TECHNO-ECONOMICAL ANALYSIS OF WOOD PELLETS PRODUCTION FOR U.S. MANUFACTURERS

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Many companies in the U.S. are entering the wood pellets market due to the increasing importance of woody biomass utilization for energy purposes. Despite a 200% increase in U.S. production, it is difficult to obtain reliable information from the research community relative to the production costs, requirements, and market trends for wood pellets. Based on comprehensive investigations, a techno-economical model for the determination of production costs for U.S. manufacturers (internal market, with sell strategy based on bagged product) was developed, considering the most important technical and financial factors that affect pellet production. Outcomes from a case-study show that pellet production is profitable for U.S. manufacturers and distributors/retailers, with more revenue margin for retailers. Sensitivity analyses were performed, showing that a pellet plant is especially sensitive to changes to the cost of biomass and labor. In addition, changes in energy and CAPEX also affect the NPV and IRR of the project, but not as significantly as biomass and labor costs. Additional findings indicate that increasing the plant size especially increases CAPEX, with labor being the least increased cost factor; in addition, production factors have to be closely monitored for small-scale producers, due to increases in operational costs.

Keywords: Wood Pellets; Production costs; Pellets Manufacturing; Wood Industries

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INTRODUCTION

Background

Wood pellets have become a successful internationally traded biomass (Junginger et al. 2008) with a market size that was projected to double from 2007 to 2010 (Savolainien 2007). Hess and Jacobson (2009) indicated that from 2002 through 2006 the internal demand of wood pellets in the United States increased by 200 percent. Moreover, production forecasts for 2012 were set at 6.0 million metric tonne (10% moisture content) per year in the U.S.; however, by the year 2009 the market capacity increased faster than forecasted, with an approximate production of 6.2 million metric tonne (Spelter and Toth 2009; Mani 2006).

Ryu et al. (2006) stated that a critical element for biomass fuels to successfully compete with other energy sources is densification; in this sense, wood pellets provide an enhanced heating value of wood per unit of volume, low moisture content, a more complete and efficient burning, with low ash and particulate emissions content, optimized transportation over long distances, and a variety of applications, from small-scale residential heating to large-scale co-firing in coal power plants (Wahlund et al. 2004; Junginger et al. 2008; Spelter and Toth 2009). Additionally, pellets can be easily produced from wood waste, forest-thinning, other biomass ingredients, and wood production by-products (PFI 2009; Bergman and Zerbe 2008).

Production and characteristics of wood pellets in the U.S. are subject to wood supply availability, and are based on a “per bag” selling strategy, instead of the common bulk delivery used in the European Union. In Western U.S., most pellets are made from softwoods sawdust, being a residue from sawmills, while in the Mountain region mills are using Lodgepole Pine (*Pinus Contorta*) trees killed by the pine beetle. In the South and Midwest, mills are using waste stream from the wood flooring and furniture business, while in the East, mills are using hardwood that is unsuitable for lumber (PelletSales 2009). The Southern US is drastically increasing its production capacity, with recently opened large size factories, and a reliable supply of southern yellow pine (Green Circle 2010). Based on the wide variety of biomass that can be used for its manufacturing, wood pellets have become attractive as an alternative fuel; however, in the U.S., the wood pellets market is still behind in demand and internal utilization as compared to mature markets such as Canada and Europe, which have applications for residential heating as well as industrial and commercial energy production (Hoque et al. 2006). By 2006, there were 600,000 homes in the U.S. using wood pellets for heat (PFI, 2006), increasing to 800,000 in 2007 (Biomass Energy Resource Center 2008), and with an estimated 1,000,000 residences/business by 2010 (PFI 2010), but data is scarce on industrial and commercial applications and their future development.

In the U.S, around 90 plants are producing wood pellets, with many more to come into full production in the near future, having a 33 percent forecast increase in manufacturers from 2006 to 2010 (Hess and Jacobson 2009; Peksa-Blanchard et al. 2007). Despite this increase, it is difficult to obtain reliable information from the research community about production costs, requirements, and market trends for wood pellets in the U.S. Several efforts have been performed to identify, compare, model, and calculate production costs of wood pellets in Europe (Thek and Obernberger 2004; Di Giacomo and Taglieri 2008; Stahl and Wikström 2009; Mahapatra et al. 2007) and in Canada (Mani 2006; Chau et al. 2009); but more information is needed for the U.S. wood pellets market, regarding production and financial characteristics, logistic barriers (market pricing habits, transportation, storage, and operating costs, Swaan and Melin 2008), and specific parameters for the determination of competitive wood pellets prices (biomass delivered cost, equipment, energy consumption, and labor costs (Thek and Obernberger 2004).

Objective

The main objective of this project was to develop and validate a techno-economical model that estimates the production costs of pellets, as well as performing financial and sensitivity analyses for pellets production in the U.S. internal market (bagged pellets market).

METHODS

The techno-economical model for pellets production was developed in Microsoft Excel 2007®; detailed information on the characteristics of the model is provided in the following paragraphs.

General Aspects of the Model

The first step for the development of the techno-economical model for pellet production costs is the identification of all the individual processes necessary for pellet manufacturing (Fig. 1).

