

**ECONOMIC AND ENVIRONMENTAL IMPACT OF
BIOGAS PLANTS IN WESTERN GHATS OF
KARNATAKA STATE**

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**DEPARTMENT OF FORESTRY AND
ENVIRONMENTAL SCIENCE
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BANGALORE**

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SEPTEMBER, 2020



*Affectionately
dedicated to
my beloved
ones 😊*

**DEPARTMENT OF FORESTRY AND ENVIRONMENTAL
SCIENCES
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

CERTIFICATE

This is to certify that the thesis entitled "ECONOMIC AND ENVIRONMENTAL IMPACT OF BIOGAS PLANTS IN WESTERN GHATS OF KARNATAKA STATE" submitted by Mr. HANUMANTHAGOUDA PATIL, ID No. PALB 8239 in partial fulfilments of the requirement for the degree of MASTER OF SCIENCE (Agriculture) in ENVIRONMENTAL SCIENCE to the University of Agriculture Sciences, Bangalore, is a record of *bona-fide* research work done by him during the period of his study in this University under my guidance and supervision, no part of the thesis has been submitted for the award of any degree, diploma, associate ship, fellowship or other similar titles.

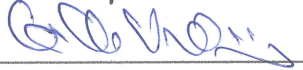
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(Hanumanthagouda Patil)

ECONOMIC AND ENVIRONMENTAL IMPACT OF BIOGAS PLANTS IN WESTERN GHATS OF KARNATAKA STATE

HANUMANTHAGOUDA PATIL

THESIS ABSTRACT

Renewable resources are promising energy resources that the mankind can rely upon. Due to its many advantages it is drawing attention in several countries. One of them is biogas which is particularly important in rural areas. The present study was conducted in two district of Western Ghats in Karnataka. In order to estimate the economic and environmental impact of biogas plants, the profile of biogas users were analyzed by considering different factors such as age, education, annual income, land holding, family size, livestock possession, fuelwood , kerosene consumption, health, environment and economic impact before and after installation of biogas plant. The study revealed that, more number of respondents from agricultural background and has primary education (40.83%), medium age level (59.17%) and high income (47%), below poverty (33%). And after adoption of biogas improves the health impact by decreasing the occurrence of various diseases, and installation of biogas has reduced dependency on forest tree species by displacing consumption of fuel wood, reduction in the usage of kerosene reduced the dependency of fuel wood consumption by 56.99 per cent as compared to before, and also release of Greenhouse gases was reduced to 56.90 per cent and 80.83 per cent due to the combustion of fuel wood and kerosene respectively, in addition to this economic benefit of biogas achieved by increased B:C ratio and payback period was achieved within 3.5 year of biogas adoption and the biogas slurry is mainly used as organic manure that replaces chemical fertilizers by reducing soil pollution and increasing soil fertility that boost up crop yield.

September, 2020

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Major advisor

ಕರ್ನಾಟಕ ರಾಜ್ಯದ ಪಶ್ಚಿಮ ಘಟ್ಟಗಳಲ್ಲಿ ಜೈವಿಕ ಅನಿಲ ಸ್ಥಾವರಗಳ ಸ್ಥಾಪನೆಯಿಂದಾಗುವ ಆರ್ಥಿಕ ಮತ್ತು ಪರಿಸರದ ಮೇಲಿನ ಪರಿಣಾಮ

ಹನುಮಂತಗೌಡ ಪಾಟೀಲ್

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ನವೀಕರಣಬಹುದಾದ ಸಂಪನ್ಮೂಲಗಳು ಮಾನವಕುಲಕ್ಕೆ ಭರವಸೆ ನೀಡುವ ಹಾಗೂ ಅದರ ಮೇಲೆ ಅವಲಂಬಿತವಾಗಿರುವ ಶಕ್ತಿ ಸಂಪನ್ಮೂಲಗಳು. ಇದರ ಅನೇಕ ಅನುಕೂಲಗಳಿಂದಾಗಿ ಇದು ಹಲವಾರು ದೇಶಗಳಲ್ಲಿ ಗಮನ ಸೆಳೆಯುತ್ತಿದೆ. ನವೀಕರಣಬಹುದಾದ ಸಂಪನ್ಮೂಲಗಳಲ್ಲಿ ಒಂದಾದ ಜೈವಿಕ ಅನಿಲವು ಗ್ರಾಮೀಣ ಪ್ರದೇಶಗಳಲ್ಲಿ ಪ್ರಧಾನ ಪಾತ್ರವಹಿಸಿದೆ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವನ್ನು ಕರ್ನಾಟಕದ ಪಶ್ಚಿಮ ಘಟ್ಟದ ಎರಡು ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಗಿದೆ. ಜೈವಿಕ ಅನಿಲ ಸ್ಥಾವರಗಳ ಆರ್ಥಿಕ ಮತ್ತು ಪರಿಸರದ ಮೇಲಿನ ಪರಿಣಾಮವನ್ನು ಅಂದಾಜು ಮಾಡಲು, ಜೈವಿಕ ಅನಿಲ ಬಳಕೆದಾರರ ವಯಸ್ಸು, ಶಿಕ್ಷಣ, ವಾರ್ಷಿಕ ಆದಾಯ, ಭೂ ಹಿಡುವಳಿ, ಕುಟುಂಬದ ಗಾತ್ರ, ಜಾನುವಾರುಗಳ ಸ್ವಾಧೀನ, ಸೌದೆಯ ಬಳಕೆ ಜೊತೆಗೆ ಸೀಮೆಎಣ್ಣೆ ಬಳಕೆ, ಆರೋಗ್ಯ ಮತ್ತು ಪರಿಸರ ಮುಂತಾದ ವಿಭಿನ್ನ ಅಂಶಗಳನ್ನು ಪರಿಗಣಿಸಿ, ಜೈವಿಕ ಬಳಕೆದಾರರ ಆರ್ಥಿಕ ಹಾಗೂ ಪರಿಸರದ ಮೇಲಿನ ಪರಿಣಾಮವನ್ನು ವಿಶ್ಲೇಷಿಸಲಾಗಿದೆ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಿಂದ ಹೊರಬಂದ ಫಲಿತಾಂಶವೇನೆಂದರೆ, ಅತಿ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ಪ್ರತಿಕ್ರಿಯಿಸಿದವರು ಕೃಷಿ ಹಿನ್ನೆಲೆಯಿಂದ ಬಂದವರು ಮತ್ತು ಅವರ ಪ್ರಾಥಮಿಕ ಶಿಕ್ಷಣ (40.83%), ಮಧ್ಯಮ ವಯಸ್ಸಿನ (59.17%), ಹೆಚ್ಚಿನ ಆದಾಯ (47%) ಮತ್ತು ಬಡತನ ರೇಖೆಗಿಂತ ಕಡಿಮೆ (59.17%) ಎಂದು ತಿಳಿಸಲಾಗಿದೆ. ಜೈವಿಕ ಅನಿಲವನ್ನು ಅಳವಡಿಸಿಕೊಂಡ ನಂತರ ಆರೋಗ್ಯಕ್ಕೆ ಸಂಬಂಧಿಸಿದ ವಿವಿಧ ಕಾಯಿಲೆಗಳ ಸಂಭವವನ್ನು ಕಡಿಮೆ ಮಾಡುವುದರ ಮೂಲಕ ಆರೋಗ್ಯದ ಪರಿಣಾಮವನ್ನು ಸುಧಾರಿಸುತ್ತದೆ ಹಾಗೂ ಜೈವಿಕ ಅನಿಲ ಸ್ಥಾವರಗಳ ಸ್ಥಾಪನೆಯು ಸೌದೆಯ ಬಳಕೆಯನ್ನು ಕಡಿಮೆ ಅಥವಾ ಸಂಪೂರ್ಣವಾಗಿ ಕಡಿತಗೊಳಿಸುವುದರ ಮೂಲಕ ಅರಣ್ಯದಲ್ಲರುವ ಮರಗಳ ಮೇಲಿನ ಅವಲಂಬನೆಯನ್ನು ಕಡಿಮೆ ಮಾಡಿದೆ, ಮೊದಲಿಗೆ ಹೋಲಿಸಿದರೆ ಸೀಮೆಎಣ್ಣೆ ಬಳಕೆಯು ಕಡಿಮೆಯಾಗಿರುವುದರಿಂದ 56.99% ರಷ್ಟು ಮರಗಳ ಮೇಲಿನ ಅವಲಂಬನೆ ಕಡಿತವಾಗಿದೆ ಹಾಗೂ ಹಸಿರು ಮನೆ ಅನಿಲಗಳ ಬಿಡುಗಡೆಯನ್ನು ಕ್ರಮವಾಗಿ ಸೌದೆ ಮತ್ತು ಸೀಮೆಎಣ್ಣೆಯ ಬಳಕೆಯಿಂದಾಗಿ ಶೇಕಡಾ. 56.90 ಮತ್ತು 80.83ಕ್ಕೆ ಇಳಿಸಲಾಗಿದೆ. ಜೈವಿಕ ಅನಿಲದಿಂದ ಆರ್ಥಿಕ ಲಾಭದೊಂದಿಗೆ ಬಿಸಿ ಅನುಪಾತದಲ್ಲಿ ಏರಿಕೆಯಾಗಿದ್ದು, ಜೈವಿಕ ಅನಿಲ ಸ್ಥಾವರ ಪ್ರಾರಂಭ ಮಾಡಿದ 3.5 ವರ್ಷದೊಳಗೆ ಮರುಪಾವತಿ ಅವಧಿಯನ್ನು ಸಾಧಿಸಿದೆ ಮತ್ತು ಜೈವಿಕ ಅನಿಲ ಸ್ಥಾವರದಿಂದ ಹೊರಬಂದ ತ್ಯಾಜ್ಯವನ್ನು ಸಾವಯವ ಗೊಬ್ಬರವಾಗಿ ಬಳಸುವುದರಿಂದ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರಗಳ ಬಳಕೆ, ಮಣ್ಣಿನ ಮಾಲಿನ್ಯವನ್ನು ಕಡಿಮೆ ಮಾಡಲಾಗಿದೆ ಮತ್ತು ಮಣ್ಣಿನ ಫಲವತ್ತತೆಯನ್ನು ಹೆಚ್ಚಿಸುವ ಮೂಲಕ ಅಧಿಕ ಇಳುವರಿ ಪಡೆಯಲಾಗಿದೆ.

ಸೆಪ್ಟೆಂಬರ್. 2020

ಅರಣ್ಯ ಮತ್ತು ಪರಿಸರ ವಿಜ್ಞಾನ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ
ಬೆಂಗಳೂರು-65

(ಎಂ. ಮಹದೇವ ಮೂರ್ತಿ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Economic and Environmental impact of Biogas plants in Western Ghats of Karnataka state



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INTRODUCTION

- India is one of the countries with the greatest renewable energy production. Considering its tropical location and abundant sunshine, India has an ideal environment for biomass production.
- Replacing biomass energy with biogas may help to solve several problems commonly faced with biomass fuels.
- Biogas is a renewable and a hygienic form of energy that supplements the traditional and commercial energy sources due to its environmental friendliness permitting for well-organized waste utilization and nutrient recycling.
- Therefore, Biogas can provide clean and non-polluting energy in rural areas. Implementation of biogas plant has contributed to improved control and recycling of dung and waste.

OBJECTIVES

- To study the environmental benefits of biogas plant
- To know the impact of biogas adoption on the health of farmers

MATERIAL AND METHODS

- The study was carried out in two districts of Western Ghats in Karnataka, namely Uttara Kannada and Belagavi. Four villages were selected from each districts randomly and considered for the study on the basis of the number of biogas beneficiaries to attain the objectives of present study.
- List of biogas beneficiaries from each selected village was prepared and percentage of biogas beneficiaries were selected on the basis of users and a pre-tested schedule was used to collect the information.
- The most significant greenhouse gases are water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄) and Nitrous oxide (N₂O). The emission factors of GHG for various fuel combustion developed by IPCC, 1996 guidelines were used for the estimation of GHGs.



Plate: 1. Floating and Decnabandu type of biogas plant



Plate: 2. Fuelwood consumption and biogas for cooking

RESULTS

Table: 1. Fuel wood consumption before and after biogas installation(N=120)

Sl. No.	Average fuelwood consumption	Before Biogas Installation (Kg/ household)	After Biogas Installation (Kg/ household)	Fuelwood Saving (Kg/ household)	Percentage Fuelwood Saving
1	Per day	18.23	7.84	10.39	56.99
2	Per year	6562.8	2822.4	3740.4	
Annual expense on Fuelwood/household/ year @ INR Rs. 2/kg		13125.6	5644.8	7480.8	

Table: 2. Total emissions of greenhouse gases by fuelwood

Sl. No.	Respondent	Average Fuelwood consumption (kg/ household /month)	GHG	Emission in (kg/month / household)	Emission in (Kg/year/ household)	Total Emission of GHG (kg /Household/ year)
1.	Before installing biogas plant	546.92	CO ₂	768.96	9227.58	9962.63
			CH ₄	45.94	551.29	
			N ₂ O	15.31	183.76	
2.	After installing biogas plant	235.42	CO ₂	331.00	3971.95	4288.35
			CH ₄	19.78	237.30	
			N ₂ O	6.59	79.10	

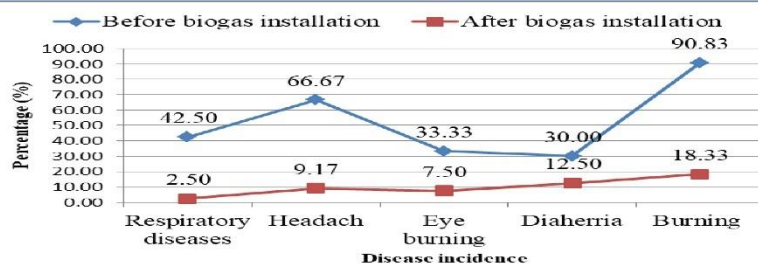


Fig: 1. Disease incidence after biogas installation (N=120)

DISCUSSION

- Fuel wood consumption per household was decreases 6562.80 kg / household / year and 2822 kg / household / year before and after biogas plant installation and per cent fuel wood saving of about 56.99% (Table 1.). This clearly shows that dependency of the people on the forest for the fuelwood consumption was reduced after adoption of biogas plant as a energy resource.
- Greenhouse Gas (GHG) emission from fuelwood burning per household shown in Table 2. It indicates that, total amount in kg of CO₂ emission per household per year was found to be 9962.63 kg before installation and it has reduced to 4288.35 kg emissions per household per year after installation. (Here different GHG values converted into CO₂ emission)
- Further, clearly shows that installation of biogas plant had replaced the use of fuel wood and also reduced GHG emission.
- Incidence of diseases before and after biogas plant installation is presented in Fig.1. Before biogas installation higher number of respondents were suffering from various diseases and after installation of biogas plant it was eventually reduced.

