Health Impact of Using Solar Panels: Experience from Island Communities in Bangladesh

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Abstract

Renewable energy is one of the most efficient and effective solutions to the environmental pollution problem in Bangladesh. Solar energy has high potential in rural island areas. The study aims to find solar energy's impact on health by examining whether there is a difference in health costs before and after installing solar panels in rural Bangladesh. Primary data were collected randomly from 300 sample respondents by questionnaire survey method in the study area. Stratified sampling method was used to collect data for analysis. Sample paired t-test and a binary logistic regression model were used here as statistical tools for analyzing data exploring the environmental impact of solar energy on the health of the sample respondents. The results show that the respondents' health costs, both in total and item-wise, were reduced to a great extent after using solar energy. Although the above study results might help the stakeholders understand the positive impact of using solar energy on human health, particularly in the off-grid areas and the environment as a whole in Bangladesh.

Key Words: Solar Energy, Health Impact, Household Subscribers, Island Communities, Bangladesh.

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1. Introduction:

The generation and transmission of energy have huge impacts on the environment. While the conventional ways of generating energy pose a threat to the environment including a rise in the level of harmful radiation as well as pollution of air, water, and other media. Renewable energy technologies offer a creditable solution to many environmental hazards related to fossil fuel use (Energy Commissions, 1995 and 1997). Solar energy-based systems offer significant environmental solutions by reducing carbon dioxide emissions and lowering waste product emissions compared to the energy sources like gas, coal, diesel, and other non-renewable energies. This greatly contributes to sustainable development (Tsoutos*et al*., 2005). According to the report of the Bangladesh Power Development Board (BPDB 2023), there is a daily average shortage of 1,500 to 1,700 MW in power production.

More than 67.21% of the power plants in Bangladesh are based on natural gas, 2.35% are coal based and 5.52% are diesel-based, whereas, hydropower based power plants are very scant in quantity amounting to only 2.58% of the total electricity production and generation (Bangladesh Economic Review, 2019).Moreover, Heavy Fuel Oil(HFO) based plants have recently been introduced which are now contributing around 22.34% of the total electricity supply (BPDB, 2012).

Although the Government of Bangladesh (GOB) has set a target to generate 5% of total electricity from renewable energy sources by 2015 and 10% by 2020, it is still far from meeting this target. Infrastructure Development Company Limited (IDCOL) with its 56 partner organizations pioneered the solar home system (SHS) program in Bangladesh. Grameen Shakti (GS) is a leading partner organization of IDCOL that has played a significant role in increasing the number of SHS installations in different rural villages of Bangladesh.

The production of power from solar energy, like other non-conventional energy sources, is free from such pollute consequences. There are some adverse impacts of oil burning on health. Hence, the indirect costs associated with the production of energy by conventional systems must be

included in the estimation of production costs to obtain the true economic value. This would help in assessing the economic viability of the solar photovoltaic (SPV) system in the context of the rural electrification program.

Against this backdrop, solar energy can be a convenient option for energy production on a large scale in Bangladesh. Moreover, due to this ideal geographic location and climate, the country receives plenty of sunlight that can be used to generate ample electricity in rural areas ((Islam, 2008). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring. In 2021, CO_2 emissions for Bangladesh were 106.9 million tones. CO_2 emissions in Bangladesh increased from 3.5 million tons in 1972 to 106.9 million tons in 2021 growing at an average annual rate of 7.34% (World Data Atlas Bangladesh Environment 2023).

As a matter of fact, the production and use of 1.4 million tons of SHSs throughout the country may minimize about 0.8 million of carbon emissions a year (Hoque*et al*., 2014). However, since 1996 Bangladesh is using SHSs only in its rural off-grid areas including the islands. Off late, the use of SHSs has been extended to rural roads, urban streets, and highways across the country (Hoque*et al*., 2014).