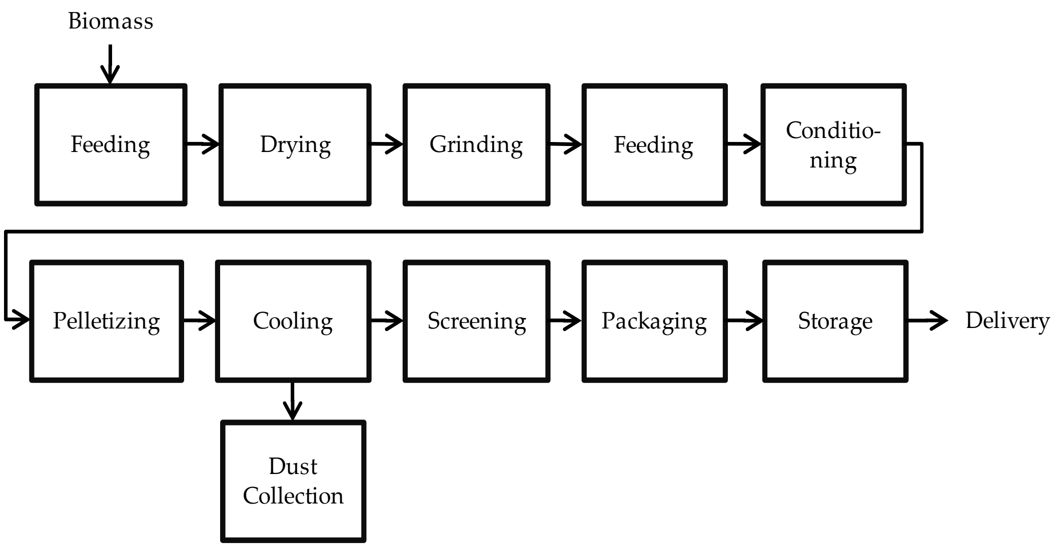

Fig. 1. Typical manufacturing process for wood pellets

The processes in Fig. 1 are typical for a pellet production facility. Processes such as grinding or drying depend on the raw material characteristics; if the raw material comes already dried and/or in the adequate particle size, then these processes are not required. It is assumed that collection, storage, and transportation of the biomass to the facility are outside the boundaries of the model (i.e., they can be performed by another company, or another division of the same company), and the biomass cost is "as-delivered" to the factory gate. A model developed at NC State University that deals with delivered costs of biomass (Gonzalez et al. 2010), according to hauling distances and biomass type, was used for the as-received cost of raw material (in this case, utilizing debarked roundwood, loblolly pine, hauled an average distance of 50 miles) into the factory, totaling $63/metric tonne (estimations for other biomass types may be included in the wood pellets model, once the delivered biomass cost has been calculated from Gonzalez et al, 2010). Storage and delivery after production of wood pellets are also considered to be outside the boundaries of the model.

In order to facilitate the development of the techno-economical model, three main areas were identified in a conceptual scheme (Fig. 2).

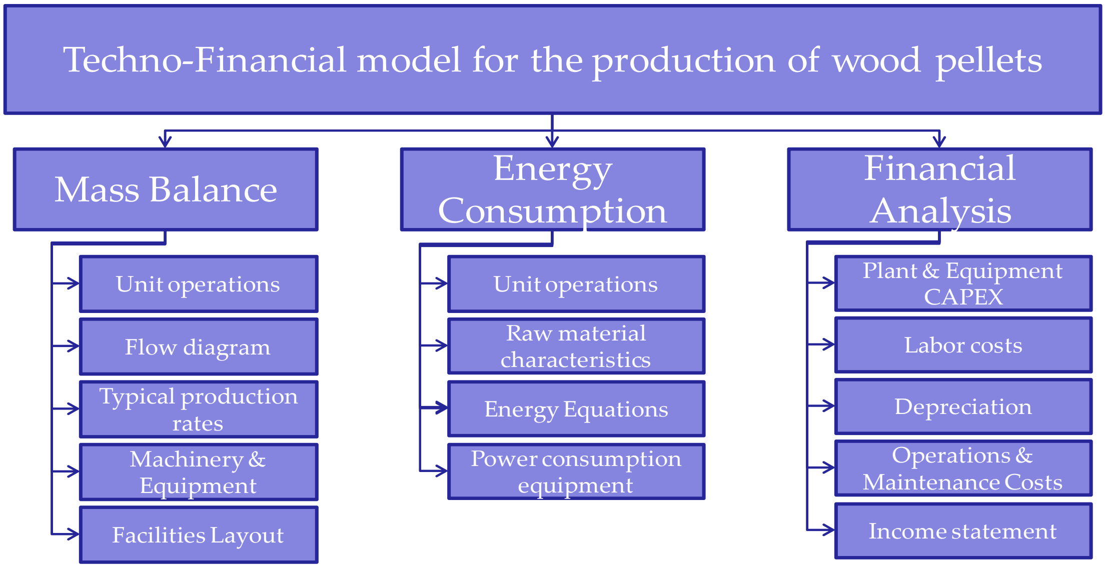

Fig. 2. Conceptual model for the production of wood pellets under U.S. conditions

The first area (Fig. 2) considered for the model was a detailed mass balance, facilitating the understanding and calculation of production rates, amount of biomass entering and leaving each unit operation, losses, capacity, and efficiency of machinery and equipment. The energy consumption (central section in Fig. 2) indicates the amount of energy required for pellets production, depending on the raw material and energy consumption of the equipment. The final area is a comprehensive financial analysis, considering a fixed delivered cost of raw material and containing information of plant and equipment costs (CAPEX), labor costs and structure, depreciation, operation and maintenance costs, and an income statement, summarizing the financial information for a given year (Fig. 2).

Additionally, the main inputs for the model were identified as: annual production (metric tonne), number of working hours per year (considering number of shifts per day), factory location, type and characteristics of biomass used, moisture content as delivered, and pellet quality standard. When these inputs are entered in the model, the mass, energy balance, and financial spreadsheets are automatically updated.

