company, or just one to check and set aside as inconsequential.)

6. Competitive Advantages

> "Profitability varies widely between industries, but also within industries. The measure of attractiveness of an industry does not necessarily determine the profitability of a company entering the industry. There are profitable companies in unattractive industries, and failures in attractive ones. Success is often based on the ability to sustain a competitive advantage over others."[13]

There are more than sixty fuel pellet plants in the United States, and some new pellet plants are being developed. The companies operating these pellet plants compete against each other for shelf space and market share, and an agricultural biomass pellet plant in Minnesota would have to compete against some number of them. All of these pellet companies were probably built by entrepreneurs who believed they would gain and maintain some competitive advantages. Some have succeeded, and others have not.

An agricultural biomass pellet plant should only be developed if there is reason to believe it will hold some competitive advantages and be able to overcome competitive disadvantages. This chapter describes some possible competitive advantages and disadvantages for an agricultural biomass pellet company (and its competitors). A thorough feasibility study for an agricultural biomass pellet company would address these topics.

Economies of Scale

The potential for economies of scale are discussed in the previous chapter. Judging by recent development in the biomass pellet industry, new entrants believe in these economies of scale.

Existing pellet plants in the United States are generally small – they produce an average of less than 20,000 tons of pellets annually. This is because most U.S. pellet plants were built as add-on enterprises to sawmills and other wood products facilities, and the pellet plants were sized for their small volumes of wood shavings or sawdust.

[13] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 22.

Canadian pellet plants are newer and larger than the average U.S. plant. Karwandy reports that the average pellet plant in Canada has production capacity of about 60,830 tons. He explains that Canadian pellet plants are larger than U.S. pellet plants because they are located near "world class sawmills that generate much larger volumes of sawdust, planer shavings and other whitewood residue," and they are designed to be competitive in the export market.[14]

Urbanowski describes a recently completed wood pellet plant in British Columbia as follows:

> The largest pellet producer in British Columbia is Premium Pellet, located in Vanderhoof. This plant was built at a cost of about $20 million, and is capable of producing over 20 tonnes of pellets per hour and is rated at 180,000 tonnes per year. This plant is located on the site of a sawmill and is vertically integrated with that sawmill.[15]

Developers of wood pellet plants in the United States are following the Canadian's lead to seize economies of scale and other competitive advantages. New plants (completed or under development) in the U.S. include a 140,000-ton plant in Corinth, Maine (which could be doubled in size in the near future); a 145,000-ton plant in Baxley, Georgia; a 100,000-ton pellet plant in Schuyler, New York; and a 100,000-ton plant in Somerset County, Maine. The biggest wood pellet plant in the world is being built in Jackson County, Florida. This $65 million pellet plant is scheduled to begin production in December 2007. It will be capable of producing 550,000 tons of wood pellets annually.

One might think these large-scale wood pellet plants would not be competitive threats to an agricultural biomass pellet company in Minnesota because their business is oriented to the European export market. But new large-scale pellet plants are being built in Canada, Scandinavia, Germany, Russia, Africa and South America to serve the European market, too. For U.S. pellet companies, profits in the European market may shrink due to price competition, exchange rates, or ocean freight charges. Then, if a fuel pellet market emerges in the upper Midwest, it may be more profitable for these companies to transport large quantities by rail to Minnesota than to ship pellets across the ocean.

There has not been a great deal of activity in development of agricultural biomass pellet plants, probably because there is no apparent demand for agricultural biomass pellets. Nevertheless, in Missouri, a company is reportedly building a 10-ton/hour agricultural biomass pellet plant at a total cost of about $6.6 million. This company intends to produce about 100,000 tons of pellets per year using corn stover, grasses and straws as primary feedstocks. Closer to home, news articles have reported that large-scale agricultural biomass

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[14] Karwandy, Jeremy, Pellet Production from Sawmill Residue: a Saskatchewan Perspective, Forintek Canada Corp., March 2007. p. 16.

[15] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 34.

pellet plants may be constructed in Bird Island and Willmar, Minnesota. Reports indicate that these will be 8-ton/hour plants or bigger.

There is little doubt that a small agricultural biomass pellet plant would be at a significant competitive disadvantage to larger pellet plants sooner or later. If a 4-ton/hour pellet plant is enjoying a market for its pellets, there is a good chance an 8-ton/hour pellet plant will take that market away.

Integrated Enterprises

Many of the wood pellet enterprises are "add-ons" to sawmill companies and other enterprises in the primary and secondary forest products industries. These wood pellet enterprises have numerous economic and logistical advantages over stand-alone wood pellet plants. (They share facilities, equipment, labor, excess "waste" heat, administrative/management capacity, and goodwill value in addition to raw materials.)

Integrated enterprises are possible for agricultural biomass pellet production, too. An agricultural biomass pellet plant could be built adjacent to a grain elevator (which could provide a productive use for underutilized capacity) or a soybean processing plant (which may provide soybean hulls for feedstock), for example. Already, some agricultural processing companies offer to pelletize hulls and other residue just to increase their bulk density and improve their handling characteristics. If a market develops for agricultural biomass pellets, these companies may assign resources to produce and market fuel-quality pellets. These companies could be tough competition for stand-alone agricultural biomass pellet companies.

Pellet Quality

Price is not the only factor of marketability; the quality of fuel pellets matters, too. Superior quality is a competitive advantage. Conversely, pellet inferiority (or just a bad reputation) is a significant disadvantage.

Presently, the fuel pellet industry is dominated by wood pellets, and several documents report that 95% of the wood pellets sold in the U.S. are identified by their manufacturers as "premium pellets," which means that they have an ash content of less than 1%. Several industry observers have suggested in conversations that they don't believe all pellets advertised as "premium" really have ash content of less than 1%. Nevertheless, it is possible to produce a premium fuel pellet with white wood (no bark content). The same cannot be said for most agricultural by-products and residues.

According to the Oak Ridge National Laboratory, most agricultural residues have heating values in the range of 6,450 to 7,300 Btu/pound, while woody materials have heating values in the range of 7,750 to 8,200 Btu/pound. Specifically, corn stover has a gross heating value that is only 86% to 90% of the gross heating value for hardwood and softwood.[16] This means

[16] Scurlock, Jonathan, "Bioenergy Feedstock Characteristics," Oak Ridge National Laboratory, U.S. Department of Energy. Available at http://bioenergy.ornl.gov/papers/misc/biochar_factsheet.html.

that corn stover fuel pellets should sell at a discount to wood pellets because they deliver less energy per pound.

Wood ordinarily has low chloride and alkali content. Agricultural by-products and residues generally have higher chloride and alkali content, which is discussed at length in the Product Viability chapter of this feasibility study guide. Wood pellets are usually hard and durable due to the lignin content and characteristics in wood. Some agricultural biomass materials would not bind together as well as wood, resulting in an inferior fuel pellet.

Additives and binders may be used to improve an agricultural biomass pellet, but such measures would not be necessary if agricultural materials were as good as wood as fuel pellet feedstock. In short, wood pellet companies would have a competitive advantage over most agricultural biomass pellet companies because their feedstock makes better pellets.

All agricultural materials are not the same in terms of the characteristic that affect pellet quality. Having a steady supply of agricultural feedstock that is lower in ash, chloride and alkali and that binds into a stronger pellet would be an advantage relative to other agricultural pellet producers.

Pellet Production Costs

The equipment and operating requirements for an agricultural biomass pellet plant are different depending on the planned feedstock. To illustrate, consider corn stover delivered in large round bales and dried distillers grains from corn-based ethanol plants.

Corn stover bales must be run through a shredder or a grinder, and then the corn stover probably requires drying in a large rotary drum dryer. Neither of these stages are necessary for dried distillers grains. Corn stover flows through a pellet mill at a rate of about 2.0 to 2.5 tons/100 horsepower/hour. Dried distillers grains flow through a pellet mill at a rate of 6.5 to 7.0 tons/100 horsepower/hour, according to the results of testing by a pellet mill manufacturer. Clearly this has significant implications for the capital and operating costs of pellet production.

This points to a potential competitive advantage for agricultural biomass pellet companies over some of the new wood pellet companies that intend to use green wood chips for feedstock. The moisture content of green wood can be as high as 55%. The moisture content of baled agricultural residues would be under 25% almost always. The production rate of wood through a pellet mill is only 1.0 to 1.5 tons/100 horsepower/hour. Thus, compared to green wood, corn stover would require only half as much energy to dry; and the same pellet mill could produce about twice as many corn stover pellets as wood pellets.[17]

[17] According to Urbanowski, a typical wood pellet plant near a sawmill uses 70% shavings at 19% moisture content and 30% wet sawdust with 53% moisture content, for a blended moisture content of about 29%. Agricultural biomass pellet plants would not have such a significant advantage over these wood pellet plants. (Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 60.)

Energy Costs

Electricity is a major cost item for a pellet plant; and if feedstock requires drying, the fuel for the dryer is a significant expense. If a market develops and matures for agricultural biomass pellets, eventually, they probably will become a low-margin commodity product. The competitiveness of a pellet plant may be determined by its energy costs. All other factors being equal, a pellet plant that is dependent on propane or fuel oil would probably not be able to compete against a pellet plant that uses biomass fuel or natural gas.

An entrepreneur is well advised to "shop" for low energy costs before making a site selection. In a feasibility study, a demonstration of energy cost-competitiveness would be persuasive.

Presently, agricultural pellets could be produced and sold at lower prices than some alternatives (propane and electricity) and higher than others (coal and natural gas). Some people believe that the cost of fossil fuels and electricity will increase such that agricultural pellets become not only less expensive than those traditional alternatives, but agricultural pellets become so much less expensive that an investment in a agricultural pellet stove, furnace or water heater would have a reasonably short payback period. This could happen. However, it is important to note that it takes a lot of energy to harvest and haul agricultural residues, produce agricultural pellets, and deliver them to market. As the costs of fossil fuels and electricity increase, so will the cost of agricultural pellets.

Feedstock Costs

Feedstock costs are a pellet company's largest single operating expense – the financial analyses included in this feasibility study guide suggest that feedstock costs may account for half of the total annual operating budget. (Even if a pellet plant is integrated with a sawmill or soybean processing plant, the opportunity cost of the feedstock would be greater than any operating expenses.) In a feasibility study for an agricultural biomass pellet plant, it would be important to justify the expected feedstock costs relative to the costs for other agricultural and wood feedstock.

Dry, small-particle feedstock is better in the pelleting process because it doesn't require shredding or drying, but it is generally more expensive, whether it is an agricultural processing by-product (hulls or distillers grains) or a wood industries by-product (sawdust).

Prices for some agricultural processing by-products may not have been driven up yet, but they probably will as soon as there are competing demands for them. This is an advantage for an agricultural biomass pellet company that intends to use corn stover, straw and grasses. Demand-driven scarcity is not a likely problem.

Prices for wood industries and agricultural by-products are unpredictable; and as suggested above, one must consider the pellet production costs associated with a particular feedstock to assess its value relative to another feedstock. Presently, however, large quantities of wood chips would be cheaper than corn stover on a dry-ton basis, and sawdust would be cheaper than soybean hulls or dried distillers grains.

On the other hand, Urbanowski writes:

> One promising substitute (for wood pellets) is pellets made of grass or straw. The energy value of these products is only 75% of that of wood, but the availability of feedstock may be much better and the economics of production has potential to be superior. These fuels have higher ash and impurities content but that is not as important in commercial applications. A mass shift from wood to alternate pellets by the large institutional and commercial customers is a very real potential threat to the wood pellet industry.[18]

Essentially, Urbanowski's argument is that utilities and other large customers of biomass fuel make purchasing decisions based on least cost per Btu, regardless of impurities and durability. If agricultural feedstock costs can be pushed below wood feedstock costs, then agricultural biomass pellets would replace wood pellets in the large-customer market. This may be true, but wood pellet producers could reduce their feedstock costs, too, if they don't have to worry about meeting a premium pellet standard. Rather than relinquish a market to agricultural biomass pellet producers, wood pellet producers probably would use wood with bark, logging residues and any other low-cost feedstock to compete on price.

Transportation Costs

Transportation costs would be absorbed by an agricultural biomass pellet company regardless of who pays the trucker. Feedstock suppliers may be paid on a delivered-ton basis, but this simply means the suppliers would build hauling costs and profit into the prices they charge the agricultural biomass pellet company. Likewise, the customary practice in the fuel pellet industry is to post pellet prices "at the plant gate" – customers must pay for shipping. When comparing energy product prices, customers recognize those shipping fees as an additional cost of the fuel pellets, which reduces the price customers would be willing to pay for the fuel pellets absent any shipping charges.

Again, if a market for agricultural biomass pellets matures into one with many buyers and suppliers, it will be much like other commodity markets with tight margins. Proximity to feedstock and customer markets and access to low-cost transportation may determine viability and profitability.

In fact, at least two industry analysts have made the argument that achieving transportation efficiencies is more important than maximizing economies of scale. Joseph King offers an interesting perspective. He argues that the potential for biomass pellets are lowest when competing against fuels for large-scale thermal energy loads (such as power generation) and highest when competing at the retail level for small-volume customers who tend to pay highest prices for all forms of energy.[19] Therefore, the biomass pellet industry need not scale

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[18] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 32.

[19] King, Joseph E., Coriolis, "Reducing Bioenergy Costs by Monetizing Environmental Benefits of Reservoir Water Quality Improvements from Switchgrass Production: Pelletized Switchgrass for Space and Water Heating," Lawrence, Kansas, September 1999. p. 3.

up for large industrial customers. King suggests building pellet plants of the smallest size that economies of scale permit (as small as 2 to 3 tons per hour) to minimize transportation distances from the field to the pellet plant and from the pellet plant to customers.[20]

Urbanowski goes so far as to assert that the structure of the biomass pellet market in North America could be described as "localized monopolies" because any cost advantages achieved by competitors are negated by transportation costs to get the competitor's product to a local supplier's market. Therefore, local companies are able to hold their markets even if they aren't efficient producers (but Urbanowski acknowledges that competition from a more distant supplier is a possibility).[21]

Perhaps a small-scale (2 to 3 tons/hour) agricultural biomass pellet plant would enjoy a "localized monopoly," but investing a million dollars based on such a complacent assumption seems risky. A better approach may be to realistically account for transportation economies when appraising the feasibility of an agricultural biomass pellet plant in an increasingly competitive market.

Advantage of Being Second

According to Urbanowski, some industry observers estimate the worldwide demand for wood pellets to be 30 million tonnes annually, and the supply is only 4 million tonnes.[22] To some, this might mean now is a great time to build an agricultural biomass pellet plant in Minnesota. This might also be a good time to do nothing but observe market developments.

In Minnesota and Wisconsin, there is not a large wood pellet industry, but this may change. With a declining paper industry, a wood pellet industry may be developed to productively use equipment, labor and other resources that previously supplied pulpwood to the paper mills. Agricultural biomass pellet companies may not be able to compete profitably against modern, large-scale wood pellet companies in the same regional market. (Of course, neither a wood pellet industry nor an agricultural biomass pellet industry will prosper if the regional market for fuel pellets does not grow.)

Some observers think that ethanol plants may become industrial customers for agricultural biomass pellet companies if the process heat systems in ethanol plants are converted from

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[20] King further recommends the following plan: A company would market a residential-scale boiler that operates at high efficiency using biomass pellets with high ash content. The boiler would supply hot water on a year-round basis and supplemental heat during the heating season. Pellets would be delivered in bulk, thereby saving bagging, retailing and transportation costs. The delivery vehicle would be a medium-size grain truck with a pneumatic pellet pump. Pellets would be blown into a storage bin near the boiler. Ash would be vacuumed from a disposal bin. Two to four deliveries per year would be typical for residential customers. King recognizes there are several barriers to near-term implementation of this plan.

[21] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 47.

[22] Urbanowski, Ernie, p. 46.

natural gas to biofuels; but it is also possible that ethanol companies could also *become* agricultural biomass pellet companies. If an ethanol company installs a pellet mill to pelletize distillers grains, it could sell pellets in the livestock feed or fuel markets, wherever the price is highest. In Minnesota, ethanol plants are now producing about 2 million tons of dried distillers grains annually. If a market develops for agricultural biomass pellets, one must view these ethanol plants as potential competitors on the supply side.

There might be a worldwide demand for 30 million tonnes of pellets, but this demand cannot necessarily be reached profitably from Minnesota. To justify an agricultural biomass pellet plant, one must look at the reachable market. Today, there does not seem to be one; and there are no apparent reasons to be among the first suppliers in this undeveloped market with a large-scale agricultural biomass pellet plant. The opportunities for early excess profits seem remote. (It is highly unlikely that the agricultural biomass pellet industry will follow a track anything like the ethanol industry's.) If the early entrants successfully "prime" a viable market for agricultural biomass pellets, then it would soon become a commodities market where there would be room for numerous suppliers.

It seems that the best strategy might be to watch others go first and spend their money trying to develop profitable production systems and markets. Then, if the market calls for more suppliers of biomass pellets, developing a second-generation pellet plant might make sense (assuming that competitive threats from wood pellet companies, ethanol producers and others are defeatable). Immediately, companies developing second-generation pellet plants would have a competitive advantage over the first companies for having not exhausted capital resources learning lessons the expensive way.

7. Contingency Plans

It is important to have contingency plans. For example, if the business plan for an agricultural biomass pellet company is to have a single primary feedstock source (a soybean processing plant, for example), a feasibility study should address what would be done if that feedstock supply is disrupted or terminated.

In some feasibility studies, efforts are made to address what options would be available if the original business plan fails entirely. (A section devoted to this topic is usually included in the final version of a feasibility study document only if there are some good options.)

The total capital investment in an agricultural biomass pellet plant would likely be $5.0 million or more. The worst-case scenario would be this: Business operations are terminated; there are no viable alternative uses for the facility; there are no buyers; debt holders require that the plant be disassembled and the components sold on the used equipment market. In this event, lenders (who get first recovered capital until they are made whole) would likely take a loss, and equity investors would probably recover none of their investment.

Given that there is not a sizable market today for agricultural biomass fuel pellets, it would be prudent to consider in the early business planning stages how to avoid the worst-case scenario. Doing so may prompt some location and design decisions that would improve future business opportunities in the wood pellet or livestock feed industry for first or subsequent owners.

8. Political Environment

There might be much to say in a feasibility study about the political environment and how it affects the viability of an agricultural biomass pellet enterprise. One would *expect* the political environment to be advantageous, but this is not certain. At the state and federal level, energy and tax policy will probably continue to favor renewable energy generally; but it remains to be seen whether the political environment may promote the agricultural biomass pellet industry specifically. It may not. So far, this much is true: no markets for agricultural biomass pellets have been created by state or federal actions related to energy or the environment.

If an energy tax (carbon or Btu tax) is imposed, agricultural biomass pellets may become less expensive than coal or natural gas. Thus, an energy tax could promote fuel-switching from coal and natural gas to agricultural biomass pellets. Recall, however, that the entire agricultural biomass pellet production process is energy-intensive. An energy tax would increase the cost of producing and delivering agricultural biomass pellets, thereby providing an advantage to other renewable energy resources.

In Minnesota, a State statute requires that 25% of total energy used in the state be derived from renewable energy resources by the year 2025. Neighboring states have also adopted renewable portfolio standards and “good-faith” objectives for renewable energy production. If agricultural biomass pellets prove to be a least-cost renewable energy resource, then one would expect electric utilities to co-fire agricultural biomass pellets with coal in existing power plants.

In the coming years, specific state statutes could help or hurt an agricultural biomass pellet industry. It is conceivable that a state legislature may approve a statute requiring that biomass be co-fired with coal wherever practicable. This would obviously help an agricultural biomass pellet industry. On the other hand, a state could prohibit utilities from meeting renewable resource requirements by co-firing biomass with coal (because the legislature wants to promote wind power first). Another possibility would be for a state to require that qualifying renewable energy resources have a high “energy ratio” of energy outputs to all energy inputs. This would not favor agricultural biomass pellets.

Another opportunity for the agricultural biomass pellet industry may be in the transportation fuels sector. Producing ethanol requires a lot of energy. There has been some discussion of requiring ethanol producers to switch from fossil fuels to biofuels in order for their ethanol to be eligible for the federal blenders’ tax credit. In fact, if such a requirement is imposed, ethanol producers would probably be given ample time to comply, and then ethanol producers would have multiple fuel options (including their own co-product). Therefore, this should not be viewed as an imminent opportunity for new agricultural biomass pellet companies.

Beyond state and federal purview, the viability of an agricultural biomass pellet company in Minnesota might be affected positively or negatively by energy, tax and trade policies of the European Commission. Today, favorable policies in Europe draw a lot of wood pellets from the United States and Canada, and European demand is justifying the growth of the American and Canadian wood pellet industries. If by some government actions this European market shrinks, wood pellets may flood the domestic markets where otherwise agricultural biomass pellets would be sold.

In sum, it would be a mistake to assume that a political environment that is generally favorable towards renewable energy resources will necessarily provide a profitable market for agricultural biomass pellets. At present, there are no mandates or incentives that are propelling development of an agricultural biomass pellet industry.

9. Permitting and Government Approvals

A feasibility study ordinarily identifies the permits and government approvals that would be required to construct and operate a facility and outlines a plan to obtain them. Depending on the circumstances, it may be necessary to hire an environmental consulting firm and legal counsel to assist with the government approval process (especially if anyone starts talking about petitioning for an Environmental Impact Statement).

If an agricultural biomass pellet plant is going to be located in a municipality, then the project may require review and approval by one or more municipal bodies (a planning commission, a zoning board, an economic development commission, and/or a city council). In addition to building permits, there may be a need for a zoning variance, a conditional use permit and perhaps other approvals. If local residents and businesses raise objections (due to concerns about dust, noise, rodents, traffic, fire risk, etc.), the review and approval process could be long, frustrating and ultimately fruitless. The local authority may also be willing to grant approval only subject to conditions which limit operational flexibility immediately or in the future. Unless a municipality is offering valuable economic development incentives, it’s hard to think of any good reasons to try to locate an agricultural processing facility within municipal boundaries.

At the state level, it is advisable to inform the Minnesota Pollution Control Agency (MPCA) of intentions to build any kind of processing plant as soon as the location, equipment and processes can be described. MPCA staff can assist in determining the required environmental review and approvals. Most likely, an air emissions permit would be required. If there would be a dryer in the plant, this equipment component would cause the most concern for the potential release of volatile organic compounds and particulate matter.

Depending on the roadways at the proposed plant location, it may be necessary or desirable to work with the Minnesota Department of Transportation or the County Public Works Department on a turn lane, signage or other accommodations. Discussions should be started early to ensure that there can be safe and efficient truck traffic in and out of the proposed site.

There are probably many community populations and County Boards that would be eager to have a new agricultural processing plant and employer in their counties. When choosing a site for an agricultural biomass pellet plant, it might be a good idea to develop a list of site requirements and desirable features. This list could be shared with local officials and community leaders in multiple counties, who would be invited to propose sites that would be fully supported by the local governments. They may promise not only an expedited permitting and approval process, but significant economic incentives, too.

10. Agricultural Biomass Feedstock

An agricultural biomass pellet enterprise would require a viable feedstock supply system. The feedstock could be agricultural processing by-products (e.g., soybean hulls), crop residues (e.g., corn stover), dedicated energy crops (e.g., switchgrass), or perhaps whatever becomes available at the time.

This feasibility study guide does not provide a fully developed conceptual basis and proof of concept for a feedstock supply system. Feedstock descriptions and prices should be viewed as illustrations. When a feasibility study is produced for an agricultural biomass pellet company, the proof of a viable feedstock supply system will be an essential section.

The cost of feedstock (including collection, processing, hauling and storage costs) would be a critical determinant of the economic feasibility of an agricultural biomass pellet company. If it takes significantly less labor, equipment and energy to bring agricultural biomass to a pellet plant than to bring wood to a pellet plant, then the pellet company that uses agricultural biomass would have a competitive advantage (not necessarily a sufficient competitive advantage, but an advantage nevertheless).

Cost is not the only important consideration. Two others are:

- Characteristics and consistency of feedstock in terms of physical and chemical composition, and absence of tramp material, too.

- Reliability of feedstock supply system (which is improved by having more suppliers and less competition for the feedstock).

There are numerous potential agricultural biomass feedstocks. Some of these are:

Corn stover	Wheat straw	Soybean straw
Corn cobs	Roadside grass	Hay
Switchgrass	Other grass crops	Distiller's grains
Soybean hulls	Oat hulls	Oat screenings
Sunflower hulls	Wheat middlings	Corn screenings
Sugar beet pulp	Glycerol	

Feedstock characteristics – the particle size, moisture content, physical and chemical composition – will determine equipment requirements, energy consumption, production rates, and pellet quality. Selection of feedstock requires analysis of trade-offs: a more expensive feedstock (such as dried distillers grains) would have superior characteristics to a less expensive feedstock (like corn stover).

Wood is not a feedstock that is considered in this feasibility study guide because the subject is an agricultural biomass pellet enterprise. However, when readers are developing feasibility studies for their own companies, they may consider the possibility of using wood (including sawdust and shavings). Wood materials could be used in a blend with agricultural feedstock or used separately when wood is available at lower cost. Wanting the flexibility to use wood as feedstock has implications for equipment selection and perhaps site selection, too, which is why it should be considered in the feasibility study.

10.1 Agricultural Processing By-Products

Agricultural processing by-products – distillers grains, soybean hulls, oat hulls, wheat middlings, etc. – could be excellent feedstock for agricultural biomass fuel pellets. Advantages of these feedstocks can include:

- Consistent feedstock characteristics
- Minimal tramp material
- No debaling, shredding or first-stage grinding required
- No drying required (for some but not all processing by-products)
- Low energy consumption in hammermilling and pelleting
- High pellet mill throughput rates (up to 3 times higher than corn stover)
- Low wear and tear on equipment

Regarding pellet quality, a durable pellet can be produced with most agricultural processing by-products; but, like other agricultural materials, these materials generally have higher ash and chlorides content than wood. Thus, fuel pellets made with the agricultural processing by-products probably would not pass the Pellet Fuels Institute's proposed ash standard of less than 2% (for standard residential pellets) or its maximum chloride content recommendation of less than 300 parts per million.

The disadvantages of agricultural processing by-products relate to long-term reliability of supply and the cost of by-products. Wherever a pellet plant might be built in Minnesota, there would not be many agricultural processing plants that generate sizable quantities of by-products within 50 miles, 100 miles or 200 miles. Thus, the number of potential feedstock suppliers would be small, and the total supply could be drastically reduced if just one plant shuts down or quits selling by-products. This is one element of the unreliability of supply.

Another element of unreliability is the potential for price increases of such a magnitude that a pellet enterprise can no longer afford to purchase by-products (the effect of which would be the same as if the supplier quit selling by-products). A pellet company that is dependent on agricultural by-products for feedstock would be vulnerable; it is conceivable that an increase in the price of feedstock could force the pellet company to cease operations.

As corn and soybean prices have increased, so have the prices of just about all other agricultural products and by-products that can be used as livestock feed (or biomass fuel). For example, as recently as the fall of 2006 it was reasonable to assume a price of $70/ton for soy hulls. In September 2007, soy hulls are selling for around $100/ton in the Midwest (with the buyer paying freight). The price of wheat midds is $79/ton, and dried distillers grains are selling for more than $100/ton.[23]

Oat hulls provide an illustration of why an agricultural biomass pellet enterprise may not want to rely heavily on a feedstock that happens to be abundant and low-cost today. General Mills generates about 90,000 tons of oat hulls annually at its Twin Cities cereal plants. In the past, these oat hulls were usually sold as a low-value livestock feed for about $15/ton, which equates to about $1.00/million Btu. In February 2007, the University of Minnesota obtained a permit to co-fire oat hulls in its Southeast Steam Plant in Minneapolis, but US Steel and at least one other boiler operator had also decided to co-fire oat hulls. The price of oat hulls has since doubled (at least), and there is more demand for oat hulls than supply. It is reasonable to expect that the future price of oat hulls will be determined in a dynamic market by its energy value or livestock feed value, whichever is higher. [24]

It is noteworthy that US Steel is apparently shipping loose (not densified) oat hulls about 200 miles to Mountain Iron, Minnesota, for use in its boiler, and the University is blending loose oat hulls with coal. Thus, low-density agricultural by-products do not have to be in pellet form to be co-fired with coal in a boiler.

If, however, a buyer wants to purchase pelletized agricultural processing by-products, some are available. A number of processing plants have pellet mills. Generally, these plants sell by-products (soy hulls, wheat midds, oat screenings, etc.) in loose form, and they offer pellets for only $10-$15/ton more.

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[23] "By-Product Feed Price Listing." University of Missouri Extension, September 13, 2007. Available at http://agebb.missouri.edu/dairy/byprod/bplist.asp.

[24] Nelson, Carl, Renewing Rock-Tenn: A Biomass Fuels Assessment for Rock-Tenn's St. Paul Recycled Paper Mill. Green Institute, Minneapolis, Minnesota, March, 2007. p. 30.

A lot of agricultural processing by-products would be superior feedstocks to corn stover, straw or any kind of grass. If an agricultural biomass pellet company was guaranteed a long-term supply of, say, soybean hulls, there would be no need for a tub grinder and a dryer in the pellet plant. Furthermore, pellet production (tons/hour) could be three times greater using soybean hulls than corn stover as feedstock. This would justify paying a higher price for soybean hulls than for corn stover.