SUMMARY

- Biogas technology is cheaper and much easier than that of other biofuels, high percentages of biogas plant beneficiaries expressed that biogas burns completely without smoke.
- Greenhouse gas emission was reduced after the adoption of the biogas plant, when compared to traditional use of fuel wood and kerosene. Eventually it improved the surrounding environment by reducing pollution and maintaining the cleanliness and there by, improving hygiene and reducing the adverse effect on health of people.

Advisory Committee

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LIST OF ABBREVIATIONS / NOTATIONS

Abbreviations / Notations	Description
%	Per cent
/	Per
=	Equal to
±	Plus or minus
0	Degree
&	And
cm	Centimeter
cu.m	Cubic meter
cm ³	Cubic centimeter
<i>et al.,</i>	and others
etc	Etcetera
Fig	Figure
h	Hour
hp	Horse power
i.e.,	that is
Rs	Rupees
Gg	Gigagram
kg	Kilogram
Sq. mi	Square mile
m ³	Cubic meter
LCA	Life Cycle Analysis

Abbreviations / Notations	Description
TJ	Tera Joule
ARI	Acute Respiratory infection
PM	Particulate Matter
HAP	Household Air Pollution
CHPU	Combined Heat and Power Unit
NHV	Net Heating Value
GWP	Global Warming Potential
EFi	Emission Factors inventories
LPG	Liquefied Petroleum Gas
KVIC	Khadi and Village Industries Commission
KSFMBC	Karnataka Sustainable Forest Management and Biodiversity Conservation Project
SHG	Self Help Group
GHG	Greenhouse Gas
BDTC	Biogas Development and Training Center
IREDA	Indian Renewable Energy Development Agency Limited

I INTRODUCTION

India is one of the countries with the greatest renewable energy production. As of 2019 data, 35 per cent of India's installed power generation capacity comes from renewable sources, produces 17 per cent of the total electricity of the country. According to Paris Agreement India has committed to an expected national contribution goal of achieving 40 per cent of its total electricity production from non-fossil fuel sources by 2030. Through the Central Electricity Authority Strategy blueprint, the country is aiming for an even more ambitious goal of 57 per cent of the total electricity output from renewable sources by 2027 (Anon., 2016)

Considering tropical location, abundant sunshine and rains, India having an ideal environment for biomass production. The huge agricultural potential of the country with large quantities of agricultural residues can be used in heat and power applications to meet electricity demand. IREDA reported that, biomass is capable of supplementing coal to the range of about 260 million tonnes, saving about 250 billion per year. The capacity for biomass energy in India is projected to include 16,000 MW of biomass energy and another 3,500 MW of cogeneration from bagasse. Biomass includes bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute waste, groundnut shells and sawdust.

India has a long tradition of practicing an anaerobic digestion and biogas technologies. Waste water treatment units have been developed in the country which generates renewable energy from sewage gas. However, there is still considerable untapped potential. At certain cases, waste from the distillery industry is often processed into biogas to run a gas turbine for on-site power generation.

Biogas is the gas which is produced by decomposition of organic wastes. Biogas is rich in methane and generates energy when burnt, which in return can be used for heating, lighting etc. It meets many requirement of suitability which fulfills a basic need as cooking fuel allows efficient use of local resources such as dung and other organic waste.

Biogas helps to establish indigenous growth using local skills and technology, provides relief from drudgery and contributes to improvement of the climate. The realization, its undoubted potential, led in the late 1970's to the publicity of biogas plants as a solution to the huge fuel crisis in a significant way. At present India has the world's second largest biogas programme after china.

Biogas technology is one of the suitable choices for meeting the rising energy needs of Indian rural areas. Biogas is a clean and comfortable fuel for cooking and lighting in households, biogas effluent slurry used as organic manure, a by-product. More specifically, biogas allows biologically and economically viable use of the local resource-cattle dung. Biogas can also be produced with other organic matter, in addition to dung including the waste of human. Biogas has gained prominence in India for these reasons, and is the largest and most influential of all government-implemented rural renewable energy programmes.

Today's issues arise from the forest loss, spread of desert, soil erosion, growing population and industrialized animal husbandry, ecological balance destruction, and waste accumulation. As a result politics need to tackle current and future issues require a new direction and diplomacy, new leadership and new policies. In a much more diverse and economically interdependent world, the developing nations economic and security interests must be recognized in a wider, global sense.

The economic and environmental benefits required are achieved through sustainable resource recovery and utilization initiatives, as well as programmes for developing nations. In developing countries, the use of anaerobic digestion in an integrated resource recovery system is critical in solving both ecological and economic problems. By the middle of the 20th century, most nations were aware of biogas technology. However, from 1973 onwards real concern in biogas was raised with the advent of the energy crisis, which attracted general attention to the reduction of fossil fuel, energy supplies and the need to establish renewable source of energy, such as biogas. Now importance of biogas was well recognized as an efficient and non polluting source of energy (Alayi *et al.*, 2016).

Usually, biogas digesters act as an important method to suggest the access energy in rural areas and dramatically improves the health (Srinivasan, 2008). Biogas technology contributes to reduction in emitting greenhouse gases. In addition, a proper functioning of biogas system, in particular, may provide users and the community benefits resulting in resource conservation and environmental protection (Yadvika *et al.*, 2004).

The livestock sector plays a crucial role in the agricultural economy of India. Whereas, agriculture contributes 23 per cent to the country's GDP, employs 59 per cent of the labour force in 2016. The share of agriculture in the livestock sector is about 19.6 per cent, accounting for up to 4.5 per cent of total GDP (Anon., 2016).

Substituting biomass energy with biogas may help to reduce several problems commonly faced with biomass fuels. Therefore, implementing biogas systems has contributed to improved control and recycling of dung and night soil. The digested slurry has high degree fertilizer (Li *et al.*, 2005).

Biogas fuel helps to minimize emissions of greenhouse gases by removing use of fuel wood, crop residues, kerosene consumption, and biogas plants reduces the dependency on forest tree species. Use of bio slurry has reduced soil nutrient depletion by providing organically rich nutrients leading to increased crop yields.

In this backdrop, the present study on “**Economic and environmental impact of biogas plants in Western Ghats of Karnataka state**” was carried out with the following objectives:

1. To examine the socio-economic profile of Biogas using farmers
2. To know the impact of Biogas adoption on the health of farmers
3. To study the Economic and Environmental benefits of Biogas plant

II REVIEW OF LITERATURE

Biogas is one of the best alternative cooking energy in rural areas. The government of India extending subsidy for installation of biogas plants, this technology has number of benefits, like gas for cooking and lightning, which significantly decrease the health hazards, improve socio-economic impact on societies, creates a wide breadth of positive environmental impact and leads to greenhouse reduction and digested slurry obtained from the biogas plants can be used as enriched bio-manure.

The review of literature related to the objectives of the research study are presented under the following sub headings:

2.1 Socio-economic profile of biogas using farmers

2.2 Impact of biogas adoption on the health of farmer

2.3 Economic and environmental benefits of biogas plant

2.1 Socio-economic profile of biogas using farmers

It is essential that the existing social and economic system is first surveyed to obtain background information about biogas using farmers this will allow to identify the needs of the target farmers as well as the key constraints.

Pandey and Chaturvedi (1993) stated that biogas can provide clean and non polluting energy in rural areas. It was also expected to generate employment, environmental stability and energy self-reliance. It could meet the ever growing energy demand and reduces India's dependency on oil imports. Biogas production is stimulated by a popular publicity campaign and subsidized construction of biogas plants. It is estimated that 30 Mt of cattle dung and the 50 Mt of straw burned each year for energy purposes in India are resulting in a loss of about 60 Mt of humus. Valuable minerals with an equivalent of about 2,00,000 tonnes of nitrogen fertilizer are also wasted.

Anuradha (1995) studied the socio-economic viability of Deenabandhu biogas plant, in Guntur district". In which respondents comprised of low, middle and high

income families. The use of biogas plant resulted in saving of 20-30 minutes of cooking time/day. The total cost for the installation of a gas plant by the families ranged from Rs. 5,340 to 5,430. It was concluded that Deenabandhu biogas plant was an efficient device for the rural families. The families were socially and economically benefitted and also satisfied with the performance of the Deenabandhu biogas plant.

Dutta *et al.*, (1997) experienced Indian NGO about Action for Food Production (AFPRO) in promoting biogas programmes. The work has been carried out since 1984 with the collaboration of the Canadian Hunger Foundation (CHF). Information is presented in a study that functional status of installed biogas plants. The implementation impact on the quality of life of biogas users, especially that of women, the economic benefits of biogas, and entrepreneurship development. Reports are recorded from 12 implementing NGOs spread over eight states in different agro-climatic regions, including evaluations of 482 biogas plants in 56 villages, semi-structured interviews with a sample of biogas user and non-user households, and in-depth discussions with NGO personnel gathered between December 1996 and May 1999.

Ramachandra *et al.*, (2000) worked on domestic energy consumption patterns in Uttara Kannada district, Karnataka state, India and reported that, with survey of 1304 households from 90 villages in the Kumta taluk shows that most of them still use traditional stoves for cooking (97.92%) and water heating (98.3%). Season-wise cooking fuel wood requirement for the coast and hilly zones, ranges from 1.98 and 2.22 (summer) to 2.11 and 2.51 (monsoon), respectively, while for water heating (for bath and washing), it ranges from 1.17 ± 0.02 (coast) to 1.63 ± 0.05 (hilly). Seasonal variation is evident from the range 1.12 and 1.53 (summer) to 1.22 and 1.73 (monsoon) for coastal and hilly zones, respectively.

Bhat *et al.*, (2001) revealed that 43 per cent of rural households (HH) had dung resources to operate biogas plants and 65 per cent of them had already built biogas plants. 100 per cent of the plants built were functioning satisfactorily and 85 per cent of HH with biogas plants met all their cooking energy needs with biogas, improving the quality of life of women. The presence of multiple agencies in the dissemination network,

participation of entrepreneurs competing to assist households in all aspects of biogas plant construction, commissioning, procuring subsidy, guaranteed performance and free servicing contributed to the high rate of success.

Vedamurthy (2002) in his study on arecanut growers of Shimogga district in Karnataka noticed that 48.66 per cent of the respondents belonged to high income category, while 34.00 per cent and 17.34 per cent were noticed in medium and low income category respectively.

Kurian (2004) studied socio - economic and environmental impact of Bio Gas Programme with special reference to the Karunapuram and Kanchiyar Panchayaths of Idukki District. The purpose of the study was to assess the social, economic and environmental impact of the biogas on the adopters on the one hand and to document the experience of Malnad development society (MDS) in planning, implementing and organizing biogas programme. Malnad development society (MDS) used a host of simple but innovative techniques to popularize the biogas programme. Its achievement in Biogas nearly comes to one third of the total achievement of the State of Kerala. Biogas has revolutionized the kitchen, generating fuel and manure.

Jayaprada (2007) conducted a study on impact of Karnataka Vikas Grameena Bank on agriculture development of beneficiary farmers and reported that majority farmers were in the medium annual income group (48.70 per cent before joining SHG to 58.30 per cent after joining SHG). The difference values indicates the improvement in annual income of the beneficiaries i.e. a shift from low annual income category to medium annual income category and high annual income category were observed.

Khambalkar *et al.*, (2008) worked on the status of biogas plants in Akola district, India. They found that nearly 13136 number of biogas plants were installed in the district. Nearly 140 biogas plants were installed in the fourteen selected villages of the seven blocks in the district. Out of these, Operating conditions were observed in just 30 biogas plants of 21 per cent. The study showed that the biogas owners of the district have

problems in the use of dung and water to run the biogas system. The majority of people were found to have biogas plants of floating dome type (KVIC).

Joon *et al.*, (2009) conducted survey of household energy consumption pattern in a village of Jhajjar district of Haryana, India in 2007. They covered heterogeneous population belonging to different educational, income and social groups. Dung cakes, crop residues, and firewood were found to be the three main fuels used for cooking, though LPG was also used along with biomass fuels. Income was an important factor determining the choice of fuel for cooking, but there were some socio-cultural and technical factors which were equally important in making fuel preferences at the household level.

Laxmi and Vadivalaghan (2011) in their study reported that 8.7 per cent of the members were illiterates, 6.5 per cent of them have no formal education but know to read and write, 14.3 per cent of the women have education from class 1st to 5th, 19.3 per cent were in the category of 5th to 9th class, 18.3 per cent of them were educated up to 10th level, 23.3 per cent of them have education up to plus two and 8.7 per cent of the members were undergraduates.

Hamlin (2012) investigated twenty-one households with fixed dome biogas digesters and interviewed with plant owners in order to gauge the social and economic impacts of digester use in addition to understand current challenges relating to biogas technology and the future of the industry. Biogas was deemed financial, due to the monthly savings incurred on purchased fuel. In addition, families benefit from improvements in plant growth and crop yield through bio-slurry use. The financial benefits are likely greater when switching from liquid petroleum gas (LPG) to biogas as opposed to changing from collected wood to biogas.

Irfan (2013) revealed that in total 147 respondents were interviewed from the rural area of the district Faisalabad. The study examines sources of information, reason for installing biogas plant, motivation of installing, source of fuel used after installing biogas and the satisfactory level of the respondents. This study helps to understand the

reason behind the adoption of biogas technology and furnish the intervention strategies for development.

Iqbal *et al.*, (2013) studied factors leading to the adoption of biogas technology and reported that socio-economic factors influence biogas technology adoption significantly in Faisalabad. Specifically, the probability of a household adopting biogas technology increases with increase in age of head's household, the number of cattle, size of land owned and household head education. Family size was noted to have a significant positive relationship with the adoption of the biogas, household income proved to be a key factor in influencing a household's decision to adopt biogas technology; it is also positively related to the adoption rate.

