Floresta e Ambiente 2019; 26(4): e20160427
https://doi.org/10.1590/2179-8087.042716
ISSN 2179-8087 (online)

Original Article

Wood Science and Technology

Economic and Environmental Analysis of Pellets' Production in Rio Pardo Watershed, Brazil

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ABSTRACT

Economic and environmental aspects of residues energetic use in Brazil are extremelly important. In one hand, the country is today a recognized bioenergy producer in a global scenario; on the other, it is still struggling to provide a reliable renewable energy supply to rural communities. Local demand could be supplied through small investments using local forest mill residues as feedstock to produce value-add bio-based energy fuels. Therefore, this work aims at evaluating wood pellets production as an alternative source for supplying regional heat demand for drying grains and tobacco in the Rio Pardo Watershed (RPW), Brazil. It presents techno-economic analysis and risk assessment for a pellet plant supplied by sawmill residues available at the RPW. The results showed the economic feasibility of pellets production in the RPW. The pellets can be a clean, renewable alternative energy source to firewood for supplying farms demand for drying grains and tobacco.

Keywords: forest residues, bioenergy, forestry economics, crops drying.

1. INTRODUCTION AND OBJECTIVES

Forests are recognized as a fundamental part of the carbon cycle and have been the focus of initiatives to reduce greenhouse gas (GHG) emissions. Thanks to the advent of technologies, such as pellets, wood residues will probably be one of the most important sources of biomass used to produce energy (heat, power and fuels), allowing the production of clean and efficient energy bioproducts from forest residues (Burden, 2012).

Biomass as raw material to generate bioenergy is of outstanding value. Not only because it is a renewable source, but also because it creates additional income and jobs in agricultural communities (Müller et al., 2005). Brazil is recognized as an emerging pellet producer and consumer, being part of the top 30 largest pellets' producers in the world scenario; however, its internal pellets consumption is still small, 75,000 t/year (Thrän et al., 2017). The country had around 18 industrial pellet plants in 2013, of which 13 operating and most of them working below capacity (50%) (Abipel, 2014). Still, the new plant projects are focusing on exporting rather than supplying local energy needs.

Bioenergy has the potential to benefit farming communities in Brazil while bringing sustainability to agricultural activities. However, there is a lack of studies focusing on the feasibility of pellets production to supply the local communities energy demand.

A community that could benefit from pellets production is the Rio Pardo Watershed (RPW), a region formed mainly of tobacco farmers; which consume more than one billion stacked meters of firewood per crop season (Farias et al., 2017). The region is facing a firewood shortage, where about 50% of the farmers need to purchase firewood from long distances, which is more expensive and results in extra GHG emissions from transportation (Farias, 2013). Besides economic and environmental impacts, the current situation has social consequences as well; it results in more farmers leaving the rural areas inflating the cities with an untrained workforce.

In one hand, the RPW is facing firewood supply shortage; on the other, there is an excess of sawdust produced at the local sawmills with no established market. Furthermore, it has become an environmental issue because of storage limitations at the sawmills. In 2012, the province environmental regulation office released that there are 107 sawmills registered in the RPW (Rio Grande do Sul, 2013). According to Couto et al. (2004), approximately 50% of the sawn lumber volume produced in small and medium-size mills became residues, such as sawdust, sideboard and shavings.

Therefore, it is clear the opportunity to evaluate pellets production as an alternative to supply farmers' energy demand in the RPW. This paper aims to provide valuable decision-making information considering environmental and economic perspectives towards energy sources alternatives to supply the energy demand in the RPW. Moreover, we perform a risk assessment through a Monte Carlo simulation to model the uncertainties in market price, capital and feedstock costs.

2. MATERIALS AND METHODS

2.1. Study region

The RWP is located in south of Brazil, in the state of Rio Grande do Sul (RS). The area is geographically located at coordinates 28º50' to 30º 00' of South latitude and 52º15' to 53º00' of west longitude. The watershed area is 3,636.79 square kilometers, which is constituted of 13 municipalities. The region natural forest formation is the Seasonal Deciduous Forest, integrating the Atlantic Rainforest biome (Marcuzzo et al., 1998).

2.2. Sawmill residues

The sawdust amount available in the RPW was retrieved from literature and government data. The following procedure was employed to estimate the amount of sawdust available for pellets production: the total number of sawmills (Rio Grande do Sul, 2013) multiplied by the average wood volume sawn by the sawmill in tonnes per day (Farias, 2017) multiplied by a sawdust yield factor (Brand, 2010). Twenty-one working days per month were considered to define the amount of sawdust available.