Mass Balance

The mass balance section is based on the unit operations defined for the pellet production process, being automatically updated whenever any input of the model changes, or if any of the processes become optional, such as drying or grinding, as discussed previously. Mass losses are considered for each process, and they can be defined by the user; however, it is typical for a pellet factory to re-circulate any crumbles, fines, or defective pellets into the particle reduction operation; thus the mass losses in the system are reduced. The moisture content of raw material changes throughout the process, being decreased to 6±1% in the drying, increased to 10±1% in the conditioner, and decreased to a final moisture content of 7±1% during the pellet milling, screening, and cooling processes. The machinery efficiency was set at a default value of 100%, except for the screening operation, in which 10% of the mass not converted to durable pellets is re-circulated. Machinery efficiencies can be modified by the user, automatically updating mass losses. It is also considered that steam addition is necessary in the conditioning unit of the pellet mill, for softening the fibers (Leaver 2008); this steam was produced by an 800 kWh boiler; no heat recovery was considered in the factory.

Energy Consumption

The data for energy consumption of each unit operation was obtained from the literature and verified by interviewing several pellets manufacturers. Data for the drying, grinding/hammermilling, and miscellaneous units (such as packing and bagging) were obtained from Digiacomo and Taglieri (2009); data regarding pellet milling and cooling were obtained from manufacturers specifications (Lange 2009), and data for the screening operation was obtained from Mani (2006). Figure 3 summarizes the combined energy consumption of each unit operation (% of the total energy consumed).

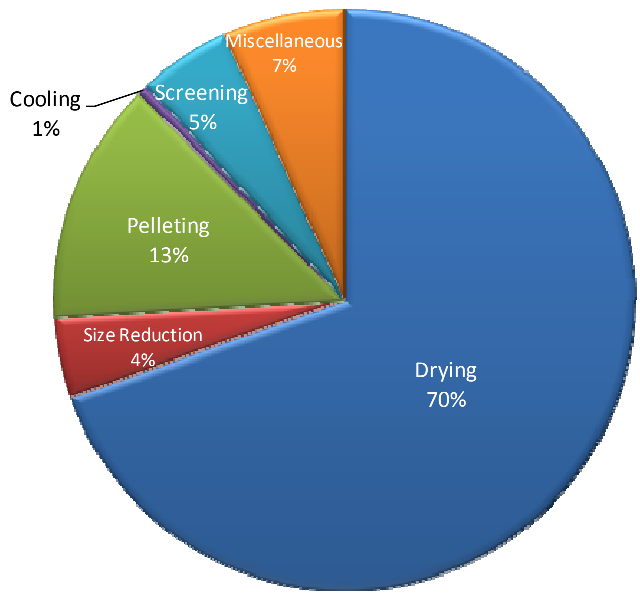

Fig. 3. Energy consumption of each operation performed in the factory

An energy summary spreadsheet shows the total energy consumption per year, the cost of electricity according to the location of the facility, cost of steam produced from natural gas boiler, and the current cost of electricity for industrial applications (updated every month by the Energy Information Administration EIA 2009), according to the required annual production. In the model, addition of wood-waste boilers is not included; such addition has potential to substantially improve the costs of energy for the facility if availability and supply can be reliably ensured on a long term basis.

Financial Analysis

Facilities and machinery capital expenditure is a core element in the model. Since the received raw material is debarked roundwood, it is assumed that a debarking process is not required. Prices for industrial equipments were obtained directly from manufacturers and distributors (dryer, chipper, hammermill, pellet mill, cooler, screener/shaker, and bagging system), while peripheral and miscellaneous equipment such as feeders, conveyors and front-end loaders, as well as building and office spaces were calculated from recent literature (Samson et al. 2000; Campbell 2007) and adapted to the year 2009 using the CWCCIS (Civil Works Construction Cost Index System) conversion index. Equipment prices (capital investment per unit) obtained from Samson et al. (2000) were based on a one metric tonne per hour production rate (and equipment capacity). In order to calculate the capital investment for equipment having a different capacity a scale-up of the capital investment, from the original size equipment, is performed automatically in the model. Perry's Chemical Engineering Handbook (1997) recommends the power law rule for this purpose; this rule estates that: $Inv = Inv_L x (P/P_L)^{0.7}$, in which *Inv* represents the capital investment according to the plant size requirements, Inv_L represents the capital investment of the original equipment, and P and P_L represent the capacity required on the equipment, and the capacity of the original equipment respectively, and the calculated result is presented in the cost per each equipment column. This method provides a way of calculating the capital investment for larger capacity equipment, based on the size and capital cost of the original machine. A scaling factor of 0.7 is used in the equation, based on Andersson et al. (2006), since some process equipment involve several parallel units instead of one single large unit. The CAPEX section of the model incorporates this formula to calculate machinery capacities when bigger sizes are required. Indirect costs and contingency costs were 24% and 10% of the total calculated facilities and machinery total, based on Woodworth et al. (1997). Storage capacity was added to the CAPEX, representing 7.6% of the total plant building space (Thek and Obernberger 2004). Plant and equipment depreciation was calculated using a MACRS-7 method, and was automatically updated if any values contributing to the CAPEX were modified.

The labor requirements of the model (structure, number of shifts, wages, benefits, and fringes) were obtained and modified from Campbell (2007), and the Bureau of Labor Statistics (2009). Labor structure is automatically increased depending on the plant capacity, since the number of workers required for operations depends on production rates. For instance, the model utilizes 3 production workers per shift for capacities below 4 metric tonne/hour, and 1 supervisor, forklift operator, and maintenance technician. For capacities higher than 4 metric tonne/hour, the model adds one more worker on each category per shift, for every 4 metric tonne/hour production increase. Administrative personnel are not dependent on production rate; thus, its number changes with the addition of a controller and accounting assistants for capacities higher than 100.000 metric tonne/year. This information is summarized as a total annual cost of direct and indirect labor.