In developing countries especially in rural areas, around 3 billion people rely mainly on kerosene, firewood and charcoal, agricultural waste, and animal dung to meet their energy needs for lighting and cooking. Kerosene emits smoke and creates indoor air pollution which is responsible for asthma, cough, sinus, headache, eye irritation, bronchitis, etc. Each year close to 3.8 million people die prematurely from illnesses attributable to household air pollution. Among these 3.8 million deaths, 27% are due to pneumonia, 18% from stroke, 27% from heart disease, 20% from chronic obstructive pulmonary disease, and 8% from lung cancer (World Health Organization 2018).

In island areas of Bangladesh, most of the people use kerosene lamps for lighting and then perform various household works like cooking, making

handicrafts, studying, praying/worshipping, making dinner, etc. in the evening and early at night. As a result, indoor air pollution causes their chronic sinus, headache, eye irritation, and various respiratory diseases. But the solar panel does not emit any carbon and supplies smoke-free lighting. So the people of the island areas can protect themselves from suffering from these kinds of diseases by using solar energy in their homes and thereafter they can save their hard-earned money by reducing the costs of treatment, which will help them lead healthy and comfortable lives. In this context, further, it is pertinent to mention a survey result that the production and use of 1.4 million tons of SHSs throughout the country may minimize about 0.8 million of CO_2emissions a year (Hoque et al., 2014). By this time, Bangladesh has almost 15 years of experience using SHSs. Although, the use of SHSs has been extended later on to rural roads, urban streets, and highways across the country, actually, since 1996 Bangladesh has been using SHSs in its rural off grid areas including the islands.

Against this backdrop, taking some island areas in Bangladesh as a study area, this study intends to fill the research gap by analyzing the following issues and questions as research.

1. Whether the health condition of the users has improved after using solar panels in the selected island areas of Bangladesh; and
2. Whether health costs of the island communities in Bangladesh have fallen due to solar panel-induced clean environment.

2. Literature Review

Bangladesh is one of those countries that are most vulnerable to climate change effects in the world and substantially dependent on imported petroleum which poses a big burden for the economy and additionally creates 0.2667 tons of per capita CO_2 emissions in the country (Ahiduzzaman and Islam, 2011). But a prediction based on the experiment done in six different districts in Bangladesh explored that 1.4 million of SHSs can minimize 0.8 million tons of CO_2 emissions each year (Hoque et al. 2014). Similarly, Lie et al. (2013) found that renewable and cleaner energy sources and technologies available to households could reduce CO_2

emissions significantly. Akella et al. (2009) also showed that the rate of reduction of emissions over the years increased after the introduction of renewable energy in distant areas.

Although conventional energy sources significantly boost economic progress, they damage the environment and public health in general. A relevant instance in Odisha, India, is that household pollution resulting from conventional energy sources like kerosene could be limited by solar electrification, thus improving the environmental standard (Mishra and Behera, 2016). To the rapid development of solar power plants, Turney and Fthenakis (2011) attributed the fact that even large-scale solar power plants did not occupy more land than coal power plants per Kilowatt -hour life cycle. They also found that removing forests to make space for solar-based power plants caused CO_2 emissions of about 36g $CO_2kWh^{-1,}$ which was still significantly lower than emissions from coal-based plants, which was 1100g CO_2kWh^{-1}.

It is worthwhile to review here some studies conducted recently by Manisalidis et al. (2020), Tran et al. (2020), Brace et al. (2020), Mannucci and Franchini (2017), Brac et al. (2020), and Padia et al. (2010) related to the impact of indoor air pollution on human health. Manisalidis et al. (2020) narrated in their study that indoor air pollution has an impact not only on climate change but also on public health due to increased morbidity and mortality. Many diseases are caused by the pollutants in the air in humans via respiratory problems. The major diseases are chronic obstructive pulmonary disease, asthma, bronchitis, lung cancer, cardiovascular events, and central nervous system. They also commented that public awareness coupled with multidisciplinary approaches by scientific experts and national and international organizations must address the emergence of this threat and propose sustainable solutions.
Tran et al. (2020) also found that inhaled air pollutants are associated with allergic diseases and pulmonary diseases, such as asthma, atopic dermatitis, allergic rhinitis, chronic inflammatory pulmonary diseases, and chronic obstructive pulmonary disease (COPD). COPD diseases result

from an enhanced chronic inflammatory response in the airways and the lung to toxic PM or indoor air pollutants. Tran et al. demonstrated in their study that women, especially in developing countries, have a great risk for COPD because of exposure to household smoke from burning kerosene.

