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A biomass energy flow chart for Fiji

Vineet V. Chandra[*], *Sarah L. Hemstock*

Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Suva, Fiji

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ABSTRACT

Terrestrial above ground biomass production and utilization was analyzed for Fiji for the years 2003–2012. The total production of biomass was estimated to be 72.67 PJ of which 24% is from food, 44% of agricultural residues, 10% dung and 22% from forestry. Of the 72.67 PJ biomass produced only 11% was used as fuel, 12% as industrial wood and 24% as food. The unutilized biomass resulted into a loss of 38.5 PJ of energy (44 GJ per capita or 2.56 Mt of wood equivalent) which is 53% of the total biomass theoretically produced. Scrutiny of the availability and use of biomass resources is important if biomass energy is to be used on a sustainable basis. Lack of detailed literature in this area in Fiji potentially opens a path for further detailed studies to understand the full contribution of biomass to future sustainable energy supply.

1. Introduction

Fiji is a small island nation situated between 177°E and 178°W Longitude and 12° to 22° S Latitude in the Pacific comprising of over 300 islands, spread over a land mass of 18,272 km^2. The largest island is Viti Levu, which covers 10,390 km^2, followed by Vanua Levu with 5538 km^2. Together they account for 87 percent of the land area and 90 percent of the population. The larger islands, especially Viti Levu, Vanua Levu, Taveuni, Kadavu and the Lomaiviti group, are quite mountainous and of volcanic origin.

Fiji has 1,827,000 ha of total land area of which 815,000 ha (45%) are forests, approximately 10% is arable, 4% is under permanent crops, 10% is under permanent pastures, and 31% under other land-use categories [1]. Although bagasse has been used as a primary energy source for many years, methodologies for assessing the potential of other sources of biomass energy potential are still developing in Fiji. Sugar production has been an industry in Fiji from 1872 [2] and since then it has played an important role in the country's economy and has been providing biomass (bagasse) energy for all four sugar mills, with surplus electricity production being exported to grid.

From the 769,439 MWh electricity generated nationally in 2008 [3], 66.8% is from renewable energy resources and the other 33.2% is met from imported petroleum for diesel generators. From the renewable energy sources 4.1% is met from biomass which is supported by bagasse and wood chips. Fig. 1 below depicts the energy consumption of 41.7 PJ [4] by sector in Fiji and Fig. 2 shows the electrical energy supported by different sources.

The objective of this research is to assess the biomass potential by means of a biomass energy flow chart. Terrestrial above ground biomass production and usage in Fiji was analyzed for ten years from years 2003–2012 using FAOSTAT-derived data [6] and specific energy values were derived from past work [7–10].

* *Corresponding author*. Tel.: +679 3231990.
E-mail addresses: chandra_v@usp.ac.fj, vineetvishalchandra@gmail.com (V.V. Chandra).
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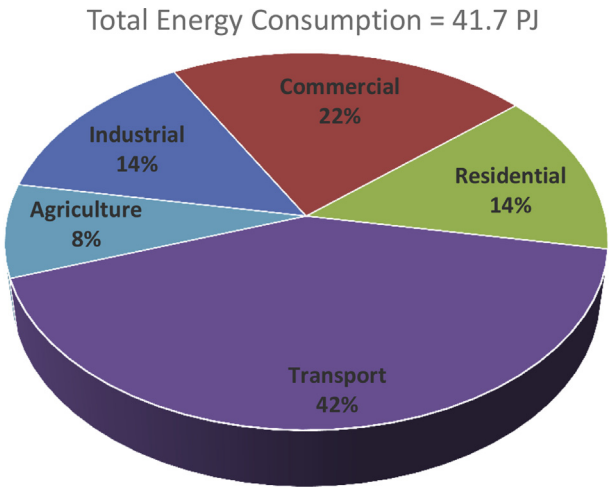

Fig. 1 – Energy consumption by sector [5].

Agriculture, forestry and livestock were three main areas of biomass production under investigation. A total biomass production, available theoretical energy, present utilization level and potential available biomass residue from agriculture and forestry was calculated. All biomass energy flows were followed from its production at source and harvested through to end use and clustered into an end use group such as food, fuel and residues.

2. Methods

2.1. Data source

The following approach was utilized to estimate the total theoretical biomass available.

- Data on agricultural production (food), forestry removals and livestock production were obtained from FAOSTAT, 2014.

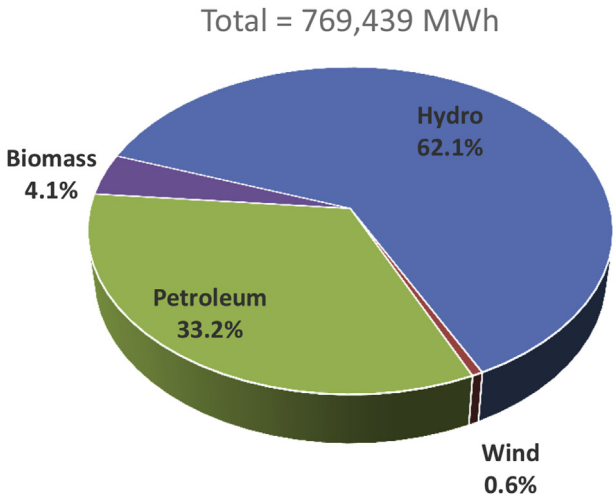

Fig. 2 – Electrical energy supported by different sources [3].

2.2. Production data (agriculture, livestock and forestry)

Crop production data consist of annual average for the years 2003–2012 [6]. The data source were verified with other sources to provide more inclusive assessment [11,12]. Crop residues and by-product were derived using technical coefficient and conversion factors obtained from various sources after verification [7–10,13–15]. The lack of inclusive field data for Fiji lead to the use of conversion factors and heating values derived from field studies in countries with similar production characteristics.

Annual dung production was established from the livestock population and calculated using coefficients verified using various sources which take into consideration the production of fresh dung per animal, the dry material content and seasonal factors [8,10,16]. Livestock population data was derived from FAOSTAT.

Potentially recoverable residues from forestry and agricultural lands used were estimated using the method recommended in literature by Ref. [10]. The uncollectable residues were considered where possible including efficiency of collection, however the economics of the process were not considered. Previous literature [10] indicated that only 60% of total above ground wood cut results as commercial stemwood.

The production and the flow of biomass in the form of food, industrial materials, fuel, etc. used the end-use analysis method in which known production values were used to estimate the end use of energy flows.

2.3. General assumption

The assumptions below apply to the entire article unless otherwise stated.

i.) Agricultural crop and above ground biomass production were considered by this research – water surfaces were not included as biomass energy production in this study.
ii.) All roundwood volumes were assumed to be solid with the conversion equivalence of 1 m^3 of solid roundwood = 1.3 tonne [7,10]
iii.) The following energy values (GJ/t air dry, 20% moisture content) assume direct combustion: 1 tonne fuelwood = 15 GJ; 1 tonne of stemwood = 15 GJ; 1 tonne forest and tree harvesting residues = 15 GJ; 1 tonne charcoal = 31 GJ and conversion efficiency of fuelwood to charcoal = 15% by weight [7,10].
iv.) The term "end use" refers to the gross biomass energy devoted to specific use such as food, fuel etc.

3. Results

3.1. Primary production established on agriculture, forestry and livestock

3.1.1. Agricultural production (annual crop and residues)

Average annual agricultural production (crop and residue) totaled 6,799,752 tonnes, with a potential energy of 49.1 PJ. The