Consumables costs for a pellet production facility are an important factor to be considered, and these were assumed to be directly linked to the production (no consumables were assumed for office and administrative labor). It is assumed that the majority of pellets for the U.S. market are sold to retailers and distributors in 40 lb bags, which may cost \$0.12 to \$0.25/bag; it is assumed that a durable plastic bag (0.0035 to 0.005 mils) with one-color printing would cost \$0.2 (Campbell, 2007), and 50 bags are needed per each metric tonne of product. In addition, a pallet of product holds 50 bags (1 metric tonne) of pellets, and the cost of each EU approved 40x48, 2-way entry pallet (pallets that can be entered by a forklift and pallet jack from only the two ends) is \$14.35 (Far packaging Company 2009). The model considers that these pallets are for a one-time use once delivered to the distributor/retailer. Additional improvements of costs can be achieved if pallets are considered for multiple uses. Additional packing material is required for support and fixing of the bags to the pallets. Slip sheets and stretch wrapping is required, and its cost is estimated at $4.00 per metric tonne ($4.00 per pallet). Additional costs include parts and replacements (dies and rollers for pellet mills, and spare parts for hammermills) ($3.00/metric tonne), marketing and sales fees, and incentives (assumed to be $6.00/metric tonne), which accounts for marketing and sales costs for promotions, discounts, rebates, broker fees, placement fees, and other forms of compensation and incentives (Campbell 2007). A final spreadsheet contains pricing information for the type of biomass selected to be pelletized. This information was based on a model provided by Gonzalez et al. (2010), which calculates biomass delivered cost to factory gate (debarked roundwood).

An income statement spreadsheet summarized the financial information of the company for the current and upcoming years (projected), based on every cost incurred in the production of wood pellets. The income statement incorporates an add-in calculation of the price of pellets for a desired Internal Rate of Return (pre-determined IRR of 6%, 8%, 10%, 12% and 14%, with no inflation rate assumed).

RESULTS AND DISCUSSION

In order to analyze the outputs results that can be obtained from the techno-economical model, a case study is described next. Since the majority of factories producing pellets for the internal U.S. market are in the range of 30 to 100 thousand metric tonne/year, the case study described considers a pellet plant producing 75,000 metric tonne/year (7±1% Moisture Content of final product, MC, in order to reach a premium grade product according to Pellet Fuel Institute Standards, PFI) of pellets. The plant is assumed to operate 50 weeks/year, seven days/week, with three shifts of 8-hours/day, totaling 8,400 production hours, from which 112 hours/year are dedicated to maintenance and unexpected shutdowns. It was assumed that the pellets were to be produced from southern yellow pine (55% MC). Debarking was assumed not to be required in the factory; drying and grinding of the raw material, however, were assumed to be required, and the pellets were to be sold to retailers in 40 lbs bags.

Case Study Results

Mass balance calculations indicated a production rate of 8.93 metric tonne/hour of pellets in order to meet 75,000 metric tonne/year rate (75,000 metric tonne/8400 hours = 8.93 metric tonne/hour), with an energy consumption of 4,932.15 (41,430,066.24 kW/year) kWh (Table 1).

Table 1. Annual Electrical Consumption and Cost (for U.S. average location)

Annual electrical energy consumption	41,430,066.24	kW/year
Average Electricity cost	0.0689	$/kWh
Total energy cost per year	2,854,531.56	$/year

Capacities, number of machines, building size, and capital and installation costs (CAPEX) were calculated by the model assuming two separate lines operating in the facility. Table 2 shows CAPEX calculations adapted for the case study, and validated by several pellet manufactures.

Table 2. CAPEX for a 75.000 metric tonne/year Plant, Expressed in Thousands of Dollars

Item	Capacity (t/h)	Number required	Cost per equipment	Installation cost	Total Equipment costs	Total Installation costs	**Total Equipment + Installation costs**
Conveyors & misc equipment	-	8	29	10	228	78	**307**
Front-end loader	-	2	113	-	226	-	**226**
Feed hopper	-	13	10	4	132	54	**186**
Dryer, burner & air system	5	5	140	204	700	1,020	**1,720**
Hammer mill	8	2	55	78	110	157	**267**
Live bottom bin	-	13	175	14	2,275	181	**2,456**
Pellet mills(s)	5	2	535	168	1,070	336	**1,406**
Pellet cooler	5	2	150	37	300	73	**373**
Pellet shaker	8	2	15	40	29	79	**109**
Boiler (800 Kwh)	-	4	110	1	440	4	**444**
Bagging bin	-	2	4	9	9	19	**27**
Bagging system	10	2	36	14	73	28	**101**
Fork lift	-	2	22	-	44	-	**44**
Site and site preparation	-	1	156	-	156	-	**156**
Paving, receiving station, load area	-	1	60	-	60	-	**60**
Building & office space	-	1	1,020	-	1,020	-	**1,020**
Total equipment costs					**$ 6,872**	**$ 2,030**	**$ 8,902**
Storage warehouse							$ 78
Indirect costs (24%)							$ 2,155
Contingency (10%)							$ 1,114
Total installed costs							**$ 12,249**

In addition, the model includes an additional 24% of the CAPEX for indirect costs, 10% for contingency, and 7.6% of the total building cost for short- term storage warehouse (Woodworth et al 1996), bringing the total installed costs of the factory to $12,249,000. This short-term storage is considered necessary at the exit of the bagging process, for further palletizing and wrapping of the bags prior to be loaded in distribution trucks, for this instance, the warehouse area is considered to be an open-wall facility, with no requirements for temperature/gas sensing devices, or forced ventilation systems, which may be required for long term storage, or bulk delivery of pellets.

