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Are renewable energy subsidies in Nepal reaching the poor?

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ABSTRACT

The Government of Nepal has been providing subsidies to promote biogas technology since the 1970s and Solar Home Systems (SHS) since the 1990s. This study uses nationally representative survey data to examine the extent to which these subsidies benefitted the rural poor. We find that only 5% of households who are eligible for a biogas subsidy have adopted biogas; and only 2% of biogas adopters are below the poverty line, as compared to a poverty rate of 19% in the country. For SHS, 27% of the households eligible for subsidy have adopted the technology, and 25% of the adopters are below the poverty line. The SHS subsidy program is much more accessible to the poor as compared to the biogas subsidy program for two main reasons. First, Solar Home Systems are much cheaper than biogas plants, and so are more accessible to the poor after the subsidy, and second, the SHS subsidy is geographically targeted toward poor areas, while the biogas subsidy is not.

Introduction

Globally, 1.3 billion people have no access to electricity and 2.8 billion still rely on solid cooking fuel (IEA, 2012). Most of these people live in rural areas (SE4ALL, 2013). Studies suggest that access to modern energy services is a primary prerequisite for poverty reduction and sustainable human development (Practical Action, 2010). In this context, the Sustainable Development Goal number 7 is to ensure universal access to affordable, reliable and modern energy services by 2030.

In Nepal, 66% of households (33% of the urban households and 72% of the rural households) were using firewood as their main source of cooking fuel in 2001. After a decade, in 2011, 64% of households (26% of the urban households and 73% of rural households) were still using firewood for cooking (CBS, 2002, 2012).

With regard to lighting, the proportion of households using electricity as their major source of lighting had increased from 40 to 67% between 2001 and 2012. When disaggregated by area, the increase in usage was from 83 to 94% in urban areas and from 32 to 60% in rural areas.

The Government of Nepal has been promoting renewable energy technologies (RETs) for a long time. However, an aggressive promotion of RETs started when the Government started providing a subsidy for biogas in 1992 and for Solar Home Systems (SHS) in off-grid areas in 2000 with the aim of providing access to clean energy to the rural poor (Government of Nepal, 2000). The subsidy policy was revised in 2009 and 2013 with a similar focus of helping the rural poor to adopt RETs (Government of Nepal, 2009, 2013).

Using nationally representative data, we examine the effectiveness of the renewable energy subsidy policy in helping poor households in rural areas to adopt renewable energy technologies. Our results indicate that only 5% of the eligible households for the biogas subsidy had adopted the technology as of 2011. Among the biogas adopters, only 2% were below the poverty line. The subsidy for Solar Home Systems seems to be relatively effective in reaching the poor, where 27% of subsidy-eligible households had adopted the system by 2011, with about 25% of the adopters below the poverty line.

Brief background of subsidy policy for RETs in Nepal

Since the early seventies, RET projects have been promoted in Nepal to reduce rural poor people's dependency on firewood for cooking and fossil fuels for lighting (Gurung, Ghimeray, & Hassan, 2011; Pokharel, 2003). More recent developments include establishment of the Alternative Energy Promotion Center (AEPC) in 1996 as a lead body to promote RETs in Nepal; and the introduction of subsidies for RETs in the Rural Energy Policy in 2006. The goal of the Rural Energy Policy was to reduce rural poverty through the provision of clean and reliable energy technologies in off-grid areas. In order to target the subsidy, villages were classified according to poverty, remoteness, and caste/ethnicity.

This is not the first time that attempts have been made to provide RETs to rural poor. Biogas was promoted in Nepal since the 1970s; and solar-PV-based rural electrification was first started in the late 1980s. But, in both instances, adoption of these technologies was

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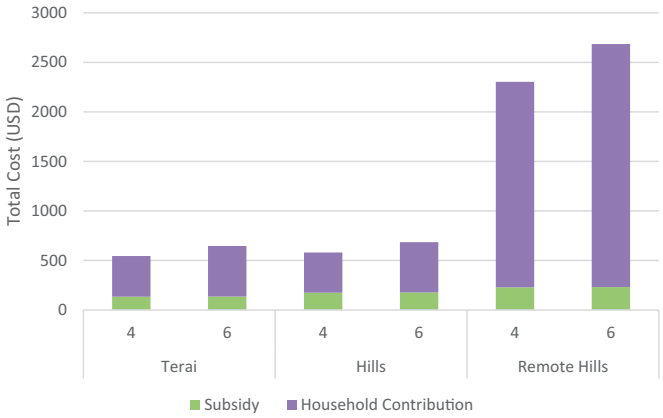

Fig. 1. Total Cost, Household Contribution and Subsidy for biogas plants in year 2010.

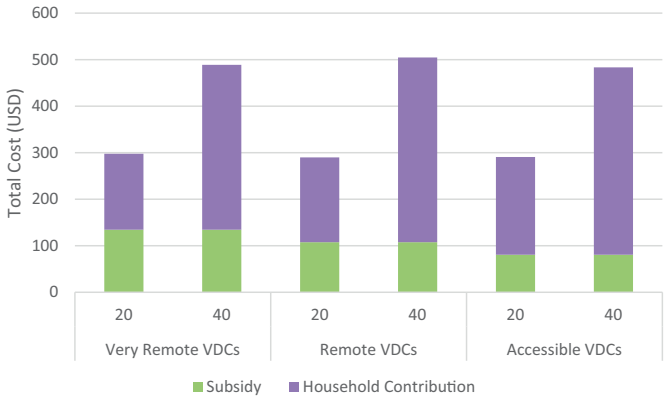

Fig. 2. Total Cost, Household Contribution and Subsidy for Solar Home System in year 2010.

minimal until subsidies were provided through the Biogas Support Program and AEPC (Piya & Rai, 2003; Pokharel, 2003).

Subsidies for biogas dissemination started with the provision of an interest-free loan in 1975. From the inception of the programs, only households with at least one cow or buffalo have been eligible for the subsidy, since without animal dung biogas plants cannot produce gas.[1] This requirement excludes the rural poor and urban households who do not or cannot own cattle. The subsidy policy was revised in 1996, 1999, and 2006, where larger subsidies were proposed to smaller biogas plants and remote hilly areas. In addition additional subsidy provision was in place for socially disadvantaged ethnic community.

