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Original Article

Availability and Cost-benefit of using Coconut Residues as Biomass Energy Source in Top Coconut-producing Municipalities in Negros Occidental, Philippines

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ABSTRACT

Coconut residues as a potential energy feedstock are well-documented. However, studies dealing with its availability and cost-benefit effect on the environment and the economic situation of coconut farmers in the Philippines are limited. This study answered these concerns through theoretical and available biomass estimation, greenhouse gas (GHG) estimation, farmers' willingness to supply (WTS) determination and additional income estimation from selling residues as biomass feedstock in Negros Occidental, Philippines. A total of seven municipalities was surveyed. Descriptive statistics was used to analyze data. The total available potential of coconut biomass in the surveyed municipalities was 76,148.18 MJ/ha/yr. Computations revealed that fully converting the province's coconut biomass available potential to electricity will generate $392.33x10^6$ kg of CO_2, which is half of what is produced when using pulverized coal. Further computations showed revenue losses for the farmers ranging from Php 698.59 - 1,284.12/yr. Use of all available coconut residues can generate ample energy and GHG emissions lower than the traditional fuel. However, it does not contribute to the economic upliftment of coconut farmers. The current market price for biomass feedstocks is too low to be an alternative source of income to traditional coconut residue use.

KEYWORDS: *coconut biomass, economic benefit, greenhouse gas emission, Negros Occidental*

1 INTRODUCTION

The use of biomass in co-generation of energy is common in the sugar industry in Negros Occidental, Philippines. Bagasse, a sugar cane residue, is burned to create heat in the process of sugar-making. Such practice will be elevated through the establishment of three biomass power plants in the province. One of these is the San Carlos BioPower, Inc. in San Carlos City which is now at the research and development stage. It will produce 20 megawatts (MW) of power by using sugar cane residues as feedstock and other locally available agricultural residues as a supplement (Fuel: San Carlos BioPower Inc., 206). The other two power plants, the North Negros BioPower, Inc. in Manapla and South Negros BioPower, Inc. in La Carlota City are nearing completion of construction. Each will generate 25 MW of electricity. The three biomass power plants will produce a total of 70 megawatts (MW) of electricity (Zabaleta, 2016). This development creates a need to assess the potential of agricultural residues in the province as biomass energy source.

One potential biomass energy source is coconut (Banzon, 1980; Siengchum *et al.*, 2013; Acda, 2015; Pestañoand Jose, 2016; Su *et al.*, 2006; Tsai *et al.*, 2006; Tsamba *et al.*, 2006), an important agricultural product in Negros Occidental. The province has the largest area planted with coconuts (34, 578 ha), the most number of bearing trees (2,440,502 individuals), and the highest volume production (116,341.3 metric tons) in Western Visayas (Philippine Statistics Authority, 2015). Since it is a significant coconut producer in the region, it can produce considerable quantities of residues such that it can augment the supply of the primary feedstock, sugarcane. The lower heating values (LHV) of coconut residues are also higher than that of sugarcane bagasse which is at (16.56 MJ/kg) (Biomass Atlas of the Philippines, 2000). The LHV of the husk and shell is 21.75 MJ/kg and 25.32 MJ/kg (Biomass Atlas of the Philippines, 2000), while that of the petiole is 16.7 MJ/kg (Banzon, 1980). Also, its harvest is more frequent than that of sugarcane because it occurs quarterly (Mercado, 2015) instead of semi-annually; so, the feedstock supply is replenished sooner. However, there is no existing estimate on the available potential of coconut residues in Negros Occidental.

The theoretical biomass potential of coconuts in Negros Occidental can easily be computed from secondary data sources on crop yield volume and cultivated area (Voivontas *et al.*, 2001). However, it is the available potential that gives a more precise measure of biomass that can be supplied for energy production.

