# Statistical Analysis of Benefits of Renewable Energy-Examples from Biogas Consumers of Nepal

Jyoti U. Devkota*‡, Chanda Prajapati**, Swechhya Singh**, Binu Hada**

*Department of Natural Science, Mathematical Sciences Group, Kathmandu University, G.P.O. Box 9303,Kathmandu, Nepal.

**Department of Environmental Science and Engineering, Kathmandu University, G. P. O. 6250,Kathmandu, Nepal.

(devkotajb@ gmail.com, chanda_prajapati@hotmail.com, swechhya.singh@gmail.com, binuhada@hotmail.com)

‡Corresponding Author; Jyoti U. Devkota, G. P.O. Box 9303, Kathmandu, Nepal, Tel: +977 9841539845, devkotajb@gmail.com

*Received: 17.04.2014 Accepted: 04.06.2014*

**Abstract**- Twelve hours of power outages daily from the national grid in the current season and up to sixteen hours in the lean period is the state of commercial energy in Nepal. Women in rural areas spend a considerable amount of their time in the collection of firewood, where it is mostly used for cooking. With ever increasing population in the developing world and depleting fossil fuel reserve, this dependence shows a rising trend. In this paper various benefits related to the use of renewable energy are minutely analyzed. Time spent in the collection of fire wood before and after the construction of plant, distance travelled in the collection of firewood before and after, time saved and firewood saved are some of the variables which try to assess the benefits of a biogas plant. These results are based on the data of a socio-economic survey of 400 households, where information about a typical middleclass Nepalese family using biogas and inhabiting in rural areas, its economic, social background and the resulting change are collected. This survey was conducted during September – December 2010 in three different rural settings of Nepal. The questionnaire for this survey was carefully pretested and refined. All the possible sources of error were identified and carefully eliminated. Thus generating error free data for biogas users of Nepal, where due to the lack of awareness of various stakeholders even officially recorded data are limited and defective. These results will help policy makers and planners in making better marketing strategy.

**Keywords** Box plots, Chi-Square test, Database, Sample Survey, Renewable Energy

## 1. Introduction

Energy requirement of many developing countries including Nepal are satisfied from traditional, commercial and renewable sources. According to 2011 census, 94 % of the total households in mountain depend on wood and firewood for fuel and cooking [1]. The rural urban differential in the use of wood/ firewood for cooking is stark. The use of firewood is in 73 % of rural and 25% in the urban areas. Firewood, agricultural residues and animal dung forming a major part of traditional biomass, dominate Nepal's small energy sector. Here lean periods are marked by power outage for 16 hours daily. The share of electricity for lighting for the households is 67.2 5%, according to 2011 census. Fuel wood was the largest energy source in Nepal providing about 77% of the total energy demand in 2008/2009. Agriculture residue and animal dung contributed about 4% and 6% respectively. Share of the petroleum fuel in the total energy system was about 8%. Coal and electricity contributed about 4% in the total energy supply [2]. Dependence on firewood also implies that the women spend their times in the collection of firewood. This time could have been utilized for working in the farm, helping children in studies and in other income generating activities. Cost of firewood per kilogram in Nepal now ranges from Rs 5-Rs 8. A switch over to a source of renewable energy is not only a suitable adaptation strategy to climate change but it also provides cost effective solutions to other problems typical to the developing world.

Biogas plants were promoted by the government of Nepal in the agriculture year 1974/75 as a part of special program. This program installed 250 plants in different parts of Nepal under the supervision of governmental and non governmental agencies. As a part of alternate energy year 2009/2010

government of Nepal planned to install 100,000 biogas plants in 70 districts [2]. In face of various problems enveloping the developing world including long hours of load shedding, acute problems of energy supply, shortage of cheap and efficient fuel, shortage of other many usable commodities and growing environmental pollution, a switch over to renewable energy source seems to be a plausible solution.

