TECHNO-FINANCIAL ANALYSIS OF WOOD PELLET PRODUCTION IN THE PHILIPPINES

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JARA AA, DARACAN VC, DEVERA EE & ACDA MN. 2016. Techno-financial analysis of wood pellet production in the Philippines. A techno-financial analysis was performed to determine production cost of wood pellets manufactured in the Philippines using woody biomass as feedstock. Capital and operating costs of the pelleting operation were estimated using three framework conditions. Effects of plant capacity and price of feedstock on production cost were determined. Results showed that wood pellets could be economically produced in the Philippines with production cost of about 88–92 USD tonne^{-1} at production rate of 1 tonne hour^{-1} using woody residues such as sawdust and shavings at a price of 30–40 USD tonne^{-1}. Specific cost of pellet produced could significantly be reduced at a higher plant capacity. Cost of feedstock, equipment and personnel were the major cost factors in pellet production. Pellet production cost was significantly influenced by production rate and cost of raw materials.

Keywords: Biomass, renewable energy, wood waste, bioenergy, densification

INTRODUCTION

Philippines adopted the Renewable Energy Republic Act 9513 of 2008 providing framework for the exploration and development of renewable energy resources in the country. Potential sources of renewable energy such as biomass, solar, wind, hydro, geothermal and ocean energy were targeted for sustainable development to reduce the country's dependence on fossil fuel. Biomass is among the country’s sources of renewable energy (Samson et al. 2001). It can play a major role in helping reduce oil imports if efficient energy conversion technologies are developed to produce heat, power and liquid fuels. Studies have shown that woody biomass can be converted to fuel pellets for industrial and residential heating requirements (Di Giacomo & Taglieri 2009). Wood pellets are solid fuel made from dry sawdust compressed through a die under high pressure. Its geometry (6–8 mm in diameter and 30–60 mm long) facilitates transport, compact storage and controlled feeding to burners and boilers (Hartmann & Lenz. 1999). In comparison with traditional fossil fuels, emissions of nitrogen oxide (NOx), sulphur oxide (SOx) and volatile organic compounds during thermal processes are also very low (Olsson & Kjallstrand 2004). These attractive properties set wood pellets apart from other densified solid fuel such as briquettes and have caused its demand to soar in the last few years. Wood pellets are widely used in Sweden, Finland, Italy, US, UK, Canada, South Korea and Japan as fuel of boiler and furnaces to generate heat for residential and industrial requirements. Wood pellet production and its international flow made it one of the most successfully traded biomass products to date (Vinterback 2004, Stahl & Wikstrom 2009, Heinimo & Junginger 2009).

Considering the high demand for wood pellets abroad, wood processing companies in the Philippines are showing interest to enter the bioenergy market. These companies, e.g. sawmills and furniture plants, have significant volume of wood residues for the production of wood pellets. However, to start a commercial pellet production, it is essential to determine capital investment and production costs for specific market conditions that will yield feasible technical and economic operation. Unfortunately, no studies have been conducted to determine the feasibility of pellet production in the Philippines. Several framework studies have been reported to determine technical and economic feasibility of pellet production in various countries (Thek & Obernberger 2004, Mani et al. 2006, Trigkas et al. 2009, Pirraglia et al. 2010, Nolan et al. 2010, Uasuf & Becker 2011). However, the results were market specific and applicable only to certain geographical regions. The present paper reports on the technical and financial analysis of the wood pellet production in Philippines and sensitivity analyses of important cost production factors in the pellet production process.

