Cheaper Fuel and Higher Health Costs Among the Poor in Rural Nepal

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Received: 1 March 2011 / Revised: 17 August 2011 / Accepted: 26 August 2011 / Published online: 4 October 2011

Abstract Biomass fuels are used by the majority of resource poor households in low-income countries. Though biomass fuels, such as dung-briquette and firewood are apparently cheaper than the modern fuels indoor pollution from burning biomass fuels incurs high health costs. But, the health costs of these conventional fuels, mostly being indirect, are poorly understood. To address this gap, this study develops probit regression models using survey data generated through interviews from households using either dung-briquette or biogas as the primary source of fuel for cooking. The study investigates factors affecting the use of dung-briquette, assesses its impact on human health, and estimates the associated household health costs. Analysis suggests significant effects of dung-briquette on asthma and eye diseases. Despite of the perception of it being a cheap fuel, the annual health cost per household due to burning dung-briquette (US\$ 16.94) is 61.3% higher than the annual cost of biogas (US\$ 10.38), an alternative cleaner fuel for rural households. For reducing the use of dung-briquette and its indirect health costs, the study recommends three interventions: (1) educate women and aboriginal people, in particular, and make them aware of the benefits of switching to biogas; (2) facilitate tree planting in communal as well as private lands; and (3) create rural employment and income generation opportunities.

Keywords Asthma · Costs of illness · Dung-briquette · Eye disease · Indoor air pollution · Nepal · Probit

INTRODUCTION

Biomass fuel use in poorly ventilated kitchens pollutes indoor air. In addition to firewood and crop residues,

biomass fuel includes bricked and dried animal dung, commonly called dung-briquette, dung-pats, dung-cake or *guintha*, is being used by the resource poor households in South Asian countries, including Nepal, India, Bangladesh, and Pakistan (Fig. 1). Over 10.3% of the households in Nepal use dung-briquette as a primary cooking fuel (CBS 2004). In Nepal about 69.1% of the households use firewood as the main cooking fuel, 10.3% use dung-briquette, 8.2% use liquid petroleum gas, 4.7% use kerosene and the rest use minor fuels like crop residues and saw dusts (CBS 2004). In terms of energy consumption, the share of dung-briquette in the country accounts for 7% (MOPE 2000). Although the share of dung-briquette in terms of overall energy consumption is relatively low, it has serious health impacts on resource poor people in rural and remote parts of southwestern Nepal, who depend primarily on this type of fuel for household cooking.

The reliance of resource poor people on dung-briquette for household cooking is linked to their dependency on livestock-integrated subsistence agriculture for food as well as fuel (Johansson et al. 2010). For the rural farmers, who rear large ruminants, such as cattle (*Bos indicus*) and buffalo (*Bubalus bubalis*), dung-briquette incurs no out-of-pocket expenses. Even the poorest of the poor households, who are unable to keep animals, collect dung from trails of animals or rangeland, and prepare dung-briquettes. Although the use of dung-briquette appears a free byproduct of livestock raising, there can be indirect costs to the households as a result of increased health problems through indoor air pollution. Though there are other costs of dung-briquette use, such as decreased farm productivity as less farm-yard manure is left for manuring, increased drudgery to women in making and using the dung-briquettes, and emission of carbon dioxide and carbon fumes (REDP 2000) the study focuses on the health costs.

Fig. 1 Common scene of dung-briquette drying in rural areas

The health cost is a major, but poorly understood cost of using dung-briquette in household cooking. Smith (2000) estimates that nearly half a million premature deaths annually are attributable to the use of the biomass fuels. Literature attributes respiratory and eye diseases in developing countries to indoor air pollution from burning of biomass fuel (Ellegard 1996, 1997; Ezzati and Kammen 2001; Smith et al. 2000). The smoke from burning biomass is toxic as it contains carbon monoxide, fine carbon particulates, nitrogen dioxide and hydrocarbons; all at concentrations far in excess of the safe level (USEPA 2008). In addition, the smoke from the dung-briquette burning can also cause metal toxicity as a result of the presence of biological metals, especially iron and copper in dung (Anthony 1971) as well as metals in the soil which is often mixed with dung to make briquettes.

The clean energy sources, such as hydropower, wind-power and solar power, are neither readily accessible nor generally affordable to the resource poor households in low-income countries. Liquefied petroleum gas and natural gas are relatively safer but they are also not affordable to the poor. Biogas generated through bio-methanization, anaerobic digestion of biological materials to produce methane, is a clean energy source for cooking suitable for

sedentary agro-pastoralist households and works well in rural communities in tropical regions (UNEP 2006). Biogas generated from animal dung is an alternative clean fuel source suitable for those agrarian households who use dung-briquette not only because of health implications, but also the gasification process leaves germ-free digested slurry that can serve as a good source of manure. Thus, small-scale biogas plants are technically feasible, financially viable and environmentally clean (Berglund and Börjesson 2006; Johansson et al. 2010; Arthur et al. 2011). Biogas production has several benefits to poor households and disadvantaged communities. This article argues that reduced indoor air pollution makes the household members healthier, and substantially reduces out-of-pocket health care expenses. The use of digested slurry as organic manure increases crop productivity and thus enhances food security. Moreover, food safety risk is also reduced as the digested slurry is free from pathogens, such as *E. coli* and *Salmonella* spp. The social benefits are the reduction in public health care expenditures and greenhouse gas emissions. Realizing the potential of biogas to reduce deforestation due to reduced firewood collection and also to minimize greenhouse gas emission, Nepal government, under the clean development mechanism (CDM) of the