Unfortunately, it may not be possible for an agricultural biomass pellet company to contract for a long-term supply of soybean hulls. If it is possible, the seller (a soybean processor) would probably not agree to a fixed price schedule, but instead would insist on a floating price. Then, in the long-run (assuming an agricultural biomass pellet industry develops), it is likely that the price of soybean hulls to all buyers would fully reflect their superior value as pelleting feedstock. In other words, the price of soybean hulls would increase until the competitive advantage of having a supply of soybean hulls is all but erased.

That said, a feasibility study for an agricultural biomass pellet company should certainly assess opportunities to purchase agricultural processing by-products on a regular and intermittent basis, and it would make sense to plan receiving and feedstock storage facilities for these by-products. Depending on circumstances, a business plan that relies heavily on a supply of by-products could be viable (if, for example, the pellet plant would be built next to a large soybean processing plant as a joint venture). Nevertheless, it would probably be prudent to leave room in the pellet plant for a tub grinder and a dryer.

10.2 Corn Stover and Soybean Straw

Corn stover and soybean straw are the most plentiful agricultural biomass residues in Minnesota, and there are a lot more corn and soybean farmers than there are agricultural processing plants. Thus, supply curtailment by one supplier is not significant risk. The comparable risk, however, is that many farmers facing the same general economics and agronomics may choose to not harvest their crop residues. There has been a lot of talk about large-scale commercial harvesting of crop residues in recent years, but no model has been proven yet.

In recent years, numerous studies have assessed the biomass potential of corn stover and other crop residues. It is difficult to compare them in a side-by-side fashion due to their different purposes and methodologies, but each analysis makes some contribution to the body of knowledge. Several analyses, including one that was produced for this feasibility study guide, are discussed below for two reasons. First, the conclusions about feedstock availability and costs are credible. Second, this presentation may provide useful models for how feedstock information may be presented in a feasibility study for an agricultural biomass pellet company.

ORNL Corn Stover Estimates

Robert Perlack and Anthony Turhollow of Oak Ridge National Laboratory produced a report in 2002 titled Assessment of Options for the Collection, Handling, and Transport of Corn Stover. They concluded that corn stover can be collected, stored, and hauled for $42.70 to $47.10/dry ton (which is about $34 to $38/ton as baled) using conventional baling equipment at a scale necessary to provide sufficient feedstock for a 500 to 2,000 dry ton/day processing facility.[25] (This scale exceeds the scale contemplated in this study for an agricultural biomass pellet plant. The largest pellet plant scoped for this study is one that would require about 400 tons per day at most.)

The study by Perlack and Turhollow is somewhat dated, and their estimate of corn stover collection costs was probably optimistic, but their report contains excellent information nevertheless. Of particular interest is their realistic estimate of corn stover collection potential, based on the following assumptions:

- 30% of the land in the region is planted in corn.
- 50% of farmers contract to sell corn stover.
- 3.3 dry tons/acre of corn stover are produced (with 140 bushel/acre corn yield).
- 1.1 tons of corn stover are scheduled to be harvested each year.
- 10% of corn stover goes uncollected due to weather and other reasons.
- 10% of collected corn stover is lost due to handling and decomposition.

With these assumptions, Perlack and Turhollow determined the following corn stover collection area requirements and haul distances:[26]

Annual Feedstock Requirement (Dry Tons/Year)	Stover Collection Area (Square Miles)	Average Straight-Line Haul Plus 30% for "Winding Factor" (Miles)
166,670	1,740	21.7
333,330	3,470	30.7
666,670	6,950	43.4

The above table indicates that an annual feedstock requirement of 166,670 dry tons would require a corn stover collection area of 1,740 square miles, which is smaller than the area of Renville County plus Redwood County (with 983 square miles and 874 square miles, respectively). In 2006, 41% of the land in these two southwestern Minnesota counties was planted in corn, and yields in these counties exceeded 170 bushels per acre. Note again that Perlack and Turhollow assume 30% of land would be planted in corn, and yields would be

[25] Perlack, Robert D. and Anthony F. Turhollow, Assessment of Options for the Collection, Handling, and Transport of Corn Stover. Oak Ridge National Laboratory, Department of Energy, Oak Ridge, Tennessee, September 2002.

[26] Perlack, Robert D. and Anthony F. Turhollow, p. 5.

140 bushels per acre. Taking into account these differences, it appears that far more corn stover could be collected in just Renville and Redwood Counties than would be needed for the largest pellet plant considered in this feasibility study guide.

As shown in the table above, Perlack and Turhollow found that doubling the annual feedstock requirement from 166,670 to 333,330 tons increases the average hauling distance by only nine miles, from 21.7 to 30.7 miles. This only increases feedstock costs by about $1.00/dry ton. This is an important finding: Whether much larger quantities of feedstock are needed or much lower participation rates among farmers must be offset, the required expansion of the production region does not correspond to much longer average haul distances or to much higher transportation costs.

Caution is advised when reviewing Perlack's and Turhollow's findings because the cost assumptions are outdated. Nevertheless, their justification of corn stover availability and their findings related to tonnage requirements, hauling distances and consequent impact on total feedstock costs are illuminating.

CARD Cost Estimate for Corn Stover

Proponents of cellulosic ethanol have been wishful thinkers about the future costs of corn stover. In a May 2007 assessment of biofuels and their impact on agricultural markets, the Center for Agricultural and Rural Development (CARD) of Iowa State University disputed the common belief that technology and efficiency improvements are going to drive down corn stover costs. In commenting on research produced by the National Renewable Energy Laboratory, the authors write:

> While we agree with much of the research in this report, we disagree with one key assumption. The report details all of the costs associated with the baling and transportation of corn stover, and these calculations sum to $62 per dry metric ton. This is about $31 for a 1,265 pound bale of 15% moisture stover. The authors arbitrarily assume that this cost will be reduced to $33 per dry metric ton in the future through 'improved collection.' We are of the opinion that farmers and agricultural equipment manufacturers have already squeezed costs from this system, and we do not expect these costs to fall dramatically.[27]

[27] Tokgoz, Simla, Amani Elobeid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang (Edward) Yu, Fengxia Dong, Chad E. Hart and John C Beghin, Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa, May 2007. p. 39.

The authors of the CARD report offer the following estimate of corn stover collection costs for 1,265 pound bales as follows:

Baling	$10.10
Staging	$ 2.25
Lost nutrient value	$ 4.00
Premium to farmers	$ 5.50
Total	$21.85 per bale (or $34.55 per ton)
Hauling	$15.00 ($.30 per mile per bale for 50 miles)
Total to Plant	$36.85 per bale (or **$58.26 per 2,000 pound, 15% moisture ton**)[28]

Soybean Straw

The viability of soybean straw as a feedstock is questionable. In an often-cited study titled Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, it is reported that USDA and DOE found that 40% of soybean residue is "logistically removable" but that none is "sustainably removable."[29] Likewise, closer to home, AURI did not include soybean straw in an assessment of biomass resources in Kandiyohi County, Minnesota, even though soybeans are grown on more than 110,000 acres in that county, because removing an amount of soybean straw that would justify the harvesting cost could potentially create a carbon imbalance and negatively affect soil nutrition, tilth and erosion protection.[30]

Perhaps soybean straw will be a more suitable feedstock in the future. When soybeans were introduced in the early 1900s, soybeans were produced as a forage crop. Through the past century, varieties were developed that improved soybeans as an oil crop. Now, interest in ethanol and solid biomass energy has turned some attention to development and production of high-biomass soybean varieties. New soybean varieties are being developed that might yield three tons or more of dry biomass per acre (which would be comparable to corn stover tonnage).

Regardless of concerns about removing soybean straw from fields, it is harvested on some farms in the Upper Midwest for various purposes including the manufacturing of construction materials; and there are companies interested in organizing collection of soybean straw on a large scale.

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[28] Tokgoz, Simla, Amani Elobeid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang (Edward) Yu, Fengxia Dong, Chad E. Hart and John C Beghin, Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa, May 2007. p. 39.

[29] Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2005. p. 55.

[30] Biomass Resource Assessment (of Kandiyohi County, Minnesota). Agricultural Utilization Research Institute, Waseca, Minnesota, July 2006. p. 7.

A presentation by Agristrand Soy Board, an Iowa company, seems to indicate that the company plans to organize collection and delivery of 390,600 bales of soybean straw (1,200 pounds each) from 235,000 acres for production of construction panels and fiber board. Agristrand's presentation suggests that the economics of producing construction material with soybean straw would allow Agristrand to pay a price of $50.00 per ton delivered, which would yield net income to farmers as follows:[31]

Payment to Farmer	**$52.50/acre**
Farmer's Costs	
Baling	$14.00
Trucking	$10.50
Nutrient Replacement	$ 2.52
Net Income	**$25.48/acre or about $24.27/ton**

Local Feedstock Supply Estimates

To ensure that this chapter of the feasibility study guide provides realistic information based on local practices, an experienced and knowledgeable custom harvester of agricultural residues was hired to assist in the design of feedstock supply scenarios. The author of this feasibility study has made adjustments to estimates and calculations produced by this custom harvester, however. Therefore, the custom harvester is not necessarily responsible for any information contained in this feasibility study guide.

Corn stover and soybean straw are the agricultural residues of primary interest in this feasibility study guide due to their abundance in Minnesota. However, readers who are familiar with wheat straw harvesting may find comparative information useful, and wheat straw could be a viable feedstock in some areas of Minnesota. Therefore, cost information for wheat straw procurement is provided in this section.

In the past, harvesting corn stover and soybean straw has not been a common practice in Minnesota; generations of farmers have been taught that corn stover and soybean straw should be left on the fields. This could make it difficult to establish an agricultural residue supply system. Nevertheless, it is assumed in the following hypothetical feedstock supply plan that 20% of farmers would be interested initially in contracting their corn fields for stover harvesting.

If farmers believe corn prices will be high relative to soybean prices, then farmers would be inclined to grow corn-on-corn (instead of a corn-soybean alternating rotation). When farmers grow corn-on-corn, there may be sound agronomic advantages to removing some residue from fields between corn crops (or after a second corn crop and before a soybean crop). Furthermore, some residue removal may be beneficial when less intensive tilling practices are used with alternating crops of corn and soybeans. Thus, farmer participation may increase above 20%.

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[31] Agristrand website at http://www.agristrand.com.

The business and logistics of procuring large quantities of agricultural residue would be no small challenge. All aspects of procurement would be managed directly by staff of the pellet business or largely assigned to a contractor (which could be a producer-owned supply cooperative). Regardless, someone must negotiate contracts with the farmers for their harvested agricultural residue or for their acreage which would be harvested by a custom harvester.

A large-scale custom harvesting system may work as follows: First, fields would be monitored during the growing season to determine if enough acres are under contract (based on expected yields). As harvest time approaches, arrangements must be confirmed with farmers, and maps and information would be distributed to custom harvesters and truckers. Then the custom harvesters would coordinate field activity with the farmers to design an efficient and uninterrupted schedule of operations from field to field. After farmers finish their harvest, the custom harvesters would begin their operations. The custom harvesters would chop or mow corn stover; and then, when the corn stover is dry enough, they would rake and bale the corn stover. Soybean (and wheat straw where it is available) would be baled without intermediate steps between the farmers' harvest and the custom harvesters' baling.

The custom harvesters would move the bales of agricultural residue to an appropriate location near the edge of the field where the bales would be left until they are collected for delivery to the pellet plant. A commercial trucking company would be under contract to load and haul bales from the farmers' roadside (or farmers' storage areas) to the pellet plant as feedstock is needed.

Farmers would be responsible for insuring the bales of agricultural residue while they are on the farmers' property, but the pellet company would incur the risk of dry matter loss, moisture content gain, and other damage due to exposure while the bales are stored at the roadside. (Perhaps the pellet company would pay a premium price for bales stored under a structure or for bales that meet certain weight and moisture standards.)

Payments to farmers for crop residues. It is assumed that farmers would require compensation equal to about 1.5 times the full nutrient value of the residue removed from their fields (without regard for any argument whether nitrogen removal should be counted). Based on fertilizer prices for the fall 2007, farmers would require \$22.20/ton for corn stover and \$10.50/ton for soybean straw. These amounts are calculated as follows:

CORN STOVER

	Price/ Pound	**Pounds Removed/ Ton Residue**	**Nutrient Value**
Nitrogen	\$0.35	15.0	\$ 5.25
Phosphorous	\$0.55	6.0	\$ 3.30
Potassium	\$0.25	25.0	\$ 6.25
TOTAL			**\$14.80**

\$14.80 X 1.5 = \$22.20/Ton

SOYBEAN STRAW

	Price/ Pound	Pounds Removed/ Ton Residue	Nutrient Value
Nitrogen	$0.35	12.0	$ 4.20
Phosphorous	$0.55	1.8	$ 1.00
Potassium	$0.25	7.2	$ 1.80
TOTAL			**$ 7.00**

$7.00 X 1.5 = $10.50/Ton

It is hard to say whether most farmers would value their corn stover and soybean straw as suggested above. Some might think this is a good deal, especially those who are concerned about too much organic matter build up when they grow corn-on-corn. Others might not think they would be fairly compensated for the resulting compaction and loss of soil tilth. What is probably true is this: If corn and soybean prices remain high, farmers will be more interested in doing whatever they think they can to maximize their corn and soybean yields than earning a few dollars by selling crop residues.

It is assumed that wheat straw would not be priced on the basis of nutrient value removed. The custom harvester engaged to help develop agricultural residue feedstock scenarios has found that a common price paid to farmers in the past has been $25.00/ton. If corn production replaces wheat production, the price of wheat straw could rise, but the $25.00/ton price still seems to be a reasonable price assumption for the purposes of this feasibility study guide.

On-field bale storage. It is estimated that a 160-acre corn field would yield about 680 bales of corn stover, which would require on-field storage of approximately 1.25 acres of land (including untilled area for trucks and loading equipment to operate). The on-field storage area would have to be well drained and open so that there is ample air flow through the bales; and it would have to be reasonably near the roadway, but not such that the bales would obstruct drivers' view or snow would drift from the bales across the road. Local set-back ordinances may also be applicable.

Compensation to the farmer for this storage area may be based on three times the local land rental rate – three times because the area of rented land is small. For a 1.25 acre area in or around Redwood County, Minnesota, this would be about 3 X $125/acre X 1.25 acres = $468.75, which equals about $0.70/bale or about $1.12/ton for corn stover. (In an estimate of costs for soybean straw and wheat straw, a guess of $2.00/ton is used to roughly account for there being fewer bales per acre but not a proportionate reduction in area required for access and loading.)

Custom harvesting and hauling costs. The custom harvester provides the following information on the operations of harvesting corn stover:

> Stalk chopping is a very important part of making dry corn stover bales. The process cuts the stalk from the ground, cuts the stalk into baleable particle size, and opens the

stalk to promote drying. A properly adjusted and operated stalk chopper is critical to harvesting dry stover. The charge for stalk chopping in this region is $12.00/acre. Raking is also necessary for making corn stover bales; this process gathers the dried stover and places it into rows that can be easily picked up by balers. The best operator and equipment can do this while keeping soil out of the row. The charge for raking corn stover is $5.50/acre. Having skilled operators running the balers is important for many reasons but one of the most obvious is to efficiently make a high quality package which will store the product well while keeping the elements from damaging the product. The current charge for cornstalk baling in this area is $10.50/bale.

A large round net wrapped cornstalk bale will typically weigh about 1,250 pounds, soybean straw 1,400, and wheat straw 1,100. Round bales will be preferred in this region for many reasons (most widely available, lower capital requirements, net wrap provides protection from the weather, and lower fuel used per ton harvested).

The use of specialized automated self load and unload bale trailers is also critical. These machines reduce the number of times a bale is handled and therefore the bales will have less damage to them and they will also be able to be stored more compactly, neat and on less land. The cost for roadsiding bales in this region is $3.25/bale.[32]

The custom harvester expects the charge to bale and roadside soybean straw and wheat straw would be the same as the charge for corn stover ($10.50/bale for baling and $3.25/bale for roadsiding) even though the bales per acre and bale weights vary. This is due in part to corn stover being harder on equipment than either soybean straw or wheat straw, according to the custom harvester.

The custom harvester makes an important point regarding the custom rates indicated above. These custom rates are based on custom harvesters using equipment that they have opportunities to use for other purposes throughout the crop season. If custom harvesters are required to invest in new equipment that would only be used to harvest crop residues for a large pellet plant, then the rates would have to be higher to provide a return on investment in that dedicated equipment.

Some might think that single-pass harvesting systems will soon cut in half the costs of corn stover collection and delivery. Work conducted by the National Renewable Energy Laboratory and cited by the Biotechnology Industry Organization casts doubt on this. A comparison of costs for collection and delivery using custom baling versus one-pass harvesting suggests that a one-pass harvesting system would yield savings of about $6.66 per delivered ton where corn yields are approximately 170 bushels per acre (and this savings is reliant in part on the availability of rail transportation from collection sites to a processing plant).[33] A savings of $6.66/ton is certainly significant. In a competitive commodities

[32] These paragraphs and other information attributed to the customer harvester are contained in an unpublished document titled "Pellet Mill Feasibility in Southwest Minnesota," by Eric Woodford, August, 2007.

market, this savings could be the difference between profitability and bankruptcy. Nevertheless, $6.66 is only about 10% of total estimated collection and delivery costs for corn stover. It would be hard to call this a technology breakthrough of revolutionary impact.

It is assumed that bales would be hauled to the pellet plant on semi trailers. The cost for loading, unloading and strapping is estimated at $3.00/bale, and the hauling rate would be $3.00/loaded mile. Corn stover loads would be 30 bales (18.75 tons) or 23 bales (14.4 tons). Truckers apparently prefer to haul 23-bale loads because they are safer. (There are customized semi trailers that require no strapping and that are "self unloading." Use of this specialized equipment could reduce total hauling costs and make bale hauling much safer.)

The total cost estimates for corn stover, soybean straw, and wheat straw are as follows:

BASE CASE	**Corn Stover**	**Soybean Straw**	**Wheat Straw**
Pounds/Bale	1,250	1,400	1,100
Tons/Acre	2.65	0.9	1.3
Costs/Ton			
Farmer Compensation	$22.20	$10.50	$25.00
On-Field Storage Rent	$ 1.12	$ 2.00	$ 2.00
Stalk Chopping	$ 4.53		
Raking	$ 2.07		
Baling	$16.80	$15.00	$19.09
Roadsiding	$ 5.20	$ 4.64	$ 5.91
Loading	$ 4.80	$ 4.28	$ 5.45
Hauling	$ 4.80	$ 4.28	$ 5.45
(30-bale loads, 30 miles)			
TOTAL – BASE CASE	**$61.52**	**$40.70**	**$62.90**
HAULING SCENARIO 2			
Hauling	$ 6.26	$ 5.58	$ 7.11
(***23-bale loads***, 30 miles)			
TOTAL – SCENARIO 2	**$62.98**	**$42.00**	**$64.56**
HAULING SCENARIO 3			
Hauling	$10.43	$ 9.30	$11.85
(***23-bale loads***, ***50 miles***)			
TOTAL – SCENARIO 3	**$67.15**	**$45.72**	**$69.30**

[33] Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock. Biotechnology Industry Organization, Washington, DC, 2006. pp. 19-20.

The above variations on hauling costs demonstrate the sensitivity to the size of loads and the distance hauled. In the base case above, it is assumed that 30-bale loads of corn stover would be hauled 30 miles at $3.00/loaded mile. Hauling costs would be $4.80/ton. If only 23-bale loads are hauled, and the average distance is 50 miles, then hauling costs would be $10.43/ton. (Some trucking companies may charge a minimum hauling fee in addition to the loading fee, which would establish a floor on hauling costs/ton.)

Availability of corn stover and soybean straw. As stated previously, it is assumed that 20% of farmers would make their corn stover available, either harvesting it themselves or contracting their corn acreage to a harvester. It is noteworthy that this assumption is much more conservative than Perlack's and Turhollow's with respect to farmer participation. They assumed 50% farmer participation. Thus, Perlack and Turhollow would estimate two and one-half times more participating acreage per section.

An analysis was produced to estimate the production radius around a pellet plant that would be required to obtain different quantities of corn stover and soybean straw (assuming that 20% of farmers would make their soybean straw available, too). The scenarios are based on 2006 crop production in Redwood County, Minnesota as estimated by USDA National Agricultural Statistics Service. Two different rotations were considered:

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
1.	Corn	Corn	Soybeans	Corn	Corn	Soybeans
2.	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans

In 2006, 80.6% of land in Redwood County was in either corn or soybean production. The split between crops was 52.5% of acres in corn production, and 47.5% in soybean production. This means that in an average section of land in Redwood County, corn was grown on 269 acres, and soybeans were grown on 243 acres. This suggests a county-wide cropping practice similar to the second rotation above.

For both rotations, it is assumed that corn stover and soybean straw would each be harvested every other year of production. This means that in six years of the first rotation, corn stover may be harvested in years one and four, and soybeans may be harvested only in year six. In six years of the second rotation, corn stover may be harvested in years one and five. Soybean straw may be harvested in years two and six.

When corn stover is harvested, the yield would be approximately 2.65 tons per acre ("as-is" tons, not "dry" tons); the soybean straw yield would be 0.9 tons per acre. These estimates are based on the custom harvester's average yields over the past eleven years of agricultural residue harvesting.

Based on these assumptions, calculations were made to determine the production radius required to obtain tonnages of corn stover and soybean straw in regions similar to Redwood County. Finding of this exercise are as follows:

	Feedstock Required (Tons)	Corn-Corn-Soybeans Radius Required (Straight-Line Miles)	Corn-Soybeans Radius Required (Straight-Line Miles)
Corn	100,000	18.76	21.67
Stover	80,000	16.78	19.38
	50,000	13.26	15.32
	30,000	10.27	11.87
Soybean	100,000	45.56	37.18
Straw	80,000	40.75	33.25
	50,000	32.21	26.29
	30,000	24.95	20.36

To interpret this table: If 100,000 tons of corn stover are required, and the prevalent cropping practice is corn-corn-soybean rotations, then the production region required would be a circle with a radius of 18.76 miles. If the prevalent cropping practice is corn-soybean-corn-soybean rotations, then the production radius would be 21.67 miles. (The circle would be larger for the second rotation because corn would be grown on fewer acres in the production region in any given year.)

The mileages shown in the table above are straight-line mileages from the circumference of the supply region to the center where the pellet plant is located. Perlack and Turhollow add 30% to the radius mileage to approximate actual road miles with turns. If we assume that the dominant rotation will remain corn-soybeans, and we want a feedstock supply plan that brings to the plant 100,000 tons of corn stover and 30,000 tons of soybean straw, then the feedstock supply region and hauling mileages (including the 30% turning factor) would be:

	Tons	Supply Region	Mileage
Corn Stover	100,000	21.67 miles radius	28.17 hauling miles
Soybean Straw	30,000	20.36 mile radius	26.47 hauling miles

Recalling calculations of hauling costs, the estimated cost to haul corn stover 30 miles is \$4.80/ton or \$6.26/ton (in addition to loading costs), depending on whether 30 bales or 23 bales are hauled on a trailer. The estimated hauling cost for soybean straw is \$4.28/ton or \$5.58/ton again depending on whether 30 bales or 23 bales are hauled. These are probably reasonably good estimates of the hauling costs for a feedstock supply plan for 100,000 tons of corn stover and 30,000 tons of soybean straw.

This demonstrates that if corn stover and soybean straw are the primary feedstocks for an agricultural biomass pellet enterprise in the southern third of Minnesota, a plausible scenario can be constructed in which feedstock availability is not a restricting factor, and hauling costs are not prohibitive. It seems there are more critical determinants of the overall economic viability of an agricultural biomass pellet enterprise than these.

Concluding comments of corn stover and soybean straw. The above analysis is somewhat speculative. It is conceivable that large quantities of corn stover and soybean straw could be put under contract, but this has not been proved; and it is not yet known what price would be required by farmers initially and long-term.

With the current high prices for corn and soybeans, farmers are probably happy with their net income per acre, and their bankers are not concerned about farmers' ability to make loan payments. (Bankers are probably more concerned about farmers' ability to pay off loans early.)

As total compensation for nutrient loss, soil compaction and profit, Perlack and Turhollow assumed farmers would require only $10/dry ton of corn stover.[34] This amount may have been enough when corn was selling for $2.20/bushel, but not now. The analysis in this feasibility study guide suggests a payment of $22.20/ton. Some farmers might consider this amount insufficient if they think removing corn stover might reduce their future corn or soybean yields. On the other hand, this may be too generous for farmers who intend to grow corn-on-corn and believe there may be agronomic advantages to removing some of the biomass from their fields.

The Biotechnology Industry Organization describes colloquies conducted in 2001 and 2003 by the Department of Energy with farmers, potential agricultural biomass processors and other stakeholders. Farmers apparently said they expect at least $50/dry ton (about $40/ton "as is") for baled corn stover, or a return of at least $20/acre net margin (assuming the farmers would do bale and road-side the corn stover).[35] This was when fuel and fertilizer costs were considerably lower, and corn and soybean prices were much lower, too. If farmers expected $50 per dry ton then, they would want more now to offset their higher costs. Even with higher payments, farmers may not be inclined to compact their soil, remove nutrients and organic material, and wear out their equipment– all of which might jeopardize their corn and soybean income the following year – for $20/acre net margin.

A feasibility study for a pellet company that would use corn stover and soybean straw as primary feedstock should provide some proof that the feedstock supply plan is viable. The best evidence may be actual farmer, harvester and trucker commitments.

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[34] Perlack, Robert D. and Anthony F. Turhollow, Assessment of Options for the Collection, Handling, and Transport of Corn Stover. Oak Ridge National Laboratory, Department of Energy, Oak Ridge, Tennessee, September 2002. p. 15.

[35] Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock. Biotechnology Industry Organization, Washington, DC, 2006. p. 9.

10.3 Hay and Grasses

Low-Quality Hay

Alfalfa is selling at high prices, and if alfalfa production declines as producers grow corn instead of alfalfa, the price of alfalfa should remain high. Good quality alfalfa will most likely remain much more valuable as livestock feed than as fuel pellet feedstock. (Alfalfa pellets with 17% protein content are selling for $180 to $200/ton as of September 2007.)

Hay is a good pellet feedstock. The production rate for hay in a pellet mill is close to the production rate for corn stover, and almost twice the rate for wood; and the durability of hay pellets is good.

Low-quality and damaged hay are available in some quantity every year, and this could be an economical fuel pellet feedstock. Even with alfalfa prices as high as they are, a buyer may be able to purchase low-quality and damaged hay (on an unpredictable basis) at prices in the range of $40 to $60/ton, delivered to a pellet plant.

If the low-quality hay that is delivered is actually roadside grass, it could carry a lot of dirt, which would increase the ash content of the fuel pellets. Another possible problem with this material is there could be a lot of tramp material (rocks, bottles, metal objects, etc.) that could cause a pellet plant shutdown.

An agricultural biomass pellet company may want to try buying and using low-quality hay. If it proves to be a nuisance, the practice could be discontinued. (Keeping this option open requires no prior planning if the primary feedstock would require debaling and drying since these would be the first stages for processing low-quality hay, too.)

Switchgrass

It has been suggested that switchgrass (and other herbaceous perennials) should be grown as an energy crop. The technical viability of switchgrass production and co-firing with coal in a large utility power plant was demonstrated with the Chariton Valley (Iowa) Biomass Power Project, but this project did not demonstrate the economic viability of switchgrass. (This project also showed that switchgrass, and by logical extension, other crops and crop residues, do not have to be densified – cubed or pelleted – to be co-fired with coal. The alternative demonstrated with this project is to install and operate a debaling/chopping station ahead of a dedicated fuel delivery system into a power plant boiler.)

Recently, a farmer who participated in the Chariton Valley switchgrass project estimated that the cost per ton for delivered switchgrass as follows:

	Cost/Ton
Growing, cutting and baling	$60
Storage and transportation	$25
Compensation to the farmer	$30 to $40
Total delivered cost/ton	$115 to $125

This estimate may seem high, but one must bear in mind that farmers are looking at the alternatives of growing $3.50/bushel corn and $8.00/bushel soybeans. In current market conditions, farmers aren't likely to understate their costs of production for any crops.

Furthermore, this farmer's estimate is not much higher than switchgrass price requirements determined by researchers at the Center for Agricultural and Rural Development (CARD) of Iowa State University. They recently concluded (2007) that farmers would consider producing switchgrass instead of corn under either of the following scenarios:

	Scenario A	**Scenario B**
Switchgrass yield/acre	4 tons	6 tons
Price/ton	$110	$82

In judging corn stover more viable than switchgrass, the CARD researchers concluded, "In addition to some of the same disadvantages associated with baling and moving corn stover, switchgrass in the Corn Belt must also compete against corn and soybeans for land. Corn stover does not have this hurdle because it is a by-product of corn production."[36]

A Canadian organization, Resource Efficient Agricultural Production (REAP-Canada), has been a proponent of switchgrass production for a number of years. In 2001, REAP produced "A Process and Energy Analysis of Pelletizing Switchgrass." REAP's pelleting trials were limited – only nine metric tons of switchgrass were pelletized – but the results are significant. REAP found that switchgrass pellets can be as hard as alfalfa or wood pellets, but "less than optimum binding characteristics resulted in greater fine production during pelleting and handling. The loss of fines during the pelleting, cooling, and temporary storage stages produced a percentage yield of 91% on a dry matter basis…Switchgrass appears to lack natural binding properties…and improving pellet durability is a major research and development priority for successful commercialization."[37]

According to a representative of a pellet mill manufacturer, which has conducted testing of numerous agricultural materials in its pellet mills, switchgrass is a difficult material to pellet. The pellet production rate for switchgrass is about the same as for hardwood (while the production rate of corn stover is estimated to be twice the rate for hardwood and switchgrass).

