Energy Policy 114 (2018) 598–608

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

A comparative study on household level energy consumption and related emissions from renewable (biomass) and non-renewable energy sources in Bangladesh

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ARTICLE INFO

Keywords:
Biomass
Emission
Energy expenditure
Firewood
Income
Non-renewable

ABSTRACT

In developing countries, securing clean and equal energy access for all is often constrained by lack of understanding of households' energy dependency and influencing factors. This study investigates household-level energy consumption patterns, relevant socioeconomic factors and carbon-emissions from various energy sources. Using a semi-structured questionnaire, we conducted an explorative survey of 189 households in three income groups in a suburban region of Chittagong, Bangladesh. Results suggest that most of the households heavily depend on biomass energy that accounts for 87% of their monthly energy consumption and about two-thirds of energy expenditure. Contrariwise, dependence on non-renewable energy is minimal and accounts for households' 31% monthly energy expenditure. The rich households tend to rely more on electricity, candle, liquid petroleum gas (LPG) while their consumption of the non-renewables is significantly higher than that of medium-income and poor households. Income, education and landholdings of households are positively correlated with expenditure for consuming convenient energy sources such as firewood, electricity and LPG. Firewood, the biomass fuel used most for cooking, is an energy source with the highest carbon emissions—monthly about 192 kg carbon dioxide equivalent per household. Our research findings offer insights to enhance household-level clean energy access in Bangladesh and countries alike.

1. Introduction

Non-renewable and renewable energy sources constitute a percentage of about 81 and 14, respectively, of the global total primary energy supply (IEA, 2017). The share of non-renewable fuels include oil, coal, and natural gas, while renewable energy sources (RES) include biomass, sunlight, wind, tides, waves, hydro and geothermal. In 2015, the percentage of renewable energy in global final energy consumption was about 14% (IEA, 2017), of which traditional biomass contributed with about 9% as one of the major RES, especially in the developing countries (REN21, 2016). Globally, the proportion of biomass energy will reach 50% by 2050 in terms of consumption (Mondal and Denich, 2010). Biomass, a combination of different organic compounds, is mainly derived from three sources: agricultural residues, forest residues, and energy crops (Guta, 2012). Generally, biomass refers to rice husk, crop residues, jute sticks, wood, leaves and forest residues, animal waste, municipal waste, etc (Hossen et al., 2017). Conversion of biomass into bioenergy for the production of heat and electricity occurs via two widespread technologies: direct combustion and gasification (Mondal and Denich, 2010), which play vital roles in the substitution of non-renewable fossil fuels. Locally available traditional forms of biomass are used via direct combustion mostly in rural areas of the developing countries. However, increased use of biomass in an efficient way via improved technology can potentially contribute to a clean environment by reducing emissions and representing a promising source of electricity and gas (Hossen et al., 2017).

1.1. Bangladesh energy sector and potential of biomass

In Bangladesh, the demand for energy (with an annual growth rate of 10%) are currently not being met (GOB PD, 2011). According to the World Bank (2014), the per capita energy use in Bangladesh was 215.52 kg of oil equivalent (kgoe) in 2013, which was very low compared to those of its neighboring countries, such as, India, Pakistan, Srilanka, and Bhutan. In Bangladesh, only 61% of the population have access to electricity, with a per capita consumption of 293.03 kWh a^{-1} (kilowatt hour per year) (REN21, 2016; World Bank, 2014). About 91% of the country's total electricity generation depend on non-renewable

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https://doi.org/10.1016/j.enpol.2017.12.037
Received 9 June 2017; Received in revised form 30 November 2017; Accepted 22 December 2017

energy sources (natural gas, furnace oil, diesel, coal), with natural gas being the largest contributor (69%) (BPDB, 2015). Nevertheless, the demand for electricity is higher than the production throughout the country (Islam et al., 2014a; Mondal and Denich, 2010). The government of Bangladesh (GOB) commenced importing crude oil and electricity from other countries, albeit at high costs (Amin et al., 2016). Bangladesh has spent almost 5 billion US$ to import 5450 thousand tons of crude oil and petroleum products in 2014; additionally, approximately 7% of the overall electricity supply were imported in the same year (BBS, 2014; BPC, 2015; BPDB, 2015). The GOB aims to provide electricity for citizens by 2020 (GOB PD, 2011; Power System Master Plan, 2016). Natural gas accounts for 75% of the primary energy consumption and has long been used in industries, fertilizer factories, and in domestic and transport sectors (BP, 2013). However, the reserves of natural gas and coal are limited in comparison to the development needs of the country (Ahmed et al., 2013; Huda et al., 2014). Thus, within the next few decades, Bangladesh will be aiming to confront the serious energy crisis caused by over-dependence on non-renewable fossil fuels (Ahmed et al., 2014; Islam et al., 2014a).

Renewable energy sources represented only about 1% of the total electricity generation in 2015 (BPDB, 2015), which the GOB has envisioned to reach up to 10% by 2020, as declared in the Power System Master Plan, 2016 of Bangladesh (GOB PD, 2011; Power System Master Plan, 2016; REN21, 2016). Among the renewable energy sources, solar and biomass energy may have the highest potentials (e.g. Ahmed et al., 2013; Amin et al., 2016; Islam et al., 2006; Mondal and Denich, 2010). Traditional biomass fuels are predominant sources of rural energy, contributing over 90% to the total primary energy supply (BBS, 2010; Mainali et al., 2014) to meet cooking, commercial, and industrial needs (Rahman et al., 2013), mainly in the form of agricultural residues (46%), wood wastes (34%), and animal dung (20%) (Huda et al., 2014; Islam et al., 2014b). However, biomass as a source of clean energy to avoid traditional uses appears worth mentioning when integrated with the Clean Development Mechanism (CDM) project, which entails using improved cooking stoves, thus reducing carbon dioxide (CO_2) emissions and deforestation, as well as generating employment and income supports (Miah et al., 2009; Uddin and Taplin, 2009).

