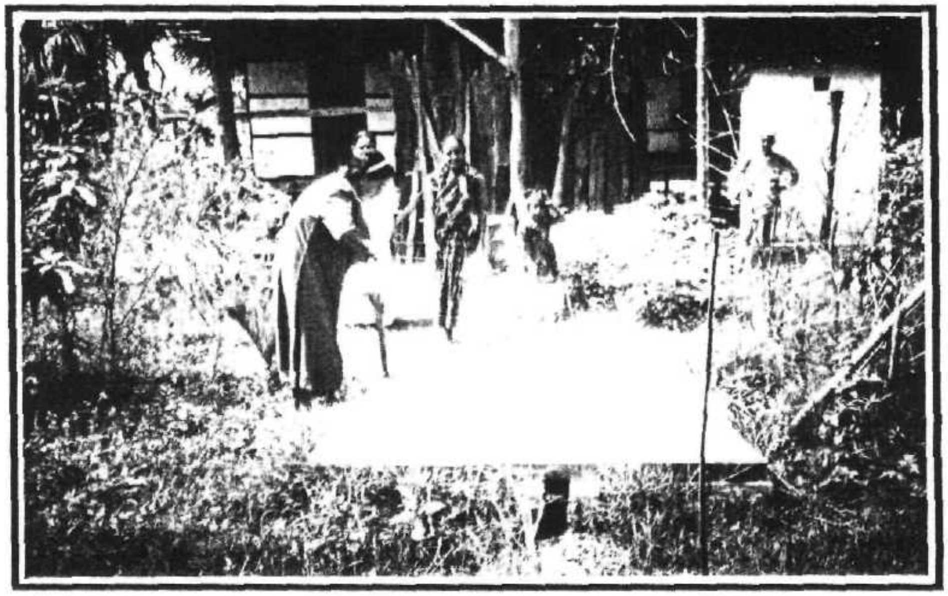
RESEARCH STUDY ON OPTIMAL BIOCAS PLANT SIZE DAILY BIOCAS CONSUMPTION PATTERN AND CONVENTIONAL FUEL SAVING



Final Report

Submitted to

Biogas Support Programme (BSP)

Submitted by

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ABBREVIA TIONS AND ACRONYMS

ADB/N	-	Agricultural Development Bank of Nepal
B/C	-	Benefit-Cost Ratio
Bhari	-	Local Unit used to Quantify the Fuel-wood (1 bhari = 30 kg approx..)
BSP	-	Biogas Support Programme
CBS	-	Central Bureau of Statistics
DevPart	-	Development Partners (P) Ltd.
DG1S	-	Directorate General for International Co-operation, The Netherlands
FRA	-	Female Research Assistant
FY	-	Fiscal Year
GGC	-	Gobar Gas Company
GR1	-	Grihini Gobar Gas Company
gm	-	Gram
Ha	-	Hectares
HH, hh	-	Household
HMG/N	-	His Majesty's Government of Nepal
HRT	-	Hydraulic Retention Time
hr.	-	Hour(s)
KfW	-	Kreditanstalt fur Wiederauibau
Kg.	-	Kilo gram
KGY	-	Kishan Gobar Gas Ugyog
Km.	-	Kilometre
LPG	-	Liquid Petroleum Gas
Ltr	-	Litre
Muri	-	Local Unit used to measure the Weight of Cereals
MS	-	Microsoft
NA	-	Not Applicable
NBL	-	Nepal Bank Limited
NGO	-	Non-governmental Organisation
NRG	-	Nepal Rastriya Gobar Gas Company
O & M	-	Operation & Maintenance
PC	-	Personal Computer
RBB	-	Rastriya Banijya Bank
Rs.	-	Rupees
SLC	-	School Leaving Certificate
SNV	-	Netherlands Development Organisation
SPSS	-	Statistical Package for Social Sciences
ToR	-	Terms of Reference
TS	-	Total Solids
VDC	-	Village Development Committee
VS	-	Volatile Solids
Wt.	-	Weight

PREFACE AND ACKNOWLEDGMENT

Biogas Support Programme (BSP), a joint venture of SNV-Nepal, KfW, ADB/N, RBB, NBL and recognized Biogas Plant Construction Companies, hired DevPart Consult in October 1998, to undertake a research study on, **'Optimum Biogas Plant Size, Daily Biogas Use Pattern and Conventional Fuel Saving'.** The study was carried out during the period June 1998 to October 1999 in four ecological zones, namely; High Hills, Middle Hills, Inner Terai and Terai Regions of the country, which were represented by Syangja, Nuwakot, Chitwan and Morang districts respectively. This report is the outcome of the research study.

The core members of the field study team comprised of a Senior Civil Engineer as the Team Leader/ Principal Researcher and eight Female Research Assistants. The Team Leader was assisted by two socio- economists and a technical assistant to monitor the field activities. Besides, two Computer Operators assisted the Team Leader to entry and refine the data and information. The Team Leader took overall responsibility of analysing and processing the data collected in the Held. The following personnel were involved to execute the study:

Mr. Prakash C. Ghimire	-	Team Leader / Senior Civil Engineer
Ms. Archana Bhattarai	-	Research Associate / Socio-economist
Mr. Subash Ghimire	-	Research Associate / Socio-economist
Mr. Guna B. Lama	-	Research Associate / Sr. Overseer
Ms. Kalpana Ojha	-	Research Assistant (Morang)
Ms. Kopila Nepal	-	Research Assistant (Syangja)
Ms. lndra Kumari Rijal	-	Research Assistant (Syangja)
Ms. Sachina Tamang	-	Research Assistant (Nuwakot)
Ms. Ganga Rimal	-	Research Assistant (Nuwakot)
Ms. Brinda Ghimire	-	Research Assistant (Chitwan)
Ms. Goma Baniya	-	Research Assistant (Chitwan)
Ms. Subindra K.C.	-	Research Assistant (Chitwan)
Ms. Sangeeta Pokhrel	-	Computer Operator / Data Processor
Mr. Megh Nath Dhakal	-	Computer Operator / Data Processor

Preliminary works of the study commenced from April 1998 and the actual research works commenced from July 17, 1998. Of the total study period of 15 months, a complete cycle of one year was spent on the field investigation and data collection in respective households with and without biogas plants sampled for the study.

Three Quarterly Reports were submitted to BSP in November 1998, March 1999 and June 1999. This is the Final Report of the study. This report is divided into ten chapters. Chapter-1 is an introductory chapter that addresses study objective, expected outputs, methodology etc. Sequences of activities carried out during the course of the study have been described in Chapter-2 and Chapter -3 deals with socio-economic characteristics of sampled biogas and non-biogas households. Data and information on operation, functioning and overall performance of biogas plants in different conditions are highlighted in Chapter-4. Biogas Use Patterns of the households under study have been summarised in Chapter-5 and Chapter-6 deals with use of biogas and conventional fuel sources. Chapter-7 deals with optimum size of biogas plant and, lab analysis reports of raw dung and digested slurry have been presented in Chapter-8. The overall conclusions have been discussed in Chapter-9, and the last chapter, Chapter-10 contains the list of relevant reference materials used on course of the study. Executive summary of the study, lists of abbreviation used in the text etc, have been given in the beginning and some relevant appendix materials are included at the end of the report.

