Energy Policy 38 (2010) 5696–5707

Contents lists available at ScienceDirect

Energy Policy

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

Determinants of household energy consumption in India

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ARTICLE INFO

Article history:
Received 15 December 2009
Accepted 6 May 2010
Available online 12 June 2010

Keywords:
Household energy consumption
Energy access
India

ABSTRACT

Improving access to affordable modern energy is critical to improving living standards in the developing world. Rural households in India, in particular, are almost entirely reliant on traditional biomass for their basic cooking energy needs. This has adverse effects on their health and productivity, and also causes environmental degradation. This study presents a new generic modelling approach, with a focus on cooking fuel choices, and explores response strategies for energy poverty eradication in India. The modelling approach analyzes the determinants of fuel consumption choices for heterogeneous household groups, incorporating the effect of income distributions and traditionally more intangible factors such as preferences and private discount rates. The methodology is used to develop alternate future scenarios that explore how different policy mechanisms such as fuel subsidies and micro-financing can enhance the diffusion of modern, more efficient, energy sources in India.

1. Introduction

Providing clean and affordable energy reliably for poor households in developing countries is an important prerequisite in the fight against poverty. Even though rural households often have an easy access to traditional forms of energy—firewood, charcoal and agricultural residues—to fulfil their basic energy needs, these fuels carry adverse effects, such as emissions of particulate matter that are harmful to health, deforestation and environmental degradation. The greater time needed for gathering, transporting and using these fuels also reduces the prospects for using this time in more productive work or education. In addition, as women and children are more likely to suffer from many of these adverse effects, the issue has an important gender and equity dimension (Pachauri, 2004b). The low efficiency associated with the direct combustion of biomass in traditional devices is also sub-optimal from a societal and technical perspective (Reddy, 2003).

A large concentration of people relying on the traditional forms of energy can be found in India, and improving the access of the poor to modern energy has been on the agenda of the government of India since independence. Electrification has especially received much attention within the policy arena, and a summary of past electrification measures can be found in Bhattacharyya (2006). Kerosene and LPG—the main modern cooking fuels in India—have also been subsidized since long, although there has been pressure to limit these subsidies more recently (Gangopadhyay et al., 2005). However, as electricity is rarely used for cooking or heating in India, electrification cannot be seen as an effective solution for reducing the consumption of traditional fuels and the above-mentioned detrimental impacts associated with their use. It should be noted, though, that electricity is required for sufficient lighting and associated with several additional benefits, e.g. improved education and employment possibilities (Kanagawa and Nakata, 2008).

Literature on household energy requirements in developing countries, particularly for the case of India, is extensive. The traditional view on fuel choice has been the "energy ladder" approach (e.g. Leach, 1992), according to which households switch to more convenient energy forms as their disposable income increases. A partial critique of this approach has been presented by Masera et al. (2000), who observed from data on rural Mexican energy consumption that households do not ascend a "ladder" but rather follow a "stacking" procedure, i.e. traditional fuels are not completely discarded with rising income, but rather used in conjunction with modern fuels due to cultural preferences.

The importance of income as a factor affecting fuel use is, however, apparent, even in the case where the switch to modern fuels is not always complete. For Indian consumers, Pachauri (2004a) found that the statistically most significant factors determining households' energy consumption were income and location, whether rural or urban. However, the factors likely to

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doi:10.1016/j.enpol.2010.05.017

affect fuel choices vary by location, financial circumstances and household preferences. Therefore, the energy choices of consumers with different income and location should be assessed separately in energy policy analysis, in contrast to the "representative consumer" approach normally followed in most economic models.

There have been some previous attempts on formal modelling of household energy choices, using a linear cost-minimization solution concept, e.g. by Kanagawa and Nakata (2007, 2008) for the case of India, and by Howells et al. (2005) for an African village. These studies, however, suffer from a number of shortcomings, for instance they disregard consumer heterogeneity, the high discount rates of the poor and differing preferences. A system-dynamic model for India (van Ruijven, 2008, Chapter 6) addresses these issues partially, but does not account fully for all the factors mentioned above. Studies employing logit models of fuel choices have also been conducted. E.g. Reddy (1995, 1996) distinguishes between different income groups in their fuel choice models for Bangalore, India. However, they do not carry out any policy analysis or provide recommendations for the future based on their model results.

This paper therefore intends to establish a stronger framework for modelling the energy choices of households, by explicitly accounting for the heterogeneous economic conditions and preferences of populations living in rural and urban settings, in, order to analyze effective policy choices to improve the penetration of modern cooking fuels among the poor. We start by discussing existing energy consumption patterns in Indian households, based on data from a nationally representative consumer survey. A basic, microeconomic choice model is then presented, serving as the backbone of our energy choice model. This is further expanded to incorporate different practical determinants relevant to the choice problem in the model. We also present a sensitivity analysis for certain key parameters included in the model. The choice model developed is then implemented as the MESSAGE-Access model within the MESSAGE linear cost optimization framework (Messner and Strubegger, 1995). As an application of the MESSAGE-Access model, the effect of fuel subsidies and improved financing options on the future adoption of modern cooking fuels in India is assessed in the final section of the paper.