Data is power as many important problems can be isolated through the correct analysis and prognosis of this data. Especially in the developing world data are erroneous and faulty. In such cases results are unreliable. Good quality data with maximum information requires proper planning. Steps from the stage of design of experiments, collection of data to the final analysis and interpretation has to be properly worked out. It results in minimum error data ensuring wider interpretability and application. It also minimizes statistical bias. The latent information stored in the data can extracted with the help of appropriate statistical methodologies. The interrelationships between various variables of minimum error data can be studied using advanced statistical techniques like principle components analysis, factor analysis, logistic regression, multiple regressions. Various methods very popular in practice such as pie charts, bar chart, histogram, mean, mode, and median are effective but they cannot exploit full potential of the data. Thus most of the information stored in the data goes underutilized if only very simple statistical tools such as mean, median or mode are used.

This paper stresses on interdisciplinary applications of statistics to a problem from energy, by stating some results obtained from the statistical analysis of benefits of biogas to its consumers. In the modern world of depleting fossil fuels and ever increasing dependence on energy sources, this topic is of great relevance. Here the benefits of biogas are quantified and analyzed with the help of statistical tools. It is based on data collected from a socio-economic survey of 400 consumer households with information on 467 variables. The survey was based on the principles of minimum error data discussed in the preceding paragraph. It was conducted from September 2010 - December 2010 in three different rural settings of Nepal. The benefits of biogas are quantified in terms of several variables. Some are namely firewood saved; time saved, reduced fuel expenses and reduced pollution. This section is followed by the methodology section elaborating on the various statistical methodologies used in the analysis of the data. Further the process of data generation through the design of questionnaire and actual implementation of the survey is elaborated. All the steps from data generation to data analysis are carefully elucidated. This is followed by result and discussion comprising of detailed analysis and interpretation of the results obtained from this interdisciplinary application. Conclusion section summarizes the results.

## 2. Material and Methods

### *2.1. Data Generation and Questionnaire*

Generation of error free data is of crucial importance especially in countries like Nepal. The data collected by different governmental and nongovernmental bodies cannot be relied on for their accuracy. Lack of awareness of all the stake holders of this process including public is one of the main reasons [3]. Further lack of coordination between several governmental and non governmental bodies has also resulted in the duplication of the collected data. The process of generation of data for this study was thoroughly exercised for identification and elimination of possible sources of error. The process of data generation, verification and rectification were properly planned. All the sources of error were properly identified right from the stage of questionnaire development. The objective of this study was generation of error free data that could serve as a baseline for other research. This study generated data that were error free and could be relied upon. A questionnaire comprising of 59 questions and requiring 40-45 minutes to complete was designed. The draft questionnaire comprised of 62 questions before it was tested on 30 households in Sudal VDC, Bhaktapur. The response of the consumers was noted and the answer options were accordingly refined and updated to remove errors, ambiguity of answers and smoothness in the flow of answers. In these 59 questions information was collected on topics such as the age distribution of 2272 individuals of different age groups living in 400 households, amount of landholdings, livestock and their fuel wood expenses before and after the installation of plants. So with these structured questions, information can be obtained about households that haven't installed biogas.

Firstly the age distribution of the family is studied by asking questions related to age and educational status of the family members. Then the socio economic status of the consumer is assessed through questions on the number of livestock, occupational status, extent of agricultural holdings, type of house, ownership of the house (own or rented) and source of water. Then the impact of biogas in their life is studied through questions on source from which they first heard of biogas, major purpose of its installation, name of organization from which they got support in cash or kind in its construction, and their monetary expenses at the installation. Then the frequency of operation of the biogas plant is considered by asking about frequency of feeds. This is followed by questions on the winter summer differential in the production of gas by biogas plant. The collection of firewood, family members involved in the collection of firewood, amount of firewood used before/after, fuel expenses before/after, frequency of hospital visits before/after, use of spare time and details of cooking activities using the biogas are all asked in detail. Before and after questions aim at knowing in details about the change in the lifestyle after the consumers started using biogas as an energy source. To reduce ambiguity all the possible answers were categorized into several categories. This ensured minimization of errors due to confusing questions or answers. . Queries on who keeps the profit, who decided for the plant, which is responsible for its operation and under whose name it is registered are questions aimed at mathematical analysis of extent of female empowerment in that community.