This study is first of its nature to analyse the wide-ranging issues related to the optimum biogas plant size, biogas use patterns and conventional fuel saving after the installation of biogas plants. This study has resolved various issues on plant functioning and has also raised more issues for further consideration. Further studies on the identified and unresolved issues will be crucial for the successful

promotion of Biogas technology in the country. It is hoped that the findings and recommendations of the study will be able to make humble contribution for the speedy and sustainable promotion of biogas technology in rural areas in Nepal.

The study team received help and advice from a large number of people in the course of the study, without which the completion of the study would have been difficult. First of all, the study team extends its appreciation to all, the name of whose do not appear in the acknowledgement list,

DevPart sincerely acknowledges Biogas Support Programme, SNV-Nepal, for entrusting it to undertake this challenging assignment. We would especially like to mention Mr. Felixter Heegde, the then Programme Manager, Mr. Sundar Bajgain, Programme Manager and Mr. Willem Boers, Biogas Engineer of BSP, who deserves special thanks for the valuable time and support they extended for this study. Their continued co-operation and consideration on extending the time of for the study are sincerely acknowledged. Similarly, Mr. Bajgain and Mr. Boers BSP, also helped us with useful comments and suggestions on the draft report, that is gratefully acknowledged. Mr. Balaram Shrestha and other staff members of BSP co-operated us with their timely and prompt assistance whenever requested, that is also gratefully acknowledged. Thanks are also due to all the staff of the technical section of BSP for their supports in respective study areas. Most importantly, we would like to express our gratitude for the BSP family's diligent and patient to bear with us despite a great delay in submitting this Final Report.

DevPart cordially extends its sincere thanks to all office bearers and local masons from KGY, GRI and NRG for their unfailing supports and co-operation during the study. We would especially like to acknowledge the help of Mr. Nelra Neupane of the then GRI, Mr. Keshab IChadka and Mr. Madhav Dhungana of KGY and Mr. Pam Narayan Sharma and Mr. Suman Raj Gin of NRG. Most importantly, DevPart cordially extend their thanks to all the biogas and non-biogas households sampled for the study who provided their valuable time and co-operation for the whole one year of the study cycle. Without their assistance and co-operation this study would not have been possible. We hope that the study truthfully reflects the views, problems and perceptions of these people to a great extent.

Thanks are also due to Prof. dr.ir. G. Lettinga from Wageningen Agricultural University in Holland, Prof. George Chan of Tokyo University in Japan, Dr. Look Hulshoff-Pol from TBW GmbH in Germany, Dr. Do Ngoc Quynh from Renewable Energy Centre of Can The University in Vietnam who provided with us very useful suggestions.

DevPart places on record it's sincere acknowledgement of BSP, SNV-Nepal's confidence in placing this assignment in our care.

Prakash C. Ghimire
Chief Executive

EXECUTIVE SUMMARY

- Realisation of the fact that the present cost of biogas plant could not be brought down by other means other than by using the generated gas more efficiently, a research study on 'Optimum Biogas Plant-size, Biogas Use Pattern and Conventional Fuel Saving' was proposed by BSP, The outcome of this study is expected to be used to convince actors in the sector like companies and banks to construct the appropriate size of plant given availability of dung; and draw up stricter quality norms regarding size selection.

- The major objectives of the study were; to obtain reliable data regarding the actual savings on conventional fuel for an average biogas household in the hills and the Terai; to obtain reliable data regarding the replacement value of biogas vs. conventional cooking fuels; to determine which plant volume is most efficient (cost effective) given average annual temperature and daily feeding; and, to collect accurate data regarding the daily gas consumption patterns for different family consumption, climate zones and seasons.

- The study was carried out by DevPart Consult Pvt. Ltd. in 80 biogas and 40 non-biogas households for complete one-year cycle in Syangja, Nuwakot, Chitwan and Morang districts that represented High-hills, Mid-hills, Inner-Terai and Terai regions of the country. Activities carried out included; appointment of research assistants to the selected study areas; preparation of data recording and reporting formats; orientation to the research assistants and members of households selected for study on the aim and objective of study and their roles in successful completion of the study; installation of gas metres, thermometers and other appliances as required, and delivery of other necessary equipment to the biogas households that are selected for the study; accurate measurement of conventional fuel use, quantity of gas use, recording of digester as well as ambient temperatures; laboratory analysis of total and volatile solids in slurry and digested slurry; and in-depth analysis of field findings and preparation of final research report.

- The majority of the biogas households under study were that of Brahmins/Chhetris (80%) followed by Newars (11.25%), Tamangs (3.75%), Giri (2.5%), Magars (1.25%) and Gurungs (1.25%). Similarly the ethnicity of sampled non-biogas households are Bhramin/Chhetri (82.5%), Newar (5%), Kumal (5%), Giri (2.5%), Chaudhary (2.5%) and Damai (1%). The average family size was 5.85 person per household for biogas households and 6.57 for non- biogas households. The families in both the cases had agriculture as the main source of income. Majority of the biogas households (79%) had at least one person involved in cash earning from their jobs. This figure for non-biogas households was 74%.

- The average land holding size per family was 21.5 ropani (1.07 ha.) for biogas households and 18.6 ropani (0.93 ha.) for non-biogas households which was to some extent similar to the national land holding size per family being 19.2 ropani or 0.96. Similarly, the average cattle holding size was 5.4 and 6.2 for biogas and non-biogas households respectively. The literacy rate of the selected biogas households was found to be 88.68% and that for non-biogas households is 86.92% The average family size, ethnicity, land holdings, production and consumption pattern, livestock ownership, literacy pattern etc. are quite similar in both biogas and non- biogas households. In other words the figures are comparable. It is therefore, expected that the study findings are comparable.

- The outcome of the study indicated that the whole quantity of dung produced is not collected and that collected is not wholly fed into the plant. It showed that out of the average theoretical available dung (calculated based upon number of cattle) of 40 kilograms, 36.87 kilogram (92.18%) is collected and 33.37 (83.43%) of theoretical available quantity and 90.51% of the collected dung) is fed into the digester. The average feeding rate comes to be 4.77 kilogram per cubic meter volume of the digester, which is far less than the prescribed quantities of 6 and *1.5* kilogram in hills and terai respectively. The average feeding is 74.62% of the prescribed rate. Conclusively, the plants are underfed. It is encouraging to note that some of the plant owners who do not own cattle collect dung from outside. Out of the 80 households under study, 24 of them collect dung from outside to feed into their plants.

- The outcome of the study revealed that in majority of the plants (67.5%), the dung-water ratio is maintained to 1:1. However, 5% of the total plants were found to have the ratio more than 1:1.1 and another 27.5% have ratio less than 1:0.9. In other words, 67.5% of the total plants are fed with appropriate quantity of water; 5% of the plants are fed with lesser quantity of water than the prescribed one and the remaining 27.5% plants receive more water.

