

Energy consumption pattern and renewable energy alternatives in Madi Kalyanpur, Chitwan, Nepal

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Abstract

Energy consumption pattern and greenhouse gases emission are interrelated. The unsustainable use of biomass and widespread use of commercial energy are of the major sources of greenhouse gas emission. The alternative to kerosene for lighting is solar home system (SHS), which is one of the potential renewable technologies for rural electrification. The present study has analyzed household energy consumption pattern and greenhouse gases emission from energy consumption practices as well as environmental and economic benefits of SHS in Madi Kalyanpur Village Development Committee of Chitwan district. For the purpose, the primary data were collected through household questionnaire survey, key informant interview (KII) and focus group discussion (FGD). The analysis has shown that 22% of household use all types of energy, i.e. fuel-wood, LPG (liquefied petroleum gas), biogas and SHS as the sources of energy. Thirty-five percent households use fuel-wood, LPG and SHS, 24% use fuel-wood, biogas and SHS, 1% used LPG and SHS, 5% use biogas and SHS, 4% use LPG, biogas and SHS and 9% use fuel-wood and SHS as a source of energy. Almost all people have been using SHS for the lighting purpose. The average annual greenhouse gases emission per household from fuel-wood and liquefied petroleum gas consumption was 7.89 ton and 0.17 ton of CO₂ equivalent respectively. Typically, a 40 Wp SHS reduced the consumption of kerosene by 42 liter annually for lighting that displaced 0.11 ton of CO₂ equivalent per household per year. The simple payback period for typically 40 Wp SHS was found to be nine years with no subsidy, seven years with subsidy from Alternative Energy Promotion Centre and two years with Indian Government Grant. Similarly, the benefit-cost ratios were found to be 3.1, 3.5 and 4.6 for the systems with no subsidy, with AEPC subsidy and with Indian Grant, respectively.

Key words: Cost-benefit Ratio, Cost Payback Period, Greenhouse Gases Emission, Solar Home System

Introduction

Biomass is an indigenous energy source in Nepal. Three broad types of energy sources exist in Nepal: commercial, traditional and alternative energy (WECS, 2010). Energy that is environmentally friendly and can be used repeatedly without depletion is regarded as a renewable energy. This includes energy like wind, solar and geothermal energy. Speaking strictly, the forms of renewable energy are environmentally favorable, with no significant negative impacts and are economically viable (Upadhaya, 2008).

In Nepal, the solar energy has been used traditionally for drying the crops, clothes, fuel-wood and crop residues. The solar energy potential in Nepal is estimated to be about 26 million MW (CRI/N, 2005). The first recorded use of Solar PV in Nepal can be traced back to 1963, when Civil Aviation Authority of Nepal installed a Solar PV system in Bhadrapur, Jhapa airport to run navigation equipment. Its use for domestic electrification started in July 1993,

when Pulimarang Solar Village Electrification Project (PSEP) was initiated and implemented by Centre for Renewable Energy (CRE) with the financial support from Solar Electric Light Fund (SELF), a USA based non-profit organization. The use of Solar PV for domestic electrification gained momentum from 1996, since when Alternative Energy Promotion Centre (AEPC) was established with the objective of developing and promoting renewable energy in Nepal. It formulated the policy to provide subsidies to the household in rural areas willing to install SHS (AEPC/ESAP, 2010).

An immediate impact of solar home system (SHS) in the environment comes from its replacement of traditional sources of power for lighting like kerosene, candle. The SHS provides light even at night through battery storage, providing additional time to children for their study. The solar PV technology in Nepal has shown a tremendous growth. This unprecedented growth of solar

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PV in Nepal is mainly due to three reasons- good solar radiation potential, poor access to the national grid electricity throughout the country, and increasing power cuts in urban area (Malla & Niraula, 2012). The number of SHS installation in the rural areas of Nepal by AEPC and other programs had already been more 3,30,000 as of July 2013 (AEPC, 2013).