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It is also important to enumerate the current uses to estimate and commercial value of the coconut residues. This will shed light on the opportunity costs of diverting the use to biomass energy production (Altman *et al.*, 2015). Whether using coconut residues as biomass energy source brings economic benefits to farmers is another important question. One of the objectives of using renewable energy such as biomass was to uplift the economic situation of the farmers (Commission of the European Communities, 2005). This is crucial since coconut farmers in the country remain at subsistence level (Vista *et al.*, 2012).

Research on the physicochemical characteristics of coconut residues such as shell, husks, and petioles, as well as on their emissions, when converted through pyrolysis and torrefaction, reveal that coconut residues can provide energy that was comparable to coal (Pestaño and Jose, 2016). However, its overall impact was not well studied. Coconut plantations in the country are also extensive and may be remotely located (Mendoza and Samson, 2006). Thus, its spatial distribution is a major consideration since transportation can adversely affect the profitability of the power plant (Voivontas *et al.*, 2001) as well as its environmental impact on greenhouse gas (GHG) emissions.

Assessment of the economic and environmental impacts on GHG emissions of using coconut residues for biomass energy generation will reveal if it is beneficial to the farmers and the environment. The results can serve as a basis for policy makers and investors for developing biomass power plant facilities that are partially dependent on coconut residues in Negros Occidental.

2 MATERIALS AND METHODS

Study site

Negros Occidental is on the northwestern side of Negros Island, the fourth largest island in the Philippines. The province belongs to the Western Visayas region, together with five other provinces; namely, Aklan, Antique, Capiz, and Iloilo.About 80% of its agricultural land is cultivated. Fifty-four percent (54%) of its agricultural land is planted with sugar cane while the rest is planted with other crops like coconut, which is the focus of this study. Among the provinces in Western Visayas, it has the largest area planted with coconuts at 34,578 ha. It also has the highest annual volume production at 116,341.3 mt. Thus, it is assumed that the province generates a significant quantity of coconut residues for bioenergy production. However, most coconut farmers do not solely depend on coconut farming for their income (Vista *et al.*, 2012). It has 32 municipalities with a total population of 3,059,000, based on the 2015 census (PSA, 2016). Its people rely primarily on agriculture. The province is a suitable site for this type of study because of existing and upcoming biomass power plants that create a demand for more crop residues.

Data collection

Respondents were selected using non-random multi-level sampling. The top 10 municipalities and cities with the largest area planted with coconuts were identified. Seven cities and municipalities (San Carlos City, Escalante City, Sagay City, Cadiz City, Calatrava, Toboso, Manapla) were selected based on their proximity to the proposed biomass power plants. Cocal barangays, i.e., with >50 ha of land planted with coconuts trees were identified based on the recommendation of the Philippine Coconut Authority (PCA)—Negros Occidental Provincial Office. Only the cocal barangays were involved in the study since the questions in the research instrument were specific to coconut farmers. These barangays were recommended by the PCA based on accessibility and security.

The total sample size was computed by summing up the population of coconut farmers in the seven areas then setting the confidence level at 95% and the margin of error at 5%. This led to a sample size of 371; however, only 366 were interviewed. The number of respondents per municipality and city was computed by proportionate sampling which resulted to the following sampling distribution: 42 in San Carlos City, 94 in Calatrava, 84 in Toboso, 62 in Escalante City, 30 in Sagay City, 48 in Cadiz City, and 11 in Manapla.

Finally, respondents per barangay were identified using snowball technique. Surveys were administered by local enumerators who were familiar with the chosen barangays, the people, and the local language. This was also to overcome the language barrier since the questionnaire was in English.

Surveys were conducted using a structured questionnaire designed to capture the characteristic of the crop dynamics of coconuts, utilization and commercial values of residues, and farmers' WTS residues to the biomass power plants in Negros Occidental. Information gathered in these interviews was used in the computation for the available biomass potential and the estimation of the potential additional income of coconut farmers. The questionnaire was pre-tested in the municipality of La Castellana, Negros Occidental on March 17, 2017. This was to test its reliability and improve its quality. It was revised according to the feedback of the respondents.