Mannucci and Franchini (2017) comment that the deleterious effects of ambient air pollution on human health have been consistently documented by many epidemiologic studies worldwide, and it has been calculated that globally at least seven million deaths are annually attributable to the effects of indoor air pollution. Indoor air pollution also seriously threatens human health, especially in low-income countries that still use biomass fuels as an energy resource.

Brace et al. (2020) argued that around 50 percent of people in developing countries rely on kerosene, coal, and biomass in the form of wood, cow dung, and crop residues for domestic energy. These materials are typically burnt in simple stoves with incomplete combustion. Consequently, women and young children are exposed to high levels of indoor air pollution every day. They added that indoor air pollution is a major global public health threat requiring greatly increased efforts in the areas of research and policy-making. Research on its health effects should be strengthened, particularly in relation to tuberculosis and acute lower respiratory infections. They desired a more systematic approach to developing and evaluating interventions, with clearer recognition of the interrelationships between poverty and dependence on polluting fuels.

Padilla et al. (2010) stated that one-half of the world's population is exposed to high concentrations of solid fuel smoke (biomass and coal) that are produced by inefficient open fires, mainly in the rural areas of developing countries. Solid fuel smoke contains the most toxins in tobacco smoke and associated diseases, such as tuberculosis, asthma, and respiratory tract cancer. Moreover, interstitial lung diseases may also be associated with solid fuel smoke inhalation.

In this background, renewable energy is good worldwide not only from a socio-economic viewpoint but also from an environmental perspective; thus, a number of researches have been done addressing the environmental

and renewable energy issues. Kaygusuz (2002)'s study is worth mentioning here. He emphasized the utilization of renewable energy and pointed out its major environmental impacts from the sustainable development view in Turkey.

Imports in this country supply more than half the energy demands. High energy consumption has caused a rise in air pollution, ultimately becoming a major environmental concern for the country. As a cure for this situation, his suggestion was to go for renewable energy resources, which offer effective solutions to the long-standing environmental concerns in Turkey. Similarly, Nandi and Ghosh (2016) also indicated in favor of using renewable energy, and that wind–PV- diesel system has good feasibility with a 0% capacity of shortage and wind-diesel system has feasibility with a 5% annual capacity of shortage at all locations. The authors recommend that this kind of hybrid system will lower approximately 44% Green House Gas (GHG) from the atmosphere.

Earlier Nandi and Ghosh (2009) had analiyzed the data of the meteorological department for 1992-2003, which indicates that an intelligent power system can be developed over the year if solar energy technology is merged with wind energy technologies for the region Sitakunda. Rio and Burguillos (2008) showed that renewable energy sources have greater potential for sustainable development. They tried to contribute in this regard by integrating a theoretical framework and a comprehensive analysis of the impact of renewable energy on sustainability locally.

Similarly, Bahauddin & Salahuddin (2012) narrated that in Bangladesh, around 65% people lack access to electricity, and 44% live below the poverty line. They suggested combating these situations; renewable energy is one of the prospective sources to meet demand-supply. Hossain et al. (2015) narrated that to fulfill this huge demand for electricity; alternative energy sources must be used, like solar, wind, tide, etc., very effectively, which are also called renewable energy sources. Wadud et al. (2013) stated that to meet the energy crisis Bangladesh has experienced renewable sources like biogas, bio-fuel, solar energy, wind energy, tidal energy,

geothermal power, hydropower, etc. The authors suggested that renewable energy can be treated as an ideal solution for economic development.