The government of Nepal started subsidizing Solar Home Systems since the 1990s. Only those households that are not connected to the national or local grid are eligible for SHS subsidies. The current policy targets geographically remote Village Development Committees (VDCs) or households located in these VDCs (Government of Nepal, 2013). Thus, households living in VDCs listed as "very remote" receive a greater subsidy than households living in "remote" VDCs. The households living in "not remote" VDCs receive the least subsidy for SHS.[2] Within targeted VDCs, the subsidy provided depends on the size of the SHS, with 10–18 watt-peak systems receiving a smaller subsidy than those with a peak output that is higher than 18 W.

The total cost of a typical household biogas plant varied from 500 to 700 USD in the Terai and the hills, whereas in the high (remote) hills, it cost around 2700 USD due to high transportation costs for the construction materials (AEPC, 2010). The program emphasized plants of 4 or 6 cubic meters, useable by households with just one cow or buffalo. Taking the price from the year 2010 and considering only 4 and 6 cubic meter biogas plants, it is found that after the subsidy a household paid around 400 to 500 USD[3] in the Terai and the hills, respectively, whereas households residing in the remote hills paid 2000–2400 USD for the same size of biogas plant due to the additional cost of transporting the construction materials (Fig. 1). The actual subsidy is around 20–30% of the total cost of biogas plant in Terai and hills, whereas in the high hills it is around 10% only.

In 2010 the costs of 20-watt and 40-watt SHS were USD 300 and USD 500, respectively (AEPC/ESAP, 2011). Households living in the very remote area pay less than households living in accessible VDCs. For a 20-watt system, a household paid around 160–210 USD depending on the location. The share of the subsidy in the total cost of a Solar Home System would be 28–45% for a 20-watt system and 17–27% for a 40-watt system (Fig. 2). These subsidies are given to the companies who first install the system and later claim the subsidy amount after verification. Households pay the remaining costs net of subsidy.

Comparing the costs of the two technologies, we see that households tended to pay considerably less for SHS than for biogas plants. Adding to this up-front cost differential is the fact that biogas plants also require considerably more labor to operate than SHS. The daily operation of biogas requires the collection of dung,[4] mixing it with water, and management of the slurry. In contrast to this, the SHS is easy to operate. Once installed, the household can simply switch it on to get lighting.

Data and variables

This study is based on secondary data obtained from the Nepal Living Standard Survey III 2010/11 (CBS, 2011a), which adopted the methodology of the World Bank's Living Standard Measurement Survey (LSMS). This survey collected information on various indicators of households' living standards from a nationally representative sample of 5988 households drawn from 499 primary sampling units (PSUs). For this purpose, Nepal was divided into 14 different strata based on geographical and ecological regions. The PSUs were selected from the 14 strata using Probability Proportional to Size (PPS), where size was based on the number of households. From each PSU, 12 households were randomly selected (CBS, 2011a).

In the sample, about 62% of all households owned at least one cow or buffalo, thus making them eligible for the biogas subsidy. Likewise, 19% of households were not connected to grid electricity because they resided in an off-grid rural area, thus making them eligible for the SHS subsidy.

The analysis of biogas and SHS technology was carried out using the full sample (5988 households) and sub-samples of subsidy-eligible households (3279 for biogas and 1008 for SHS). We use the full sample to examine the extent to which the eligibility criteria help to target poor households. Then we use the sub-samples of households that are eligible for the subsidies to assess how adoption varies by income and other characteristics within the eligible groups.

Biogas is used for cooking meals and requires animal dung to produce flammable gas whereas SHS is used for lighting and requires

[1] Thirteen households in the sample do not own cattle but still own biogas. They may get dung from relatives, neighbors, or a landlord, and share the biogas with them.

[2] The categorization of the VDCs is done by the Ministry of Federal Affairs and Local Development.

[3] 1 USD = NPR 74.36 (Annual Average of the year 2010 from www.onda.com).

[4] Open grazing is less practiced in Nepal these days as most of the forests are managed by communities who restrict open grazing. There is tendency of keeping cross-breed cattle which require stall-feeding. Therefore, households collect fodder from forest and their own lands and stall-feed cattle. Further, fields have standing crops for most of the year. These practices limits the movement of cattle and so households do not need to collect dung from a large grazing area for much of the year. It can, therefore, be worthwhile for even poor households with a single cow to adopt biogas plants.

sunshine to recharge the battery. Therefore, we estimate separate regression models for biogas and SHS.[5] The dependent variable for biogas is a binary variable that equals 1 if the household adopts biogas and 0 otherwise. Similarly, the dependent variable for SHS equals 1 if the household adopts SHS and 0 otherwise. Explanatory variables include observable variables as well as spatial fixed effects that control for unobservable variables, which are explained below. The observable explanatory variables include *household poverty*, *subsidy category*, *ethnicity*, *remittance*, *credit*, and *household demographics*.