The use of kerosene has negative impact on health and environment. Most of the household income was used to spend for kerosene and income-generating activities were limited. It was difficult for children to read in light of kerosene. To avoid these drawbacks of kerosene lighting, renewable energy technology has been emerged; among which SHS is best suited for the country like Nepal. The general perception of the people is that SHS is more costly than kerosene due to its high installation cost. Thus, this study has analyzed, whether SHS is really a viable option or not from the environmental and economic perspective. Madi Kalyanpur Village Development Committee (VDC) of Chitwan district (Buffer Zone of Chitwan National Park), still far from access to the grid electricity and almost all houses have installed SHS, was selected the sample VDC for the present study. Besides, only limited studies have been done regarding the potential of SHS to reduce greenhouse gases in consideration with economic prospects. Thus, the present research was carried out to fulfill such research gap focusing on current energy consumption pattern along with the analysis of economic and environmental benefits of SHS.

Materials and Methods

The present study was of descriptive type and based on primary as well as secondary data. The area was selected purposively for the study, as there was already 698 SHS installed till 2010 AD under subsidy scheme of AEPC (AEPC, 2010) and the area was deprived of grid electricity. By the year 2014, the installation of SHS has increased to 1339 (AEPC/NRREP, 2014). The number of sample households was calculated using the empirical formula (Arkin & Colton, 1963; Paudyal, 2007). About 98% of household has SHS, so all the households were assumed to be SHS users (according to KII and FGD).

$$\text{Sample size, } n = \frac{NZ^2 P (1-P)}{Nd^2 + Z^2 P (1-P)}$$

Where,

n= Sample size (70)

N= Total number of households (1705) (CBS, 2012)

Z= Abscission of normal curve, i.e. Confidence level (at 95%, Z=1.96)

P= Estimated population proportion (0.05 this maximizes the sample size)

d= Margin of error limit (+/-5%)

The sample size was calculated as 70, but 86 samples (households) were taken which is also 5% of 1705 (total household). The total samples were first stratified among nine wards of the VDC along

with its household proportion. After that, samples were taken with SHS user through household questionnaire survey. Ms-Excel was used for calculation and interpretation of the data. Using emission factor (EPA, 2014) in the data obtained from questionnaire survey, the GHGs emission from the current energy consumption practices and its reduction by introducing solar energy technology was obtained.

Calculations

Estimation of green house gases (GHGs) emission and reduction potential

The emission factors for various types of fuel combustion given by EPA (2014) were used for GHGs emission and reduction from respective fuels (Table 1). The global warming potential of GHGs is given in Table 2.

Table 1 Emission Factors of Combustion of Various Fuels

S.N.	Fuel source	Emission factor (CO ₂ e)
1.	Fuel wood	1.830 kg/kg
2.	Kerosene	2.689 kg/lit
3.	LPG	2.953 kg/kg

EPA (2014)

Table 2 Global Warming Potential (GWP) Factors

S.N.	GHG	100 year GWP factor
1.	CH ₄	25
2.	N ₂ O	298

(IPCC, 2007 cited in EPA, 2014)

Simple cost payback period

Payback period is defined as, in what year the total percentage of the purchase price is get back as a function of energy saving. It was simply calculated as;

$$\text{Simple cost payback period (CCP)} = \frac{C_{in}}{C_s - C_{om}}$$

Dhoubhadel (2010)

Where,

C_{in} = Installations cost of PV System, i.e. initial investment cost taken as average for 40 Wp, NRs 23,000, NRs. 17,000 and NRs 6,000 for no subsidy, with subsidy from AEPC and with Indian Government Grant, respectively.

C_s = Annual cost saved by utilizing the PV system was taken as saving in terms of cost of kerosene consumed per year. Average value of fuel consumption per month (3.5 liter/month and operating and maintenance cost taken as constant, i.e. NRs. 300/year) prior to using SHS was calculated based on survey.

C_{om} = Annual operation and maintenance cost of SHS was taken in terms of cost of distilled water consumed per year, cost of charge controller, bulb, wire, switch per year (NRs. 800 constant throughout lifetime of SHS) and assuming battery life of 5 years (battery cost of NRs. 10,000).

