Theoretical Bioenergy Potential in Cambodia and Laos

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Abstract: This paper investigates theoretically potential energy of residues of some biomass sources in Cambodia and Laos by considering agricultural residues and forestry residues for the year 2006 since both country have limited access to grid-quality electricity. The theoretical potential biomass energy of rice husk, straw, corn cob, cassava stalk, bagasse and sugarcane trash and logging residues, sawnwood and plywood residues are calculated by using their lower heating values (LHV). The potential biomass energy obtained from these residues in Cambodia can contribute approximately 1.4 Mtoe to the total final energy consumption of Cambodia. On the other hand, 0.6 Mtoe biomass energy can be obtained potentially from the biomass residues in Laos, 2006. Furthermore, the paper presents the theoretical bioethanol production from some biomass residues such as rice straw, corn stover, bagasse, and cassava pulp in Cambodia and Laos. The potential bioethanol production in Cambodia is about 0,648 Gl for the year 2006 whereas 0,355 Gl of bioethanol can be produced in Laos from 2006 biomass residues. The potential results are investigated in whole country level and they do not consider the collecting and transportation cost of the biomass residues, their possible other usage purposes, exports and imports.

Keywords: *Biomass, Energy Potential, Crop Residue, Cambodia, Laos.*

1. Introduction

Due to the increase in energy demand and environmental concerns over fossil fuel consumption, biomass has been of interest in recent years in terms of renewable energy source [1]. Biomass energy can be converted into useful energy for both traditional and modern uses. Firing for cooking and heating is a simple example of traditional uses. In modern uses allow to conversion of biomass in the form of electricity, steam and liquid biofuels next to the heating use [2].

Ethanol, as a modern form of biomass energy, can be converted from any kind of starchy biomass source which is rich in sugar content. Agricultural crops, forestry products and their residues are potential sources for ethanol production. Ethanol has a great energy potential in terms of transportation fuel. It can be blended with gasoline and used in the commercial forms of E5, E10 and E85 [2, 3].

This study estimated the biomass energy potential of Cambodia and Laos in terms of agricultural and forestry biomass residues as solid fuel and their ethanol production capacity considering production quantities in 2006. In order not to cause any conflict between food and energy production and considering the high poverty rates of Cambodia and Laos, this study only focused on the biomass energy obtained from agricultural residues and forestry wastes. Mainly, the potential of biomass energy of rice husk, rice straw, corn cob, cassava stalk, bagasse, and trash of sugarcane were estimated. Furthermore, the residues of coconut-husk, shell, and frond- and groundnut-shell- were considered as potential biomass energy sources for Cambodia. Moreover, the study found that some residues such as rice straw, corn stover, bagasse and cassava pulp have a potential to contribute a considerable amount of bioethanol in both countries. Finally, the amount of potential energy obtained from biomass residue resources examined for Cambodia and Laos was compared to the total final energy consumptions of the countries in the same year.

2. Methodology

The production data of each biomass resource was obtained from FAO statistics (FAOSTAT) [4]. The production quantities in 2006 for related biomass sources were used in order to compare the available energy consumption in 2006 for Cambodia and Laos. The production data statistics of Laos taken from FAO were also compared with the statistics presented in National Statistics Centre of Lao PDR [5]. Both production data statistics were found to be consistent. However, Cambodian production data statistics presented in FAOSTAT was used without any modifications as only data source in this study. Also, in order to estimate the amount of agricultural biomass residues RPR (residue-product ratio) values were used. The RPR values of rice husk are specific for Cambodia and Laos. However, the RPR value of rice straw, which is specific for Laos, was also used for Cambodia. These values were taken from previous studies carried out in these countries [6, 7]. However, other biomass residues were calculated in this study by taking the RPR values which have been used in similar studies conducted for Thailand [8]. On the other hand, recovery rates (RR) of forestry biomass residues were used in this study to estimate the available amount of logging residues, mill residues and plywood residues. The recovery rates of mill residues and plywood residues were taken from FAO [9]. On the other hand, recovery rate of logging residues were based on the study of A. Koopmans and J. Koppejan for Cambodia and Laos [10].
Lower Heating Values (LHV) of agricultural residues were taken from the study conducted for Thailand biomass energy estimations [8]. LHV of forestry wastes, however, were based on values studied by Suzuki and Yoshida (2009) [11].