The direct and indirect labor force required for a 75.000 metric tonne/year plant totals 30 people over 3 shifts per day, with total labor costs of $3,762,150 per year ($3,235,650 direct labor, $526,500 indirect labor). Costs of consumables, as described in the methods section, were calculated according to the production rate, accounting for $2,321,600 per year. Additional costs (as described in methods) accounted for $500,250 per year. These operating costs are summarized in Table 3.

Table 3. Summary of Operating Costs for a 75.000 metric tonne/year Plant,

Operating Cost	$/year
Direct Labor	3,235,650
Indirect Labor	526,500
Consumables	2,321,600
Additional Costs	500,250
Total Operating costs ($/year)	6,584,000

Case Study Analysis

Segmentation of the production costs is useful to understand their influence on the total costs of producing wood pellets (Fig. 4). The most important cost driver was represented by biomass (27%), closely followed by labor costs (24%). Energy and consumables represented 17% and 15%, respectively. Depreciation represented 11% of the non-cash costs per metric tonne, and taxes and others (marketing fees, incentives, and maintenance costs) represented the smallest cost in pellets production, being 3% each.

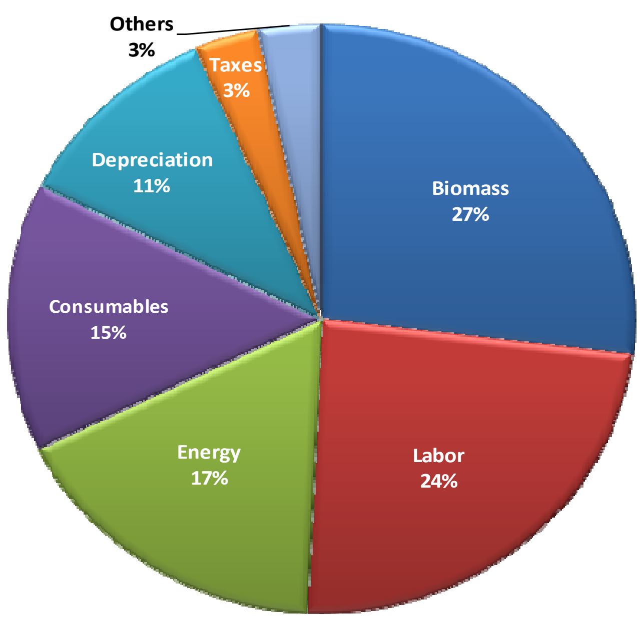

Fig. 4. Share costs of wood pellets per metric tonne

The model indicates a total production cost of $203.7/metric tonne, which is obtained in the income statement by assuming no inflation, depreciating according to MACRS-7, and with a CAPEX spending schedule of 20%, 40%, and 40% from the year 2009 through 2011. In addition, an add-in function in the income statement made it possible to back-calculate the corresponding price per metric tonne of pellets, to achieve a specific expected internal rate of return (IRR), with a discount rate set at 12% by default. Figure 5 shows the net present values (NPV) of the plant, and selling price of pellets when the model is adjusted to 6%, 8%, 10%, 12%, and 14% IRR using this add-in function.

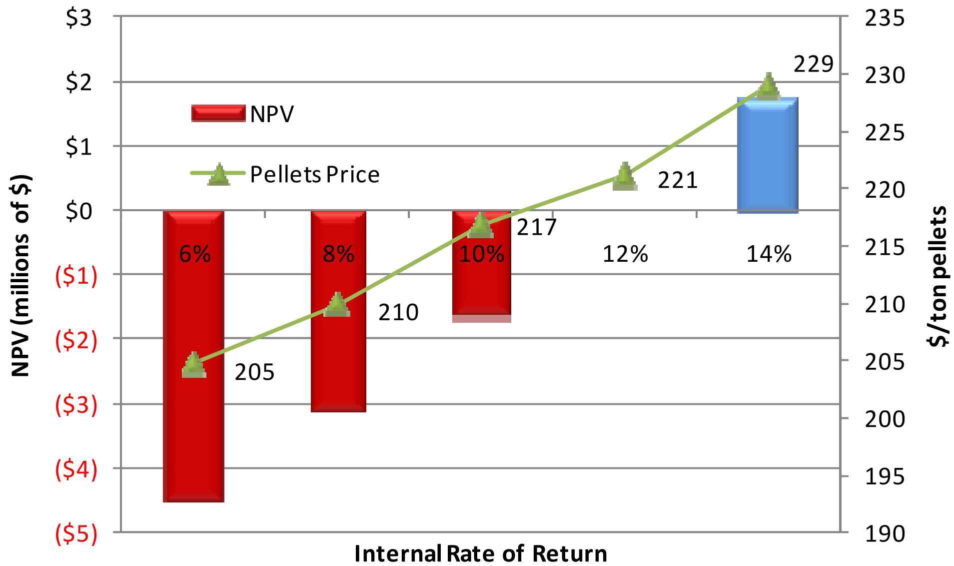

Fig. 5. Net present value (NPV) and price of pellets for the case study, adjusted to different IRRs

Figure 5 indicates that in order to obtain a positive NPV, the back-calculated price of pellets at the factory gate has to be higher than $221/metric tonne. Assuming that a price of $229/metric tonne (for a 14% IRR) is more desirable, and having production costs of $203.7/metric tonne, this adjusted price indicates an achievable revenue margin of $25.3/metric tonne for producers.