MATERIALS AND METHODS

Pellet production model and boundary

A typical wood pellet production process was used for the techno-financial evaluation in this study (Figure 1). A production capacity of 1 tonne hour^{-1} producing 8 mm diameter wood pellets for power generation and heat requirement of processing plants was used as baseline scenario. Cost of biomass collection, storage and transportation to the pelleting facility were included in the total cost calculation. However, delivery of wood pellets to end-users was considered outside the boundary of the model and was not included in the cost calculation. Three framework conditions deemed suitable for Philippines were considered in the calculation of pellet production costs and energy consumption (Table 1). Production rate of 1 tonne hour^{-1} was considered suitable for a small wood pellet plant where feedstock could be provided by small tree farmers and cooperatives. The final moisture content (MC) of wood pellets was assumed to be less than 10%. All scenarios were based on seven days per week and three shifts per day operation, i.e. 85% capacity utilisation, including scheduled and unscheduled shutdowns.

Capital cost

The different types of cost in pellet production were classified into two groups, i.e. capital and operating costs. The annual capital cost was calculated by multiplying the capital recovery factor with investment cost. The capital recovery factor (e) was calculated using the equation,

$$e = \frac{i\,(1+i)^N}{(1+i)^N - 1}$$

where i = interest rate on invested capital per year and N = useful life of the equipment (years). Interest rate of invested capital was taken at 7% annually.

Capital cost consists of purchase and installation costs of all equipment and general

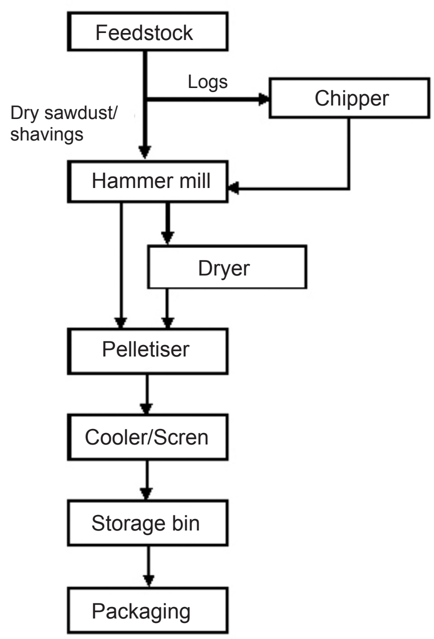

Figure 1 Typical wood pellet production flow chart

Table 1 Framework conditions for calculation of pellet production costs

Parameters	Scenario 1	Scenario 2	Scenario 3
Feedstock (raw material)	Dry sawdust and shavings	Wet sawdust and shavings	Round wood
Pellet production rate, tonne h^{-1}	1.0	1.0	1.0
Annual operating hours (3 shifts, 7 days per week), hour $year^{-1}$	7446	7446	7446
Annual pellet production, ton $year^{-1}$	7446	7446	7446
Cost of feedstock, USD $tonne^{-1}$	40	30	67

investment to build and operate the pellet plant. The cost of equipment was based on quotations from several manufacturers from China and Europe or published literature sources in 2014. Equipment was selected based on their cost-effectiveness and suitability under Philippine conditions. Type, capacity, required electric power and maintenance cost were considered in the selection. Installation cost including freight cost to Philippines was considered as 25% of the purchase cost of equipment. Investment cost of equipment was taken as the sum of the purchase and installation costs. Peripheral equipment included costs of motors for feeding screws, sieving machine, fans and air locks. General investment included land acquisition, construction of building, warehouse and road, office furniture and fixtures, electricity connections, vehicles, forklifts, control systems, engineering, market introduction and planning.

Operating cost

The operating cost included costs of feedstock, fuelwood for the dryer, electricity to run the machines, diesel fuel for the vehicles, salaries of personnel (direct labour) and maintenance cost. Feedstock cost included purchase of logs or wood residues from tree farmers, cooperatives and furniture processing plants. Feedstock for pellet production were dry sawdust or a mixture of wet sawdust (50%) and shavings (50%) from hardwood (*Dipterocarpaceae* spp.) or logs from fast-growing plantation trees (*Gmelina, eucalyptus*) (Table 1). Dry sawdust and shaving are abundant and widely available in furniture and wood processing plants in Philippines. Dry sawdust and shavings were supplied at < 16 % and logs at 55% MC. The average prices of raw materials were based on quotes from local tree farmers or furniture companies, at average transport distance of 60 km to the pellet plant (Table 1).