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[36] Tokgoz, Simla, Amani Elobeid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang (Edward) Yu, Fengxia Dong, Chad E. Hart and John C Beghin, Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa, May 2007. p. 40.

[37] Jannasch, R., Y. Quan, and R. Samson. A Process and Energy Analysis of Pelletizing Switchgrass. Resource Efficient Agricultural Production (REAP-Canada), 2001. p. 1.

In summary, research and testing suggests that the demerits of switchgrass as pellet feedstock are these:

- Farmers would have to be promised $80/ton or more to grow and deliver switchgrass, which is more than the cost of corn stover and other feedstock options;
- Switchgrass has poor binding characteristics; switchgrass pellets are not durable; and
- Switchgrass pellets are more expensive to produce than other agricultural biomass pellets because the production rate (tons/hour) is lower.

If an agricultural biomass pellet enterprise intends to use switchgrass as a feedstock, then the feasibility study should probably address how these demerits would be somehow overcome.

10.4 Feedstock Supply Management

Finally, a feasibility study for an agricultural biomass pellet company should recognize that organizing and managing a feedstock supply system that involves numerous producers and suppliers would be a time-consuming burden for either company staff or a contractor. Perlack and Turhollow offer this assessment for a corn stover supply system:

> "There is also likely to be considerable administrative requirements associated with the procurement of corn stover. These administrative costs will include planning the collection operations, selecting operators, and coordinating the actual sequencing of operations. In order to account for these costs, we assume a 5% administrative operations expense levied on collection, hauling storage, and farmer payments."[38]

On 100,000 tons/year at $60.00/ton of corn stover (delivered), this 5% administrative expense would be $300,000 annually. In this feasibility study guide, it is assumed that these activities would be accomplished by administrative and management personnel at considerably lower cost than $300,000 per year.

11. Product Viability

Generally, biomass fuel pellets (that is, wood and agricultural biomass pellets) are a viable product. They are a functional and versatile form of densified biomass fuel. Fuel pellets are easy to handle and transport with densities in the range of 40 pounds/cubic foot. Their small, cylindrical shape and exterior sheen give pellets excellent flow characteristics; they can be

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[38] Perlack, Robert D. and Anthony F. Turhollow, Assessment of Options for the Collection, Handling, and Transport of Corn Stover. Oak Ridge National Laboratory, Department of Energy, Oak Ridge, Tennessee, September 2002. p. 15.

moved efficiently with augers, pneumatic conveyors and other conventional equipment that is commonly used to move agricultural grains. With small, uniform size and moisture content under 10%, pellets burn evenly and completely. For household users in good physical condition, 40-pound bags of pellets are manageable; and fuel pellets do not emit an offensive odor or have other aesthetic flaws.

Probably the most important attribute of biomass fuel pellets is their environmental superiority to other energy forms (which is a subjective judgment, of course). An argument could be made that they are "carbon-neutral" and do not contribute to global warming. They are a renewable energy source, and "sustainable" practices could be used in the production of fuel pellets and their feedstocks.

Biomass fuel pellets have two primary markets. They have a retail market where they are generally delivered in 40-pound bags for use in residential and small commercial appliances (primarily supplemental heating stoves but also some furnaces and other appliances). Included in this market would be farms where pellets are burned to generate heat for multiple purposes.

The second market is in the industrial, institutional and utility sectors where large quantities of fuel pellets are burned in boilers and other energy conversion systems, often co-fired with coal. This market is well developed in Europe, but not in the United States.

The criteria of product viability in both markets are largely the same, but requirements relative to those criteria may differ. ("Product viability" in this chapter is not about market appeal or the economics of fuel pellets versus other fuels. The following discussion of product viability is about the physical characteristics of fuel pellets and their suitability for intended purposes.)

11.1 PFI Fuel Standards for Residential/Commercial Uses

Agricultural biomass pellets are not common. Most fuel pellets are wood, and most wood pellets that are marketed for retail sales are labeled as "premium" pellets. This is supposed to mean they have ash content of less than 1%, according to the current grading system of the Pellet Fuels Institute (PFI) which is a "non-profit association that serves the pellet industry."

PFI recently proposed a new pellet grading system which will cast wood pellets in a much more favorable light than agricultural biomass pellets. The proposed "PFI Fuel Standards" serve as a useful organizing tool for a discussion of product viability because a new agricultural biomass fuel pellet enterprise would most likely be challenged to justify its product relative to these standards. This justification may be provided in a feasibility study.

The proposed new PFI Fuel Standards are contained in the table on the following page, and a detailed discussion of the new standards is provided at the Pellet Fuels Institute website: www.pelletheat.org.

Proposed New PFI Fuel Standards

Analysis Parameter	Residential/Commercial Densified Fuel Standards: Super Premium	Premium	Standard	Utility	Residential/Commercial Corn Fuels: Premium	Standard	Grain Fuel Standards	Industrial Fuel Standards
Bulk Density, lbs/cubic foot	40 - 46	40 - 46	38 - 46	36 - 46				
Diameter, inches	0.250 (6.35mm) to 0.285 (7.25mm)	0.250 (6.35mm) to 0.285 (7.25mm)	0.250 (6.35mm) to 0.285 (7.25mm)	0.250 (6.35mm) to 0.285 (7.25mm)	0% over 5/8 inches	0% over 3/4 inches	To	To
Pellet Durability Index	>= 97.5	>= 97.5	>= 95	>= 95			Be	Be
Fines, % (at the mill gate)	<0.5	<0.5	<0.5	<0.5	[<1]	[<3]	Determined	Determined
Inorganic Ash, %	0 - 0.5	0 - 1	0 - 2	0 - 6				
Length, % Greater than 1.5 inches	<1	<1	<1	<1				
Moisture, %	<= 6	<= 8	<= 8	<= 10	[<12]	[<15]		
BTUs - Need to specify on the bag	As-Rec. +/- 2SD	As-Rec. +/- 2SD	As-Rec. +/- 2SD	As-Rec. +/- 2SD	[As-Rec. +/- 2SD]	[As-Rec. +/- 2SD]		

It is required that PFI manufacturer members label their product as to which grade of material is in the bag and that they disclose the type of materials (e.g. oak, maple, cedar, fir, corn, wheet straw, etc.) as well as all additives being used, and if there are any chemically treated materials.

It is recommended that manufacturers include on their bags the membership logo and in a printed block the guaranteed analysis.

It is recommended that all Residential/Commercial Fuels limit chloride content to below 300 ppm.

It is recommended that all feedstock materials be evluated initially for ash fusion properties and then periodically thereafter if ash fusion problems arise to minimize problems with ash fusion in the appliances

PFI prohibits the use of seed corn that has been chemically treated with insecticides in Residential/Commercial appliances.

Generally, agricultural biomass pellets are likely to be judged inferior to wood pellets by these standards. White wood pellets (made without bark) may meet the standards for "Premium" or "Super Premium" pellets, while agricultural biomass pellets are more likely to fall in the "Utility" grade.

Bulk Density

Agricultural biomass pellets may have a lower bulk density than wood pellets. The current PFI standards, which are to be replaced, require a minimum bulk density of 40 pounds/cubic foot. The new PFI standards will allow bulk densities in the range of 36 to 40 pounds/cubic foot for "Utility" grade pellets. Some but not all agricultural biomass pellets are likely to fall in this lower range, depending on ingredients and the pelleting process.

Durability

The new PFI standards establish a durability criterion called the Pellet Durability Index (PDI). The PDI is a test result. In the test, pellets are subjected to a mechanical agitation process (to simulate transportation and handling). The PDI score is the percent of pellets that survive the test intact.

The durability test provides a measurement of fragments and fines caused by transportation and handling. This is an important factor. Users want a minimum of fines because they create a dust cloud when a bag of pellets is poured into a hopper. Furthermore, fines are likely to be dropped into the ash pan without being burned.

Different agricultural biomass materials have different binding characteristics. Switchgrass, for example, is a poor feedstock in terms of pellet durability; pellets made with corn stover could probably pass the durability criterion for "Utility" and "Standard" pellets.

Durability will be determined by the production process as well as by the feedstock. Drying is a critical stage in this regard – if the dryer is too hot, the feedstock will not bind well. Durability also will be affected by how feedstock is conditioned, the suitability of the die for the feedstock, and other factors that can be changed in the production process. Binding additives can be used to improve durability, too.

Fines

In addition to the durability standard is a standard for fines (dust, particles and small fragments) generated in the production process. PFI's proposed standard for fines is exacting – not more than 0.5% by weight – but the point of measurement is at the pellet plant, not a testing laboratory. Therefore, this standard should be achievable at any pellet plant regardless of feedstock provided there are pellet cooling and screening stages in the production process and suitable conveyors after the pellet mill.

Btu Content

The energy content (measured in British thermal units, or Btu) are to be specified on a pellet bag, but there will not be standards for the different grades of pellets. Generally, however, the Btu content of agricultural biomass pellets will be lower than the Btu content of wood pellets. The Btu content will be largely affected by the ash content and the moisture content, for which there will be standards in PFI's proposed grading system.

Moisture Content

The moisture content standard for Super Premium pellets will be less than 6% moisture content. Meeting this standard would increase the energy content of pellets, but trying to achieve this standard would have implications for the drying, conditioning and pellet milling processes that might not be worth it. The standard of equal to or less than 8% moisture content (for Premium and Standard pellets) is achievable, but probably not without a dryer unless very uniform, low-moisture feedstock can be reliably procured and processed before the feedstock absorbs moisture in storage. The Utility standard of equal to or less than 10% moisture content may be the most practical design standard for an agricultural biomass pellet plant that uses agricultural residues as feedstock.

Ash Content

Ash content is an important characteristic for a number of reasons:

> First, inorganic ash is not combustible. Therefore, the energy value of a high-ash fuel is lower than the energy value of a low-ash fuel.
>
> Second, high ash content requires that the ash pan be dumped more frequently. Ash is simply messy stuff to clean up in and around a pellet appliance.
>
> Third, ash can shut down the pellet appliance when the ash tray is full or when chunks of melted ash (called "clinkers") are formed, causing inconvenience and discomfort.
>
> Fourth, ash can reduce the efficiency of the pellet appliance when it builds up on the burn pot surfaces (reducing air flow) and coats the heat exchanger tubes (reducing the delivery of heat).

The ash characteristics of an agricultural feedstock will depend on the plant, where and how it is grown (with what fertilizers and other chemical applications), and how it is harvested. Until the agricultural feedstock is tested, the ash characteristics, and thus the suitability of that feedstock for fuel pellets, are unknown.

PFI's proposed standards for inorganic ash content in residential/commercial densified fuels are:

Fuel Pellet Grade	**Ash Content**
Super Premium	0 to 0.5%
Premium	0 to 1.0%
Standard	0 to 2.0%
Utility	0 to 6.0%

The white wood (without bark) of most tree species has an ash content less than 1%, but most agricultural by-products and residues have ash contents over 2%. The Agricultural Utilization Research Institute (AURI) recently obtained proximate and ultimate analyses on several potential agricultural materials for fuel pellets. The results for ash content were:

Feedstock	**Ash Content***
Corn Stover	5.01%
Soybean Straw	3.65%
Wheat Straw	7.82%
Switchgrass	5.51%
Blue Stem Grass	6.00%

The following are results of analyses previously reported by AURI. [39]

Feedstock	**Ash Content***
Shelled Corn	1.23%
Corn Gluten Feed	4.30%
DDGS **	4.13%
Dried Distillers Grains without Solubles	2.24%
Soybean hulls	4.22%
Sunflower Hulls	3.13%

* Test results are on a dry matter basis.

** The University of Minnesota was involved in some research that entailed analyzing DDGS from 34 different ethanol plants. The average ash content in the DDGS of 34 ethanol plants was found to be 6.00%. (These results can be found at www.**ddgs**.umn.edu/profiles/us-internatl%20comparison%20tables%20January%202006.pdf)

Researchers at the North Central Sun Grant Center of South Dakota State University summarized numerous published analyses and studies that address the composition of herbaceous biomass materials. Their report is useful because it illuminates statistical variation around mean values for feedstock characteristics. One of the feedstock characteristics the researchers examined is ash content as a percent of dry matter. The range of ash content values for corn stover is 4.2% to 7.5%. The range for wheat straw is 1.4% to 10.2%, and the range for switchgrass is 4.4% to 8.5%.[40] These findings of variation in feedstock are important. They indicate uncertainty and variability, but they also may indicate that there might be potential to control ash content to some degree.

[39] "AURI Fuels Initiative: Agricultural Renewable Solid Fuels Data," Agricultural Utilization Research Institute, Waseca, Minnesota.
[40] Lee, DoKyoung, Vance N. Owens, Arvid Boe, and Peter Jeranyama, Composition of Herbaceous Biomass Feedstocks. North Central Sun Grant Center, South Dakota State University, Brookings, SD, 2007. pp. 8-9.

Based on the results of available analyses, it appears that fuel pellets produced with most agricultural residues and by-products would fall into PFI's Utility grade.

Ash is made up of minerals and salts, and the properties of ash will differ by its elements. Ash is generally measured by weight, and it is for the PFI fuel standards. Ash content is the weight of all non-combustibles in fuel pellets expressed as a percentage of the total weight of the pellets, but the volume and other characteristics of ash may be more important than the weight. Light, flaky ash is more voluminous, and it will not remain in the burn pot and ash tray. This ash will be deposited throughout the appliance which reduces its efficiency, and cleaning an appliance that is filled with this ash is an unpleasant chore.

The new PFI Fuel Standards recommend that feedstock materials be evaluated for their "ash fusion properties." Ash fusion is a term which refers to the process of non-combustible ash melting and then forming solids (creating "clinkers" which are like lava rocks or slagging which is a hard coating on surfaces inside the appliance. The lower the ash fusion temperature of a fuel pellet, the more troublesome these formations will be.

Some stove manufacturers are designing their appliances to enable owners to use fuels other than premium wood pellets (low-grade wood pellets, agricultural biomass pellets, corn, pits, etc.). Multi-fuel appliances, as they are called, have a larger ash drawer, more flexible fuel feed systems, and grates and venting designs that can accommodate fuels with different moisture, fines and ash content. Until these multi-fuel appliances achieve significant market penetration, it cannot be said that agricultural biomass pellets are a substitute product for wood pellets in common use.

From a practical standpoint, an agricultural biomass pellet (or a mixed agricultural biomass/wood pellet) with a relatively low and benign ash content (i.e., ash that is grainy, not flaky, with a high ash fusion temperature) could probably be burned without incident in an appliance whose manufacturer recommends premium wood pellet only. Any representations to this effect in a feasibility study should only be made with some proof or attribution to a credible source, however.

In a feasibility study for an agricultural biomass pellet enterprise, it would be important to quantify and characterize the ash. An important part of the feasibility analysis might be test burns of the agricultural biomass pellet in various pellet fuel appliances.

Chloride Content

Chloride causes corrosion of metals, and alkali chlorides (potassium chloride and sodium chloride) cause slagging and fouling in a combustion system, which is why chloride is a subject of the PFI Fuel Standards. The new PFI Fuel Standards do not set specific values for chloride content in the different grades of fuel pellets. Instead there will be only a recommendation that chloride content should be below 300 parts per million (0.03%). Without question, chloride content is a problem for agricultural biomass pellets, if for no other reason because of PFI's recommendation. By establishing a recommendation of less than 300 parts per million, PFI has put most agricultural biomass out of conformance.

Proximate and ultimate analyses recently obtained by the Agricultural Utilization Research Institute indicate the following chlorine contents:

Feedstock	**Chlorine Content*** **
Corn Stover	1,030 ppm (parts per million)
Soybean Straw	1,430 ppm
Wheat Straw	298 ppm
Switchgrass	1,950 ppm
Blue Stem Grass	2,010 ppm
Crude Glycerol	18,150 ppm
Shelled Corn (#2)	586 ppm

* Test results are on a dry matter basis except those for crude glycerol.

** Chlorine and chloride are not the same. Chlorine was tested in these ultimate analyses, but the PFI standard is for chloride. Nevertheless, a laboratory technician at Minnesota Valley Testing Laboratories has stated that the results are indicative of the presence of chlorides in comparable concentrations.

The previously referenced University of Minnesota analysis of distillers grains with solubles from 34 ethanol plants found an average chloride content of 900 parts per million.

The University of Minnesota conducted other research on the chlorine content of biomass materials to support the University's application for an air emissions permit to co-fire oat hulls in its Southeast Steam Plant (which the Minnesota Pollution Control Agency approved). The University tested numerous samples of oat hulls for chlorine content and found that "the chlorine content range for oat hulls is relatively narrow, with a maximum content of 1,800 ppm (0.18%)."[41] (This maximum chloride content is six times the Pellet Fuels Institute's recommended maximum level of 300 ppm for residential/commercial densified fuel).

As part of the air emissions permitting process, the Minnesota Pollution Control Agency requested that the University compare the chlorine content of oat hulls to the chlorine content of different wood species to establish whether the chlorine content of oat hulls is a significant issue. The analysis produced by the University of Minnesota includes a table of various laboratory analysis results "extracted from a literature review database, (which) indicates that untreated wood contains chlorine at much lower levels than oat hulls" as follows:[42]

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[41] Air Emission Permit No. 05301050-021: Amendment to Air Emission Permit No. 05301050-011 Issued to the University of Minnesota and Foster Wheeler Twin Cities, Inc for the University of Minnesota Twin Cities Southeast Steam Plant. (Attached Fuel Chlorine Analysis produced by the University of Minnesota on May 26, 2005.) Minnesota Pollution Control Agency, February 14, 2006.

[42] Air Emission Permit No. 05301050-021: Amendment to Air Emission Permit No. 05301050-011 Issued to the University of Minnesota and Foster Wheeler Twin Cities, Inc for the University of Minnesota Twin Cities Southeast Steam Plant. (Attached Fuel Chlorine Analysis produced by the University of Minnesota on May 26, 2005.) Minnesota Pollution Control Agency, February 14, 2006. p. 7.

Wood Feedstock	Chlorine Content
Birch and maple	270 parts per million (ppm)
Oak, birch and maple	180 ppm
Mixed hardwood chips	290 ppm
Pine chips	200 ppm
Pine chips (with bark)	70 ppm
Hybrid poplar	90 ppm

The chloride content of any feedstock will vary from one sample to the next. This means that the fuel pellets produced with agricultural biomass will have higher or lower chloride content, depending on the bale or bucket full of feedstock. Nevertheless, it is generally true that agricultural biomass has higher chloride content than wood, and this is likely to remain the case as long as potassium chloride – potash – is a common fertilizer.

The relatively high chloride content of agricultural biomass is perceived as a demerit for agricultural biomass fuel pellets; but the extent to which the higher chloride content would actually cause more corrosion, slagging and fouling in pellet appliances and venting does not seem to be well documented. Multi-fuel pellet appliances are advertised as "corrosion-resistant." If multi-fuel appliances made with corrosion-resistant stainless steel achieve significant market penetration, then the issue of chloride content in agricultural biomass pellets should become a lesser concern.

Feedstock and Pellet Standards and Tests

There are tangible criteria for assessing the viability of agricultural biomass fuel pellets for residential/commercial uses: energy value, durability, moisture content, ash content and chloride content. By these criteria, agricultural biomass pellets are generally inferior to wood pellets. With almost any feedstock, pure agricultural biomass fuel pellets will have lower Btu content and higher ash and chloride content than high-quality wood pellets. (Depending on the feedstock and production process, agricultural biomass pellets could have comparable durability and moisture content to wood pellets.) Most agricultural biomass fuel pellets would be inferior to shelled corn, too, by the criteria of durability, ash content and chloride content. This does not mean, however, that agricultural biomass fuel pellets are not a viable product.

Viability criteria can be tangible (scientific measures of energy content, etc.), but the standards of viability are subjectively established. To illustrate, PFI previously decided that a "Standard" fuel pellet could have inorganic ash content up to 3%. The new PFI Fuel Standards for a "Standard" pellet allow inorganic ash content up to only 2% (even while manufacturers are redesigning their pellet appliances to accommodate higher ash content).

Regarding chloride content, PFI explains in its "Rational (sic) Behind the Proposed New PFI Standards" that European countries have standards ranging from 200 ppm to 800 ppm, but "the new standards are incorporating a general recommendation that chloride concentrations be kept below 300 ppm until enough information is present to set an actual limit."[43] This

[43] Pellet Fuels Institute "Rational Behind the Proposed New PFI Standards." Available at the Pellet Fuels Institute website at www.pelletheat.org.

might be interpreted to mean that PFI doesn't have a sufficient scientific basis for setting a 300 ppm chloride standard, so PFI will *recommend* a 300 ppm threshold, which is just higher than the chloride content of commonly used wood species and lower than most agricultural biomass.

Clearly, the new PFI standards will distinguish "Premium" and "Super Premium" wood pellets from agricultural biomass pellets, which would most likely fall into a "Utility" grade, (whatever that is supposed to connote). Whether the PFI standards will be relevant in the future depends in large part on appliance manufacturers. If they build and warranty "multi-fuel" appliances that handle agricultural biomass pellets well, then PFI's grading system would matter less. This assumes, of course, a demand for pellet appliances that may not exist, however. The features of multi-fuel appliances won't matter if the appliances are not sold in sufficient quantities to create a critical mass of demand for fuel pellets.

Also important will be the subjective judgment of retailers regarding the viability of agricultural biomass pellets. Retailers may be resistant to stocking fuel pellets of different ingredients and grades because of shelf space considerations, exclusivity agreements with wood pellet companies, and other reasons. If, however, a retailer stocks agricultural biomass pellets, and then customers complain about their performance, that retailer would certainly make a negative judgment about the viability of agricultural biomass pellets.

It would be a shame to build a $5.0 million pellet plant to produce agricultural biomass pellets that would be rejected by appliance manufacturers, retailers and consumers. Before spending money on other development tasks, it would be a good idea to identify and test the agricultural biomass materials and different pellet mills that may be used. An independent laboratory can be engaged to test and report the physical and chemical characteristics of feedstock and pellets. Finally, the performance of the pellets should be tested in different appliances to assess lighting ease, flame stability, ash characteristics (circulation, slagging, fouling, formation of "clinkers," etc.), and other product viability factors. A feasibility study for an agricultural biomass pellet company would be strengthened considerably by inclusion of the results of this research, testing and analysis.

11.2 Viability in Industrial, Institutional & Utility Sectors

Biomass fuel can be used to produce process heat and electricity in manufacturing facilities. Wood and pulp waste are commonly used fuels in paper mills, for example. Biomass can also be used as primary or secondary fuel in district heating facilities and utility-scale power plants. Wood, again, is the most common biomass fuel in these uses.

Biomass can be directly combusted. It can also be gasified or processed by other technologies into different solid, liquid and gaseous fuels. Biomass can be blended with other fuels. For examples, pipeline-quality "bio-gas" can be blended in natural gas pipelines, and solid biomass can be co-fired with coal.

Co-Firing in Europe

In Europe, wood has become a popular fuel in district heating systems and in other large-scale industrial and utility plants because carbon dioxide produced by biomass combustion does not count (by various methods for various purposes) in calculations of greenhouse gas emissions. Wood pellets, ground wood, and wood chips are burned separately or co-fired with coal in European facilities for the purposes of achieving environmental and energy security objectives at some greater cost than using only coal.

The European Commission produced an excellent study on co-firing biomass with coal. The authors found:

> In general, the energy systems which co-fire biomass with coal are more expensive than dedicated coal systems. Therefore, reasons for co-firing are primarily connected with environmental benefits rather than cost-savings.
>
> There are many successful co-firing systems, however there are various constraints that may be encountered…The constraints related to co-firing can include fuel preparation, handling and storage, milling and feeding problems, different combustion behavior, possible decreases in overall efficiency, deposit formation (slagging and fouling), agglomeration, corrosion and or erosion, and ash utilization.
>
> The degree of these difficulties depends on the quality and percentage of biomass in the fuel blend, type of combustion and/or gasification used, the co-firing configuration of the system, and properties of coal. With proper combination of these elements many power plants practice co-firing without major problems. The importance of the problems rises however with increased biomass/coal ratios, and when low quality biomass is used as a feedstock, especially in direct co-firing systems without dedicated biomass infrastructure.[44]

The Europeans have found that biomass pellets (mostly wood pellets) have some superior characteristics over other forms of biomass including high bulk density, uniform size and consistent energy value. With proper facilities and equipment, biomass pellets can be transported, handled and stored efficiently. Biomass pellets can also be crushed or pulverized with coal and blended consistently. Biomass pellets have proved to be less than ideal in a co-firing environment, however:

> Despite numerous benefits of utilizing pellets in co-firing systems, there are also challenges related to it. Problems can appear during uploading and unloading of pellets, as they can be sensitive to mechanical damaging (easily disintegrate and cause dust and handling problems). Some of the pelletized biomass handle very poorly when wet, as pellets absorb moisture from the surrounding air and can swell,

[44] Maciejewska, A., H. Veringa, J. Sanders and S.D. Peteves, Co-firing of Biomass with Coal: Constraints and Role of Biomass Pre-Treatment. Directorate-General Joint Research Centre, European Commission, Luxembourg, 2006. pp. 56 and 8.

> lose shape (and) consistency, and cause handling problems. Therefore pellets should be stored in a dry condition, or storage times should be minimized to prevent absorbing atmospheric moisture.[45]

That said, European demand for wood pellets continues to increase. This is evidence that biomass pellets are a viable product for co-firing with coal in the industrial, institutional, and utility sectors. Again, it is important to keep in mind that wood pellets have been used extensively in Europe, but agricultural biomass pellets have not been.

Chlorides in Agricultural Biomass Pellets

There may be viability issues related to alkali chlorides (particularly potassium chloride and sodium chloride) contained in agricultural biomass pellets. As explained previously, chlorides cause corrosion, and alkali chlorides cause slagging and fouling. This is generally not a problem associated with wood pellets, but it is a problem with pellets made from agricultural biomass.

> "Alkaline metals that are usually responsible for fouling of heat transfer surfaces are high in biomass ashes and are released in the gas phase during combustion…The elemental composition of ash (alkali metals, phosphorus, chlorine, silicon and calcium) affects ash-melting behavior. Even a small concentration of chlorine in the fuel can result in deposition of harmful alkaline and chlorine compounds on boiler heat transfer surfaces."[46]

According to the authors of the European Commission report, burning coal (which contains sulfur) with high-chloride biomass can mitigate the corrosive effects of the chloride. (Under certain conditions, alkali chlorides can react with sulfur dioxide to form alkali sulfates which are less corrosive than chlorides. Then, however, hydrogen chloride is formed and discharged, which can create an air emissions issue.) The presence of sulfur only reduces the severity of corrosion; it doesn't eliminate corrosion due to chlorides. Therefore, the European Commission report suggests anybody co-firing coal and agricultural biomass should be concerned about the impact on repair requirements, down-time and useful life.

The European Commission report takes this issue so seriously that it describes some rather drastic measures to reduce negative effects of chlorine and alkali chlorides. One suggestion is to pre-treat the biomass by washing (leaching) it with water to remove potassium, sodium and chlorine. Another option would be to add chemicals to the agricultural biomass during the conditioning stage prior to pelleting. "Results show that an additive of ammonium sulphate, which converts gaseous potassium chloride into potassium sulphate (a much less corrosive compound), could result in reduced corrosion rates and deposit growth rates by

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[45] Maciejewska, A., H. Veringa, J. Sanders and S.D. Peteves, Co-firing of Biomass with Coal: Constraints and Role of Biomass Pre-Treatment. Directorate-General Joint Research Centre, European Commission, Luxembourg, 2006. pp. 72-73.

[46] Maciejewska, A., H. Veringa, J. Sanders and S.D. Peteves, p. 30.

50%. Another option is adding to the process dolomite or kaolin, which increases ash melting point, and can reduce negative effects of alkali compounds."[47]

Chlorides in Ash

As previously discussed, agricultural biomass pellets would have a higher ash content than wood pellets, but this would not cause a handling problem in an industrial/institutional/utility co-firing environment. In fact, agricultural biomass generally has a lower ash content than coal. So, the quantity of ash is not a problem, but the chemical content of the ash might be.

If agricultural biomass pellets are co-fired with coal, then agricultural biomass ash would mix with coal ash. (This would be the case unless there are parallel co-firing combustion systems, each with its own fuel feeding, combustion, and ash handling system.) The presence of biomass ash in the coal ash may reduce its value or render it unmarketable as a concrete ingredient, which is ordinarily the highest value use of coal ash. This would depend on the concentrations of alkali chlorides.

This may be an important issue for utilities and other operators of large coal-fired systems. If they currently rely on ash sales revenues, then they would have to be persuaded – and their customers would have to be persuaded – that inclusion of agricultural biomass ash would not negatively affect the characteristics of the concrete. This may require rigorous testing to determine conformance with industry standards, and, in the case of concrete for roadway construction, approval by departments of transportation. This may all be perceived as an unnecessary by utilities, which could choose to co-fire wood pellets instead (which have much lower alkali chloride levels) or not co-fire biomass at all.

Chlorides Issue: Lessons from U.S. Projects

It is hard to say how difficult these issues related to chlorine and alkali chlorides would be for a producer of agricultural biomass pellets trying to sell pellets in the industrial, institutional and utility sectors. Clearly, Europeans are concerned about the potential for corrosion, slagging, fouling and other problems, and these issues have received attention in agricultural biomass projects in the United States.