Household poverty is equal to 1 if the household falls below the official poverty line. We used the region (stratum)-specific poverty lines provided by the Central Bureau of Statistics. The national average of the stratum-specific poverty lines in 2010–11 was a per-capita annual expenditure of NPR 19,261 (USD 259). According to (CBS, 2011b), the estimation of poverty is done through the Cost of Basic Needs approach.
Subsidy category indicates subsidy categories for biogas and SHS. The subsidy for biogas is categorized into three categories, i.e., 15 remote districts without road access (1 if the household resides in these districts, 0 otherwise), 20 districts of the *Terai* (1 if the household resides in one of these districts, 0 otherwise) and 40 accessible districts (1 if the household resides in one of these districts, 0 otherwise). Similarly, for SHS, the subsidy is categorized as not remote subsidy category area (1 if the household resides in one of these districts, 0 otherwise), remote subsidy category area (1 if the household resides in one of the remote districts, 0 otherwise) and very remote subsidy category area (1 if the household resides in one of the very remote districts, 0 otherwise).
Ethnicity is an important variable not only because the *Dalit* and backward communities reside in rural areas and are generally poor (Pattanayak & Lewis, 2012) but also because the subsidy policy has prioritized *Dalit* ethnic groups for RETs delivery. There are hundreds of ethnic groups in Nepal but for the purpose of our analysis we have categorized ethnicity into five major categories: *Brahmin* and *Chhetri* (1 for yes and 0 otherwise) as higher castes and *Dalit*, *Janajati*, *Madhesi* and other ethnicities as lower castes.
Remittance refers to money received by a household when a member works abroad who may send back money for particular expenses such as construction of biogas or purchase of SHS. Given this possibility, the study investigates if remittance has some role to play in the adoption of RET or not. It is a dummy variable that is defined by the remittance received by a household (1 if the household receives remittance and 0 for no remittance).
Credit plays a vital role in the adoption of RETs since some households do not take loans whereas other households take loans from two major sectors: informal and formal. In the research, the informal sector is defined as friends, relatives and landlords (1 for yes, 0 otherwise). The other dummy variable is for households taking loans from NGOs and cooperatives (1 for yes, 0 otherwise) that are part of the formal sector. Since there are households who have access to national banks, these households are represented by the variable "households taking loans from banks" (1 for yes, 0 otherwise), which too come under the formal sector. It was expected that the credit support would help poor households to adopt the RETs.
Household demographics include the household size, sex of household head (1 for male and 0 for female), age of household head, number of school-going children, and the highest level of education among the household members.[6]

Fixed effects are used to control for spatial unobserved effects in order to correct for the omitted variable bias. The Central Bureau of Statistics reduced 14 strata to 12 analytical domains by merging mountain areas of the mid-and far-west regions and merging the *Terai* area of the mid-and far-west regions (CBS, 2011b). We use fixed effects at the level of the analytical domain.

Results

Distribution of biogas and SHS adoption

In Nepal, about 19% of households were below the poverty line in 2010–11. Of the 3% of households who adopted biogas, only 2% were below the poverty line, whereas of the 6% of households that adopted SHS, about 25% were below the poverty line. Thus, only a tiny fraction of the biogas subsidy went to the poor, but a much larger fraction of the SHS subsidy went to the poor.

To investigate the distribution of biogas and SHS among rich and poor, Figs. 3 and 4 display the fraction of households that owns a biogas plant and SHS within each decile of annual per capita household consumption. The figures are plotted using the entire sample (5988), which includes both subsidy-eligible and non-eligible

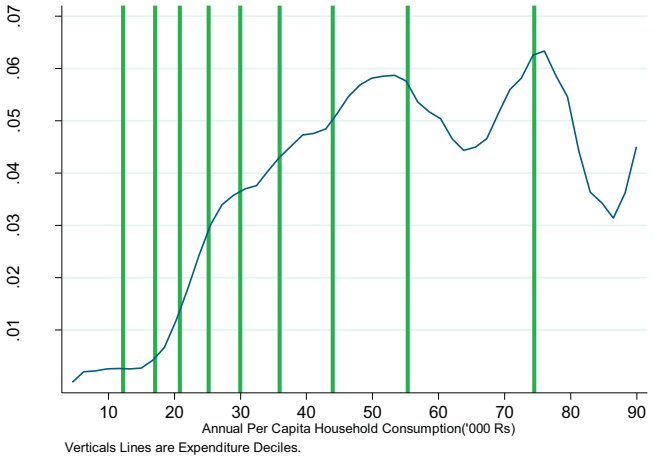

Fig. 3. Fraction of households owning biogas ($N = 5988$). The last decile is not reported in the graph as there were very few households adopting biogas and the annual per capita household consumption ranges between 89 thousand and 510 thousand.

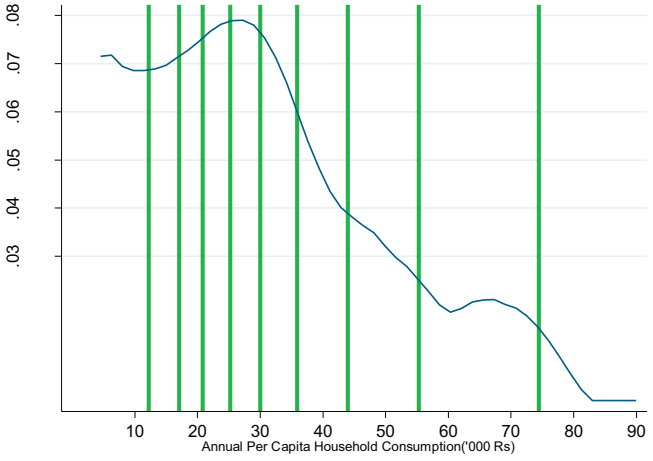

Fig. 4. Fraction of households owning SHS ($N = 5988$). The last decile is not reported in the graph as there were very few households adopting biogas and the annual per capita household consumption ranges between 89 thousand and 510 thousand.

[5] The data show that only 3 households in the sample have both biogas and SHS, which are too few to consider a joint analysis using multiple-choice models.

[6] If any member of a household has 15 years of education, which is the highest for all members of the household, then that household is given education level of 15 years.

households. These figures indicate that in the first decile, less than 1% of households own biogas while about 7% households own SHS. The percentage of households adopting biogas plants increases as one moves up through the consumption deciles while it is just the opposite for SHS. These figures show very clearly that the distribution of benefits favors richer households in the case of biogas and poorer households in the case of SHS.

In Nepal, households that are below twice the average poverty line (about 38,000 NPR), while they may not be officially poor, are clearly households with low incomes, since this amounts to the equivalent of just 518 USD. About 48% of households are below twice the poverty line, while 35% of biogas adopters and 57% of SHS adopters are in this category. This again illustrates that the SHS subsidy does a better job of reaching poorer households.

Figs. 5 and 6 display the fraction of the population owing biogas plants and SHS within each decile of annual per capita household consumption for the *subsidy-eligible households*. The figures are plotted using subsidy-eligible households i.e. 3279 for biogas plants and 1008 for SHS. Among subsidy-eligible households the probability of adoption increases with household per capita expenditure, for both biogas and SHS, although there is no clear increase beyond the 7th decile in the case of SHS. This is not surprising because richer households will always be better able to afford even a subsidized technology.