carbon trade, provides a subsidy of US\$ 70 to 100 per biogas plant, which covers about 20% of the total cost of installation of a biogas plant. Many commercial banks and credit cooperative have credit schemes in place to help install household biogas plants. However, in spite of these support services, only 2.4% (that corresponds to 106 853) of the households in Nepal have built a biogas plant (CBS 2002, 2004).

The challenges to change the established habits and practices of using dung-briquette and non-adoption of the biogas technology in spite of the availability of a range of institutional supports are less understood. This article argues that this reluctant behavior among the rural people in fuel switching can be attributed to their ignorance to the range of economic, environmental, and social benefits of clean energy, particularly the reduction in indoor air pollution and associated health complications. The inadequacy of the available information limits household decision makers to choose the right fuel for them, and planners and policy makers to facilitate the transition to cleaner energy production.

The study quantifies the health costs of burning dung-briquette among the rural poor taking biogas fuel as a reference. It aims to develop linkages between the biomass fuel and health outcomes taking the dung-briquette as an example. More specifically, the study assesses health effects of using dung-briquette; estimates its household health costs and compares with the price of biogas, and, finally, explores the factors that affect the household preference to use dung-briquette.

MATERIALS AND METHODS

The research methods comprise hospital visits, interviews and a household survey. The Kapilvastu District Hospital in the study area was visited to find the nature of air pollution related health problems reported by patients. Interviews with the attending physicians in the hospital revealed that the major air pollution related respiratory diseases were asthma with high prevalence and chronic obstructive pulmonary disease (COPD), the latter with lesser prevalence but higher severity. Another major smoke-related problem was eye disease, such as red eyes, watery eyes and light sensitivity.

Though the diseases diagnosed in the hospital were obviously linked to air pollution, it was not clear from the hospital information that whether the patients came from the households using dung-briquette or the biogas or some other fuels for cooking. Moreover, among the poor in the rural Nepal, many of the diseases go untreated or at least not properly treated making the hospital data inadequate for the analysis. In such a situation of data gap, the study

resorted to a household recall survey of disease symptoms that were visible or perceivable to the rural dwellers.

Household and individual level primary data were collected from a sample of 331 rural households (175 dung-briquette users and 156 biogas users) from six villages¹ in the Kapilvastu District of Southwestern Nepal (Fig. 2). To facilitate the case-control comparison of the data, the villages were purposively selected to find a good mix of households using dung-briquette and those using biogas under similar socio-economic and cultural settings. The households using other types of fuels as the primary source of cooking fuel were excluded from the sampling frame: the households using exclusively the dung-briquette constitute the first sampling frame, and the households exclusively using biogas comprise the second sampling frame. In the sample villages, 350 households were found using dung-briquette and 312 households using the biogas. Fifty percent households were selected randomly from each sampling frame using systematic sampling with a random start. There were altogether 2142 individuals including male, female, and children in the sample households. The survey was conducted using a structured questionnaire with modules on fuel use, demographic structures, socio-economic conditions, and prevalence of the diseases and their costs. The questionnaire was pre-tested in the study area, and necessary revisions were made for final administration.

The empirical analysis was done in a household consumption framework. The study began with the notion of household welfare represented by an indirect utility function, where the utility was derived from consumption of various goods and services. As the health of the family members was affected negatively by dung-briquette fuel, it was necessary to consider an expanded form of a household utility function that included specific health-related variables. It was assumed that with the given exogenous income and time, and available information, the households attempted to maximize their utility with consumption, leisure and fuel attributes. The time and budget constraints implicitly captured the opportunity costs of the leisure.

In an attempt to maximize utility, given the full information, the households would have chosen a combination of fuels that maximized their utility from cooking services, fuel efficiency, and health care within the given budget and other resource constraints. But, the health costs being indirect, it was hard to believe that the households had full information to maximize their utility. The health effects of dung-briquette were analyzed at the individual level whereas the household shadow value of the health and fuel choice decisions at the household level. The policy

¹ The villages comprise of the Village Development Committees (VDCs) of Gajehada, Motipur, Niglihawa, Badganga, Hathausa, and Kopuwa.

Fig. 2 Map of the study area

variables were identified through the analysis of the factors affecting dung-briquette use by the households.

Empirical Framework for Health Costs Estimation

The health effects of dung-briquette were estimated at individual level and the health costs were aggregated at the household level. The explanatory variables used for hypothesis testing were grouped into four categories: (1) emission-exposure variables (type and amount of fuel use, kitchen structure and exposure), (2) household characteristics (ethnicity, age, education, wealth), (3) village characteristics (proximity to highways and forests), and (4) and habits (smoking and pet ownership).