To put the chloride content of agricultural biomass in perspective, corn stover contains about 0.1% chlorine, which is about five times more than most wood species; but turkey litter has chlorine content of about 0.5%, or five times that of corn stover. A manufacturer's representative for a fluidized-bed combustion system indicated that turkey litter could be a primary fuel as long as the system is built with corrosion-resistant stainless steel; and turkey litter is the primary fuel for the Fibrominn power plant in Benson, Minnesota. It seems then that agricultural biomass, with a lower chlorine content than turkey litter, could be a fuel in any ***new*** plants that are properly designed for such a fuel.

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[47] Maciejewska, A., H. Veringa, J. Sanders and S.D. Peteves, Co-firing of Biomass with Coal: Constraints and Role of Biomass Pre-Treatment. Directorate-General Joint Research Centre, European Commission, Luxembourg, 2006. p. 53.

Results of two projects where coal and agricultural biomass are co-fired in ***existing*** facilities are promising, too. The Chariton Valley (Iowa) biomass power project involves co-firing switchgrass with coal at Alliant Energy's Ottumwa Generating Station. In May 2006, a 1,675-hour test burn was completed. More than 15,600 tons of switchgrass were co-fired with coal. Among the stated purposes of this test were to assess slagging and fouling and to estimate potential corrosive effects on the boiler. Apparently, the test results were generally positive (but one might question whether a test of less than three months duration could be conclusive regarding long-term impacts on boiler efficiency, reliability, and repair and replacement requirements).

For the Chariton Valley project, an important project milestone was achieved when the Iowa Department of Transportation approved fly ash resulting from 5% switchgrass co-firing for inclusion in concrete on state highway projects. The approval was viewed as critical because Alliant Energy has historically sold its fly ash from the Ottumwa Generating Station as an ingredient in concrete for road construction. Obtaining this approval was the focus of a great deal of testing, analysis and deliberations; it was feared that failing to obtain the approval would be a "deal-breaker." In the end, it appears that the presence of chlorides in the ash would not necessarily turn a profitable product into a problematic waste.

The University of Minnesota operates what is known as the Southeast Steam Plant to produce heat and power for the Twin Cities campus. As explained in a report by the Green Institute, the University of Minnesota is now permitted to co-fire wood and oat hulls with natural gas, coal and fuel oil. Currently, about 25% of the University's boiler heat is supplied by oat hulls "without any boiler problems," according to the Green Institute.[48]

The University of Minnesota conducted extensive analyses to support its application for an amendment to its air emissions permit to allow co-firing oat hulls. One simple analysis is particularly illuminating. The University of Minnesota found the range of chlorine content in 11 samples of oat hulls was 880 ppm to 1,800 ppm. However, when oat hulls and coal were blended at 9% oat hulls and 91% coal, the chlorine content of three tested samples of blended fuel was only 100 ppm to 130 ppm.[49] Thus, by simply blending high-chloride agricultural biomass with coal, the concentration of chlorides is reduced significantly. (Furthermore, as discussed previously, the presence of sulfur in the coal may mitigate the corrosive effects of the chlorides.)

Preference for Wood Pellets

In Europe, wood pellets are commonly co-fired with coal. Wood pellets are more expensive than coal, but they are co-fired in European heating and electric generation plants nevertheless to achieve energy security and environmental objectives. The European use of

[48] Nelson, Carl, Renewing Rock-Tenn: A Biomass Fuels Assessment for Rock-Tenn's St. Paul Recycled Paper Mill. Green Institute, Minneapolis, Minnesota, March, 2007. p. 28.

[49] Air Emission Permit No. 05301050-021: Amendment to Air Emission Permit No. 05301050-011 Issued to the University of Minnesota and Foster Wheeler Twin Cities, Inc for the University of Minnesota Twin Cities Southeast Steam Plant. (Attached Fuel Chlorine Analysis produced by the University of Minnesota on May 26, 2005.) Minnesota Pollution Control Agency, February 14, 2006. pp. 4-5.

wood pellets really says nothing at all about the viability of agricultural biomass pellets in the United States.

Wood is superior to agricultural biomass in terms of energy content and chemical composition. The chlorine and alkali chlorides content of agricultural biomass may not be terribly damaging to a large-scale boiler if the agricultural biomass is co-fired with coal in a relatively small percentage (less than 10% agricultural biomass); but, in fact, the long-term impacts of corrosion, slagging and fouling on boiler efficiency, reliability and longevity are not known. Until they are known with a high level of certainty, utilities are likely to prefer using only coal or co-firing wood instead.

Likewise, when choosing concrete it would be understandable for a contractor to "rather be safe than sorry." Thus, bridge builders may not be inclined to use concrete containing corrosive compounds. This is not to say that agricultural biomass is not a viable fuel for co-firing with coal, but merely to suggest that perhaps a sufficient proof of viability, particularly with respect to its chlorides content, has not yet been established.

Pellet Form

Pellets have some excellent characteristics, including consistency of shape, density, moisture content and energy value; and pellets can be blended and pulverized with coal, unlike some other biomass forms. However, pellets can disintegrate in mechanical handling systems, and they lose functionality when they absorb moisture. In short, pelleting biomass does not create an impervious form.

Perhaps for the industrial, institutional and utility sectors, it would be instructive to consider pellets in terms of whether biomass pellets are a "superior solution" (rather than a "viable product"). After all, pelleting biomass requires equipment, energy and labor. One should incur the costs to pellet biomass if pelleting appears to be the only solution or the most cost-effective solution to a problem or challenge. In the past decade, there have been numerous opportunities to choose the solution of pelleting biomass for large-scale biomass projects in the upper Midwest, but pelleting hasn't been chosen yet.

- For the Chariton Valley switchgrass project, the fuel processing "solution" is to deliver bales of switchgrass to a processing facility adjoining the Ottumwa Generating Station. The bales are shredded, and the switchgrass is blown into the boiler. This is a sufficient processing solution to convert farmers' large round bales of switchgrass into boiler fuel.

- The Fibrominn power plant in Benson, Minnesota has arrangements for turkey litter to be shipped from western Wisconsin, a distance of more than 200 miles. This "solution" does not entail pelleting the turkey litter to improve its hauling and handling characteristics.

- The University of Minnesota is receiving large quantities of oat hulls at its Twin Cities campus for co-firing with coal in the Southeast Steam Plant. Oat hulls do not have ideal physical characteristics, but there is no need to incur the expense of pelleting the oat hulls for transportation, storage or blending.

- When the St. Paul cogeneration facility had quality control problems with its wood supply, its solution was not to contract for pelleted wood. Instead, an off-site receiving and processing station with grinding and screening equipment was developed to ensure that wood delivered to the cogeneration plant meets fuel specifications.

- At the University of Minnesota – Morris, a biomass gasification facility is under construction. The primary fuel is intended to be corn stover. To date, the project team has apparently not anticipated a problem for which pelleting the corn stover is the only solution or the most cost-effective solution.

Biomass pellets would work in all of these facilities, but pellets simply aren't necessary. For these facilities, pelleting the biomass would be over-processing; it would not make economic sense to pay for pelleting when all they need is grinding and/or drying.

The examples above are relatively large-scale. It could be that the economics and physical possibilities are different for smaller-scale industrial, institutional and utility plants, especially those located in densely developed areas with restricted space. For them, buying, storing and using pellets may be a more cost-effective solution. To date, however, there does not seem to be a market for biomass pellets to fuel heating and power systems in these sectors. Thus, the viability of this solution is not evident.

Market Opportunity

Practically speaking, most operators of coal-fired heating and power systems in industrial, institutional and utility plants are probably not eager to go to the trouble and expense necessary to co-fire agricultural biomass pellets. This would entail performing engineering and environmental tests and analyses, obtaining an amended air emissions permit, designing and constructing new facilities (for receiving, storage and fuel delivery), developing new operational practices and risk management strategies, creating new business relationships, and more. Then the results may be higher fuel costs (at least until a carbon tax is imposed), reduced efficiency and reliability, and higher maintenance and repair costs.

Utilities may not view co-firing biomass with coal as a viable solution until they must solve a new problem – one that relates to greenhouse gases or a renewable energy mandate. From a utility's perspective, co-firing biomass may be a less expensive renewable energy solution than developing and operating new wind power or dedicated biomass energy projects. Even then, however, the utility would seek out the least expensive biomass material that can be co-fired, which may not be agricultural biomass and it may not be in pellet form.

Are agricultural biomass pellets a viable product in the industrial, institutional and utility sectors? Perhaps they are today. If not, perhaps they will be in the future. Today, however, a feasibility study could not make any credible claims of opportunities to sell agricultural biomass pellets in this market unless proof can be exhibited in the form of an executed long-term fuel supply contract.

12. Technical Feasibility

The technical feasibility section of a feasibility study is most important for a project that relies on new technology or a new application of existing technology. The equipment and processes in a pellet plant are proven technologies that were commercialized many years ago. If the intention is to build and operate a fully equipped pellet plant using conventional equipment, then the technical feasibility section of a feasibility study could be short. (There are, however, decisions about facilities and equipment that warrant some explanation in the technical feasibility section, at least in some broad terms to describe a general approach or strategy.)

On the other hand, a plant design and operating plan could be so innovative that a presumption of technical feasibility is not justified. An example of this might be a pellet plant that would have an integrated biomass-fired heat (for drying) and electrical generation system. This would require a technical feasibility justification.

If the plan is to build a pellet plant without a tub grinder or a dryer, or without ample feedstock and finished product storage, then there would be some questions to answer in the technical feasibility section. In a nutshell, not having a dryer means having little margin for deviation on feedstock specifications; not having storage facilities means having little margin for error or disruption in a "just in time" operating plan. The technical feasibility section could address the basis for such certainty and what might be done if something goes wrong.

Another set of technical feasibility issues would arise if pellets with some exact physical and chemical characteristics are to be produced from a precise recipe of agricultural biomass ingredients (plus binders and additives perhaps). Then there would be technical questions about individual feedstock specifications, substitutability of feedstocks, blending process, pellet specifications, quality control, variability tolerance, and other matters. (Introducing such sophistication might seem like a good idea until commercial operations actually begin.)

In the technical feasibility section, it may also be appropriate to discuss the controllable variables that affect production rates and pellet quality, to the extent that these will be managed to enhance the overall viability of the pellet plant. These include feedstock specifications (as received), storage and handling practices, first-stage grinding size, dryer temperature and drying time, moisture content of particles exiting the dryer, hammermill screen size, conditioning process settings (temperature, moisture, time, etc.), pellet die specifications, cooling time, and more.

The Pellet Fuels Institute is recommending a Quality Assurance/Quality Control (QA/QC) program to ensure that a pellet plant's production consistently conforms to the parameters identified on the product label and specified in domestic and export transactions. Details of the Pellet Fuels Institute QA/QC program can be found at the PFI's website: www.pelletheat.org. If the intended market for the agricultural biomass fuels is one that would likely expect a rigorous quality assurance program, then this might be addressed in the technical feasibility section.

13. Plant Requirements and Capital Costs

This chapter contains information about the facilities and equipment required for a viable agricultural biomass pellet plant, but in fact requirements vary by more than just size. A first-stage tub grinder and dryer may be necessary, but not if the only feedstock will be dry, small-particle material. An automated bagging system may be more or less economical than a manual bagging system, but perhaps there is no need for a bagging system at all. There is a wide range of possible scenarios for feedstock delivery and finished product shipment, and each scenario may require different feedstock and pellet storage facilities.

The information provided in this chapter is intended to serve as only a guide or a starting point from which pellet plant developers will depart as they take into account their unique feedstock supply options and pellet market opportunities. Generally, the approach taken in this chapter is to "err on the high side," which is to say making sure that specifications and cost estimates meet or exceed requirements.[50]

As discussed previously, the exercise of planning and budgeting a pellet plant is difficult because there are no engineering companies or contractors that have created and used project templates or design packages to build numerous pellet plants; and there are no industry standards or best practices for pellet plant design and construction.

For this feasibility study guide, a thorough literature search was conducted to assemble available reference materials and analyses on pellet plants and their capital and operating costs. In addition, price quotations and budget estimates were obtained from engineers, contractors, and manufacturers' representatives. While the cost information contained in this document is useful for general estimating purposes, it is not sufficient to justify an actual project budget. The price estimates for the plant and equipment are non-binding, and they were not obtained in a bidding or negotiating process. While reasonable efforts were made to identify and estimate the cost of all required items for a pellet plant, some may have been

[50] Some industry observers recommend going further than "erring on the high side." They recommend that a pellet plant be initially designed to allow increasing the production capacity by simply adding a parallel pellet mill. Providing room for another pellet mill in the plant layout probably makes sense. Whether it would also make sense to initially install oversized equipment is less certain. For example, installing a dryer capable of drying twice as much feedstock would add a significant amount to the capital budget, and also result in higher operating costs because the drying stage would be less efficient than it would be with a properly sized dryer. There is not a "right" answer to this issue; it is a matter of business approach for each pellet plant developer to resolve.

overlooked and others double-counted. When a real project is developed, the project engineer and general contractor would be expected to assemble the entire project budget, ensuring that all required items are budgeted once, based on best-available pricing.

Used Equipment

Used pellet plant equipment is available, but only new equipment is budgeted in this feasibility study guide. The underlying presumption of this feasibility study guide is that a pellet plant would be built to succeed, not to fail. The equipment should therefore be selected based on specific criteria, not picked because it is available and cheap, and the plant should start with a full economic life ahead of it (and warranties, too).

Mr. Averill H. Cook, who recently produced a document for AURI titled "The Challenges and Economics of Pellet Production," offers a cautionary point on the subject of used equipment. He suggests that feeder bins, conveyors, grinders, and storage bins that were previously used in other facilities could be rebuilt and reused in a pellet plant; but "it is advised that careful attention be given to using any used equipment, especially pellet mills…A number of feed mills that have been retrofitted for the manufacture of fuel pellets have been destroyed by fire or have caused fatal accidents as a result of trying to make machinery work in an application for which it was not designed."[51]

Basis for Equipment Requirements and Capital Budget Estimates

In this chapter, descriptions and capital budget estimates are presented for five agricultural biomass pellet plants which are described as:

2-Ton/Hour ("farm-scale")
4-Ton/Hour
8-Ton/Hour
14-Ton/Hour (first estimate)
14-Ton/Hour (second estimate)

The number of tons/hour refers to tons of finished pellets that each plant could produce, not tons of feedstock.

Some explanation of the following capital budget estimates is necessary. The capital budget estimates for the first four pellet plants are based on one manufacturer's pelleting equipment. For each plant size, a manufacturer's representative provided equipment descriptions and price estimates for the hammermill, conditioner, pellet mill, cooler and screener. Descriptions and price estimates for the primary grinder, dryer and bagging/palleting systems were obtained from other vendors.

The capital budget estimate for the "farm-scale" 2-ton/hour pellet plant provides a fair accounting of equipment costs and some guesswork on how much a resourceful farmer would spend on engineering and installation.

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[51] Cook, Averill H. "The Challenges and Economics of Pellet Production." Document produced for Agricultural Utilization Research Institute, 2007. pp. 1-2.

A contractor assisted in the development of a detailed capital budget estimate for an 8-ton/hour pellet plant. Budget estimates for the 4-ton/hour plant and the first 14-ton/hour plant were extrapolated from that budget estimate.

The second capital budget estimate for a 14-ton/hour pellet plant is based on the equipment of several manufacturers. An engineer assisted in assembling prices for the equipment included in this budget estimate, and he also provided cost estimates for engineering, project management, building construction, equipment installation and other costs.

Two separate capital budget estimates were produced simultaneously for the 14-ton/hour pellet plant to validate one estimate against another and to test how much a capital budget estimate would vary based on selection of different manufacturers' equipment. The 14-ton/hour plant size was selected for this purpose because a pellet plant of this size is probably the most economically viable.

Neither the contractor (who assisted with the capital budget estimate for the 8-ton/hour pellet plant) nor the engineer (who assisted with the capital budget estimate for the second 14-ton/hour pellet plant) is responsible for the presentation of any capital budget information contained in this feasibility study guide. The author made adjustments to their cost estimates for various reasons which are explained in the following discussion. (Assumptions underlying the cost estimates are believed to be reasonable, but they warrant critical review by competent professionals before the cost estimates are used or cited for any purpose.)

The capital cost estimates provided in this chapter and used in the financial analyses should be considered approximate and for informational purposes only. These estimates should not be relied upon for any business or investment decisions whatsoever. The purpose of this capital cost presentation is to offer one set of budget estimates that may be used for comparative purposes and to provide guidance for a project-specific feasibility studies. The capital cost estimates should not be viewed as sufficiently justified for a feasibility study.

Site and Site Preparation

A pellet plant should be located on high ground where there is good access to unrestricted highways. Railroad service is probably not essential, but it could be advantageous.

The site needs electrical service and should have natural gas service to fire a dryer and meet other thermal loads, even if the initial plan is to have no dryer or a solid fuel-fired dryer. Utility costs are significant enough for a pellet plant that a criterion for site selection should be electrical and natural gas rates. There is no need for a large water supply.

If the business basis of an agricultural biomass pellet company is a long-term arrangement with a single source of feedstock, such as an ethanol plant, the pellet plant may be built next to the feedstock source. If there isn't a single-source, it would make sense to select a location in reasonable proximity to large volumes of multiple potential feedstocks – logging and sawmill residues as well as agricultural biomass.

Similarly, it may be advisable to build a pellet plant near (or on the same highway as) a committed long-term customer (a municipal utility perhaps) or in a region where the market for fuel pellets is expected to be strong (although it is hard to say why a particular region might be strong). A word of caution: Selecting an otherwise inferior site just because it is near a single feedstock source or a single customer could prove regrettable if that entity quits doing business with the pellet plant.

Pellet plants can generate traffic, noise, dust, and disputes with neighbors – the fewer neighbors to a pellet plant, the fewer potential disputes. Unless there are compelling reasons to build a pellet plant near existing commercial, industrial or residential development, a location without neighbors would be better.

An 8-ton/hour pellet plant and all of its facilities could occupy six to ten acres of land, depending on feedstock storage and warehouse space, but it would be prudent to purchase a larger parcel than the minimum requirements. With more land, there is room for expansion or reconfiguration of storage and truck flow, and a noise and dust buffer could be maintained between the plant and new neighbors.

The cost for a site and site preparation is subject to numerous factors. A reasonable estimate is $156,000 for the site and site preparation. An additional $60,000 is budgeted for paving between the buildings and at the receiving station and load-out area.

The budget estimate – guess really – for site and site preparation is for an 8-ton/hour pellet plant that would require large areas for feedstock and product storage facilities. A smaller pellet plant whose feedstock is dry agricultural processing by-products (which could be stored in grain bins) would require a smaller parcel, but depending on the location and work required, the site, site preparation and paving costs could exceed $216,000. This budget estimate is used in the following financial analyses for all pellet plants except the "farm-scale" pellet plant.

Pellet Plant Building and Offices

The features of a pellet plant building and offices and their associated costs are somewhat subject to the owners' preferences. A budget estimate of $1,020,000 is based on a cost of $50/square foot for a building that is 20,000 square feet in total size plus $20,000 for build-out of the offices. This size building would accommodate all of the equipment of a pellet plant, including a primary grinder and rotary drum dryer. (If room for a tub grinder and rotary drum dryer are not to be provided, the size of the building could be reduced by 4,000 square feet, and the cost by $200,000.) The building would provide an area for staging loaded pallets from which they would be moved to the storage warehouse or loaded on trucks, but it does not provide for long-term storage space.

The 20,000-square foot building corresponds approximately to the requirements for an 8-ton/hour pellet plant (with room for the initial installation of one pellet mill and a second pellet mill to be added later). The size and cost of a building for a smaller capacity or larger capacity pellet plant would not change proportionately with the change in production capacity – a 4-ton/hour pellet mill doesn't require half the footprint of an 8-ton/hour pellet mill. Entirely removing components (like the primary grinder, dryer or bagging system) would change the footprint more than downsizing each equipment component (but not providing space for later installation of these components could be a mistake).

In the following financial analyses, it is assumed that the 20,000-square foot building would be sufficient for the 14-ton/hour plant, and it is assumed that the cost of a building for the 4-ton/hour plant would be 80% of the cost of the building for the 8-ton/hour plant. When a project-specific feasibility study is produced, it may include a drawing of the plant layout showing the dimensional requirements of the pellet plant building. Then the cost of the building can be estimated more accurately.

It is assumed that the pellet plant with 2-ton/hour production capacity would fit into an existing building, the cost of which would not be charged to the capital budget for the "farm-scale" plant. (Similar assumptions are made throughout this analysis for the 2-ton/hour pellet plant such that the capital budget estimate is essentially the sum of costs to specify, purchase and install the equipment.)

Receiving Station and Scale

An agricultural biomass pellet plant should probably have a receiving station that could accommodate a variety of feedstocks. It is assumed that some feedstock would be dry, small-particle material, such as oat hulls or distillers grains, which would require different handling and protection from the weather than large round bales of corn stover.

Rough estimates of $130,000 and $120,000 were obtained for a receiving station with a scale. These estimates are reasonably validated the reported 2002 cost of $110,000 for a commercial-scale, baled-crop receiving station.[52]

Regardless of the production capacity of a commercial-scale pellet plant, a fully sufficient receiving station and scale probably would cost about $130,000. Conceivably, however, a pellet plant could operate without a receiving station and scale. Trucks and trailers could simply be unloaded or dumped, and payment would not be based on weight and measured quality as received. (Certainly if a "farm-scale" pellet plant were to be installed in an existing farm building, the expense of a receiving station and scale would not be incurred.)

Feedstock Storage

It is difficult to foresee what feedstocks may become available to a pellet plant and what assumptions should be made regarding when feedstock would be delivered and used to determine storage requirements.

For the purposes of this feasibility study guide, it is assumed that corn stover, soybean straw and grasses will be the primary feedstocks, and most large round bales of these feedstocks will have been stored outside on field edges without a tarp or roof over them. Upon delivery,

[52] Sokhansanj, Shahab and Anthony F. Turhollow, "Biomass Densification – Cubing Operations and Costs for Corn Stover." Applied Engineering in Agriculture, Volume 20(4): 495-499, 2004, p. 497.

these bales would be stored outside at the pellet plant on a 300' X 400' asphalt storage lot that is sloped and drained. (This storage lot should not be crushed rock because the rocks would end up in the pellet plant equipment; and it should not be dirt or grass because the bales would wick moisture from the ground.) For an 8-ton/hour pellet plant, this storage lot would be more than large enough to hold a two-week supply of feedstock.

This storage lot is estimated to cost $360,000. (This budget estimate does not include a roof, which may be a cost-effective improvement. Walls may not be desirable; they actually inhibit air-drying.) It is assumed that this 120,000-square foot storage lot would be constructed for the 8-ton/hour plant and the 14-ton/hour plant. For the 4-ton/hour plant, it is assumed that a lot half this size would be constructed at the same unit cost of $3.00/square foot.

Assuming the primary storage lot would not have a roof, there probably should be a partially enclosed storage facility (with a roof and walls but large door openings on at least two walls) for bales that were previously stored under cover (not standing uncovered at the field side). Small-particle agricultural processing by-products and wood residues could also be stored in this facility. A bare, uninsulated 20,000-square feet warehouse structure suitable for this purpose is estimated to cost about $280,000. (This warehouse would be a big pole building; the walls would not have the lateral strength of a grain storage building.)

The owners of an agricultural biomass pellet plant could try to run it on "just in time" delivery of feedstock, thereby reducing feedstock storage requirements, but the operational disruptions resulting from unreliable delivery may cost the pellet company more than was saved in the capital budget. (One might think that building for "just in time" delivery of feedstock might be more viable if the primary source of feedstock is a single agricultural processing plant, but there would still be supply interruptions due to weather, shutdowns, and other events.)

It is assumed that that the 4-ton/hour, 8-ton/hour and 14-ton/hour plants would all have a 20,000-square foot warehouse structure for feedstock and other storage needs. For the "farm-scale" 2 ton/hour pellet plant, it is assumed that feedstock storage facilities would not be constructed.)

Pellet Storage Facilities

If a pellet company's customer is an electric utility that co-fires pellets with coal in a baseload power plant on a year-round basis, then that pellet company would have an advantage with respect to pellet storage requirements. The pellet company would only need storage for two circumstances: when the electric utility's power plant is not operating or when the pellet plant is down. (In the latter situation, the pellet company would presumably need pellets in storage to meet its delivery obligations to the electric utility.)

More likely, a pellet company would sell pellets to residential and commercial customers that burn fuel pellets for space heating. Thus, its customers only need a significant quantity of pellets during the heating season, and they won't want to store pellets for months before the heating season starts. A pellet company that distributes fuel pellets through retailers rather than sells directly to customers would face the same situation. Retailers would not want to maintain an inventory of fuel pellets for months before the heating season starts.

Thus, pellet companies need adequate storage or provisions for storage elsewhere. Urbanowski indicates that some wood pellet plants have on-site storage for 40% of their annual production.[53]

Pellet companies that serve the residential and small commercial markets are likely to "package" fuel pellets. This entails filling and sealing 40-pound bags and stacking and wrapping 50 bags on each pallet for a one-ton deliverable load. These palleted loads present a storage challenge.

The primary option selected for this feasibility study guide is a warehouse in which loaded pallets would be put on pallet racks five high. A 100' X 200' warehouse with five-high pallet racks and doors on both ends could hold approximately 4,000 tons of bagged pellets on pallets. This size warehouse would not be sufficient to hold all of the inventory produced in the months preceding the heating season, but it may be enough to allow a pellet company to establish workable schedules for pellet bagging, palleting and shipping. The cost for such a warehouse is estimated to be $350,000.

When that warehouse is full, other options must be used. A realistic possibility is to store palleted bags of pellets outdoors with durable tarp coverings (at some risk of product damage). Alternatives to storing finished product on site would be to lease storage space near markets or pay retailers to store product they will later sell by giving significant discounts on pellets delivered before the heating season. Another approach could be to bag and pallet product on a "just in time" basis only (which might be feasible with large storage facilities for loose pellets and an efficient, high-volume bagging and palleting system).

Large quantities of fuel pellets could be stored in one or several grain storage bins or in a grain storage building. Loose fuel pellets could later be loaded into trucks or trailers for bulk delivery, or they could be conveyed into the bagging area of the pellet plant where the pellets would be bagged and palleted.

Tall hopper-bottom silos may be the best option from an operational perspective, but they would be the most expensive storage option. Large industrial grain bins with flat bottoms are a more economical option than hoppers; but the best option from an economic and operational perspective may be a large grain storage building. A grain storage building with capacity of about 24,000 tons (960,000 bushels) would cost about $1,480,000 ($1.54/bushel capacity). This grain storage building coupled with the pallet warehouse described above would provide storage for about one-third of the annual production of a 14-ton/hour plant.

It is assumed that an 8-ton/hour pellet plant would produce 48,000 tons of pellets annually, but production could hit 60,000 tons if it produced pellets at full production capacity for

[53] Urbanowski, Ernie, Strategic Analysis of a Pellet Fuel Opportunity in Northwest British Columbia. Simon Fraser University, Burnaby, British Columbia, Canada, Summer 2005. p. 17.

7,500 hours in a year. In this event, the operator of the pellet plant would not regret having 24,000 tons of storage capacity for loose pellets. Nevertheless, for the 8-ton/hour plant, it is assumed that the grain storage building would have capacity for 16,000 tons. The estimated cost would be $987,000, assuming the same unit cost as for the larger grain storage building.

For the 4-ton/hour pellet plant that produces 24,000 tons per year (perhaps as many as 30,000 tons in a terrific year), it may be reasonable to assume that the warehouse space for 4,000 tons of bagged and palleted product would be needed, but the storage capacity for loose pellets could be reduced to about 8,000 tons. This too would be a large grain storage building, and budgeted unit costs of $1.54/bushel capacity are expected to be sufficient. Thus, the estimated cost of this grain storage building would be about $493,000.

For the "farm-scale" 2-ton/hour pellet plant (which would be expected to produce only 4,000 tons of pellets per year), it is assumed that pellet storage facilities would not be constructed.

It may be obvious to the reader that there are no "right" answers for the size, type and cost of storage facilities for feedstock and finished product. This is a matter for each feasibility study to address based on assumptions and business operating plans for feedstock supply, pellet production, and product sales and delivery.

Primary Grinder

If the feedstock for a pellet plant may be large particles of wood or agricultural biomass, or if the feedstock is baled material, the pellet plant would probably need two grinders, with the first being referred to in the feasibility study guide as the primary grinder. The primary grinder is usually a heavy-duty hammermill, tub grinder, "hog" or shredder. The primary grinder is a powerful piece of equipment, designed to process large chunks of wood or densely baled agricultural material (and most other materials, too) into smaller pieces – usually less than two inches in all dimensions.

Not all pellet plants have a primary grinder. A pellet plant that uses only sawdust for feedstock would have no need for a primary grinder; nor would a pellet plant that uses only small-particle agricultural processing by-products like oat or soybean hulls.

Even if the operating plan for a pellet plant is to use only agricultural processing by-products, it would probably make sense to build the pellet plant with room for a primary grinder to be added later. If the supply of agricultural by-products is curtailed, or if a decision is made to convert to production of wood pellets, then a primary grinder may be needed. (Just having a primary grinder that is not used could be beneficial, too, if it provides negotiating advantage against suppliers of small-particle agricultural by-products.)