Raugei and Franki's (2009) study focused on photovoltaic (PV) energy and its socio-economic and environmental impact. They found that the PV energy sector is flourishing fast, and the technical specification for PV has substantially improved over the last two decades. Based on this scenario, if economic incentives are carried over the next ten to twenty years, PV seems set for a glittering future and is supposed to play a vital role in the future energy sector. At the same time, they added that it would contribute to reducing the environmental impact of the electricity supply. In this connection, Mbake et al. (2010) stated that a reduction in the customs duties and taxes on imported PV modules by as much as 30% would extend the use of small-scale and eco-friendly PV mini-grids in distant regions of North Cameroon, which has an annual isolation of at least 5.55 kWh/m^2/ day.

Some research in Bangladesh context has been conducted on energy generation focusing on renewable energy, carbon emission by them on a large scale, and their effect on the environment on a small scale. The following section includes a review of the research.

Dulal et al. (2021) showed a picture of the percentage share of total energy generation capacity (MW) and carbon emission output over 5 years (2017-2021) in Bangladesh. The percentage share of energy generation from oil is 38.19 percent, and carbon emission is 47.81 percent; indigenous oil is 33.13%, and carbon emission is 41.47%; imported oil is 5.07%, and carbon emission is 6.34%; indigenous gas is 46.19 percent and carbon emission 43.06%, indigenous coal 6.13% and carbon emission 9.09 percent and from renewable energy 9.48 percent and carbon emission 0.04 percent. Therefore, indigenous oil generates a high percentage of carbon output relative to its percentage share of total energy generation capacity, and renewable energy produces no carbon emission.

Sohag et al. (2020) stated renewable energy share is only 3% of its total energy consumption and production. Now, the GOB is promoting

renewable energy projects to promote the renewable energy trend and sustainability in Bangladesh. The electricity generation in Bangladesh from fossil fuels affects the nation's sustainability and results in high carbon emissions, which are still a cause for worry. There is a need for renewable sources of energy which can fulfill the power demands of towns and industries of Bangladesh.

Chowdhury et al. (2018) viewed that incorporating renewable energy and the transportation system can be significantly beneficial for the economy and environment of Bangladesh. The energy produced by the PV system can provide up to 13 792 kWh/ year. Approximately 21% of the total production can be used in the charging station for charging electric vehicles, and the rest of the energy can contribute to the national grid. Moreover, using the proposed concept of green transport will ultimately reduce greenhouse gas emissions by 52 944 kg/ year.

The literature reviewed above has been found to be related mostly to the impact of air pollution on human health and the impact of renewable energy, particularly solar energy, on the environment. But neither in Bangladesh nor in the rest of the world that a study has found to be contributing to exploring the health impact of solar energy on rural households. Whereas some studies (i.e., Bahauddin and Salahuddin, 2021) found that a large number of people, around 65%, have no access to grid electricity have been living in the rural, e.g. inland and island villages in Bangladesh and are increasingly inclining towards installing the solar panel.

The literature matrix of the above literature is provided below

Author/Year	Objectives	Variables	Findings	Suggestions
Manisalidis et al.(2020)	Indoor air pollutants	Asthma, bronchitis, lung cancer, and central nervous system	Indoor air pollution has an impact on public health and increased respiratory diseases.	Public awareness coupled with multidisciplinary approaches by scientific experts and national and international organizations must address the emergence of this threat and propose sustainable solutions.

Tran et al. (2020)	Indoor air pollutants	Asthma, atopic dermatitis, allergic rhinitis, pulmonary diseases, chronic inflammatory pulmonary diseases, chronic obstructive pulmonary diseases	Enhanced chronic inflammatory responses. Specially developing countries women have a great risk for COPD because of exposure to household smoke from burning kerosene	Reduce indoor air pollution
Brac et al. 2020	Indoor air pollutants	Kerosene, coal, biomass, wood, cow dung, and crop residues for domestic energy	Women and young children are exposed to high levels of indoor air pollution every day	They added that indoor air pollution is a major global public health threat requiring greatly increased efforts in the areas of research and policymaking. Research on its health effects should be strengthened, particularly in relation to tuberculosis and acute lower respiratory infections. They desired a more systematic approach to developing and evaluating interventions, with clearer recognition of the interrelationships between poverty and dependence on polluting fuels.
Padilla et al. 2010	Indoor air pollutants	Tuberculosis, asthma and respiratory tract cancer	Solid fuel smoke contains the most toxins in tobacco smoke and associated diseases, such as tuberculosis, asthma, and respiratory tract cancer. Moreover, interstitial lung diseases may also be associated with solid fuel smoke inhalation	.