Type and Amount of Fuel Use, Kitchen Structure and Exposure

It was hypothesized that the use of dung-briquette increased asthma and eye problems. The more food to be cooked the larger the amount of fuel they use, which would be a typical experience of larger families. Several confounding factors and effects modifiers were envisaged. For example, a separate kitchen from the dwelling room was expected to decrease the indoor pollution related health problems among the rural dwellers. It was also hypothesized that longer the hours of cooking higher the air pollution and the associated health problems. As women spend more time indoor than their male counterparts, it was believed that women would suffer more from the smoke as compared to men. It was also hypothesized that the members working as a family cook would suffer more from respiratory illnesses and eye diseases than other members. Subsequently, the health problems were hypothesized to be

lower among the bread winners who work outside the home than among the dependent members.

Ethnicity, Age, Education, Wealth

Tribal communities were more primitive as compared to other communities in terms of the biomass fuel use, and it was hypothesized that the former would suffer more from air pollution related diseases than the latter. In terms of age, older people were expected to experience more severe health problems arising from indoor air pollution. Similarly, more educated persons were expected to experience less severe smoke-related health problems than less educated and illiterate individuals. As the prosperous households owned a television set, it was taken as an indicator of wealth determining the health of the family members. Similarly, a higher income was hypothesized to reduce the air pollution-related health problems.

Proximity to Highways and Forests

The distance to the highway was taken as a proxy for outdoor air pollution, and it was hypothesized that farther the dwelling from a highway lesser the air pollution related health problems. The distance to the forest was taken as another variable that would affect air pollution related health problems. People living near the forest were expected to be healthier than those living farther.

Smoking and Pet Ownership

Smoking habit was taken as yet another confounding factor that was believed to cause respiratory health problems. Passive smoking is, however, not included in the model as

a possible cause of asthma. Unlike smoking habits, passive smoking is reported as one of the environmental triggers of asthma, but a causal relation has not been established in the literature (EPA 1993). Though Plaschke et al. (1999) reported the effect of pets on asthma, it was not included in the study because only few households kept pets, mostly local dogs. The dogs were not generally permitted to enter the dwelling house.

Based on the interviews with general physicians working in the district hospital, occurrence of asthma and eye diseases were taken as the dependent variables. The two visible symptoms of asthma suggested by the physicians during the interviews were ‘a need to stop for breathing when walking at own pace’ and ‘wakening at night with shortness of breath’ (Pant 2008). Jansson et al. (2007) based on his study in Sweden also reported shortness of breath and wheezing as the symptoms of asthma. Similarly, the visible symptoms of the eye disease were red eye, watery eye and light sensitivity. Siddiqui et al. (2005) in a study of the health problems of firewood burning in Pakistan have also used shortness of breath or wheezing as the symptoms of asthma, and watery eye, red eye, eye irritation and eye pain as the symptoms of eye diseases.

The following exposure response function was estimated using probit equation:

$$\begin{aligned} \Pr(H_{ij} = 1) \\ = \alpha + \beta_1 F_j + \beta_2 P_{ij} + \beta_3 K_j + \beta_4 E_j + \beta_5 V_j + e_{ij}, \end{aligned} \quad (1)$$

where H_{ij} was the prevalence of disease symptoms on person i in household j . The explanatory variables were a vector of fuels used by household j (F_j), a vector of person-specific attributes of person i in household j (age, gender, education, earning, smoking and working as cook) (P_{ij}), vector of kitchen characteristics in household j (outside kitchen, ventilation, and cooking time) (K_j), vector of household characteristics in household j (ethnicity, family size, income, and asset) (E_j), vector of village characteristics where household j was located in terms of distance to highway and distance to forest (V_j), and the error term (e_{ij}).

The shadow value of the health among the family members in a household was estimated using the cost of illness method. Health costs were estimated based on the actual expenditures reported by the households in diagnostic tests, including X-ray and laboratory examinations, fees charged by the doctors and hospitals, costs of medicine and travel costs to and from the hospital (or health post). The costs of additional dietary expenses resulting from illness were also included in the estimate. The patients’ time away from the work and the time of care-giver were estimated and valued using the opportunity cost of time lost at the prevailing wage rate. The total cost of illness

thus estimated was the household shadow value of the health. The product of household shadow value of health and the marginal effect of dung-briquette on the health gave us the lower bound for the health costs of burning dung-briquette. Finally, the household health cost of using dung-briquette fuel was compared with the cost of installation of a biogas plant.

Empirical Framework for Household Decision on Dung-briquette Use

Since cattle and buffaloes are valuable assets for rural households, it was hypothesized that larger the number of the animals and the size of land a household owns, lesser the probability of using dung-briquette. Likewise, longer the distance from the forest, costlier is to collect fuel wood and higher is the probability of using dung-briquette. Similarly, the tribal communities were more traditionally bound and more likely to continue the habits and practices of using dung-briquette. As in the previous model, higher income and education were hypothesized to reduce the use of dung-briquette. These variables were fitted to a probit model to identify the factors affecting the household decision to use dung-briquette. The following probit model was estimated.

$$\begin{aligned} \Pr(\text{dungfuel} = 1) = & b_0 + b_1 C + b_2 B + b_3 F + b_4 L \\ & + b_5 D + b_6 E + b_7 I + b_8 Em + b_9 Ef + e, \end{aligned} \quad (2)$$

where $\Pr(\text{dungfuel} = 1)$ was probability score of using the dung-briquette as the main cooking fuel. The explanatory variables were number of cattle (C), number of buffaloes (B), family size (F), land holding (L), distance to forest (D), ethnicity (E), household income (I), men’s education (average years of schooling of men) (Em), women’s education (average years of schooling of women) (Ef) and error term (e).