Jyothi *et al.*, (2013) in their study on impact of Income Generating Activities (IGA) on the socio- economic and cultural conditions of rural women beneficiaries of KSFMBC project described that there was an increase in percentage change due to income generating activity taken after joining SHG in the determinant like family education (22 %).

Kasthuri *et al.*, (2014) reported from their study that more than 51.2 per cent of the members belong to the family size of 4 members. As far as small family is concerned, 18.8 per cent of the respondents belong to it.

Alayi *et al.*, (2016) studied that achieving “Sustainable Development” is a formidable challenge in the present world. It concerns technologies that can help manage growth while considering economic, social, and environmental sustenance of the society. In fact, modern energy services must be evolved and deployed in all aspects of the development process e.g., energy and communications, energy and industry, energy and the environment, energy and agriculture, energy and education, and energy and public health and safety. Biomass can be used to provide sustainable supply of the required energy through biogas, vegetable oil, biodiesel, producer gas, and by directly burning the biomass.

Biogas plants were mostly installed in those houses that have higher number of family members ranged from 12 to 15. Saving on energy expenditure was 53.3 per cent due to use of biogas. It appeared that 43 per cent women were getting more benefits from biogas by saving 50 per cent of their time. Total monthly saving in term of socio-economic and health was 48\$ by the use of biogas plant of single household (Abdullah *et al.*, 2017).

Patel *et al.*, (2017) conducted the study in Barwani district of Madhya Pradesh to evaluate the impact of adoption of biogas plant on the socio-economic status of biogas users. The result revealed that the majority (62.00 per cent) of the respondents possessed medium impact of adoption of biogas plant on the socio-economic status, while 21.33 per cent of the respondents possessed high and 16.67 per cent possessed low impact of adoption of biogas plant on the socio-economic status.

Cucui (2018) in his research studied about management of waste (chicken debris and slaughter) resulting from chicken slaughtering activities using biogas installation (BI) is shown to be a viable alternative that places the economic entity at intercept if waste recycling and production of electricity, heat and digest. The purpose of this research was to identify the economic impact generated using BI, which processes organic wastes resulted from processing flow of meat chicken slaughter house.

2.2 Impact of biogas adoption on the health of farmers

Behar *et al.*, (1998) studied smoke emission from fuels is an important source of indoor air pollution. Two hundred children in the age group of 7-15 were selected randomly. The most symptomatic children were those whose households used kerosene (52 %) and mixed fuels (46 %) although different symptoms were present in varying extent in all four groups of children. Cough, cold, congestion or phlegm for one week or more occurred more frequently with mixed fuel use followed by kerosene. The present study thus showed that mixed fuel and kerosene fuel had worst effects on respiratory system in children whose households used these fuels.

Smith *et al.*, (2000) critically review was conducted of the quantitative literature linking indoor air pollution from household use of biomass fuels with acute respiratory infections in young children, which is focused on, but not confined to, acute lower respiratory infection and pneumonia in children under two years in less developed countries. Biomass in the form of wood, crop residues, and animal dung is used in more than two fifths of the world's households as the principal fuel.

Ezzati and Kammen (2001) studied that by using longitudinal health data coupled with detailed monitoring of personal exposure from more than two years of field measurements in rural Kenya to estimate the exposure-response relation for particulates smaller than 10 mm in diameter (PM-10) generated from biomass combustion. Longitudinal data on ARI and acute lower respiratory infections (ALRI) were recorded at weekly clinical examinations. Exposure to PM-10 was monitored by measurement of PM-10 emission concentration and time-activity budgets. With the best estimate of the exposure-response relation, they found that ARI and ALRI are increasing concave functions of average daily exposure to PM-10, with the rate of increase declining for exposures above about 1000-2000 mg/m³.

Li *et al.*, (2005) reported that 67 per cent of the households expressed reduction in smoke-related hazards. The primary benefits of improved health among biogas households were due to reduced indoor smoke indirectly reducing health-related expenses. Indoor climate dramatically improved as a result of using clean biogas stoves instead of burning fuel wood, straw and dung cakes would mean that a lot of problems with hazardous smoke particles would be avoided.

Fullerton *et al.*, (2008) studied that one-third of the world's population burn organic material such as wood, dung or charcoal (biomass fuel) for cooking, heating and lighting. This form of energy usage is associated with high levels of indoor air pollution and an increase in the incidence of respiratory infections, including pneumonia, tuberculosis and chronic obstructive pulmonary disease, low birth weight, cataracts, cardiovascular events and all-cause mortality both in adults and children.

Parikh and Jyoti (2010) studied inter-linkages of gender, energy use, health and hardships in the Himalayan State of Himachal Pradesh in India. The study is based on survey with questionnaires covering 4296 individuals, 729 households, 84 villages and nine districts where biomass fuels meet 70 per cent of household fuel needs. Girls below 5 and females in 30-60 age-groups have higher proportion of respiratory symptoms than males of similar age-groups.

Dohoo (2012) evaluated the impact of low tech compost digesters, which generate biogas for cooking, versus traditional fuel sources on the respiratory health of nonsmoking Kenyan farm women. Biogas women demonstrated slightly better spirometry results but differences were not statistically significant, likely due to limited latency between biogas digester installation and spirometry testing. These findings suggest that using biogas in cookhouses improves respiratory symptoms but long-term impacts on lung function are unclear.

Sharma and Nema (2013) worked on the applicability of biogas technology in rural development and greenhouse gas mitigation. A survey was carried out in Bhopal-Sehore region to investigate satisfaction level and benefits actually experienced by the biogas users. This survey included 22 families which were using biogas for cooking purposes and slurry as fertilizer, 100 per cent families experienced less time consuming and convenient cooking with biogas and all of them noticed health improvement, 96 per cent of them are using digested biogas slurry as fertilizer and all of them stated that it is very helpful in improving soil structure and yield.

Suksohale *et al* (2013) studied some of the highest exposures to air pollutants in developing countries occur inside homes where biofuels are used for daily cooking. Inhalation of pollutants may cause deleterious effects on health, symptoms like eye irritation, headache, and diminution of vision were found to be significantly higher in biomass users. Abnormal pulmonary function, chronic bronchitis, and cataract in biomass users were significantly higher than other fuel users. Thus women exposed to biofuels smoke suffer more from health problems and respiratory illnesses when compared with other fuel users.

Jain (2014) reported that per cent of beneficiaries of biogas plant expressed the benefits like the efficient way of energy conversion (saves fuelwood), the benefit of providing a non polluting and renewable source of energy was by 96 per cent. Similarly high percentages of beneficiaries of biogas plant expressed since biogas burns clean, homes do not fill with smoke and ash.

Rafiqul and Shamim (2014) reviewed opinion of biogas plant owners about the impact of biogas on health and environment. 80 per cent male and 90 per cent female said that biogas improved their mental health, 70.30 per cent male and 80.39 per cent female agreed that biogas improved their physical health and 90.3 per cent male and 69.6 per cent female agreed that biogas improved their financial condition. A significantly higher number of male and female thought that various diseases were either decreased or no change was observed after installation of biogas plant.

Horvath *et al.*, (2016) reported that biogas can be produced from various organic waste streams or as a by-product from industrial processes. Beside energy production, the degradation of organic wastes through anaerobic digestion offers other advantages, such as prevention of odor release and reduction of pathogens. Moreover, the nutrient rich digested residues can be utilized as fertilizer for recycling the nutrients back to the fields.

Naz *et al.*, (2017) investigated for the first time the association between HAP from cooking fuel and under-five mortality using the 2013 Pakistan Demographic and Health Survey (PDHS) data. The result revealed that HAP from cooking fuel is associated with a modest increase in the risk of death among children less than five years of age in Pakistan, but particularly in those aged 12-59 months, and those living in poorer socio-economic conditions.

2.3 Economic and environmental benefits of biogas plant.

Consult (2004) reported based on assumption that the lifespan of biogas plant has 20 years. The installation of biogas has reduced the expenditure of the household users on fuel purchase, thereby saving Rs. 2,125 monthly, which is equivalent to an annual saving of Rs. 25,499. The study also reported that the economic value of the bio-slurry shows

that the investment can be gained back in 3 to 4 years. It is estimated that the use of bio-slurry annually saves 39 kg of nitrogen, 19 kg phosphorus and 39 kg of potash per household.

Eco Securities (2004) reveals that the carbon reduction per year per plant from the displacement of fuel wood, agricultural residues, dung, and kerosene is nearly 4.6 tonnes of carbon equivalents. Biogas plants having the size of 6m³ displace the use of three tonnes of fuel wood or 38 liters of kerosene annually and reduce 4.9 tons of carbon dioxide equivalents per year (Devkota, 2007). Shrestha (2010) reported the biogas plants of sizes 4, 6 and 8 m³ mitigates about 3, 4 and 5 tonnes of carbon dioxide per plant per year in the hills.

Singh and Sooch (2004) studied comparison of three prevalent models, *viz.* KVIC, Janta and Deenabandhu. Irrespective of the model, as the capacity of the biogas plant increases, the installation, as well as the annual operational cost increase proportionately. With increase in capacity, the payback period decreased exponentially with the exponential character being highest for the KVIC model, followed by the Janta and then the Deenabandhu model. However, on the basis of comparative economics, the Deenabandhu model was found to be the cheapest and most viable model of biogas plant.

Bajgain and Matthew (2005) reported that by installing biogas systems, the annual consumption of fuel wood was reduced to two tons per household and this provided an equivalent protection of 6,790 hectares of forest per year through 11,395 operational biogas plants. The study was done during dark hours to know the use of biogas for lighting.

Kumargoud *et al.*, (2006) worked on impact of biogas technology on rural women at villages of Shimoga district, Karnataka and they reported that after adoption of biogas, about (87.50 %) respondents found that their agricultural production has increased by 15-30 per cent due to use of biogas slurry, 80 per cent of the owners also opined that it help in soil fertility, water holding capacity and structure of the soil, majority (95 %) of the respondents using biogas for cooking, saves (71.50 %) time for cooking after biogas

installation, reduces (91.50 %) deforestation and maintains ecological balance, reduction (89.50 %) smoke and fire related hazards related to eye and cough, reducing (93.50 %) in import bills of petroleum and chemical fertilizers.

Clemens *et al.*, (2006) compared cattle slurry and cattle slurry with potato starch as additive during the process of fermentation, during storage and after field application. The addition of potato starch strongly enhanced CH₄ production from 4230 l CH₄ m⁻³ to 8625 l CH₄ m⁻³ in the fermenter at a hydraulic retention time (HRT) of 29 days. GHG emissions from slurry stores were more important than emissions after field application. Co-digestion of slurry with additives such as starch has a large potential to substitute fossil energy by biogas. On a biogas plant, slurry stores should be covered gas-tight in order to eliminate GHG emissions and collect CH₄ for electricity production.

Yu *et al.*, (2007) studied all types of energy sources, including straw, fuel wood, coal, refined oil, electricity, LPG, natural gas, and coal gas, which were substituted by biogas, were analyzed based on the amount of consumption for the years from 1991 to 2005. It was found that biogas provided 832749.13 TJ of energy for millions of households. By the employment of biogas digesters, reduction of greenhouse gases (GHG) was estimated to be 73157.59 Gg CO₂ equivalents (CO₂-eq), and the emission by the biogas combustion was only 36372.75 Gg CO₂-eq of GHG. Energy substitution and manure management, working in combination, had reduced the GHG emission efficiently. The majority of the emission reduction was achieved by energy substitution that reduced 84243.94 Gg CO₂, 3560.01 Gg CO₂-eq of CH₄ and 260.08 Gg CO₂-eq of N₂O emission. It was also predicted that the total production of biogas would reach to 15.6 billion m³ in the year 2010 and 38.5 billion m³ in the year 2020, respectively. As a result, the GHG emission reductions are expected to reach 28991.04 and 46794.90 Gg CO₂-eq, respectively.

Akella *et al.*, (2009) studied the social, economic and environmental effects of renewable energy. The uses of renewable energy system, instead of, conventional energy system, to control the social, economic and environmental problems have been discussed. The results indicated that the trends of total emission reduction in different years, which

is exponentially increasing after the installation of renewable energy system in remote areas.

Katuwal and Bohara (2009) presented the current status and discuss benefits of the biogas technology in Nepal. Improved health, increased crop productivity, saved time for women are some of the major benefits to the users. It provides economic benefit to the country through reduced deforestation and carbon trading. In addition, by reducing greenhouse gas emission, the technology helps in mitigating global warming and climate change. Thus biogas is a renewable, sustainable and clean source of energy that provides multiple benefits; locally and globally. With some exception, cattle dung has been used primarily as an input and the technology is limited to households only. More systematic and comprehensive study supported by research and development is required to use other degradable waste such as municipal waste to produce biogas on a large scale.

Pathak *et al.*, (2009) in his study calculated global warming mitigation potential (GMP) and thereby earning carbon credit of a family size biogas plant in India, GMP of the existing and target biogas plants in the country and atmospheric pollution reduction by a family size biogas plant. The GMP of a family size biogas plant was 9.7 t CO₂ equiv. year⁻¹ and with the current price of US \$10 t⁻¹ CO₂ equiv., carbon credit of US \$97 year⁻¹ could be earned from such reduction in greenhouse gas emission under the clean development mechanism (CDM). A family size biogas plant substitutes 316 L of kerosene, 5,535 kg firewood and 4,400 kg cattle dung cake as fuels which will reduce emissions of NO_x, SO₂, CO and volatile organic compounds to the atmosphere by 16.4, 11.3, 987.0 and 69.7 kg year⁻¹, respectively. Presently 3.83 million biogas plants are operating in the country, which can mitigate global warming by 37 Mt CO₂ equiv. year⁻¹.

Arthur *et al.*, (2011) studied there are vast biomass resources including organic waste in Ghana that had the potential of using as feedstock for biogas production, to reduce the over reliance on wood fuel and fossil fuel, and to help to reduce greenhouse gas emissions which may be affecting climate change. Ghana having the technical potential of constructing about 2,78,000 biogas plants, only a little over 100 biogas plants has so far been established. This paper presents the energy situation and the status of the

biogas technology and utilization in Ghana. It also presents the potential benefits, prospects and challenges of the biogas technology.