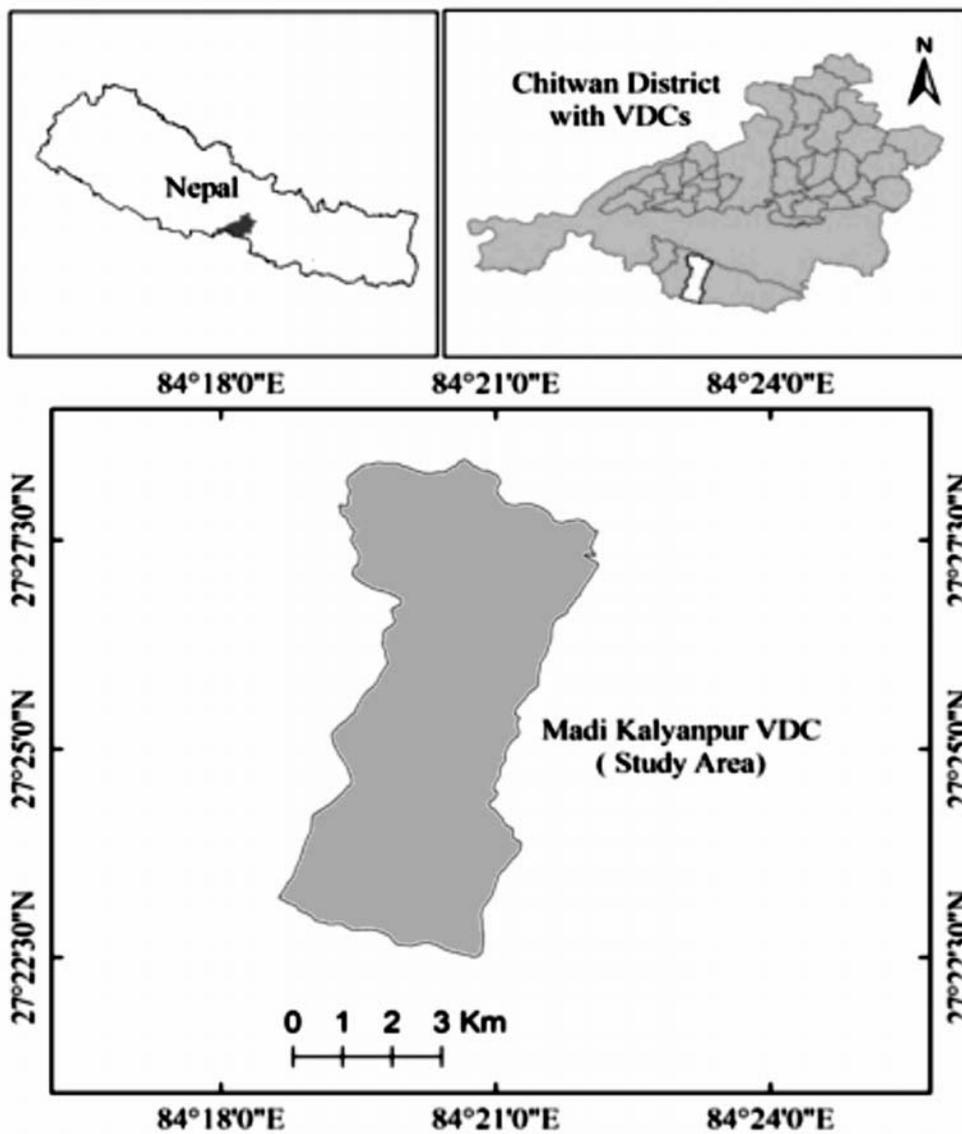


Figure 1 Location of the study area

Financial benefit

The amount of money saved from the kerosene consumption for lighting, due to installation of SHS for lifetime of 25 years (NRLE, 2014) was taken as financial benefit. The price of kerosene in 25 years lifetime was calculated with the inflation rate of 9.47% (NRB, 2014). The price of kerosene in the study area was NRs. 110 during survey.

Cost-benefit analysis

Cost-benefit analysis evaluates alternative risk levels by comparing the value of the expected gains with the associated costs. For cost-benefit analysis, the cost of SHS installation and its operating and maintenance cost required for smooth running of SHS was calculated, and benefit was calculated in terms of cost saved

due to reduction in use of kerosene with inflation rate of 9.47% (NRB, 2014). Benefit-cost ratio (BCR) was estimated for the analysis of cost-benefit, where net present value (NPV) was calculated with 7% interest rate (NRB, 2014).