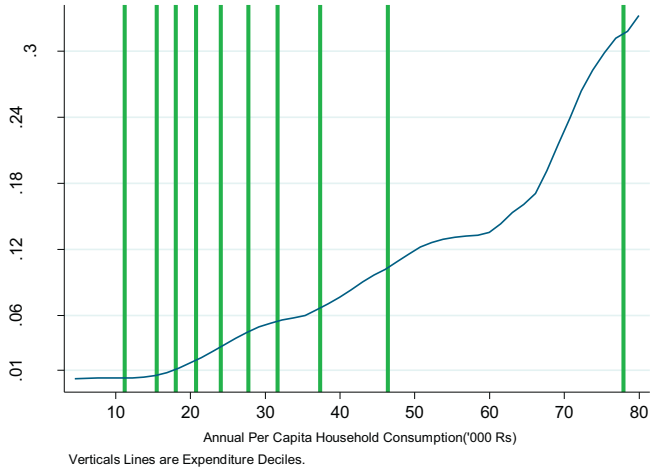

Fig. 5. Fraction of households owning biogas within the subsidy targeted population ($N = 3279$). The vertical lines are the mean value of each decile.

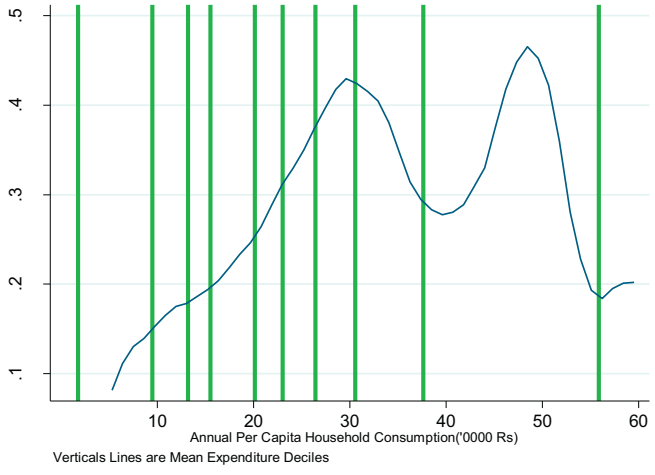

Fig. 6. Fraction of households owning SHS within the subsidy eligible population ($N = 1008$).

Summary statistics of major variables

Table 1 presents the summary statistics of the variables used to examine the adoption of biogas and SHS, for the two sub-samples used in the regression analysis, those eligible for the biogas subsidy (3279 households) and those eligible for the SHS subsidy (1008 households).

Table 1 shows that 5 and 27% of subsidy-eligible households have adopted biogas and SHS, respectively. Around 23 and 35% of subsidy-eligible households for biogas and SHS are below the poverty line, respectively.

The Subsidy Policy 2006 grouped the Districts into three major categories for biogas: remote districts without road access, districts of *Terai* (plains), and accessible districts. About 16% of biogas-subsidy-eligible households reside in remote districts without road access, while 50% of households live in accessible districts.

Similarly, for SHS the national Subsidy Delivery Mechanism specifies that subsidies can only be distributed to those households that are not electrified (i.e., not connected to the national or local grid). The Subsidy Policy 2006 grouped the Village Development Committees (VDC), the smallest administrative unit in Nepal until very recently, into three major categories for SHS: remote VDCs, very remote VDCs and not remote VDCs. Based on the criteria, higher subsidy amounts were allocated to very remote VDCs relative to remote and not remote VDCs. 58% of SHS-subsidy-eligible households reside in accessible VDCs while 36% of households live in very remote VDCs.

Regression results

In this section, we discuss the results of the regression analysis to investigate the factors that influence the adoption of biogas and SHS. Table 2 shows the marginal effects of the Logit model estimated with analytical domain fixed effects. The model is estimated using subsample of households that are eligible for the biogas and SHS subsidy.

As the main objective of this study is to observe the distribution of RET adoption between rich and poor households, the impact of the household poverty variable on biogas and SHS adoption is particularly important. In case of biogas, household poverty, one of the policy explanatory variables, is negative and statistically significant at the 1% level. The probability of a household adopting biogas decreases by around 46% if the household is below the poverty line (when other variables are evaluated at their mean values). The subsidy classification has shown that the probability of adopting biogas increases by 26 percentage points if the household falls under remote districts without road access compared to the accessible districts. This is because the accessible districts have other better cooking solutions such as liquefied petroleum gas (LPG). In case of SHS, Table 2 shows that the poorer households are 18 percentage points less likely to adopt SHS than richer households, a result that is statistically significant at the 1% level. Remoteness, on the other hand, has no effect on the adoption of SHS, which indicates that adoption is evenly distributed among the subsidy eligible areas.

Dalit, Janajati and *Madhesi* ethnic groups have less biogas adoption than the upper-caste *Brahmin* and *Chhetri* group. The probability of a household adopting biogas is 38, 18, and 42 percentage points lower if the household belongs to the *Dalit*, *Janajati* and *Madhesi*, respectively. In contrast, households from the *Madhesi* ethnic group are 15 percentage points more likely to adopt SHS technology than households from the *Brahmin* and *Chhetri* ethnic groups.

The coefficient of remittances is positive and statistically significant at the 5% level. The probability of a household adopting biogas increases by around 12 percentage points if the household receives remittance. For SHS, the coefficient of remittance is also statistically significant at

Table 1
Summary statistics for households eligible for the biogas and Solar Home System subsidy.