Garfi *et al.*, (2014) assessed the environmental benefits of implementing low-cost digesters in small-scale farms in Colombia by using the LCA methodology. Results showed that digesters implementation considerably reduced (by up to 80%) potential environmental impacts associated with manure handling, fuel and fertilizer use in the small-scale Colombian farms. This was mainly due to their reduction of LPG and synthetic fertilizer use which were replaced by biogas and digestate. An economic assessment showed that low-cost digesters reduced expenses associated with cooking fuel and fertilizer purchase by 80 per cent.

Tajebe (2016) assessed about the contribution of biogas plant for the problem of deforestation in particular and its advantage for sustainable development in general was lacking. The results confirmed that the scattered 10,678 bio-digester plants started to bring tangible benefits. Commencing this movement about 8732 tonnes of charcoal 27,162 tonnes of fuel wood and 5336 hectares of forest was saved. Moreover, about 66,463 t of biomass and 485 t of fossil fuel was substituted with the total implemented plants. This leads to the reduction of 64,684 t CO₂ eq. per year. Besides, 43,662 kt of organic matter is made available as organic fertilizers.

Abdullah *et al.*, (2017) conducted a study in which design was based on questionnaire, field visit, observation and manipulation. The results of questionnaire showed that installation of biogas plant has resulted in economic, social and health improvements by reducing expenditure of fuel and fertilizer along with time saving and lessen cases of disease

Valerio Paolini *et al.*, (2018) studied the current knowledge about the impact of biogas technology. The survey reports the emission rate estimates of the main greenhouse gases (GHG), namely CO₂, CH₄ and N₂O, according to several case studies conducted over the world. The current knowledge on the environmental impact induced by final use of digestate is critically discussed, considering both soil fertility and nitrogen release into

atmosphere and groundwater; several case studies are reported, showing the importance of NH₃ emissions with regards to secondary aerosol formation. The biogas upgrading to biomethane is also included in the study: with this regard, the methane slip in the off-gas can significantly reduce the environmental benefits.

Camacho *et al.*, (2019) studied life cycle analysis (LCA) to evaluate the environmental impact of biogas production and utilization substituting for grid electricity, natural gas grid and transport fuels, with a focus on Greenhouse Gas (GHG) emissions. The results demonstrate significant reductions in greenhouse gas emissions for the biogas as a fuel scenario due to the displacement of fossil petrol and diesel fuels (scenario 3), with savings of between 524 and 477 kg of CO₂ equivalent (per MWh of energy provided by the fuels). The utilization of biogas for electricity generation saved around 300 kg of CO₂ equivalent per MWh of electricity injected into the grid.

Hijazia *et al.*, (2019) reported calculations for the specific greenhouse gas (GHG) emissions of electricity from biogas driven CHPUs in dependence of engine load. Following the methodology of life cycle assessment and using measured data from five real-world biogas plants in Bavaria, they investigated the following scenarios for the operation of the CHPU: (1) full load, (2) 80 per cent load response and (3) 60 per cent load response. As electrical efficiency and engine load are positively correlated, partial load operation results in higher specific GHG emissions of electricity from biogas. The impact of decreasing efficiency of the CHPU under partial load on overall specific GHG emissions turned out to be higher than the influence of methane slip from the engine. Furthermore, the increase of further efficiencies such as higher yields, efficient use of synthetic and organic fertilizers.

III MATERIAL AND METHODS

This chapter deals with research methods and techniques used in the study. It mainly describes the procedure followed in the selection of districts, villages, and respondents. Besides description of locale, the variables studied and their measurement procedure, data collection methods and use of statistics have also been outlined. They are presented under the following headings.

3.1 Location of the study

3.1.1 Geography of Western ghats

India is in Southern Asia. It has the second-largest population in the world. With respect to area, India is the 7th largest country in the world. It lies on the Indian plate, which is the northern part of the Indo-Australian Plate. The Indian subcontinent is three side surrounded by water bodies. It is easily recognizable on the world map. The Western Ghats, also known as Sahyadri (Benevolent Mountains), is a mountain range that covers an area of 140,000 square kilometers (54,000 sq mi) in a stretch of 1,600 kilometers (990 mi) parallel to the western coast of the Indian peninsula, traversing the states of Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra. The Indian peninsula tapers southwards resulting in the division of the Indian Ocean into two water bodies. They are the Bay of Bengal and the Arabian Sea ([https://www.toppr.com/guides/general-knowledge/introduction to Indian geography](https://www.toppr.com/guides/general-knowledge/introduction-to-indian-geography))

3.1.2 Population

India is the second most populous country of the world after China. Population of India is projected close to 1.38 billion or 1,380 million in 2020 or 138 crore, compare to 1.366 billion in 2019. Population growth rate for 2020 is projected at 0.99 per cent. There are 71.7 crore males and 66.3 crore females living in India. India accounts for a meagre 2.4 per cent of the world surface area yet it supports and sustains a whopping 17.8 per cent of the world population. It is now estimated that by 2027, India will most likely overtake China to become the most populous country on the earth with 1.47 billion

people. And by 2030, India will cross the 1.5 billion mark. Population of India will peak in 2059 with 1.65 billion people.

Population of India, which at the turn of the twentieth century was only around 238.4 million, increased by more than five times in a period of 110 years to reach 1210 million at 2011. Population of India increased by 3.35 times since independence. 68.86 per cent Indian lives in rural areas and 31.14 per cent lives in urban areas. As of 2020, Share of population in the age group 0-14 is 26.16 per cent. Share of economically active population (15-59 years) is 63.72 percent. 10.12 per cent Indian has age more than 60 year. Population density of India is 460 people per sq. km (1190 per sq. mile) (<http://statisticstimes.com/demographics/population-of-india.php>).

3.1.3 Karnataka

The Indian state, Karnataka is located 11°30' North and 18°30' North latitudes and 74° East and 78°30' East longitude. It is situated on a table and where the Western and Eastern Ghats ranges converge into the complex, in the western part of the Deccan Peninsular region of India. The State is bounded by Maharashtra and Goa States in the north and northwest; by the Arabian Sea in the west; by Kerala and Tamil Nadu States in the south and by the States of Andhra Pradesh and Telangana in the east Karnataka extends to about 750 km from north to south and about 400 km from east to west. It is situated at the angle where the Western Ghats and Eastern Ghats of South India converge into the Nilagiri hills. Karnataka has a total land area of 191,791 km² and accounts for 5.83 per cent of the total area of the country (measured at 3,288,000 km²). This puts it in seventh place in terms of size. With a population of 61,130,704 it occupies eighth place in terms of population. The population density which stands at 319 persons per km² is lower than the all-India average of 382. (https://en.wikipedia.org/wiki/Geography_of_Karnataka Landforms of Karnataka).

3.1.4 Uttara Kannada

Uttara Kannada, formerly known as North Canara, is a district in Karnataka. The main geographic feature of the district is the Western Ghats or Sahyadri range, which

runs from north to south through the district. According to the 2011 census Uttara Kannada has a population of 1,437,169, roughly equal to the nation of Switzerland or the Hawaii state of US. This gives it a ranking of 346th in India (out of a total of 640). The district has a population density of 140 inhabitants per square kilometre (360/sq mi). Its population growth rate over the decade 2001-2011 was 6.15 per cent. Uttara Kannada has a sex ratio of 975 females for every 1000 males. ([https://en.wikipedia.org/wiki/Uttara Kannada](https://en.wikipedia.org/wiki/Uttara_Kannada))

3.1.5 Belgaum

Belgaum (also and officially known as Belagavi) is a city in the Indian state of Karnataka located in its northern part along the Western Ghats. Belgaum is located at 15.87°N 74.5°E. It has an average elevation of 751 metres (2,464 feet). the city is in the northwestern parts of Karnataka and lies at the border of two states, Maharashtra and Goa on the western Ghats (50 km from the Goa state border) the district comprises 1278 villages with an area of 13,415 km² and a population of around 4.8 million according to the census of 2011. Belgaum district is the biggest district of Karnataka situated near the foothills of the Sahyadri mountain range (Western Ghats) at an altitude of about 779 m, as per the provisional 2011 India census, the population of Belgaum is 488,292, and its urban / metropolitan population is 610,189 males constitute 51 per cent (309,689) of the population and females 49 per cent (300,500). Belgaum has an average literacy rate of 78 per cent, higher than the national average of 65 per cent of those literate, 54 per cent are males and 46 per cent are females (<https://en.wikipedia.org/wiki/Belgaum>).

3.2 Sampling techniques

In this study, the sample was drawn through the application of multi-stage sampling method.

3.2.1 Selection of study area

The study was carried out in two districts of Western Ghats in Karnataka, namely Uttara Kannada and Belagavi, villages were selected to attain the objective of the present study.

3.2.1.1. Selection of villages: Four villages were selected from each districts randomly and considered for a study on the basis of the number of biogas beneficiaries (Table 3.1).

3.2.1.2. Selection of respondents: A list of biogas beneficiaries of each selected village was prepared and per centage of biogas beneficiaries were selected on the basis of users (Table 3.1).

3.2.1.3. Schedule: A pre-tested schedule was used to collect the information (Annexure-1).

3.2.2 Measurement of variables

In the present study, the sample was drawn through the application of multi-stage sampling method.

Table 3.1: Information about data collection

Name of District	Villages	Number of farmers	Total farmers
Uttara Kannada	Adavi mane	15	60
	Vajagadde	15	
	Haleri koppa	15	
	Heggumblu	15	
Belagavi	Bekkinkere	15	60
	Hirehattihole	15	
	M.K Hobli	15	
	Gaddikoppa	15	
Total Sample			120

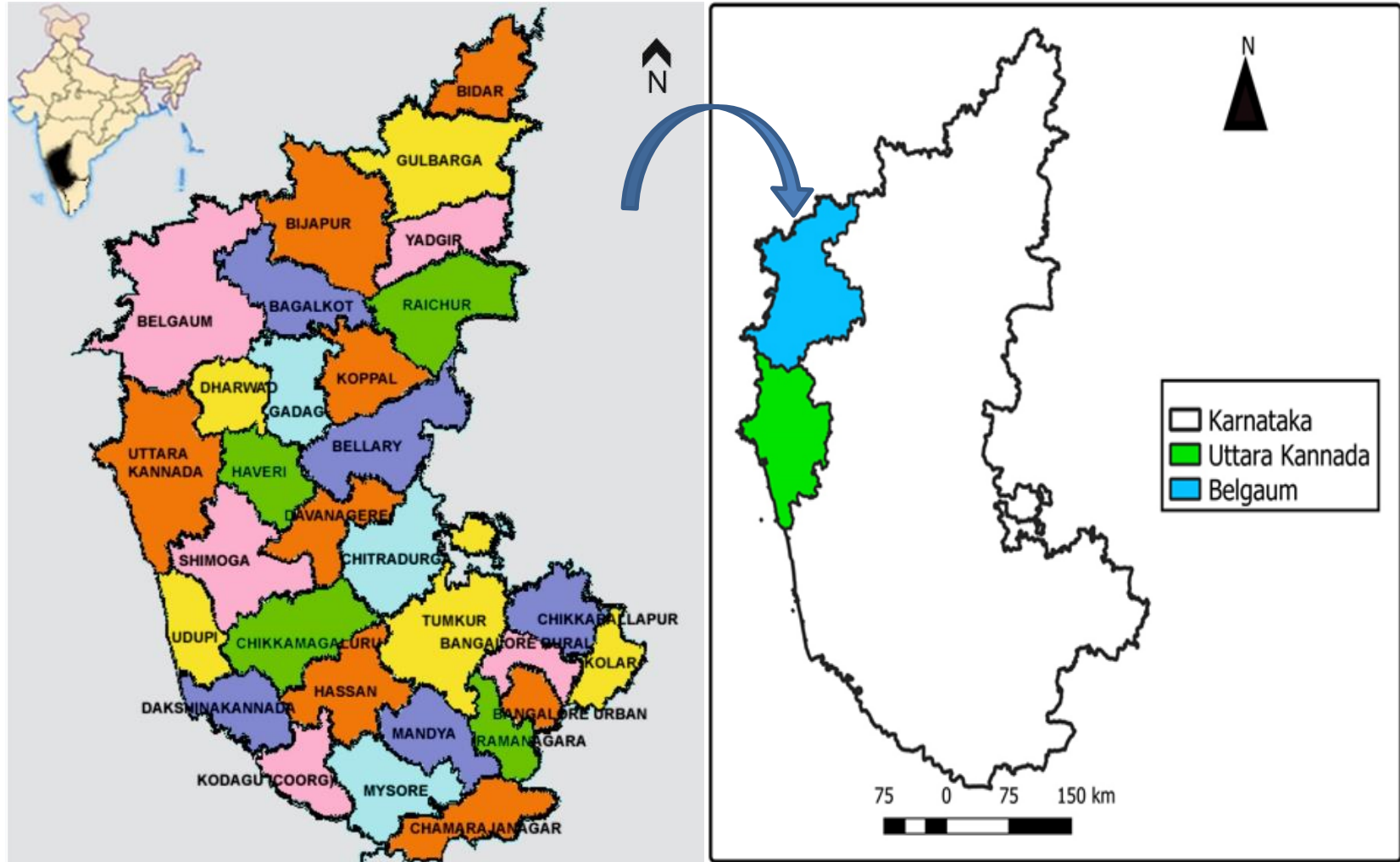


Plate 1: Map showing the study area of Uttara kannada and Belgaum districts in Western ghats

Table 3.2: Variables and their measurement

Variables	Measurements
Dependent variable	
Impact of adoption of biogas plant on the socio-economic status of the biogas users	Structured schedule and interaction with beneficiaries
Independent variables	
a) Age	Chronological age in completed years, procedure followed by Prita (2001) and Hinge (2009)
b) Education	Procedure followed by Raghavendra (2005) and Jayaprada (2007)
c) Annual Income	Based on report of the Integrated energy policy, planning commission, Government of India (2012)
d) Farm size	Anon., (2019).
e) Family size	Scale developed by Venkataramaiah (1983)
f) Livestock possession	Structured schedule

3.2.2.1 Dependent variable

Impact of adoption of biogas plant on the socio-economic status of the biogas users (Table 3.2).