Bioethanol production calculations in Cambodia and Laos for the year 2006 were carried out in the light of the ethanol yield according to a study by Kim and Dale (2003) [2]. That study was conducted by first calculating theoretical ethanol yields of each biomass residue and converting this theoretical yield to possible yield by assuming that ethanol production efficiency from other crop residues is equal to approximately 67%, which is the ethanol production efficiency of corn stover [2]. The same procedure was followed to estimate the potential bioethanol production in Cambodia and Laos.

This study did not consider the imports and exports of any biomass sources. All the potential residues of biomass sources in Cambodia and Laos were calculated in the study without considering their other possible usage purposes and the losses due to the transportation.

3. Results

3.1. Agricultural Residues

3.1.1. Rice

Rice is the main agricultural crop and staple food in both Cambodia and Laos. 84.4% of cultivated area in Cambodia is used for rice cultivation and it constituted 25% of Cambodian agricultural GDP in 2006 [12]. In Laos 80% of area under cultivation has been devoted to rice. Rice accounted for 38% of agricultural GDP, which is higher than Cambodia (1999) [13, 14]. High amount of rice production in both countries contributes to high availability of rice residues such as rice husk and rice straw. These residues could be an option for any biomass energy systems. Rice husk is the outer cover of rice which comes from rice milling process as by-product. The unutilized rice husk mainly causes waste disposal problems and breathing problems because of its low density. The usage of rice husk as solid fuel can be a promising way to avoid these problems and provide considerable amount of useful energy [15]. Rice straw, on the other hand, is another by-product of rice and great bio-resource since it is one of the richest material in terms of its lignocelluloses [16]. However, it has to be taken into

account that rice straw is an import fodder for animals in Cambodia. RPR and LHV of rice husk and rice straw are shown in the Table 1 with their calculated potential energy values.

Table 1. 2006,rice residues biomass energy

	Rice (Mt)	Rice Residue	RPR	Residue (Mt)	LHV (MJ/kg)	Potential Energy (10^6GJ)
Cambodia	6.26 [4]	Husk	0.27 [8]	1.69	12.85 [8]	21.73
		Straw	0.33 [7]	2.07	14 [17]	28.92
Laos	2.66 [4]	Husk	0.25[7]	0.67	12.85 [8]	8.56
		Straw	0.25 [7]	0.88	14 [17]	12.31

3.1.2. Maize

Since maize is the second most produced crop after rice for both Cambodia and Laos, it can supply a considerable amount of corn cob as biomass energy source. Moreover, the chemical and physical properties of corn cob enable it to be suitable feedstock for several energy generation methods [14]. Table 2 below shows potential energy obtained from corn cob.

Table 2. 2006, corn cob biomass energy

	Maize (Mt)	RPR	Corn cob (Mt)	LHV (MJ/kg)	Potential Energy (10^6GJ)
Cambodia	0.38 [4]	0.25 [8]	0.09	16.63 [8]	1.57
Laos	0.45 [4]	0.25 [8]	0.11	16.63 [8]	1.87

3.1.3. Cassava

Cassava is another important agricultural crop in Cambodia and Laos as staple food and animal feed in similar way as in many subtropical regions [18]. Cassava stalk, the residue of cassava, is an agricultural biomass feedstock which can be used for biomass energy purposes. Its primary energy was tabulated in Table 3 for Cambodia and Laos.

Table 3. 2006, cassava stalk biomass energy

	Cassava (Mt)	RPR	Cassava stalk (Mt)	LHV (MJ/kg)	Potential Energy (10^6GJ)
Cambodia	2.18 [4]	0.088[8]	0.192	16.99 [8]	3.26
Laos	0.17 [4]	0.088[8]	0.015	16.99 [8]	0.26

3.1.4. Sugarcane

Bagasse and top and trash of sugarcane are the main residues of sugarcane. While bagasse is dry, fibrous residue remaining after sugarcane stalk after extraction of juice, trash of sugarcane is the remaining of the plant in the field after the harvest [19]. The primary biomass energy of bagasse and trash of sugarcane was tabulated by assuming their RPR and LHV as same in Table 4.

Table 4. 2006, sugarcane residues biomass energy

	Sugarcane (Mt)	Sugarcane Residue	RPR	Residue (Mt)	LHV (MJ/kg)	Potential Energy (10^6GJ)
Cambodia	0.14 [4]	Bagasse	0.250 [8]	0.035	6.43[8]	0.228
		Trash	0.302 [8]	0.043	6.82[8]	0.292
Laos	0.217[4]	Bagasse	0.250 [8]	0.054	6.43[8]	0.349
		Trash	0.302 [8]	0.066	6.82[8]	0.447

3.1.5. Groundnut Shell and Coconut

Groundnut shell and coconut husk - rough exterior shells of the coconut -, shell, and empty bunches and frond can be counted as considerable biomass energy sources in Cambodia. Table 5 was prepared to show the potential biomass energy value of these residues.