	Variables	Biogas		Solar Home System	
		Mean	Standard deviation	Mean	Standard deviation
Dependent variable	Biogas adoption = 1 if household has biogas, 0 otherwise	0.047	0.006		
	SHS adoption = 1 if household has SHS, 0 otherwise			0.273	0.446
Poverty	Household poverty = 1 if household annual per capita expenses are less than NPR 19,261 (Nepali Rupees), 0 otherwise	0.234	0.0112	0.349	0.477
Subsidy category (biogas)	Remote districts without road access (15 districts) = 1 if household resides in the 15 remote districts, 0 otherwise	0.163	0.0193		
	Districts of the *Terai* (20 districts) = 1 if household resides in the 20 remote districts, 0 otherwise	0.333	0.0212		
	Accessible districts (40 districts) = 1, 0 otherwise	0.503	0.0256		
Subsidy category (SHS)	Not remote subsidy category area = 1,0 otherwise			0.583	0.493
	Remote subsidy category area = 1,0 otherwise			0.06	0.237
	Very remote subsidy category area = 1, 0 otherwise			0.357	0.479
Ethnicity	*Brahmin* and *Chhetri* ethnicity = 1, 0 otherwise.	0.339	0.17	0.373	0.152
	Dalit ethnicity = 1, 0 otherwise.	0.147	0.009	0.16	0.011
	Janajati ethnicity = 1, 0 otherwise.	0.298	0.016	0.41	0.015
	Madhesi ethnicity = 1, 0 otherwise.	0.196	0.014	0.05	0.006
	Other ethnicity = 1, 0 otherwise	0.017	0.004	0.004	0.002
Remittance	Household receiving remittance = 1, 0 otherwise.	0.264	0.0129	0.174	0.379
Credit	Household with no credit = 1, 0 otherwise	0.301	0.459	0.3	0.458
	Household taking loan from friends, relatives and landlords = 1,0 otherwise	0.465	0.012	0.578	0.494
	Household taking loan from NGO and cooperative = 1, 0 otherwise	0.077	0.006	0.07	0.256
	Household taking loan from banks = 1, 0 otherwise	0.158	0.008	0.052	0.221
Household demographics	Household size	5.271	0.0564	5.16	2.325
	Sex of household head = 1 if male, 0 otherwise	0.761	0.009	0.751	0.433
	Age of household head in years	47.79	0.274	46.29	14.64
	Number of school-going children	1.867	0.0323	1.932	1.494
	Maximum education years in the household	5.145	0.112	4.34	4.58
	Number of analytical domains	11		6	
Number of observations		3279		1008	

the 1% level; the households receiving remittances are 10 percentage points more likely to adopt SHS than households that do not receive remittances.

Access to finance is widely discussed in the renewable energy literature (Glemarec, 2012; Pattanayak & Lewis, 2012). The probability of a household adopting biogas is 12 percentage points higher if the household takes a loan from a bank in comparison with a household that does not take a loan from any source. One reason for this is that the interest rate is comparatively low in banks in comparison with other financing mechanisms such as NGO, cooperative and money-lenders in informal market. However, borrowing money from the formal or informal sector does not appear to be associated with SHS adoption. Lenders in the formal sector, such as cooperatives and banks, do not maintain a loan portfolio for SHS.

The education level, measured as "maximum years of schooling of a household member", is statistically significant at the 1% level for both technologies. A one-year increase in the highest education level of a household member is associated with a 1.4 percentage-point increase in the probability of the household adopting biogas and 10 percentage-point increase in the probability of a household adopting SHS. These results indicate that an increase in the socio-economic status of the household increases the probability of adoption of biogas and SHS.

Targeting the right households – analyses from focus group discussions for biogas and SHS

In order to further understand the actual situation on the ground and complement the results from the countrywide data on renewable energy technology adoption, ten focus group discussions were held with the private-sector technology suppliers and with non-adopters in March and May 2014. These discussions were held in Kathmandu, Ilam, Jhapa and Dhangadi districts with suppliers and in Ilam, Jhapa, Doti and Dhangadi with non-adopters of the RETs.

Four focus group discussions were conducted with the biogas companies and one with biogas non-adopters. Likewise, four focus group discussions were conducted with Solar Home System (SHS) companies and one with the non-adopters. Four different checklists were prepared for the focus group discussions for biogas companies, SHS companies, biogas non-adopters and SHS non-adopters. Based on the checklists, using the free mind mapping software (wisemapping.com), the information was tabulated, categorized and analyzed.

Supply-side strategies for biogas

For both biogas and SHS, the Alternative Energy Promotion Centre (AEPC) is the government agency that is responsible for identifying the technology suppliers. It is also responsible for offering subsidies to encourage the use of these technologies. As explained above, these subsidies are offered to the companies who supply the technologies rather than directly to households.

To encourage the adoption of biogas, AEPC first selects qualified companies to construct biogas plants. These construction companies are responsible for promotional activities, plant installation and after-sales services. At the beginning of every fiscal year, each company presents a plan that outlines the districts it intends to target and the number of biogas plants that it intends to build. If a company fails to construct at least 70% of the number of plants set out in its annual plan, then it is disqualified for the next fiscal year. These biogas plant construction companies provide skilled labor, pipes and fittings, as well as appliances and accessories. They also provide details of all the installations they undertake to the AEPC and claim the subsidy they are eligible for after the installation has been completed.

While individual companies have their own promotional strategies, there are a few commonalities that every company adopts in order to select households for biogas plant construction (see Fig. 7). First, companies select locations based on information provided by local residents or by their staff. Then, they do a walkthrough visit using bikes or

Table 2
Fixed effect logit regression results for biogas and Solar Home System adoption.

	Variables	Marginal effect	
		Biogas	Solar Home System
Poverty	Household poverty (below poverty line)	−0.460*** (0.094)	−0.184*** (0.049)
Subsidy category (biogas)	Remote districts without road access	0.260*** (0.063)	
	Districts of the *Terai*	−0.058 (0.058)	
Subsidy category (SHS)	Very remote subsidy area		0.039 (0.049)
	Remote subsidy area		0.008 (0.075)
Ethnicity	*Dalit* ethnicity	−0.381*** (0.079)	−0.08 (0.061)
	Janajati ethnicity	−0.179*** (0.054)	0.045 (0.034)
	Madhesi ethnicity	−0.424*** (0.074)	0.154** (0.067)
	Others	−0.398*** (0.112)	0.017 (0.251)
Remittance	Household receiving remittance	0.122** (0.048)	0.102*** (0.038)
Credit	Household taking loan from friends, relatives and landlords	−0.048 (0.057)	0.019 (0.035)
	Household taking loan from NGO and cooperative	0.098 (0.08)	0.036 (0.058)
	Household taking loan from banks	0.124** (0.055)	0.021 (0.074)
Household demographics	Household size	−0.012 (0.014)	0.030*** (0.01)
	Sex of household head (1 if male, 0 otherwise)	0.115* (0.059)	0.011 (0.042)
	Age of household head	0.002 (0.002)	0 (0.001)
	Number of school-going children	0.024 (0.022)	−0.001 (0.015)
	Maximum household education	0.014*** (0.005)	0.10*** (0.003)
	Observations	3275	955
	Number of analytical domains	11	6
	Analytical domain FE	Yes	Yes
	Pseudo R-squared	0.182	0.06628