The drying system used in this study is a rotary drum dryer connected directly to a wood fired furnace, supplying heat from the combustion of biomass fuel. The cost of drying included electricity consumption of the dryer motor and the cost of sawdust or fuel wood that provided thermal energy to evaporate water in the feedstock. The heat required to evaporate 1 kg of water was assumed to be 2.6 MJ with target feedstock moisture content of 16%. The cost of wood fuel varied according to the amount of raw material dried.

The energy requirement of the pelleting operation was divided into electrical, heat and fossil fuel energy. The total electrical energy requirement corresponded to the electricity required to run the hammer mill, dryer, pellet mill, cooler, screw feeder, conveyor and miscellaneous equipment. The cost of electricity for all pelleting operations and electrical installations was based on an electric rate of USD 0.1189 kW h^{-1}. A simultaneity factor of 80% was included to account for electrical installations not operating at full load at the same time. Direct labour included plant staff involved in pellet production, i.e. foreman, labourers, forklift operator and vehicle driver.

The annual service and maintenance costs was calculated as a percentage of the investment cost of each unit, spread over their useful life, taking into consideration the different wear and utilisation periods. Equipment subject to significant wear and tear was allocated with 10–15% maintenance costs.

Overhead cost

Overhead cost included insurance and property taxes, sales and marketing cost, working capital and indirect labour and materials. Insurance and property taxes were estimated as percentage of total investment in accordance with Philippine taxation guidelines. Indirect materials and utilities were calculated as 2% of direct material cost for scenarios 1 and 2 and 5% for scenario 3. Direct cost included cost of feedstock, electricity and direct labor. Personnel costs were divided into direct and indirect labor. Indirect labor included supervisory and administrative staff. Steam conditioning of feedstock, lubricant and external binders were not included in the cost analysis.

Sensitivity analysis

Sensitivity analysis for each scenario was performed to determine the effect of various cost factors on total production costs. The main factors analysed were specific cost of pellet production against plant capacity and cost of raw material. These factors were increased by two to three folds to assess effects of potential changes of variables on total production cost. The following equation was used to estimate the cost of equipment at higher plant capacity when the cost at lower capacity was known (Peters & Timmerhaus 1991).

$$\frac{C_2}{C_1} = \left(\frac{S_2}{S_1}\right)^R$$

where C_1 and C_2 = costs of equipment while S_1 and S_2 = corresponding capacities. An exponent R value of 0.6 was used in this study.

RESULTS AND DISCUSSION

The cost of pellet production was broken down into general investment, grinding, drying (if used), pelletisation, cooling, storage, peripheral equipment, overhead, personnel and raw material (feedstock) (Tables 2–4). The investment cost of equipment (purchase cost and installation), annual capital cost and the specific cost of pellet production (USD tonne^{-1}) were calculated. Table 5 shows type, capacity and maintenance cost of equipment selected. Table 6 shows the required number of personnel and their respective annual salaries. Pellet production using dry sawdust with production rate of 1 tonne hour^{-1} (7,446 tons of pellets annually) was used as baseline scenario (scenario 1) and compared with typical scenarios (scenarios 2 and 3) in Philippines. Scenarios 1–3 were also used to investigate the effects of plant capacity and cost of raw materials on pellet production cost.

Total production costs were mainly from operating cost (feedstock and electricity costs), followed by the overhead and capital costs (Figure 2). The maintenance costs were relatively of minor significance (Figure 2). Operating cost was about 75% of total production cost for scenarios 1 and 2. Operation cost of scenario 3, however, was about 20% higher in comparison with scenarios 1 and 2. This was primarily because scenario 3 used logs feedstock that required electrical energy for grinding to convert raw materials to sawdust and heat energy for drying. In addition, the cost of logs from plantation tree species used for scenario 3 was about 3.5 times more expensive compared with sawdust and shavings for scenarios 1 and 2. Use of binders or lubricants to consolidate or improve pellet properties further increased operating cost. The cost of the pellet mill had the largest share (46%) among the capital cost of pelleting equipment. However, the cost of the dryer (18%) became significant if scenario 2 or 3 were used.