Moisture and high heating value (HHV) are crucial characteristics when considering biomass as raw material to produce pellets. Therefore, five random samples were collected and evaluated to obtain the HHV and moisture at Laboratório de Ensaios em

Combustíveis da Fundação de Ciência e Tecnologia, located in Porto Alegre, RS, Brazil. The analysis of the moisture followed the NBR 14660 (ABNT, 2004) and the HHV followed the D5865 (ASTM, 2010).

Around 84.6% of the sawn lumber in the region comes from plantations of Eucalyptus species (Farias, 2017); consequently, it was assumed that the sawdust is predominantly *Eucalyptus* sp. It is also important to emphasize that sawmills at the study region run using wood assortments from planted forests, maintaining the native forests preserved (Farias, 2017).

2.3. Economic assessment

The amount of sawdust available and its moisture were used to define production capacity and equipment size and cost. Edifications costs, operation hours, labor, electricity consumption, line production losses and maintenance were acquired from personal communications with technicians of the equipment supplier Lippel, located in Agrolândia, in Santa Catarina (SC) state, Brazil.

The sawdust delivered cost at the mill gate was assumed to be the sawdust price traditionally applied to plywood market in Rio Grande do Sul (R$ 50.00 per tonne delivered). The pellets price used to calculate the deterministic cash flow before taxes was assumed at R$ 346.66/t. The pellets price free on board varied from R$ 480.00 to R$ 600.00/t, in the Brazilian market (Garcia et al., 2016); therefore, it is reasonable to have a price below R$ 480.00/t at the plant gate.

2.4. Economic metrics

The investment criteria calculated were: net present value (NPV) (equation 1), which represents the current return on the investment according to its duration (Rezende & Oliveira, 2001); internal rate of return (IRR) (equation 2), which denotes a discount rate that results in a zero NPV (Silva et al., 2007); average cost (AC) (equation 3), which is a result of the division between net production and costs in the horizon period (Silva et al., 2007); and finally, the break-even point (BEP) (equation 4), it is a number of sales which results in an equal amount of revenues and costs; therefore, there is no profit or debt at the BEP (Dias, 1992). The Microsoft Excel® was used for all calculations.

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} \quad (1)$$

NPV: net present value; R_t: net cash flow at time t in years; n: total number of periods t; i: discount rate.

$$\sum_{t=0}^{n} RV(1+IRR)^{-t} = \sum_{j=0}^{n} C_t(1+IRR)^{-t} \quad (2)$$

IRR: internal rate of return; RV_t: revenues at time t in years; C_t: costs at time t in years; n: total number of periods t.

$$AC = \frac{\sum_{t=0}^{n} C_t (1+i)^{-t}}{\sum_{t=0}^{n} PT_t (1+i)^{-t}} \quad (3)$$

AC: average cost; Ct: net costs value at time t; PTt: net production value at time t; i: discount rate; t: time in year "n".

$$BEP_{(u)} = CF \div MC \quad (4)$$

$BEP_{(u)}$: break-even point in units; MC: contribution margin defined by unitary price minus variable unitary cost; CF: fixed unitary costs.

The discount rate used was 10.9% corresponding to Brazilian Selic rate (Special System for Settlement and Custody) verified in September 2014 (Banco Central do Brasil, 2014). This rate is formed by the inflation index plus a remuneration rate.

Part of the biomass consumed supplies the pellets plant's drying system; therefore, after drying the sawdust, the plant capacity is 6 t/h of biomass at 10% moisture, according to Lippel technicians. Taking into account 2,016 operating hours per year and 3% of production losses, the estimated pellets production is 11,733.12 t/year, considering half production in the first semester due to plant installation and workforce training.

This analysis does not consider commercialization and marketing costs. Pellets selling price considered was R$ 346.66/t. Equipment depreciation rate was 10% and 2.5% for buildings; residual value was not contemplated. The fixed costs are the plant, site, administrative labor, maintenance, opportunity cost and depreciation. The variable cost contains operational workforce, electricity and raw material. A cash flow diagram is presented in Figure 1.

