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# Renewable Energy (Solar) and its Impact on Rural Households' Welfare (Case Study of Badakhshan Province, Afghanistan)

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## Abstract

Energy is a pre-requisite for economic development of a nation. Particularly least developed countries that are not financially able to electrify densely populated rural areas tend to solve this problem through solar energy. Due to CO<sub>2</sub> emissive and cost effectiveness characteristic of renewable energy, it attracted the global climate change debates attention. This study analysed the impact of solar energy on rural households' welfare. The primary data gathered through questionnaire from 200 households in Fayzabad city of Badakhshan province, Afghanistan using random sampling approach. Regression analyses measured welfare through education, health, income and environment. The results showed, that studying hour as an indicator of education remained the same as before at night shift like the nights they used bulbs, local generator electricity or kerosene for lightening purposes, furthermore it was found, households' health status somehow bettered in terms of less hospital visits in a month and their saving increased while using solar power than before paid higher amount for per kilowatt local generator electricity. Energy production via solar panels are not that much full accessible in high capacity to avoid families from destroying environment by collecting wood and fuel for cooking and heating purposes. The research recommends, government should pay more attention to support rural households through further investment on SHS (Solar Household System). And this could easily provide at least primary need of demanders like lightening, heating and cooling purposes.

**Keywords:** Renewable Energy, Afghanistan, Rural Development, Regression Analysis

## Introduction

Energy is a key component of international accepted living standard. Increasing demand for electricity is in line with global and regional economic development. According to the recent evaluation of the World Bank, renewable energy mass production including hydropower reached to 2,195 GW, of which 402 GW is solar PV capacity in 2018 (Zervos, 2018).

Afghanistan is one of the least developed countries of central Asia that drastically suffers from lack of energy. Despite of having abundant natural water basins in central and north eastern regions, sunny days, gas and unexcavated oil mines, it still pays millions US dollar for importing energy from neighbouring countries annually (Rahmatullah Safi, 2019). World Bank recent energy figures shows 97.7 % of Afghan urban citizens have access to electricity, while there is not an accurate data about energy access in most populated rural areas (economy, 2020). But what we exactly know, the only partially accessible energy in suburbs are small-scale diesel generator or off-grid renewable solar electricity. According to the Ministry of Energy and Water, Afghanistan has 300 sunny days throughout its regions and its solar energy production capacity is 222 GW (Sharafmal, 2016). Beside weak education, agriculture, governance, health services and so on, the most significant challenge of citizens who live in suburbs areas are energy shortage. Therefore the only cheap and accessible energy for rural regions are solar, that at least replaced traditional lightening and heating facilities since 2001.

Globally, many published research papers focusing on multi-dimensional impact of solar energy utilization in rural development. A research conducted in Thailand evaluated the efficiency of government's SHS (Solar Household System) project in rural regions, shows that 78% of beneficiaries are providing their electricity need via solar, which distributed by government, furthermore their finding indicates the cause for broken and non-functioning solar facilities in households are misuse and lack of knowledge in utilizing solar energy component including converter, battery and panel (Jitiwat Yaungket, 2013). In the same vein, another research in Malaysia introduced this country as solar energy rich because of its sunny day in a year and clean environment policies. Their result shows that, beside other electricity production factors solar energy can definitely electrified rural households and this in turn helped the country to reduce greenhouse gases (Farhad Hossain, 2015). One of the key problems in electrifying rural areas is the geographical inaccessibility and high cost connection of those areas with national electricity extension system. Considering this, government of India planned solar distribution as an alternative to electrify rural areas. Buragohain 2012 researched the functionality of the program and found, electrifying remote states improved living condition specially schooling (Buragohain, 2012). Internationally, scholars have assessed effects of solar energy on poor and destitute population. As a research in Bangladesh indicates, access to clean solar energy impact beneficiaries' health, through omitting fuelwood and kerosene from their lightening tools basket that produce indoor pollution, consequently this helps households to decrease hospital visits who complained from eye and respiratory disease (Sabbir Ahmed Khan, 2014). Research papers also reported decreasing cost effectiveness of SHS (solar household system), such as Byrne with colleagues evaluated the cost efficiency of off-grid solar energy in autonomous Mongolia state of China. The result shows solar energy is financial cheap rather than gasoline and wind energy. Of course this helps households to save more many instead of payment for expensive per kW gasoline and wind energy.