An additional transportation cost is added to this price, assuming that pellets have to be loaded, hauled, and unloaded from the factory to retailers and distributors, with trucks loading 20 metric tonne/truck (Rhode 1999), and a travelling average distance of 50 miles. This transportation cost is assumed to be similar to that reported by Brechbill and Tyner (2008), having a fixed element of $15/metric tonne, and a variable element of $0.12/mile, giving a total of $15.3/metric tonne in the case study. This transportation element, added to the pellet price determined for a 14% IRR ($229/metric tonne), totaled $244.3/metric tonne at the retailers/distributors gate. When comparing this price to an average retailer selling price of $276/metric tonne for the U.S. internal market (Pirraglia et al. 2010), a revenue margin of approximately $31.7/metric tonne can be obtained by retailers. Based on the fact that the majority of factories in the U.S. are in the range of 70,000 metric tonne/year (Spelter and Toth, 2009), similar to the 75,000 metric tonne/year assumed for the case study, it demonstrates that the wood pellets industry is profitable for both the majority of producers and distributors/retailers in the internal U.S. market.

Case Study Sensitivity

Sensitivity analyses were performed for the case study by modifying the most critical variables of the model, while observing the behavior of the NPV and IRR for a fixed selling price ($229/metric tonne). This fixed selling price is similar to that obtained when a 14% IRR is desired, and ensures profitability and positive NPV of the factory. Changes of ±25% in biomass cost, labor costs, energy costs, and CAPEX were studied for this fixed selling price, and are described below.

Biomass Cost Sensitivity

When increasing the cost of biomass by 25% (Fig. 6), the project can be adversely affected in its IRR, having a negative NPV of -$1.68 million (10% IRR). Reductions by 25% in the biomass cost resulted in a high increase in the NPV ($6.3 million) and IRR (19%), demonstrating the sensitivity of a pellet plant to changes in the raw material cost. In order to offset the impact of an increased biomass cost, pellets plants might negotiate long-term agreements with suppliers located close to wood baskets, in order to minimize changes in cost for the raw material. In addition, it must be taken into consideration that the raw material availability and hauling distance is an element that heavily influences the cost of biomass, making this element more likely to have cost fluctuations, further enhancing its sensitivity.

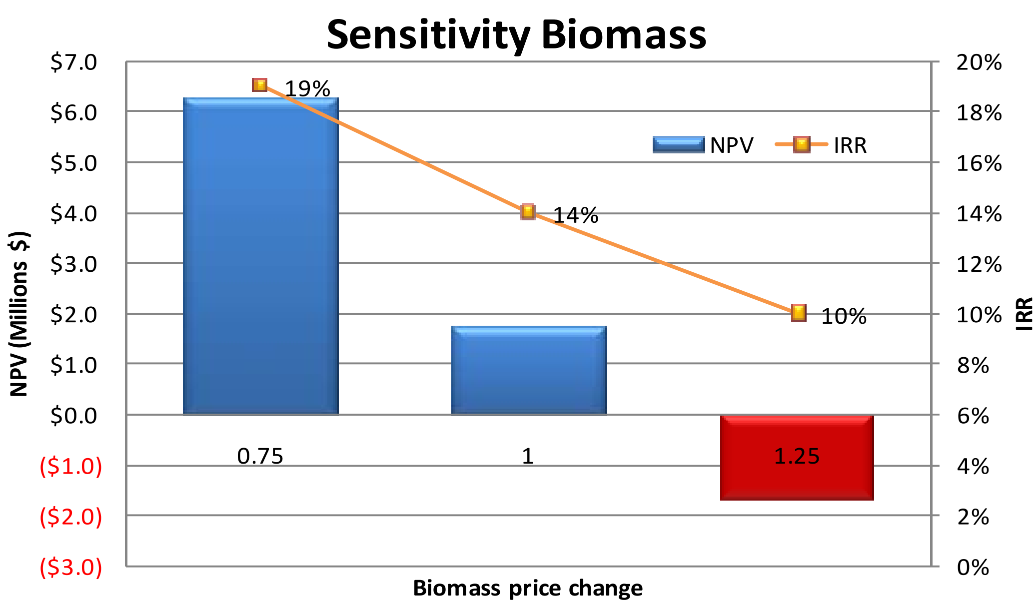

Fig. 6. Sensitivity of NPV and IRR of the pellet plant with changes on biomass cost

Labor Costs Sensitivity

The second most important sensitivity factor of the project was determined when analyzing changes in labor costs (Fig. 7). These changes caused a variation from $5.8 million to -$1.9 million in the NPV of the project for decreases/increases in labor costs. The IRR of the project also showed a variation from 19% to 10%.

