Household Energy Consumption Pattern in Rural Areas of Bangladesh

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Abstract

The availability of energy is an important determinant of the quality of life in human settlements. An exploratory study was carried out on household level to find out the energy consumption pattern and consumer's preference with its environmental impacts inter-relating socio-demographic and geographic factors in the disregarded villages of Kabirhat Upazila under Noakhali District, Bangladesh. The study revealed that 95% of the households use biomass, 72% kerosene, 53% electricity, 23% LPG and 60% candle as fuel types. The study also revealed that rural households use fire wood, cow-dung, leaves & twigs, branches, straw and rice husk as biomass energy mainly for cooking (98.3%). It was found that rural households collect 42.6% of biomass from their own homestead and agricultural lands. Households mean expenditure for total energy was US$ 6.17 per month with total income US$ 148.11. The ratio of the total monthly energy expenditure to the total monthly income was 4.34%. It was also found that the per capita energy expenditure of households is US$ 1.29 with explicit and implicit costs. Seven fuel wood species were identified as the most preferred species used by households. The information of this study is helpful to formulate policies support tools to take into account the future challenges for demand of biomass fuel resources, their sustainable utilization, promotion, and development.

Keywords: Biomass, Commercial fuels, Consumption, Emission, Expenditure, Total energy

1. Introduction

Energy is one of the fundamental factors in the functioning of any civilized society needed to improve better life style and socio-economic development of the country. More than half of the world's population live in rural areas, who depend mostly on biomass for their energy supply, and have no access to modern form of energy (Demirbas & Demirbas, 2007). In many developing countries in Asia like India, Pakistan, Myanmar, Nepal and Bangladesh, the rural household energy consumption constitutes over 70% to the national energy use (ADB, 1998; Koopmans, 2005). Households are the foremost end user of biomass and commercial energy, which varies between rural and urban populations, between low and high-income groups within a country. Energy resources in Bangladesh comprise commercial and biomass resources. Commercial energy resources in Bangladesh include natural gas, candle, petroleum products, coal, and hydroelectricity. Petroleum products include diesel, kerosene, furnace oil, motor spirit, and others. Biomass resources includes wood, bamboo, twigs, wood shavings, sawdust, bark, roots, shell and coir of coconut, agricultural residues such as paddy husk and bran, straw, jute stick, charcoal and cow dung. Bangladesh has few indigenous renewable energy sources, and, the country is heavily dependent on the imported fossil fuels.

In Bangladesh, the rural households mainly depend on biomass fuels, kerosene, electricity, candle and LPG (liquefied petroleum gas) for their primary sources of energy supply (Asaduzzaman *et al*., 2010; Miah *et al*., 2010). However, the contribution of biomass fuels to total primary energy supply in Bangladesh is about 60% (LGED & FAO, 2006; MoPEMR, 2008). The country is one of the most densely populated countries in the world. Population density is about 990 persons per km^2 and the population growth rate is 1.54% per annum (BBS, 2010). Due to the increasing population growth, per capita arable land area decreased from 0.07 ha in 1990 to 0.05 ha in 2009 (BBS, 2010). Nevertheless, per capita energy consumption increased from 5 GJ (giga joules) in 1977 to 6.2 GJ in 2009 (Kennes *et al,*. 1984; IEA, 2009). The combination of high population growth with decreasing arable land as well as growing energy demand put immense pressure on biomass resources. Likewise, low per capita income and slow economic growth are considered to be the major impediments in transforming biomass energy into more modern energy forms in the near future (Bari *et al.* 1998). Therefore, the country is expected to remain heavily dependent on biomass resources for energy supply in the near future. Energy use variation not only subsists in rural and urban regions, but also varied in lower and higher earner groups within a country and between national and international levels (Pachauri, 2004). Indeed, access to safe, reliable and affordable energy is crucial to development, as virtually all-potential economic activity will be dependent on some form of energy services (UNDP, 2000). The poorer the country, the greater is the consumption of biomass. With the decline of biomass resources in many regions, rural families must spend more time and energy to obtain their bare fuel necessities, thereby increasing the stresses on fragile household survival.

Rural energy consumption in LDCs constitutes the majority of total national energy use. The social and economic costs of insufficient supplies of household fuels are high and rising rapidly. According to UNDP and World Bank estimates based on investigations in 15 LDCs, household energy consumption accounts for 30-95% [compared with 25-30% in developed countries (DCs)] of total energy use. More than half of the energy consumed in households is used for cooking in most of the developing countries. Therefore, any savings in energy consumption in cooking can have a significant impact on reducing the total household energy requirements in these countries. Natural emission of CO_2 from living animals, humans, wetlands, volcanoes, and other sources is nearly balanced by the same amount being removed from the atmosphere by plant photosynthesis and by the oceans. Human activity, on the other hand, is disturbing this equilibrium by generating increased CO_2 from fossil fuels (i.e. coal, gas, and petroleum products; and combustion via electricity generation, transportation, industry, and domestic use). Similarly, different types of biomass fuels are also responsible for carbon dioxide emission. The results of these imbalances are believed to be greenhouse effects: global warming, melting of polar ice sheets and caps, a rise in sea levels and subsequent coastal inundations, and damage to agriculture and natural ecosystems, among others. Therefore, it is important to study CO_2 emission from human activity in a developing country such as Bangladesh, which is highly vulnerable to its adverse effects.

According to Heruela (2004), as biomass energy, fuel wood is the most dominant energy carrier both in the rural and urban areas where the main users are in the domestic, commercial and industrial sectors. In the rural areas of Bangladesh biomass, contribute an essential role for almost 74.5% of the people (FAO, 2009). Since the energy crisis of the 1970s, rural household energy consumption has become a common focus for analyses in less developed countries (LDCs).