RESULTS

This section presents results in four subsections. The first subsection describes the statistics of the variables used in the study, which follows the probit estimation of the health effects of dung-briquette use and the health costs, respectively in the second and third subsections. The final subsection presents the factors affecting household decision to use dung-briquette.

Description of Variables

The descriptive statistics of the variables used in the model for estimating the health effects on the individual family members and those used in household adoption model are presented and described in Table 1. The statistics for the

Table 1 Descriptive characteristics for the individual and household analysis

Variable	Description	N	Mean	Standard deviation
<i>Statistics for individual members of the sample households</i>				
1 Dung-briquette	Reside in dung-briquette user household = 1, otherwise = 0	2142	0.57	0.50
2 Kitchen outside	Reside in house with kitchen outside = 1, inside = 0	2142	0.37	0.48
3 Ventilation	Reside in house that has ventilated kitchen (having at least one window) = 1, not ventilation = 0	2142	0.73	0.44
4 Cooking time	Reside in household that takes time to cook food (minutes/day)	2142	60.72	21.79
5 Male	Male = 1, female = 0	2142	0.49	0.50
6 Tribal	Tribal family = 1, non-tribal = 0	2142	0.51	0.50
7 Age	Years	2142	26.55	18.71
8 Education	Years of schooling	2142	4.41	4.53
9 Earning member	Persons is an earning member = 1, otherwise = 0	2142	0.34	0.47
10 Smoking	Smoking habit at present	2142	0.09	0.29
11 Working as cook	Working as a cook = 1, otherwise = 0	2142	0.25	0.43
12 Television	Television set in the residence = 1, otherwise = 0	2142	0.56	0.50
13 Household income	Annual income of his/her household US\$	2142	632.11	1226.34
14 Family size	Number of the family members in his/her household	2142	7.67	3.07
15 Highway	Distance of the residence from the nearest highway in km	2142	6.58	4.78
16 Forest	Distance of the residence from the nearest forest in km	2142	6.01	5.26
<i>Statistics for sample households</i>				
1 No of cattle	No of adults in the household (age one year or more)	331	1.34	1.36
2 No of buffalo	No of adults in the household (age one year or more)	331	1.30	1.42
3 Family size	Number of the family members in the household	331	6.58	2.74
4 Land holding	Agricultural land holding in hectare	331	0.76	0.21
5 Distance to forest	Distance of the household from the nearest forest in km	331	5.78	5.18
6 Tribal	Ethnic group tribal = 1, otherwise = 0	331	0.47	0.50
7 Household income	Annual household income US\$	331	593.80	1143.52
8 Male education	Average years of schooling of males age 10 years and more	331	5.31	3.40
9 Female education	Average years of schooling of females age 10 years and more	331	3.55	2.72

km kilometers, US\$ United States Dollars

Source: Survey 2009

individual health model consists of personal characteristics: gender, age, education, earning, smoking and cooking, and household characteristics: fuel use, kitchen location, ventilation, cooking time, household assets, household income, family size and location of the dwelling house. Although the individual characteristics are self-explanatory, it would helpful to explain how household characteristics affect individual health outcomes. For example, out of the 2142 individuals in the two samples, household primarily using either dung-briquette or biogas, 57% of them reside in the house using dung-briquette and rest stay in the house with biogas as the primary cooking fuel. Similarly, 37% of them stay in the house with kitchen outside of the dwelling

space and 56% of them live in the house with at least one television set.

A household, on an average, keeps 1.34 cattle and 1.30 buffaloes. The animals give dung that can either be used for dung-briquette making or in biogas plants. The average household size was 6.58 persons which is slightly higher than the national average of 5.20 persons (CBS 2002). Similarly, the average land holding size is 0.76 ha that compares closely with the national average of 0.79 ha (CBS 2006). The average distance from the household to the forest is 5.78 km. About 47% of the sample households were aboriginal tribes, mostly Tharu. The average income of the sample households was US\$ 593.80 per annum. Men

Table 2 Distribution of prevalence of asthma and eye diseases by exposure and demographic variables

	Variable	Level	<i>n</i>	Asthma mean		Eye diseases	
				Mean	Standard error	Mean	Standard error
1	Gender	Female	1089	0.028	0.005	0.084	0.008
		Male	1053	0.030	0.005	0.067	0.008
2	Ethnicity	Other ethnicity	1052	0.034	0.006	0.068	0.008
		Tribal	1090	0.024	0.005	0.083	0.008
3	Fuel	Biogas	931	0.025	0.005	0.060	0.008
		Dung-briquette	1211	0.033	0.005	0.088	0.008
4	Kitchen location	Inside	1358	0.032	0.005	0.072	0.007
		Outside	784	0.026	0.006	0.083	0.010
5	Ventilation	No	569	0.032	0.007	0.068	0.011
		Yes	1573	0.029	0.004	0.079	0.007
6	Smoking	No	1939	0.027	0.004	0.070	0.006
		Yes	203	0.054	0.016	0.138	0.024
7	Work as cook	No	1615	0.027	0.004	0.063	0.006
		Yes	527	0.036	0.008	0.116	0.014

Source: Survey 2009

were more educated than women. Average education for men was 5.31 years of schooling whereas for women it was 3.55 years.