After establishing new government in 2001 and inception of country's reconstruction program, many projects planned to invest, which one of them was electrify rural regions with solar energy. Since then reports and few research papers written about capacity analysis, efficiency and applicability of the projects. For instance, Fahim and Upham assessed the policies and potential of Afghanistan renewable energy. They explored, Afghanistan has high solar energy potential that will exceed its basic need for decades. In spite of complex institutional energy management, there is more chance to use the resources for development of the sector (Fahimi, 2017). In addition, Afghanistan renewable energy union (AREU) evaluated the role of climate and geography situation of Afghanistan for renewable energy, stating investment on renewable energy going to be more profitable due to its favourability and still 5000 solar projects are implemented in hydropower and solar energy production (Fattahi, 2016). Raheleh with colleagues, assessed the cost efficiency of Afghanistan energy sector. Their findings indicate, in a situation that investment on energy sector for instance, hydropower plant is not affordable for some more coming years, they suggested, solar energy as a reasonable alternative to meet the current market demand both in urban and rural areas (Raheleh Rostami, 2016). Moreover Shohib and Ariaratnam studied the improvement impacts of solar projects on two towns of Parwan province. They found solar projects improved the socioeconomic condition of the households in general, but do not particularly effected the career and income generating activities (Ahmad Shoaib, 2016).

Consequently, given all literature in Afghanistan, there is still a gap on welfare evaluation of solar energy, furthermore lack of literature in assessment of SHS (Solar Household System) in rural areas of Afghanistan and its efficiency on households' living condition seems to be quite weak. Thus, this research through quantitative method considers to explore exclusively welfare impact evaluation of solar energy through education, health, saving and environment. The target population situated in most remote province of Afghanistan that called Badakhshan which is 750 km far from capital Kabul. Badakhshan has 1.1 million population, of which 10% has access to the local diesel generator electricity from 5 to 10 PM. This provinces is known as one of the major natural water basin, but unfortunately highly suffers from lack of electricity.

## Methodology

This study is quantitative and relying on primary data from Fayzabad city of Badakhshan Province, Afghanistan. For this purpose a questionnaire designed based on literature review and used to collect first hand data. The reason behind gathering first data was lack of literature source and empirical evidence from latest renewable energy development since inception in 2001. The questionnaire items were measured using a set of Likert-scale, binary and coding. A group of 200 households observed from target population using random sampling, a method in which, all target population has equally likely chance to include in interview. Although welfare is a broad concept and describes by many internationally accepted factors, but this research merely used education, saving, health and environment as dependent variable to explain households welfare. Education measured by grades the student member of target households got in last semester during solar energy usage and saving was the amount of money a household do not obliged to pay for local diesel generator electricity monthly. Health measured using binary YES/No if a household member recently got sick, while environment asked respondents to what extend they care about their living compass cleanness and greenness. In order to reach to a realistic result based on household status, each mentioned dependent variable formed in to a liner regression models as below,

$$\text{Education} = \beta_0 + \beta_1 \text{age} + \beta_2 \text{gender} + \beta_3 \text{marital status} + \beta_4 \text{number of educated children} + \beta_5 \text{family income} + \beta_6 \text{study hours} + \varepsilon \dots \dots \dots (1)$$

$$\text{Saving} = \beta_0 + \beta_1 \text{family income} + \beta_2 \text{power expenses} + \varepsilon \dots \dots \dots (2)$$

$$\text{Health} = \beta_0 + \beta_1 \text{family income} + \beta_2 \text{sickness} + \beta_3 \text{number hospital visits} + \varepsilon \dots \dots \dots (3)$$

$$\text{Environment} = \beta_0 + \beta_1 \text{family income} + \beta_2 \text{wood purchase} + \beta_3 \text{coal} + \beta_4 \text{oil} + \beta_5 \text{gas} + \varepsilon \dots \dots \dots (4)$$

For further investigating the topic, some hypothesis developed based on above linear regression model as follows,

**H01:** Solar energy increases study hours at night.

**H02:** Solar energy decreases health problem through decreasing indoor pollution.

**H03:** Solar energy has positive impact on households' monthly saving.

**H04:** Solar energy is environmental friendly.

The developed hypothesis will be tested at 95% level of confidence in each linear regression.

## Result

The main target behind this research was to figure out how the solar energy effected the deprived rural household welfare, concentrating on education, income, health and environment. A set of independent variables used to assess their impact on dependent variables. Multiple regression analysis was the econometrics model to conduct the analysis and test the developed hypothesis. Since current research used linear regression, therefore it was important to test each linear model by ANOVA at 95% level.

Table 1: Model test by ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	468.291	6	78.049	14.138	.000b
Residual	927.446	168	5.521		
Total	1395.737	174			

a. Dependent Variable: Education

b. Predictors: (Constant), Oil, Income, Wood, M.Status, Gender, Expense, Coal, Age

The education model tested via ANOVA and the result indicates that it is statistically significant at  $p$  value  $< 0.05$ . Meanwhile linear regression model of education assessed the effectiveness of independent variables on dependent and tested the research hypothesis, which illustrated in table 2.