Ouedraogo (2006) for Africa, Rao & Reddy (2007) and Pachauri (2004) for India states that the inertia of the household energy preference and consumption pattern are due to some factors such as economic condition, household size, sex, age distribution of the households members, age of the holdings, nature of the occupation, low living standard, education attainment of the principal wage earner and of the family members and high frequency of cooking certain meals. Highest per capita energy consumption country is Canada (17179 kWh) while, in Bangladesh per capita energy consumption is only 214.4 kWh (International Energy Statistics, 2006) (Table-1).

Table 1. *Global Energy Consumption*

Country	Per capita consumption (kWh)	Country	Per capita consumption (kWh)
Canada	17179	United Kingdom	6206
USA	13338	Russia	5642
Australia	11126	Italy	5644
Japan	8076	India	631
France	7689	Bangladesh	214.4
Germany	7030		

Pokharel (2004) studied on energy economics of cooking in urban households in Nepal; Xiaohua & Zhenming (1996) studied the survey of rural household energy consumption in China; Agrawal and Singh (2001) studied on energy allocation for cooking in India; In Bangladesh, Miah & Alam (2002) worked on deforestation and green house gas emission due to consumption of wood fuel by the brick fields of Hathazari Upazila, Chittagong; Sakar & Islam (1998) carried out research on rural energy and its utilization in Bangladesh; Akther *et al*., (1999) studied the homestead biomass fuel energy situation of a forest rich district, Cox's Bazar; Jashimuddin *et al.,* (2006) studied on the preference and consumption pattern of biomass fuel in some disregarded villages of Bangladesh. Miah *et al.,* (2003) also studied on the biomass fuel use by the rural households in Chittagong region.

Very limited studies have been carried out solely in the domestic level to explore on the whole energy consumption prototype in disregarded villages of Bangladesh. In the present study, an attempt is made to analyze the emission of organic carbon from biomass fuels, overall energy utilization pattern and its influencing issues in the disregarded rural areas of Kabirhat Upazila of Noakhali District, Bangladesh. It is expected that the study will give useful information on Bangladesh's contribution to global greenhouse gas emission of biomass energy from households sector during cooking activities and may lead to planning and decision making regarding global warming, energy employment, climate change, and sea level rise in Bangladesh.

2. Data sources and methods

2.1 Description of the data source

The study was undertaken at Kabirhat Upazila of Noakhali District,Bangladesh located between 22047´ N and 91011´ E, with an area of 160.43 km^2 (Figure 1). Topography of study area is generally flat with a coastal island in the south. A tropical monsoon climate prevails with an average temperature of 13.6^{0}C to 33.0^{0}C and average annual rainfall of 3403 mm (Information from Department of Environment, Noakhali Sadar Centre), which is unevenly distributed and often unreliable. Kabirhat Upazila consists of 7 Union Parishads, 74 Mauzas, 40258 households and 69 villages with the population of 201296 (BBS, 2010). It has a total cultivated land of 8202 ha and fellow of 683.5 ha. Males constitute 54.75% of the population, and Females 45.25%; Muslim 85% and the remaining are the follower of Hindu and Christian (BBS, 2010). The population-increasing rate is 1.74, population per household 5 and average literacy rate 46.09%. There are almost 76.113 km road is made with brick and stone and almost 298.217 km road is muddy. Electricity has been connected with about 3580 households of 28 villages. Main occupations of this Upazila include agriculture, agricultural labourer (who works in the other agricultural lands), wage labourer, commerce, service, transport workers, fishing etc. (BBS, 2010).

2.2 Methods

The study involves income and expenditure information as well as other social and demographic survey and the consumption pattern of household energy utilization scenario in the disregarded rural areas of Kabirhat Upazila under Noakhali District, Bangladesh. The assessment was accomplished through inter-personal interviews with the household head by several times during June-December 2009. The interviews contained a set of both closed and open-ended questions related to fuel wood use. These questions served to quantify household fuel wood use and identify factors influencing patterns of fuel wood use. Firstly, a systematic survey was conducted to identify the users of biomass energy prior to details survey. Domestic energy consumption level was assessed as study area has very limited supply of electricity facility and natural gas due to inconvenience transportation system.

2.2.1 Sampling Procedure

The study was conducted through the Multistage Random Sampling technique using semi-structured questionnaire. The series of selection was from Upazila to Union, from Union to Village and then different selected households. Out of 7 Unions of Kabirhat Upazila, 4 Unions namely; Danshalik, Naruttampur, Sundulpur and Danshiri were selected. From each of the Union, three villages were selected based on the socio-economic information obtained from Union Parishad office. Again, from each of the village, five households were selected randomly totalling 60 households. The randomization was carried out using the random number table at every stage. From Dhanshalik union, Lamsiprashad, Gullakhali and Omarpur villages; from Naruttampur union, Falahari, Mirzanagar and Paduah villages; from Sundulpur union, Ramnathpur, Maddo Sundulpur and Kandir Para villages; and from Danshiri union, Nabogram, Jagdananda and Alipur villages were selected for the study (Figure-1).

Fig.1. *Study area map*

2.2.2 Data processing and analysis

Based on equal percentile, 4 cut points were placed to make income group in all the values of monthly income of the households. So, five income groups (US$) were formed where G1: <=85.71; G2:85.72-114.29; G3: 114.30-171.43; G4:171.44-214.29; and G5: 214.30+. The width percentage was 20.00. To compare the means of the different parameters Games-Howell multiple comparison test was carried out. The literacy of the household members was coded with the meaningful number i.e. Illiterate=0, Primary=05, Secondary=10, Higher Secondary=12, Graduate=16 and Post Graduate=17. Based on the usual time-span of the degree awarded in Bangladesh the coding was done. To find out the weighted score of literacy of the households, all the education values of each household were summed and then it was divided by the family members except the infants. The data processing and analysis were carried out by the statistical package 13.0. Finally, a paired ranking exercise was also conducted to find out the respondent's preference for different fuel wood species.