3.2.2.2 Independent variable

3.2.2.2a. Age

It referred to the chronological age of the respondents in completed years at the time of investigation. The procedure followed by Prita (2001) and Hinge (2009) was used to categorize the respondents into three age groups (Table 3.3).

Table 3.3: Age of respondents

Sl. No.	Categories	Years
1.	Young	Below 31 years
2.	Middle	31 to 50 years
3.	Old	Above 50 years

3.2.2.2b Education level

It is operationalized as the number of years of formal education the farmers have undergone. Procedure followed by Raghavendra (2005) and Jayaprada (2007) was used in this study with some modifications. The respondents were grouped into seven categories with the following scoring pattern (Table 3.4).

Table 3.4: Education level of respondents

Sl. No.	Categories	Score
1	Illiterate	0
2	Primary school (1-4 th)	1
4	High school(8-10 th)	3
5	Pre university (11-12 th)	4
6	Graduate	5
7	Post graduate	6

3.2.2.2c Annual income

It refers to the annual income of the biogas user through all sources. On the basis of data collected, the respondents were classified into following categories, based on report of the Integrated Energy Policy, Planning Commission, Government of India (2012) (Table 3.5).

Table 3.5: Annual income

Sl. No.	Categories	Income/year
1.	Below poverty line	(Below ₹ 24,000/-)
2.	Low income	(₹ 24,001 to 50,000/-)
3.	Medium income	(₹ 50,001 to 1,00,000/-)
4.	High income	(Above ₹ 1,00,000/-)

3.2.2.2d Farm size

It refers to the number of hectares of land owned and used for cultivation by an individual. The respondents were categorized based on the Ministry of agriculture and farmers welfare report as follows (Table 3.6).

Table 3.6: Farm size

Sl. No.	Categories	Score
1	Marginal farmers (Upto 1.00 ha)	1
2	Small farmers (1.00 to 2.00 ha)	2
3	Semi Medium farmers (2.00 to 4.00 ha)	3
4	Medium farmers (4.00 to 10 ha)	4
5	Large farmers (10 ha and above)	5

3.2.2.2e Size of family

It refers to the total number of the members of an individual family including both male and females living together under one roof and having a common mode of cooking. Measurement and scoring was done with slight modification by using the socio-economic status scale developed by Venkataramaiah (1983) and the family size was categorized as under (Table 3.7).

Table 3.7: Family size

Sl. No.	Categories	Score
1	Small	1-3 members
2	Medium	4-6 members
3	Large	7-9 members
4	Very large	Above 9 members

3.2.2.2f Livestock possession

In this study, respondents were categorized according to their animal possession (Table 3.8).

Table 3.8: Possession of livestock

Sl. No.	Categories	Score
1.	Low	<3
2.	Medium	2 to 5
3.	High	>5

3.3 Health benefit after biogas plant installation

Health impact of biogas by opined with farmers through various disease

Eye infection

Respiratory disease

Diarrhea

Headache

3.4 Economic and environmental benefit of biogas installation

3.4.1 Economic benefit of biogas plants

Evaluation of investment in biogas in biogas plants was made in terms of annual cost, annual returns, payback period and benefit to cost ratio for 2.4 and 6 cu.m size of biogas plants at present capacity utilization and full capacity utilization.

3.4.1.1 Annual cost:

Annual cost (AC) find out by addition of annual fixed cost (F) and annual maintenance cost (M)

$$AC = F+M$$

Fixed cost was calculated by the following formula

$$F = \frac{I(1 + r)^n + D}{20}$$

Where, F = Annual fixed cost

I = Total initial investment

r = Interest rate

D = Depreciation = I / life span of biogas plant

n = Number of year of repayment

Some of the assumptions are made to get the annual cost.

- a. Life span of biogas plant (20 year)
- b. Interest rate (12 per cent)
- c. Junk value of biogas plant (0)
- d. Operation cost at present capacity utilization same as full capacity utilization

Maintenance cost computed by adding cost of labour for feeding, cleaning and related work.

3.4.1.2 Cost of production per cubic meter of biogas

Production cost per cubic meter of biogas at different capacity utilization is calculated using the formula

$$PC = \frac{AC \times 100}{SP \times CU \times 365}$$

Here,

PC = Production cost/cu.m of biogas (₹/cu.m)

AC = Annual cost (₹)

SP = Size of the plant (m³)

CU = Capacity utilization (Per cent)

3.4.1.3 Annual returns

Annual returns are calculated based on replacement value of biogas with other fuels. According to Sampath Kumar (1999), Replacement value of different fuels is fuel wood 3.5 kg, Kerosene 0.6 ltr, LPG 0.4 kg.

3.4.1.4 Payback Period and B: C (Benefit to cost) Ratio

Payback period and B: C Ratio calculated using formulas such as,

$$PBP = \frac{I}{AR - AC} \qquad B: C \text{ ratio} = \frac{AR}{AC}$$

Here,

I = Initial total investment

AR = Annual returns

AC = Annual cost

3.4.2 Greenhouse Gas Emission (GHG)

The gases in the atmosphere that absorb radiation are known as "Greenhouse Gases" because they are largely responsible for the greenhouse effect. The greenhouse effect, in turn, is one of the leading causes of global warming. The most significant greenhouse gases are water vapour (H₂O), carbon dioxide (CO₂), methane (CH₄) and

nitrous oxide (N₂O). The emission factors of GHG for various fuel combustion developed by IPCC, 1996 guidelines were used for the estimation of GHGs (Table 3.9).

Table 3.9: Emission factors of combustion for various fuels (IPCC 1996)

Fuel source	Greenhouse Gas	Emission Factors inventories	CO ₂ emission
Kerosene*	CO ₂	2.457 kg/ltr	2.457 kg/ltr
	CH ₄	0.35 g/ltr	0.007 kg/ltr
	N ₂ O	0.063 g/ltr	0.020 kg/ltr
Fuel wood**	CO ₂	1.406 kg/kg	1.406 kg/kg
	CH ₄	4.00 g/kg	0.084 kg/kg
	N ₂ O	0.091g/kg	0.028 kg/kg

Note: GWP of CO₂ = 1, CH₄ = 21 and N₂O = 310 (Randall, 2002)

* NHV (Net Heating Value) of Kerosene = 35 MJ/litre (RWEDP, 2001)

** NHV (Net Heating Value) of Fuel wood (15-20Per cent mcwb) = 15.5 MJ/kg (RWEDP, 2001)

Efi = Emission factor for inventories of GHG, kg GHG/unit fuel combustion.

3.4.3. Environmental impact after biogas plant installation

Bad odour in household

Indoor pollution

Dirt in surrounding

Use of firewood

3.5 Method of data collection

The interview schedule was designed for collecting the relevant information of selected variables. The questions in interview schedule framed were simple, clear and directly related to the purpose of the study and arranged in logical sequence. The data were collected by personal interview with respondents. Practically, all the respondents had

answered the questions fully, which was indicative of the fact that good rapport could be established between the investigator and respondents.

3.6 Statistical analysis of data

For the purpose of fulfilling the objectives of the study, data were analyzed the result are processing as per the objectives is presented in the form of tables and chart. Details of results prescribed in the form of mean or average and percentage.

Arithmetic mean:

It is the sum of all the values of the observations divided by the total number of observations, symbolically, it is represented as;

$$\bar{X} = \frac{\sum X}{n}$$

Where,

\bar{X} : Arithmetic mean

$\sum X$: Sum of all values of observations N: Total number of observations

n: Total number of respondents

Frequency and percentage:

Frequency and percentage were used to know the distribution pattern of respondents according to variables. Percentages were used for standardization of size by calculating the number of individuals that would be in a given category if the total number of cases were 100.



Plate 2: Floating drum type biogas model



Plate 3: Interacting with farmers



Plate 4: Exchanging information with the biogas plant owner



Plate 5: Fixed type biogas plant



Plate 6: Using biogas for cooking purpose



Plate 7: Fuel wood consumption

IV RESULTS AND DISCUSSION

The present study entitled "Economic and Environmental Impact of Biogas plants in Western Ghats of Karnataka State, India" was conducted in various villages of Uttara Kannada and Belagavi Districts are presented, discussed and organized according to the study objectives.

4.1 Socio-economic profile of biogas using farmers

Variables included in the study were selected on the basis of the extensive review of literature and discussion with experts. Efforts are made to define each general level concept to the operational level, so that variable can be measured.

4.1.1 Age

The respondents age was seen as the length of a number of years in their lives. It is a significant factor in experiencing benefit. Age is categorized as Young, Middle and Older groups (Prita, 2001; Hinge, 1999) .

Table 4.1: Distribution of the respondents according to their age

(n=120)

Sl. No.	Age	Frequency	Percentage (%)
1	Young age (below 31 year)	5	4.17
2	Middle age (31-50 year)	71	59.16
3	Old age (above 50 years)	44	36.67

It is observed from Table 4.1 that a majority of respondent (59.16%) were of middle age, whereas more than one-third (36.67%) and 4.17 per cent of respondents were of old and young age (Fig.1).

4.1.2 Education level

Education level helps to understand the farmers community knowledge and growth. Its the factor that has the high impact on all the aspects of the life of a person.

Details about the respondent education are presented in Table 4.2. It is evident from data that a large number of respondents of (40.83%) had studied upto primary education, followed by 30.00 per cent up to high school, 15.00 per cent up to graduate level, 5.83 per cent up to pre-university level, 5.00 per cent were illiterate, and a merely 3.33 per cent had studied upto post-graduate level.

Table 4.2: Distribution of the respondents according to their education level

(n=120)

Sl. No.	Education	Frequency	Percentage (%)
1	Illiterate	6	5.00
2	Primary school (1-7 th)	49	40.83
4	High school(8-10 th)	36	30.00
5	Pre - university (11-12 th)	7	5.83
6	Graduate	18	15.00
7	Post graduate	4	3.33

The result in Fig.2 shows a positive relationship between the knowledge and the effect of biogas plant adoption on consumers of biogas. This may be due to the fact that the desire to study and know about biogas and its benefits is more the education. Similar observations were made by Jayale (1992) and Jain (2014).

4.1.3 Annual Income

It refers to the annual income of the biogas user from all sources. On the basis of data collected, the respondents were classified into following categories, based on report of the Integrated Energy Policy, Planning Commission, Government of India (2012).

The Table 4.3 subjected to percentage distribution of the respondents according to their annual income. The data indicated that out of total respondents, high income level farmers constituted 47 per cent, followed by below poverty farmers about 33 per cent, low income level 16 per cent and medium income level 5 percent (Fig.3). It is interpreted that an individual with high annual income is more oriented towards having higher

wisdom of biogas plant as access to knowledge about biogas and its installation becomes easier as compared to individuals with the low-income group.

Table 4.3: Distribution of the respondents according to their annual income

(n=120)

Sl. No.	Income level (₹)	Frequency	Percentage (%)
1	Below poverty line (below 24000/-)	39	33
2	Low income (24000-50000/-)	19	16
3	Medium income (50000-100000/-)	6	5
4	High income (more than 100000/-)	56	47

4.1.4. Farm size

Farm size is determined by the size of the land holding. Land size is an important factor in inspiring the farm family to learn new information. Farm size was divided into five category viz, marginal, small, semi-medium, medium and large categories. (Annon, 2019)

Table 4.4: Distribution of respondents according to their farm size

(n=120)

Sl. No.	Farm size	Frequency	Percentage (%)
1.	Marginal farmers (Up to 1.00 ha)	46	38.33
2.	Small farmers (1.00 to 2.00 ha.)	49	40.83
3.	Semi Medium (2.00 to 4.00 ha.)	19	15.83
4.	Medium farmers (4.00-10 ha)	6	5.00
5.	Large farmers (10 ha and above)	0	0.00

Result presented in the Table 4.4 represents the frequency distribution of the farm size of the respondents. The results indicate that 40.83 per cent were small farmers,

followed by 38.33 per cent marginal farmers, 15.83 per cent semi medium, and 5.00 per cent medium farmers (Fig.4).

Gautam *et al.*, (1994) conducted a survey on the socio-economic status of owners of biogas plants in Madhya Pradesh State, and reported that the size of the biogas plant was significantly correlated with ownership of land.

4.1.5. Family size

The family size of the total respondents was divided into four categories, small, medium, large and very large family sizes, based on contact with the respondents Venkataramaiah, (1983).

Table 4.5 indicates how the respondents are distributed according to their family size. From the table it is clear that 50.83 per cent of respondents had medium size of family, 22.50 per cent had small size family, large family constituted 19.17 per cent and respondents having very large family was about 7.50 per cent. (Fig.5.)

Family size may have helped to determine the effect of biogas plant adoption on the socioeconomic status of consumers of biogas with respect to improved biogas technology. This may be due to the fact that individuals within the family have more social contact with individuals of different groups and different forms of organization and thus have more improved biogas construction and development and are receiving more potential advantages for the biogas plant.