Mathematically,
$$NPV = \sum_{T=0}^n \frac{Value\ T}{(1+rate)^T}$$

$$BCR = \frac{PV_{benefits}}{PV_{costs}} \quad \text{Shively \& Galopin (2014)}$$

Where,

PV_{benefits} = Present value benefit

PV_{costs} = Present value cost

If PV_{benefits}/PV_{costs} > 1, option is considered feasible

Results and Discussion

Energy consumption scenario

Different household used different types of energy for fulfillment of their need. The result showed 22% of household use all types of energy, i.e. fuel-wood, LPG, biogas and SHS as the source of energy, 35% use fuel-wood, LPG and SHS, 24% use fuel-wood, biogas and SHS, 1% use LPG and SHS, 5% use biogas and SHS, 4% use LPG, biogas and SHS, and 9% use fuel-wood and SHS as the source of energy (Fig. 2).

GHG emission from energy consumption practices

Fuel-wood was the main source of energy that contributed to the most in the emission of greenhouse gases. Fuel-wood and LPG used per household per year was 4311 kg and 57 kg respectively that contributed about 7889.13 kg (7.89 ton) and 168.32 kg (0.17 ton) of CO₂-equivalent respectively. The high amount of GHG emission from fuel-wood was due to the use of high amount of fuel-wood to fulfill energy demand. The methane emission leaked from the biogas plant without burning was not considered in the calculation of GHGs emission.

Status of SHS

All households had SHS, as there was no provision of grid electricity due to Chitwan National Park. In the study area, SHSs were installed both with subsidy (through AEPC and Indian Government) and without subsidy scheme. Only in ward no. 5, SHSs were installed with subsidy scheme brought by Indian Ex-army through Indian Government. The used solar panel capacity ranged from 20-290 Wp. There was maximum use of solar panel of capacity ranging between 20Wp and 50 Wp, i.e. about 78% of which is slightly consistent with the result of TRUST (2003), i.e. the most popular size in Nepal is 35-45 Wp PV modules and 50% of them were of 40 Wp. Moreover, the used solar battery capacity ranged from 35 to 175 Ah. About 40% of household used solar battery of capacity 57 Ah. Eighty one percent of household of study area used the solar battery ranged from 35 to 75 Ah that is nearly consistent with the result drawn by Khanal (2014) that 76% battery range from 35 to 75 Ah. The result showed that there was maximum use of solar panel and battery having capacity 40 Wp and 57 Ah respectively. This might be because of the basic purpose of SHS (lighting, radio

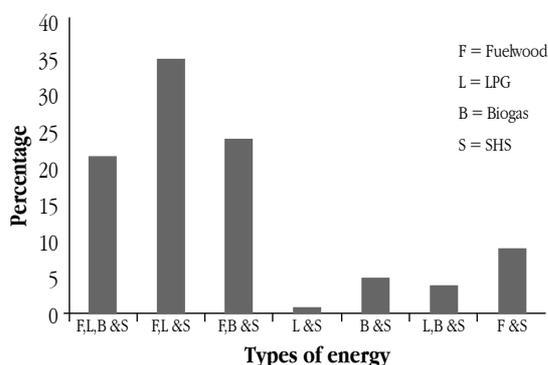


Figure 2 The different types of energy used

and mobile charge) would be to fulfill through the capacity of SHS of that range. In addition, the larger capacity of SHS was used for TV, water pumping, internet and fridge. From the study, it was found that the average lifetime of battery was 5 years. Though the guarantee given by suppliers was 2 years, it was found that many of the batteries were operational even for 5 years. It might be because of regular maintenance like supply of distilled water and placing it in safe place.

Energy consumption activities of SHS

Among the surveyed households, 100% respondents were found to use SHS for lighting and mobile charge, as there was no grid electricity. The main reason for installation of SHS was lighting and mobile charge. In addition, TV, fan and others were also the reasons. Use of SHS was in accordance with capacity of solar panel and battery as well as the duration of light bulb use. The larger capacity of SHS was installed for the purpose of TV, fan, fridge, internet and water pumping.