2.2.3 Estimation of organic carbon in biomass fuels

Biomass samples were collected from study area to assess the organic carbon content from each of the energy carrier. Fresh weights were recorded by electric balance. Samples were dried in electric oven at about 110ºC for about 48 hours to evaporate all the moisture contents present. Then, dried weights of samples were recorded (Brown *et al.,* 1989).

Samples were grind into fine powder using stone grinder. Then porcelain crucibles were washed with 6N HCL and distilled water and dried in an oven at 110ºC for about 1hour. Oven dried grind samples were taken in pre-weighted crucibles. The crucibles were placed in the muffle furnace. Then furnace was adjusted at 550ºC, heating was increased slowly and after reaching at 550 ºC, ignition was continued for 1 hour. The crucibles were cooled slowly keeping them inside the furnace. The crucibles with ash were weighted and percentage of organic carbon was calculated as Allen *et al.,* (1986).
The formula and calculations are the following:

$$\%Ash = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

$\% C = (100 - \% Ash) \times 0.58$(considering 58% carbon in ash free biomass energy) (Allen *et. al.,* 1986).
Where,
C = Organic carbon
W_1 = Weight of crucibles
W_2 = Weight of sample + Crucibles
W_3 = Weight of ash + Crucibles

3. Results and discussions

3.1 Socio-economic background

The 26.7% respondents were female while 73.3% male. Among all the respondents, 28.3% were businessmen, 15% were housewives and the remaining was engaged in other activities. It was also observed that among the female most of the respondents were engaged in household activities (Housewife), so they were highly available to make them the respondents. This was explained by the research observation of Parikh *et al.,* (2001).

It was observed that most of the respondents were below the graduate level. Only 6.7% respondents were found post-graduate. The graduate respondent were 15% while higher secondary passed were 21.7%, secondary passed were 20% and primary were 15%. Among the literacy of the respondents 21.7% were found illiterate. The literacy was low in households with large family size. It was also observed that among the respondents 23.3% were Hindu while 76.7% were Muslim. Most of the respondent's family sizes were 4, 5 and 6 which were 26.7%, 31.7% and 21.7% respectively of the total surveyed households.

3.2 Energy consumption pattern of rural households

In the rural households' biomass, electricity, kerosene, LPG (Liquefied Petroleum Gas) and candle were found as the energy carriers. The study revealed that the 95% households, electricity 53%, kerosene 72%, candle 60% and LPG by 23% of households (Table 2) used different types of biomass. It was also observed that in the rural areas on an average 82.49 (SE, 2.60) kg biomass, 56.73 (SE, 4.25) kW-h electricity, 2.55 (SE, 0.26) litres kerosene, 0.30 (SE, 0.02) kg candle and 3.28 (SE, 0.35) litres LPG were used per household per month. Biomass and electricity were found significant different within same income groups of households.

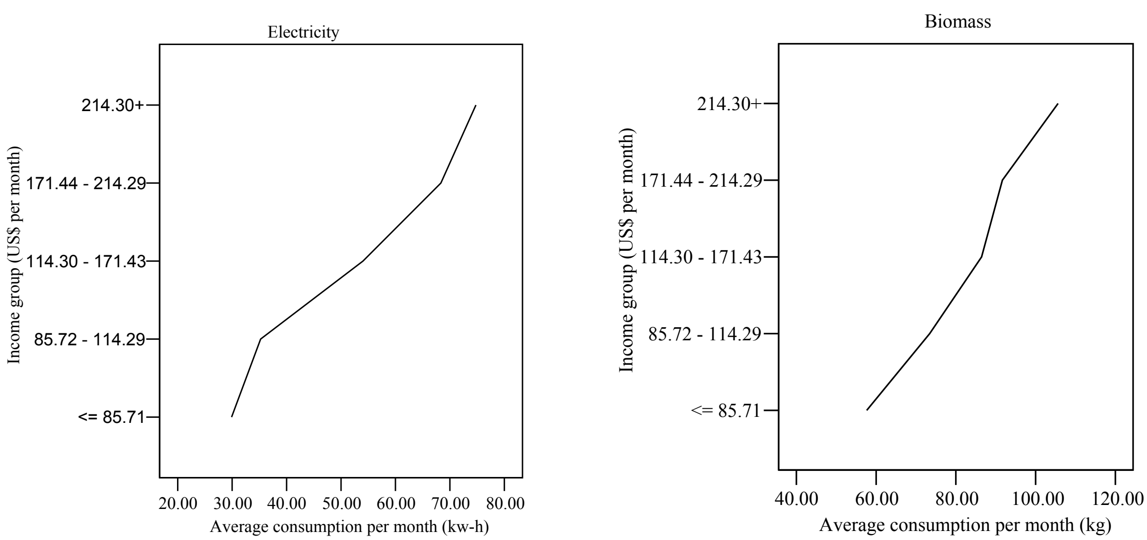
For biomass consumption, there was no significant difference between income group 3 and 4 at 5% level of significance. However, the income groups 1, 2 and 5 were significantly different from each other. For electricity consumption, income groups 1 and 2 were significantly different from the group 3 and income groups 1, 2 and 3 were significantly different from groups 4 and 5 at 5% level of significance (Table 2).