- 42 plants out of the sampled 80 were attached with latrines. There exists a relationship between latrine attachment and dung feeding. Out of the total 45 plants which receive less than 80% of the prescribed feeding, 27 (60%) are attached with latrines. Similarly, 7 out of the 8 plants, which receive feeding less than 40% of the prescribed rate have latrines attached to them. In other words, the owners believe that when latrine is attached to the plant, lesser quantity of dung than prescribed would be sufficient

- The total amount of gas production from biogas plants under study have been assessed based upon stove and light burning hours and based upon the meter readings. The efficiencies of biogas plants have been calculated in two ways. The first one is gas production based upon actual burning hours versus theoretical expected production and the second one is gas production based upon actual burning hour versus theoretical expected production based upon actual amount of dung fed into the digester. In the first case, out of the total 80 plants under study, 12 have efficiencies less than 40%, 25 have efficiencies in between 40 to 60% and 26 have efficiencies in between 60 and 80. The remaining 17 plants have more than 80% efficiency. In the second case. The corresponding figures are 2, 9, 28 and 41 respectively.

- It is encouraging to note that the reduction in gas production during winter months (Magh, Falgun) is not too much. The average gas production is maximum (1020 litre/day/plant) during the month of Shrawan (July-August) and minimum (840 lit/day/plant) during the month of Magh(January/February). Similarly, 4 cubic meter capacity plants in Syangja produced 1055 litres of gas per day during the month of Shrawan and the corresponding figure in Magh was found to be 677.5. Similarly, the production figures in Nuwakot, Chitwan and Morang were 790, 775 and 438 litres respectively during Shrawan and the corresponding figures were 665, 640 and 395. The average production from this size of plant in all four sites was 770 litres in Shrawan and 650 litres in Magh. It indicated that the reduction in gas production was only 15%.

- The outcome of the study showed that there is no major co-relation between the direction of plant from household and gas production. However, 10 out of 31 plants located in the eastern direction have efficiency more than 80% which is not the case in other directions. Although not very much, gas production is more in those plants, which receive direct sunlight for longer duration.

- Top filling over dome influences gas production to some extent. In the first case, 15 out of 17 plants that have efficiency more than 80% have top filling more than 26 centimeter and in the second case, out of 41 plants that have efficiency more than 80%, 32 plants (78.05%) have more than 26 cm deep top filling over dome.

- The study outcome indicated that plant efficiency increases with the latrine attachment. Out of the 41 plants that have efficiency more than 80%, 24 of them have latrine attached. Similarly, out of 11 plants that have efficiency less than 40%, 8 of them have no latrine attached. The co- relation coefficient of latrine attachment and gas production is 0.3235. This value is positive, which indicates that gas production has been increased due to the attachment of latrines into the plants.

- Biogas production per kg of dung was observed to be 40, 33, 38 and 54 litre for latrine attached plants in Syangja, Nuwakot, Chitwan and Morang respectively, The corresponding figures for plants with out latrine attachment are 34, 33, 30 and 32 litre respectively. The average value is 43 litre for latrine attached and 33 litre for plants with out latrine attachment. The overall average is 38 litre/kg of dung.

- The outcome of the study suggested that a biogas stove consumes a maximum of 443 litre and a minimum of 210 litres of gas per hour. The average figure is 290 litre. Similarly, in the case of lamp it is 166 litres per hour. The average figure in the case of biogas stove seems to be too low. The reason for this might be the non-functioning of gas metres in some of the plants. During field study it was observed that majority of the gas meters had problems in functioning. Hence, the figure is still debatable.

- The average gas use pattern does not differ much in the four study areas. It may be because of quite similar socio-cultural conditions existing all over Nepal. The peak hour of gas use falls in the range of 6 to 8 o'clock in the morning. From 10 p.m. to 4 a.m. no gas is used, which is the lean period. Similarly very little amount of gas is used in between 11 a.m. to 3 p.m.. The general gas use pattern varies a bit during winter season.

- Non-biogas households needed more than 4 hours time in all the four study areas to cook food where as the corresponding time for biogas households was about 3 hours. The average saving of time to cook due to the installation hence is found to be I hour 36 minutes, 48 minutes, I hour 3 minutes and 1 hour 9 minutes respectively for Syangja, Nuwakot, Chitwan and Morang respectively. The average time saving is 1 hour 9 minutes. The co-relation coefficient of total stove burning hour and family size was observed to be 0.7432. The positive relationship indicates that the total number of persons residing in households is one of the important governing factors for stove burning. Similarly, the co-relation coefficient of total stove burning hour and total dung fed into biogas plant is 0.521. This indicates gas production is directly proportional to dung fed.

- The use of firewood for biogas households was found to be 1.61 kg (Chaitra) to 2.24 (Magh) kg per day. Non-biogas households used firewood in the range of 5.69 kg to 6.32 kg. In an average non-biogas households used 10.68, 5.03, 4.67 and 5.14 kg of firewood per day in Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 3.92, 0.89, 1.17 and 1.09 kg. The saving, thus, was 6.76, 4.14, 3.5 and 4.05 kg per day respectively. The total saving was calculated to be 1668.30 kg per year per household.

- The outcome of the study indicated that an average of 49.21 (Magh) to 118.14 (Shravan) milliliter of kerosene was consumed by the biogas-households in a day where as the non-biogas households used 72.87 to 196.08 milliliters. In an average non-biogas households used 153.76, 141.85, 140.32 and 135.57 milliliter of kerosene per day in Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 113.64, 47.78, 81.22 and 35.62 milliliter. The saving thus, were 40.12, 94.07, 59.10 and 99.95 milliliter per day respectively. The total saving was calculated to be 27 litres per year per households. There is no specific co-relation between average use of firewood and kerosene and the family size.

- The outcome of the study indicated that the households under study in all the four areas used very little quantity of the remains of fodder. The non-biogas households used 0.65, 0.2, 0.14 and 0.35 kg of fodder stems per day respectively in Syangja, Nuwakot, Chitwan and Morang. Similarly the biogas households used 0,17, 0.09, 0.03 and 0.08 kg of fodder stem per day per households in Syangja, Nuwakot, Chitwan and Morang respectively. The average figures were 0.33 and 0.09 kg respectively for non-biogas and biogas households respectively which gave an average saving of 0.24 kg per day per household. In total 87.60 kg of fodder stem was saved per day per household.

- The non-biogas households in Syangja, Nuwakot, Chitwan and Morang used 0.03, 0.26, 0.34 and 0.40 kg of dung-cake respectively where as the biogas households in Chitwan and Morang used 0.02 and 0.14 kg of dung-cake respectively. The biogas households in Syangja and Nuwakot did not used dung-cake. The average use of dung cake was observed to be 0.3 kg per day per HHs in non-biogas households and 0.04 in biogas households, which gave a total saving of 0.26 kg per day per household.

- An average of 0.29, 1.96, 0.95 and 0.27 kg per day per households of the agricultural residues were used in non-biogas households of Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 0.20, 0.06, 0.10 and 0.04 kg. The average was 0.87 kg for non-biogas households and 0.10 kg for biogas households.

- The outcome of the study showed that the replacement values of biogas vs. conventional cooking fuels are 3.7 for fuel-wood, 6.3 for agricultural waste and 7.5 for dung-cake. Conventional fuels equivalent to Rs.4025.70, Rs.3563.12, Rs.3120.70 and Rs.3631.50 respectively for Syangja, Nuwakot, Chitwan and Morang is saved per year per household. The average saving is Rs.3659.02.