Over 70% of the population live in rural areas (World Bank, 2013), where income limitations prevent rural households from accessing convenient forms of energy. All rural areas are not well developed and lack access to modern facilities and the electrification network (Islam et al., 2014a; Mondal and Denich, 2010); therefore, the rural population depends on kerosene and candles for lighting. By contrast, rural areas with electrification, but without access to the national gas supply network, rely on the use of biomass for cooking and heating (Ahiduzzaman and Islam, 2011; Halder et al., 2014). Additionally, rural poor people often cannot afford buying liquefied petroleum gas (LPG) for cooking. However, rural people's consumption pattern of traditional biomass fuel is regulated by socioeconomic factors such as literacy of household and availability and cost of biomass, and resources around them (Jumbe and Angelsen, 2011; Rao and Reddy, 2007). For example, home garden (or homestead forests) occupy 0.3 million ha of land (12% of the total forest cover in the country) and play a potential role in providing wood fuels and forest residues (BFD, 2016). Conversely, the rural people of northern regions in Bangladesh, where forests are sparse, mainly rely on agricultural residues, including rice straw, rice husk, rice bran, jute stalk, dung cake, etc. (Halder et al., 2014; Hassan et al., 2014; Huda et al., 2014; Jashimuddin et al., 2006).

1.2. Objective (s) of the study

Several studies have investigated the energy-use pattern in different rural areas of Bangladesh and found variation in energy consumption (e.g. Foysal et al., 2012; Hassan et al., 2012; Miah et al., 2010, 2011a). At the household level, the study by Akther et al. (2010a), Jashimuddin et al. (2006); Miah et al. (2003) found that traditional use of biomass energy had a significant contribution to the rural energy supply in the southern and central part of Bangladesh. Others documented the shortage of biomass, specifically firewood in forest-rich and degraded areas, due to overexploitation of the resources (Akther et al., 2010b, 2010c; Hassan et al., 2014; Miah et al., 2009; Nath et al., 2013). However, according to Hassan et al. (2012), little information is available on rural households' energy consumption patterns and their expenditure on various types of energy, quantity, and sources of fuels. For instance, Miah et al. (2003) did not consider natural gas and other non-biomass fuels in the study conducted in Chittagong region. Moreover, studies on village level energy consumption patterns in regions close to urban areas are scarce. Energy consumption patterns vary with the locations of the study area: urban, suburban, and rural and the proximity to forest areas (Heltberg, 2005; Miah et al., 2011a; Rahut et al., 2014). The present study represents villages with heterogeneity in energy supply. Furthermore, our study area represents the heterogeneous features of the households in terms of income and landholdings, which is a vital aspect to study socioeconomic factors as driving forces of energy consumption and expenditure (Akther et al., 2010a; Behera et al., 2015; Heltberg, 2005; Ouedraogo, 2006; Pachauri, 2004; Reddy and Srinivas, 2009). The emission reductions in using traditional biomass fuels were emphasized; therefore, study taking into account the CO_2 emissions from using biomass energy need to be carried out for the potential development of bioenergy in Bangladesh (Miah et al., 2011b).

From the above-discussed studies, it is evident that there is a dearth of comprehensive information regarding consumption and expenditure of renewable (biomass) and non-renewable energy and their comparisons in rural Bangladesh. Furthermore, no research was so far conducted on CO_2 emissions released from the usage of energy fuels in rural and suburban areas of Bangladesh. In addition, how socioeconomic factors of the households influence the expenditure for energy consumption at household level were not properly reflected in previous studies. Therefore, our key research question addresses "What is the pattern and variation in household consumption and expenditure of non-renewable and biomass energy among different income groups?" Based on this question, we aimed at investigating household level consumption and expenditure of non-renewable and biomass energy, along with their sources and end uses, and related socioeconomic factors (household size, income, literacy, and landholdings) under three income groups in a suburban region of Chittagong, Bangladesh. We also studied the CO_2 emitted from the monthly consumption of the biomass and non-renewable energy fuels. Our goal was to provide policy makers, researchers, and concerned stakeholders with an energy resource base, especially in the context of sustainable energy supply for the development of rural Bangladesh and countries alike.

2. Materials and methods

2.1. Study site

The study was carried out at Hathazari Upazila[1] of the Chittagong District, located between 22°24′ and 22°38′N latitude and 91°41′ and 91°54′E longitude, with an area of 25,500 ha (Fig. 1). The region includes 3252 ha of public forest and 17,665 ha of cultivated land (BBS, 2013). In the South, the Upazila borders to Bayjid Bostami and Chandgaon Thanas, which are under the jurisdiction of the Chittagong City Corporation. Geographically, the area consists of small hills with poor stocks of public forests and private plantations (woodlot).

Total population of the Upazila is about 431,748, with

[1] In the governance system of Bangladesh, Upazilas (sub-districts) and Unions are regarded as the most important local government strata and social institutions. An Upazila consists of a few Unions, which are composed of many villages and/or wards. Village and ward are the two lowest units of the local government system, and their activities are governed by the Union office.