Table 4.5: Distribution of the respondents according to their family size

(n=120)

Sl. No.	Family size	Frequency	Percentage (%)
1	Small (1-3 members)	27	22.50
2	Medium (4-6 members)	61	50.83
3	Large (7-9 members)	23	19.17
4	Very large (above 9 members)	9	7.50

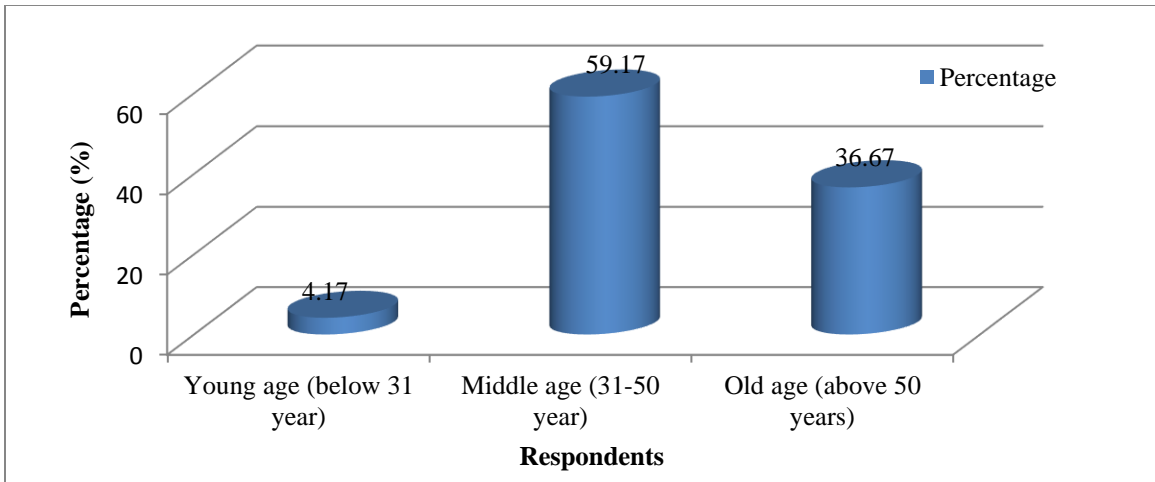


Fig. 1: Distribution of respondents according to their Age

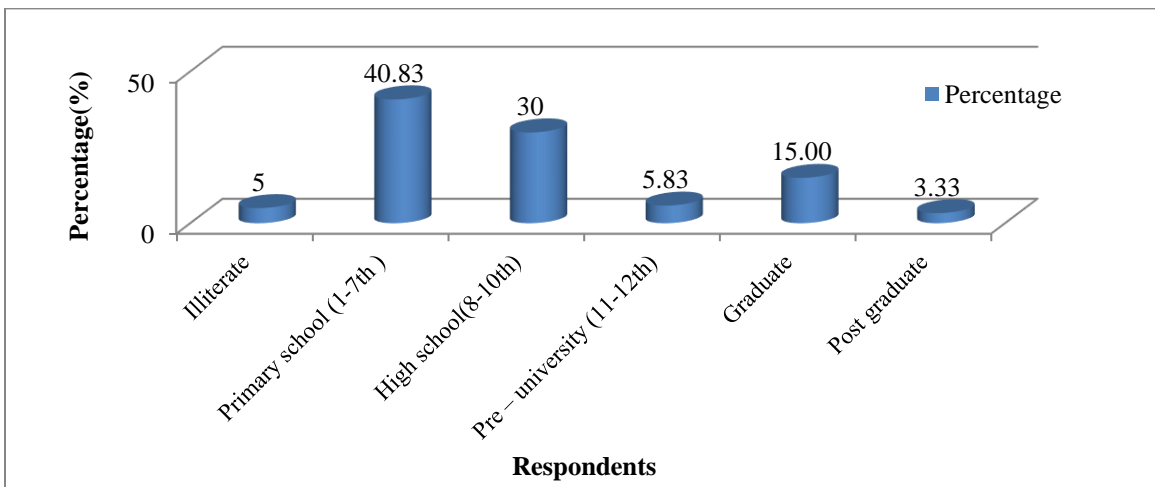


Fig. 2: Distribution of respondents according to their Education level

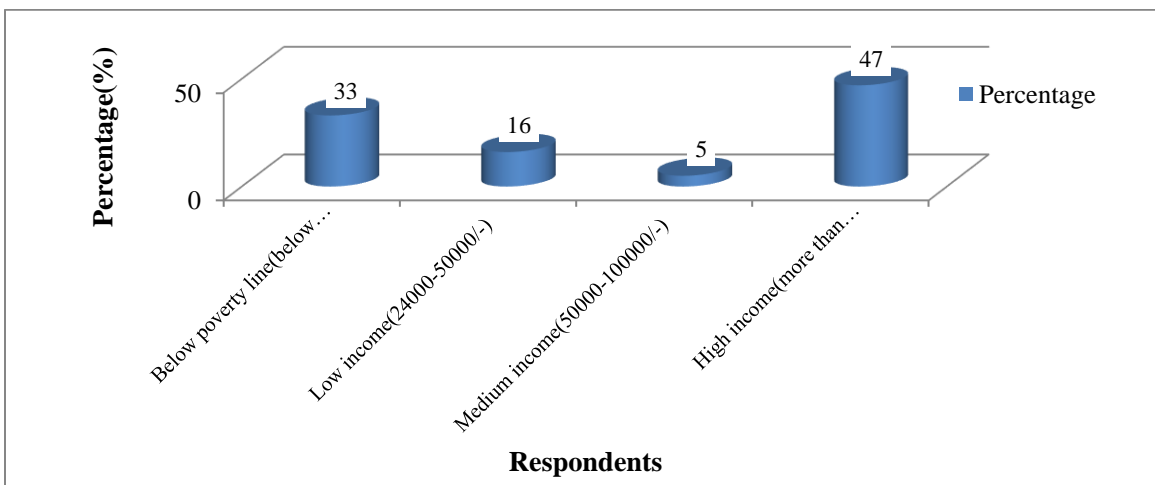


Fig. 3: Distribution of respondent based on annual income

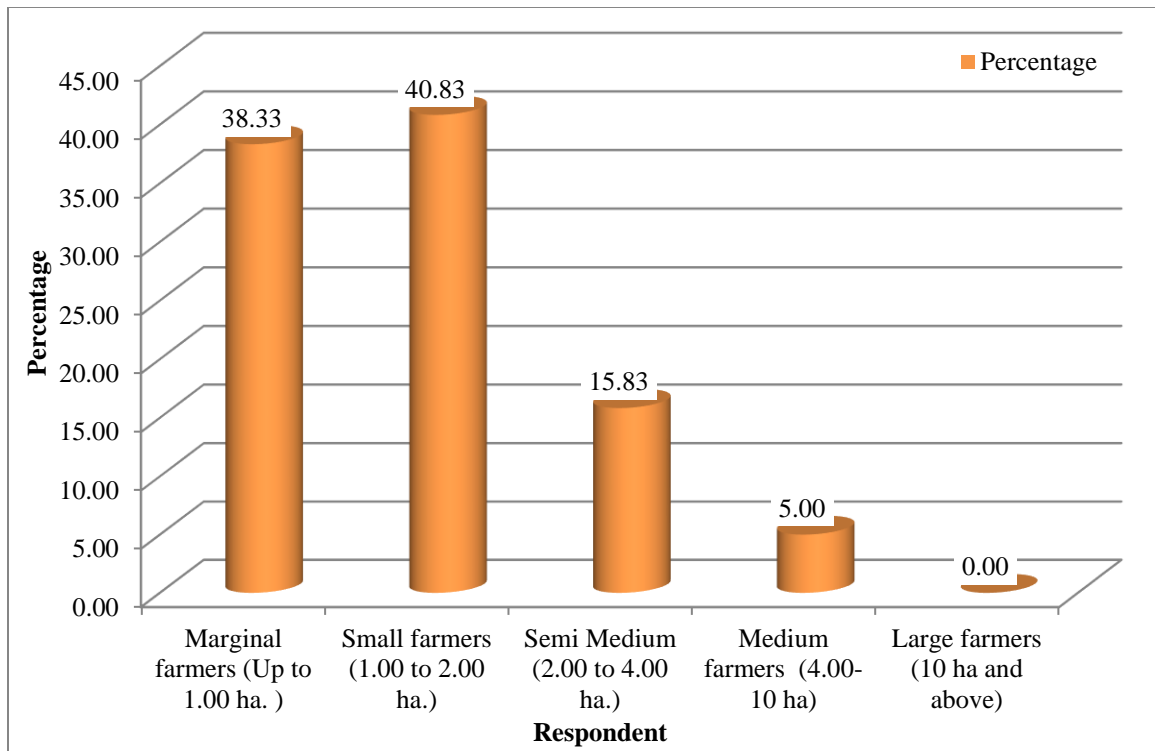


Fig. 4: Distribution of respondents according to their Farm size

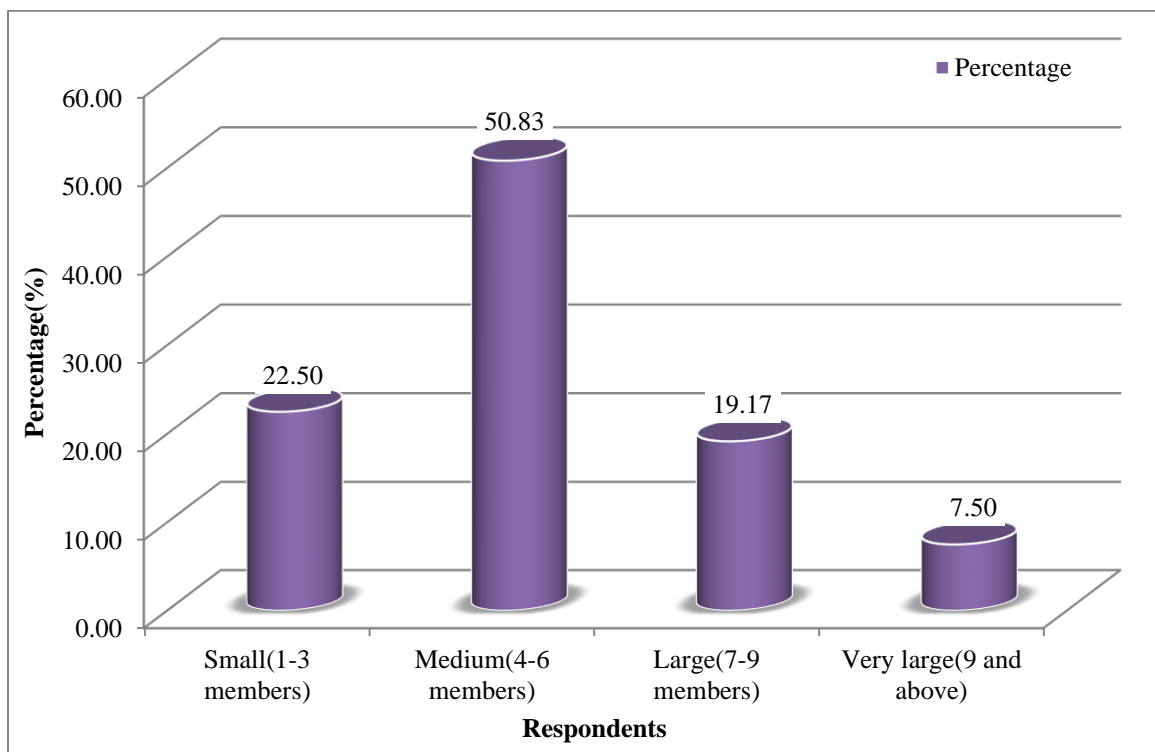


Fig. 5: Distribution of the respondents according to their family size

4.1.6 Livestock positions among respondents

Biogas households of livestock were surveyed based on the types of animals they keep *viz.*, buffalo, cow, ox and sheep; it can be classified as follows based on the total number of livestock holdings by respondent.

Table 4.6 provides information about the total livestock holding of the respondents that owned biogas in their households and run the biogas with the waste of livestock. The result shows that more number of respondents (43.33%) had low level livestock possession, while 40 per cent and 16.67 per cent of respondents had medium and high level of livestock possession respectively (Fig.6).

The number of animals is a significant factor in determining the progress of biogas technology, as this helps to increase both benefit and biogas production. Jayale (1992), and Jain (2014), made similar observations.

Table 4.6: Livestock positions among respondents

(n=120)

Sl. No.	Livestock	Frequency	Percentage (%)
1.	Low (<3.0)	52	43.33
2.	Medium (3.0-5.0)	48	40.00
3.	High >5.0	20	16.67

4.1.7 Reasons for undertaking the biogas activities

The question was posed with the answer of all owners of biogas plants to know the reasons behind the use of biogas plants. All respondents were categorized into six factors in the answer type, which received more than one response. The specifics are set out below.

Table 4.7 clearly shows that about 94.17 per cent are built biogas by the motivation from BDTC and followed opinioned that less fuelwood consumption

(85.83%), motivation from existing biogas plant owner (70%), saves time and energy about 44.17 per cent and merely because of non-availability of other source (28.33%) and easy for cooking (13.33%) respectively.

Shrestha, (2010) found the diversified reasons for the installation of biogas plant. By his survey, seemed the lack of knowledge among the biogas households in use and storage of bio-slurry as fertilizer.

Table 4.7: Reasons for biogas using

(n=120)

Sl. No.	Reasons for biogas installation	No. of Respondents	Percentage
1	Save time and energy	53	44.17
2	Easy to cook	16	13.33
3	Motivation from BDTC	113	94.17
4	Non-availability of other fuel sources	34	28.33
5	Motivation from existing biogas plant owner	84	70.00
6	Less fuel wood collection	103	85.83

4.2 Impact of biogas adoption on health of farmers

The health and hygiene benefits of biogas plants were asked among the responded with direct interaction by considering based on disease incidence and family health condition.