- Optimum size of biogas plant has been assessed based upon; availability of feeding material (quantity of dung produced); biogas use pattern (maximum capacity of storage tank needed to fulfil the demand of peak hours); and average family size and required burning hours

- Average quantity of dung available in all the four study areas did not differ much. Households in Chitwan produced an average of 40.05 kg of dung per day where as that in Morang is 36.75 kg. In all the cases, the recommended size of plant is calculated to be 6 cum based upon the average quantity of dung available and the hydraulic retention time of 70 days for hilly regions and 55 days for Terai regions.

- The results of study showed that for a family having four or less members, 4 cum capacity plant is enough. Similarly, the average size of plant for Syangja, Nuwakot and Chitwan is 6 cum where as it is 4 for Morang. In other words, smaller sized plant is sufficient to fulfil demands in Terai regions in comparison to those in hilly regions. The biggest size needed is 8 cum capacity for families having more than 10 members in Chitwan and Nuwakot. The outcome of the study indicates that the presently adopted plant-sizes in most of the cases are bigger.

- The analysis of gas use pattern showed that the minimum capacities of gas storage tank needed are 42%, 45%, 40% and 35% of the daily gas production respectively for Syangja, Nuwakot, Chitwan and Morang. The maximum capacity is, thus determined by the value in Nuwakot, which is highest of all the values. Therefore, the dome should be able to store 45% of the daily gas production to fulfil the demand of peak hours. Assuming that 38 litres of gas is produced from 1 kg of dung, which is the average value as per the outcome of this study; and the presently adopted hydraulic retention times of 55 days for the Terai and 70 for the hills; the capacity of dome in cubic meter should be 1.03, 1.54, 2.05 and 2.57 cum respectively for plants of 4, 6, 8 and 10 cum capacity for Terai Regions, The corresponding figures for hilly regions are 0.82, 1.23, 1.64 and 2.05 cum. The reduction in volume of dome thus ranges from 6% to 18% in Terai and 25% to 34% in hills.

- As in the case of volume of dome, the volume of outlet could also be decreased by a considerable quantity. The percentage of decrease ranges from 7% to 32% in Terai regions and 26 to 46% in the hilly regions for plants of different capacities.

- All the plants are financially viable in Syangja. The cost per cubic metre of biogas generation is only Rs.6.68 for 4 cum plant in comparison to Rs. 9.39 for 8 cum plant. The C/B ratio is very high (1.78) for 4 cum plant and that for 8 cum plant is 1.27. 4 cum plants are most cost- effective in

Syangja. Similarly for Nuwakot too, all the plants have B/C ratio more than 1, and 6 cum capacity plant is most cost-effective. The cost of biogas generation is highest (Rs.9.92/cum) for 10 cum plant and lowest (Rs.7.21/cum) for 6 cum plant. However, for Chitwan, 4 cum plants have C/B ratio less than 1, which indicates that the owners are not receiving benefit to the expected level. Biogas plants of other capacity have C/B ratio more than 1. The cost of biogas generation falls in the range of Rs.7.23/cum for 10 cum plant to Rs.9.28/cum for 6 cum plants. It is rather discouraging to note that the plants of 4 cum capacity are not functioning well in Morang. The cost of biogas generation is Rs. 15.47/cum for this type of plants, which is very much higher than that for other capacity plants. The C/B ratio hence is very low (0.69) for 4 cum plants. However, for biogas plants of 6, 8 and 10 cum capacity, C/B ratio and cost per/cum of biogas are 1.06, 1.21, 1.38 and Rs.10.I5, Rs.8.83 and Rs.7.77 respectively. In other words, 10 cum capacity plants are most cost-effective.

- The main outcome of the study is that there are possibilities of reducing the size of gas storage tank (dome) and outlet (displacement chamber). Similarly, there are possibilities to jump into smaller sized biogas plant from the presently adopted ones to achieve the same magnitude of benefits that is being received from existing plants of bigger sizes. This in one hand will reduce the investment cost and in the other will help in optimal operation of plants. Major complications in biogas plants that are encountered due to under-feeding or over-sizing, such as entry of slurry in pipeline etc. could be eliminated to a great extent.

- The outcome of the study would help in convincing actors involved in the sector like biogas construction companies, banks, and farmers to construct appropriate size of biogas plant given the availability of feeding material (dung). The outcome of the study could also be used to draw up stricter quality norms regarding size-selection that are acceptable to all the actors involved. Finally, it is expected that the outcome of the study fulfil the expected objectives of the study.

1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 General

This is the Final Report of the research study on **'Optimum Biogas Plat Size, Daily Biogas Consumption Pattern and Conventional Fuel Saving',** submitted to Biogas Support Programme (BSP) by DevPart Consult Pvt. Ltd.

The study was carried out for a complete cycle of one year in Syangja, Nuwakot, Chitwan and Morang districts to represent four ecological zones of the country. This report presents the outcome of the research study.

1.2 Background

Nepal has a population of more than 20 million people; 80% of which live in remote areas and most of them have no electricity facilities. Because of the rugged terrain and other geographical difficulties, these areas are costly to be reached by extending the already overburden electric grid. Wind and solar energy exploitation evolves sophisticated technology, which are capital-intensive. Installation of micro and mini hydropower plants too is not feasible in many areas due to unavailability of perennial water sources. Hence, to solve the energy problem of Nepal; a fast, easily implemented, cost efficient, small scale, completely decentralised renewable alternatives which is technically feasible and economically viable has to be promoted Biogas is well realised to be such alternative in Nepalese context.

Though the dissemination of biogas plant in Nepal in an experimental basis began some forty years back, the government of Nepal took real interest in this technology as a possible alternative to traditional biomass fuel in the rural areas only after twenty years in 1975 to commemorate the Agriculture Year by providing interest free subsidised loans to install biogas plants. The 'Energy Research and Development Group' established under the Tribhuvan University in the wake of the world energy crisis also contributed positively on biogas technology development. At the same time, realisation of the growing rural energy scarcity and the effect of traditional biomass fuel on the environment necessitated search for viable technology options on the part of the technology disseminators and biogas was considered suitable to be one such alternate. Thus, in 1977, Gobar Gas and Agricultural Equipment Development Company Private Limited, popularly known as GGC, was established to initiate concrete programmes to popularise biogas technology. Among many objectives; GGC aimed at quicker dissemination of the technology for providing energy in clean and unpolluting form, reducing pressure on dwindling firewood supplies and prevent indiscriminate deforestation, eliminating the smoke filled cooking environment to prevent smoke-borne diseases and reduce drudgery, and making available enriched fertiliser as a by-product for supplementing and optimising the use of chemical fertilisers.

In the open context of HMG/N's economic liberalisation programme, other new biogas construction companies started emerging since early 1990s. Realising the usefulness and appropriateness of the , technology, the Government of Nepal has supported the wider installation of biogas plants throughout the country. Most of the existing plants in Nepal have been constructed by the GGC while ADB/N has provided necessary loans to the farmers to finance the cost of the plants. In 1992, a joint programme of ADB/N, GGC and SNV-Nepal known as 'Biogas Support Programme[1], started with one of its objectives to construct 20,000 biogas plants in the period 1992-1997 by provision of investment subsidy. Since 1994, SNV-Nepal started working with other two banks namely RBB and NBL and other private companies including GGC under the framework of BSP.A total of 23 biogas companies were recognised by BSP during the fiscal year 1995/96, which increased to 41 in 1997/98. At present, 49 companies have been associated with BSP. The Dutch Government provided various assistance including the investment subsidy of Rs.7000.00 in the Terai and Rs. 10,000.00 in hills of Nepal for the installation of biogas plant; through BSP during the first and second phases of the programme that concluded in July 1997.