*2.2. Benefits of Biogas*

Different questions assessed the benefits of biogas to its consumers. For example for the question how much time is saved after the construction of biogas plant? Options of no time saved, up to 60 min, 1-3 hours, 3 – 5 hours, more than 5 hours were given. These options are categorized as 1, 2, 3, 4 and 5, hence making the variable ordinal in nature. Similarly questions asking distance travelled for the collection of firewood before/after the construction of plant had 5 options namely none, up to 100 m, 100 – 200 m, 200-500 m and more than 500 m. These were categorized as 1, 2, 3, 4 and 5 and are also ordinal in nature. Similarly questions seeking response to reduced pollution as a benefit to the use of biogas are also of yes/no nature. It is therefore binary with codes 1 and 2 respectively. The questions seeking responses to reduced fuel expenses from male or female are of yes/no type. They are binary in nature. The response to the question on amount of firewood saved after the construction of the plant was categorized as nothing saved, up to 30 kg, 30-50 kg and above 50 kg. Ordinal data 1, 2, 3 and 4 was used to quantify these responses.

*2.3. Statistical Methodology*

Most statistical analyses distinguish between response variable and explanatory variable. In order to eliminate all the possible sources of error during the process of data generation, the answers to all the questions present in the questionnaire of the survey were classified into different categories. Categorical data analysis of the dependent and independent variables where these are various responses of biogas consumers highlight the interdisciplinary application of statistical methodology. Although categorical data are often referred as qualitative in nature, but here they are treated as ordinal data of quantitative nature. Ordered scores are assigned to them according to their categories [5]. Probability distribution of responses that are mainly binary or multiple ordered categories are approximated by binomial and multinomial. Response variables with yes/no options are binomial and those with more than two options are multinomial. The interdependence between several variables is also analysed with the help of chi square test of independence of attributes. The Pearson chi-squared statistic for testing $H_0$ is Cell probabilities equal certain fixed values $\{\pi ij\}$. For a sample of size n with cell counts $\{nij\}$, the values $\{\mu ij = n\pi ij\}$ are expected frequencies. They represent the values of expectations {E (nij)} when $H_0$ is true. To judge whether the data contradict $H_0$, we compare $\{nij\}$ to $\{\mu ij\}$. If $H_0$ is true nij should be close to μij in each cell. The larger the difference $\{nij-\mu ij\}$, the stronger the evidence against $H_0$.

$$\chi^2 = \sum \frac{(n_{ij} - \mu_{ij})^2}{\mu_{ij}} \quad (1)$$

This test statistics takes its minimum value of zero when all nij=μij. For a fixed sample size, greater differences $\{nij-\mu ij\}$ produce larger $\chi 2$ and stranger evidence against $H_0$.

Box plots help visually summarise the data in terms of quartiles and outliers. The box plot uses the median, the approximate quartiles, and the lowest and highest data points to convey the level, spread, and symmetry of a distribution of data values [6]. Here box plots have been used instead of tabular data for diagrammatic representation of different independent variables. They visually represent the interrelationship between several variables.

## 3. Results and Discussions

Relative profile of attributes across 400 households is portrayed in seven different box plots. These attributes indirectly assessed the benefits of biogas to its consumers. The dependence between distance travelled for the collection of firewood before and time saved response is highly significant. Comparative profile of the distribution these responses across 400 households of biogas consumers are given in the box plot of Figure 1. The chi-square value at 16 degree of freedom was 44.883. Similarly the dependence between the responses of distance travelled after for the collection of firewood and time saved is also highly significant. The chi-square value was 78.789 at 16 degree of freedom. Box plot of Figure 2 portrays this dependence. The concentration of most of the values is in the category 200 m – 500 m as portrayed in Figure 1. But after the construction of plant most values are concentrated in the category not travelled as shown in Figure 2. This reflects a significant reduction in distance travelled for the collection of fuel wood. Women were more sensitive to the benefits of biogas as it reduced pollution effects in a traditional firewood based kitchen. The dependence of this response to response of time saved is highly significant in case of female respondents. The chi-square value was 125.10 at 4 degree of freedom.