Theoretical potential estimation

The theoretical biomass potential is simply the quantity of residues that can be harnessed for energy based on the cultivated area and the coconut residue yield. It was calculated using the equation $B_n = A_n Y_n$ where B_n, biomass theoretical potential (t residue/year), A_n, cultivated area for crop (ha), Y_n, residue yield for crop n (t/ha/year) (Voivontas *et al.*, 2001). Values for A_n and Y_n were taken from the Negros Occidental coconut production statistics (PCA, 2015).

Available potential estimation

There are portions of the calculated theoretical potential of coconut residues that are used for other purposes. Coconut shells, for example, are used for

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charcoal while husks and fronds are used for firewood. Hence, it is the biomass that can be technically and economically harnessed for energy purposes. It was calculated using the equation, $B_{av} = \frac{f_g \Sigma_n B_n a_n LHV_n}{A_r}$ (Voivontas *et al.*, 2001). a_n is biomass available for energy production from crop n (%). A_r is area of the region under consideration (ha). B_n is biomass theoretical potential for crop n (t of residue/year). B_{av} is biomass available potential (kJ/ha/year), f_g is efficiency of the biomass collection procedure (%). LHV_n is lower heating value of the residue crop n (kJ/kg).

The LHV values used for coconut husks, shells and petioles were 21.75 MJ/kg (Biomass Atlas of the Philippines, 2000), 25.32 MJ/kg (Biomass Atlas of the Philippines, 2000), and 16.7 MJ/kg (Banzon, 1980), respectively.

GHG estimation

Coconut residues

The computed GHG emission in this study is in CO_2 equivalents. CO_2 makes up the bulk of total GHG emissions which is driven by combustion of fuels to create power (Ballantyne *et al.*, 2015). Emissions from converting coconut residues to electricity were computed using the equation based on the work of Batidzirai *et al.* (2016).

$$GHG_{coco} = E_{hc} + E_t + E_{fc}$$

E_{hc} is the CO_2 emissions from harvesting and collecting of crop residues at the farm (kg). E_t denotes the CO_2 emissions from transporting the crop residues from the farm gate to the power plant (kg). E_{fc} represents the CO_2 emissions from final conversion of the coconut residues to power (kg).

It should be highlighted that the following assumptions were made during the formulation of the equation. E_{hc} was assumed to be zero since the harvest and collection of coconuts and their residues largely rely on manual work. The CO_2 emission from manual work was considered negligible, and so was also assigned with the value of zero (0). It was also assumed that the coconut residues that will be collected at the farm gates are already dried to the prescribed moisture content (~10%). E_{fc} was assumed to be zero based on the assumption that the same amount of CO_2 had already been absorbed during plant growth (Batidzirai *et al.*, 2016). E_t was computed using the equation below.

$$E_t = \sum CDT + CDWT$$

C is emission factor, 0.117 kg CO_2 per tonne-km of transport. It is inclusive of the truck's fuel consumption, production, and maintenance (Zhang *et al.*, 2015). D is average distance of surveyed barangays per municipality (km). It was computed by averaging the distances between each surveyed barangay and San Carlos BioPower Inc., in San Carlos City. Distance was acquired by using the values from Google Maps. Elementary schools and other landmarks were used as a reference point per barangay since actual locations of farm sources were not taken during interviews. W is weight capacity of 40 tonnes per truck. T is number of trips needed to transport all of available biomass.

A 40 tonne-capacity truck is the only mode of transport considered in this study since railway transport is unavailable in the province. The above equation's first term represents the CO_2 emission of trucks as they go from the biomass power plant to the farm sources. It was assumed that it was empty. The second term represented the emission when the truck was fully loaded with 40 tonnes of residues. It was assumed to be constant, that each truck would carry 40 tonnes of coconut residues regardless of the actual volume of the residues. T was calculated by simply dividing the available biomass potential of each municipality by W.