Table 2. *Types and amount of the fuel used by the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Income group (US$ per month)	Average consumption per month				
	Energy types				
	Biomass (kg)	Electricity (kw-h)	Kerosene (liter)	Candle (kg)	LPG (liter)
G1***=<=85.71	57.63^{a*}(2.97)**	29.90^{a} (0.85)	2.40 (0.40)	0.15 (0.07)	-
G2=85.72-114.29	73.42^{b} (2.89)	35.22^{a} (1.16)	3.42 (0.55)	0.18 (0.04)	-
G3=114.30-171.43	86.44^{c} (5.44)	54.03^{b}(10.03)	3.42 (1.05)	0.27 (0.05)	4.00 (1.15)
G4=171.44-214.29	91.66^{c} (2.51)	68.34^{c} (6.99)	1.44 (0.15)	0.37 (0.04)	2.67 (0.33)
G5=214.30+	105.63^{d} (3.36)	74.77^{c} (6.68)	1.58 (0.20)	0.44 (0.06)	3.25 (0.45)
Mean	82.49 (2.60)	56.73 (4.25)	2.55 (0.26)	0.30(0.02)	3.28 (0.35)
No. of households	57	32	43	36	14
% of households	95	53	72	60	23

*Superscript letter indicates the significant difference @0.05 level than the other letter in the same column based on the income group
**Fig in the parenthesis denotes the standard error of mean
***G indicates income group

Fig.2. *Average consumption of biomass and electricity by the different income group-households of Kabirhat Upazila under Noakhali District, Bangladesh.*



Miah et al., (2003) and Pachauri (2004) state that households with standard economic condition use more commercial fuel than that of households with poor economy. The study revealed that most of the households in rural areas consume biomass as traditional fuels and some households consume LPG and candle as commercial fuels where the consumption difference was due to diverse income groups. The rural households prefer traditional energy carrier as their income was limited. The average income per month of the households was US$ 148.11 (SE, 4.78) with the minimum US$ 50 and the maximum US$ 300. In case of consumption pattern of biomass and electricity in the rural households, it was clearly shown that with the increase of the households' income, their consumption also increased (Figure 2). The study showed that biomass consumption of the income group G1 (<=85.71) was 57.63 (SE, 2.97) kg per month while it was 105.63 (SE, 3.36) kg for G5 (214.30+). In addition, electricity consumption of the income group G1 was 29.90 (SE, 0.85) kW-h, while, it was 74.77 (SE, 6.68) kw-h for the group G5.

Table 3. *Housing type and energy consumption by the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Type of house	Energy type	Dwelling size (Decimal)	Consumption per month	Percentage of the households
	Biomass (kg)	0.66 (0.06)*	76.82 (3.43)	33.33
	Electricity (kW-h)	0.69 (0.09)	46.48 (5.23)	15.23
Kacha	Kerosene (litre)	0.67 (0.07)	2.95 (0.34)	27.61
	Candle (kg)	0.67 (0.07)	0.26 (0.03)	19.04
	LPG (litre)	0.74 (0.18)	3.00 (0.77)	4.76
	Total	0.67 (0.04)	-	100 (57.7)**
	Biomass (kg)	0.99 (0.11)	89.71 (4.25)	29.16
	Electricity (kW-h)	1.08 (0.14)	61.98 (7.20)	20.83
Semi-Pucca	Kerosene (litre)	0.81 (0.08)	1.85 (0.41)	20.83
	Candle (kg)	0.96 (0.17)	0.39 (0.05)	20.83
	LPG (litre)	1.22 (0.27)	3.50 (0.86)	8.33
	Total	0.98 (0.06)	-	100 (26.4)
	Biomass (kg)	1.23 (0.28)	94.62 (4.81)	27.58
	Electricity (kW-h)	1.49 (0.34)	75.33 (9.45)	20.68
Pucca	Kerosene (litre)	1.56 (0.47)	1.50 (0.28)	13.79
	Candle (kg)	1.09 (0.27)	0.29 (0.08)	20.68
	LPG (litre)	1.68 (0.29)	3.40 (0.24)	17.24
	Total	1.38 (0.14)	-	100 (15.9)

*Figure in the parenthesis indicate the standard error of mean
**Figure in the parenthesis indicate the percentage of the households within the whole samples

It was found that 57.7% of the households were *Kacha*[1] followed by 26.4% *Semi-Pucca*[2] and 15.9% *Pucca*[3]. The study showed that the size of the dwelling home of the *Kacha* type was found lowest, 0.67 (SE[4], 0.04) decimals, while, it was highest, 1.38 (SE, 0.14) decimals for the *Pucca* type households (Table 3). The energy consumption pattern also found variable for the different housing categories. For biomass and electricity, the households of *Kacha* type had the lowest as 76.82 (SE, 3.43) kg and 46.48 (SE, 5.23) kW-h, respectively; whereas the highest consumption was found in *Pucca* type 89.71 (SE, 4.25) kg and 61.98 (SE, 7.20) kW-h, respectively. For kerosene consumption, 2.95 (SE, 0.34) litres were used by the *Kacha* type house followed by 1.85 (SE, 0.41) litres by *Semi-Pucca* and 1.50 (SE, 0.28) litres by the *Pucca* type housing (Table 3). *Kacha, Semi-Pucca* and *Pucca* showed the ascending affluence status of the households in terms of expenses paid for the house construction and for the dwelling size for most of the energy carriers. It was showed that with the increase of the affluence in terms of the housing status with their sizes, the amount of energy consumption also increased. In Indian households it had been explored by Pachauri (2004).