Comparison of specific costs between case scenarios used in this study showed that scenario 1 had lower specific costs (USD 88 tonne^{-1}) compared with scenario 2 (USD 92 tonne^{-1}) and scenario 3 (USD 212 tonne^{-1}) (Tables 2–4). The latter scenarios used wet raw materials and therefore required additional energy and fuel for drying (Figure 3). Feedstock from fast growing plantation tree species (round wood) also needed chipping and grinding, requiring additional electric energy. The specific costs of pellet production in this study were comparable with pellet production studies reported from North America (Mani et al. 2006, Uasuf & Becker 2011). However, it is higher compared with that from China (Wang & Yan 2007) but lower than that reported from European countries (Thek & Obernberger 2004). The difference in pellet

Table 2 Cost of wood pellet production for scenario 1

Cost item	Investment cost (USD)	Annual capital cost (USD year^{-1})	Maintenance cost (USD year^{-1})	Operating cost (USD year^{-1})	Total cost (USD year^{-1})	Specific cost (USD tonne^{-1})
General investment	593,334	59,250	867		605,117	8.07
Hammer mill	8,788	1251	1318	21,255	23,829	3.20
Pellet mill	53013	7548	7952	63,765	79,265	10.65
Pellet cooler and screen	4688	667	469		1,136	0.15
Packaging unit	10,250	1125	103	4251	5479	0.74
Storage bin	3063	336	31		367	0.05
Peripheral equipment	33,763	3707	338	5278	9323	1.25
Feedstock (dry sawdust)				347,480	347,480	46.67
Personnel (direct labour)				51,560	51,560	6.92
Overhead					76,543	10.28
Total	706,899	73,884	11,078	493,589	655,094	87.98

Table 3 Cost of wood pellet production for scenario 2

Equipment	Investment cost (USD)	Annual capital cost (USD year^{-1})	Maintenance cost (USD year^{-1})	Operating cost (USD year^{-1})	Total cost (USD year^{-1})	Specific cost (USD tonne^{-1})
General investment	593,334	59,250	867		60,117	8.07
Hammer mill	8788	1251	1318	21,255	23,824	3.20
Furnace	5000	549	50		599	0.80
Drum dryer	25,375	3613	254	4413	8280	1.11
Pellet mill	53,013	7548	7952	63,765	79,265	10.65
Pellet cooler and screen	4688	667	469		1136	0.15
Packaging unit	10,250	1125	103	4251	5479	0.74
Storage bin	3063	336	31		367	0.05
Peripheral equipment	41,475	4554	415	7404	12,373	1.66
Feedstock (wet sawdust and shavings)				364,811	364,811	48.99
Personnel (direct labour)				51,560	51,560	6.92
Overhead					79,230	10.64
Total	744,986	78,893	11,459	517,459	687,041	92.27

cost could be due to differences in plant capacity used, salaries of personnel, cost of feedstock and electricity. The price of pellets, as indicated by Argus 90 day wood pellet index, was about USD 172 tonne^{-1} (Argus 2015). Spot price of wood pellet from various internet sources in China varied from USD 90 to 110 tonne^{-1}.