The third phase of BSP, which commenced during 1997/98, is a joint programme of HMG/N, KfW and SNV-Nepal in co-operation with ADB/N, NBL, RBB and recognised biogas companies. It also works closely together with other relevant organisation and sector agencies to fulfil the programme objectives. Under this programme, among various technical and other assistance, a flat rate subsidy is being provided. The rate of subsidy is categorised into three groups-Rs.7,000.00 for Terai districts, Rs.10,000.00 for hilly districts with proximity to modern transportation facility and Rs.12,000 for other remote hilly districts that are still to be linked with motarable roads. Based upon the recommendations of the Mid Term Evaluation Team, subsidy on 15 and 20 cum plants has been extracted from the current fiscal year and that for 10 and 8 cum plant has been decreased by Rs. 1000.00. However, for districts with lower penetration of biogas technology, an additional subsidy of Rs. 1000.00 is provided.

The overall objective of BSP III is to further develop and disseminate biogas as an indigenous, sustainable energy source in rural areas of Nepal. To achieve this objective, BSP has been initiating various research and development activities. This present study entitled, 'Optimum Biogas Plant Size, Daily Biogas Use Pattern and Conventional Fuel Saving' is one of such research studies.

1.3 Study Rationale

It has been realised that for the achievement of the targeted increase of biogas plant construction in Nepal, the plant themselves will have to be as cost effective as possible. Given the present situation, plant cost in Nepal can not be or can marginally be reduced per plant unit. However, it is possible that using of the plants more efficiently can bring down the cost of the generated gas and thereby biogas can become more competitive with conventional energy sources.

In this regard, a study was felt needed to be undertaken on the efficiency (read optimum plant size) of biogas plants. The outcome of this study is expected to be used to:

- convince actors in the sector like companies and banks to construct the appropriate size of plant given availability of dung; and
- draw up stricter quality norms regarding size selection.

The efficiency of biogas plants is largely depending on size and feeding. However, the efficiency is also determined by the gas storage capacity of the plant. The plants in Nepal are presently designed to be able to effectively store 55-60% of the daily gas production based on a minimum dung feeding and 40 litres/kg of dung as production. These design parameters are based on assumptions. The study was expected to give answers by examining whether these assumptions are realistic or not.

1.4 Aim of the Research Study

The following were the aims of this study.

1.4.1 Conventional Fuel Savings

- To obtain reliable data regarding the actual savings on conventional fuel for an average biogas household in the hills and the terai.

- To obtain reliable data regarding the replacement value of biogas vs. conventional cooking fuels.

1.4.2 Optimum Plant Size

In order to facilitate the implemented in maximising the benefits of the plant for the users:

- To determine which plant volume is most efficient (cost effective) given average annual temperature and daily feeding.

1.4.3 Daily Gas Consumption Pattern

In order to be able to make changes to the design to make it more in line with the daily needs of the user:

- To collect accurate data regarding the daily gas consumption patterns for different family consumption, climate zones and seasons.

1.5 *Specific Objectives*

More especially the study had the following objectives:

- to measure and compare the amounts of fuel wood, agricultural waste, dun cakes and kerosene used by rural household with and without biogas
- to calculate the average replacement value of biogas as compared to traditional cooking fuels
- to provide a clear indication which plant volume is most suitable given a certain dung availability and climate condition
- to measure the digestion of dung in the biogas plant in relation to feeding (HRT) and temperature by identifying the total solids (TS) and volatile solids (VS) contents of raw dung as well as digested slurry
- to come to a more efficient and reliable plant design by identifying the actual needed effective gas storage capacity for the average family and plant size by measuring the daily gas consumption patterns
- to measure the influence of site selection and top filling on the gas production, particularly in winter time

1.6 Activities

The sequence of activities executed for the successful completion of the study were:

- selection of clusters with high penetration of biogas and identification of appropriate households for the study
- appointment of research assistants to the selected study areas
- preparation of data recording and reporting formats
- orientation to the research assistants and members of households under study on the aim and objective of study; their roles in successful completion of the study; methods of filling of the data recording format and reporting formats
- installation of gas metres, thermometers and other appliances as required, and delivery of other necessary equipment to the biogas households that are selected for the study
- accurate measurement of conventional fuel use, quantity of gas use, recording of digester as well as ambient temperatures
- laboratory analysis of total and volatile solids content in slurry and digested slurry
- In-depth analysis of field findings and preparation of final research report.

1.7 Limitations

It is a fact that the outcome of this type of research study heavily depended upon the factual reporting on behalf of respective household under study, It was encouraging to note that all the households were co-operative and they were well aware of their roles and responsibilities. No major problems from their parts were encountered during the study period besides minor problems in Syangja. However, some problems as mentioned hereafter were met which had negative impacts on the findings of the study.

1.7.1 Non-functioning of Gas Metre and other Equipment

Non-functioning of Gas Meters imported from China was the major problem encountered during the study period. Some of the gas meters installed in biogas households indicated technical problems with them. In Morang, four of the twenty gas metres stopped functioning after six weeks of operation. About a month after the installation these metres started to give a hissing sound. Few days later, the speed of the rotors was observed to be quite slower than it used to be. Gradually, the speed went on decreasing and after about 15 days they stopped functioning. As per the instruction manual provided by the manufacturer, the reason for such breakage could be the presence of dust or water in biogas. While inspecting the households no such problem was observed. Similar problem was observed in three of the plants in Chitwan, five of the plants in Nuwakot and four of the plants in Syangja.

Keeping view this problem with gas metres, some additional metres were imported to enable continuation of the study in those households where such problem existed. Although the damaged gas meters were replaced on time, it was observed that there was no consistency in the reading of these meters. This has affected the study.

The thermometers were also damaged after six to seven months of operation. Replacement of new one was not possible due to various reasons.

1.7.2 Problems with Fittings and Appliances

Most of the plants under study were older than one year and hence the duration of guarantee period on behalf of respective biogas companies on fittings and appliances was already over. In this circumstance, whenever problems were met with fittings and appliances, the owners did not show interest to replace them. Most of them thought that DevPart would solve these problems. As it was compulsory for DevPart that the plant operated with maximum efficiency, those works were carried out on its own costs. This has resulted in additional works to be done. To assure that all the plants under study were functioning well, a mason in each site was appointed. They monitored the plants and rectified the problems, if any. Some of these problems also had minor negative impacts on the outcome of the study.

1.8 Organisation of Report

First, Second and Third Quarterly Reports have already been submitted to BSP in earlier dates. This is the fourth and final report, which also incorporates the contents of earlier reports. The M.S Access database (70 MB) prepared during the course of the study is also submitted with this report.