Table 2: Regression analysis of education.

Model	Coefficient Std.error	Standardized Coefficient Beta	t	Sig.
Constant	.933		.734	.464
Age	.020	.117	1.737	.084
Gender	.381	-.006	-.099	.921
M/Status	.183	-.028	-.421	.674
Family/No	.043	.474	7.338	.000
Income	.000	.236	3.706	.000
Study hour	.037	.007	.115	.909

Dependent variable: Education

As table 2 shows age as demographic variable has 0.117 coefficient. Furthermore gender coefficient is .381, while marital status is 0.183. Family member has also a positive coefficient of 0.043. The two key explanatory variables are income and study hour. Income with .236 coefficient has statistically accepted, that shows one year more education as result of using solar energy increases income 0.236. Study hour with 0.007 coefficient almost indicates near to zero effect and statistically rejected as well, because student member of families invest their night shifts for watching entertaining TV programs rather than studying.

In current research saving used to measures whether utilizing solar helped families to positively alter their financial status. Consequently model tested and linear regression assessed.

Table 3: Saving regression model ANOVA test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	2328026680.97	5	465605336.195	18.729	.000b
Residual	4201450804.738	169	24860655.649		
Total	6529477485.71	174			

a. Dependent Variable: Saving

b. Predictors: (Constant), Expense, Age, Gender, Income, M.Status

Saving regression model is statistically significant and shows that model fit in explaining relation between dependent and independent variable.

Table 4: Regression analysis of saving

Model	Coefficient Std.error	Standardized Coefficient Beta	t	Sig.
Constant	.933		-.396	.000b
Income	.000	.571	9.152	.000
Electricity/kw fees	.037	.063	1.009	.314

a. Dependent Variable: Saving

Income as key analysing of above model shows, it has .571 coefficient and is statistically significant as well. In means one thousand investment on solar panel, battery and other appliance could increase saving through local

electricity reduction in cost by 571 AFN, while expenses has 0.063 coefficient, stating investing on solar energy per 1000 Afn could increase 6.3 Afn which is indeed a reduction comparing the time families fully applied local electricity for daily activities.

Table 3: Health regression model ANOVA test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.259	7	.751	.467	.000b
Residual	268.878	167	1.610		
Total	274.137	174			

a. Dependent Variable: Health

b. Predictors: (Constant), Info, Gender, M.Status, Appliance, Income, Expense, Age

ANOVA test for health regression model indicates that, this model is statistically significant

Table 4: Regression analysis of health

Model	Coefficient Std.error	Standardized Coefficient Beta	t	Sig.
Constant	.496		5.183	.000
Expense	.000	.055	.695	.488
Income	.000	-.011	-.135	.892
Sickness	.008	.038	.495	.621
N/hospital visits	.004	-.088	-1.086	.279

a. Dependent Variable: Health

The indoor pollution due to burning wood fuel for lightening and heating purposes may cause eye and respiratory problems. Health measured if respondents visited hospital complaining from aforementioned health problems. The sickness coefficient shows that 3.8 percent relates to the health status of respondents. Furthermore number of hospital visits in a month 8.8 per cent decreased as result of using solar energy.

Table 3: Environment regression model ANOVA test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	5745648.192	8	718206.024	46.620	.000 <sup>b</sup>
Residual	2557315.488	166	15405.515		
Total	8302963.680	174			

a. Dependent Variable: Environment

b. Predictors: (Constant), Oil, Income, Wood, M.Status, Gender, Expense, Coal, Age

Environment ANOVA test shows this model is statistically significant and dependent and independent variables positively has relation with each other.

Table 6: Regression analysis of environment

Model	Coefficient Std.error	Standardized Coefficient Beta	t	Sig.
Constant	44.973		-2.977	.003
Wood purchase	.000	-.039	-.900	.370
Coal	.059	.824	18.880	.000

Oil	.192	.149	3.244	.001
Gas	.623	-.031	-.694	.488

Dependent Variable: Environment

Predictors: (Constant), Oil, Income, Wood, Expense, Coal,

The environment regression model postulates that, one percent investment in solar energy decreased pollution by 3.0% by less wood purchasing but is statistically insignificant. Coal has 82.4% effect on increasing pollution and fuel coefficient shows less polluting effect with coefficient of 14.9%. Gas as CO<sub>2</sub> emission factor has negative coefficient, stating one kW solar panel energy decrease gas usage 3.1 Kg.