Pulverized coal

GHG emissions from using pulverized coal were also taken for comparison using the following equation.

$$GHG_{coal} = PE$$

GHG_{coal} is CO_2 emission from using coal to generate the same amount of power. P is CO_2 emission of 970.37 kg/MWh (Petrescu *et al.*, 2017). E is energy produced from using all available coconut biomass (MWh).

P includes the CO_2 released from the supply chains of coal (underground mining to preparation), and limestone (extraction to transportation). Limestone is used to remove the sulfur from the gas produced during fossil fuel combustion. E value used was 792,763.34 MWh. It is the equivalent of the total annual available biomass potential which is 76,148.17 MJ/ha/yr.

Additional income estimation from selling crop residues

This portion of the study estimated the additional income that farmers will potentially gain from selling crop residues to power plants as a biomass feedstock. This illustrates whether the use of coconut residues as biomass feedstock will be more profitable to the farmers. This was computed by using the following formula:

$$I_{add} = I_{bio} - C_{opp}$$

I_{add} is the farmers' net benefit from supplying coconut residues to biomass power plants. I_{bio} is the income from selling coconut biomass to power plants. This was supposed to be calculated by using the current buying price of San Carlos BioPower, Inc. as a reference value. Since the willingness to pay (WTP) of the San Carlos BioPower, Inc. was not acquired due to the company's confidentiality policies, the current buying price of rice husks as alternative fuel was used as a proxy. The unit prices in each major island group are the following: Php 0.10/kg in Mindanao (Chodai Co., Ltd., 2016) and Php 1/kg in Luzon (Dela Cruz, 2008). The latter was based on a news report that a cement factory in Luzon was offering to buy rice husks as a substitute for coal in generating heat for cement making. The same article reported that rice producers were selling rice husks to anyone interested for Php

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1,000/ton as of July 2008 (Dela Cruz, 2008). The former, on the other hand, was taken from a feasibility study on biomass fuel export and power generation projects in Mindanao, Philippines, a report commissioned for the benefit of the Japanese government. The report explicitly stated that rice husks are being sold for P0.10/kg to cement factory for the same purpose as stated in Luzon as of September 2015. Both information is based on interviews with the rice producers.

C_{opp}, meanwhile, is the opportunity cost of selling coconut residues as biomass feedstock. This is the revenue lost by the farmers from selling residues for their current uses e.g. coconut husk and fronds as firewood, and shells as charcoal.

I_{bio} was computed by using the equation $I_{bio} = P_{bio}\,Q_{bio} - C_{bio}$. P_{bio} is the current buying price of the residues for use as alternative to fossil fuels. Q_{bio} is the quantity of residues sold as biomass feedstock. C_{bio} is the cost of selling residues for such purpose. This includes but is not limited to collection, processing, and transport of the residues within the farmgate. It was valued using the money and labor spent on the residues before they are sold to the prospective buyer. Labor was monetized based on the average income of the coconut farmers in the area. The value used for this was Php 18.75 per hour based on the daily compensation earned by farm workers on a *pakyawan* or wholesale compensation system. Farmers reported during the interviews that under this system, they are paid around Php 150.00 per day to do farming tasks during harvesting and planting seasons. Since the number of working hours vary depending on the work, it was set that the job has to be finished within 8 working hours.

C_{opp} was computed by simply summing up the income generated from selling the residues for their current uses. It was calculated by using the following equation.

$$C_{opp} = \sum_{n} P_{use}\,Q_{use} - C_{use}$$

P_{use} is the selling price for a specific use. Q_{use} is the quantity of items sold. C_{use} is the cost incurred for selling for a specific use.

P_{use} was based on the unit prices reported by the farmers. However, the units of quantity used by the farmers varied; some residues were sold or bought by sack, piece, and kg. The values were all converted to kg to calibrate the price. A sack was estimated to contain 40 kg of residues. The weight per piece was based on the average weights found in literature. Dried shell weighs 0.18 kg per piece, husk weighs 0.40 kg per piece (Banzon, 1980), and petiole weighs 2.17 kg (Zuniga *et al.*, 1965).