The physicians working in the district hospital reported that married young ladies and old women in the district despite of them being non-smokers had chest infection and recurrent coughs to the extent of addicted smokers. The problems were reported to be recurring and escalating leading to asthma and in some cases eventually to the extent of COPD, which makes patients difficult to breathe often leading to permanent disability and death. It was also reported that the indoor air pollution from the dung-briquette and other biomass fuels also caused eye diseases. The asthma symptoms were reported by 3% of the individuals (62 persons) among the sample households. Similarly, more than 8% of the individuals (163 persons) reported various symptoms of the eye diseases. Distributions of the prevalence of asthma and eye diseases by exposure and demographic variables are presented in Table 2. The results show that the tribal people have less prevalence of asthma (2.4%) as compared to non-tribal (3.4%). Current smokers have higher prevalence of the asthma (5.4%) as compared to non-smokers (2.7%). More women (8.40%) suffered from eye diseases than men (6.7%). Unlike asthma, the eye diseases were more prevalent among the tribal communities than others. As expected, larger proportion of the smokers (13.8%) suffered from the eye diseases as compared to the non-smokers (7.0%). Similarly, larger proportion of the people working as household cooks (11.6%) suffered from eye diseases than the non-cooks (6.3%). The results indicate

that exposure to the pollution increased the incidence of asthma and eye diseases.

Health Effects of Dung-briquette Fuel

The results of the probit estimation show that the use of the dung-briquette significantly increases the probability of developing asthma (Table 3). After controlling other confounding factors, the use of the dung-briquette increases the risk of the asthma by 1.5%.

Effects of the confounding factors on the asthma such as age, location of the households, ownership of assets, and the level of income are also presented. The risk of asthma significantly increases with the increase in the age of a person. With aging, the effect of air pollution cumulates over the years and reaches to the threshold level in the later years. The risk of the asthma also increases as the distance from the forest increases as the forest provides fresh air that reduces risk of developing an asthmatic condition. The households farther from the forests have no such amenities, and hence face a significantly higher risk of asthma. The probit estimation explains over 14% of the variations in the asthma disease. Unexpectedly, ownership of asset and income are not significantly affecting the development of the asthma, which implies that resource poor people are not only the victims of air pollution. It can be concluded from the analysis that stopping the use of dung-briquette can decrease the asthma among the rural dwellers. Ethnicity is an effect modifier. The risk of the asthma is lower among the aboriginal people than others. Though the results without the use of the tribe variable do not differ much than

Table 3 Effects of dung-briquette burning and other variables on asthma and eye diseases

Dependent variable		Symptoms of asthma				Symptoms of eye diseases	
		With tribal		Without tribal			
Explanatory Variable		Marginal effect (dF/dx)	$P > z $	Marginal effect (dF/dx)	$P > z $	Marginal effect (dF/dx)	$P > z $
1	Dung-briquette	0.015**	0.045	0.011*	0.100	0.047***	0.000
2	Kitchen outside	−0.003	0.532	−0.003	0.553	0.015	0.160
3	Ventilation	−0.003	0.639	−0.002	0.760	0.002	0.862
4	Cooking time	0.000	0.768	0.000	0.772	0.0005**	0.040
5	Male	0.005	0.427	0.005	0.442	−0.006	0.612
6	Tribal	−0.010*	0.098			0.004	0.744
7	Age	0.001***	0.000	0.001***	0.000	0.003***	0.000
8	Education	−0.001	0.396	−0.001	0.392	0.001	0.484
9	Earning member	−0.008	0.143	−0.008	0.142	−0.010	0.325
10	Smoking	−0.005	0.489	−0.005	0.456	−0.003	0.820
11	Working as cook	0.003	0.663	0.002	0.721	0.025*	0.052
12	Television	−0.002	0.693	−0.003	0.664	−0.008	0.471
13	Household income	0.000	0.673	0.000	0.716	0.0001*	0.107
14	Family size	−0.001	0.365	−0.001	0.201	−0.002	0.301
15	Distance to highway	−0.001	0.171	−0.001	0.313	−0.003**	0.031
16	Distance to forest	0.001**	0.043	0.001*	0.051	0.002*	0.075
	LR χ^2 (16/15)	79.96***		77.180***		146.23***	
	Pseudo R^2	0.141		0.136		0.127	

$N = 2142$. *** 1% level of significance, ** 5% level of significance, and * 10% level of significance

Source: Field Survey 2009

the results with the tribe, the effects of the dung-briquette are slightly lower in the former estimation than the latter which may be due to an aggregation effect.