Sohag et al. 2020	stated renewable energy share is only 3% of its total energy consumption and production.		The electricity generation in Bangladesh from fossil fuels affects the nation's sustainability and results in high carbon emissions, which are still a cause for worry. There is a need for renewable sources of energy which can fulfill the power demands of towns and industries of Bangladesh.	
Dulal et al. (2021)	showed a picture of the percentage share of total energy generation capacity (MW) and carbon emission output over 5 years (2017-2021) in Bangladesh		Indigenous oil generates a high percentage of carbon output relative to its percentage share of total energy generation capacity, and renewable energy produces no carbon emission.	

3. Objective of the Study

The study aims to find solar energy's impact on health by examining whether there is a difference in health costs before and after installing solar panels in rural Bangladesh, especially in some selected islands.

4. Survey Design and Research Methodology

The survey was designed to extract data on the health status and treatment cost changes of the households in the island areas after using solar panels. Primary data of the study were collected randomly from 300 sample household by open-end questionnaire survey method. Stratified sampling method was used to collect the data for analysis.

The following formula (Cochran, 1953) was used to calculate the sample size

$$n = \frac{z^2.p.q}{e^2}$$

Where, n = number of respondents, z = table value, error or level of significance (5%), p = success factor and q = failure factor.

Additionally, Saunders et al., (2011, p.219) state that if the population size is 1,00,000 or more, with 95% confidence level, and 5% error margin, the minimum sample size should be 383. The researcher supplied 383 questionnaires to the sample respondents and collect data. Out of that 38 questionnaire are not filled and 45 questionnaire which are rejected due to scarcity and incompleteness of information. So, finally the researcher has chosen 300 respondents for analysis. The questionnaire has been designed to give a particular focus on the pre-and post-installation of SHSs so that the environmental impact on health in island areas could be measured.

Statistical Software SPSS 22 was used to compute the data. Sample pair t-test and a binary logistic regression model were designed here as statistical tools for analyzing data and exploring the environmental impact of solar energy on the health of the sample respondents. With an equal size of samples for two independent groups defined as before installing solar panels and after

installing solar panels, paired t-test was used to see whether there existed any difference in the health costs in the two periods, i.e., before and after using solar panels. The null and the alternative hypothesis were, therefore,

H_0: The difference between mean health costs before and after installing solar panels is zero (i.e., $\mu = 0$), and

H_1: There is a difference between mean health cost before and after installing solar panel ($\mu \neq 0$)

The test statistic follows a t-distribution and is defined as,

$$t = \frac{\sqrt{n}\,(\bar{d} - \mu)}{sd} \text{ ---------- (1)}$$

Where $\bar{d}$ = mean of the differences between pairs of observations at two points in time, sd = standard deviation, μ =assumed population mean.

Moreover, to examine whether the health condition of the respondents has improved based on their own perception, the following binary logistic regression model (Gujrati, 2018) was fitted.

$$Y = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_2 + \beta_3 X_3)}} \text{ ---------- (2)}$$

Where Y_i is the perceived health condition of the household before and after using solar energy, X_2 is a dummy variable that represents the two distinct time periods involving using or not using solar panels, and X_3 represents the income of the household. A dependent dummy variable has been used to measure the differential health impact of using or not using solar panels. Since the respondents' answer about their health condition before and after installing a solar panel is categorical, i.e. 'yes' or 'no', the binary logistic model is a suitable way to test this categorical answer. The binary logistic regression

model can also be expressed as a log-likelihood ratio. The logit model here can be written as:

$\ln(Y_i/1\text{-}Y_i) = \beta_1+\beta_2X_{2i}+\beta_3X_{3i}$

Where $Y_i = 1$, if the respondents say that their health condition has improved after the installation of solar panels, and $Y_i= 0$ if they say that their health condition is not improved after installing solar panels.