4.2.1 Disease incidence after biogas installation

The distribution of incidence of diseases before and after biogas plant installation is presented in Table.4.8. Here higher number of respondents thought that various diseases 33.33 per cent respondents noticed eye infection before installation 7.50 per cent respondents noticed after installation, respiratory diseases 42.50 per cent respondents noticed before installation, only 2.50 per cent noticed after installation like that headache

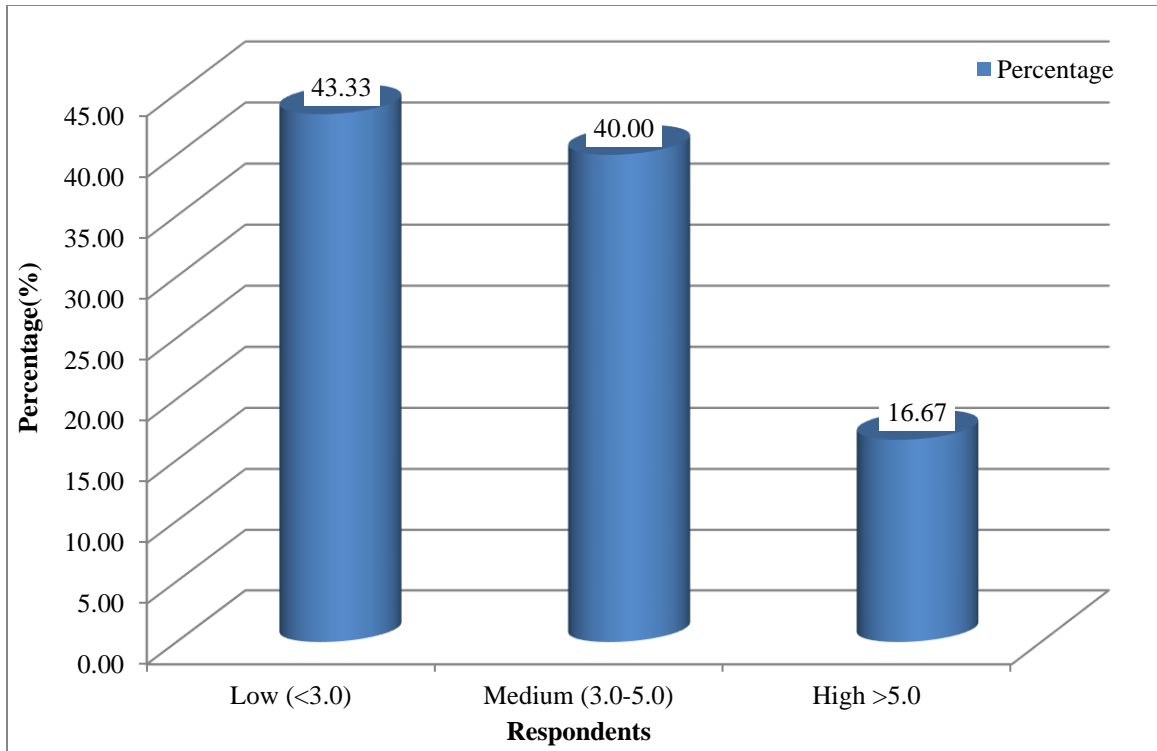


Fig. 6: Livestock possession among respondents

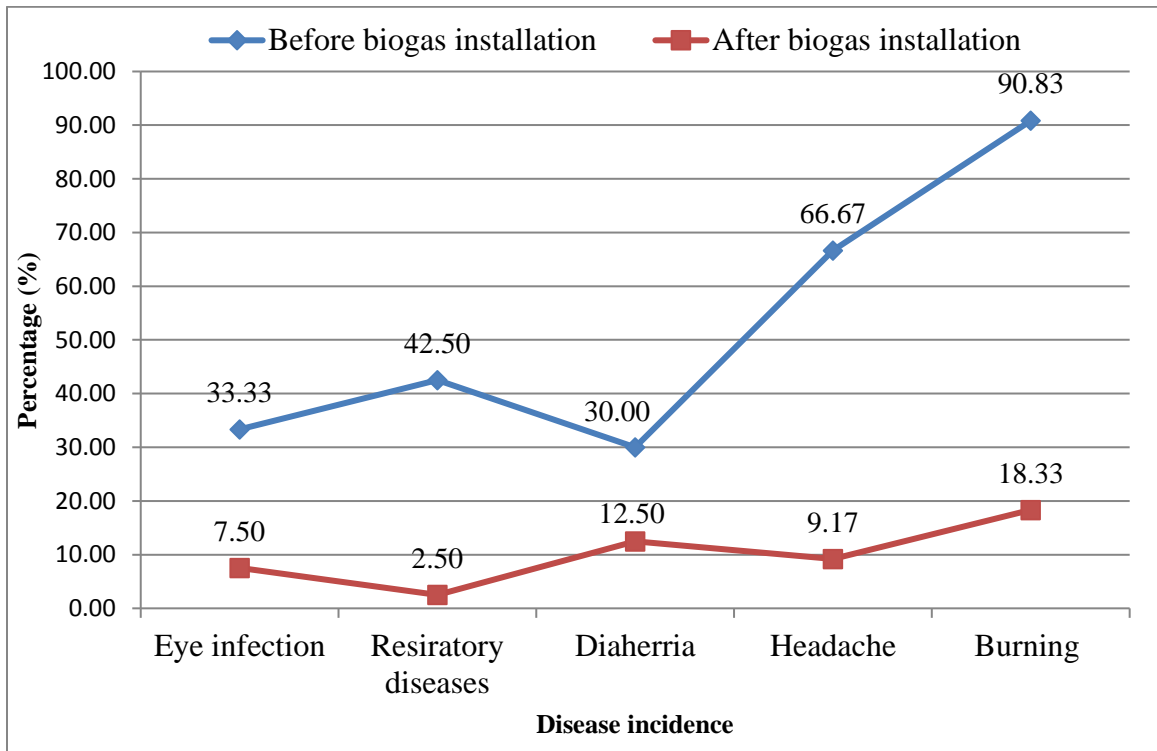


Fig. 7: Distribution of disease incidence level before and after biogas installation

noticed 66.67 per cent respondent before installation 9.17 per cent respondent noticed after installation, 30 per cent are opined that diarrhea before installation of biogas 12.50 per cent noticed after installation, followed by 90.83 per cent burning cases are noticed before installation of biogas 18.33 per cent are noticed after installation of biogas, this overall will be concluded that the disease incidence before biogas installation is more and after installation of biogas it will eventually reduce (Fig.7).

Table 4.8. Incidence of diseases before and after biogas installation.

Disease	Before biogas installation	After biogas installation
Eye infection	40 (33.33%)	09 (7.50%)
Respiratory diseases	51 (42.50 %)	03 (2.50%)
Diaherria	36 (30.00%)	15 (12.50%)
Headache	80 (66.67%)	11 (9.17%)
Burning	109 (90.83%)	22 (18.33%)

4.3 Economic and environmental benefit of biogas

Evaluation of the feasibility of biogas was made in terms of annual cost, annual return, payback period and benefit to cost ratio, for 2, 4, 6 cu.m biogas plants at present capacity utilization and full capacity utilization.

Some of the greenhouse gas emissions are causing the current climate change in the world and it can be traced through human activity, particularly in developed countries, has resulted in the high concentration of these gases, specifically CO₂, CH₄ and N₂O. The largest source of greenhouse gas emissions lies in the inefficient use of conventional biomass resources such as fuel wood, crop waste, animal dung etc.

4.3.1. Economic benefit of biogas: Annual cost estimation

Result of the annual total cost for different size of plants was shown in Table 4.9. It shows that annual fixed cost is more compared to operational cost in different size of biogas plants.

Table 4.9: Annual cost in rupees for different size of biogas

Cost of particular	Size of biogas plants (m ³)		
	2	4	6
Total installment cost (₹)	18158.89	36317.79	54476.68
Depreciation (₹)	907.94	1815.889	2723.834
A) Fixed cost (₹)	1062.3	2124.6	3186.89
B) Operational cost (₹)	600	1000	1200
Total cost (A+B) (₹)	1662.3	3124.6	4386.89

4.3.2. Cost of production of different cubic meter (m³) biogas

Values of the cost of production given in the Table 4.10. Production cost per cu. m of biogas found to be 2.85, 2.68, 2.50, rupees for plant size 2, 4, 6. respectively at present capacity utilization and the production cost decreased to 2.28, 2.14, 2.00 rupees for different biogas size 2, 4, 6 cu.m at full capacity utilization

Table 4.10: cost of production of biogas in Rs /m³ at different capacity

Particulars	Size of biogas plants (m ³)		
	2	4	6
A) 100% capacity utilization			
Annual biogas production (cu.m/year)	730	1460	2190
Production cost (₹)	2.28	2.14	2.00
B) Present capacity utilization (80%)			
Annual biogas production (m ³)	584	1168	1752
Production cost (₹)	2.85	2.68	2.50

4.3.3 Annual return of different cubic meter (m³) biogas

The values of annual return from different size of biogas plants presented in Table 4.11. It was noticed that current capacity of utilization of biogas were 80 per cent as compared to full capacity utilized biogas plants and fuels, present capacity utilization 6 cu.m highest of 29608.80 and lowest of 12264 rupees can be realized if biogas is valued at rate of LPG and fuel wood respectively, and it can be more about 37011 and 15330 rupees if biogas used in full capacity.

Table 4.11: Annual return from biogas in rupees in comparison with different fuels

Types of Fuel	Replacement value of biogas	Cost of fuel (₹/ unit)	Size of biogas plant (m ³)					
			2		4		6	
			FCU	PCU	FCU	PCU	FCU	PCU
Fire wood	3.5 kg	2	5110	4088	10220	8176	15330	12264
Kerosene	0.60 ltr	25	10950	8760	21900	17520	32850	26280
LPG	0.40 kg	42.25	12337	9869.6	24674	19739.2	37011	29608.8

FCU: Full capacity utilization

PCU: Present capacity utilization

4.3.4 B:C Ratio and Payback period

The data of B:C Ratio and Payback Period shown in Table 4.12. B:C Ratio of biogas in comparison to fuel wood is less than three at present capacity utilization and at full capacity utilization it will be more than three. In case of kerosene and LPG, B:C Ratio increases and payback period decreases with increased size of adoption. Full capacity utilization B:C Ratio increased and Payback period decreased compared to at present capacity utilization of biogas, so larger size of biogas adoption taking very short time to recover the cost of investment compared to lesser size of biogas adoption.

Table 4.12: B:C (Benefit to cost) Ratio and payback period (PBP) of different sizes of biogas plant in comparison with the different fuel

Particular	Size of biogas plants (m ³)					
	2		4		6	
	B:C	PBP (Year)	B:C	PBP (Years)	B:C	PBP (Years)
Fuel wood						
FCU	3.07	5.27	3.27	5.12	3.49	4.98
PCU	2.46	7.49	2.62	7.19	2.80	6.92
Kerosene						
FCU	6.59	1.96	7.01	1.93	7.49	1.91
PCU	5.27	2.56	5.61	2.52	5.99	2.49
LPG						
FCU	7.42	1.70	7.90	1.69	8.44	1.67
PCU	5.94	2.21	6.32	2.19	6.75	2.16

4.3.5 Environmental benefit of biogas plants: fuel wood consumption pattern before and after installation of biogas.

The average fuel wood consumption per household was calculated from Table 4.10 as 6562.80 kg / household and 2822 kg / household at the biogas plant before and after the adoption, and percent of fuel wood saving 56.99 per cent shown in Table 4.13. This clearly shows the dependency of the people on the forest for the fuelwood consumption will reduce after adoption of biogas as an energy source.

Table 4.13: Fuel wood consumption before and after biogas installation

Sl. No.	Average fuelwood consumption	Before Biogas Installation (Kg/ household)	After Biogas Installation (Kg/ household)	Fuelwood Saving (Kg/ household)	Percentage Fuelwood Saving
1	Per day	18.23	7.84	10.39	56.99
2	Per year	6562.8	2822.4	3740.4	
Annual expense on Fuelwood/household/ year @ INRs. 2/kg		13125.6	5644.8	7480.8	

4.3.6. Greenhouse gas emission by fuel wood per household

Table 4.13 represents Greenhouse Gas (GHG) emission from fuelwood burning per household and total CO₂ Emission in kg per household per year by considering the total fuelwood consumption per household though Table 4.14. It shows that before using biogas plant the total amount in kg of CO₂ emission per household per year was found that 9962.63 kg and it has reduced to 4288.35 kg emissions per household per year by installing and using biogas plant.(Here different GHG values converted into CO₂ emission)

Table: 4.14. Total emissions of greenhouse gases by fuelwood

Sl. No.	Respondent	Average Fuelwood consumption (kg/ household /month)	GHG	Emission in kg/ month / household	Emission in kg/year/ household	Total Emission of GHG in kg /Household/ year
1.	Before installing biogas plant	546.92	CO ₂	768.96	9227.58	9962.63
			CH ₄	45.94	551.29	
			N ₂ O	15.31	183.76	
2.	After installing biogas plant	235.42	CO ₂	331.00	3971.95	4288.35
			CH ₄	19.78	237.30	
			N ₂ O	6.59	79.10	

Shrestha (2010) reported that by installation of biogas and replacement of fuel wood, GHG emission reduced from 6,025.538 kg of CO₂ emission/year to 3,656.6519 kg of CO₂ emission/year. Greenhouse gas (including 6613.99 kg of CO₂ emission/year/plant) for a biogas household.

4.3.7. Greenhouse gas emission by kerosene per household

(n=120)

Table 4.15 shows the total greenhouse gas emission from kerosene utilizing by family, here different GHG are converted into CO₂ Emission in kg per household per year by considering the total kerosene consumption per household, It shows that before using biogas plant the total amount in kg of CO₂ emission per household per year was found that 165.93 kg and it has reduced to 31.80 kg emissions per household per year by installing and using biogas plant. (Here different GHG values converted into CO₂ emission).

Table: 4.15. Total emission of Greenhouse gases by kerosene

Sl. No.	Respondent	Average kerosene consumption (kg/household /month)	GHG	Emission in kg/month / household	Emission in kg/year/ household	Total Emission of GHG in kg /Household/ year
1.	Before installing biogas plant	5.57	CO ₂	13.68	164.13	165.93
			CH ₄	0.04	0.47	
			N ₂ O	0.11	1.34	
2.	After installing biogas plant	1.07	CO ₂	2.62	31.45	31.80
			CH ₄	0.01	0.09	
			N ₂ O	0.02	0.26	

4.3.8. Environmental impact after biogas installation

In Fig 8 clearly shows that 92.50 per cent, 96.60 per cent, 95.83 per cent, 97.50 per cent, (more than one opinion given) are opinioned that biogas installation reduces surrounding environmental related impacts such as reduction indoor pollution, reduction of dirt in surroundings, absence of bad odour, reduction in firewood usage respectively, this how biogas installation positively impact on environment.