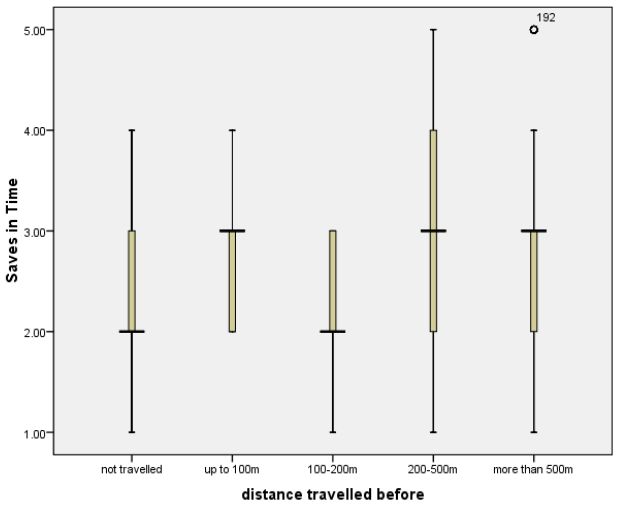


**Fig. 1**: Relation between distances travelled before and time saved

But in males this dependence was not significant with a chi-square value of 1.387 at 4 degree of freedom and a p value of 0.846.

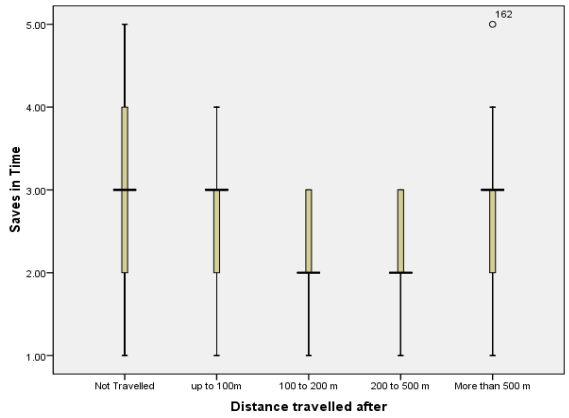


**Fig. 2**: Relation between distances travelled after and time saved

These results statistically validate this fact that in rural areas of Nepal most of the time of the women is spent in the traditional firewood based kitchen. Time spent here by females is substantial in contrast to males; hence this test shows that men are not sensitive to these benefits in terms of reduced pollution effects. The gender differential to this response can be obtained from Figure 3 and Figure 4. A comparison between different categories of responses between time saved and firewood saved is given by box plot of Figure 5. The yes/no response of reduced fuel expenses to the categorical-ordinal data response of time saved is portrayed in Figure 6 and Figure 7. A comparison between these two figures also gives the gender differential. Chi-square test of dependence of response of reduced fuel expenses to time saved showed significant results for male respondents with a p value of 0.037 at 4 degrees of freedom. The chi-square value is 10.193. But the response of female is not significant at 5 percent level of significance with a p value of 0.069. The chi-square value is 8.707 at 4 degrees of freedom.