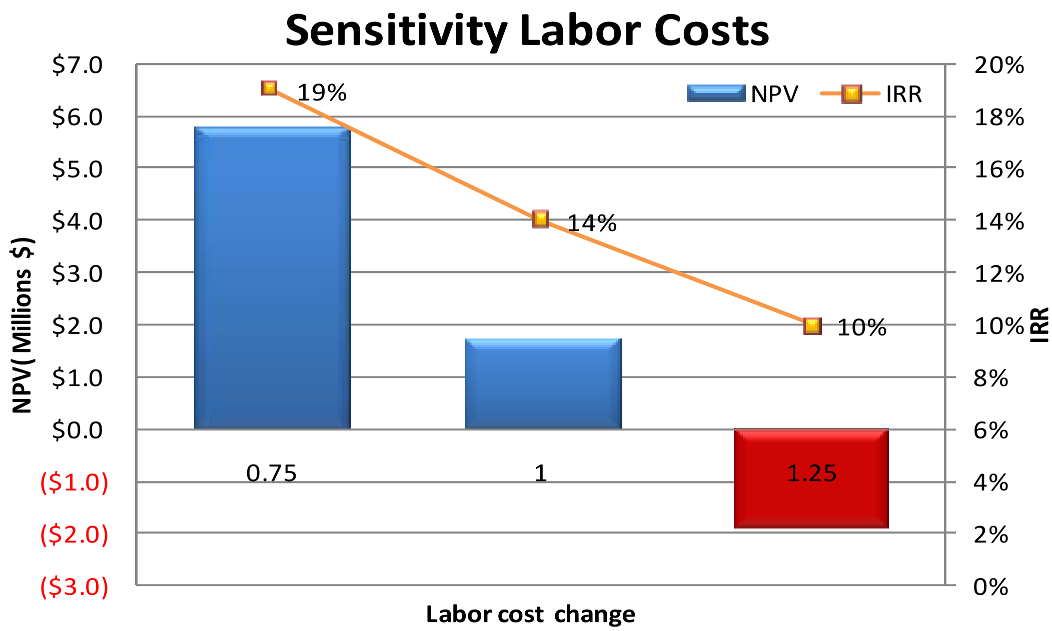

Fig. 7. Sensitivity of the pellet plant project to changes in labor costs

Considering that a pellet factory operates with few personnel, and that it was previously demonstrated that labor costs have a high impact on costs per metric tonne of pellets produced (Fig. 4), it becomes extremely important to adequately dimension, plan, and monitor the personnel needs of a pellet plant.

CAPEX Sensitivity

CAPEX represents the third most sensitive cost element when compared to biomass and labor costs; the NPV of the project was notably increased when the CAPEX is reduced (Fig. 8), becoming almost 3-fold bigger than the original NPV ($4.64 million vs. $1.73 million). In addition, the IRR of the project was more sensitive to decreases in CAPEX (increase from 14% to 19%), while an increase in CAPEX only reduced the IRR by 2% (14% to 12%).

Energy Costs Sensitivity

Changes in energy (Fig. 9) did not tend to affect the project as much as biomass or labor costs were projected to. However, a 25% increase in energy could still produce a low NPV ($243,443), while the IRR was not significantly affected between actual energy costs and the increased costs (14% IRR vs. 12% IRR). A different case occurred for the decrease of energy costs, which can highly increase the NPV of the factory. In this sense, the sensitivity to energy costs increase can be offset with the self-generation of energy, either to be utilized in the factory, or to be sold to the power grid. Additionally, energy sensitiveness can be reduced for the case in which drying and other operations are not required, since the drying process represents 70% of the total energy consumption of the factory, but it must be taken into consideration that dried raw material costs are higher.