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: There are 12 analytical domains in the country. We include domain-level FE in order to control for the effects of geographic factors.

bicycles or on foot based on the location. During the walkthrough, they try to identify households that could afford biogas. Their basic criteria for selecting households relate to the size of livestock stalls, house types and the size of the rice straw stacks. When they find around 10 or more potential households, they then identify an influential person or a household in the locality and try to convince that person or household to construct a biogas plant. This is often done by going to the common meeting places in a village where local leaders gather. Biogas construction companies also ask lead households or individuals to gather 10 more households that they think might be interested in having a biogas plant; if a lead household is successful in doing that, then, they are normally offered some discount on the price of their plant. After households have been selected, a biogas expert from the construction company visits them and explains the costs and benefits of biogas plants and outlines the available subsidies. The companies also offer to construct demonstration biogas plants at a discounted rate if this is required to convince households to act. If a household commits to have a biogas plant, they are asked to provide a minimum of one thousand rupees as an advance.

University students and students from rural areas who are studying in cities are an ideal conduit through which biogas use can be promoted and propagated as such students often see the benefits of biogas plants in their adopted locales and motivate their parents back home to install one. Another way in which companies generate demand for biogas plants is by nominating an agent who will get a bonus if he/she recruits households for biogas plant installation. Such agents are often local schoolteachers, lower-level Village Development Committee officials, the representatives of local political parties and local traders. Such people are selected as agents because of their social status and powers of persuasion.

Biogas non-adopters

Although biogas non-adopters were from subsidy eligible area and had heard about biogas technology and the biogas subsidy scheme, they were not certain about the actual price of biogas and the amount of subsidy provided. Non-adopters mentioned that it would be easier for them to use biogas if they could rear cattle. However, they noted that they did not have enough land and human resources to both rear cattle and operate a biogas plant. In addition, it was noted that LPG was easily available. Smaller 'new generation' families reported that they found it easier to use LPG than biogas even though LPG was costlier. These families said that they were too busy with their work and other activities to get involved in the operation of a biogas plant (see Fig. 8).

Supply-side strategies for SHS

The promotion and distribution of SHS technology take place in a manner similar to the promotion and distribution of biogas. First, AEPC identifies companies that are eligible to supply SHS. Eligibility depends on a variety of factors such as the company's experience, its finances and its human resources. Eligible suppliers are then allowed to supply SHS to targeted VDCs. Currently, there are some 71 solar technology suppliers. These are almost all Kathmandu-based. The suppliers import solar photovoltaic systems from countries such as Germany, China, India and the USA.

While most SHS suppliers work all over Nepal, they focus more on the mid- and far-western regions of the country, which are largely

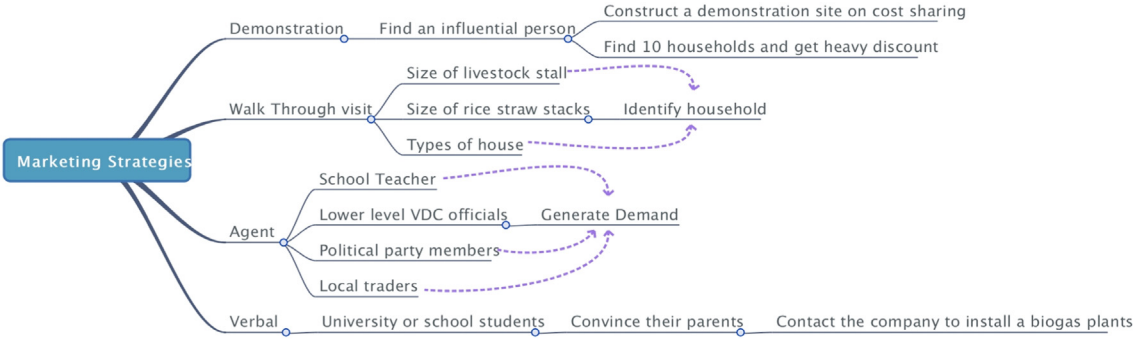

Fig. 7. Marketing strategies of biogas companies.

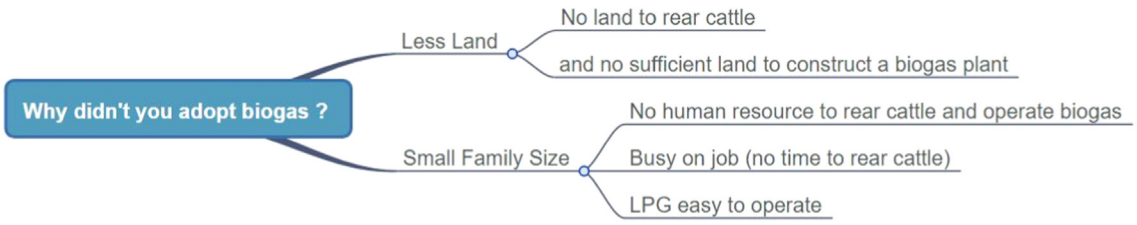

Fig. 8. Reasons for non-adoption of biogas.