2. NSSO survey on household energy consumption

This study is largely based on a large consumer survey, carried out by National Sample Survey Organisation (NSSO) of India between 1999 and 2000 (NSSO, 2000). In the survey the respondents were asked to state, among others, their energy consumption for different energy forms in energy and expenditure terms in the past 30 days. In addition to expenditure, the survey also includes home-grown fuel sources for traditional fuels. The NSSO surveys, which involve the energy questionnaire every five years, involve a large sample of households and cover the whole of India, and thus can be assumed to be representative of the nation as a whole.

The energy consumption data from the 1999/2000 survey has already been analyzed extensively in a number of papers, and a more in-depth analysis can be found e.g. in Bhattacharyya (2006), Gangopadhyay et al. (2005) and Pachauri (2007). The survey data have also been used to estimate the elasticities of different energy forms by Gundimeda and Köhlin (2008); to identify barriers for improving energy efficiency by Reddy (2003); to construct a measure of energy poverty by Pachauri (2004b) and to model urban fuel choices by Farsi et al. (2007).

As households with different socioeconomic status are likely to make differing choices regarding their energy use, the household heterogeneity should be taken into account in models. For this differentiation, the households' expenditure level and nature of surroundings—whether urban or rural—were used, as these factors were identified to be the statistically most significant determining households' energy consumption patterns by Pachauri (2004a). The NSSO survey data were therefore split into 10 consumer groups—labelled R1–R5 for the rural and U1–U5 for the urban population, with expenditure rising with the group number—consisting of expenditure quintiles for the urban and rural populations.

From Fig. 1, which portrays the survey data split between the consumer groups, we can see that the energy consumption patterns of the groups are very distinct. The rural population relies largely on traditional fuels. Even though electricity, kerosene and LPG consumption increases with rising expenditure levels, traditional fuel use also increases in absolute terms and dominates the fuel mix of rural households, even after accounting efficiency differences. On the other hand in urban areas the switch from traditional to modern fuels is more apparent as the absolute amount of traditional energy consumption is decreasing with rising expenditure.

An interesting feature can also be seen from an analysis of the sources of firewood, the main traditional fuel source consumed, illustrated in Fig. 2. The figure shows that for some 20% of households even in the lowest expenditure quintile purchase their firewood. This would thus indicate that the market for traditional fuels is functional even within the lowest expenditure

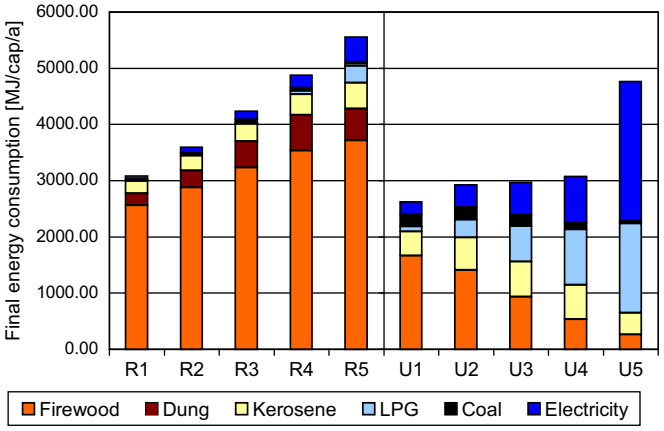

Fig. 1. Household final energy consumption (MJ/cap/a) of the 10 consumer groups.

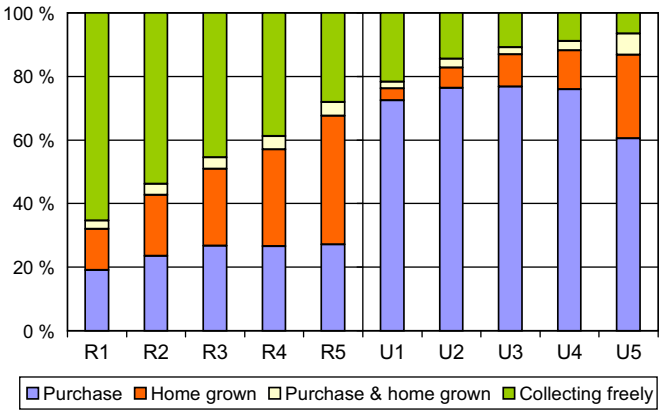

Fig. 2. Sources of firewood of the 10 consumer groups.