The study showed that poor educational status was a foremost obstacle to choose the efficient energy carrier by the households. Households with highest literacy score 10.33 (SE, 0.66) had 3.28 (SE, 0.35) litres LPG consumption per month, while, the lowest 6.77 (SE, 0.53) literacy scored households had 2.55 (SE, 0.27) litres kerosene consumption per month (Table 4). The weighted literacy score of the household 7.67 (SE, 0.49) consumed 82.49 (SE, 2.60) kg biomass per month and enjoy 56.73 (SE, 4.25) kw-h electricity with 8.46 (SE, 0.58) literacy scored (Table 4). From the study the average family size was found 4.96 (SE, 0.16) with minimum of 2 and maximum of 8. Both median and mode of the family size were 5. The highest, 31.7% households had the family size 5 followed by 26.7%, 4 and 21.7%, 6 and similar. Rao and Reddy (2007) for India presented that household with higher educational status was the positive influence to choose the competent energy carrier. The present study found out the same trend as well. Normally, households with larger family size shows lower earner group who do not have enough money to use the modern and efficient energy type (Rao & Reddy, 2007). The present study did not find the stronger significant relationship of the family size with the literacy and income of the households.

1.Houses built with low-cost traditional construction materials like mud, thatch, etc.
2. Houses built with both traditional and modern construction materials such as tin, wooden frame and cement and brick.
3.Houses built with relatively higher-cost modern construction materials, like brick and cement.

4. SE stands for Standard error of mean

Table 4. *Energy consumption and literacy of the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Energy types	Average consumption per month	Weighted score of the literacy of the households
Biomass (kg)	82.49 (2.60)* [57]**	7.67 (0.49)
Electricity (kW-h)	56.73 (4.25) [32]	8.46 (0.58)
Kerosene (litre)	2.55 (0.27) [43]	6.77 (0.53)
Candle (kg)	0.30 (0.02) [36]	8.75 (0.56)
LPG (litre)	3.28 (0.35) [14]	10.33 (0.66)

*Figure in the parenthesis indicates the standard error of mean
**Figure in the parenthesis indicate the number of households

3.3 Sources of energy carrier

From the study it was found that 42.6% households collected biomass from their own homestead and agricultural lands, 27.8% from common forests such as road side plantation and 24.5% from market (Table 5). The households directly bought commercial fuels such as candle, kerosene and LPG from the market. Electricity was transmitted and sold to them mostly (76.2%) by the Power Development Board (PDB) of Bangladesh and remaining 23.8% was from the solar energy (Table 5). Agrawal and Singh (2001) state that rural communities meet most of their fuel wood demands from multiple and more accessible sources, such as twigs gathered from hedges and fallen from trees, or residues from other uses of wood in the rural economy, as well as using crop residues and animal dung. Mlambo & Huizing (2004) for Zimbabwe states that significant alternative sources of fuel wood are found to be cultivated lands, dilapidated or unwanted wooden structures, woodlots and riverbanks.

Table 5. *Sources of different energy types by the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Energy types	Energy sources					
	Solar energy	Neighbor	Market	Common forests	PDB	Own homestead & agricultural lands
Biomass	-	3*(5.1)**	14 (24.5)	16 (27.8)	-	24 (42.6)
Electricity	10 (23.8)	-	-	-	32 (76.2)	-
Kerosene	-	-	43 (100)	-	-	-
Candle	-	-	36 (100)	-	-	-
LPG	-	-	14 (100)	-	-	-

*Figure in the parenthesis indicates the number of households
**Figure in the parenthesis indicates the percentage value

3.4 Types of biomass and its end-uses

Firewood, branches, leaves & twigs, straw, rice husk and cow-dung were found as biomass in the rural households energy use. It was found that 26.5% households used firewood, 14.9% branches, 21.9% leaves & twigs, 4.7% straw, 21.4% husk and 9.35% cow-dung as biomass energy. Own homestead and agricultural lands was the most dominant sources of the straw for the 100% households and of the rice husk for the 87% households. Conversely, market was the most frequent sources of the firewood for the 68.4% households and nearly 81% households collect leaves and twigs from common forests (Table 6).

The 100% households (Table 7) used firewood, leaves & twigs, branches and cow-dung only for cooking. The other biomass energy carriers were also used for the cooking purpose by most of the households. On the other hand, 90% households used straw for paddy parboiling while it was nearly 24% for rice husk.

Table 6. *Biomass types and sources used by the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Biomass types	Biomass sources				
	Market	Neighbor	Own homestead and agricultural lands	Common forest	None
Firewood	39*(68.4)**	-	18 (31.6)	-	-
Leaves & twigs	-	3 (6.4)	6 (12.8)	38 (80.9)	-
Branches	1 (3.1)		12 (37.5)	19 (59.4)	-
Rice husk	5 (10.9)	1 (2.2)	40 (87)	-	-
Straw	-	-	10 (100)	-	-
Cow-dung	6 (30)	9 (45)	5 (25)	-	-
No Biomass	-	-	-	-	3 (100)
Households Mean	23.7	6.0	42.3	26.5	1.4

*Figure in the parenthesis indicates the number of households
**Figure in the parenthesis indicates the percentage value

Miah *et al.,* (2003) and Jashimuddin *et al.,* (2006) observed the comparatively same results in the households sectors of the other disregarded places of Bangladesh. They identified that socio-economic condition of the households is the basic influencing factor to prefer the desired fuel types. In the developing countries, household energy consumption is mostly used for cooking and it comprises about half of the total energy use in household. So, energy savings and its future management are mostly related with energy used for cooking (Pokharel, 2004).