Management of damaged battery

About 71% of the respondents used to sell damaged battery to scrap collector. The scrap collector used to pay around Rs. 2000 for the used battery. Only 15% of the users used to return to the dealer for getting discount on new battery. In addition, rest 14% of them used to throw away battery because they did not know that battery could be returned to dealer and scrap collector. Dealers, suppliers, or users did not give attention on taking and returning back battery. Thus scrap collector collect all the non functional battery paying little price. Scrap collectors collect battery so as take and sell the lead present on the battery.

GHG emission reduction due to installation of SHS

SHS was the alternative and renewable energy technology in the study area. Due to the use of SHS, the use of 42 liters kerosene was displaced annually (3.5 liter/month) per household that largely reduced the emissions of GHGs. SHS reduced 0.11 ton of GHGs in terms of CO₂-equivalent per household per year. The study carried out by Shakya and Shrestha (2006) showed that SHS replaced the use of kerosene for lighting purpose, which reduced 0.104 ton of CO₂ emission annually that is nearly consistent with the result of the present study.

Economic Benefit of SHS

Simple cost payback period

The cost payback period was calculated typically for 40 Wp solar PV panel, as use of SHS with that capacity was maximum in number in the study area. Considering 25 years lifetime for solar panel and 5 years for battery; the payback period of SHS was found to be 9, 7 and 2 years for no subsidy, with subsidy from AEPC and from Indian Government Grant, respectively, excluding inflation rate.

Table 3 Calculation of simple cost payback period

Scheme	Cin (NRs)	Cs (NRs)	Com (NRs)	Cs-Com (NRs)	CPP (Year)
Without subsidy	23,000	4920	2400	2520	9
With subsidy from AEPC	17,000	4920	2400	2520	7
With Indian Government Grant	6000	4920	2400	2520	2

Table 4 Calculation of Financial Benefit

	Weekly	Yearly	(NRs)
Avg. kerosene consumption per HH (liter)	0.87	42	-
Price of kerosene (NRs/liter)			110.0
Cost of kerosene consumed in 25 yrs (A)			459413.0
Operational & maintenance cost in 25 yrs (B)			7500.0
Total cost of kerosene in 25 yrs (A+B)			466913.0

The payback period of SHS was much less with Indian Government Grant compared to no subsidy scheme; this might be because of the greater subsidy amount, i.e. NRs 15,000. According to Hoque and Das (2013), the average value of cost payback period was found to be 4.2 years for 50 Wp solar panel with the lifetime of 20 years, such a decrease in payback period might be because the average kerosene saved by 50Wp system was around 20.50 liter/month which was more than the result of the present study.

Financial benefit

It was found that the use of SHS with 40 Wp capacity reduced the use of 42 liters (3.5 liter/month) of kerosene for lighting annually per household. The average monthly replacement of the kerosene for lighting after installation of SHS was estimated to be 4.48 liters per household per month (TRUST, 2003), which is a bit higher, but nearly consistent with the result (3.5 liters per month) obtained in this study. The reason behind heterogeneity in use of kerosene per month might be due to different kerosene consumption period, family size and place. The saving in total cost of kerosene to be consumed in 25 years could cover the cost of SHS installation. The cost saved from kerosene for lighting was NRs 4, 66,913, while taking a 9.47% inflation rate in kerosene and assuming that the baseline lighting kerosene remains unchanged for the period of 25 years.

Cost benefit analysis

The study showed that benefit-cost ratio was greater than one, which means the use of SHS is feasible. The benefit-cost ratio was found 3.1:1, 3.5:1 and 4.6:1 for no subsidy, subsidy from AEPC, and from Indian Government Grant, respectively.

Conclusion

Energy is the fundamental need of human. The present study has found that there was a substantial use of fuel-wood for cooking and preparation of animal feed along with LPG and biogas.

- All people use SHS for lighting, as the area was deprived of grid electricity, far from the major market centre (Bharatpur) and an availability of other energy sources in the area is limited.
- The use of kerosene was displaced for lighting (yearly 42 litre) due to installation of SHS, which reduced the emissions of GHGs to large extent.
- The SHS was found to be economically beneficial as benefit-cost ratio was found to be 3.1:1, 3.5:1 and 4.6:1 for system with no subsidy, subsidy from AEPC and from Indian Government Grant respectively.
- Thus, SHS is one of the best alternatives in reduction of CO₂ emission by replacing burning kerosene for lighting and is economically beneficial.

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