Figure 4 shows the effect of production rate on the specific cost of pellet production. The pellet plant was assumed to operate

Table 4 Cost of wood pellet production for scenario 3

Equipment	Investment cost (USD)	Annual capital cost (USD year^{-1})	Maintenance cost (USD year^{-1})	Operating cost (USD year^{-1})	Total cost (USD year^{-1})	Specific cost (USD tonne^{-1})
General investment	593,334	59,250	867		60,117	8.07
Chipper	7250	1032	725	10,628	12,385	1.66
Hammer mill	8,788	1251	1318	21,255	23,824	3.20
Furnace	5000	549	50		599	0.08
Drum dryer	25,375	3613	254	13,535	17,402	2.23
Pellet mill	53,013	7548	7952	63,765	79,265	10.65
Pellet cooler and screen	4688	667	469		1136	0.15
Packaging unit	10,250	1125	103	4251	5479	0.74
Storage bin	3063	336	31		367	0.05
Peripheral equipment	48,775	5355	488	8467	14,310	1.92
Feedstock (logs)				1,239,338	1,239,338	166.44
Personnel (direct labour)				51,560	51,560	9.92
Overhead					70,227	9.43
Total	759,536	80,726	12,257	1,412,799	1,576,009	211.66

Table 5 List of pellet plant equipment, specifications and percentage of maintenance cost

Equipment	Type and capacity	Required electric power (kW)	Service and maintenance cost (%)
Chipper	Ring type, 1 tonne hour^{-1}	15	10
Hammermill	Ring type, 1 tonne hour^{-1}	30	15
Furnace	Direct combustion, wood fired		1
Dryer	Rotary drum dryer	14	1
Pellet mill	Ring die type, 1 tonne hour^{-1}	90	15
Pellet cooler/sieve	Counter flow	6	15
Packaging unit	Automatic bag sewing and weighing	6	10
Storage bin	Silo type		1
Peripheral equipment		12	1

at 85% capacity (7,446 hour year^{-1}). In all three scenarios, an increase in production rate decreased pellet production cost. This was mainly due to economics of scale for larger pellet plants. For instance, about 50% decrease in specific production cost could be realised if production rate increased from 1 tonne hour^{-1} to 6 tonne hour^{-1} (Figure 4). Similar negative correlation between pellet production rate and specific production costs was observed (Thek & Obernberger 2004, Mani et al. 2006). No substantial increase in capital cost was observed at higher plant capacity from 1 to 6 tonne hour^{-1}. However, specific cost decreased considerably with increasing rate of pellet production (Figure 4). Apparently, small scale pellet production was more expensive to operate resulting in higher specific cost of pellets.

The effect of feedstock price on pellet production cost is shown in Figure 5. Considering

Table 6 Direct and indirect labour required for pellet production

Direct labor	Number	No. of shifts	Salary (USD year^{-1})
Foreman	1	3	14,600
Laborer	5	3	30,800
Forklift driver	1	3	6160
Total			51560
Indirect labor			
Plant Manager	1	1	8111
Administrative staff	2	1	7300
Truck driver	1	1	2839
Electrician/Mechanic	1	1	3650
Total			21,900

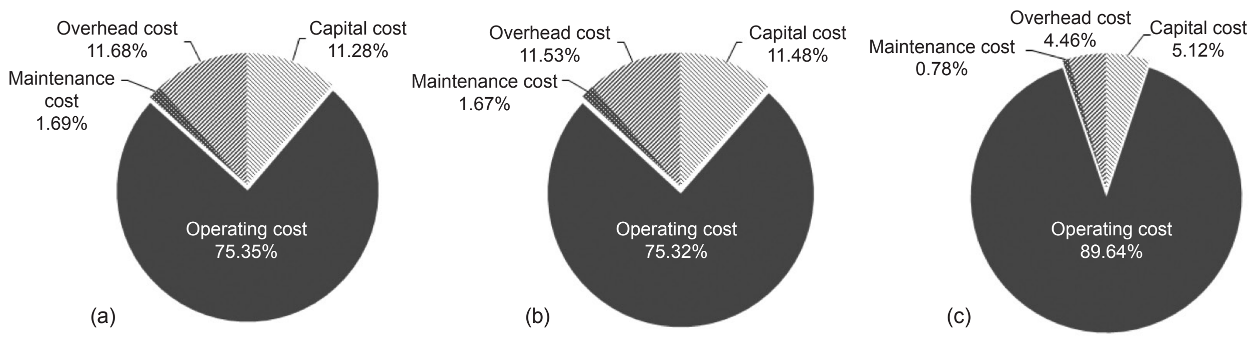

Figure 2 Components of total production cost for (a) scenario 1, (b) scenario 2 and (c) scenario 3