The results show that the dung-briquette use increases the risk of eye diseases by 4.7%, which is statistically significant. The other variables aggravating the risks of the eye problems are the age and occupation. A year increase in the age increases the probability of having eye diseases by 0.3%. Similarly, working as a household cook increases the probability of the eye disease by 2.5%.

Distance to the forest also determines the problem of eye diseases. Every kilometer increase in the distance of the house from the forest increases the risk of the eye diseases by 0.2%. However, higher household income and longer distance from the highway significantly decrease the eye diseases. The household income affects well-being in a complex way leading to a better living that decreases the risks of the diseases. The distance to the highway is taken as an indicator of outdoor air pollution in the villages. Intuitively, the outdoor air pollution in the vicinity of highways is higher than that in the farther areas. Time spent in cooking per meal, however, gives an unexpected result. The longer is the cooking period less is the problem of the eye disease. This is because leaving the fire unattended during cooking meals takes longer time for cooking and at the same time reduces the exposure of the cook to the smoke.

It can be safely inferred from the above findings that the use of dung-briquette increases asthma and eye diseases among the rural people in general and that of the family cook in particular. As the comparisons are made among the households exclusively using dung-briquette and biogas, there is little possibility that other biomass fuels would confound the above findings.

Household Shadow Value of Health and Costs of Fuel Switching

The cost of illness study shows that, on an average, one case of the asthma costs US\$ 73.78 per annum (Table 4). The largest portion of this cost (76.6%) goes to the purchase of prescription medicines followed by 10.3% for the cost of visits to doctors' office, 9.4% for dietary expenses due to illness, 3.3% for laboratory tests and 0.4% for wage loss of patients and care-givers. The costs of laboratory tests and doctors' fees are not high in Nepal, particularly in government subsidized public hospitals.² As the wage rate is very low (about US\$ 0.17 per hour) the wage lost of the patients and their care-givers is very low.

² As the cost-benefit analysis is done at the household level, the public sector expenditures to hospitals are not included in the estimates.

Table 4 Shadow value of asthma and eye diseases

Cost heading	Asthma (62 cases)			Eye diseases (176 cases)		
	Mean (US\$)	Percent	Standard deviation	Mean (US\$)	Percent	Standard deviation
1 Hospital/Doctor Fees	7.57	10.3	21.81	2.66	8.5	7.65
2 Laboratory Costs	2.43	3.3	5.08	1.45	4.7	12.81
3 Medicine purchase	56.52	76.6	192.41	24.38	78.1	119.10
4 Dietary expenses resulting from illness	6.97	9.4	35.47	2.62	8.4	21.25
5 Wage lost due to work days lost due to illness	0.21	0.3	0.76	0.07	0.2	0.30
6 Wage lost due to time spent by family member(s) on care taking	0.09	0.1	0.28	0.04	0.1	0.18
Total	73.78	100.0		31.24	100.0	

Source: Field Survey 2009

Similarly, one case of eye disease treatment, on an average, costs US\$ 31.24 per annum. As in the case of asthma, the major portion of the cost goes to medicines (78.1%) followed by fees of hospitals and doctors (8.5%) and the dietary expenses due to the illness. The imputed value of the wage loss is very small as in many cases the resource poor people work in spite of relatively minor eye diseases.

Based on the above findings, it can be concluded that out-of-pocket expenses, particularly to buy prescription medicines are much higher than the imputed value of the labor as drug plans to cover expenses on medicines are neither accessible nor affordable to the resource poor people in Nepal.

Change in the household shadow value of health due to the switching from dung-briquette to biogas is the product of the costs of illness and change in the risks of the illness due to fuel switching aggregated over the household size. As one case of the asthma disease costs US\$ 73.78 per annum and the use of the dung-briquette increases the risk of the asthma by 1.5% to the sample individuals, the use of dung-briquette increases the risk of the asthma by US\$ 1.11 per annum. When the costs are aggregated for the family of 6.58 members, the annual costs of the asthma due to dung-briquette use amount to US\$ 7.28 per household. Similarly, as one eye disease treatment costs US\$ 31.24 per annum and the use of the dung-briquette increases the risk of the eye disease by 4.7%, the use of the dung-briquette increases the risk of the eye disease by US\$ 1.47 per annum. Annual costs of eye diseases due to burning of dung-briquette amount to US\$ 9.65 per household. Taking these two diseases, asthma and eye problems, the annual costs of the loss of health for each household is US\$ 16.94. These estimates, however, do not include the psychological and emotional costs of pain and sufferings that the patients, care-givers, and their kiths and kin bear.

For the rural households, the best fitting alternative available to the dung-briquette is biogas. The same dung

that is used to make briquette can be fed to the biogas plants to generate cooking gas and the slurry generated from the digester can be used as organic manure to grow crops. In the study area, biogas plants were introduced 15 years ago, and the adopter households have been using biogas plants successfully. The average cost of construction of a 6.87 m³ dome-sized biogas plant is US\$ 311.46, and the average subsidy available through biogas companies that administer the subsidy is US\$ 45.65 per plant. This subsidy is, however, much lower than the rate of the subsidy (US\$ 70–100) fixed by the government. As the average life of the biogas plant is 30 years, the annual depreciation³ of a biogas plant is US\$ 10.38 (Pant 2008). Thus, the annual cost of a biogas plant is 61.3% lower than the health costs of using the dung-briquette (US\$ 16.94). With the lack of culturally appropriate research-based information on costs and benefits of using biogas, rural households are reluctant to adopt the biogas technology as an alternative to dung-briquette. It is intriguing to learn why rural people are still using dung-briquette for cooking food, which is the subject matter of the following subsection.