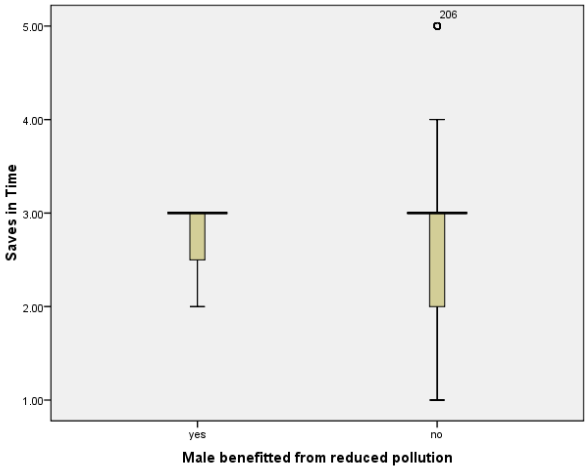


**Fig. 3:** Relation between reduced pollution and time saved (male)

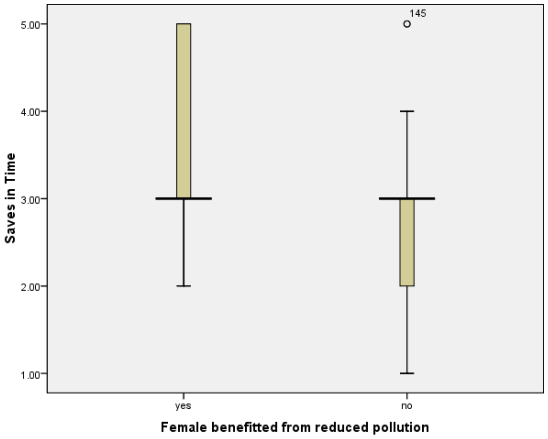


**Fig. 4**: Relation between reduced pollution and time saved (female)

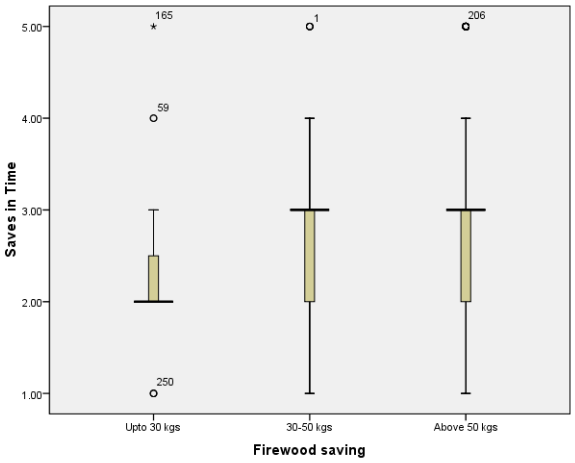


**Fig. 5**: Relation between firewood saved and time saved

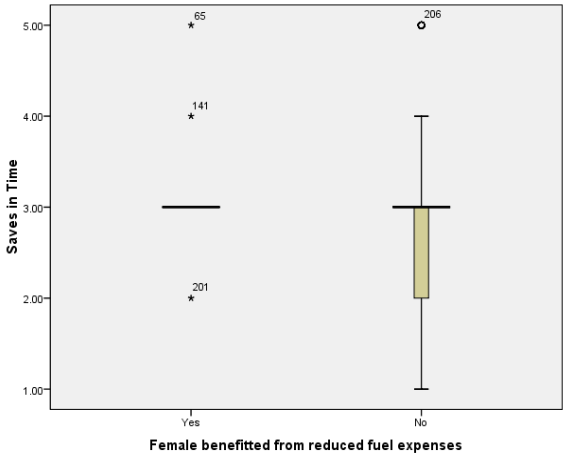


**Fig. 6:** Relation between response of reduced fuel expenses and time saved (female)

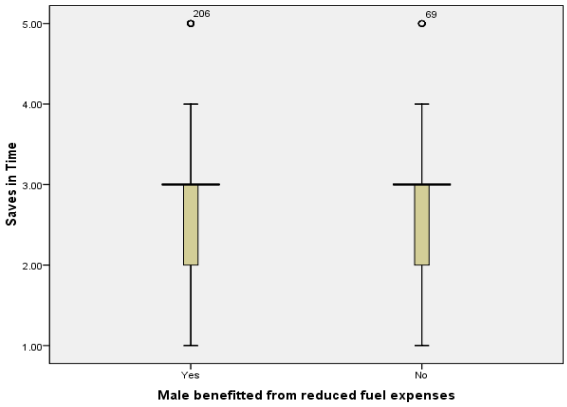


**Fig. 7**: Relation between response of time saved reduced fuel expense (male)

The frequency distribution of the 400 households of biogas consumers with respect to the various benefits are represented with the help of bar graphs given from Figure 8 – Figure 12. In response to the question on distance travelled for the collection of firewood before a biogas plant was constructed in their household 57.2 percent of the households responded more than 500 m, 19.2 percent covered 200-500 m and 9.2 percent households had covered no distances. The response wise distribution is represented by Figure 8. After the installation of biogas plants, the households not covering any distance increased from 9.2 percent to 49.5 percent. And those households still covering more than 500m reduced from 57.2 percent to 22 percent. This change is reflected in Figure 9. In response to the questions on the amount of time saved per day, 1-3 hours was the modal response with 48.8 percent, 3-5 hours with 5.8 percent and more than 5 hours by 9.2 percent. We see that in 49.5 percent households the dependence on firewood for their day to day cooking need reduced to zero. This mathematically justifies that time spent in the kitchen and in the collection of firewood was drastically reduced. The difference in the response of male family members and female family members with respect to reduced fuel expenses and reduced pollution expenses is reflected in Fig. 11 – Fig. 14. In response to the question on whether the installation of biogas plants resulted in reduced fuel expenses 56.5 percent of the males and only 5.8 percent of the female replied in affirmative. This can be validated by the fact that in most of the households, men handle the cash. This makes them more sensitive to the benefits of renewable energy as a cost effective alternative. In response to question on reduced pollution 27.8 percent female responded in affirmative in contrast to 1 percent of male respondents, reflecting that female are more sensitive to this issue. In traditional settings female spend more time in the kitchen and a switch over to a clean energy source makes them less prone to the effects of pollution in traditional kitchen. The distribution of response to the question on the amount of firewood saved is given in Fig. 15. We see that 61.5 percent households claim that more than 50 kg of firewood is saved after biogas is used as a source of renewable energy.