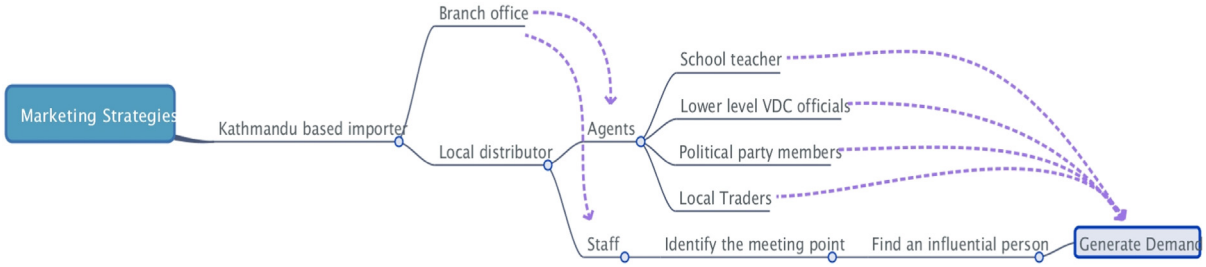

Fig. 9. Marketing strategies of SHS companies.

un-electrified. While selecting the districts to target, they collect information on the number of households without electricity and the number of VDCs targeted by the AEPC. They also collect information on population size. After screening the location, they look for potential distributors. They favor distributors that are financially capable and that have good marketing networks and good transaction reputations. Some suppliers open a branch office at district headquarters and employ staff to cultivate a demand for SHS at the village level. Once the demand for SHS has been fully met in a village or district, they close their branch office and move on to another area. Distributors may also nominate village agents or hire marketing staff to identify potential buyers. The focus group discussions suggest that the first priority of suppliers is often to identify demand from villages near their district headquarters because this helps to minimize their transportation costs and the overhead costs of their employees.

Most Nepali villages have a "meeting point" or a small tea stall or local beverage shop where people from the village gather for informal discussions about regular village events and national political issues and where they also come to listen to the news on the radio. Most of the people who gather in these tea stalls are local elite (i.e., they are local political leaders, teachers or comparatively rich household heads). The focus group discussions indicate that the agents or marketing staff of SHS suppliers or distributors first visit these meeting points and try to convince the people who are gathered there to adopt SHS. If anyone shows interest, then they ask him to convince ten more people. This person therefore becomes an entry point to a village or someone who can generate demand within an area. See Fig. 9.

SHS non-adopters

The non-adopters of SHS were from the eligible population and they are not much aware of the technology even though they had seen SHS in neighboring households and knew that it provided lighting at night. When asked about solar companies, they said that nobody had ever visited these households to provide information about SHS although they had heard about the presence of a few people in their village who had installed SHS. Some of the adopters reported that they had bought SHS from a company's district headquarters. In such instances, we found that there had been no discussion or public meetings.

During the focus group discussion, non-adopters showed a high level of interest in buying SHS as they were facing difficulties in using traditional fuels for lighting (not only did they require much effort, they also emitted harmful fumes and smoke). However, since they said that they could not afford to install the system, they thought that smaller and cheaper systems would be more feasible. They also said that they would be able to afford systems priced between NPR 3000 (USD 30) and NPR 4000 (USD 40). They specified that such systems should be able to power three lights in addition to providing mobile charging. That said, some non-adopters showed no interest whatsoever in buying SHS as they had easy access to dry-cell torches that were cheaper than SHS and had the added advantage of very low monthly expenses compared to the cost of installing, maintaining and replacing the SHS when it gets old. See Fig. 10.

Findings

Fig. 11 summarizes the major findings. The top panel compares the density functions of household consumption for the two subsidy-eligible populations with that of the population as a whole. For both subsidy-eligible populations, the densities are shifted to the left indicating that the percentage of rich people in the subsidy-eligible populations is lower than in the whole population. However, this shift is much less for biogas than for SHS. This shows that the eligibility criteria

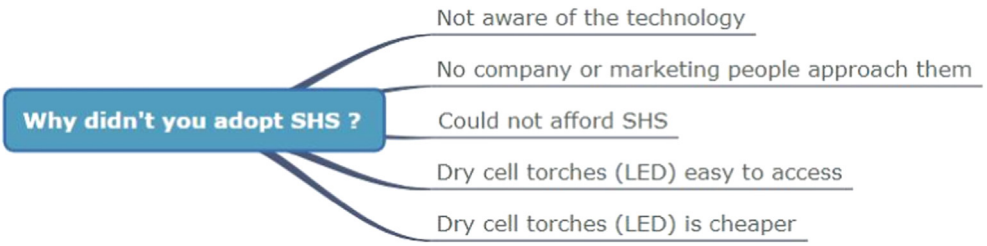

Fig. 10. Reasons for non-adoption of SHS.

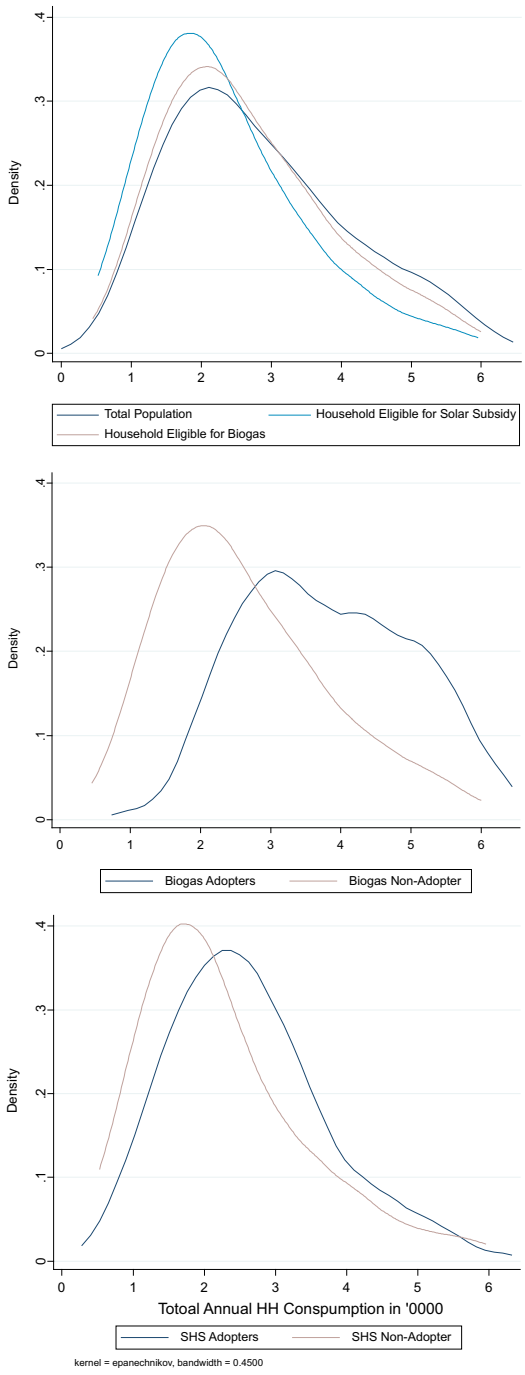

Fig. 11. Distribution of subsidy eligible households for biogas and SHS, and the adopters and non-adopters of both the technologies.

do tend to remove richer urban households, but much more for SHS than for biogas. This is because of the requirement of living in an area without a grid connection for receiving SHS subsidies.