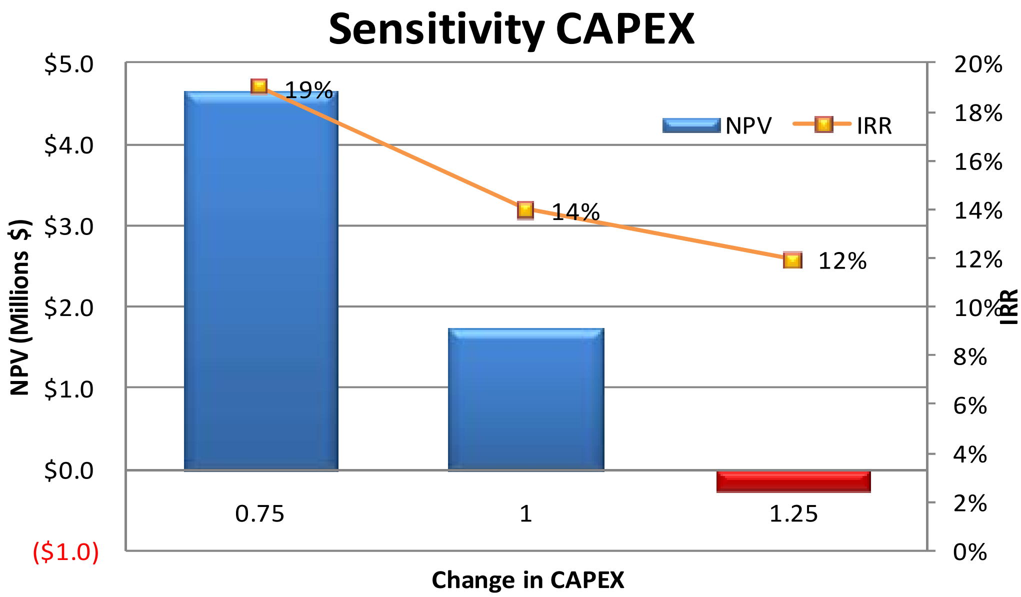

Fig. 8. Sensitivity of the pellet plant to CAPEX variations

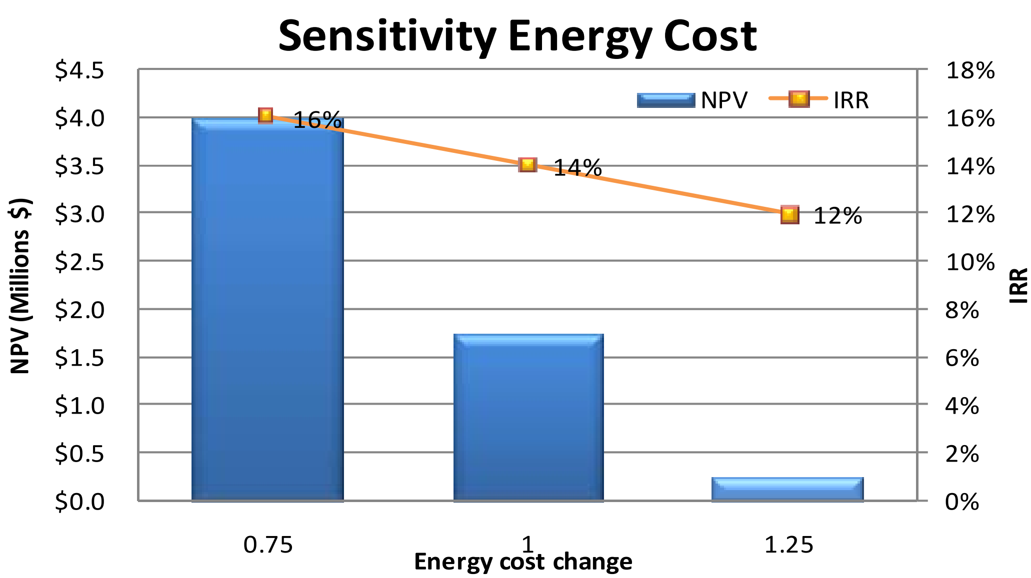

Fig. 9. Sensitivity of the project to Energy costs

Additional Remarks

Since new plants in the U.S. are significantly increasing in size, and many well established factories are in the production range of 75 thousand metric tonne per year, a comparison of the costs between large and medium sized factories for the internal market is important. Table 4 shows the detailed costs of pellets production, and the values obtained for two different plant sizes (75 thousand metric tonne/year vs. 125 thousand metric tonne/year).

Table 4. Costs Comparison, 75 vs. 125 thousand metric tonne/year (thousands of dollars)

Description	75.000 metric tonne/year plant		125.000 metric tonne/year plant	
Labor	$	3,763	$	3,763
Consumables	$	2,322	$	3,816
CAPEX(with indirect costs & fees)	$	12,249	$	19,259
Energy	$	2,695	$	4,758
Taxes	$	520	$	2,668
Other costs	$	501	$	834
Biomass	$	4,050	$	6,750
Total	**$**	**26,861**	**$**	**41,848**
% Increase from factory size	**-**		**36%**	
Selling price for a 12% IRR	**$**	**219**	**$**	**187**
Price difference	**-**		**17%**	

The change in size of a factory of 75,000 metric tonne/year to 125,000 metric tonne/year represents a total cost increase of 36%. This change in costs is mainly due to changes in CAPEX and energy, to adapt for the requirements of a large factory. However, advice should be taken when making direct comparisons for the CAPEX of two different size factories, since the model utilizes the power law (Perry et al. 1997) to scale-up the CAPEX, and it represents only an approximation of the capital investment for the new factory size. Labor costs are the least influencing factor for this comparison, since indirect labor was not changed for this plant capacity (being lower than 100.000 metric tonne/year), and direct labor did not considerably increase when increasing the plant size. In addition, a factory producing 125,000 metric tonne/year has a selling price that is 17% lower than the one required for a 75.000 metric tonne/year factory (considering a selling price of $219/metric tonne, which determines a zero NPV, at 12% IRR). This difference in prices allows a bigger factory to have a wider revenue margin and capture market share by having lower prices than smaller competitors; however, large factories require larger wood sources, making it difficult for them to rely on a single wood source or waste wood stream to supply the factory. Thus, costs and production conditions have to be closely monitored for small scale manufacturers, in order to be able to effectively compete with larger producers on a price only basis, while supply conditions have to be accurately determined for large factories in order to remain competitive on a long term basis.

As a final remark, the model and case study was validated with the assistance of several wood pellets producers in the Southern U.S., with production rates higher than 75,000 metric tonnes/year, who reviewed the model and case study, considering their own production conditions as well as all the relevant details and variables for pellet production, validating that results obtained from the model were accurate, since similar costs and prices were obtained by them, and up-to-date according to market conditions.

CONCLUSIONS

This research focused on the development of a techno-economical model for evaluating the feasibility of pellet production for the internal market in the U.S. The main conclusions from this project are:

1. Previous research and technical information from producers indicated that the most important variables for wood pellets production are: biomass type (species, moisture content, and form of delivered biomass), plant and equipment prices, energy costs, and labor structure.
2. Pellet production for the U.S. internal market is profitable for both producers and distributors/retailers, for selling prices higher than $241.3/metric tonne, considering actual price trends and transportation costs. The pellets business proves to be more profitable for retailers/distributors ($31.7/metric tonne vs. $25.3/metric tonne revenue margin for producers). However, specific production costs should be closely monitored for small-scale producers in order to effectively compete with larger producers.
3. Sensitivity analyses determined that biomass and labor costs were the most important cost drivers for wood pellets. In this sense, pellet production was especially sensitive to biomass cost. Thus, long term agreements for the supply of biomass located near the pellet factory may minimize raw material costs.
4. Additionally, labor represented a very sensitive cost factor, and it needs to be accurately dimensioned in order to reduce its potential negative impact on the NPV.
5. Energy costs represents an important price-reduction factor if drying is not considered in the operations, since it accounts for 70% of the total energy consumption; however, the impact of using previously dried raw material must be evaluated in detail. In addition, a strategy of energy co-generation from the factory may positively reduce the sensitiveness of this factor in the overall production costs.
6. CAPEX was the third sensitive cost factor of the pellet plant. A CAPEX reduction strategy may be achieved by better machinery effectiveness, higher unit capacities, or reduction of unit operations such as drying, grinding or hammermilling, but further analyses must be conducted regarding increases in the raw material costs, since activities such as drying must be performed by suppliers, increasing the delivered cost of biomass.

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Article submitted: June 17, 2010; Peer review completed: August 25, 2010; Revised version received and accepted: September 17, 2010; Published: September 17, 2010.