Table 7. *End uses of different biomass energy by the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Biomass types	Biomass used for		
	Cooking	Paddy parboiling	None
Firewood	57* (100)**	-	-
Leaves & twigs	47 (100)	-	-
Branches	32 (100)	-	-
Rice husk	35 (76.1)	11 (23.9)	-
Straw	1 (10)	9 (90)	-
Cowdung	20 (100)	-	-
No Biomass	-	-	3 (100)
Households Mean	89.3	9.3	1.4

*Figure in the parenthesis indicates the number of households
**Figure in the parenthesis indicates the percentage value

3.5 Energy expenditure

Average monthly household expenditure for total energy was US$ 6.17 (SE, 0.28) per month while the total monthly income of the household was US$ 148.11 (SE, 4.78). The households had to pay US$ 4.23 (SE, 0.45) per month for using LPG followed by biomass 2.54 (SE, 0.07), electricity 2.28 (SE, 0.17), kerosene 1.64 (SE, 0.17) and candle 0.62 (SE, 0.06). The ratio of expenditure of LPG to the total monthly energy expenditure and to the total monthly income was 49.93% and 2.26%, respectively followed by biomass, 44.14% and 2.04% respectively; electricity 34.79% and 1.49% respectively; and kerosene 30.70% and 1.68% respectively (Table 8). The ratio of the total monthly energy expenditure to the total monthly income was 4.34%.

Table 8. *Expenditure for different energies in the households and their ratio to the total expenditure for energy and total monthly income of the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Energy types	Expenditure per month (US$)	Ratio of expenditure of energy type to the household total expenditure for energy (%)	Ratio of expenditure of energy type to the household total income (%)
Biomass	2.54 (0.07)*	44.14	2.04
Electricity	2.28 (0.17)	34.79	1.49
Kerosene	1.64 (0.17)	30.70	1.68
Candle	0.62 (0.06)	9.71	0.41
LPG	4.23 (0.45)	49.93	2.26
*Figure in the parenthesis indicates the standard error of mean			

There was a significant relationship between per capita household expenditure for energy consumption and total income at both P<0.01 and P<0.05 level of significance. With increasing income, households tend to move from the cheapest and least convenient fuels to the most convenient and usually expensive types of fuel like LPG and electricity. As a result, total households expenditure for energy increases. So, there is a strong positive relationship between growth in per capita income and household demand for commercial fuels. It was also found that the per capita energy expenditure of households was US$ 1.29 (SE, 0.06).

Households with lower income spend less money for energy consumption than households with higher income. Pachauri & Spreng (2002) states that household energy requirement have increased significantly, both in total and per capita terms over the study period. Rao & Reddy (2007) concludes that demand for commercial fuels rises more rapidly with increase in household income.
The study showed that there were significant relationship between monthly total household expenditure for biomass and total monthly income of the household. When disposal income of the households increases then they use more biomass as traditional energy. There was a significant relationship between household expenditure for electricity consumption and total income at P<0.01 significant level. There was a positive relationship between total expenditure for electricity per month and total monthly income. The study revealed that people with higher income spent more money for electricity than people with lower income group. When income of the households increases, they search for better energy sources. As a result, households moved from kerosene to electricity for lighting, cooking and to other new appliances of electricity.

Average expenditure per month for firewood was US$1.52 (SE, 0.06) followed by leaves & twigs US$ 0.27 (SE, 0.01), branches US$ 0.29 (SE, 0.01), rice husk US$ 0.54 (SE, 0.03), straw US$ 0.29 (SE, 0.02) and cow-dung US$ 0.36 (SE, 0.02). Household expenditure for different biomass types to the total expenditure for energy were 25.59% for firewood, 5.26% for leaves & twigs, 5.33% for branches, 9.21% for rice husk, 4.95% for straw and 7.73% for cow-dung (Table 9). The ratio of the expenditure to the total income of the households were 1.18% for firewood, 0.24% for leaves & twigs, 0.23% for branches, 0.41% for rice husk, 0.24% for straw and 0.39% for cow-dung (Table 9).

Table 9. *Expenditure for different biomass energy in the households and their ratio to the total expenditure for energy and total monthly income of the households of Kabirhat Upazila under Noakhali District, Bangladesh*

Energy types	Expenditure per month (US$)	Ratio of expenditure of energy type to the household total expenditure for energy (%)	Ratio of expenditure of energy type to the household total income (%)
Firewood	1.52 (0.06)*	25.59	1.18
Leaves & twigs	0.27 (0.01)	5.26	0.24
Branches	0.29 (0.01)	5.33	0.23
Rice husk	0.54 (0.03)	9.21	0.41
Straw	0.29 (0.02)	4.95	0.24
Cowdung	0.36 (0.02)	7.73	0.39
*Figure in the parenthesis indicates the standard error of mean			

The study showed that there was significant relationship between total household expenditure for energy consumption and total land ownership at P<0.01 significance level. It was observed that when total land ownership of the households increases, then they consume more and more energy.

The study revealed that there was a significant relation between total household expenditure for energy consumption and size of dwelling home at P<0.01 significant level. It was found that households with large sizes of dwelling home consume more energy for lighting and other households' activities. So household's expenditure for energy consumption increases with the increase in the size of dwelling home.

The study showed that there was a significant relationship between total household expenditure for energy consumption and total family members of the household at P<0.01 significance level. It showed that people with more family members consumed relatively more energy for cooking, lighting and other household activities. However, per capita energy consumption did not increase with the increase in family size. Wier *et al.,* (2001) states that in the developing countries especially in the rural poor areas per capita energy consumption reduces with the increase in family size. The household size is more in poorer households and cannot afford modern fuels; as incomes are lower (Rao & Reddy, 2007).

The study showed that there was a significant difference between total household expenditure for energy consumption and type of the households at P<0.01 significant level. It was observed that households with *Pucca* dwelling type spend more for energy consumption on comparison with households with *Semi-Pucca* and *Kacha*. People live in *Pucca* houses have higher expenditure level than those live in *Kacha* house.