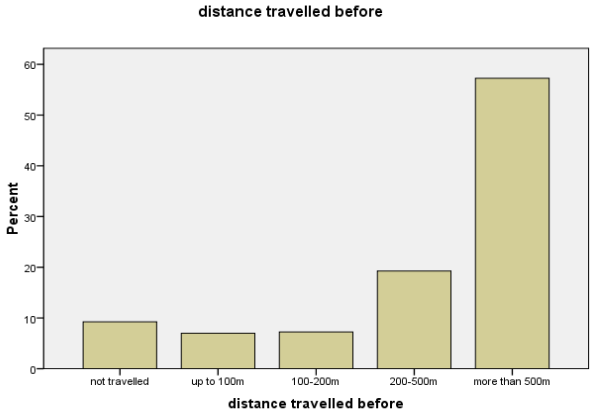


**Fig. 8:** Bar graph of response to distance travelled before


**Fig. 9**: Bar graph of response to distance travelled after

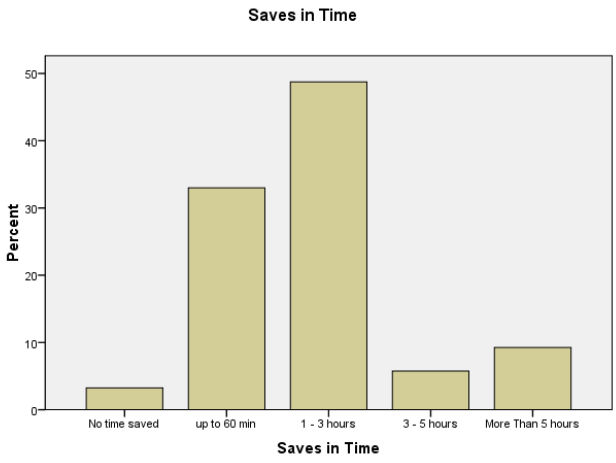


**Fig. 10**: Bar graph of response to the amount of time saved

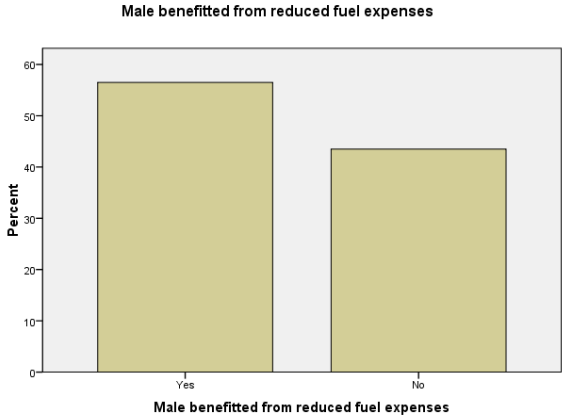


**Fig. 11**: Bar graph of response to reduced fuel expenses by male

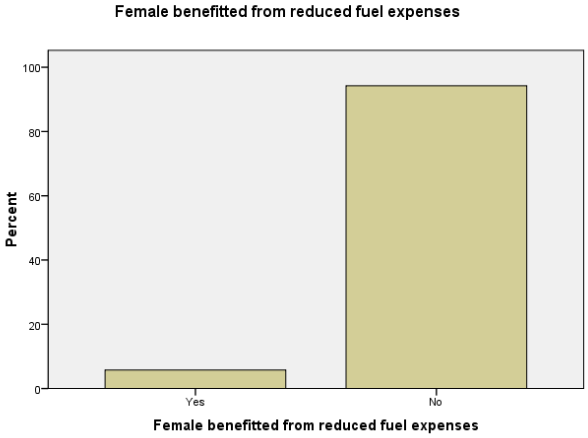


**Fig. 12**: Bar graph of response to reduced fuel expenses by female

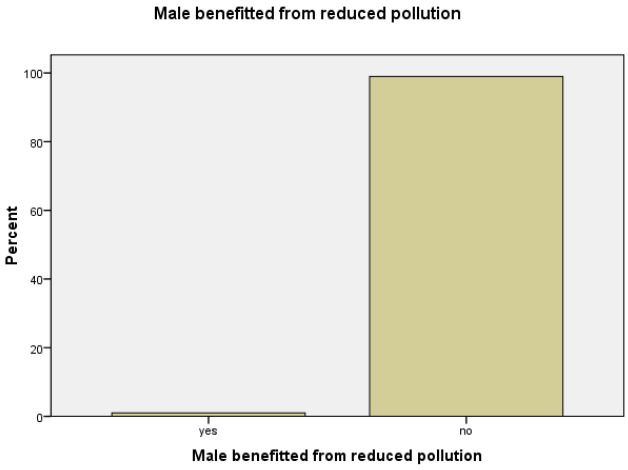


**Fig. 13**: Bar graph of response to reduced pollution by male

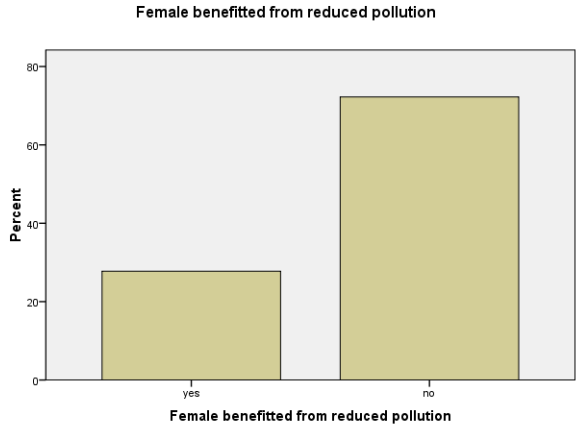


**Fig. 14**: Bar graph of response to reduced pollution by female

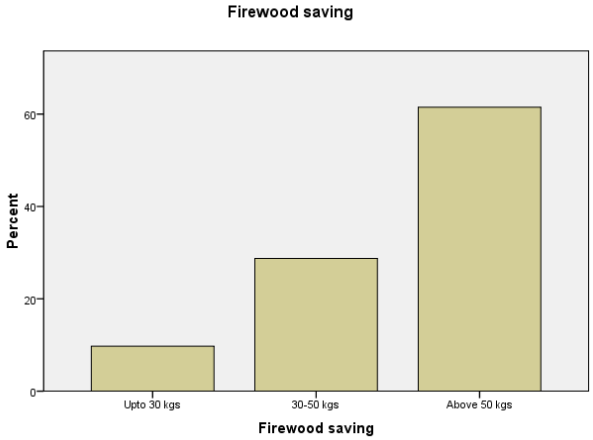


**Fig. 15**: Bar graph of response to amount of firewood saved per month

## 4. Conclusion

This paper minutely analyses the benefits of a source of renewable energy namely biogas. The distribution of response of the consumers to the benefits of biogas is analyzed with the help of various statistical methods. The results of this paper are very relevant as it quantifies the benefits of biogas in particular and renewable energy in general, with the help of various statistical methods. The interelationship between various benefits are analysed. Many of these benefits are applicable to other sources of renewable energy. This is based on the data of 400 households collected during a survey conducted in three different rural settings of Nepal. During this process all the steps from the questionnaire design to data entry were meticulously planned. Thus this paper is based on the data that can be assured for its quality and come from a developing region where even governmental statistical records cannot be relied for their quality and accuracy. Lack of awareness and incentives of various stakeholders are some of the factors responsible for this state of matter. The respondents were asked in total 59 questions that assessed in details about