A critical specification of the primary grinder is the hopper size; it has to be large enough to accept large round bales. A 200-horsepower tub grinder with a list price of $684,950 was recommended by a manufacturer's representative based on an expectation that the feedstock would probably be baled corn stover, soybean straw or switchgrass, but that the primary grinder would have to be able to process logging residue and other wood materials, too (with required throughput rates of 14 to 16-tons/hour for agricultural biomass and 8-tons/hour for wood).

The same requirements were explained to another manufacturer's representative who recommended a low-speed, high torque shredder that would handle the dimensions of large round bales, break bales of any material (including dense bales of plastic), and chop agricultural and wood materials to the desired size. The manufacturer's equipment price estimate for this shredder is $650,000. (Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation or any connected equipment. The total installed cost of a primary grinder dryer might be about 50% more than the equipment price estimate.) Whether a pellet plant is designed to produce 8-tons/hour, half as much or twice as much, this would probably be an appropriate primary grinder if one is to be installed.

Given the high cost of a primary grinder, it may be appropriate to defer purchasing one if a sufficient and reliable supply of small-particle feedstock has been contractually arranged. If, however, the feedstock supply plan is to bring large bales of corn stover, soybean straw and grasses to the pellet plant, then a primary grinder probably has to be included in the initial capital budget.

A $650,000 grinder probably would not be purchased for a farm-scale 2-ton/hour pellet plant. The operator would most likely find a less expensive piece of equipment for debaling and chopping – maybe a chainsaw.

Dryer

Most literature on pelleting biomass suggests that feedstock should be dried to moisture content *around* 10%; but, according to one manufacturer's representative, feedstock entering the conditioner at moisture content of 13% to 15% is ideal. Then the feedstock would only be heated in the conditioner, and it would be dehydrated rather than hydrated.

Some reports indicate that feedstock with moisture content as high as 17% can be pelleted. This may be true, but it seems unlikely that the resulting pellets would meet high commercial standards in terms of moisture content, durability and energy content. (Perhaps these pellets would deteriorate if they are sealed in plastic bags for months, but they would perform well enough if they are shipped in bulk immediately after production for co-firing with coal in an industrial boiler.)

A dryer is used in pellet plants to reduce the moisture content of wood and agricultural materials from as high as 55% to usable levels. There is not a single "ideal" moisture content for feedstock entering the hammermill – it depends on the binding characteristics of the feedstock and the effects of the hammermill, conditioning process and pellet mill on the moisture content of the finished product. The primary goal is to produce durable pellets with moisture content in the 6% to 10% range, the lower the better. The moisture content of the feedstock is monitored and controlled through the stages of processing to reach that goal.

The issues related to moisture content of incoming feedstock, the extent to which moisture content can be affected in the conditioning and pelleting stages, and the maximum moisture content of a viable fuel pellet are important topics to be addressed in a project-specific feasibility study. The conclusion might be that a dryer would not be needed, which would significantly reduce estimates for capital and operating costs.

Like a primary grinder, a dryer is an expensive component, and a dryer requires a lot of energy to operate, too. A dryer can be a source of particulates and volatile organic compounds, thus complicating the environmental review and permitting process for a pellet plant. Furthermore, dryers are susceptible to fire and explosion. It is understandable that one would want to avoid purchasing and operating a dryer, but it may be unavoidable unless a pellet plant has arranged a reliable long-term supply of agricultural biomass that is consistently dry. In the following financial analyses, it is assumed that all plants would have dryers except the farm-scale pellet plant.

Rotary drum dryers are commonly used in wood pelleting and alfalfa dehydration plants, and this would be an appropriate dryer for just about any agricultural biomass. Rotary drum dryers are available in different designs and sizes, and they can be fired with natural gas, propane, fuel oil or solid fuel (biomass). The basic rotary drum dryer is a rotary drum with an attached burner that blows heated air through the tumbling feedstock. The drum may be designed as a single-pass (once-through) or a triple-pass drum.

Pricing, energy requirements, and performance information were obtained from three vendors of rotary drum dryers. Dryers were specified and budgeted for pellet plants ranging in production capacity from 2 tons/hour to 14 tons/hour.

Drying requirements were described as follows: The average moisture content of incoming feedstock would be 20%; dried feedstock would have to be 10% moisture content. The dryer must be able to achieve excellent drying performance and energy efficiency in that 20%-to-10% scenario; but the dryer must also be capable of drying feedstock from 30% to 10% moisture content with satisfactory throughput and energy efficiency. (In fact, all of the dryers budgeted could achieve satisfactory throughput rates with feedstock as high as 50% moisture content.)

Below are budget estimates for natural gas or propane-fired dryers. The capacity indicated for each dryer is not the throughput rate. It is the production capacity of the pellet plant for which the dryer would be suitable.

DRYER

2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
$176,000 to $180,000	$192,000 to $240,000	$268,000 to $335,000	$426,000 to $690,000

(Important note: These are equipment price estimates *only*. They do not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connected equipment. The total installed cost of a dryer might be about 50% more than the equipment price estimate.)

The author of this feasibility study guide has no basis to believe that the lower priced dryers for each plant size are not suitable for the intended purposes, so their costs are used in the following financial analyses. Given the wide price ranges, however, care should be taken when selecting a rotary drum dryer for a pellet plant. A project-specific feasibility study may explore what accounts for the significant price differences between brands.

As stated previously, it may make sense to over-size components in a pellet plant so that capacity may be increased later by adding a second or third pellet mill in a parallel configuration. Over-sizing the dryer may not make sense, however. An exercise completed with the assistance of a manufacturer's representative shows that drying feedstock in a full dryer would use 30% less energy (Btu) than drying the same amount of feedstock in a half-full dryer. This is enough to have a significant impact on operating costs and net income.

As with a primary grinder, if a dryer isn't going to be installed initially, the pellet plant and equipment configuration should be designed so that a dryer can be added later. If the pellet plant is not designed for the later addition of a dryer, it is unlikely one would fit. The dimensions of a rotary drum dryer for an 8-ton/hour pellet plant would be about 112' length, 11' width, and 30' height.

(The price of a rotary drum dryer for a farm-scale pellet plant was obtained to satisfy interest, but it is assumed that a dryer would not be installed. It is assumed instead that if dry feedstock is not available, the pellet plant would not be operated.)

Biomass-fired dryer. As mentioned above, a dryer could use solid (biomass) fuel instead of natural gas or propane. The additional equipment required for a biomass-fired dryer would be a fuel storage and handling system, a feed hopper, a solid fuel feeder, and a solid fuel burner. Budget estimates for this additional equipment were obtained from one manufacturer.

In an 8-ton/hour pellet plant, this manufacturer's standard gas-fired dryer would cost about $268,000 (plus 50% or so for engineering, installation, etc.). The additional cost for the solid fuel feed hopper, feeder and burner would be about $132,000 (plus 50% or so for engineering, installation, etc.). This does not include the cost of a fuel storage bin and handling system, which could add an additional $100,000 to the total price. For discussion purposes, let's say the total additional cost of a biomass fuel-fired dryer would be about $300,000 for an 8-ton/hour pellet plant.

If natural gas prices remain level at $8.90/million Btu, then annual natural gas costs for drying might be about $186,000. If sawdust at 10% moisture content (the manufacturer's specified solid fuel) could be obtained at a delivered cost of $60/ton, and it contains 16.5 million Btu/ton, then the fuel cost (to the plant gate) would be $3.64/million Btu. If all additional operating expenses associated with using biomass fuel add $2.00/million Btu, then the total fuel costs for the biomass-fired dryer would be $5.64/million Btu (compared to

$8.90/million Btu for natural gas). Based on this "back of the envelope" analysis, the biomass-fired dryer might be able to achieve fuel cost savings of almost $70,000/year, for a simple payback of about 4.3 years.

The hard part may be to find and secure a reliable long-term supply of dry sawdust or other suitable fuel. (Of course, one option would be to produce usable fuel from the agricultural biomass that is used to make pellets.) When a feasibility study is produced for an agricultural biomass pellet plant, it may be worthwhile to fully develop and analyze the option of a biomass-fired dryer. For the purposes of this feasibility study guide, however, it is assumed that the dryer would operate on natural gas.

Secondary Grinder - Hammermill

The hammermill grinds feedstock to the particle size for pelleting. This is ordinarily ¼ inch particle size or smaller (not larger than the diameter of the pellet to be produced). The particle size passed through the hammermill is determined by the screen, which is changeable. Generally, smaller particle size increases the density and hardness of the pellet; but if the feedstock is too finely ground, it can lose its fibrous characteristics and not bind into a durable pellet. A pellet plant operator is advised to experiment with different screen sizes and operating parameters (including moisture content of feedstock entering the hammermill) to optimize pellet production performance and pellet attributes.

Most hammermills are built to grind loose pieces of feedstock that are the size of a matchbook or smaller. This is why a primary grinder may be necessary if the delivered feedstock is baled corn stover or other large-piece agricultural materials (or logging residues).

Budget estimates for hammermills of different sizes and specifications were obtained. Hammermills suitable for both agricultural residues and wood materials were specified. One manufacturer provided budget estimates and equipment descriptions which suggest that the same hammermills could be used for agricultural residues or wood, but the throughput of agricultural residues would be about twice the throughput of wood with any given hammermill. Thus, a hammermill that could process four tons of wood per hour could process eight tons of agricultural residues.

Another manufacturer's representative generally concurred. However, he suggested that a hammermill designed to process wood could handle agricultural residues, but a hammermill designed for agricultural residues might not be powerful and durable enough for wood in on-going commercial operations. When selecting equipment for a pellet plant, it would be important to ensure that the hammermill was designed for the hardest material that it might be used to process. In most pellet plants, that would be wood, even if the initial business plan is to produce agricultural biomass pellets.

Below are budget estimates for hammermills. The capacity indicated for each hammermill is not the throughput rate. It is the production capacity of the pellet plant for which the hammermill would be suitable (assuming agricultural feedstocks).

HAMMERMILL			First	Second
2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
$31,200	$31,200	$36,200	$47,000	$96,000

(Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connected equipment.)

In the budget estimates shown above, there are two prices shown for a hammermill suitable for a 14-ton/hour agricultural biomass pellet plant, and the second hammermill costs more than twice as much as the first. This cost difference relates to outstanding questions regarding the interchangeability of hammermills designed for wood and agricultural biomass.

The higher budget estimate of $96,000 appears to be a reasonable, conservative estimate for planning purposes. The company representative for this hammermill indicated that it would be more than sufficient for a pellet plant intended to produce wood pellets at a rate of 8 ton/hour or agricultural biomass pellets at a rate of 14-ton/hour. On the other hand, the author of this feasibility study guide has no basis for believing that the hammermill specified for the first 14-ton/hour plant would be insufficient.

Conditioner and Pellet Mill

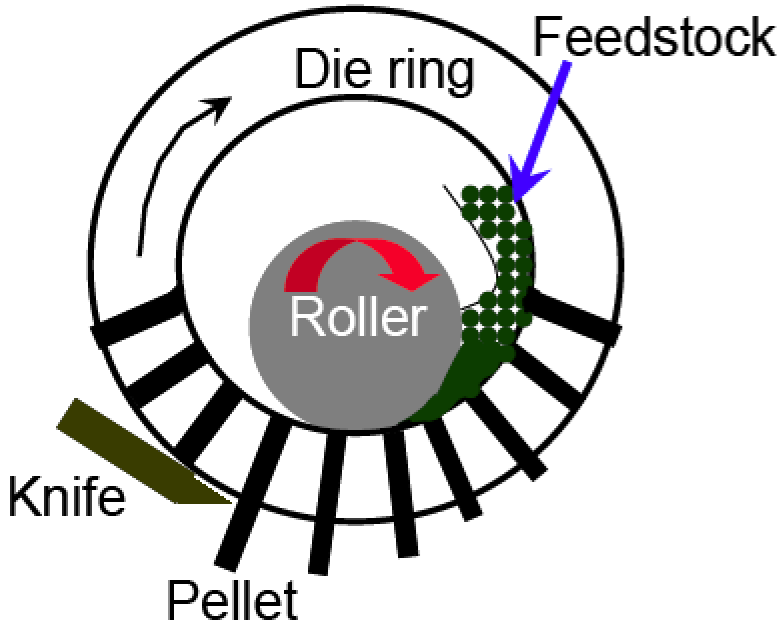
After feedstock is processed through the hammermill, it is conditioned and then pelleted. The conditioner and pellet mill are integrated components. Cold, dry biomass material will not bind into pellets by simply applying pressure. In the conditioner and pellet mill, the temperature of feedstock must be raised to 220 to 240 degrees Fahrenheit with sufficient moisture so that the natural lignins will release or separate. The lignins then bind the pellet together after pelleting and cooling. Proper conditioning is not only important for pellet quality, but it allows the feedstock to pass through the pellet die with less mechanical energy required and less wear on the equipment.

One method of conditioning is to treat the feedstock with steam. Moisture is needed to soften the feedstock, and it also serves as an effective heat transfer medium. This requires a boiler, but not a very large one by industrial standards. A 100-horsepower boiler is sufficient to generate the steam for a 14-ton/hour pellet mill. An alternative hydration method is to spray the feedstock with water, but hydration is not necessary if the feedstock enters the conditioner with high moisture content.

Additives, such as binders or chemicals used to offset chloride content, can be blended into the feedstock in the conditioning stage. (No added binder would be needed with most agricultural feedstocks because their natural lignins are sufficient. Switchgrass might be an exception.)

Pellets are produced by the pellet mill, which extrudes conditioned feedstock through a die ring with holes in it. The holes are the diameter of the pellets to be produced. The most common pellet size is ¼" diameter, but 3/8" pellets may become popular for burning in multi-fuel appliances or larger equipment.

As shown in the diagram below, the feedstock enters the cavity inside the die ring. The die ring rotates, and roller assembly turns, squeezing feedstock into the die holes. Heat, moisture and pressure cause the feedstock to become compacted or densified in the die holes, and the particles bind together. Then, when the cylindrically shaped material passes through the die ring, the newly formed "pellet" is cut off with a knife or allowed to break off.



This illustration is copied from "Grass Pelleting – The Process," Bioenergy Information Sheet #7, Cornell University Cooperative Extension, Updated 2-13-06.

(There is another kind of pellet mill, but the principles of pellet extrusion are the same. This other kind of pellet mill has a flat die, which looks like a platter mounted horizontally. Rollers on top of the die press the feedstock through holes to the underside where a cutting blade cuts the pellets to length.)

A challenge of starting up a pellet plant is optimizing the pellet mill by experimenting with different pellet dies and different settings. As explained by Karwandy:

> Depending on the material being pelletized (i.e., different species of wood, agricultural residues, charcoal, etc.), 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 not be compressed and simply pass through the

holes. Resistance is adjusted by changing the size of hole or the number of holes on the die. Bigger holes or more holes lead to less resistance.[54]

This feasibility study guide is not intended to be primer on pellet plant operations. Suffice it to say that there are numerous die designs with different hole configurations. The choice of dies (and the characteristics of the conditioned feedstock) significantly affects pellet quality, plant production performance, and maintenance and repair costs.

Generally, pellet mills that are designed primarily to produce wood pellets are heavier and operate at different speeds than pellet mills for livestock feed. Pellet mills range in size from 40 horsepower to 500 horsepower. A general rule of thumb is that 100 horsepower (HP) is required to produce one ton of wood pellets per hour. Thus, a 400-HP pellet mill would be sufficient for a 4-ton/hour wood pellet plant. Most agricultural feedstocks would have higher throughput rates as shown in the table below, which is based on research and testing conducted by a pellet mill manufacturer.

Feedstock	**Hourly Production of 400-HP Pellet Mill (Tons)**
Hardwood	4 to 5
Softwood	5 to 6
Switchgrass	4 to 5
Soybean straw	5 to 7
Hay	7 to 9
Sugar beet pulp	8 to 9
Corn stover	8 to 10
Wheat straw	9 to 11
Oat hulls	11 to 13
Soybean hulls	22 to 25
Wheat middlings	22 to 25
Corn distillers grains	26 to 28

Looking at the table above, one might think that the key to success is to use oat hulls, soybean hulls, wheat middlings and corn distillers grains as feedstock. Then an agricultural biomass pellet plant could produce more tons of fuel pellets; and with these "superior" feedstocks, there would be no need for a primary grinder or a dryer. This may be true.

On the other hand, the production rate for soybean hull pellets versus wood pellets may not matter. There is a retail market for wood pellets. The same cannot be said for soybean hull pellets (or fuel pellets made with other agricultural biomass). If a market develops for agricultural biomass pellets, then presumably demand for these superior feedstocks would increase, as would their prices, until the competitive advantages of these feedstocks are erased.

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[54] Karwandy, Jeremy, Pellet Production from Sawmill Residue: a Saskatchewan Perspective, Forintek Canada Corp., March 2007. p. 13

For the purposes of this feasibility study guide, it is assumed that others will get all of those superior agricultural feedstock; and the users of this guide would use process corn stover, soybean straw, damaged hay and grasses. Based on the above information provided by one pellet mill manufacturer and the production estimates provided by other pellet mill manufacturers, a rough rule of 2 tons/hour per 100 horsepower is apparently justified. This means that a 400-horsepower pellet mill should be expected to produce 8 tons/hour.

For consistency and to err on the conservative side, however, this rule is not used to estimate production in the largest pellet plants budgeted, each of which would have two 400-horsepower pellet mills. The representatives of two manufacturers were asked to provide budget estimates for pellet mills and other equipment that would produce 8 tons/hour of wood pellets, but that would be suitable for producing agricultural biomass pellets, too. One of these manufacturer's representative indicated that his company's pellet mills (that is, two 400-HP pellet mills) would produce 14 to 16 tons/hour of agricultural pellets, but his conservative guidance was to use an assumption of 14 tons/hour. There is no basis for assuming one of these plants would be able to produces more than the other. Therefore, the assumption of 14 tons/hour is used for both of these largest pellet plants.

Below are budget estimates for the conditioners and pellet mills. Note that some conditioners and pellet mills require a boiler. Boiler sizes of 50 horsepower for the smaller pellet plants and 100 horsepower for the larger pellet plants were recommended by a manufacturer's representative.

CONDITIONER/PELLET MILL				**First**	**Second**
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
Conditioner	$ 43,900	$ 43,900	$ 44,700	$ 87,900	$ 73,200
Boiler	$ 45,000	$ 45,000	$ 51,000	$ 51,000	None
Pellet Mill(s)	$ 96,300	$125,800	$232,100	$442,600	$459,300
Total	**$185,200**	**$214,700**	**$327,800**	**$581,500**	**$532,500**

(Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connected equipment.)

Pellet Cooler

When pellets are released from the pellet mill, they are fragile and hot – over 200 degrees Fahrenheit – and they contain excess moisture. The pellets are immediately delivered to a pellet cooler. In this stage, the hot pellets are spread on a "bed," and ambient air is drawn through the pellets to evaporate excess moisture and to cool the pellets to about 80 degrees Fahrenheit. This process allows the lignins to solidify, thereby improving the hardness and durability of the pellets, and it prevents the pellets from "sweating" after they are bagged.

Below are budget estimates for pellet coolers. (The author of this feasibility study guide had doubts about the cost of a cooler for the first 14-ton/hour pellet plant. To ensure a sufficient budget estimate, the cost of a cooler for an 8-ton/hour pellet plant was simply doubled.)

PELLET COOLER				First	Second
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
	$ 31,800	$ 31,800	$ 34,900	$ 69,800	$ 92,000

(Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connecting equipment.)

Pellet Shaker/Screener

After the pellets are cooled, the pellets are conveyed to a pellet shaker or screener which separates dust, particles and fragments – anything that fits through a 3/16" screen – from the whole pellets. The fines and fragments are returned for re-pelleting, or they can be used as biomass fuel in a solid fuel-fired dryer or heating system. (It is reasonable to expect that less than 3% of material will be screened out by the pellet shaker/screener. If it is significantly more than 3%, there probably is a problem with the feedstock or the production process.)

Below are budget estimates for pellet shakers/screeners.

SHAKER/SCREENER				First	Second
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
	$ 18,300	$ 18,300	$ 18,300	$ 18,300	$ 26,100

(Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connecting equipment.)

Bagging and Palleting System

The most common package for the retail market is 40-pound bags of pellets stacked and wrapped on pallets. This is expensive packaging. Just the cost of consumables – bags, pallets, slip sheets, and wrap – can cost $11.50/ton, and bagging pellets can require more labor than producing pellets.

Mani determined that two people are required for pellet production, but three laborers are required for bagging pellet in 40-pound bags (using a bagging/palleting system that is less than fully automated, judging by Mani's capital budget).[55] If these laborers cost $20/hour, and they bag and pallet 8 tons per hour, then the labor cost of this stage would be $7.50. Total bagging and palleting costs (not including storage and handling) would be about $19.00/ton.

For a bagging and palleting operation, pellets are conveyed to a bag-out bin after screening. A scale and bagger are beneath the bag-out bin. There are different equipment options with

[55] Mani, Sudhagar, Shahab Sokhansanj, Xiaotao Bi, and Anthony Turhollow, "Economics of Producing Fuel Pellets from Biomass." Applied Engineering in Agriculture, Volume 22(3): 421-426, 2006. p. 424.

their own operating procedures, but the essential steps are to weigh a correct amount of pellets, drop the pellets into a bag, and seal the bag. Fifty bags of pellets are then stacked on a pallet for a load of one ton. The palleted loads are wrapped with shrink wrap, and then moved to a trailer for shipment or moved to inventory storage.

The capital cost of a bagging system are affected by the capacity and degree of automation. A small pellet plant cannot justify a fully automated system, but a large plant needs one. (If a bagging and palleting operation is to keep up with production at a rate of 8 tons per hour, 400 bags would have to be filled, sealed and palleted every hour of operation.)

Below are budget estimates for bagging and palleting systems based on information provided by several companies. The manufacturer's representative called the bagging system for the 4-ton/hour pellet plant "semi-automated." The bagging and palleting systems for the 8-ton/hour and 14-ton/hour plants are fully automated. The system estimated at a cost of $450,000 is capable of filling, sealing and palleting 14 bags/minute, which corresponds to about 17 tons/hour.

BAGGING/PALLETING SYSTEM				**First**	**Second**
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
	$ 30,000 to $ 40,000	$ 40,000 to $ 80,000	$450,000 to $522,000	$450,000 to $522,000	$450,000 to $522,000

(Important note: This is the equipment price estimate *only*. It does not include taxes, freight, engineering/project management, installation, conveyors, feeders or any connecting equipment.)

It is possible that the farm-scale plant, which may produce about 4,000 tons of pellets annually, would not need a bagging and palleting system at all. Instead, the operator may sell pellets in bulk from the plant site or through a local retailer. It is assumed in the following financial analyses that such an option is viable. Thus, the cost of a bagging and palleting system is not included in the capital budget for the farm-scale, 2-ton/hour pellet plant.

The lower budget estimates for bagging and palleting systems for the other plant sizes are used in the financial analyses ($40,000 for the 4-ton/hour plant and $450,000 for the larger plants).

Conveyors, Tanks and Other Fixed Equipment

The primary components of a pellet plant are described and budgeted in the preceding pages. There are, however, many other equipment items that are required in a pellet plant. These include equipment structures and supports, conveyors, tanks, hoppers, feeders, filters, air system, blowers, dust collectors and more. In total, all of these equipment items cost more than the pellet mill.

Most of the items in this cost category are the numerous conveyors and containers (tanks, hoppers, etc) in a pellet plant. To and from every stage in a pellet plant is a conveyor or some kind of equipment to move feedstock or finished product. Screw and chain conveyors are used for feedstock, as are bucket elevators and pneumatic systems. Finished pellets require gentle handling, however, so low-speed belt conveyors are used in the final stages. The estimated cost of conveyors and other material-moving equipment in the second 14-ton/hour pellet plant is $208,600.

For the same 14-ton/hour plant, tanks and hoppers are estimated to cost $676,000. Designing the configuration of tanks and hoppers could get complicated, too. If fuel pellets are to be made with an exact "recipe" of two or more feedstocks, then multiple in-feed hoppers may be required; and these hoppers might be located in front of different equipment components, depending on the processing the different feedstocks would require and the best way to "blend" the recipe. (For example, corn stover may be fed into the primary grinder; wet distillers grains may be fed into the dryer; dry oat hulls may be fed into the hammermill; and glycerol may be fed into the conditioner.)

Additional equipment (feeders, filters, air systems, dust collectors, etc.) in the second 14-ton/hour pellet plant are estimated to cost $117,400. Thus, the total cost estimate for "conveyors, tanks and other fixed equipment" in this plant is $1,002,000.

For the 8-ton/hour pellet plant, the total cost estimate for "conveyors, tanks and other fixed equipment" is $1,130,000. That this amount is substantially more than the amount shown for the second 14-ton/hour plant does not indicate an error. For the 8-ton/hour pellet plant, structural supports and access platforms are budgeted in this line item. For the second 14-ton/hour pellet plant, those items are included as part of "mechanical installation."

The author of this feasibility study guide has little confidence in the budget estimate for the 2-ton/hour pellet plant – it's a guess based on the assumption that a mechanically inclined and resourceful farmer will scavenge tanks, adapt used conveyors, and otherwise find low cost ways to put together a pellet plant in a farm building.

CONVEYORS, TANKS AND OTHER FIXED EQUIPMENT

2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**First 14-Ton/Hr.**	**Second 14-Ton/Hr.**
$200,000	$790,000	$1,130,000	$1,356,000	$1,002,000

The amounts shown above for conveyors, tanks and other fixed equipment seem remarkably high, but they are based on estimates prepared by qualified professionals working independently of each other, and their estimates are reconcilable. Perhaps some economies could be achieved in this category of capital costs, but the author of this feasibility study guide does not know how. *This illustrates the importance of obtaining binding price quotations and bids for all of the equipment items specified in a detailed project design before financing and contractual commitments are made.*

Engineering and Project Management

Estimated engineering and project management costs for the 8-ton/hour pellet plant are $150,000 (which is less than 2.5% of the total project budget). The engineering and project management costs to build a smaller pellet plant with the same count of equipment items and the same equipment configuration would not be much less, and these costs for a larger plant would not be much more. Therefore, a budget estimate of $75,000 for engineering is used for the 4-ton/hour plant, 8-ton/hour plant and first 14-ton/hour plant. Budget estimates for project management are adjusted by $25,000 for these plants as shown below.

For the second 14-ton/hour pellet plant, "book" assumptions were provided by a manufacturer's representative. Assumptions for hours and hourly rates were used to estimate engineering costs of $94,000. For project management, an estimate of $111,000 was determined by applying an industry standard percentage. (The industry standard percentage is 4%; the base is total costs of all project parts ***not*** provided on a turn-key basis.)

For the 2-ton/hour plant, it is assumed (guessed) in the following financial analyses that owner would require a total of $30,000 in engineering and project management assistance.

ENGINEERING/PROJECT MANAGEMENT				**First**	**Second**
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
Engineering	$20,000	$ 75,000	$ 75,000	$ 75,000	$ 94,000
Project Mgmt.	$10,000	$ 50,000	$ 75,000	$100,000	$111,000
Total	**$30,000**	**$125,000**	**$150,000**	**$175,000**	**$205,000**

Freight and Sales Taxes

The prices for equipment components generally do not include the cost to deliver the equipment to the project site. According to a manufacturer's representative, an industry standard estimate for freight costs is 4% of equipment price. This is the basis for the freight cost estimates shown below. (Freight costs may appear high, but bear in mind the size of pellet plant equipment. For example, a rotary drum dryer for a 14-ton/hour plant is 152 feet long and 13 feet wide.)

No allowance is provided for sales taxes in the following financial analyses.

FREIGHT				**First**	**Second**
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
Freight	$19,000	$79,000	$117,000	$144,000	$131,000

Mechanical Installation and Electrical Installation

The equipment components for a pellet plant will be unassembled when they are delivered to the plant site. At the plant site, the components must be assembled and installed. In project planning and budgeting, this work is ordinarily described as having two parts, mechanical installation and electrical installation.

For mechanical installation in the second 14-ton/hour pellet plant, the cost estimate is based on an industry standard percentage that is 32% of costs of equipment not provided on a turn-key basis. The work corresponding to this industry standard percentage of 32% for mechanical installation includes, among other items, the costs of foundations, structures and supports, and access platforms. For electrical installation, the cost estimate is based on an industry standard percentage that is 20% of costs of equipment not provided on a turn-key basis. The work corresponding to this industry standard percentage includes, among other items, the cost of all electrical controls.

For the 8-ton/hour pellet plant, mechanical installation is estimated to cost $550,000, and electrical installation is estimated to cost $400,000. These costs are lower than the industry standard percentages for mechanical and electrical installation, but this may be partially explained by the inclusion of costs for structures, supports and other auxiliary equipment in the equipment category of "conveyors, tanks and other fixed equipment."

For the 4-ton/hour plant and the first 14-ton/hour plant, mechanical and electrical installation cost estimates are based on the estimate for the 8-ton/hour plant. These estimates are accurate enough for the purposes of this feasibility study guide, but they should not be used or cited without prior review by a qualified professional. The estimate for the farm-scale, 2-ton/hour plant is merely a guess for the amount of work the owner would contract out.