The study explained that there was a significant difference in total household expenditure for energy consumption and literacy rates of the household members at P<0.01 significant level. It was observed that where more household members were engaged in education, there was more expenditure for energy in terms of lighting. With the increase in educational status of the household members, preference for the modern fuels increases. As the number of years spent by the household members at school, increases the probability of opting for modern fuels. It has been espoused by the study of Rao & Reddy (2007).

3.6 Preference of fuel wood species

A total of sixteen different types of fuel wood species were identified in the study area by the local women who have been primarily used especially for the purpose of household cooking (Table 10). Most women are often forced to use whatever is available in their own homestead and marginal lands. The preference was mainly based on characteristics of wood, such as heavy wood with slow burning, strong fire, and long-lasting embers. Normally households with huge land ownership raise block plantation for the production of timber and fuel wood. It was also observed that these 16 fuel woods were the main source of branches, leaves and twigs used by the households of the study area. The respondents of poor socio-economic class and few landowners were the dominant collector of branches, leaves and twigs from the adjacent roadside plantation of Forest Department.

Table 10.Commonly used fuel wood species by the rural households of Kabirhat Upazila of Noakhali District, Bangladesh

Local name	Scientific name	Local name	Scientific name
Coconut[a]	*Cocos nucifera*	Sonalu[c]	*Trewia nudiflora*
Sil-koroi[c*]	*Albizia procera*	Raintree[c*]	*Albizia saman*
Boroi[a]	*Ziziphus maurutiana*	Tal[c]	*Borasus flabellifer*
Jam[a]	*Syzygium cumini*	Khajur[c]	*Phoenix sylvestris*
Mandar[c*]	*Erythrina orientalis*	Sissoo[b]	*Dalberzia sissoo*
Kadam[c*]	*Anthocephalus chinensis*	Am[a*]	*Mangifera indica*
Akashmoni[b*]	*Acacia auriculiformis*	Tentul[a]	*Tamarindus indica*
Sirish[c*]	*Albizia lebbeck*	Katbadam[a]	*Terminalia catappa*

[a]Species that are planted in the homestead land through household owner

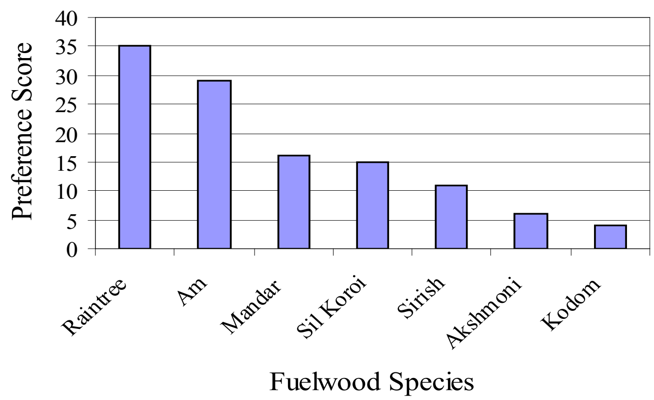
[b] Species that are planted on the road side by the Forest Department

[c] Species that are planted in the marginal land, homestead area and road side through private owner

*Species that are dominantly used by the households of the study area.

Through a paired ranking exercise, seven fuel wood species were identified as the most preferred by the household women. It was observed that Raintree (*Albizia saman*) was the most preferred fuel wood species followed by Am (*Mangifera indica*), Mandar (*Erythrina orientalis),* Sil Koroi (*Albizia procera),* Sirish (*Albizia lebbeck),* Akashmoni (*Acacia auriculiformis),* and Kodom (*Anthocephalus chinensis),* respectively (Fig. 3). The study also showed that on an average 17.19% households used Raintree (*Albizia saman*) followed by 14.25% Am (*Mangifera indica*), 7.86% Mandar (*Erythrina orientalis),* 7.37% Sil Koroi (*Albizia procera),* 5.40% Sirish (*Albizia lebbeck),* 2.94% Akashmoni (*Acacia auriculiformis),* and 1.96% Kodom (*Anthocephalus chinensis)* respectively. These most preferred species take less time to mature and drying; and are easy to propagate in and around the homestead of the study area. Mahiri (2003) states that *Acacia spp.* was recorded most preferred fuel wood species for the household of Kenya due to its wood quality.

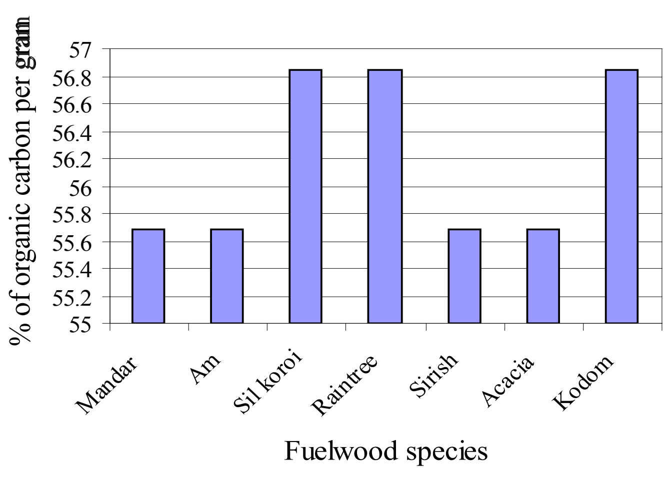
Fig.3. *Preferred fuel wood species used by the rural households of Kabirhat Upazila of Noakhali District, Bangladesh*