For biogas adoption, the requirement of cattle ownership not only disqualifies richer urban households but also excludes the poor rural households who cannot afford to have cattle, leaving ground to the middle-income rural households for biogas adoption. This is seen in the middle panel that shows the density function of adopters shifted to the right of the density function of non-adopters among the subsidy eligible population. This is because adopting a biogas plant is expensive. Even after the subsidy, it may cost a household more than 40,000 NPR, which is almost twice the annual consumption expenditure at the poverty line. Therefore, richer households within the subsidy-eligible population are more likely to adopt biogas.

The bottom panel shows a similar, but much smaller, effect for SHS with the density function of adopters being to the right of the density function of non-adopters. Solar Home Systems cost less than biogas plants, with households paying less than 20,000 NPR in the more accessible locations. Therefore, although richer households are more likely to invest in SHS within the subsidy-eligible population, the lack of adoption of SHS by poor households is less severe than for biogas. It may also be that households find electric light more of a necessity than biogas for cooking so that more of the poorer households adopt it. This is also reflected in much higher overall adoption rates for SHS as compared to biogas.

Government subsidies for both the technologies are geographically targeted but the level is different. Biogas is targeted at district level (both rural and urban) whereas SHS is targeted at selected rural villages. In addition, the subsidy is distributed through private companies who construct/sell the biogas and the SHS. The companies look for higher probability of adoption once approached, and thus they target richer households in the eligible areas.

Conclusions and policy recommendations

Using representative household survey data, we analyze whether the subsidy policy of the government of Nepal is helping the rural poor to adopt renewable energy technology. We find that only 5% of households eligible for a biogas subsidy have adopted biogas and only 2% of the total biogas adopters are below the poverty line. There are many reasons why the Government has made only limited progress in its objective of providing alternative clean cooking energy to the rural poor. A major reason is the way the private sector is incentivized under the public-private partnership model adopted for this purpose. Though highly regulated by the Biogas Support Program and AEPC, not only do companies experience difficulties in identifying and engaging with the poor, they also have very little interest in approaching the poor since the amount of subsidy is minimal and poor households do not find the subsidy scheme sufficient for adopting the RETs. Thus, even when the companies could identify poor households, it was clear that visiting these households was not profitable for them as the probability of adoption is very low for poor households. Given that the biogas subsidy is targeted at the district level (which covers a large area), biogas technology suppliers tend to target families that are easier to reach, and relatively richer (with sufficient land and cattle), thus overlooking poor families that are eligible for the subsidy but are more difficult to reach with low probability of adoption. The supplier companies reported that it was difficult to make poor households understand the available technology and subsidy mechanisms. Added to this is its high cost despite the subsidy as the subsidy only covers maximum 30% of the total installation costs.

The subsidy program for SHS has been more successful at reaching the poor, with 27% of eligible households having adopted SHS for lighting and 25% of SHS adopters being below the poverty line. However, though the Government of Nepal has been promoting SHS for more than two decades as a means to increase the clean energy access of poor and marginalized households, 60% of households below the poverty line who are eligible for the subsidy (since they live in off-grid areas) have not yet adopted it. While the geographical targeting of the SHS subsidy has meant that it has reached its target area and that it is helping to provide off-grid households with access to clean energy to light their houses, the incentives generated by the public-private partnership model stymies efforts to reach the subsidy eligible poor households. Private SHS companies have little interest in investing their time in convincing poor households to take up SHS. The perception among poor households that they should get RETs for free makes private companies reluctant to visit them. Thus, private companies focus more on relatively richer households because such households are financially more capable of installing RET systems than poor households. To help overcome this problem, geographical

targeting may be more effective in reaching the rural poor if it is done using the smaller wards as the targeted units rather than VDCs.[7]

One of the objectives of the United Nations initiative on Sustainable Energy for All (SE4ALL) is to ensure universal access to modern energy services by 2030. Our study therefore recommends policy alternatives to reach the rural poor with such services. Firstly, a new classification of various groups of poor households and the targeting of these groups with specific programs would be needed to enable Nepal to meet the United Nations'SE4ALL objectives. Secondly, to effectively reach out to the poor, it is imperative to revise the way in which the subsidies are targeted now, targeting wards within VDCs where poverty is high. In the case of the biogas subsidy, for instance, it should be targeted at the VDC level where it is currently targeted at the district level. Thirdly, a different subsidy delivery mechanism and business model should be developed in order to provide clean energy to the rural poor; one such mechanism could be the introduction of the battery charging station concept; another would be for private companies to be given some quota to provide biogas to the poor households that have a cow or a buffalo. Fourthly, as there are various governmental agencies already reaching the poorest sections of Nepal's population, the AEPC could collaborate with these agencies to reach the rural poor. For example, the Poverty Alleviation Fund and the Leasehold Forestry Program focus on the rural poor households with a mechanism to identify such households. Collaboration between AEPC and such programs could deliver clean energy services more effectively to the rural poor.

It is clear that a different mechanism is needed to reach the rural poor. Our research, however, has not analyzed all the possible mechanisms for reaching the poor, leaving ground for future research. Research and development is another avenue for improving the quality of the biogas plants while reducing the installation costs. This may entail the replacement of some expensive construction materials or the adoption of a different business model. In addition, electricity production in Nepal is increasing. If the hydropower plants that are under construction or planned are completed on time, then Nepal would have enough electricity to meet its peak demand. In that case, electric induction cookers would be another clean cooking solution. And for the off-grid households it would be innovative to test the solar based induction cookers and promote them if the upfront and operation cost is cheaper than biogas. For SHS, the future looks brighter as the cost of the technology is falling.

[7] A VDC (Village Development Committees) was an administrative unit (until 2016), divided into 9 wards. Now, several VDCs are clubbed together for making a rural municipality.

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