several socioeconomic and design parameters. But this paper concentrates more on questions and responses related to the benefits of biogas. Questions relating to the distance travelled before/after the biogas plant was installed in their households indirectly assessed their time involvement. The question on time saved cross checked this response. Similarly the gender differential is analyzed with questions on reduced fuel expenses and reduced pollution for male and female separately. The patterns of distribution of response of one variable over different values of other variables are portrayed with the help of box plots. These are represented from Fig. 1- Fig. 7. The behavior of each variable is individually studied with the help of bar graphs from Fig. 8 – Fig. 15.

Chi-square test of independence of attributes tested the significance of the dependence between different variables.

Different variables assessing the extent of benefits of biogas to its consumers were individually analyzed. They are coded in ordinal scale. Saves in time is an ordinal data with categories 1, 2, 3, 4, 5 representing no time saved, up to 60 minutes saved, 1- 3 hours saved, 3-5 saved and more than 5 hours saved respectively. Similarly distance travelled before is an ordinal data with categories 1, 2, 3, 4 and 5 representing not travelled, up to 100m, 100-200m, 200-500m and more than 500m respectively. Similarly distance travelled after also has same categories. Firewood saving is also an ordinal data with three categories 1, 2 and 3 represented by up to 30 kg saved, 30 – 50 kg and more than 50 kg saved. The rest of four variables are binary yes/no variables. Here 1 is represented by yes and 2 by no