5. Results and Discussion

Table 1 provides descriptive statistics of the socio-economic and demographic characteristics of the respondents. The variables used in the analysis include, age, gender, education, and income of the respondents.

Table 1: Descriptive Statistics of the Variable

Variable	Definition	Mean	SD	Max.	Min.
Age	Respondents' Age	44.73	11.84	85	24
Gender	Male and Female (Male=1, Female=0)	0.95	0.23	1.00	0.00
Education	Years of schooling (Illiterate=0, Class= 1, ------;	6.98	4.03	18	0.00

	Masters= 18)				
Income	Income per month of the respondents (both users and nonusers).	17470	10503	70000	1500

Source: Survey data. The total numbers of respondents are 300.

Table 1 shows the mean, standard deviation, maximum value, and minimum value of the variables. The table shows that the average age of the respondents was 44 years and the range of the age was from 24 to 85 years. The average years of schooling of the respondents were about 7, somewhat near the junior high school level. The level of education among the respondents however varied from masters to illiterate. The average income of the respondents, dominated by males, was about Tk. 17,470 per month along with a maximum income of Tk. 70,000 and a minimum income of Tk. 1,500 per month. It is further observed that the coefficient of variation in age, education, and income of the respondents calculated by using their standard deviation and mean were around 27%, 58%, and 60% respectively, which indicates that the average income and average education are relatively more spread out over the average values.

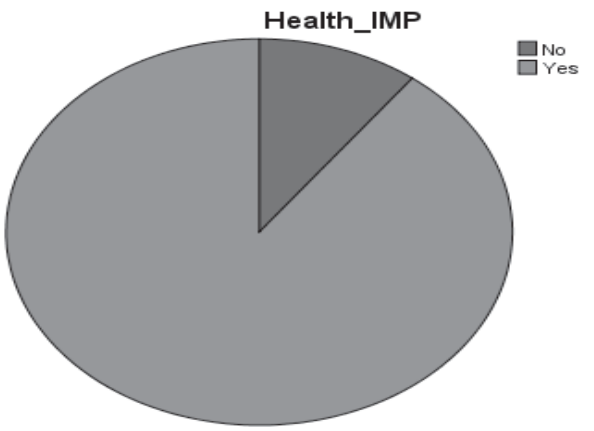
Table 2 and the accompanying figure display the response of the households about their health status before and after using solar panel. While asking a dichotomous question, respondents were very much positive about their health improvement after using solar panels, which is evident from the table and the figure.

Table 2: Impact of Solar Energy on health

Question	Yes		No		Total
	N	%	N	%	N
1. Respondents are getting a clean environment.	251	76.80	49	23.20	300
2.Respondents'health condition improvement.	270	82.60	30	17.40	300

Source: Author's calculation based on household Survey data

Figure 1: Graphical presentation of data in Table 2



Source: Table 2 (Statistical Tools: SPSS 22)

Tables 2 show that out of 300 respondents, 251 (76.80%) feel that they are getting a clean and less smoky environment after using the solar panel. The remaining 23.20% do not feel so. Moreover, when the respondents were asked

about their health condition improvement, 270 (82.60%) respondents opined that their health conditions had improved after using solar panels. To see if the sample response on various indicators of health improvement differed significantly between the two groups expressing positive and negative views about health improvement, a set of sample pair t-tests were performed. Table 3reportsthe results of the sample pair t-test for 7 pairs of variables.