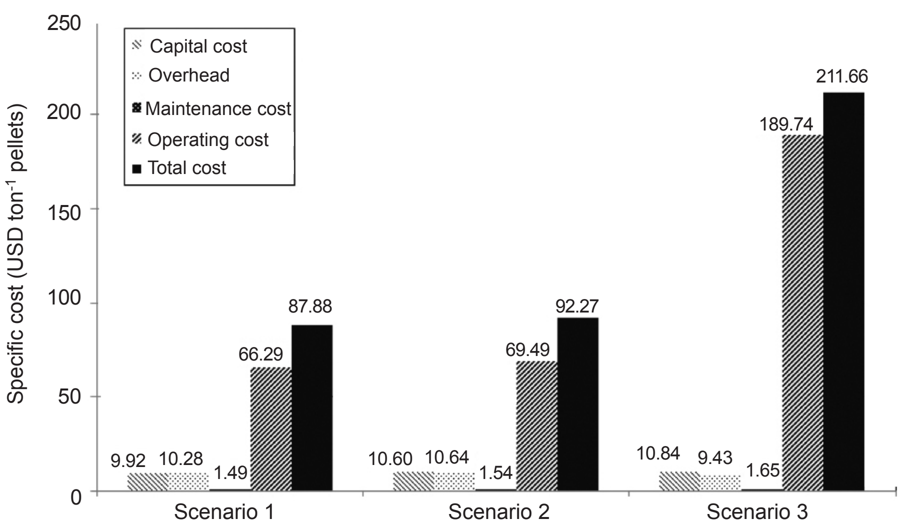

Figure 3 Specific cost of pellet production for different scenarios

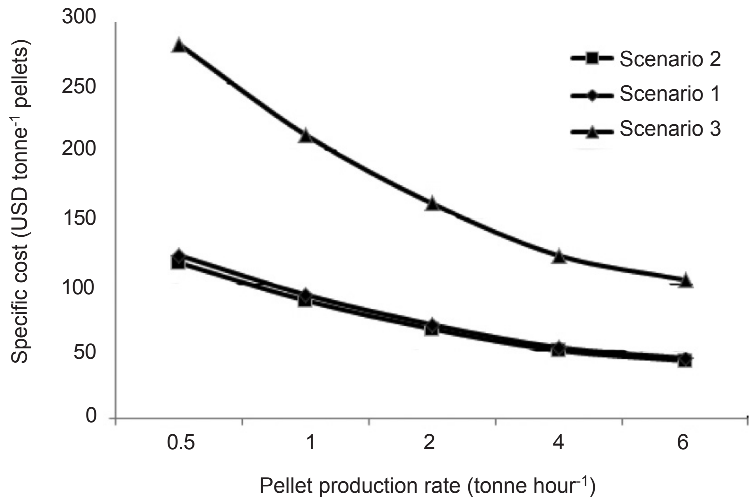

Figure 4 Effect of production rate on specific cost of pellet production

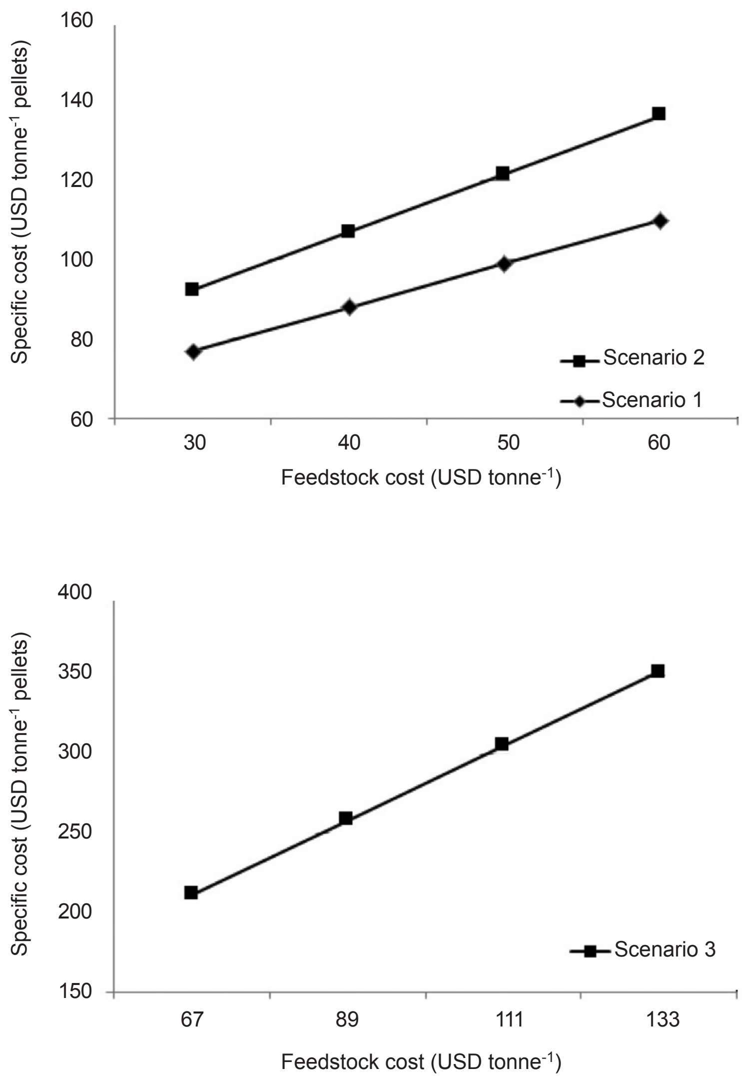

Figure 5 Effect of feedstock price on pellet production cost

potential variation in the price of different raw materials from 30 to 60 USD tonne^{-1} for scenarios 1 and 2, the resulting pellet production cost would range to about USD 77–136 tonne^{-1} of pellet produced. However, small changes in the price of feedstock within each scenario appeared to have minor effect on production cost (Figure 5). It is apparent that feedstock price could substantially affect specific production cost. High feedstock cost such as plantation tree species could bring pellet production cost above that of natural gas. This would make production of wood pellet economically unattractive.

In general, the study showed that wood pellets could be produced economically in Philippines with production cost of about USD 88–92 tonne^{-1} using woody residues such as sawdust and shavings as feedstock. These wood processing residues were readily available especially in furniture making provinces of Pampanga and Cebu. Cost of raw materials from USD 30–40 tonne^{-1} with moisture content below 16% could be obtained from wood processing plants in various locations in the country. Cost of feedstock, equipment and personnel were the major cost factors in pellet production. Cost of pellet production was influenced by production rate and price of raw materials. Increasing production capacity decreased production cost while increasing price of raw materials increased operating expenses, which eventually made pellets more expensive.

CONCLUSIONS

A techno-financial analysis was performed to determine production costs of wood pellets manufacture in Philippines using three different framework conditions. Woody biomass consisting of sawdust and shavings or fast growing tree species was used as feedstock. Capital and operating costs of pellet production were calculated using different plant capacities and feedstock price. Results showed that wood pellets could be economically produced with production cost of about USD 88–92 tonne^{-1} of pellets using sawdust and shavings at a price of USD 30-40 tonne^{-1} at about 16% MC. Cost of feedstock, equipment and personnel were the major cost factors in pellet production. Cost of pellet production was influenced by production rate and price of raw materials. Increasing production capacity significantly decreased production cost while increasing price of raw materials increased operating expenses.

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