2.0 ACTIVITIES CARRIED OUT

2.0 ACTIVITIES CARRIED OUT

2.1 Identification of Household for Study

Selection of clusters and identification of appropriate households for the study commenced immediately after the signing of the agreement with BSP in April 1998. As per the ToR, the following were the criteria to select study households:

- Two study areas for both terai (plain area) and hill districts
- The minimum elevation of households in hills to be more than 800 meters above sea level.
- To facilitate observation works and minimise the influence of dung quality on measurement, all four areas have to have a high biogas penetration.
- In each area, 5 plants each of 4, 6, 8 and 10 m3 has to be identified for observation purposes. Two out of these 5 plants have to have an attached toilet in use.
- Plants should be in use for at least six months.
- The families using the plants have to be willing and capable to co-operate for one year in the study.
- 10 non-biogas household selected per study area have to be socially and economically comparable to the average biogas household.

Keeping in view the rate of penetration of biogas, the following districts were proposed for carrying out the study during the time of proposal submission:

In hilly regions:	Kaski or Syangja Nuwakot or Kavrepalanchock.
In terai regions:	Chitwan or Nawalparasi Morang or Jhapa

However, the actual work of selection of districts and identification of households for study turned out to be a very difficult and time-consuming task than it was realised earlier. The study team had to consider about 15 VDCs in 8 different districts. The districts of Kavrepalanchock, Nawalparasi and Jhapa were omitted during the initial stage, as there were not enough numbers of 4 cubic metre capacity plants in those districts. The following VDCs/Districts were considered and visits were made to identify the households during the initial phase:

- Bidur Municipality in Nuwakot district
- Bharatpokhari VDC in Kaski district
- Putalibazaar Municipality, Chandikalika and Arjun Chaupari VDCs in Syangja district
- Handi Khola and Padampokhari VDCs in Makawanpur district
- Bhiman VDC in Sindhuli district
- lndrapur, Kerabari, Banigama and Bayarban VDCs in Morang district
- Beltar VDC in Udayapur district
- Mangalpur, Birendranagar and Bachhyauli VDCs in Chitwan district

The main problem in finalisation of study area was the unavailability of 4 cum plants. The specific problems encountered in these districts were:

a. In Bidur Municipality, ward no. 9 consisted of considerable numbers of 6 cum plants, just enough nos. of 4 and 8 cum plants and only three 10 cum plants. Some of the plant owners in this cluster did not show their interest to co-operate for the study. Afterwards, all the wards of the municipality were considered and plant owners were consulted. This site was selected as one of the study areas after two consecutive visits. The identified biogas households were heavily scattered and hence two Field Research Assistants (FRA) were considered to be appointed to facilitate the observation works.

b. In Bharatpokhari VDC in Kaski district, there were enough numbers of 4, 6, and 8 cum plants. However due to non-existing of 10 cum capacity plants, the adjoining areas in Lekhnath Municipality were also considered. After several visits to the site, the team concluded that this area was not suitable for study due to non-co-operative attitude of the plant owners.

c. Syangja is one of the districts where biogas plants have been installed in clusters. There were considerable numbers of plant constructed in various VDCs in the district among which Chandi Kalika, Khilung Deurali, Arjun Chaupari and Putali Bazaar Municipality were noteworthy. In Chandi Kalika *VDC*, there were enough numbers of 4, 6 and S cum capacity plants but that of 10 cum plants was insufficient Most parts of Arjun Chaupari and Khilung Deurali VDCs where biogas plants are constructed lie at an altitude below 800 metre. Even the transportation to these VDCs during summer was felt to be problematic due to the Andhi Khola. For these reasons, Putali Bazaar Municipality was considered for the study and household visits were made accordingly. To fulfil the criteria as set out in the ToR, the study team had to consider a vast stretch of area. Keeping in view the location of study households, two FRA were considered for this study area.

d. In Handikhola VDC in Makawanpur, there were enough numbers of 4, 6, and 8 cum plants but the plants of 10 cum did not exist. For this, the adjoining VDC of Padampokhari was considered. However, the 5 plants of 10 cum capacity located in Padampokhari VDC were heavily scattered in five wards. Moreover, because of Rapti River that How's in between the highway and the VDCs, and absence of crossing facility, transportation and communication to and from Handikhola VDC during summer is very difficult. All these led to the rejection of this site.

e. Bhiman in Sindhuli is one of the VDCs where a considerable numbers of biogas plants have been constructed during the last three years. There were enough plants of required capacities in this VDC. However, the Kamala River (lowing in between the VDC was felt to be a major problem to monitor the activities in the left bank of the river. There was no crossing facility and one had to walk for about 4 hours to reach the other bank using the existing crossing in the upstream. The trail on the left bank passes through difficult terrain and forest which is quite difficult and dangerous. Moreover, the political problem existing in the area was a major threat for smooth operation of the proposed study,

f. There were enough plants of 6, 8 and 10 cum capacity in Indrapur VDC in Morang but the lack of 4 cum plant was a problem here. For this, the adjoining VDCs of Kerabari, Banigama and Bayarban were considered. After some repeated visits and sincere, the plant owners were convinced to co-operate for the study.

g. Keeping in view the number of plants constructed in Beltar area of Udayapur district, the study team made visits to this area. Though there were enough numbers of plants of required capacity in this site, transportation to this area during summer was observed to be a major problem. Moreover, some of the plant owners expressed their unwillingness to participate in the study despite several attempt made by the study team to convince them.

h. The other site considered in the terai region was Chitwan district. The only 6 plants of 4 cum capacity installed in the district were found to be scattered in three different VDCs in the districts that too were located at the opposite directions. Viewing the unavailability of study areas in other terai districts, this site was selected although the plants were scattered heavily. To solve the problem of facilitation, appointment of three FRAs was considered.

In this manner, the activity of household selection became a time-consuming task. It took more than two months to finalise the study areas in contrary to the expectation made during the time of proposal preparation that it will not consume more than a month. Though little late it was done, the final result was very satisfying, as the study areas were located in four ecological zones in the country, viz:

- Morang representing the terai region that have altitude up to 150 meters from the mean sea level
- Chitwan representing the inner terai region that have altitude in between 200 to 350 metres
- Nuwakot representing the low hills area that have altitude in between 500 to 650 metres
- Syangja representing the hilly region that have an altitude more than 800 metres

It was expected that the spread of study area in four ecological zones would result in better output. The locations of study areas have been shown in the map given in page-11.