## Discussion

For obtaining an accurate result from analysed data, some hypotheses developed at  $p\text{-value} < 0.05$  to study the impact of solar energy on considered explanatory variables. Based on findings, education null hypothesis rejected at  $p\text{-value} < 0.05$ . It implies rural schooling system is not that systematic and in line with recent updated of primary education regulation. Second, hourly TV entertainment programs till mid-nights disordered student's learning schedule and made them to do not pay attention to school homework. In case they plan to study till late night, early night TV programs cause fatigue and then are hardly able to cover study hour and eventually feel asleep. Installing solar panel and using for primary task like, mobile charging, lightening, and water boiling has reduced diesel generator electricity usage in a month which is 0.039\$ cent per kW. The hypothesis for saving is statistically approved. Each Afghani families pay for diesel generator electricity is reduced in term of solar power utilization. This finding is in line with current living situation of the target population, who benefits from local diesel generator only from 5 to 10 PM. This saving effect of off-grid solar energy supports by Byrne and Shen, who conduct a research to evaluate the cost effectiveness of solar in Mongolia and autonomous region of china (Jones Byrne, 1998). Since the research conducted in a province, which residence are socio-economic poor and are not connect to local electricity, therefore lightening and heating tools are traditional relying on wood and kerosene. The target pollution was already using wood for heating water, meanwhile for families who are not connect to the local electricity, kerosene is the only tool for lighting purposes. Both wood and kerosene are producing indoor pollution that results at least respiration and eye problems. In this research health problem assessed by number of hospital visits and type of sickness. The null hypothesis is rejected and alternative proves that solar energy did not decrease indoor health problems, even though a tiny decrease in number of hospital visit has seen in the model. It means solar could only ease the lightening objective of beneficiaries in case study area and the wood usage for cooking and heating still remains as the merely tool that is highly CO<sub>2</sub> emissive. The findings in case of kerosene is in line with Stojanovski et al (2016).

Among many solar energy definition, one of them is described as environmental friendly, thus this research evaluated to find to which extend solar energy usage pattern protected environment. Wood, gas, fuel and coal purchase were the sub-variables to explore the environmental impact of renewable energy. Normally rural residences in case study area provide wood at the cost of forest destruction. The current research result shows, applying solar panel as electricity production source could not avoid households from wood, fuel, coal and gas utilization for routine needs and the null hypothesis rejected and indicates that target population still uses wood and coal for routine heating and cooking purposes. In some ways it is through, because total installed solar panel capacity in each household is between 50-500 W and due to low income in households level it seems impossible to buy high voltage panel and batteries to run cooking stove or heating water for entire house system, therefore they still rely on wood, coal and gas that definitely emit carbon. Despite of all mentioned environmental assessment, solar energy could reduce coal and gas as burning factor for heating water inside kitchen. The finding is supported by Zakaria Zoundi, who have assessed the role renewable energy in CO<sub>2</sub> emission between 1980-2012 (Zoundi, 2017).

## Conclusion

Nowadays, the issue of rural electrification turned in to a big challenge for lease developed countries. Electrifying rural areas through hydropower, coal and fuel electricity is quite expensive and the only cheap and

accessible alternative for suburbs electrification is solar energy. Evidences from Southeast Asian countries shows, access to solar power eased the governments' rural electrification program and almost fundamentally changed living condition for poor portion of societies. Afghan government took some serious step to reduce electricity shortage through establishing small-scale hydropower, solar and wind power projects Since 2001. Meanwhile, due to cheap and accessible solar panels in rural areas, households increasingly replacing the traditional facilities to solar appliance. Fayzabad city of Badakhshan province, Afghanistan constituted the target population, where 200 household randomly selected for interview. The research is quantitative relying on primary data gathered using questionnaire. Considering the willingness for solar energy utilization, this research study conducted to evaluate rural household welfare after solar energy application for their heating and lightening purposes. The welfare concept here analysed using education, health, saving and environment. Furthermore some hypothesis developed regarding welfare explaining variables. In order to explore a concur result the four mentioned variables explaining welfare were formed in two four linear regression model. The result shows, that one hour solar energy usage at night will increase 7% which is 4.5 minutes, but this relation is statistically rejected at p-values>0.05 level. In addition saving regression model result indicates that replacing local diesel generator electricity with solar energy decreased the expenses by 57%, meanwhile this relation were not statistically accepted. In traditional manner focusing on fuel, wood and coal for heating purposes will cause indoor pollution, considering the important of pollution on households health, it was found number of hospital visits because of respiratory and eye problems as result of indoor pollution reduced 8.8% after solar energy usage, while the findings is not statistically accepted. Environmental model expressed wood purchase, coal and fuel usage, where wood purchase assessed as habitat degradation. The result shows, since solar energy usage, wood consumption for heating purpose decreased 3.9%, whereas coal and fuel still remains substantially, but gas consumption decreased as well, because wood and gas are the element that normally uses for daily water heating purposes.

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