An NPV sensitive and risk analysis were performed through a Monte Carlo Simulation to deal with the uncertainties surrounding the investment. A variation of ± 25% in all parameters was assumed following a triangular distribution due to a lack of

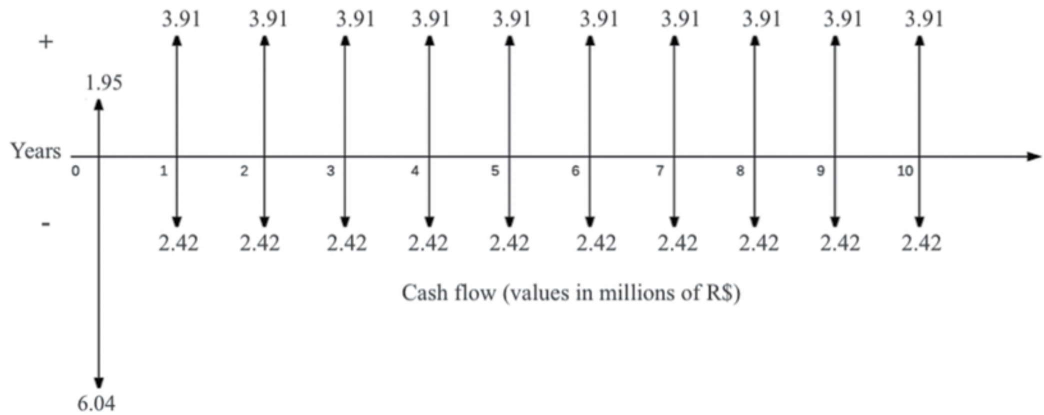

Figure 1. Pellet plant cash flow.

historical data to explore price fluctuations and cost behavior. The parameters analyzed were the capital cost (R$ 5,053,456.17), selling price (R$ 346.66/t) and raw material cost (sawdust R$ 50.00/t and wood chips R$ 40.00/t); varying randomly in 10,000 runs according to the probability distribution. The simulation was executed in the Excel Analytic Solver Platform V2016-R3 (16.5.1.0) for Education, Copyright© 2016 Frontline Systems, Inc.

3. RESULTS AND DISCUSSION

3.1. Economic analysis

Around 69.92 t/day of sawdust are available in the study region with a moisture of 32.62%, which requires drying to reduce to 10% – standard moisture required for pellets production. The sawdust HHV was 4,655 kcal/kg, which is common in the *Eucalyptus* species cultivated in the south of Brazil. Likewise, Quirino et al. (2004) evaluated 15 species of *Eucalyptus* and observed an average HHV of 4,874 kcal/kg varying between 5,023 kcal/kg and 4,217 kcal/kg.

Based on premises presented in the methodology section, pellets production in the RPW is economically feasible, achieving an NPV of R$ 6.02 M (millions), and an IRR of 43.1%, higher than the discount rate used 10.9%. These results provide decision-making input for prospective investors to analyze the investment according to rates available on the financial market and governmental funding programs. Also, it could be an opportunity to regional entrepreneurs, such as cooperatives, to invest in it.

Pellets production has shown economic growth potencial in Brazil (ABIB, 2016). In the case study presented here the BEP(u) was 5,444.15 t/year, which means that revenue is equal to total cost at this production level. Therefore, in the current production of 11,733.12 t/year the plant is working 54% above the BEP(u). The AC cost calculated in this study was R$ 153.77/t of pellets at the plant. According to the latest EIA Bioenergy repport, the pellets production in Brazil averaged at € 108.00/t (Thrän et al., 2017); around R$ 370.00/t considering an exchange rate for December 2016. This high production cost in Brazil is mostly due to the small scale and low efficiency of the exisiting plants, which are working on average at only 50% their production capacity (Thrän et al., 2017);

Considering operational costs, the AC breakdown was as follows: raw material (48%) followed by depreciation (22%), electricity (19%), labor (6%) and maintenance (5%). Since electricity was found to be one of the most representative costs, an alternative could be the use of biomass to generate plant's required electricity and heat, although it is necessary to analyze feasibility and raw material supply availability to produce energy at the plant. The raw material is the most representative cost for pellets production. Couto et al. (2004) states that the most common cost structure is characterized for raw material (27%); then commercialization (27%); loan (20%); labor (14%); electricity (5%); administration (5%); and reposition equipment or depreciation (5%).

As a preliminary conclusion, the economic analysis results show a favorable investment opportunity; however, there are limitations to be considered:

- Raw material supply reliability: for this study, average values of monthly sawdust production were considered; however, a seasonality of residues production is expected in the sawmills according to their products demand. Additionally, other residues available in the region can also be used to produce pellets.
- Market: there may be a cultural and economic barrier for pellets usage in the Rio Pardo Watershed, once they have not been introduced to the community, and there are investments necessary to adapt their current drying system enabling pellets use.
- Pellets required standards: a detailed analysis of the pellets properties produced is necessary to ensure meeting required standards for commercialization.