2.2 Establishing Working Relation with Biogas Companies

Prior to the identification of biogas households for the study, biogas plant construction companies in the respective areas were consulted and their assistance were seek for the smooth execution of the study. All the biogas plant construction companies provided their assistance in locating the biogas households and motivating them to take part in the study. Once the households were identified, one of the companies working in that area was officially selected to act as supporting company. The following were the supporting companies:

- In Morang, Indrapur branch of Grihini Gobar Company (now, Krishi Bikash Gobar Gas Company)
- In Chitwan, Parsabazaar branch of Kisan Gobar Gas Company
- In Nuwakot, the central office of Kisan Gobar Gas Company
- In Syangja, the central office of Nepal Rastriya Gobar Gas Company

Supporting companies were felt to be very necessary for easy and smooth running of the study as they bridged between DevPart Consult and the respective plant owners. Supporting companies were selected to help in carrying out the following tasks:

- Locating of biogas households
- Motivating plant owners to take part in the study
- Organizing of orientation training to the selected households for study
- Appointment of suitable FRAs
- Installation of gas metres and delivery of other equipment to the selected households
- Provide working table in their office for the FRAs
- Prompt communication
- Prompt and timely repair and maintenance in biogas plants under study in case of need
- Act as contact point

23 Appointment of Research Assistants and Orientation

The next course of action upon the identification of households for the study was the selection and appointment of required numbers of Female Research Assistants in each study area to facilitate the household members in record keeping and other aspects of the study. Keeping in view the nature of service theses persons have to render, they were tried to be appointed from among the community members where the study was proposed to be executed. Few potential females from the areas were consulted to make them clear about the nature of work they have to execute. The final selection was made once they fully realised and understood the nature of job and their role in it. While selecting such persons, the following points were considered:

- local resident of the community who have social and cultural values in that community, such as school teacher, health worker
- at least SLC passed
- women working in same community for an NGO or any other volunteer organisations
- adaptable to different situation and possessing a high degree of motivation to her work
- women having biogas in her own house were given priority
- experience of working in the grass-root level of the community and willing to travel intensively
- person having skill to ride a bicycle, for the study areas in terai and inner terai areas

Based upon the above criteria, Kalpana Ojha was selected for Morang; Brinda Ghimire, Goma Baniya and Subindra K..C. for Chitwan; Sachina Tamang and Shanta Aryal for Nuwakot; and Kopila Nepal and Indra Kumari Rijal for Syan&ja. Ms. Aryal in Nuwakot expressed her unwillingness to continue her work and Ms. Ganga Rimal was appointed to replace her from August 15, 1998.

Once these research assistants were selected, they were provided with an orientation to execute their duties effectively. They were made familiar with the use of thermometer and weighing scales, checking the records and filling in the formats etc.

2.4 Orientation to the Members of Selected Biogas Households

Once the field research assistants were appointed and oriented, the next course of action was to arrange an orientation programme for the members from all the potential households in all four selected study areas. At least a member of the households, mostly the housewife, took part in the programme organised for a whole day. They were made clear about the nature of the study and importance of their role for the successful completion. Furthermore, participants were made aware of the need for accuracy in data keeping and they were trained on the use of the measuring tools and on reporting. They were provided with clearly written formats for daily data keeping. The following were the dale and venues of orientation training in the four study areas:

Table-l: Date and Venues of Orientation Programme

SN	Study Area	Date of Orientation	Venue	No. of Participant
1.	Morang	June 22, 1998	Agriculture Sub-centre, Indrapur, Morang	36
2.	Chitwan	June 28, 1998	Local Secondary School, Birendranagar, Chitwan	14
3.	Nuwakot	May 16, 1998	Hall of Horticulture Centre, Bidur, Nuwakot	31
4.	Syangja	June 19, 1998	Hall of District Red Cross, Syangja	30

25 Preliminary Works in Identified Biogas Households

Once the households for the study were identified and the members oriented, the next course of action was the installation of gas-metres in suitable places. The respective households, were fully equipped with weighing scale to enable them to record the quantity of conventional fuel used daily wall-clock to keep records of gas-usage time, and measuring barrels to quantify the volume of dung water and slurry fed to the plant.

To install the gas metres correctly in a convenient place, the existing pipeline had to be realigned in some of the households. In most of the households, new gas taps were installed to avoid leakage of gas.

2.6 Execution of the Research Study

Though a month period was allocated during the time of proposal preparation to complete the above mentioned four tasks, it took more than three months. The reason for delay was mainly the time incurred to import weighing scales from India. In the beginning, it was expected that these machine are available at Kathmandu. However, none of the supplier was in a position to provide 120 scales at time. They requested for about 15 days or so to import it from India. However, it took about two full months to do so. In this manner, the actual work of research study in the field commenced a little later than expected. Although, all the preliminary works in the biogas households were completed at the end of June and study could have been commenced from July 1, 1998; for ease in record keeping by the rural households, the Nepali calendar was followed and the record keeping started from the first of Shravan 2055 (July 17, 1998). Activities as shown in the following table were carried out for a one-year period.

Table-2: Activities Undertaken

SN	What	How	By whom	frequency
1.	Traditional fuel used in kg	Weighing scale	Farmer	Daily
2.	Water -volume	barrel	farmer	Daily
3.	Dung -volume -consumption .	barrel sample	Farmer Laboratory	Daily Quarterly
4.	Slurry -volume -consumption	Barrel Sample	Farmer FRA/laboratory	N/A(3 + 2) Quarterly
5	Dig. Slurry -composition	Sample	FRA/laboratory	Quarterly
6.	Gas use -volume -hours	Gas metre Clock	Farmer Farmer	Daily Daily
7.	Digester and ambient Temperatures-degrees C	Dig. thermometer	Research Officer	Weekly

As shown in the table, a great deal of work was carried out by the users of the plant and the households selected for comparison. Careful guidance and monitoring of these families through daily visits was therefore essential. For this reason the FRAs as mentioned above were permanently present in all the four study areas. To give these persons the necessary guidance and to monitor the progress of the study, the study Team Leader (Research Co-ordinator) and Research Associates visited each area at least once a month. For co-operating families a remuneration of Rs. 100 per week was made available for better motivation.

As per the agreement, three lots of samples of slurry and digested slurry were collected with greater precision during the months of October, February and June. An agreement was signed between Analytical Services and Constancy, New Baneswar and DevPart Consult to execute the task **of** laboratory analysis. This laboratory had all the necessary facilities to carry out the required tasks. For the consistency of test results only one laboratory was used. The details of analysis result have been given in Chapter-8.

2.7 Data Compilation, Analysis and Reporting

All the collected data and information were fed in to the computer in MS Access database. The main database consisted of more than 28000 rows (records) and more than 60 columns (fields) for biogas households and 14000 records with more than 40 fields for non-biogas households. These information, further, were analysed using various software programmes such as MS Excel, Access, SPSS PC+ and Harvard Graphics.

2.8 Additional Works

Besides the works as mentioned above the following activities were conducted during course of the study.

2.8.1 Collection of Secondary Data and Information

Relevant secondary data and information were collected from various sources to enhance the outcome of the study. Relevant reports and literatures were reviewed and prominent persons in the Held of anaerobic technology were consulted. Among those consulted were Prof.dr.ir. G. Lettinga from Wageningen Agricultural University in Holland, Prof. George Chan of Tokyo University in Japan, Dr. Look Hulshoff-Pol from TBW GmbH in Germany, Dr. Do Ngoc Quynh from Renewable Energy Centre of Can. The University in Vietnam. They supplied with various literature and articles on anaerobic technology, which have been found useful for this study.

2.8.2 Preparation of Information Collection, Data Recording and Reporting Formats

The following formats and questionnaires were developed:

- Data recording format (to be used by the households under study); separate formats lor households with and without biogas
- Data collection format (lo be used by the FRAs to collect information on socio-economic status of households under study and other relevant aspects such as physical status and functioning of biogas plants etc.): separate formats for households with and without biogas plants
- Separate formats to be used by FRAs to note down the following:
  - ➢ Ambient temperature and Digester temperature
  - ➢ Actual quantity of dung and water being fed into the digester
  - ➢ Gas pressure before and after the use


NEPAL
LOCATION OF STUDY AREAS
N
CHINA
INDIA
KATHMANDU
1
2
3
4
Legend
1- Syangja
2- Nuwakot
3 - Chitwan
4 - Morang
BOUNDARY:
INTERNATIONAL
ZONAL
DISTRICT
SCALE
0 40 80 120 160 Km.