Factors Affecting Household Decisions to Use Dung-briquette

The results of the probit regression of the household decisions of using dung-briquette are presented in Table 5. An increase of one cattle per household increases the probability of using dung-briquette by 8.5% whereas an increase of one buffalo has an opposite effect decreasing the probability by 5.0%. This is because buffalo-dung is softer than the cow-dung and more suitable for feeding into a biogas plant than the preparation of briquette. Moreover, buffaloes are reared by better off farmers who have higher

³ For a reference, the price of one cylinder (for 14.2 kg net) of liquid petroleum gas is US\$ 18.00 and electricity tariff is US\$ 0.12 per kWh.

Table 5 Factors affecting household decision for use of dung-briquette as cooking fuel

	Variable	Marginal effect (dF/dx)	$P > z $
1	No of cattle	0.085***	0.002
2	No of buffalo	−0.050**	0.037
3	Family size	0.007	0.642
4	Land holding	−0.015	0.705
5	Distance to forest	0.021***	0.004
6	Tribal ethnic groups	0.295***	0.000
7	Household income	−0.001*	0.097
8	Male education	−0.044***	0.000
9	Female education	−0.096***	0.000
	LR χ^2 (16)	201.24	
	Pseudo R^2	0.440	
	N	331	

*** 1% level of significance, ** 5% level of significance, * 10% level of significance

Source: Field Survey 2009

affordability to install biogas plants. Another important factor to increase the use of dung-briquette is the distance of the household to the forest. Every kilometer increase in the distance to the forest increases the probability of using dung-briquette by 2.1%. This is because of the shortage of firewood in the villages that are farther from the forest. Similarly, tribal households have 30% more probability of using dung-briquette than the non-tribal households. It means the practice of using dung-briquette is mostly bound by culture and tradition. As expected, an increase in the household income significantly decreases the use of dung-briquette.

Education, particularly women's education, is another strong variable that decreases the use of dung-briquette. One year increase in men's schooling decreases the probability of using dung-briquette by 4.4% whereas the same year of women's education decreases the probability by 9.6%. It can be inferred from these results that education is a strong variable to switch from the dung-briquette to biogas, and women's education is much stronger than men's education. The probit function estimated is strong and explains 44% of the variations in the fuel choice.

DISCUSSION

If the households were operated in fuel markets, their decision to choose a particular fuel would be determined by the utility of the fuel and its market price. For non-market participants as in the case of rural Nepal, the decision of fuel choice such as dung-briquette is the opportunity cost of labor involved in the preparation and drying of the briquette and indirect health costs. Though every type of

fuel carries a cost to the households, some fuels incur direct costs (e.g., biogas), some others indirect costs (e.g., dung-briquette) and some of them incurs both costs in different proportions (e.g., firewood, liquefied petroleum gas and kerosene). The biogas fuel has direct costs of its establishment and some labor for feeding dung and water to its digester every day. The dung-briquette is prepared by the household itself and the visible cost is the opportunity cost of labor that is very low.

Indoor air pollution from the use of dung-briquette causes lung and eye diseases, and the health costs are higher than the costs of the alternative fuels. The costs of dung-briquette are borne by the user households in several ways, like discomfort, risk of fire, lower social status and health effects. The discomforts are generally endured by the resource poor people. The risk of fire is very small and the households consider the risk as nearly zero. Poverty forces them to stay in lower social status and they feel it usual as their peers are also in the same status. The linkages of using biomass fuel to human health are not clearly apparent to the less educated rural poor. Most of the time, the rural poor cannot easily attribute their diseased conditions to the type of the fuel they burn for cooking.

The study clearly shows that the use of dung-briquette increases asthma and eye diseases significantly among the rural dwellers. The annual costs of the asthma disease and eye problems due to burning of dung-briquette fuel amounts to US\$ 7.28 and US\$ 9.65 per household, respectively. Taking these two diseases together the annual value of loss of health for each household is US\$ 16.94. For the rural households, the alternative available to the dung-briquette fuel is to build biogas plants that cost US\$ 311.46 per plant for construction with annual depreciation of US\$ 10.38, which is 61.3% lower than the health costs of using dung-briquette.

Although the study precisely estimated the health costs of using dung-briquette, it may contain some selection and information biases. The selection bias comes from sample selection as only those households using exclusively either dung-briquette or biogas constituted the sampling frame. This left other fuel users and multiple fuel users beyond the scope of the study. Similarly, the information bias comes from the self-reporting. Since the study was based on self-reported symptoms of the prevalence of the asthma and eye diseases, the patients with mild symptoms and below the threshold level of disease manifestation might have been left out. Due to paucity of data, it was not possible to have one to one correspondence of the diseases reported by the household respondents with the cases reported in the hospital. In spite of these methodological limitations, the estimates are strong enough for household decision making of fuel choice and public policy making to facilitate the processes of transition to alternative fuel sources.