Table 5. Cambodia, 2006, groundnut shell and coconut residues biomass energy

	Production (Mt)	Residue	RPR	Residue (Mt)	LHV (MJ/kg)	Potential Energy (10^6GJ)
Groundnut	0.024 [4]	Shell	0.323[8]	0.0077	11.23 [8]	0.086
Coconut	0.07 [4]	Husk	0.362 [8]	0.025	14.71 [8]	0.373
		Shell	0.160[8]	0.011	16.43 [8]	0.184
		Frond	0.225[8]	0.016	14.55 [8]	0.229

3.2. Forestry Residues

3.2.1. Logging Residues

Logging residues constitute woody residues that remain after cutting in the forest area, such as tops and branches. Logging residue calculations require the amount of industrial round wood production and an average recovery rate (RR) which is generally estimated since logging can be done in many innumerable and unsystematic ways [9]. Logging recovery rate can be estimated with the idea that "6 cubic meters of logs extracted from the forest leave 4 cubic meters of waste remaining in the forests" [10]. Cambodia's and Laos' forestry biomass energy estimations were carried out and tabulated in the Table 6.

Table 6. 2006, logging residue biomass energy

	Industrial round wood (10^6CUM)	RR	Logging Residue (10^6CUM)	LHV (GJ/m^3)	Potential Energy (10^6GJ)
Cambodia	0.113 [4]	0.60 [10]	0.075	7.4 [11]	0.557
Laos	0.194 [4]	0.60 [10]	0.129	7.4 [11]	0.955

3.2.2. Mill Residues from Sawnwood Production Residues

The residues from wood-processing factories are called mill residues [11]. Therefore, the calculations are based on the amount of sawnwood production volume. Table 7 shows the primary biomass energy content of mill residues.

Table 7. 2006, mill residue biomass energy

	Sawnwood (10^6CUM)	RR	Mill Residue (10^6CUM)	LHV (GJ/m^3)	Potential Energy (10^6GJ)
Cambodia	0.002 [4]	0.43 [9]	0.0029	8.4 [11]	0.024
Laos	0.13 [4]	0.60 [9]	0.087	8.4 [11]	0.728

3.2.3. Plywood Residues

Plywood residues comprise of the which are log ends and trims, bark, log cores, green veneer waste, dry veneer waste, trimmings and rejected plywood [9]. Calculations of primary energy of plywood residues in this study are shown in the Table 8 for both countries.

Table 8. 2006, plywood residue biomass energy

	Plywood (10^6CUM)	RR	Plywood Residue (10^6CUM)	LHV (GJ/m^3)	Potential Energy (10^6GJ)
Cambodia	0.0045 [4]	0.47 [9]	0.0051	8.4 [11]	0.043
Laos	0.027 [4]	0.47 [9]	0.031	8.4 [11]	0.256

3.3. Bioethanol Production

This part of the study estimated how much bioethanol can potentially be produced from rice straw, corn stover, bagasse, cassava pulp. Bioethanol calculations were carried out on dry-based biomass residues and are shown in Table 9 in Cambodia and Laos.

Table 9.Cambodia and Laos, 2006,bioethanol production from agricultural residues

	RPR	Residue,Mt Cambodia	Residue,Mt Laos	Ethanol yield(l/t)	Ethanol,10^6l Cambodia	Ethanol,10^6l Laos
Rice Straw	0.33[7]	807	0.77	280 [2]	506	214.9
Corn Stover	1 [2]	0.38	0.45	290 [2]	109.3	130.5
Bagasse	0.25 [8]	0.018	0.03	280 [2]	4.96	7.6
Cassava pulp	0.15[21]	0.327	0.03	83.3 [21]	27.28	2.18

3.4. Final Energy Potential of Biomass

In this study the total potential biomass energy from biomass residues in Cambodia and Laos was found to be about 1.4 Mtoe ($57*10^6$ GJ) and 0.6 Mtoe ($26*10^6$ GJ) respectively. The total final energy consumption (TFEC) in Cambodia was about 4.5 Mtoe in 2005 [22]. This means that the biomass residue energy potential is about one third of the total energy consumption in Cambodia. The total final energy consumption (TFEC) in 2006 in Laos was about 2.0 Mtoe [22]. This indicates that the biomass residue energy potential estimated for Laos could contribute about 30% of the total energy consumption.