3.2. Sensitivity and risk analysis

The Monte Carlo simulation results are presented in Figure 2. After 10,000 runs varying the capital cost, selling price and raw material cost, the most likely NPV was R$ 6.02 M, the minimum was R$ –2.2 M and the maximum R$ 13.6 M. The investment has a low risk of presenting a NPV below zero and the probability of having an attractive NPV (that is, higher than R$ 3.0 M) is 84% (Figure 2).

A sensitivity analysis was also performed to understand what parameters have a higher impact on the feasibility (Figure 3). The pellets selling price has the biggest influence in the NPV. A decrease of 25% in the price results in an NPV of R$ 0.9 M (85% reduction of the most likely NPV). Secondly, the capital cost, where an increase of 25% in the capital investment results in a decrease of 15% in the NPV. The lowest impact was found for the raw materials, which presented as less than 3.5% in the results.

Market fluctuations can highly affect pellets feasibility production in the RPW. As of 2015, there was no pellets plant installed in the region, showing a market opportunity. However, the pellets usage in tobacco and grain drying has to be technically and economically evaluated, therefore, it is necessary to compare pellets, sawdust, and firewood energy consumption, not only cost.

3.3. Potential environmental benefits of pellets usage in the RPW

Firewood is the primary energy source for tobacco curing and grain drying at RPW; however, new technologies allowed sawdust and pellets usage as an energy source. The supply system (Figure 4) is an example of these technologies. In this system, farmers need to feed equipment dispenser with biomass (e.g. pellets or sawdust), then the furnace is supplied automatically, and it is controlled according to the temperature program selected. The biomass is

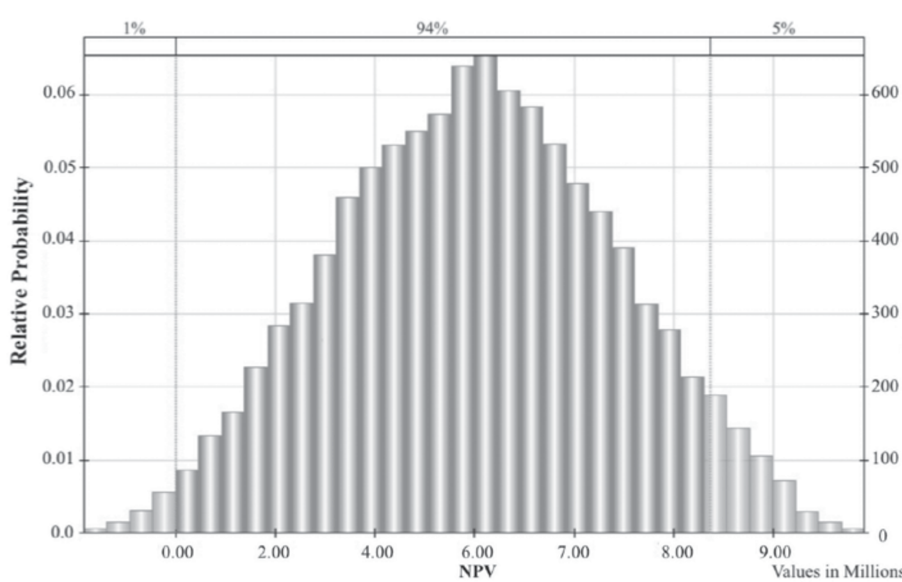

Figure 2. Monte Carlo results for NPV sensitivity.

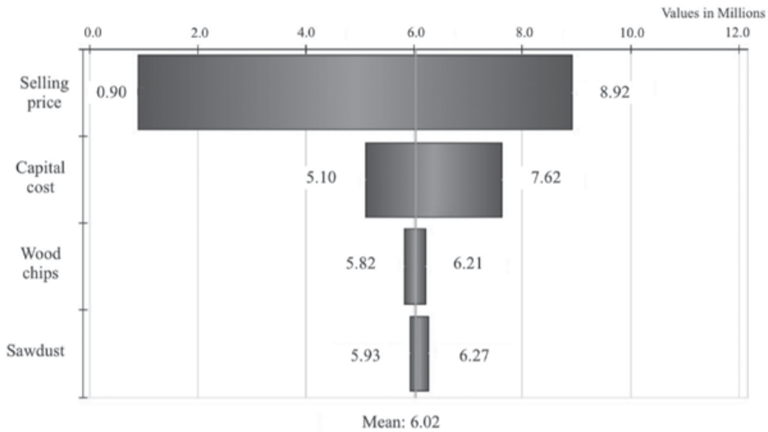

Figure 3. Sensitivity analysis of the NPV through Monte Carlo simulation.

conducted to the furnace by a screw conveyor and when the supply system dispenser is empty, a sonorous signal is emitted warning the farmer that the dispenser needs to be fed again.