Q_{use} was based on the average of the farmers' reported percentage of commercial utilization. C_{use} was the sum of the cost of collection, processing, and transport. Collection cost was computed by multiplying the number of hours it takes to collect a certain unit of residue and the hourly rate of a typical farm worker in the province. It was assumed that shells and husks are already stored at a specific area in the farm after the meat was taken. So, the time spent for collection of 40 kg shells and petioles was assumed to be one hour. Transport cost was zero since the buyers themselves come to the farm to purchase the residues.

3 MATERIALS AND METHODS

Theoretical and available potential

The theoretical potential for top coconut-producing municipalities Negros Occidental is 335,878,052.46 ton/yr. Figure 1 shows that Calatrava has the highest theoretical potential which is 210,472,783.9 ton/yr. This is expected since it has the largest area cultivated with coconuts and the most number of bearing trees. Cadiz City ranks second, Toboso is third, Escalante City is fourth, San Carlos City is sixth. Manapla has the lowest theoretical biomass potential which is around 2.9 million ton/yr only. This municipality has the smallest area planted with coconuts and the least number of trees among all the surveyed areas.

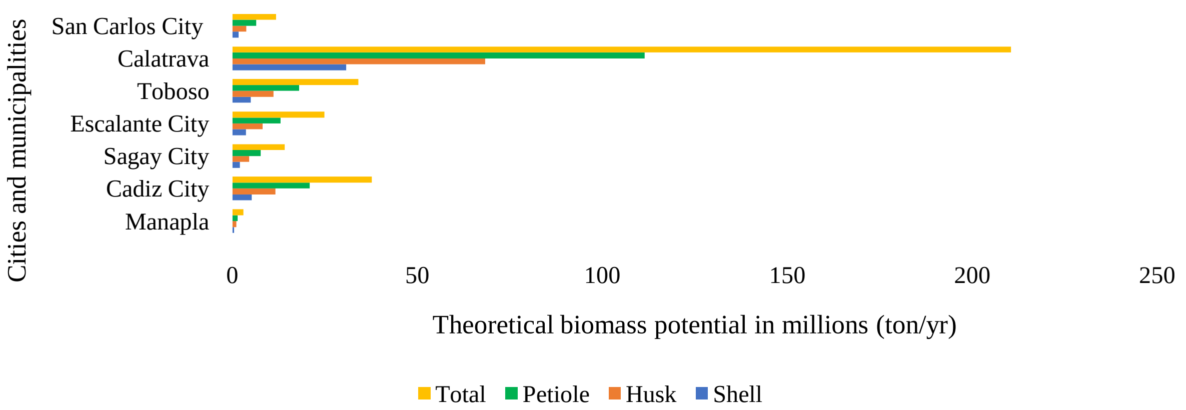

Figure 1 Summary of theoretical potential of coconut residues in top coconut-producing municipalities in Negros Occidental, Philippines

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Among the three coconut residues, the petiole has the highest theoretical potential. This is expected since its average weight is 2.17 kg which is 12 times more than the shell (0.18 kg) and 5.4 times more than the husk (0.4 kg).

Meanwhile, the available potential of coconut residues in the study area is 76,148.18 MJ/ha/yr or 792,763.34 MWh/yr. Calatrava and Manapla have maintained their rankings as the municipalities with the highest and lowest available biomass potential. The former has a total available biomass potential of 39,573.33 MJ/ha/yr while the latter has 642.02 MJ/ha/yr. The number of bearing coconut trees and the size of area cultivated with coconuts, apart from the utilization rate per residue per municipality/city are the factors that led to such results. This is contrary to information extracted from the interviews with key informants in Antique which revealed that all coconut residues are already used for household and industrial uses (Militar *et al.*, 2014).