INSTALLATION	**2-Ton/Hr.**	**4-Ton/Hr.**	**8-Ton/Hr.**	**First 14-Ton/Hr.**	**Second 14-Ton/Hr.**
Mechanical	$40,000	$385,000	$550,000	$ 660,000	$ 889,000
Electrical	$30,000	$280,000	$400,000	$ 480,000	$ 556,000
Total	**$70,000**	**$665,000**	**$950,000**	**$1,140,000**	**$1,445,000**

Wheel Loader

A wheel loader is used to move feedstock from receiving to storage and from storage to the first stage of processing, and a wheel loader has other uses at a pellet plant as well. Some documents on pellet plants suggest that a skid loader costing $35,000 to $40,000 would be sufficient, at least for a smaller pellet plant. A larger wheel loader probably would be needed to move feedstock at a commercially viable pellet plant. Averill Cook suggests that a plant producing pellets at a rate of 12 tons per hour may require a $370,000 loader.[56]

Two equipment dealers were contacted for assistance. They were told that the use of the wheel loader would be intensive – the wheel loader would handle up to thirty large round bales of feedstock per hour on a 24-hour basis, moving them to, from and around storage. The wheel loader would need sufficient reach to safely unload bales from trailers and stack bales in a pyramid. The wheel loader would be operated on a large area, perhaps six acres, and it would have to move quickly. It was explained that the wheel loader also would have to be reasonably comfortable for long work shifts on a year-round basis. Physical demands on the operator should be minimal to prevent fatigue, and visibility must be good to avoid accidents.

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[56] Cook, Averill H. "The Challenges and Economics of Pellet Production." Document produced for Agricultural Utilization Research Institute, 2007. p. 5.

Both equipment dealers recommended against large skid loaders, which are priced in the $50,000 to $60,000 range. One equipment dealer suggested a mid-size wheel loader in the $80,000 to $90,000 range. The other equipment dealer also recommended a mid-size wheel loader (21,000 pound weight, 6,000 pound load capacity, with a 110 horsepower engine). With a comfortable cab and a specialized bucket or fork, the cost would be about $110,000. This seems to be a more realistic estimate than either $35,000-$40,000 or $370,000. An estimate of $110,000 is used for all of the pellet plants except the 2-ton/hour plant, for which the assumption is that existing farm equipment would be used.

Forklift

If finished pellets are going to be bagged, palleted and wrapped into one-ton deliverable loads, a forklift would be needed to move loaded pallets into the storage warehouse and from the warehouse to trailers for shipment. It would be reasonable to plan for a warehouse with pallet racks that allow stacking five high, which has implications for the forklift specifications. (A forklift would not be needed if all finished product would be shipped in loose, bulk form. A forklift or a second wheel loader would be required, however, if finished product would be bagged in one-ton totes.)

In a commercial-scale pellet plant with production of 8 tons/hour or more, the forklift would be operated almost continuously when pellets are being bagged and palleted, and the forklift would also be used to load semi-trailers which can carry 22 to 24 loaded pallets. (The forklift would not be used when pellets are being loaded into a grain storage building or into trucks or trailers for bulk delivery.)

Two equipment dealers were contacted for technical and pricing information. A suitable forklift would have these features:

- 3,000 to 5,000 pound capacity
- Four-stage mast (for a 20-foot vertical reach)
- Liquid propane or electric power

Price estimates were obtained from the two equipment dealers, which were reconciled to price information contained in documents found through an internet search. The cost of a new forklift would be in a range of $25,000 to $33,000. (A budget estimate of $30,000 is used in the following financial analyses.)

Alternatively, a pellet plant owner could purchase a used forklift for half the cost of a new forklift, but this may be ill-advised. One “rule of thumb” is that if a forklift would be used more than four hours per day, the costs of downtime and repairs would quickly cancel the savings of buying a used forklift. A forklift in an 8-ton/hour pellet plant would certainly be used more than four hours per day.

Plant & Office Equipment and Tools

The last capital budget item is the catch-all category of plant and office equipment and tools. Capital budget estimates for other pellet plants suggest that a range up to $100,000 is realistic. Therefore, it is estimated that these costs would be as follows:

PLANT & OFFICE EQUIPMENT AND TOOLS				First	Second
	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**	**14-Ton/Hr.**
	$0	$60,000	$80,000	$100,000	$100,000

Total Capital Budget Estimates

On the following page is a table titled "Pellet Plant Capital Budget Estimates" which details the capital budgets for the five plants discussed in this chapter. It is important to stress that these are illustrative budget estimates. These capital budget estimates are not based on binding price bids, and they have not been reviewed and accepted by an engineer or contractor in the context of project contract negotiations.

The presentation of the "farm-scale pellet plant" has some appeal insofar as it indicates the lowest installed capacity cost, but the capital cost advantage could be reduced considerably by fair charges for installation labor and for facilities and equipment rent.

The economies of scale that were discussed previously in this feasibility study guide are evident in the estimates of capital costs for commercial-scale pellet plants of different sizes. The "capital cost per ton of hourly production capacity" falls as plant size increases. For the 4-ton/hour pellet plant, it is $1,375,500. For the 14-ton/hour plant it is $652,257, which is less than half the unit cost for the 4-ton/hour pellet plant. (Recall that a useless "rule of thumb" is that a pellet plant would cost $1.0 million/ton of hourly production capacity. Only coincidentally is this a good approximation for the 8-ton/hour pellet plant.)

Another way to look at the relative cost of different size plants is this: The capital budget estimates suggest that to double the production capacity from 4 tons/hour to 8 tons/hour requires a capital budget increase of about 40%. Then, to increase capacity by 75% more, from 8-ton/hour to 14-ton/hour, would require a capital budget only 19% greater than the budget for the 8-ton/hour pellet plant. Note that this apparent economy is due largely to the assumption that many requirements for the 8-ton/hour pellet plant would be the same as for the 14-ton/hour plant. (This assumption applies to the site, pellet plant building, receiving station, feedstock storage facilities, pellet warehouse, primary grinder, bagging system, and wheeled equipment.) To the extent the 14-ton/hour plant would actually have greater requirements, the additional capital costs would be more.

Once again, all of this capital cost information is provided only for guidance. When binding price quotations and bids are obtained for a real pellet plant project, the projected costs for facilities, equipment and installation may be different by a large margin from the amounts shown in this feasibility study guide.

PELLET PLANT CAPITAL BUDGET ESTIMATES FULLY EQUIPPED FOR RETAIL PRODUCT BUSINESS MODEL					
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**FIRST 14 TPH**	**SECOND 14 TPH**
	U.S. DOLLARS				
Site/Site Preparation	**0**	**216,000**	**216,000**	**216,000**	**216,000**
Plant Building & Offices	**0**	**816,000**	**1,020,000**	**1,020,000**	**1,020,000**
Receiving Station & Scale	**0**	**130,000**	**130,000**	**130,000**	**130,000**
Feedstock Storage					
Storage Lot	0	180,000	360,000	360,000	360,000
Storage Warehouse	0	280,000	280,000	280,000	280,000
Total Feedstock Storage	**0**	**460,000**	**640,000**	**640,000**	**640,000**
Pellet Storage					
Pallet Warehouse	0	350,000	350,000	350,000	350,000
Loose Storage Building	0	493,000	987,000	1,480,000	1,480,000
Total Pellet Storage	**0**	**843,000**	**1,337,000**	**1,830,000**	**1,830,000**
Plant Equipment					
Primary Grinder	0	650,000	650,000	650,000	650,000
Dryer	0	192,000	268,000	426,000	426,000
Hammermill	31,200	31,200	36,200	47,000	96,000
Conditioner/Feeder	43,900	43,900	44,700	87,900	73,200
Boiler	45,000	45,000	51,000	51,000	0
Pellet Mill	96,300	125,800	232,100	442,600	459,300
Pellet Cooler	31,800	31,800	34,900	69,800	92,000
Pellet Shaker/Screener	18,300	18,300	18,300	18,300	26,100
Bagging/Palleting System	0	40,000	450,000	450,000	450,000
Convey, Tanks, Other Fixed Equip.	200,000	790,000	1,130,000	1,356,000	1,002,000
Total Plant Equipment	**466,500**	**1,968,000**	**2,915,200**	**3,598,600**	**3,274,600**
Engineering	**20,000**	**75,000**	**75,000**	**75,000**	**94,000**
Project Management	**10,000**	**50,000**	**75,000**	**100,000**	**111,000**
Freight	**19,000**	**79,000**	**117,000**	**144,000**	**131,000**
Mechanical Installation	**40,000**	**385,000**	**550,000**	**660,000**	**889,000**
Electrical Installation	**30,000**	**280,000**	**400,000**	**480,000**	**556,000**
TOTAL PELLET PLANT	**585,500**	**5,302,000**	**7,475,200**	**8,893,600**	**8,891,600**
Other Equipment &Tools					
Wheel Loader	0	110,000	110,000	110,000	110,000
Fork Lift	0	30,000	30,000	30,000	30,000
Plant & Office Equip. & Tools	0	60,000	80,000	100,000	100,000
Total Other Equip. & Tools	**0**	**200,000**	**220,000**	**240,000**	**240,000**
TOTAL CAPITAL BUDGET	**585,500**	**5,502,000**	**7,695,200**	**9,133,600**	**9,131,600**
Capital Cost Per Ton of Hourly Production Capacity	**292,750**	**1,375,500**	**961,900**	**652,400**	**652,257**

For this feasibility study guide, capital budget estimates for two 14-ton/hour pellet plants were produced to validate one estimate against another and to test the impact of using different manufacturers' equipment prices and different methods of estimating cost items such as mechanical and electrical installation. The capital budget estimates for these plants are almost the same: $9,133,600 for the first 14-ton/hour pellet plant, and $9,131,600 for the second.

The direct operating cost estimates for these two 14-ton/hour pellet plants are the same except one plant is estimated to use more electricity than the other. The effect of this on the annual budget is only about $4,500. Therefore, there is no reason to continue presenting two 14-ton/hour pellet plants. In the following chapters, only one is shown.

The preceding chapter identifies the requirements of a fully equipped pellet plant for the "Retail Product Business Model," which is oriented to the market of households and other retail consumers that would purchase agricultural biomass pellets to use in small heating appliances. A pellet plant designed for this market must have bagging and palleting capabilities, and substantial pellet storage capacity is needed because the market is primarily seasonal. A pellet plant that is designed to produce and deliver bulk pellets on a year-round basis to utilities and other industrial and institutional customers is described and budgeted in Chapter 16.

14. Project Financing

Project financing must be assembled to fund the capital budget and meet other business development expenses for an agricultural biomass pellet company. The elements of project financing may include equity investments, debt financing, grants, and in-kind contributions (such as land or infrastructural improvements that would otherwise be included in the capital budget). A detailed project financing scenario for a 14-ton/hour pellet plant is presented in this section, and summary information for the other size plants follows.

The total capital budget for a 14-ton/hour pellet plant is $9,131,600. (A lender might require adding a contingency amount to the capital budget, but none is added for this illustration.)

In this scenario, a lender would be willing to provide debt financing for 60% of the capital budget, $5,478,960, with an interest rate of 8.5%. The loan would require interest only payments for six months during construction and the first full year of commercial operations. Then the loan would be fully amortized over ten years with equal annual principal and interest payments at the end of each year.

DEBT SERVICE SCHEDULE			
Year	**Principal**	**Interest**	**Total**
0*	$0	$232,856	$232,856
1	$0	$465,712	$465,712
2	$369,324	$465,712	$835,036
3	$400,717	$434,319	$835,036
4	$434,778	$400,258	$835,036
5	$471,734	$363,302	$835,036
6	$511,831	$323,205	$835,036
7	$555,337	$279,699	$835,036
8	$602,540	$232,496	$835,036
9	$653,756	$181,280	$835,036
10	$709,325	$125,711	$835,036
11	$769,618	$65,418	$835,036
Total	**$5,478,960**	**$3,569,967**	**$9,048,927**

* Six months during construction.

There is nothing special about the above debt arrangements – a bank may be willing to lend a higher or lower percentage of the capital budget; and the debt service schedule could be front-end loaded, back-end loaded, or (conceivably) it could be an interest-only loan indefinitely.

Assuming that no grants or in-kind contributions are offered for development of a pellet plant, the equity investment towards the capital budget would be $3,652,640 (40% of the capital budget). In addition, the equity investors would have to make an interest payment for use of the lender's funds during construction; and they would have to fund the operating budget during construction, which is assumed to be the salaries of the General Manager and Finance Manager for six months plus $40,000 for non-personnel expenses. In total, the required equity investment for a 14-ton/hour pellet plant would be:

40% of capital budget	$3,652,640
Interest payment for six months	$ 232,856
Operating budget for six months	$ 121,600
Total Equity Investment	**$4,007,096**

Using the same project financing model for all plant sizes, project financing may be as follows:

PROJECT FINANCING

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Total capital budget	$585,500	$5,502,000	$7,695,200	$9,131,600
Debt financing (60%)	$351,300	$3,301,200	$4,617,120	$5,478,960
Equity investment (40%)	$234,200	$2,200,800	$3,078,080	$3,652,640
Year 0 budget plus interest*	$ 14,930	$ 261,901	$ 317,828	$ 354,456
Total equity investment	**$249,130**	**$2,462,701**	**$3,395,908**	**$4,007,096**

*Year 0 budget plus interest is the sum of interest payment for six months and operating budget for six months during construction.

Once again, the capital budget estimates presented in this feasibility study guide may be high. Somebody may be able to build a pellet plant for 10% less, 20% less, maybe even 30% less than estimated in this document. This would change the numbers in the above table, but it would not change this conclusion: Investors would be required to put a lot of money at risk to enter the pellet fuel industry with development of an agricultural biomass pellet plant.

Initial Working Capital

Beyond the debt financing and equity investment required to get to the commercial operations date, an agricultural biomass pellet company would probably need to start commercial operations with substantial working capital to manage negative cash flow during the first year or two of business operations. Industry experts say it may take six to eighteen months to optimize plant and business operations, and it may take longer than that to develop a sufficient customer base.

With total annual expenses (not including debt service or depreciation) projected to be more than $9.0 million for a 14-ton/hour pellet plant, a pellet company could need several million dollars in the form of equity contributions or a line of credit to survive the start-up period. This working capital is not budgeted as part of the total project financing described in this chapter, but a lender may not release funds for construction of the pellet plant absent evidence that this working capital has been arranged by the owners.

15. Operations – Revenues and Expenses

A feasibility study is expected to include financial projections with an explanation and justification for key revenue and expense items. This chapter provides a discussion of assumptions and calculations necessary to estimate revenues and costs of an agricultural biomass pellet enterprise; and it offers some illustrative financial analyses and projections.

15.1 "Nth" Year Financial Projections

Financial projections can be presented in many different forms, but their conclusions are only as good as the crystal ball of the individual who produces them. In a business plan or a disclosure statement for a share offering, three or five-year operating statements may be expected. Multiple-year operating statements require a lot of guesswork about production capacity during the ramp-up years, market development, margins between prices and production costs, working capital requirements, and inflation factors; and these multiple-year operating statements can be easily manipulated to "find" different conclusions.

For a feasibility study – which is sometimes called a "proof of concept" study – a simpler financial presentation may be more illuminating and more appropriate given the level of confidence due the underlying assumptions for revenues and expenses. The author of this feasibility study guide prefers an "Nth" year financial projection. In an Nth year projection, it is generally assumed that current costs for all inputs and prices for outputs will hold true in the Nth year (so uncertain cost and revenue estimates are not arbitrarily inflated with compounding effects in out-years).

The Nth year projection is intended to be a financial picture of the business enterprise when it has matured. Thus, the enterprise is assumed to have already achieved full production ramp-up and market development. Working capital requirements are expected to have stabilized.

In an Nth year projection, it is assumed that the capital development would have been financed with a conventional combination of equity investment and debt financing (40% / 60%, for example), but there is no principal repayment in the Nth year. In effect, the debt financing is assumed to be interest-only, because theoretically principal repayment is a discretionary expenditure. Likewise, there are no assignments of dollars into either a major repair/replacement reserve fund or a debt service reserve fund. After-tax income is not calculated because there is no basis for an assumption that there would be tax liability at the level of the business enterprise.

A demerit of an Nth year projection is that it does not show how positive cash flow and key ratios would be achieved (or not) in the most critical early years of an enterprise. A reasonable argument can be made that these are next-level concerns, however. The first-level concern – the key question of a feasibility study – is whether the enterprise would be financially viable at maturity. Only if it can be demonstrated that financial viability is actually an attainable outcome does it make sense to develop the detailed financial roadmap to get there (which belongs in a business plan).

Those who use this guide to produce a feasibility study for an agricultural biomass pellet company may, of course, present financial information any way they wish; but the following discussion of assumptions and calculations are for Nth year financial projections.

15.2 Operating Assumptions

Retail Product Business Model

In this chapter, it is assumed that the commercial-scale pellet companies would bag and pallet 100% of their production for retail sales directly to consumers or through retail stores, primarily for heating season use. (The farm-scale pellet plant would not have a bagging system; it would sell loose pellets directly to consumers or through a feed store perhaps.) This is the "Retail Product Business Model." In the financial projections, it is assumed that individual customers and retailers would pay the same price for pellets, and both would pay for delivery. Thus, the financial results are not sensitive to the percentage of total production sold to individual customers versus retailers.

In the following chapter, an alternative business model is presented, the "Utility Fuel Production Plant." In the financial projections for this business model, it is assumed that the pellet plants would not require a bagging/palleting system or as much pellet storage capacity because 100% of their production would be for sales to utilities and other industrial and institutional customers with large year-round thermal energy requirements.

Achievable Production (Throughput) Rate

The achievable production (or throughput) rate of a pellet plant – the tons of pellets per hour that can be produced with a given feedstock at the highest sustainable level of productivity – is critical to a pellet company's financial performance. A higher production rate results in lower capital, fixed operating, labor and energy costs per ton.

A general rule of thumb is that a pellet mill with 100 horsepower (HP) can produce one ton of wood pellets per hour (and a pellet mill with 200 HP can produce two tons of wood pellets per hour, etc.). There is not a good rule of thumb for production rates with agricultural crops, by-products and residues because different agricultural feedstocks have very different physical characteristics. For corn stover, straws and grasses, however, a rule of two tons per hour for every 100 HP is fairly accurate.

The Nth year financial projections assume that corn stover (60%), soybean straw (20%) and damaged hay/grass (20%) would be the feedstocks for a pellet plant. A pellet mill manufacturer tested these and other agricultural feedstocks and measured the following pellet production rates:

Feedstock	Hourly Production of 400-HP Pellet Mill (Tons)
Soybean straw	5 to 7
Hay	7 to 9
Corn stover	8 to 10

Given these production rate ranges, a 400-HP pellet mill could achieve a production rate of 7.2 to 9.2 tons/hour with the assumed feedstock blend, and a pellet plant with two 400-HP pellet mills could achieve throughput of 14.4 to 18.4 tons/hour.

However, this production estimate is only indicated by the results of pellet mill tests; it is not based on reported production in an environment of continuous commercial operations using these feedstocks. There is no commercial history of pelleting corn stover and soybean straw as there is for alfalfa.[57] Thus, there is less certainty about sustainable throughput rates at which pellets can be produced with these feedstocks to meet certain standards for finished moisture content and durability.

It is also important to keep in mind that there are multiple stages in the pellet production process. Pellet milling is only one of these stages. The other stages are primary grinding, drying, hammermilling, conditioning, cooling, and screening. Persistent blockages or processing slowdowns at any stage could reduce the hourly production rate of a pellet plant.

The financial analyses in this feasibility study guide assume that a pellet plant with a 200-HP pellet mill would produce 4 tons of agricultural biomass pellets/hour, and a pellet plant with a 400-HP pellet mill would produce 8 tons of pellets per hour. The two largest pellet plant modeled in this feasibility study guide each have paired 400-HP pellet mills, which might suggest an hourly production rate of 16 tons/hour (or 14.4 to 18.4 tons/hour as indicated by the testing results shown above). However, the author has assumed that the production rate of these plants would be 14 tons/hour, based on the conservative guidance of a manufacturer's representative.

The actual pellet production rate could be more or less than these assumptions, which would significantly affect the financial performance of an agricultural biomass pellet company. In the course of a feasibility study or business planning exercise, the more equipment testing that can be done with the intended feedstocks, the higher the confidence one may have in the production rate assumptions.

Hours of Operation

Maximizing annual production of a pellet plant spreads the capital and fixed costs over the largest amount of product (resulting in lower costs per ton of pellets produced). Whether maximum production really makes sense in the context of supply and demand is another matter. For this exercise, it is assumed there is a market for all of the agricultural biomass pellets that can be produced; and the plant should be operated as many hours as possible on a year-round basis, with shutdowns only as necessary to follow a prudent maintenance schedule.

[57] Alfalfa has been pelleted in commercial pellet plants in Canada and the United States for decades. There is ample knowledge about all operational aspects of pelleting alfalfa. Equipment and parts (including dies and rollers) have been designed, tested and commercialized for alfalfa pelleting operations; certain alfalfa pellet characteristics can be deliberately achieved through feedstock specifications, die selection and equipment settings; and changes in throughput rates are predictable and controllable.

The various analyses on pellet plant operations recognize the production economies of 24-hour/day operations. Not only does this maximize capital utilization in terms of hours of use, but it increases productivity (pellets/hour) and reduces maintenance and repair costs because the number of start-ups and shutdowns (when nothing is produced but equipment breaks) is minimized.

Proponents of a 24-hour, six-days/week schedule argue that having one day per week with no production (when only the plant mechanic is scheduled to work) is the best way to ensure that a good preventive maintenance program is followed. This schedule also allows non-urgent repairs to be made in a timely manner without disrupting plant operations.

It is assumed in the following Nth year financial projections that the pellet plants with production capacities of 4 tons/hour, 8 tons/hour and 14 tons/hour would operate on a 24-hour, six-days/week schedule. The plants would be shut down for seven holidays and for a two-week maintenance (and vacation) shutdown every summer when there is no demand for heating fuel anyway. The scheduled operating year would be 7,056 hours (49 weeks X 6 days X 24 hours).

It is assumed that the 2-ton/hour pellet plant would achieve 2,000 full-production hours per year with no particular schedule.

Full Production Hours

With the above-described hours of operation, a pellet plant would be *scheduled* to produce pellets 7,056 hours per year, but the plant would not actually achieve full production for so many hours. Production at a pellet plant can be curtailed by a lot of different events. (Equipment components take time to warm up and shut down; equipment slows down, breaks down or jams up; fire or lightning shut down the plant; usable feedstock and supplies run out; employees are absent; electric power or natural gas supply is disrupted; feedstock is processed to a stage and then rejected; etc.)

Mani assumes a pellet plant will produce pellets at its full production rate 24 hours/day, 310 days/year, for 7,440 total operating hours/year – an 85% capacity factor.[58] Maybe this is a reasonable assumption for a wood pellet plant that uses only clean sawdust and wood shavings or an agricultural biomass pellet plant that uses clean agricultural processing by-products such as dried distillers grains (provided that no allowance need be made for feedstock supply disruption). This may not be a reasonable assumption for an agricultural biomass pellet plant that would use corn stover, straws and grasses, which are not homogenous and which may carry tramp material that causes shutdowns; and it may not be a reasonable assumption for a stand-alone pellet plant where feedstock, extra employees and other resources are not next door. Entrepreneurs are advised not to build their pellet plant economics around an assumption that extraordinarily high annual production hours would be achieved year after year.

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[58] Mani, Sudhagar, Shahab Sokhansanj, Xiaotao Bi, and Anthony Turhollow, "Economics of Producing Fuel Pellets from Biomass." Applied Engineering in Agriculture, Volume 22(3): 421-426, 2006. p. 423.

It is assumed in the following Nth year financial projections that the commercial-scale pellet plants would actually achieve full production for the equivalent of 6,000 hours per year (which is 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. With 6,000 full-production hours, a 14-ton/hour pellet plant would produce 84,000 tons of pellets in a year; an 8-ton/hour plant would produce 48,000 tons of pellets; and a 4-ton/hour plant would produce 24,000 tons of pellets.

Perhaps this assumption is too conservative, but entrepreneurs should keep in mind that just maintaining full crews to work 24 hours per day, six days per week on a year-round basis would be a challenge. These crews must operate a pellet plant with eight or so distinct production stages and a lot of moving parts to produce 1/4 inch diameter pellets from agricultural biomass feedstock with inconsistent characteristics and sometimes dangerous tramp material (fencing wire, rocks, tools, etc.). A pellet plant may do better than 6,000 full-production hours in one year, but expecting a plant to do so every year seems overly optimistic.

Nevertheless, total annual production is a critical assumption which would have a large effect on the projected financial performance of an agricultural biomass pellet company. If the entrepreneurs for a pellet company have such a high level of confidence in their feedstock supply system, their pellet plant design, and their operational plan that they believe their pellet plant will produce more than the equivalent of full production for 6,000 hours/year, they should use a more aggressive estimate in their feasibility study.

15.3 Revenue and Expense Items

In this section, only significant revenue and expense items will be discussed in detail. For all other items, reasonable assumptions are made; and any errors could not be of such magnitude that they would affect financial results and conclusions.

Production, Sales and Revenue

A draft of the market assessment produced by "Relevant ideas…LLC" stated, "Under current market conditions the price may have to be $120.00 per ton for standard (PFI-graded agricultural biomass pellets) and $90.00 per ton for utility (PFI-graded pellets).[59]

In the following Nth year financial projections, the base-case assumption is that a pellet plant would sell 100% of its output at a price of $120/ton.

REVENUE

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Production and sales (tons)	4,000	24,000	48,000	84,000
Revenue @ $120/ton	$480,000	$2,880,000	$5,750,000	$10,080,000

[59] Franks, Dillon, "Biomass Fuel Pellet Market in Minnesota: Assessment October 2007." Relevant ideas…LLC, October 2007. p. 4. (To be available from AURI)

Following the base-case financial projections are estimates of the impact of pellet price changes; pellet prices from $110/ton to $180/ton are tested.

Feedstock

The financial projections for all size pellet plants assume the following for feedstocks, their percentage use, average moisture content, and delivered costs:

Feedstock	Percentage of Total	Moisture Content	Delivered Cost/Ton
Corn stover	60%	20%	$63.00
Soybean straw	20%	20%	$42.00
Damaged hay/grass	20%	20%	$60.00
Average	**100%**	**20%**	**$58.20**

An easy way to improve the results of financial projections is to assume that a pellet company would be able to procure feedstock for a lower price. Reducing the average price of feedstock by $10.00/ton would reduce the cost of pellets by $11.25/ton (because it takes more than one ton of feedstock to produce one ton of pellets). This would improve net income the same as a pellet price increase of $11.25/ton. Another way to improve the financial results is to assume that feedstock would be delivered at 15% moisture content instead of 20%. This would reduce the feedstock tonnages required and drying costs.

Such optimistic assumptions may be justified or not. Performing sensitivity analyses on these feedstock variables – that is, determining how financial results are affected by changes to these variables – is a useful exercise, but planning assumptions should be changed based on new information, not a wish for a different financial outcome.

Feedstock costs for all pellet plants are expected to be greater than the sum of all other direct operating costs. They are:

FEEDSTOCK COSTS

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Feedstock costs (delivered)	$160,000*	$1,571,400	$3,142,800	$5,499,000

* Feedstock costs for the farm-scale pellet plant are assumed to be based on a price of $40.00/ton for corn stover instead of $63.00/ton to more accurately reflect the owner's perceived opportunity cost of using his own corn stover.

Plant Wages, Payroll Taxes and Fringe Benefits

As discussed elsewhere in this feasibility study guide, larger pellet plants have lower labor costs per ton of pellets produced – it probably takes the same number of workers to operate an 8-ton/hour pellet plant as a 14-ton/hour pellet plant (although there must be break-points at some production levels above which another worker is required).

Economic analyses confirm that labor costs/ton decline as hourly production increases, but there might be some exaggeration of the labor economies because their focus is on in-plant pellet production. Handling feedstock and finished product (before and after pellet milling) is more labor-intensive than watching the pellet mill discharge pellets, and one worker can only do so much. When a plant-specific feasibility study is conducted, it would be important to thoroughly analyze and estimate the labor requirements of these material-handling stages. The total number of workers required in any pellet plant will be largely affected by how feedstock is received, stored and handled, and how finished pellets are packaged, stored and loaded for delivery.

In Mani's 2006 analysis of the economics of producing biomass fuel pellets, the base-case pellet plant has production capacity of 6 tonnes/hour. Mani states that only two workers are "required for the production plant"; but three additional workers are needed for bagging the pellets.[60] Mani does not indicate personnel requirements for supervision, maintenance and materials (feedstock and pellets) handling.

NEOS Corporation reviewed wood pellet plants in 1995 and found, "Many pellet plants run with two production employees per shift and have a separate bagging operation that employs two to four people depending on volume processed and level of automation…Usually maintenance work is performed by another one to two persons. Total plant operational personnel are five to six people per shift."[61]

In 2003, an engineering and economic analysis of a pellet plant whose feedstock would be 7 tons of cotton by-products per hour was completed.[62] Even with a fully automated bagging system, the authors determined the following labor requirements:

One full-time manager (5 days/week only)
One foreman (5 days/week only)

Three 8-hour shifts per day with the following personnel:

One lead plant operator
Two floor operators
Three laborers
One wheel loader operator

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[60] Mani, Sudhagar, Shahab Sokhansanj, Xiaotao Bi, and Anthony Turhollow, "Economics of Producing Fuel Pellets from Biomass." Applied Engineering in Agriculture, Volume 22(3): 421-426, 2006. p. 424.

[61] Wood Pelletization Sourcebook: A Sample Business Plan for the Potential Pellet Manufacturer. NEOS Corporation, Lakewood, Colorado, March 1995. p. 26.