Table -3: Sample paired t statistics of respondents' health cost

		Mean	N	Std. Deviation	t-value	Sig.(2 tailed)
Pair 1	Total_Cost_Health_Before	2911	297	1669	21.40	.000
	Total_Cost_Health_After	1358	297	895		
Pair 2	Health_Cost_Asthma_Before	199	299	516	5.09	0.00
	Health_Cost_Asthma_After	98	299	284		
Pair 3	Health_Cost_Cough_Before	804	300	775	11.42	.000
	Health_Cost_Cough_After	380	300	452		
Pair 4	Health_Cost_Bronchitis_Before	97	300	421	3.29	.001
	Health_Cost_Bronchitis_After	29	300	131		
Pair 5	Health_Cost_Synus_Before	52	300	226	3.83	.000
	Health_Cost_Synus_After	19	300	92		
Pair 6	Health_Cost_Eye_Before	951	299	708	11.67	.000
	Health_Cost_Eye_After	524	299	471		
Pair 7	Health_Cost_Headache_Before	822	299	1170	9.57	000
	Health_Cost_Headache_After	316	299	477		.

Source:Author's calculation using SPSS 22

Table 3 shows that the mean (1358) and standard deviation (895) of the yearly total health cost of the respondents (based on 297 respondents; 3 did not answer under pair1) have significantly reduced after installation of solar panel from the mean (2911) and standard deviation (1669) of the same before installation of solar panel. As a result, their t value is found to be 21.40 and it is significant at 1% level (2 tailed). The paired t values of individual cost elements (Asthma = 5.09, Cough = 11.42, Bronchitis = 3.29, Sinus = 3.83, Eye = 11.67, and Headache = 9.57 are also significant at 1% level (2 tailed) showing a reduced mean (Asthma = 98.11, Cough = 380.90, Bronchitis= 29.82, Sinus = 19.04, Eye = 524.25 and Headache = 316.40 and standard deviation (Asthma =284.49, Cough = 452.75, Bronchitis = 131.80, Sinus = 92.48, Eye = 471.44, and Headache = 477.62) after installation of solar panel from mean (Asthma = 199.33, Cough = 804.98, Bronchitis = 97.17, Sinus = 52.67, Eye = 951.24, and Headache = 822.51) and standard deviation (Asthma = 516.19, Cough = 775.99, Bronchitis = 421.58, Sinus = 226.86, Eye = 708.50 and Headache = 1170.97) before installation of solar panel under pair 2, 3, 4, 5, 6, and 7 respectively. The above data analysis indicates that the null hypothesis of no difference in health cost before and after the installation of solar panels can't be substantiated. Therefore, it can be inferred that there is a significant difference between the health costs of the sample respondents before and after the installation of solar panels.

To investigate further into the health effect of solar panel use the logistic regression model has been fitted with the given data set and the results are reported in Table 4.

Table 4: Logistic Binary Regression Result

(Dependent Variable: Logit of Improvement in Health Condition, ln(Y/(1-Y))

Explanatory Variables	Coef	S.E.	Wald	df	Sig.	Exp(B)
Dummy (Before – After using SP)	2.545	.211	145.032	1	.000	12.745
Household Income	0.000	.000	24.642	1	.000	1.000
Constant	-1.877	.225	69.322	1	.000	.153

Source: Author's estimation using SPSS 22

In the above regression result, each slope co-efficient is a partial slope co-efficient that measures the change in the estimated logit for a unit change in the given regressor. Here, the dummy variable, X_2 is significant at a 1% level (p-value = 0.00) representing the time period before and after installing the solar panel. Thus, the dummy coefficient of 2.545 means with other variables held constant that if the dummy increases by a unit, the estimated logit increases by 2.545 units on average, showing a positive relationship between the two. Moreover, the expected coefficient of the dummy variable (time period) indicates that it is 13 times (12.75) more likely to have a positive effect on the health condition after using a solar panel compared to the health condition before using a solar panel. On the other hand, the explanatory variable, X_3 representing the income of the household respondents is found to be significant at a 1% level (p-value = 0.00) but it does not have any purport as the coefficient is close to zero, meaning that income does not have any effect on the health condition of the sample respondents after using a solar panel.