Figure 1.a, 1.b and 2.a, 2.b show the total final energy consumption and theoretically calculated potential biomass energy from residues and the contributions of different sources to energy potentials in ktoe in Cambodia and Laos, 2006.

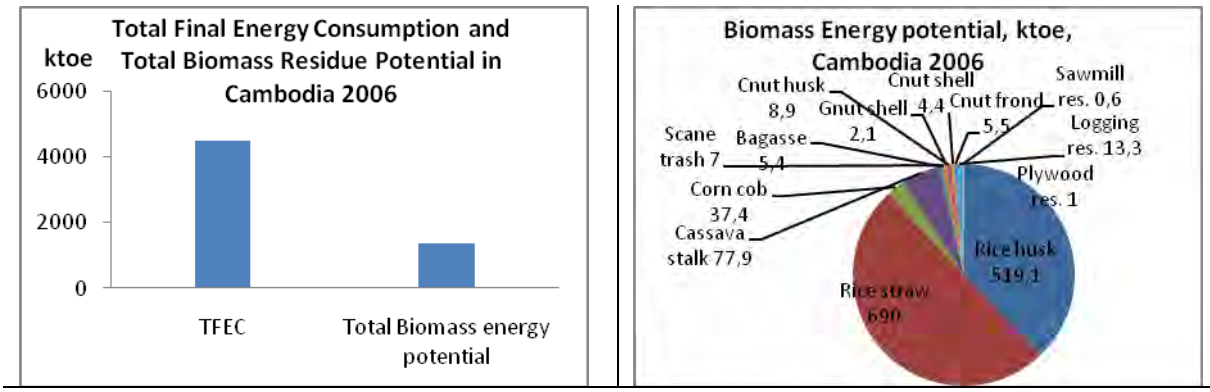
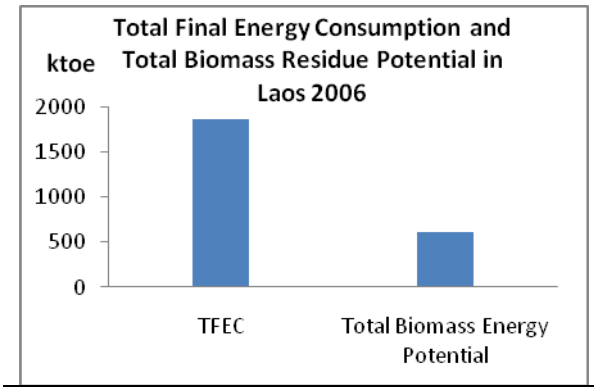


Figure 1.a. Total final energy consumption and calculated potential biomass residue energy content 1.b. Different sources of biomass residue energy potentials in Cambodia, 2006



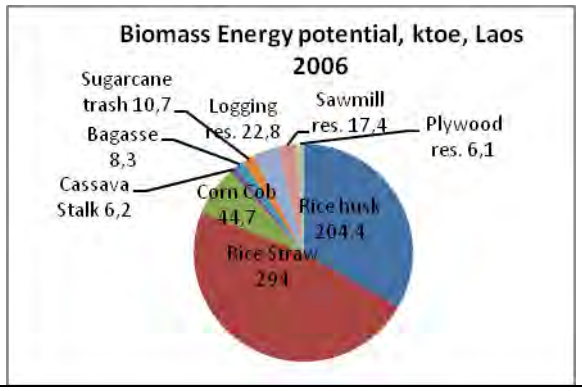
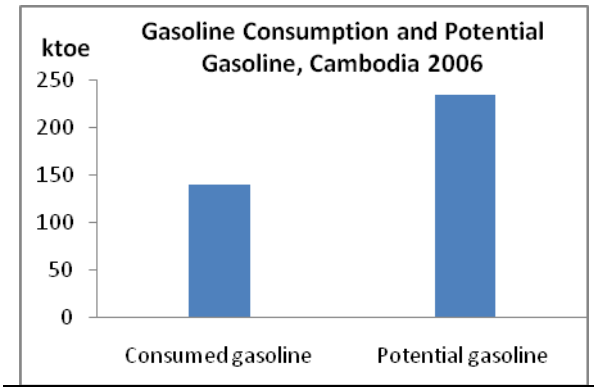