3.7 Emission of organic carbon

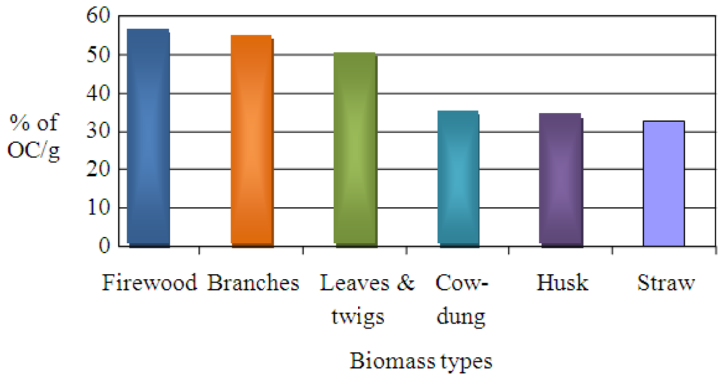
It was observed that during cooking Sil Koroi (*Albizia procera*), Raintree (*Albizia saman*), and Kodom (*Anthocephalus chinensis*) emitted 56.84% of organic carbon per gram as fuel wood species followed by 55.68% of organic carbon emission from Am (*Mangifera indica*), Mandar (*Erythrina orientalis*), Sirish (*Albizia lebbeck*), and Akashmoni (*Acacia auriculiformis*). It was also observed that the mean emission of carbon per household per month was 1.13 (SE, 0.08) gram. Overall, for biomass on an average Pucca type households were responsible for 1.38g (SE, 0.28) carbon emission per month followed by 1.3 (SE, 0.21) g and 1.01 (SE, 0.09) g respectively for Semi-Pucca and Kacha type households (Figure-4).

Fig.4. *Percentage of organic carbon content per gram in different fuel wood species used by the rural households of Kabirhat Upazila of Noakhali District, Bangladesh.*



It was observed that during cooking, paddy parboiling and similar, firewood was the largest contributor of organic carbon emission which emitted 56.17% carbon per gram followed by branches 54.52%, leaves & twigs 49.88%, cow-dung 34.80%, husk 33.64% and straw 32.48% (Figure.5).

Fig.5. *Percentage of organic carbon content per gram in different biomass types used by the rural households of Kabirhat Upazila of Noakhali District, Bangladesh*



It was also observed that on an average 3.0 (SE, 0.13) g carbon emitted from firewood per month followed by 0.42 (SE, 0.03) g for cow-dung, 0.59 (SE, 0.03) g for branches, 0.51 (SE, 0.02) g for leaves & twigs, 0.33 (SE, 0.02) g for straw and 0.32 (SE, 0.02) g for husk in the study area. It was also observed that most of the households used the leaves & twigs of *Mangifera indica* and *Albizia saman* species. The carbon emission rate was considerably high due to traditional cooking stoves used by the households of the study area. However, few families have already been adopted scientific soil cooking stoves, which contribute less carbon emission. Besides, based on economic status some households used modern gas stoves for their cooking efficiency. Wijayatunga & Attalage (2002) for Sri Lanka states that the highest level of gaseous emissions due to cooking activity occurs in the rural areas, mainly due to the relatively large use of biomass fuels. While, fuel switching in domestic cooking activities from biomass to LPG and kerosene can be used as a measure to reduce emissions due to higher stove efficiencies and lower emission factors associated with these fuels.

4. Conclusion

The result showed that in rural areas monthly household expenditure for energy, monthly income, family size, dwelling size, housing type, land ownership categories, per capita energy expenditure and educational status play an important role in determining the desired energy carriers. It was showed that most of the households used firewood and leaves & twigs as biomass for energy consumption for cooking purpose while rice husk was largely used for paddy parboiling. Own homestead and agricultural lands were the major source of biomass energy. It clearly indicates the rapid destruction of homestead forests in future, as its production is not in the sustainable basis. So, there will obviously a deforestation trend imposed in the homestead. Moreover, agricultural land gradually loses its fertility in absence of natural manure like cow dung due to its use in cooking. The study also showed that the households due to unavailability, running costs and lower economy in the rural areas, limitedly used the commercial energy like LPG. It was clearly showed that households' energy consumption diversity was completely influenced by the income of the household's member. With increasing the households income and changes in lifestyle, household will move from traditional energy use system towards an efficient energy use system.

On the other hand, large emission levels of biomass based cooking are mainly due to the use of relative inefficient cooking stoves in the large majority of households. These emissions, along with other hazardous gases from biomass burning, are of great concern, since they directly affect indoor air pollution levels, exposing the household population to health risks. Firewood and branches revealed the highest percentage of carbon emission as biomass energy. So, to reduce the health hazard and CO_2 emission, disposal income of the household should be enhanced by providing income-generating opportunities, so that they can use modern fuels. It was also observed that Raintree (*Albizia saman*) was the most preferred fuel wood species used by the households while the main and large contributor of carbon emission have come from Sil Koroi (*Albizia procera),* Raintree (*Albizia saman*)*,* and Kodom (*Anthocephalus chinensis)* equally. Therefore, it is therefore necessary to adopt some important measures targeting the production of more biomass energy with less carbon emission and its efficient use. Afforestation and reforestation programs and forestry extension could be introduced through participatory with agroforestry concept by planting fast growing tree species for sustainable use of wood fuel considering higher yield and higher fuel values such as *Acacia auriculiformis, Eucalyptus camaldulensis, Acacia mangium, Cassia siamea, Melia sempervirens, Leucaena leucocephala, Gmelina arborea, Casuarina equisetifolia,* and *Dalbergia sissoo*. From the efficiency point of view, sustainable harvesting as well as increased use of improved stoves should be ensured. Moreover, mass awareness should be created about the use of modern energy systems and these systems should also be available for the rural households.

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