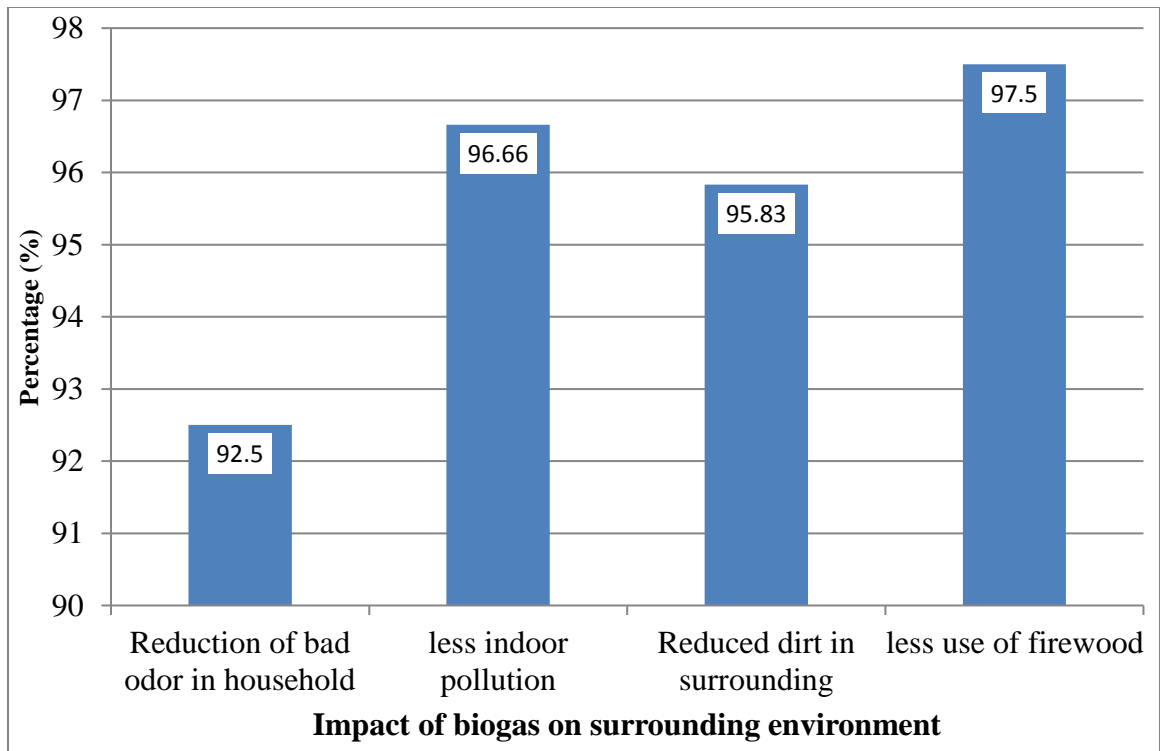


Fig. 8: Environmental impact after biogas installation

V SUMMARY

The present investigation entitled “**Economic and Environmental impact of biogas plants in Western Ghats of Karnataka state**” was undertaken in selected eight villages of Uttara Kannada and Belagavi districts of Karnataka. This study mainly for the understand the socio-economic situation, health and environmental impact of biogas beneficiaries.

Based on maximum number of user of biogas in Uttara Kannada and Belagavi district 120 biogas users were selected, then profile of biogas users were measured based on number of categories such as age, education, annual income, farm size, family size and etc., The dependent variables studied were, impact of adoption of biogas plant on the environmental status of biogas users.

The interview schedule was structured to gather the appropriate details from identified variables. The questions posed in the interview schedule were simple, clear and directly related to the studies objective, and organized in logical sequence. The data were gathered in a personal interview with the biogas users, the result of the investigations are summarized below:

- As per collected information overall socio-economic situation of the respondents such as age, education level, annual income, farm size, have significant positive impact on adoption of biogas and its maintenance.
- Livestock possession data shows that adoption of livestock mainly helps in consistent level of maintenance of biogas input such as dung.
- From the survey it could be conferred that higher number of respondents were suffering from various diseases such as respiratory diseases before the installation i.e., 42.50 per cent respondents were suffering from respiratory diseases, whereas only 2.50 per cent were noticed after installation. Similarly, the number of people suffering from headache reduced from 66.67 per cent to 9.17 per cent after installation showing positive sign. Likewise, 33.33 per cent respondents found to have suffered from eye infection before installation, 7.50 per cent respondent after installation. 30 per cent

respondents were suffered with diarrhea before installation of biogas, where it was reduced to 12.50 per cent after installation, from this it could be concluded that the occurrence of disease was more before biogas installation and after installation of biogas plant it was eventually reduced, indicating that biogas plant has positive effect on public health.

- Evaluation of the feasibility of biogas was made in terms of annual cost, annual return, payback period and benefit to cost ratio, for 2,4,6 cu.m biogas plants at present capacity utilization and full capacity utilization. In economic analysis biogas adoption at higher size with full capacity utilization is economically viable than present capacity utilization.
- Greenhouse gas emission by using fuelwood and kerosene could be reduced after the adoption of the biogas plant, eventually helps in improving the surrounding environment and also helps in maintaining the cleanliness there by improving hygiene and reducing the adverse effect on health of people using biogas plant.

High percentages of biogas plant beneficiaries expressed that as biogas burns cleanly and completely, homes were not filled with smoke and waste, saves time for women from firewood collection and reduces transportation drudgery, saves time spent in cooking and utensil washing. Further it leads to improvement in the environment, sanitation and maintains hygiene in house. Biogas technology is cheaper and much easier than that for other biofuels and is suitable for implementation on a small scale. The sanitation could be maintained by disposing off household waste and bio-wastes in useful manner. In comparison to fossil fuels, biogas helps to minimize CO₂ emissions, reduces the dependency on the forest for fuelwood and creates enriched organic manure that can complement or even substitute chemical fertilizers. Any biodegradable material can be used as a substrate for biogas production which helps to maintain the environment through energy-related recycling.

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ANNEXURES

SCHEDULE

Household Information

Name of Biogas Owner:.....Age of Owner:

Education level:..... Family Size:..... Village:

District:

Land holding

Cultivable Land (acres)	Non cultivable Land(acres)	Total Land Area (acres)

Agricultural Production

Agricultural crops	Production in kg	Consumption in kg	Saving in kg	Current Market price/kg

Livestock Ownership

Livestock	Adult	Calf	Total
The Quantity of dung production per day, kg			

Daily feeding of Biogas Plant

Sl. No.	Source	Daily feeding in Kg
1	Cow dung	
2	De-Oiled cake	
3	Poultry/ organic waste	
4	Others	

1. INSTALLATION AND FUNCTIONING OF BIOGAS PLANT

1.1. What is the motivating reason behind installing a biogas plant? (Answers can be more than one)

1.	Motivation from BDTC
2.	Non-availability of other fuel sources
3.	Motivation from existing biogas plant owner
4.	saves time and energy
5.	Less fuelwood collection
6.	Easy to cook

1.2. How much did you spend on your biogas plant?

1. INR _____ 2. Do not Know

1.3. The amount of cement, brick, pipes and labour involved in the construction of the plant

Cement	Bricks	Labor	Pipes
Number of bags	Number of bricks used	How many laborers were required?	The number of pipes used
Cost of one bag	Cost of one brick	Number of hours of each laborer	The cost of each pipe

1.4. Is your biogas plant functioning? If yes, are you satisfied with the functioning of the plant?

1. Yes 2. No

1.5. What are the main reasons for satisfaction?

1. Enough gas for cooking 2. Enough gas for lighting 3. Easy cooking/ Lighting
4. Utensils are Cleaner 5. Savings in cooking fuel 6. Workload reduction
7. Benefits from bio slurry

1.6. What are the reasons for not being satisfied?

1. Plant has failed; it does not work at all 2. Very little gas for cooking / lighting
3. Often encounter technical problems. 4. More added work
5. Food cooking in gas is not tasty.

1.7. If the plant has failed, what are the reasons for such failure?

1. Poor workmanship during construction. 2. Poor operation
3. Poor maintenance 4. Others

1.8. What is the frequency of feeding the plant?

1. Daily 2. Once in two days 3. Once in three days 4. Once in four days

1.9. How much dung is fed at one feeding? Is the amount same for all the feedstock?

(Yes/No)

1. _____kg 2. Do not Know

1.10. Do you use other feeding materials besides dung?

1. No 2. Kitchen and household wastes _____kg/day
3. Poultry droppings _____kg/day 4. Agricultural wastes _____kg/day

1.11. How much water is required to mix dung?

1. More than the volume of dung
2. Equal to the volume of dung
3. Less than the volume of dung.

1.12. What are the common problems with your plant?

1. Gas leakages through joints
2. Mal/Non-functioning of stoves
3. Slurry in pipeline
4. Clogging of pipes because of condensed water
5. Low gas production

1.13. How much INR you need per year for operation and maintenance of your plant?

1. Rs.
2. Cannot say
3. Not applicable

2 SAVING OF CONVENTIONAL FUEL SOURCES

2.1. For what purpose is biogas used?

1. Cooking only
2. Lighting only
3. Cooking and Lighting both
4. Others (specify)

2.2. How many stoves / gas lamps have you installed?

1. 1/2/3/4 stoves (single burner double burner)
2. 1/2/3/4 gas lamps

2.3. How long the stove is burnt in a day (calculate the timing on stove / lamp hour)?

1. Stove. __Hrs. Lamp __Hrs. in the evening, if used

2.4. For how many months is the gas insufficient?

1. Throughout the year
2. During winter months (from ____ to ____)
3. Other (specify)

2.5. If the gas is not sufficient what do you supplement it with? (Amount in kg/ price in INR/kg.

1. Fuel wood ____kg @ INR ____per kg
2. Dung cake __kg @ INR ____per kg
3. Kerosene ____litre @ INR ____ per liter.

2.6. How much fuel is required for cooking before the installation of biogas plant per month?

1. Fuel wood____kg @ INR____per kg
2. Kerosene____liter @ INR____per liter.
3. LPG__cylinder @ INR per cylinder of __kg
4. Electricity____unit @ INR__per unit.
5. Dung cake____kg @ INR____per kg.
6. Agricultural wastes_kg @ INR____per kg.

2.7. How much fuel is required for cooking after the installation of biogas plant per month?

1. Fuel wood____kg @ INR____per kg
2. Kerosene____liter @ INR____per liter.
3. LPG__cylinder @ INR per cylinder of____kg
4. Electricity____unit @ INR____per unit.
5. Dung cake____kg @ INR____per kg.
6. Agricultural wastes____kg @ INR____per kg.

2.8. How much fuel is required for lighting before the installation of biogas plant per month?

1. Kerosene____liter @ INR__per liter.
2. Candle ____ No @ INR____ per no.
3. Electricity____unit @ INR__per unit.

2.9. How much fuels required for lighting after the installation of biogas plant per month?

1. Kerosene____liter @ INR__per liter.
2. Candle__No @ INR____per no.
3. Electricity____unit @ INR__per unit.

2.10. Do you buy fuel wood, dried dung or agricultural wastes or collect it from common/own sources?

1. Buy fuel wood @ INR____/ kg, dung cake @ INR____/ kg and agricultural wastes @ INR__kg from vendors.
2. Collect from forest/ community land/ own land / other sources.
3. Both 1 and 2.

2.11. What is the quantity of fuel wood you buy or collect in a year?

1. Buy ___ kg/yr. 2. Collect ___ kg/yr.

2.12. How much fuel wood can you collect from the forest/ community land / own Land source in a day?

1. Less than 25 kg 2. 25-35 kg 3. 35-45 kg
4. 50-75 kg 5. More than 75 kg

2.13. What is the average time required to collect firewood (hrs/day)?

1. Less than 0.5 hr. 2. 0.5-1 hr. 3. 1-2 hrs.
4. 2-4 hrs. 5. 4-7 hrs. 6. More than 7 hrs.

2.14. Do you feel that your expenditure in fuel collection has gone down because of biogas plant?

1. No not at all 2. Yes to some extent 3. Yes significantly 4. It has gone up
5. Do not know.

2.15. Have you experienced any advantages of biogas over the other conventional fuel sources?

1. No 2. Less costly 3. Comfortable and easy to operate
4. Environment friendly 5. Energy efficient

2.16. Have you experienced any time saving after the installation of biogas plant?

1. No; time is not saved
2. Cooking _____ hrs. saved per day.
3. Collection of water ___ hrs. Added.
4. Mixing of dung and water ___ hrs. added.
5. Collection of fuel wood _____ hrs. saved.
6. Cleaning of cooking utensils ___ hrs. saved
7. Caring of cattle _____ hrs. saved / added.

3. USE OF BIOSLURRY

3.1. Do you use biogas slurry on farm?

1. Yes
2. No

3.2. If not, what do you do with the slurry?

1. Sale to others
2. Give out to others
3. Drain to water courses or drains
4. Others (Specify).

3.3. Why you do not use slurry?

1. It has lesser nutrient value.
2. It is difficult to use.
3. No land to use.
4. Other (Specify).

3.4. If Yes, What do you do with the slurry?

1. Use as organic fertilizer without composting
2. Use as organic fertilizer after composting
3. Use slurry through irrigation canal directly
4. Use as fish food.

3.5. How much fertilizer (all N,P,K) you need to use before installation of the plant?

1. Never use chemical fertilizers
2. Less than 10 kg per year.
3. 10-25 kg year
4. 25-50 kg per year
5. More than 50 kgs per year.

3.6. Have you experienced any savings in chemical fertilizer after the use bio slurry?

1. No
2. Less than 10 kg per year (INR_____ per kg)
3. 10-25 kg year
4. 25 to 50 kg per year
5. More than 50 kgs per year.

4. EFFECT OF BIOGAS ON USERS

4.1. What are the main benefits of biogas plants related to health and hygiene?

(Multiple answers)

1.	Reduction in smoke related health hazards
2.	Reduction in burning cases
3.	Absence of black soot in kitchen/house
4.	Reduced expenses related to health

4.2. Number of children of school going age, attending school

	Before biogas	After biogas
Male		
Female		

4.3. How much time is spent for the following activities before and after the installation of biogas plant?

Activity	Before		After	
	Time in	Who used to do?	Time in	Who does
Collection of wood				
Taking of cattle				
Cooking				
Cleaning of kitchen				
Collection of water				
Collection of dung				
Preparation of dung				
Plant feeding				

4.4. Did any of the family members had the following diseases/ problems before the installation of biogas plant? If yes, is there any change after the installation of biogas plant?

Disease / Problem	Before Biogas Plant	After Biogas Plant
Respiratory diseases	No/Yes	No/Yes
Headache / dizziness	No/Yes	No/Yes
Eye burning / Irritation	No/ Yes	No/ Yes
Diarrhea and dysentery	No/ Yes	No/ Yes
Burning cases	No/ Yes	No/ Yes
Any other	No/ Yes	No/ Yes

4.5. Has any of your female household members started the following activity?

1. Started attending school
2. Started income generating activity
3. Joined other groups/ institutions please specify.

4.6. What are the main demerits of biogas plants related to health and hygiene?

1. None
- 2.....
- 3.....