Fig. 3 Economic status, fuel from agriculture, and effects on wellbeing

Unprecedented advancements in alternative energy science and technology have made possible to produce modern biofuels, such as ethanol using starchy food crops (e.g., corn, sugarcane, sugarbeet, sorghum, and wheat), and biodiesel using oil producing seed crops (e.g., sunflower, rapeseed, soybean, jatropha and oil palm) (Fig. 3). Although biofuels reduce dependency on fossil fuels, reduce greenhouse gas emission, and provide new markets for agricultural produce, the use of food crops in energy production can further jeopardize food security of the poorest of the poor (Mol 2007). Technology to produce biofuels using cellulosic materials, including municipal wastes, crop byproducts, weeds and grasses, are also being developed, but land, labor and capital required for this purpose would again compete with agricultural production. The resource poor people either do not have access or cannot afford these emerging sources of fuels and other renewable energy sources, such as windpower, solarpower, and hydropower that are environmentally clean. As evident from this study, biogas is an affordable alternative to biomass fuels, such as dung-briquette and firewood, particularly in the rural areas of low-income countries.

As has become evident from this study, transition from dung-briquette to biogas is a challenge. The habits and practices of using the dung-briquette are explained by the situational contexts like geographic location, ethnicity, culture and tradition that are difficult to change. The policy instruments identified through this study to reduce dung-briquette use are forest plantation, buffalo rearing, income generation and education. As the distance to the forest

increases the dung-briquette burning, plantation of trees in village level barren lands and in agroforestry systems would be helpful to reduce the dependency on dung-briquette. Support services to keep buffaloes should go side by side with the supports for biogas promotion. Increasing the number of buffaloes needs to increase fodder supply that needs fodder tree plantation. Thus, plantation of multipurpose trees, suitable for food, fodder, and fuel, in private as well as communal lands can increase the availability of firewood, food and fodder, and reduce the use of dung-briquette. However, as the firewood also emits smoke causing respiratory diseases and eye problems (Schei et al. 2004; Melsom et al. 2001; Pant 2007), planting multipurpose tree species needs to be followed by the promotion of improved stoves that reduce the smoke from the firewood burning.

Employment and income generation is the most elusive struggle among the resource poor. As the dung-briquette burning and indoor air pollution are poverty related issues the interventions for reducing this practice should not only be cost effective but also affordable to the poor. The resource poor people decide to use dung-briquette for cooking because it is cheaper than the modern fuels to the best of their knowledge, and is generally based on their use of time-tested indigenous technology that worked in absence of alternative energy sources. The analysis of the factors affecting dung-briquette use shows that the habits and practices of using biomass fuels can be changed by educating people particularly the women. Awareness raising as a proxy for education is the most powerful

instrument for changing the behavior of people to adopt cleaner fuels. The challenge lies on making the household health costs of biomass fuels known to the household decision makers and also engaging them in the internalization of the social benefits of switching to cleaner fuels. Public policy makers and donor agencies need to internalize the external benefits, such as greenhouse gas emission reductions. The subsidy on biogas under CDM is contributing to this end, but it is evident from this study that there are still implementation challenges because the amount of subsidy provided by the biogas companies in Nepal is far lower than what the government policy has instructed. The study generated enough information that can help the decision makers to readjust the benefit–cost comparison, thereby facilitating the adoption of pollution reducing interventions like biogas and maximizing household fuel utility. Further efforts are necessary for effective implementation of such subsidies and other institutional supports, particularly through inter-sectoral policy coordination involving multiple stakeholders engaged in health, rural energy, climate, agriculture, environment, and natural resource conservation.

CONCLUSIONS

Switching cooking fuel from biomass fuels, such as dung-briquette, to biogas has multiple benefits at the household as well as societal levels. For example, households benefits from reduced health care expenditure while society benefits through reduced emission of black carbon and greenhouse gases and lower public health expenditure. But in spite of the benefits, the fuel switching is not taking place spontaneously. Thus, deliberate interventions in policy as well as practice are necessary to influence the household fuel choice. The research findings on the direct and indirect costs of dung-briquette can be used to make better fuel choices. At the household level, there is a need for taking the information of health costs of biomass fuels to the rural poor so that they can rethink their decision on the use of the conventional fuel sources, including dung-briquette. For example, creating an awareness of the health costs of the dung-briquette among the rural people can reduce the use of biomass fuels that pollutes the air. At the national level, the research findings are useful for public policy making processes so that better policies and programs would be formulated to reduce the use of biomass fuels and to increase the social benefits, such as reduced public health expenditure and greenhouse gas emission.

Acknowledgments The author acknowledges the financial support of South Asian Network of Economic Research Institutes (SANEI) for the study and would also like to thank the members of its Research

Advisory Panel for technical supports. The author is grateful to two anonymous reviewers who provided invaluable comments and suggestions on this article and also thankful to Associate Editor Jesper Stage for constructive comments and valuable suggestions.

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