Figure 2.a. Total final energy consumption and calculated potential biomass residue energy content 2.b. Different sources of biomass residue energy potentials in Laos, 2006

3.5. Bioethanol Potential

The study found that some agricultural residues in Cambodia such as rice straw, corn stover, bagasse and cassava pulp have a potential to produce approximately 648*10^6 l ethanol production for the country. However, the potential of ethanol production from same residues in Laos was estimated about 355*10^6 l. The amounts of potential bioethanol for both countries were found to be enough to correspond to the amount gasoline consumed in road transport in Cambodia and Laos. Figure 3.a, 3.d and Figure 4.a and 4.b s ummarize the gasoline consumption in 2006 and the potential gasoline production from biomass residues and the contributions of different biomass residues for gasoline productions in Cambodia and Laos, 2006 [21, 22].



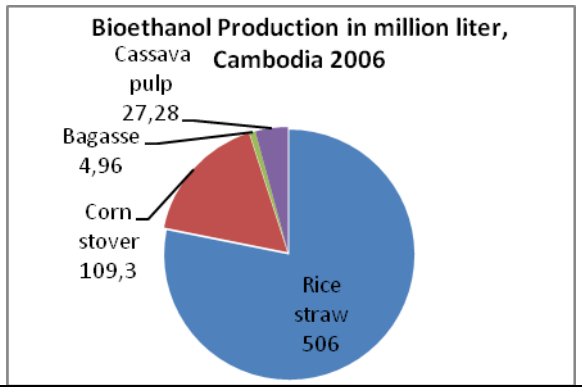
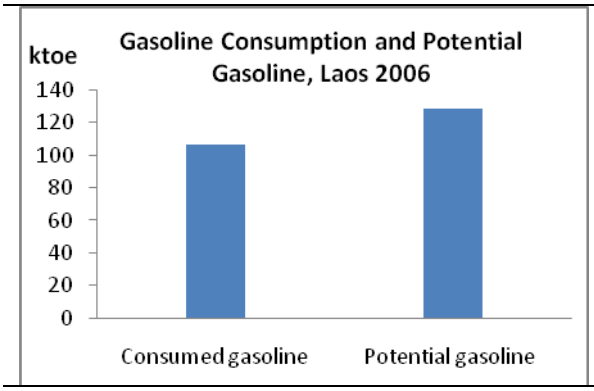


Figure 3.a. Gasoline consumption and potential biomass residue based gasoline production 3.b. Different sources of biomass residue potential for ethanol production in Cambodia, 2006



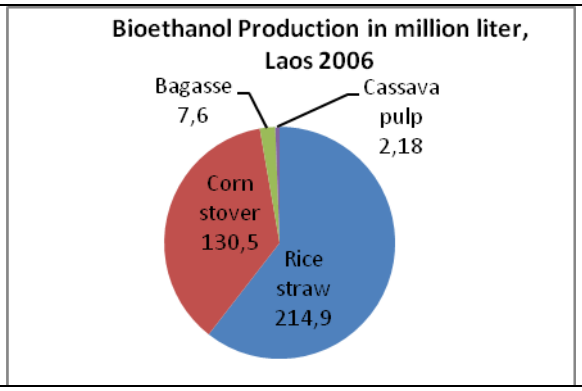


Figure 4.a. Gasoline consumption and potential biomass residue based gasoline production 4.b. Different sources of biomass residue potential for ethanol production in Laos, 2006

4. Conclusions

The results indicate that the biomass residue potential could contribute such energy production that can reach up to 30% of energy consumed in 2006 for both Cambodia and Laos. There are, however, some practical limitations and restrictions in the use of the residues such as collection and transportation of them, marketing systems and other usage possibilities. Furthermore, the results show that rice straw and rice husk in Cambodia and Laos seem to be potentially the most favorable biomass sources in terms of the quantity of biomass production availability and comparably higher contribution to biomass energy production. Totally, all biomass residues including both agricultural residues and forestry residues have a potential to provide 1.4 Mtoe and 0.6 Mtoe energy productions in Cambodia and Laos respectively.

Moreover, the study covers the bioethanol production from some residues such as rice straw, corn stover, bagasse and cassava pulp in Cambodia and Laos. Theoretically, potential bioethanol production in Cambodia has and Laos could provide approximately the same amount of energy as the present gasoline consumption is in both countries.

The results clearly show that biomass residues provide a promising potential for distributed renewable energy production in Cambodia and Laos.

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