[62] Holt, Greg, James Simonton, Mario Beruvides and Ana Maria Canto. "Engineering and Ginning: Engineering Economic Analysis of a Cotton By-Product Fuel Pellet Operation," The Journal of Cotton Science, 7: 205-216, 2003.

Thus, in addition to a manager and foreman, this agricultural biomass pellet plant would have seven employees working every shift, and this does not include a mechanic/maintenance worker.

A 100,000 ton/year biomass pellet plant is being developed in Centerview, Missouri by the Show Me Energy Cooperative. The planned feedstock is "out of condition hay, seed hulls, corn stover and other products." Regarding labor requirements, the Cooperative's website indicates that "at full capacity, the plant will run three shifts a day, five days a week, with a minimum of seven employees per shift."[63]

In the Nth year financial projections for the 8-ton/hour pellet plant and the 14-ton/hour pellet plant, it is assumed that six workers would be required for every shift. Their positions and costs are shown in the table below. The Mechanic/Maintenance Worker would work a regular schedule including Sundays (when the pellet plant is shut down), and also would be on call.

WAGES, PAYROLL TAXES AND FRINGE BENEFITS
for 8-Ton/Hour and 14-Ton/Hour Pellet Plants

Hourly Wage Employees	Hourly Wages	Hourly Cost*	Workers/ Shift	Annual Hours**	Annual Cost
Shift Supervisor	$21.00	$27.30	1	7,200	$196,560
Mechanic/Maintenance Worker	$18.00	$23.40	On-Call	2,080	$48,672
Machinery/Equipment Operators	$15.00	$19.50	4	28,800	$561,600
Bagging/Forklift Operators	$15.00	$19.50	1	7,200	$140,400
Total: Hourly Wage Employees					**$947,232**

* Hourly wages plus 30% for payroll taxes and fringe benefits.

** 24 hours/day X 6 days/week X 50 weeks = 7,200 (Employees are paid for 6 holidays; plant operates 7,056 hours.)

The wages shown in the above table are based on wage and salary information contained in the "Minnesota Salary Tool" which is available on the Minnesota Department of Employment and Economic Development's website at www.deed.state.mn.us.

For the 4-ton/hour pellet plant, it is assumed that one fewer Machinery/Equipment Operators would be required on each shift, resulting in annual labor savings of $140,400, but there is not a sound basis for this. This assumption is made just to illustrate that there must be some break-points. (In fact, it is assumed that the larger capacity pellet plants would have a fully automated bagging/palleting system, but the 4-ton/hour plant would have only a semi-automated system. With this, it is possible that the 4-ton/hour plant could require more labor than an 8-ton/hour plant.)

[63] Show Me Energy Cooperative website at www.goshowmeenergy.com.

For the 2-ton/hour pellet plant, the assumption is that total labor expenses would be equal to $15.00/hour X 6,000 hours (to achieve 2,000 full-production hours). This could include wages the owner would pay to himself and family members as well as to hired laborers.

A stand-alone pellet plant may have to schedule one more worker for each shift than an "add-on" pellet plant adjoining a sawmill or an agricultural processing plant because the add-on pellet plant may be able to "borrow" a worker when there is an unexpected absence or an unusual need for extra help. The add-on pellet plant may also routinely share workers (and equipment, too) for specific, regular tasks that do not require a full-time worker assignment. A stand-alone pellet plant does not enjoy such an economical labor arrangement.

The Nth year financial projections include plant labor costs as shown in the table below. (Plant labor includes the Mechanic/Maintenance Worker and the Shift Supervisor, but not the General Manager or Receiving Clerk.)

PLANT LABOR COSTS

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Plant labor costs (wages taxes & benefits)	$90,000	$806,832	$947,232	$947,232
Labor cost/ton (of pellets produced annually)	$22.50	$33.62	$19.73	$11.28

As virtually all economic analyses predict, the economies of scale are most pronounced for labor costs. Even with a generous assumption that a 4-ton/hour pellet plant would require one fewer worker per shift, labor costs per ton for a 4-ton/hour plant are three times greater than for a 14-ton/hour plant. To put it in different terms, the labor cost advantage of a 14-ton/hour pellet plant over a 4-ton/hour pellet plant is better than a $20.00/ton price increase.

Salaries, Payroll Taxes and Fringe Benefits – Management/Administration

An agricultural biomass pellet company would need some number of full-time professional staff to attend to all business and financial matters. A pellet business that is an "add-on" to a sawmill or an agricultural processing company has an advantage in that professional staff could be shared across business lines. (The sawmill and pellet businesses may share a Finance Manager, for example.)

The Nth year financial projections for the commercial-scale pellet plants assume that the positions in management and administration shown in the table on the following page (titled "Salaries, Payroll Taxes and Fringe Benefits") would be required.

SALARIES, PAYROLL TAXES AND FRINGE BENEFITS for all Commercial-Scale Pellet Plants			
Salaried Employees	**Salary**	**Payroll Tax/ Benefits**	**Annual Cost**
General Manager	$75,000	20%	$90,000
Finance Manager	$60,000	22%	$73,200
Marketer	$50,000	24%	$62,000
Receiving Clerk/Admin. Asst.	$30,000	28%	$38,400
Total: Salaried Employees	**$215,000**		**$263,600**

Again, the salaries shown in the above table are based on wage and salary information contained in the "Minnesota Salary Tool" which is available on the Minnesota Department of Employment and Economic Development's website at www.deed.state.mn.us.

PROFESSIONAL PERSONNEL COSTS

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Salaries, taxes and benefits	$0	$263,600	$263,600	$263,600
Costs/ton	$0	$10.98	$5.49	$3.14

Economies of scale are obvious. Whether a stand-alone pellet company produces 4 tons/hour or 14-tons/hour, certain professional positions must be filled.

Electricity

A pellet plant demands a lot of electricity, and electric costs are a significant line item in a pellet plant's operating budget. Various analyses provide estimates of electric costs for pellet plants. These are useful guides; but to estimate electric costs with reasonable accuracy, one must sum the demand and expected usage of all equipment and fixtures and then apply the local utility's electric rates (which may be negotiable for an industrial customer the size of a pellet plant). This exercise of summing electric demand can be tricky, too, because advanced motors automatically adjust for the load so they perform more efficiently than if they operated at full power all the time.

The table on the following page (titled "Electricity Usage and Cost Estimates") shows electric cost estimates for all plant sizes considered in this feasibility study guide based on 2007 demand and energy charges of a local electric distribution cooperative in western Minnesota. It is assumed (for simplicity, not necessarily accuracy) that pellet plants of all sizes would pay the same monthly demand charges of $7.00/kilowatt and energy charges of $0.035/kilowatt-hour for non-interruptible service. There would also be a service fee paid to the distribution cooperative of $60/month.

A pellet plant at even the 4-ton/hour size would likely fall into the "large power customer" category with estimated demand of 548 kilowatts (kw). The 14-ton/hour pellet plant has demand of almost 1,500 kw. This demand may put a large pellet plant in a category beyond "large power customer" in which customers pay a variable demand charge, with the highest charge for demand in the peak months of summer. In this case, the larger plant and smaller plant would not pay the same demand and energy rates.

ELECTRICITY USAGE AND COST ESTIMATES				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
Production Capacity (Tons/Hour)	2	4	8	14
Annual Pellet Production (Tons)	4000	24000	48000	84000
Annual Full Production Hours	2000	6000	6000	6000
Allowance for Idle Hours*	100	300	300	300
Total Annual Energy Use Hours	2100	6300	6300	6300
Monthly Energy Use Hours	175	525	525	525
Utility Rates				
Demand Charge/Month	$7.00	$7.00	$7.00	$7.00
Energy Charge	$0.035	$0.035	$0.035	$0.035
Co-op Service Fee/Mo.	$60.00	$60.00	$60.00	$60.00
Horsepower, KW and KWH				
Primary Grinder	-	150	150	225
Dryer	-	70	160	360
Hammermill	75	75	100	200
Boiler	50	50	100	-
Pellet Mill	100	200	400	800
Bagging/Palleting	-	20	50	50
Other	50	50	50	180
Building Boiler, Lights, Etc.	20	120	150	150
TOTAL HP	295	735	1,160	1,965
Total KW	220	548	865	1,466
Total KWH/Month	38,512	287,863	454,314	769,592
Total KWH/Year	462,147	3,454,353	5,451,768	9,235,107
Costs				
Demand Charges	$1,540	$3,838	$6,058	$10,261
Energy Charges	$1,348	$10,075	$15,901	$26,936
Co-op Service Fee	$60	$60	$60	$60
Total Monthly Costs	**$2,948**	**$13,973**	**$22,019**	**$37,257**
Total Annual Costs	**$35,381**	**$167,680**	**$264,222**	**$447,084**
Electric Costs/Ton	**$8.85**	**$6.99**	**$5.50**	**$5.32**

* Allowance for Idle Hours: Energy use when equipment is warming up, shutting down or otherwise running without production.

The electric costs/ton shown in the table above (titled "Electricity Usage and Cost Estimates") suggest that a larger plant may achieve economies of scale with respect to electricity usage. Logically, there should be some economies of scale when the same equipment is used to process more tons of product; but economies of scale are probably overstated in the table below because no adjustments are made for when motors run at less than full power.

A more important factor is equipment sizing. If one must install an equipment component that is too large because the next smaller size is too small, then electricity would be wasted operating the larger piece of equipment. Thus, the pellet plant that has perfectly sized equipment components probably would have the lowest electric costs per ton. (This is relevant to the discussion of whether to oversize equipment components initially to reduce expansion costs later.)

A high level of confidence should not be assigned to the specific values for total annual costs and electric costs/ton offered in the table above, but they are reasonably consistent with estimates found in the literature. For a fully equipped commercial-scale pellet plant (with a primary grinder, dryer and bagging system) in the service region of an electric distribution cooperative, electric cost estimates in the range of $5.30 to $7.00/ton should be safe.

Alternative electric power options. Utilities' demand and energy charges are much lower for interruptible service. Payments to an electric utility could be reduced considerably by installing a generator large enough to power the pellet plant when the electric utility would want to interrupt service during the utility's peak demand periods. In a project-specific feasibility study, it may be worthwhile to calculate the costs and benefits of installing a generator and opting for interruptible electric service.

Another possibility would be to opt out of an electric utility's service almost entirely with a biomass-fired or natural gas-fired cogeneration (or combined heat and power) system. Such a system would produce process heat, space heat and electricity for the pellet plant. With a biomass-fired cogeneration system, the requirements for procuring, handling, storing and processing feedstock would be much greater, of course; and production of the company's only product – fuel pellets – would depend on the operational reliability of a co-generation system that produces essential energy inputs. This could be viewed as a significant risk factor for the entire enterprise.

Natural Gas

It is assumed that natural gas would be used for dryer fuel. This is an important assumption. If only propane is available (assuming a gas-fired, not a solid fuel-fired dryer is installed), the estimated cost of thermal energy required for drying feedstock could be double.

A price estimate of $8.90/million Btu for natural gas is based on the current rate for firm general service customers of a natural gas utility that serves western Minnesota. The Energy Information Administration of the U.S. Department of Energy projects gradually declining natural gas prices (in real dollars) through 2014 and gradually rising prices thereafter. While natural gas prices are always subject to unforeseen spikes due to supply disruptions, a price of $8.90/million Btu is probably a good planning assumption.

The table on the following page (titled "Natural Gas Usage and Cost Estimates") shows natural gas usage to dry feedstock from 20% to 10% moisture content and from 30% to 10%. The author of this feasibility study found dryer manufacturer's representatives happy to assist with the assumptions and calculations shown in the table below.

Different dryers operate at different efficiencies; and again, sizing is important – heating a lot of air in a half-empty dryer is not a productive use of expensive energy. When selecting a dryer, it would be prudent to look at several manufacturers' models for efficiency and sizes.

Economies of scale are not an important factor with respect to feedstock drying. The most important factor affecting natural gas costs is the moisture content of the feedstock on an "as received" basis. To produce 84,000 tons of pellets from 20% moisture content (MC) feedstock, 10,500 tons of moisture must be evaporated from 94,500 tons of feedstock at a cost of about $3.79/ton of finished pellets. To produce 84,000 pellets from 30% MC feedstock, 24,024 tons of water must be evaporated from 108,024 tons of feedstock at a cost of about $8.69/ton of finished pellets. (The details of this analysis are shown in the "Natural Gas Usage and Cost Estimates" table below.)

NATURAL GAS USAGE AND COST ESTIMATES				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
Production Capacity (Tons/Hour)	2	4	8	14
Annual Pellet Production (Tons)	4,000	24,000	48,000	84,000
NATURAL GAS - Reduce 20% MC Feedstock to 10% MC				
Btu to Evaporate 1 LB Water	1,760	1,760	1,748	1,708
LB Water to Evaporate/Ton F-stock	222	222	222	222
Btu/Ton Feedstock	390,720	390,720	388,056	379,176
Tons Feedstock/Year	4,500	27,000	54,000	94,500
MMBtu/Year	1,758	10,549	20,955	35,832
Natural Gas Price ($/MMBtu)	$8.90	$8.90	$8.90	$8.90
Annual Natural Gas Cost	**$15,640**	**$93,840**	**$186,401**	**$318,738**
Natural Gas Cost/Ton	**$3.91**	**$3.91**	**$3.88**	**$3.79**
NATURAL GAS - Reduce 30% MC Feedstock to 10% MC				
Btu to Evaporate 1 LB Water	1,760	1,760	1,748	1,708
LB Water to Evaporate/Ton F-stock	445	445	445	445
Btu/Ton Feedstock	783,200	783,200	777,860	760,060
Tons Feedstock/Year	5,144	30,864	61,728	108,024
MMBtu/Year	4,029	24,173	48,016	82,105
Natural Gas Price ($/MMBtu)	$8.90	$8.90	$8.90	$8.90
Annual Natural Gas Cost	**$35,837**	**$215,023**	**$427,114**	**$730,346**
Natural Gas Cost/Ton	**$8.96**	**$8.96**	**$8.90**	**$8.69**

The above table assumes that the moisture content of feedstock should be about 10%. As discussed earlier in this feasibility study guide, one manufacturer's representative indicated that his company's conditioner and pellet mill may operate best when feedstock is 13% to 15% moisture content. Given the high cost of drying feedstock, this may be an important factor to consider when selecting a pellet mill. All other factors being equal, the pellet mill that produces a high-quality pellet with wetter feedstock may be preferred.

Recall the "back of the envelope" analysis of the payback on a solid biomass-fired dryer. Again, the additional capital cost of a biomass-fired dryer for an 8-ton/hour pellet plant may be about $300,000, and net fuel cost savings might be about $70,000/year, for a simple payback of about 4.3 years. This is an option worth exploring in a feasibility study for an agricultural biomass pellet company.

Dies, Rollers and Other Parts

Dies and rollers in pellet mills are considered consumables – they wear out and need to be replaced regularly. The useful life of dies and rollers depends on the physical characteristics of the feedstock, the suitability of the dies for the particular feedstock, and operational settings and practices.

During the first six to eighteen months, a pellet plant operator will probably use and wear out a lot of dies as the operator experiments with different dies, feedstock conditioning practices and pellet mill settings. As production practices are improved, dies and rollers are expected to last longer.

Various documents suggest on-going cost estimates of $2.00 to $6.00 per ton of pellets produced for replacement parts (including dies, rollers, blades, screens, and the numerous other parts subject to wear-and-tear in the grinder, dryer, hammermill, and pellet mill). In the Nth year financial projections for all pellet plant sizes, it is assumed that the cost of “dies, rollers and other parts” will be $3.00 per ton of pellets, as suggested by one manufacturer’s representative.

COSTS FOR DIES, ROLLERS AND OTHER PARTS

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Dies, rollers and other parts	$12,000	$72,000	$144,000	$252,000
Cost/ton	$3.00	$3.00	$3.00	$3.00

Contract Plant Repairs

All equipment components in a pellet plant require routine inspection and maintenance. Pellet mills, in particular, are maintenance-intensive, and replacement of dies and rollers is a routine activity. Primary grinders and hammermills require a lot of maintenance, too. The maintenance and minor repair workload is considered to be sufficient to keep a full-time mechanic/maintenance worker busy.

In addition, there would be a need to hire contractors to make repairs and improvements to equipment. Contractors may be hired to do sheet metal work, welding, parts fabrication, machining, motor repair, and electrical repairs. The amount budgeted in the Nth year financial projections for all plant sizes is $0.50/ton (of pellets produced), which is $42,000 for a 14-ton/hour plant. This would not be enough in a bad year, but the author of this feasibility study guide could not find any credible estimates to justify a higher budget estimate.

CONTRACT PLANT REPAIR COSTS

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Contract plant repairs	$2,000	$12,000	$24,000	$42,000
Cost/ton	$0.50	$0.50	$0.50	$0.50

Wheel Loader Operations and Maintenance

A service employee of a construction equipment dealer estimated that a 110-horsepower wheel loader would use 4.1 gallons of diesel fuel per hour at full load (maximum horsepower). This is consistent with information on wheel loaders found elsewhere. The wheel loader would not be run at full load during all 7,056 hours that the pellet plant is scheduled to be operating during the year. For the purpose of estimating fuel costs for the 14-ton/day pellet plant, it is assumed that annual use of the wheel loader would be the equivalent of 4,000 hours at full load (maximum horsepower). For the 8-ton/hour pellet plant, the annual use estimate is 3,200 hours at full load; and for the 4-ton/day pellet plant, it is 2,560 hours. The price of diesel fuel is assumed to be $3.00/gallon.

The service employee indicated that $3.00/full-load hour is a reasonable estimate for all other operating costs, maintenance and repair. This amount is included in the estimate of wheel loader operations and maintenance costs.

For the 2-ton/hour plant, a wheel loader would not be purchased, but there would still be an assignment of some operating and maintenance costs for the tractor and other equipment used in pellet production.

WHEEL LOADER OPERATING COSTS

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Wheel loader oper./mtnce.	$12,300	$39,168	$48,960	$61,200
Cost/ton	$3.07	$1.63	$1.02	$0.73

(The apparent economies of scale may look more significant than they would really be.)

Forklift Operations and Maintenance

It is assumed that the forklift would use propane fuel, but it could also be battery-powered. The specified forklift would use about 1.3 gallons of propane per full-load (maximum horsepower) hour, according to documents found and confirmation by an employee of a forklift dealer. It is assumed that the forklift would be operated the equivalent of 3,000 full-load hours in the 14-ton/hour pellet plant (which is the same as 6,000 hours at half-power), and the price of propane would be $1.65/gallon. The forklift dealer estimated that maintenance and repair costs would equate to about $1.25/full-load hour.

For the 8-ton/hour plant, the annual use estimate is 2,400 hours at full-load. For the 4-ton/hour plant, it is 1,920 full-load hours.

FORKLIFT OPERATING COSTS

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Forklift operating/mtnce.	$0	$6,518	$8,148	$10,185
Cost/ton	$0	$0.27	$0.17	$0.12

Bagging and Palleting

Packaging a conventional retail pellet product requires considerable expense after the pellets have been produced. The steps of this process are to fill and seal plastic bags with 40 pounds of pellets, stack bags of pellets on pallets (50 bags per pallet), and shrink-wrap the loaded pallets. Then the loaded pallets must be moved to storage or a loading dock. For the "Retail Product Business Model," it is assumed that 100% of the pellets produced in the commercial-scale pellet plants would be bagged and palleted for retail sales.

In addition to labor, electricity and fuel costs associated with the bagging and palleting stage, there are high costs for consumables – bags, pallets, slip sheets and wraps. Documents on the economics of pellet plants indicate that bags may cost $0.12 to $0.25/bag. A manufacturer's representative suggested that a reasonable budget estimate for durable plastic bags (.0035 to .005 mils) with one-color printing would be $0.15. Fifteen cents per bag may not seem like a big expense, but it adds up to $7.50/ton of pellets produced. Pallets, slip sheets and stretch wrapping are estimated to cost $4.00 for each loaded pallet (which is $4.00/ton). Thus, total consumables for bagging and palleting are expected to cost $11.50/ton.

COSTS FOR BAGGING AND PALLETING CONSUMABLES

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Bags, pallets and wrap	$0	$276,000	$552,000	$966,000
Cost/ton	$0	$11.50	$11.50	$11.50

Marketing/Sales Fees and Incentives

It is assumed that all of the pellets produced by the commercial-scale pellet plants would be packaged for retail sales (to be sold directly by the pellet company to consumers or to retail stores). To manage marketing and sales, a full-time Marketer is budgeted under "salaries, taxes and benefits" for management and administrative personnel. There would also be other marketing and sales costs for promotions, discounts, rebates, broker fees, placement fees, and other forms of compensation and incentives. It is assumed in the Nth year financial projections for the "Retail Product Business Model" that these costs would be $6.00/ton of pellet produced and sold by the commercial-scale pellet plants.

MARKETING FEES AND INCENTIVES

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Marketing/sales fees and incentives	$0	$144,000	$288,000	$504,000
Cost/ton	$0	$6.00	$6.00	$6.00

Property Taxes

Like other commercial/industrial property owners, an agricultural biomass pellet company would be expected to pay property taxes on the value of its real property (land and buildings). The capital costs for land, site improvements, and structures for each commercial-scale pellet plant are summed to approximate their estimated market values. The total commercial/industrial property tax rate (including the State commercial/industrial tax rate) in non-municipal areas of a southwestern Minnesota county is 2.46% of estimated market value. Estimated market values and property taxes for the commercial-scale pellet plants are as follows:

PROPERTY TAXES

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Estimated market value of real property	$0	$2,465,000	$3,343,000	$3,836,000
Estimated property taxes	$0	$60,639	$82,238	$94,366
Cost/ton	$0	$2.53	$1.71	$1.12

(The 2-ton/hour pellet plant is not assigned any property taxes in the Nth year financial projection because the pellet plant equipment would be installed in existing buildings without affecting their estimate market values.)

Depreciation

Depreciation is a non-cash expense which accounts for assets having a limited economic life. In the Nth year financial projections, it is assumed that all assets of the pellet plants would be depreciated in even annual amounts (straight-line) according to the following schedule:

Buildings:	30 years
Receiving station and storage lot:	20 years
Fixed equipment:	10 years
Wheel loader, forklift, and other equipment and tools:	5 years

DEPRECIATION

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Depreciation	$58,550	$403,500	$569,287	$682,260
Non-cash cost/ton	$14.63	$16.81	$11.86	$8.12

The apparent economies of scale are merely a reflection of the lower capital costs per ton for the larger pellet plants.

Interest on Working Capital

It is not uncommon for companies to use working capital or a line of credit to pay their expenses prior to receiving revenues attributable to those expenses. If a company borrows against a line of credit, then the company must pay interest to the lender. If a company uses internal working capital, then there is an opportunity cost which can be expressed like an interest rate.

The retail market for fuel pellets is seasonal – households use their pellet stoves during the heating season. It is assumed that the pellet plants would operate on a year-round basis, thus creating payroll and other current expense obligations which cannot always be met with current revenues. To meet current expenses, it is assumed that funds would be "borrowed" from owners or a bank. An "an order of magnitude" estimate of resulting interest expense for a 14-ton/day pellet plant is calculated as follows:

It is assumed that the pellet company would borrow funds to meet current expenses in all twelve months of the year. For the months of October through April, the company would borrow the total amount of its monthly outlays, approximately $830,000, for 30 days. For the other months, revenues would be delayed until November. Therefore, the company would borrow $830,000 in May, which the company would repay 180 days later. The company would borrow $830,000 in June, which the company would repay 150 days later, etc. The schedule below calculates the interest expense for this working capital at a 9.0% annual interest rate.

WORKING CAPITAL INTEREST EXPENSE			
Month	**Days**	**Amount Borrowed**	**Interest Expense @ 9%**
January	30	$830,000	$6,140
February	30	$830,000	$6,140
March	30	$830,000	$6,140
April	30	$830,000	$6,140
May	180	$830,000	$36,842
June	150	$830,000	$30,702
July	120	$830,000	$24,561
August	90	$830,000	$18,421
September	60	$830,000	$12,281
October	30	$830,000	$6,140
November	30	$830,000	$6,140
December	30	$830,000	$6,140
Total			**$165,789**

This same rough method was used to estimate total annual interest expenses (or opportunity costs) for each of the pellet plants, including the farm-scale plant, because its owner would have similar circumstances to the commercial-scale companies. "Order of magnitude" estimates for working capital interest expenses are:

WORKING CAPITAL INTEREST EXPENSE

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Working Capital Interest	$5,692	$64,435	$107,001	$165,789
Cost/ton	$1.42	$2.68	$2.23	$1.97

The cost/ton for working capital interest is lower for larger plants because total costs/ton are lower and thus the amount borrowed per ton is less.

Interest on Long-Term Debt

Project financing for development of a pellet plant is described in Chapter 14. In the following Nth year financial projections, it is assumed that only interest payments (at a rate of 8.5%) are due on the long-term debt.

INTEREST PAYMENTS

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Total capital budget	$585,500	$5,502,000	$7,695,200	$9,131,600
Debt financing (60%)	$351,300	$3,301,200	$4,617,120	$5,478,960

Interest payments	$ 29,861	$ 280,602	$ 392,455	$ 465,712
Cost/ton	$7.47	$11.69	$8.18	$5.54

Again, for the commercial-scale pellet plants, the cost/ton declines because the capital cost/ton is lower for the larger plants.

15.4 Financial Results – Retail Product Business Model

The reader is forewarned that the following presentations of financial results may be confusing. In this Section 15.4, ***only*** financial results for the "Retail Product Business Model" will be presented. (An alternative business model will be presented in Chapter 16.)

The Nth year financial projections for the "Retail Product Business Model" are fully detailed on pages 109 to 111:

> "*Table 15A: Assumptions*" on page 109 shows the base-case assumptions for each size pellet plant.
>
> "*Table 15B: Income Statement*" on page 110 presents gross income, expenses and net income for each size pellet plant assuming a pellet price of $120/ton (at the plant gate).
>
> "*Table 15C: Impact of Pellet Price Changes*" on page 111 shows how net income and return on equity would be affected by different pellet prices.

As described previously in this chapter, the purpose of the Nth year financial projections is only to assess whether an enterprise *might* be economically viable in the future. ***These financial projections are not predictions of financial performance in any particular year.*** When reviewing these financial projections, it is important to remember that they are intended to illustrate a hypothetical year of financial performance when:

- The company is beyond the start-up years; production and business operations have reached their highest sustainable plateau. (Many companies fail before they ever reach such a plateau.)
- All costs are based on current year prices; no inflation and no price changes caused by different supply and demand factors are assumed to have occurred.
- There are no subtractions of estimated state or federal income taxes.
- There is no payment of principal on long-term debt. Only interest on the original principal is paid. (Thus, the first claim on any net income may be the long-term debt holders'.)
- There are no payments into a debt service reserve fund or a major repair/replacement reserve fund.

The base-case financial projections for each plant (shown in *Table 15A: Assumptions* and *Table 15B: Income Statement* on pages 109 and 110) assume that the company would sell all of the agricultural biomass pellets it produces for $120.00/ton. This price is FOB the plant; that is, the customer pays this price plus the cost of shipping. Total costs/ton exceed this price for all of the commercial-scale pellet plants as shown below:

COSTS AND NET INCOME/TON

	2-Ton/Hr.	**4-Ton/Hr.**	**8-Ton/Hr.**	**14-Ton/Hr.**
Cost/ton	$101.45	$180.58	$147.84	$128.52
Net income (loss)/ton	$ 18.55	($ 60.58)	($ 27.84)	($ 8.52)

Only the farm-scale pellet plant shows a satisfactory net income and return on equity in this financial scenario. Recall, however, the assumption that many of the capital requirements for the farm-scale pellet plant (buildings, wheeled equipment, the owner's installation labor, etc.) would be provided at no charge to the pellet enterprise. Furthermore, it is assumed that the farm-scale pellet plant's feedstock (corn stover) would be expensed below market price and would not require drying; the pellet enterprise would incur no marketing or selling expenses; and labor and other operating costs would not be fully accounted.

Impact of Pellet Price Changes

Table 15C: Impact of Pellet Price Changes on page 111 holds total expenses steady for each pellet plant but changes the price of agricultural biomass pellets that the pellet company would realize on the sale of 100% of annual production. Price changes are in increments of $10/ton. (Reducing operating costs by $10/ton would have the same effect as increasing the price by $10/ton, of course.)

The first illustrative scenario is a pellet price of $110/ton (FOB the plant). This would obviously not be a viable price for any of the commercial-scale pellet plants; their net income is estimated to be negative by more than $1.5 million. With a pellet price of $110/ton, the estimated return on equity to the owner of the farm-scale pellet plant is 14%, but, again, all costs attributable to the farm-scale pellet enterprise are not accounted.

Smart people invest in companies for lots of different financial and philosophic reasons – to maximize yield, to complement other business ventures, to create a job for the investor, or to advance broader environmental, social and economic values. There are no absolutely correct investment standards.

Nevertheless, based on the information presented in this feasibility study guide, one would probably consider a commercial-scale agricultural biomass pellet company a fairly high-risk venture. If so, a sophisticated passive investor (one who is not also investing in a job or a market for his products), would only invest in a pellet company if there is a reasonable expectation for a relatively high rate of return. In an "Nth" year financial projection, an investor may want to see at least a 25% return on equity. The different size pellet plants surpass the 25% return-on-equity threshold at the following prices:

Greater than 25% Return on Equity

Pellet Plant	**Pellet Price**
2-ton/hour	$120/ton
14-ton/hour	$150/ton
8-ton/hour	$170/ton
4-ton/hour	>$180/ton

The return on equity is a useful measure, but it is easily manipulated by simply assuming a higher debt-to-equity ratio. If the equity investment is cut in half, then the return on equity almost doubles. (It would not fully double because the interest expense on long-term debt would increase with the higher amount debt-financed, thereby reducing net income.)