In areas hit by energy scarcity and climate change this paper uses the strength of various statistical methodologies in quantifying the benefits of biogas to its consumers. Several other parameters related to the socioeconomic impacts of biogas can be analyzed. These kinds of works can be done for other sources of renewable energy and the results thus obtained can be used in making optimum market strategies for other sources of renewable energy as well.

**Acknowledgements**

This work is funded by NORAD, SINTEF under Renewable Nepal Project grant number RENP-10-06-PID-379. Jyoti U. Devkota thanks the partner industry in this project, Rapti Renewable energy services and all the students of the data collection team.

**References**

[1] Central Bureau of Statistics, National report on national population and housing census 2011, Volume 1. Central Bureau of Statistics, Kathmandu, Nepal 2012, 25 - 29. (Report)

[2] WECS, Energy Sector Synopsis Report 2010. Water and Energy Commission Secretariat, Kathmandu, Nepal, 2010, 13-65. (Report)

[3] J. U. Devkota, Mortality and Fertility Models for Countries with Limited Data - Results Based on Demographic Data of Nepal, India and Germany. Lambert Academic Publishing, Saarbruecken, Germany, 2012, 2-5. (Book)

[4] J. U. Devkota, B. Hada, C. Prajapati and S Singh, "The importance of research data digitization and its statistical analysis-with examples of biogas consumers of Nepal". International Journal for Environmental Science and Development, 3 (2), 103-108, April 2012. (Article)

[5] A. Agresti, An introduction to categorical data analysis, II nd edition, Wiley series in probability and statistics, 2007, 4-35. (Book)

[6] D. F. Willaimson, R. A. Parker and J. F. Kendrick, "The Box Plot: A Simple Visual Method to Interpret Data", Annals of internal medicine 1, 110(11), 916-921, June 1989. (Article)