Burning wood is considered carbon neutral for CO_2 emissions because trees absorb and fix CO_2 from the atmosphere during their grown; then when wood is used as a fuel source, it will release the absorbed CO_2 back to the atmosphere. According to Middleton (2014), wood residues products usage as an energy source has lower environmental impact, since carbon cycle is closed with fewer atmosphere emissions.

In the RPW, it is common to observe sawdust stored in open areas due to a lack of sawmill infrastructure to place residues; as a result, gas emissions from natural wood decomposition can generate even more GHG than burning wood (Foelkel, 2011). Residues such as sawdust, wood chips and bark, once stored in open areas, generate pollutants called volatile organic compounds (Granström, 2005). For example, methane emissions begin as soon as residues are stored in open areas; the anaerobic digestion, which occurs during the decomposition process, is responsible for CO_2 and methane emissions (PCFplus, 2002).

Figure 4. Supply system used in the Rio Pardo Watershed, Brazil.

The PCFplus (2002) developed a mathematical model to calculate methane emissions from wood residues (sawdust and bark) stored in open areas in Bulgaria. In their model, the amount of methane emitted is a result of the following variables: residues volume, carbon content, decomposition constant, hemicelluloses content and methane oxidation factor. The model estimated that each tonne of wood residues could generate 1.04 m^3 of methane during the first year of decomposition.

Based on PCFplus (2002) model, it could be estimated that an amount of 1,524.87 m^3 of methane can be generated from 1,466.22 t of sawdust stored monthly in the 107 sawmills located at the RPW. It is important to point out that this estimative could vary according to temperature, and it tends to be greater in high-temperature regions, like the RPW.

In addition to decomposition emissions, the high moisture wood results in low combustion temperatures generating lower energetic efficiency and higher hydrocarbons and particulate emissions. Dried and compressed biofuels (e.g. pellets or briquettes) have low moisture and high density, thus, they present lower emissions during combustion and transportation. Wood harvesting and transportation to a distance of 400 km can achieve up to 50.3 kg of GHG emissions for each tonne of firewood (AGO, 2003).

Oliveira (2012) emphasized that NO_x, SO_x and organic compounds emissions from pellets consumption are lower than other energy forms, such as firewood. Pellets combustion is more efficient and liberates less smoke because of the lower moisture. Moreover, Pa et al. (2013), while evaluating alternative heating energy sources in Canada, found that pellets could decrease down to 38% of CO_2 emissions when replacing firewood. Especially because pellets have higher combustion efficiency which compensate pellets' production process emissions.

It is clear that wood pellets have higher potential to prevent GHG emissions when compared to other forms of wood for energy, such as firewood and sawdust. Raymer (2006) estimated that for each cubic meter of forest biomass used as bio-based fuel, the CO_2eq (CO_2 equivalent) emissions avoided vary between 0.21 t to 0.63 t depending on the replaced source. Considering Raymer's coefficient, it can be estimated that 18.11 kg of CO_2eq is avoided for each tonne of pellets used to replace firewood. Considering 11,733.12 t of pellets, it could avoid 212.05 t of CO_2eq.

It is also important to state that the discussion provided in this section is purely theoretical, and emissions measurements are necessary to provide safe estimates comparing firewood and pellets in the Rio Pardo Watershed.

4. CONCLUSIONS

This paper provided an overall environmental and economic analysis for pellets production in the RPW, RS, Brazil. It was verified that pellets production is feasible (NPV 6.02 M, and IRR 43.1%); however, pellets selling price strongly affects the project feasibility. Therefore, local pellets production from sawdust could be an alternative to managing the wood shortage in the RPW. Besides, there could also be environmental benefits from the lower GHG emissions generated if pellets replace firewood.

The results and risk analysis presented here bring the first step for introducing pellets as a source of energy to supply the RPW demand. Therefore, studies considering seasonality of raw material supply, live cycle assessment and market analyses comparing pellets with other available fuel sources are important to provide a complete scenario of pellets production in the region.

SUBMISSION STATUS

Received: 16 Sept., 2016

Accepted: 30 June, 2018

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FINANCIAL SUPPORT

The authors thank Coordenacão de Aperfeiçoamento de Pessoal de Nível Superior (Capes) and Japan Tobacco International for the financial support.

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