6. Conclusions and Recommendations

Solar Home System (SHS) provides fresh indoor air by not emitting carbon and maintaining a smoke-free environment. SHS improves environmental quality by reducing CO_2emissions and other greenhouse gases (GHG). Analysis of the data obtained from the respondents of the current study indeed supports the hypothesis that SHS improves indoor air quality. Non-users of solar panel in the island areas are heavily dependent on traditional fuel. Uses of kerosene lamps give off smoke which is responsible for respiratory diseases like asthma, cough, bronchitis, sinus, eye problem, headache, etc.

The main findings of the study are that there is a difference in health costs before and after the installation of solar panels. The mean health cost of solar panel users fell from 2,911 taka to 1,358 taka per year after the installation of

solar panels. A set of paired t-tests shows that expenditures on illnesses like asthma, cough, bronchitis, sinus, eye disease, and headache were statistically significantly reduced. The logit regression model shows that the solar panel might improve the likelihood of better health by about 13 percent. The results establish the case for building an electricity network through renewable energy in the island areas. It will not only provide a clean environment for the rural poor community but at the same time reduce their health costs, which is a double benefit for the island communities.

The environmental cost, called externality cost, of generating non-renewable energy has a negative impact on human health and habitat. Hence the indirect costs associated with the production of energy by conventional systems will increase the true economic value of energy production. But solar energy is free from smoke and CO_2 emission and at the same time environment friendly. So the production and use of solar energy create almost zero externality cost. Thus this study will provide valuable insights to renewable energy policymakers, researchers, and government and private solar accessories suppliers about the positive impact of using solar panels on health. Moreover, the study finding would help in assessing the economic viability of the SPV system in the context of rural electrification programs. Finally, the concerned bodies can use the information from the findings results to motivate the mass people to install solar panels, and thereby the non-users will feel the social, economic, and environmental significance of installing solar panels in their houses.

The study has some limitations which cannot be ignored either way. The most important limitations are the sample area and the sample size. Covering more islands and a larger sample size could have provided the result with close proximity to the inference. Another limitation of the study is variable selection, where only health cost is considered as a variable. Adding more variables like comfort, enjoyment, illness, fitness, etc. would provide a more reliable generalization. However, this study might be considered as a way to undertake further comprehensive research with a larger sample area and size.

This study promises valuable direction for the policymakers and researchers and environmentalists in Bangladesh and beyond, who are

aware of carbon emissions, climate change, and environmental pollution. The optimism this study exudes can be stated here that renewable energy sources particularly solar energy allow countries to plan future energy security as well as to prepare them for the future adverse effects of using pollution-oriented energy. As Bangladesh is naturally endowed with solar energy, it is possible to forestall the energy crisis by adopting SHS technology. As a result, it can help households especially those who live in off-grid areas get a smoke-free environment by installing solar panels and get reduced health hazards and less frequent diseases.

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Promoting Ecological Performance Through Ecological Leadership- The Mediating Role of Organizational Citizenship Behavior for the Environment

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Abstract

Grounding the notions of upper echelon theory (UET) and social learning theory (SLT), the paper intends to evaluate the impact of ecological leadership (EL) on the ecological performance of firms (EP) through inspiring employees to engage in organizational citizenship behavior for the environment (OCBE). Following the deductive reasoning approach, a self-administered questionnaire comprising a five-point Likert scale was employed to collect data among 300 operational and functional level employees serving in diverse industrial settings in Bangladesh. The convenience sampling method was applied to select the participants, and the partial least square–structural equation modeling (PLS-SEM) was used to analyze the data and to test the proposed hypothesis. The findings of the study unveil that EL is depicting an insignificant direct influence on EP, yet such leadership flair indirectly influences EP through the modeling role of OCBE as a mediator. To conclude, theoretical and empirical significances, limitations, and notes for future research are also stated in the paper.

Key Words: Ecological Performance, Ecological Leadership, Organizational Citizenship Behavior for the Environment, Environmental Sustainability.

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