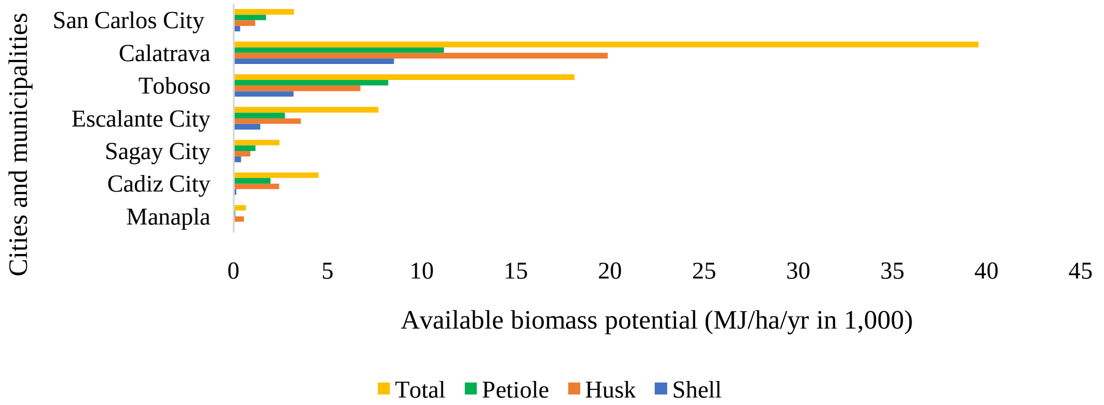

Figure 2 Summary of available potential of coconut residues in top coconut-producing municipalities in Negros Occidental, Philippines

It should be noted that the available biomass potential of coconut shells in Manapla is 0 MJ/ha/yr. Coconut shells do not remain in the farms since the primary coconut product in the municipality is de-husked mature coconuts. The rest of the cities and municipalities produce other products like copra; thus, the shells and husks remain at the farms.

It can also be observed that albeit the heaviest coconut residue, the petiole does not necessarily contribute the most to the combined available potential. This is contrary to the results on the theoretical potential. This is because the household and commercial uses of the residues have already been factored in. The rate of utilization also varies per city and municipality.

GHG emissions

Figure 3 shows the CO_2 (kg) that can be generated annually from fully converting the available biomass of each city and municipality to electricity. It can be seen that the highest CO_2 emission (192.58 x 10^6 kg) can be generated by using all the surplus residues in Calatrava. This is expected since it has the highest available biomass potential in all of the seven cities and municipalities. Thus, more trucks or trips are needed to transport all of the residues available in the municipality. This is followed by Cadiz City, Escalante City, Toboso, Sagay City, San Carlos City, and Manapla.

The estimated total annual net CO_2emissions from converting coconut residues to electricity is 392.33x 10^6 kg. This is a result of transporting all of the available biomass which will generate 792,763.34 MWh of electricity. On the other hand, the net CO_2 emission of the conversion of pulverized coal to produce the same amount of electricity is 769.27x 10^6 kg. This shows that utilization of coconut residues produces 49.0% less of CO_2 than coal.

Transportation of the biomass feedstock played a major role in the CO_2 emission since coconuts are more widely distributed and are planted in remote farming areas with limited transportation networks (Mendoza and Samson, 2006). However, it should be noted that this was under the current conditions, where harvest and collection were manual, and transportation depends on trucks. The computation was also simple and did not consider several factors, including conditions of the road, traffic, and vehicle.

Additional income estimation

Coconut farms in the study site have an average of 121 bearing coconut trees with an average fruit production of 24 coconuts per individual year. This means that annually, each coconut farm can produce 1.1 tons of husks, 0.5 tons of shells, and 3.1 tons of petioles. On average, 16.67% of shells, 14.48% of husks, and 12.57% of petioles are sold as firewood. Only 0.54% of the shells is sold as charcoal. Given the information, it was computed that each coconut farm can earn an average annual net income of Php 987.82 as shown in Table 1. This serves as the opportunity cost of the farmers if they sell their residues to power plants instead.