Another useful measure may be net income as a percentage of gross income. Perhaps a reasonable standard of investment viability for a commodity business such as an agricultural biomass pellet company is net income greater than 10% of gross income. The different size pellet plants meet this standard at the prices shown below.

Net Income > 10% of Gross Income

Pellet Plant	**Pellet Price**
2-ton/hour	$120/ton
14-ton/hour	$150/ton
8-ton/hour	$170/ton
4-ton/hour	>$180/ton

With these financial scenarios (with prices increased in relatively large $10 increments), the results are the same whether the investment standard is 25% return on equity or 10% net income. Two points are illuminated in this analysis. First, economies of scale appear to significantly affect the pellet price required for commercial-scale pellet plants to achieve economic viability. Second, a price (or operating cost) change of just $20/ton makes a tremendous difference. For example, at a price of $120/ton, the 14-ton/hour pellet plant shows a loss of $715,866, but at a price of $140/ton, it shows a profit of $964,134 (for a return on equity of 24%). Such price swings are almost inevitable in volatile energy markets.

Finally, it must be pointed out again that there is not a robust retail market for agricultural biomass pellets, and there is no price history. Thus, predicting future prices for agricultural biomass pellets is guesswork. Nevertheless, a draft market assessment produced by "Relevant ideas…LLC" suggests prices of $90/ton for "utility" pellets and $120/ton for "standard" pellets (by the Pellet Fuels Institute's proposed fuel standards). Even at the higher price of $120/ton in the "Nth" year, it appears that a commercial-scale pellet plant producing bagged pellets for the seasonal retail market would lose more than $1.5 million/year.

Table 15A: Assumptions

RETAIL PRODUCT BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
BASE-CASE ASSUMPTIONS				
Pellet mill horsepower	100	200	400	800
Annual full-production hours	2,000	6,000	6,000	6,000
Av. feedstock moisture content	10%	20%	20%	20%
Feedstock required (tons)	4,000	27,000	54,000	94,500
Corn stover price (delivered)	$40.00	$63.00	$63.00	$63.00
Soybean straw price (delivered)	$0.00	$42.00	$42.00	$42.00
Damaged hay/grass (delivered)	$0.00	$60.00	$60.00	$60.00
Corn stover use (% feedstock)	100%	60%	60%	60%
Soybean straw use (% feedstock)	0%	20%	20%	20%
Hay/grass use (% feedstock)	0%	20%	20%	20%
Pellets produced	4,000	24,000	48,000	84,000
Tons bagged and palleted	0	24,000	48,000	84,000
Pellet price per ton (at plant gate)	$120.00	$120.00	$120.00	$120.00
Capital cost of pellet plant	$585,500	$5,502,000	$7,695,200	$9,131,600
Debt financing principal (60%)	$351,300	$3,301,200	$4,617,120	$5,478,960
Interest rate	8.5%	8.5%	8.5%	8.5%
Equity investment (40%)	$234,200	$2,200,800	$3,078,080	$3,652,640
Year 0 budget plus interest due	$14,930	$261,901	$317,828	$354,456
Total initial equity required	$249,130	$2,462,701	$3,395,908	$4,007,096

Table 15B: Income Statement

RETAIL PRODUCT BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	U.S DOLLARS			
GROSS INCOME	**480,000**	**2,880,000**	**5,760,000**	**10,080,000**
EXPENSES				
Corn stover	160,000	1,020,600	2,041,200	3,572,100
Soybean straw	0	226,800	453,600	793,800
Damaged hay and grasses	0	324,000	648,000	1,134,000
Wood	0	0	0	0
Other feedstock	0	0	0	0
Storage fees	0	0	0	0
Loading and hauling fees	0	0	0	0
Total Feedstock Costs	**160,000**	**1,571,400**	**3,142,800**	**5,499,900**
Plant wages, taxes & benefits	90,000	806,832	947,232	947,232
Electricity	35,381	167,680	264,222	447,084
Natural gas - dryer only	0	93,840	186,401	318,738
Water/sewer	0	800	1,000	1,000
Dies, rollers, other parts	12,000	72,000	144,000	252,000
Contract plant repairs	2,000	12,000	24,000	42,000
Wheel loader operating/mtnce.	12,300	39,168	48,960	61,200
Forklift operating/mtnce.	0	6,518	8,148	10,185
Bags, pallets and wrap	0	276,000	552,000	966,000
Transportation (to buyers)	0	0	0	0
Total Direct Op. Costs	**151,681**	**1,474,838**	**2,175,963**	**3,045,439**
Salaries, taxes & benefits (M&A)	0	263,600	263,600	263,600
Marketing/sales fees & incentives	0	144,000	288,000	504,000
Telecommunications/internet	0	10,000	10,000	10,000
Office supplies	0	5,000	5,000	5,000
Lab Testing	0	10,000	10,000	10,000
Travel and training	0	10,000	10,000	10,000
Legal, accting., and consulting	0	20,000	20,000	20,000
Property taxes	0	60,639	82,238	94,366
Insurance	0	16,000	20,000	20,000
Depreciation	58,550	403,500	569,287	682,060
Total Sales/G&A	**58,550**	**942,739**	**1,278,125**	**1,619,026**
Interest on working capital	5,692	64,435	107,001	165,789
Interest on long-term debt	29,861	280,602	392,455	465,712
Total Interest	**35,553**	**345,037**	**499,456**	**631,501**
TOTAL EXPENSES	**405,784**	**4,334,014**	**7,096,344**	**10,795,866**
NET INCOME	**74,216**	**(1,454,014)**	**(1,336,344)**	**(715,866)**
RETURN ON INITIAL EQUITY	**30%**	**NA**	**NA**	**NA**

Table 15C: Impact of Pellet Price Changes

RETAIL PRODUCT BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	IMPACT OF PELLET PRICE CHANGES			
Pellet price per ton	**$110.00**	**$110.00**	**$110.00**	**$110.00**
Gross income	440,000	2,640,000	5,280,000	9,240,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	34,216	(1,694,014)	(1,816,344)	(1,555,866)
Return on initial equity	14%	-69%	-53%	-39%
Pellet price per ton	**$120.00**	**$120.00**	**$120.00**	**$120.00**
Gross income	480,000	2,880,000	5,760,000	10,080,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	74,216	(1,454,014)	(1,336,344)	(715,866)
Return on initial equity	30%	-59%	-39%	-18%
Pellet price per ton	**$130.00**	**$130.00**	**$130.00**	**$130.00**
Gross income	520,000	3,120,000	6,240,000	10,920,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	114,216	(1,214,014)	(856,344)	124,134
Return on initial equity	46%	-49%	-25%	3%
Pellet price per ton	**$140.00**	**$140.00**	**$140.00**	**$140.00**
Gross income	560,000	3,360,000	6,720,000	11,760,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	154,216	(974,014)	(376,344)	964,134
Return on initial equity	62%	-40%	-11%	24%
Pellet price per ton	**$150.00**	**$150.00**	**$150.00**	**$150.00**
Gross income	600,000	3,600,000	7,200,000	12,600,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	194,216	(734,014)	103,656	1,804,134
Return on initial equity	78%	-30%	3%	45%
Pellet price per ton	**$160.00**	**$160.00**	**$160.00**	**$160.00**
Gross income	640,000	3,840,000	7,680,000	13,440,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	234,216	(494,014)	583,656	2,644,134
Return on initial equity	94%	-20%	17%	66%
Pellet price per ton	**$170.00**	**$170.00**	**$170.00**	**$170.00**
Gross income	680,000	4,080,000	8,160,000	14,280,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	274,216	(254,014)	1,063,656	3,484,134
Return on initial equity	110%	-10%	31%	87%
Pellet price per ton	**$180.00**	**$180.00**	**$180.00**	**$180.00**
Gross income	720,000	4,320,000	8,640,000	15,120,000
Total expenses	405,784	4,334,014	7,096,344	10,795,866
Net income	314,216	(14,014)	1,543,656	4,324,134
Return on initial equity	126%	-1%	45%	108%

16. Alternative Business Model: Utility Fuel Production Plant

As discussed in other chapters of this feasibility study guide, a market may emerge for agricultural biomass pellets in the utility, industrial and institutional sectors. Pellets could be a substitute for coal or natural gas; they could be burned separately or co-fired. The alternative business model presented in this chapter is for a "utility fuel production plant" which would produce bulk agricultural biomass pellets for large utility, industrial and institutional customers (and the model is referred to as the "Utility Fuel Production Model" or the "Utility Model").

This chapter contains the following tables:

> "*Table 16A: Utility Model Capital Budgets*" on page 114 presents capital budget estimates for each size utility fuel production plant.
>
> "*Table 16B: Capital Budget Differences*" on page 115 shows estimated capital budget differences between the Utility Model and Retail Product Business Model. (Negative numbers indicate capital budget savings for the Utility Model.)
>
> "*Table 16C: Utility Model Assumptions*" on page 118 presents the base-case assumptions for each size Utility Model pellet plant.
>
> "*Table 16D: Utility Model Income Statement*" on page 119 presents gross income, expenses and net income for each size Utility Model pellet plant assuming a pellet price of $120/ton (delivered).
>
> "*Table 16E: Income Statement Differences*" on page 120 shows differences in expenses and net income between the Utility Model and the Retail Product Business Model. (Negative numbers indicate lower costs for the Utility Model.)
>
> "*Table 16F: Impact of Pellet Price Changes on Utility Model*" on page 121 shows how net income and return on equity for the Utility Model would be affected by different pellet prices.

Capital Budget Savings

Capital budget estimates for utility fuel production plants are shown in *Table 16A: Utility Model Capital Budgets* on page 114. On page 115 is *Table 16B: Capital Budget Differences* which presents the capital budget differences between the Retail Product Business Model and the Utility Fuel Production Model. (This table simply shows for each capital budget item, the amount estimated for the Utility Model less the amount estimated for the Retail Product

Business Model. A negative number indicates a lesser amount, or a savings, for the Utility Model.)

The estimated capital budget savings for the utility fuel production plants are significant – from $857,000 for the 4-ton/hour pellet plant to $1,870,000 for the 14-ton/hour pellet plant.

One of the significant differences would be that a utility fuel production plant would not require a bagging and palleting system. There also would be no need for a racked warehouse in which to store loaded pallets, and there would be no use for a forklift.

With the Utility Fuel Production Model, there would still be a need for loose pellet storage capacity, but it would be substantially reduced. Unlike retail customers, utility/industrial/institutional customers would use pellets on a year-round basis to generate electricity or meet other thermal energy requirements. Some pellet storage capacity would be needed for inventory to deliver when the pellet plant is down or when demand increases (with seasonal electric load peaks, for example). Pellet storage capacity would also be needed when demand drops (perhaps due to a power plant shutdown) so that the pellet plant could continue normal production. These needs could be met with smaller pellet storage buildings at the utility fuel production plants than were estimated for the retail product pellet plants.

In addition to the obvious line-item capital budget savings, the different requirements for utility fuel production plants would result in savings for ancillary equipment (conveyors, tanks, etc.), engineering, project management, freight, mechanical installation and electrical installation.

Table 16A: Utility Model Capital Budgets

UTILITY FUEL PRODUCTION BUSINESS MODEL PELLET PLANT CAPITAL BUDGET ESTIMATES				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	U.S. DOLLARS			
Site/Site Preparation	**0**	**216,000**	**216,000**	**216,000**
Plant Building & Offices	**0**	**816,000**	**1,020,000**	**1,020,000**
Receiving Station & Scale	**0**	**130,000**	**130,000**	**130,000**
Feedstock Storage				
Storage Lot	0	180,000	360,000	360,000
Storage Warehouse	0	280,000	280,000	280,000
Total Feedstock Storage	**0**	**460,000**	**640,000**	**640,000**
Pellet Storage				
Pallet Warehouse	0	0	0	0
Loose Storage Building	0	185,000	370,000	740,000
Total Pellet Storage	**0**	**185,000**	**370,000**	**740,000**
Plant Equipment				
Primary Grinder	0	650,000	650,000	650,000
Dryer	0	192,000	268,000	426,000
Hammermill	31,200	31,200	36,200	96,000
Conditioner/Feeder	43,900	43,900	44,700	73,200
Boiler	45,000	45,000	51,000	0
Pellet Mill	96,300	125,800	232,100	459,300
Pellet Cooler	31,800	31,800	34,900	92,000
Pellet Shaker/Screener	18,300	18,300	18,300	26,100
Bagging/Palleting System	0	0	0	0
Conveyors, Tanks, Other Fixed	200,000	690,000	980,000	880,000
Total Plant Equipment	**466,500**	**1,828,000**	**2,315,200**	**2,702,600**
Engineering	**20,000**	**65,000**	**65,000**	**80,000**
Project Management	**10,000**	**50,000**	**65,000**	**100,000**
Freight	**19,000**	**75,000**	**99,000**	**113,000**
Mechanical Installation	**40,000**	**375,000**	**500,000**	**800,000**
Electrical Installation	**30,000**	**275,000**	**380,000**	**510,000**
TOTAL PELLET PLANT	**585,500**	**4,475,000**	**5,800,200**	**7,051,600**
Other Equipment &Tools				
Wheel Loader	0	110,000	110,000	110,000
Fork Lift	0	0	0	0
Plant & Office Equip. & Tools	0	60,000	80,000	100,000
Total Other Equip. & Tools	**0**	**170,000**	**190,000**	**210,000**
TOTAL CAPITAL BUDGET	**585,500**	**4,645,000**	**5,990,200**	**7,261,600**
Capital Cost Per Ton of Hourly Production Capacity	**292,750**	**1,161,250**	**748,775**	**518,686**

Table 16B: Capital Budget Differences

DIFFERENCES: RETAIL MODEL AND UTILITY FUEL MODEL PELLET PLANT CAPITAL BUDGET ESTIMATES				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	U.S. DOLLARS			
Site/Site Preparation	**0**	**0**	**0**	**0**
Plant Building & Offices	**0**	**0**	**0**	**0**
Receiving Station & Scale	**0**	**0**	**0**	**0**
Feedstock Storage	0	0	0	0
Storage Lot	0	0	0	0
Storage Warehouse	0	0	0	0
Total Feedstock Storage	**0**	**0**	**0**	**0**
Pellet Storage	0	0	0	0
Pallet Warehouse	0	(350,000)	(350,000)	(350,000)
Loose Storage Building	0	(308,000)	(617,000)	(740,000)
Total Pellet Storage	**0**	**(658,000)**	**(967,000)**	**(1,090,000)**
Plant Equipment	0	0	0	0
Primary Grinder	0	0	0	0
Dryer	0	0	0	0
Hammermill	0	0	0	0
Conditioner/Feeder	0	0	0	0
Boiler	0	0	0	0
Pellet Mill	0	0	0	0
Pellet Cooler	0	0	0	0
Pellet Shaker/Screener	0	0	0	0
Bagging/Palleting System	0	(40,000)	(450,000)	(450,000)
Convey, Tanks, Other Fixed Equip.	0	(100,000)	(150,000)	(122,000)
Total Plant Equipment	**0**	**(140,000)**	**(600,000)**	**(572,000)**
Engineering	**0**	**(10,000)**	**(10,000)**	**(14,000)**
Project Management	**0**	**0**	**(10,000)**	**(11,000)**
Freight	**0**	**(4,000)**	**(18,000)**	**(18,000)**
Mechanical Installation	**0**	**(10,000)**	**(50,000)**	**(89,000)**
Electrical Installation	**0**	**(5,000)**	**(20,000)**	**(46,000)**
TOTAL PELLET PLANT	**0**	**(827,000)**	**(1,675,000)**	**(1,840,000)**
Other Equipment &Tools	0	0	0	0
Wheel Loader	0	0	0	0
Fork Lift	0	(30,000)	(30,000)	(30,000)
Plant & Office Equip. & Tools	0	0	0	0
Total Other Equip. & Tools	**0**	**(30,000)**	**(30,000)**	**(30,000)**
TOTAL CAPITAL BUDGET	**0**	**(857,000)**	**(1,705,000)**	**(1,870,000)**
Capital Cost Per Ton of Hourly Production Capacity	**0**	**(214,250)**	**(213,125)**	**(133,571)**

Nth Year Operating Expense Changes

A utility fuel production plant would have considerably lower total operating expenses than a pellet plant for the Retail Product Business Model. *Table 16C: Utility Model Assumptions* and *Table 16D: Utility Model Income Statement* (on pages 118 and 119) present Nth year financial projections for the Utility Fuel Production Model. On page 120 is *Table 16E: Income Statement Differences* which shows the differences by line item between the Retail Product Business Model and the Utility Fuel Production Model.

The significant changes from the Retail Product Business Model to the Utility Model are explained below (but it is important to remember that these are financial illustrations, not predictions).

Plant wages, taxes and benefits for the commercial-scale utility fuel production plants are reduced by the cost of one worker on each shift (the worker assigned full-time to bagging/palleting and forklift operations).

Salaries, taxes and benefits for management and administrative personnel are reduced by the cost of the Marketer. It is assumed that the General Manager and Finance Manager would manage accounts with utility, industrial and institutional customers.

The substantial costs for **bags, pallets, slip sheets and wrap** are eliminated.

Estimated **transportation** costs of $10.00 per ton to deliver fuel to utility, industrial and institutional customers are added. (Recall that customers ordinarily pay shipping costs for retail fuel pellets. It is assumed that utility, industrial and institutional customers would receive fuel pellets at their plants and pay a price/ton on a delivered basis.)

Marketing/sales fees and incentives include broker fees, placement fees, rebates, promotions, discounts, and various other marketing expenses. These are necessary costs for a commercial-scale pellet company under the retail product business model, but they are eliminated with the utility fuel production business model.

The non-cash expense of **depreciation** and **interest on long-term debt** are reduced due to changes in the capital requirements of a pellet plant.

Interest on working capital is reduced considerably because monthly revenues and expenses would be better balanced throughout the year. (Presumably, utilities and other industrial and institutional customers would have year-round demand.)

Below is a comparison of the estimated total cost/ton in the "Nth" year for the retail product business model and the utility fuel production model:

COST/TON COMPARISON

	2-Ton/Hr.	4-Ton/Hr.	8-Ton/Hr.	14-Ton/Hr.
Retail Product Model	$101.45	$180.58	$147.84	$128.52
Utility Model	$111.61	$158.03	$129.71	$114.32
Difference	($ 10.16)	$ 22.55	$ 18.13	$ 14.20

Note that the estimated cost/ton for the farm-scale pellet plant is greater with the Utility Fuel Production Model than the Retail Product Business Model. This is because the farm-scale pellet plant would not realize any of the considerable cost savings that would accrue to the commercial-scale pellet plant, but the farm-scale pellet plant would incur the new cost of transporting product to utility, industrial and institutional customers.

On page 121 is *Table 16F: Impact of Pellet Price Changes on Utility Model.* This table shows the estimated impact of pellet price changes on the financial performance of the Utility Fuel Production Model in the Nth year. To consider prices from the perspective of a utility, below is the price/million Btu (delivered) that corresponds to each pellet price. For context, most utilities and other industrial and institutional users of coal pay well under $3.00/million Btu, and average natural gas prices for very large customers (like utilities) are expected to stay under $8.00/million Btu (in 2007 dollars) over the next several years (ignoring the potential effects of a new energy tax).

Pellet Price/Ton	Price/ Million Btu
$110	$ 6.96
$120	$ 7.59
$130	$ 8.23
$140	$ 8.86
$150	$ 9.49
$160	$10.13
$170	$10.76
$180	$11.39

In the previous chapter, it was suggested that a return-on-equity threshold of 25% might be appropriate for a business venture like an agricultural biomass pellet company. The table on page 120 indicates that a company with a 4-ton/hour pellet plant would achieve a 25% return on equity in the Nth year at a price of $180/ton; a company with an 8-ton/hour pellet plant would exceed this threshold at a price of $150/ton. (Bear in mind these companies would have to survive the ramp-up years to get to this Nth year.)

For the 14-ton/hour pellet plant, a price of $130/ton (or $8.23/million Btu) is projected to yield a return on equity of 41%, but a price of $120/ton ($7.59/million Btu) would only yield a return on equity of 15%. The return on equity of 15% does not meet the threshold of 25% suggested in the previous chapter, but it could be sufficient nevertheless. A reason for a high return-on-equity requirement is a perception of high business risk. A utility customer could mitigate the business risk of developing and operating an agricultural biomass pellet plant by agreeing to a long-term fuel supply contract. For an entrepreneur or company that has not yet built a pellet plant, committing all (or most) of a pellet plant's production capacity to a utility customer under a long-term contract might seem like setting a severe constraint on upside potential; but, given the current market for agricultural biomass pellets, such a commitment may provide an essential justification for equity and debt participation.

16C: Utility Model Assumptions

UTILITY FUEL PRODUCTION BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
ASSUMPTIONS				
Pellet mill horsepower	100	200	400	800
Annual full-production hours	2,000	6,000	6,000	6,000
Av. feedstock moisture content	10%	20%	20%	20%
Feedstock required (tons)	4,000	27,000	54,000	94,500
Corn stover price (delivered)	$40.00	$63.00	$63.00	$63.00
Soybean straw price (delivered)	$0.00	$42.00	$42.00	$42.00
Damaged hay/grass (delivered)	$0.00	$60.00	$60.00	$60.00
Corn stover use (% feedstock)	100%	60%	60%	60%
Soybean straw use (% feedstock)	0%	20%	20%	20%
Hay/grass use (% feedstock)	0%	20%	20%	20%
Pellets produced	4,000	24,000	48,000	84,000
Tons bagged and palleted	0	0	0	0
Pellet price per ton (delivered)	$120.00	$120.00	$120.00	$120.00
Capital cost of pellet plant	$585,500	$4,645,000	$5,990,200	$7,261,600
Debt financing principal (60%)	$351,300	$2,787,000	$3,594,120	$4,356,960
Interest rate	8.5%	8.5%	8.5%	8.5%
Equity investment (40%)	$234,200	$1,858,000	$2,396,080	$2,904,640
Year 0 budget plus interest due	$14,930	$240,048	$274,350	$306,771
Total initial equity required	$249,130	$2,098,048	$2,670,430	$3,211,411

16D: Utility Model Income Statement

UTILITY FUEL PRODUCTION BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	U.S DOLLARS			
GROSS INCOME	**480,000**	**2,880,000**	**5,760,000**	**10,080,000**
EXPENSES				
Corn stover	160,000	1,020,600	2,041,200	3,572,100
Soybean straw	0	226,800	453,600	793,800
Damaged hay and grasses	0	324,000	648,000	1,134,000
Wood	0	0	0	0
Other feedstock	0	0	0	0
Storage fees	0	0	0	0
Loading and hauling fees	0	0	0	0
Total Feedstock Costs	**160,000**	**1,571,400**	**3,142,800**	**5,499,900**
Plant wages, taxes & benefits	90,000	666,432	806,832	806,832
Electricity	35,381	158,594	248,321	431,183
Natural gas	0	93,840	186,401	318,738
Water/sewer	0	800	1,000	1,000
Dies, rollers, other parts	12,000	72,000	144,000	252,000
Contract plant repairs	2,000	12,000	24,000	42,000
Wheel loader operating/mtnce.	12,300	39,168	48,960	61,200
Forklift operating/mtnce.	0	0	0	0
Bags, pallets and wraps	0	0	0	0
Transportation (to buyers)	40,000	240,000	480,000	840,000
Total Direct Op. Costs	**191,681**	**1,282,834**	**1,939,514**	**2,752,953**
Salaries, taxes & benefits (M&A)	0	201,600	201,600	201,600
Marketing/sales fees & incentives	0	0	0	0
Telecommunications/internet	0	10,000	10,000	10,000
Office supplies	0	5,000	5,000	5,000
Lab Testing	0	10,000	10,000	10,000
Travel and training	0	10,000	10,000	10,000
Legal, accting., and consulting	0	20,000	20,000	20,000
Property taxes	0	44,452	58,450	67,552
Insurance	0	16,000	20,000	20,000
Depreciation	58,550	359,333	460,920	565,393
Total Sales/G&A	**58,550**	**676,385**	**795,970**	**909,545**
Interest on working capital	6,359	25,277	42,445	70,701
Interest on long-term debt	29,861	236,895	305,500	370,342
Total Interest	**36,220**	**262,172**	**347,945**	**441,043**
TOTAL EXPENSES	**446,451**	**3,792,791**	**6,226,229**	**9,603,441**
NET INCOME	**33,549**	**(912,791)**	**(466,229)**	**476,559**
RETURN ON INITIAL EQUITY	**13%**	**-44%**	**-17%**	**15%**

16E: Income Statement Differences

DIFFERENCES: RETAIL MODEL AND UTILITY FUEL MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	U.S DOLLARS			
GROSS INCOME	**480,000**	**2,880,000**	**5,760,000**	**10,080,000**
EXPENSES				
Corn stover	0	0	0	0
Soybean straw	0	0	0	0
Damaged hay and grasses	0	0	0	0
Wood	0	0	0	0
Other feedstock	0	0	0	0
Storage fees	0	0	0	0
Loading and hauling fees	0	0	0	0
Total Feedstock Costs	**0**	**0**	**0**	**0**
Plant wages, taxes & benefits	0	(140,400)	(140,400)	(140,400)
Electricity	0	(9,086)	(15,901)	(15,901)
Natural gas	0	0	0	0
Water/sewer	0	0	0	0
Dies, rollers, other parts	0	0	0	0
Contract plant repairs	0	0	0	0
Wheel loader operating/mtnce.	0	0	0	0
Forklift operating/mtnce.	0	(6,518)	(8,148)	(10,185)
Bags, pallets and wraps	0	(276,000)	(552,000)	(966,000)
Transportation (to buyers)	40,000	240,000	480,000	840,000
Total Direct Op. Costs	**40,000**	**(192,004)**	**(236,449)**	**(292,486)**
Salaries, taxes & benefits (M&A)	0	(62,000)	(62,000)	(62,000)
Marketing/sales fees & expenses	0	(144,000)	(288,000)	(504,000)
Telecommunications/internet	0	0	0	0
Office supplies	0	0	0	0
Lab Testing	0	0	0	0
Travel and training	0	0	0	0
Legal, accting., and consulting	0	0	0	0
Property taxes	0	(16,187)	(23,788)	(26,814)
Insurance	0	0	0	0
Depreciation	0	(44,167)	(108,367)	(116,667)
Total Sales/G&A	**0**	**(266,354)**	**(482,155)**	**(709,481)**
Interest on working capital	667	(39,158)	(64,556)	(95,088)
Interest on long-term debt	0	(43,707)	(86,955)	(95,370)
Total Interest	**667**	**(82,865)**	**(151,511)**	**(190,458)**
TOTAL EXPENSES	**40,667**	**(541,223)**	**(870,115)**	**(1,192,425)**
NET INCOME	**(40,667)**	**541,223**	**870,115**	**1,192,425**

16F: Impact of Pellet Price Changes on Utility Model

UTILITY FUEL PRODUCTION BUSINESS MODEL "Nth" YEAR FINANCIAL PROJECTIONS				
PELLET PLANT	**2 TPH**	**4 TPH**	**8 TPH**	**14 TPH**
	IMPACT OF PELLET PRICE CHANGES			
Pellet price per ton	**$110.00**	**$110.00**	**$110.00**	**$110.00**
Gross income	440,000	2,640,000	5,280,000	9,240,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	(6,451)	(1,152,791)	(946,229)	(363,441)
Return on initial equity	-3%	-55%	-35%	-11%
Pellet price per ton	**$120.00**	**$120.00**	**$120.00**	**$120.00**
Gross income	480,000	2,880,000	5,760,000	10,080,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	33,549	(912,791)	(466,229)	476,559
Return on initial equity	13%	-44%	-17%	15%
Pellet price per ton	**$130.00**	**$130.00**	**$130.00**	**$130.00**
Gross income	520,000	3,120,000	6,240,000	10,920,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	73,549	(672,791)	13,771	1,316,559
Return on initial equity	30%	-32%	1%	41%
Pellet price per ton	**$140.00**	**$140.00**	**$140.00**	**$140.00**
Gross income	560,000	3,360,000	6,720,000	11,760,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	113,549	(432,791)	493,771	2,156,559
Return on initial equity	46%	-21%	18%	67%
Pellet price per ton	**$150.00**	**$150.00**	**$150.00**	**$150.00**
Gross income	600,000	3,600,000	7,200,000	12,600,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	153,549	(192,791)	973,771	2,996,559
Return on initial equity	62%	-9%	36%	93%
Pellet price per ton	**$160.00**	**$160.00**	**$160.00**	**$160.00**
Gross income	640,000	3,840,000	7,680,000	13,440,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	193,549	47,209	1,453,771	3,836,559
Return on initial equity	78%	2%	54%	119%
Pellet price per ton	**$170.00**	**$170.00**	**$170.00**	**$170.00**
Gross income	680,000	4,080,000	8,160,000	14,280,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	233,549	287,209	1,933,771	4,676,559
Return on initial equity	94%	14%	72%	146%
Pellet price per ton	**$180.00**	**$180.00**	**$180.00**	**$180.00**
Gross income	720,000	4,320,000	8,640,000	15,120,000
Total expenses	446,451	3,792,791	6,226,229	9,603,441
Net income	273,549	527,209	2,413,771	5,516,559
Return on initial equity	110%	25%	90%	172%

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