Table 2 shows that there was no income that can be generated from selling the residues as feedstock for biomass power generation for case A. Instead, farmers will incur an annual loss which amounts to Php 296.30 if the unit price for the residues is Php 0.10/kg. The

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farmers would be able to gain income only if the residues were sold at Php 1/kg (as in case B). However, it will only be Php 289.23 per year. Also, if the net benefit is computed, the farmers will still not gain from selling the residues to the power plant. Instead, a loss of Php 698.59 per year will be incurred.

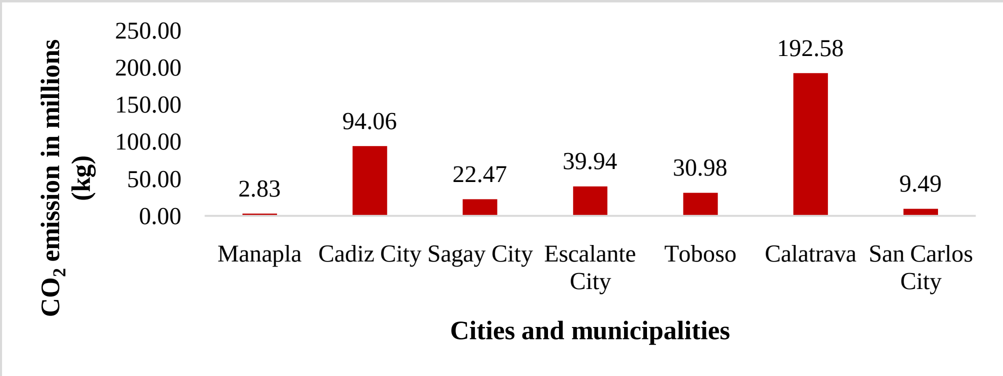

Figure 3 CO_2 emissions from fully converting available potential of coconut residues in top coconut-producing municipalities in Negros Occidental, Philippines

Table 1 Breakdown of average annual net income from coconut residues per coconut farm

	Shell as firewood	Shell as charcoal	Husk as firewood	Petiole as fire wood
Unit price per residue (Php/kg)	3.08	6.50	4.37	0.85
Quantity sold per residue (kg)	86.08	2.79	166.15	395.57
Unit production cost per residue (Php/kg)	0.70	1.00	0.75	0.43
Income per residue (Php)	204.87	15.35	601.46	166.14
TOTAL income from all residues (Php)	**987.82**			

Table 2 Potential additional income if coconut residues are sold to brokers for Php 0.10/kg and Php 1/kg

	A **Unit price Php 0.10/kg (Mindanao)**	**B** **Unit price Php 1/kg Luzon**
Income from selling coconut residues as biomass power feedstock (Php/yr)	**-296.301**	**289.23**
Price of coconut residue as feedstock for energy generation (Php/kg)	0.10	1.00
TOTAL quantity of coconut residues sold as biomass E (kg/yr)	650.59	650.59
Total cost of collection, processing	361.36	361.36
Total cost of transport	0	0
Income from current uses (Php/yr)	**987.82**	**987.82**
Potential additional income (Php/yr)	**-1,284.12**	**-698.59**

This is contrary to the claim that biomass provides alternative income for farmers (Commission of the European Communities, 2005).

4 CONCLUSION

The municipality that has the highest theoretical and available potential is Calatrava. The annual CO_2 emissions that could be generated from using all the available biomass potential of all the seven cities and municipalities is 392.33x 10^6 kg. Computation showed that farmers would incur a revenue loss of Php 698.59/kg to Php 1,284.12/kg if they sell their residues for the current buying price of Php 0.10/kg and Php 1/kg. It appears that based on the current conditions, the farmers would be better off if they continue to use and sell the residues for the same price. The use of the available biomass potential of coconut residues appears to generate ample power and a remarkably lower GHG. This is beneficial to the environment. However, it does not bring the intended economic relief to farmers. This is a key issue that needs to be addressed.

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