3.0 SOCIO-ECONOMIC CHARECTERISTICS OF HOUSEHOLDS

3.0 SOCIO-ECONOMIC CHARECTERISTICS OF HOUSEHOLDS

As mentioned earlier, a total of 120 households were selected for the study from four ecological zones of Syangja, Nuwakot, Chitwan and Morang districts; out of which 80 were biogas households and the remaining 40 were non-biogas households. These households were selected in such a manner that each study area consisted of 20 biogas and 10 non-biogas households. While deciding non-biogas households, attempts were made to select households that have similar and uniform socio-economic characteristics with the selected biogas households. As far as possible, both types of households were selected from the same locality. The findings on socio-economic characteristics of the plant owners under study are described below.

3.1 Caste

The majority of the biogas households under study were that of Brahmins/Chhetris (80%) followed by Newars (11.25%), Tamangs (3.75%), Gin (2.5%), Magars (1.25%) and Gurungs (1.25%). Similarly the ethnicity of sampled non-biogas households are Bhramin/Chhetri (82.5%), Newar (5%), Kumal (5%), Giri (2.5%), Chaudhary (2.5%) and Damai (1%). The following table shows the ethnic composition of the households under study.

TabIe-3: <u>Ethnicity of Sampled HHs</u>

Ethnic Group	Biogas HH		Non-biogas HH	
	No.	Percentage	No.	Percentage
Brahman/Chhetri	64	80	33	82.5
Newar	9	11.25	2	5
Tamang	3	3.75	0	0
Giri	1	1.25	1	2.5
Kumal	1	1.25	2	5
Magar	1	1.25	0	0
Gurung	1	1.25	0	0
Chaudhary	0	0	1	2.5
Damai	0	0	1	2.5
Total	80	100	40	100

3.2 Family Size

The total population of the 80 sampled biogas households was found to be 468 among which 236 (50.43%) were females. The average family size was 5.85 person per household. Household with maximum number of family members had 14 whereas the minimum number was 2 with a standard deviation of 2.41. It was found that among the total population, 22 persons were residing outside. Similarly, the total population in 40 sampled non-biogas households was 263 among which 123 (47.77%) were females. These households had an average family size of 6.57. Household with maximum number of family members had 14 whereas the minimum number was 4 with a standard deviation of 2.42. The following table shows information on family size of the households under study.

Table-4: Population Pattern of Surveyed Household

Particulars	Biogas HHs	Non-biogas HHs
No. of HHs studied	80	40
Total Population	468	263
Male	232	140
Female	236	123
Population out	22	23
Population in	446	240
Average Family Size	5,85	6.57
Maximum Family Size	14	14
Minimum Family Size	2	4
Standard Deviation	2.41	2.42

3.3 Economic Status

3.3.1 Occupation

The survey indicated that all of the households in both the cases had agriculture as the main source of income. Majority of the biogas households (79%) had at least one person involved in cash earning from their jobs. This figure for non-biogas households is 74%.

3.3.2 Land Holding

In rural Nepal, the amount of land holding is the main indicator to assess the economic condition of any family. In this case, while calculating the land holding, only operational land holdings were taken into account. The land use and cultivation patterns were observed to be very similar to that of the traditional Nepalese practice in all the four study areas. It was found in most of the cases that the lands were cultivated by the owners themselves. There were very few instances of land being rented. The average land holding size per family was 21.5 ropani (1.07 ha.) for biogas households and 18.6 ropani (0.93 ha.) for non-biogas households[3] which was to some extent similar to the national land holding size per family being 19.2 ropani or 0.96 ha (source: CBS, National Sample Census of Agriculture). The maximum land holding figures of the sampled biogas and non-biogas households were 128 and 85 ropanis (6.4 and 4.25 ha.) respectively and the corresponding minimum were 1.0 and 4 ropani (0.05 and 0.2 ha.). The following table shows the figures on land holdings.

Table -5: Figures On land Holdings

Particulars	*Biogas HHs*	*Non-biogas HHs*
Average Land Holding (ropani)	21.5	18.6
Maximum (ropani)	128	85
Minimum (ropani)	1	4
Total Upland (ropani)	547	210
Total Lowland (ropani)	1018	444
Total Marginal (ropani)	155	89
Total (ropani)	1720	743
Total (hectares)	86	37.15

3.3.3 Agricultural Production

The outcome of the research study indicated that the production and consumption of paddy, maize, wheat and millet were balanced in 12, 24, 22 and 30 non-biogas households respectively. The corresponding figures for biogas households were 33, 55, 60 and 70 respectively. Among the 40 non-biogas households under study, 14 had surplus of paddy, 8 had surplus of maize, 10 had surplus of wheat and 7 had surplus of millet. The corresponding figures for sampled 80 biogas households were 24, 5, 13 and 6 respectively. Similarly in sampled non-biogas households, 14 of them had deficit of paddy followed by maize and wheat deficit for 8 households each and millet deficit for 3 households where as in sampled biogas households paddy, maize, wheat and millet were deficit for 23,20,7 and 4 households respectively. The following two tables summaries the findings.

Table -6 (a): Surplus and Deficit of Ma for Agricultural Cereals

Production	Surplus HH		Deficit HH		Balance HH		Max. Surplus (Kg)		Max. Deficit (Kg)	
	BH*	NBH*	BH	NBH	BH	NBH	BH	NBH	BH	NBH
Paddy	24	14	23	14	33	12	4000	5900	1000	1200
Maize	5	8	20	8	55	14	200	900	400	480
Wheat	13	to	7	8	60	22	1000	1120	280	80
Millet	6	7	4	3	70	30	280	400	50	150
Mustard	3	4	14	10	63	26	100	2300	200	100
Potato	4	3	11	*9*	65	28	1280	400	280	200

Note: BH - Biogas Households
NBH- Non-biogas Households

Table -6 (b): Data on Production and Consumption of Major Crops (In Kg)

Variables		Mean		Minimum		Maximum	
		BH	NBH	BH	NBH	BH	NBH
Paddy:	Production	1561.25	1607	0	0	8000	7500
	Consumption	1205.5	1327.5	40	500	4000	3200
	Surplus	265.75	279.5	(1000)	(1200)	4000	5900
Maize:	Production	204.88	335.25	0	0	800	1600
	Consumption	246.75	284.88	0	400	800	1000
	Surplus	(41.88)	50.38	(400)	(480)	200	900
Wheat:	Production	184.25	157.25	0	0	1600	1200
	Consumption	130.38	78	0	0	600	2X0
	Surplus	53.87	79.25	(280)	(80)	1000	1120
Millet:	Production	76.88	78.75	0	0	600	500
	Consumption	67.5	68.13	0	0	600	400
	Surplus	9.38	10.63	(50)	(150)	2K0	400

Note: Figures in brackets indicate deficit
BH - Biogas Households
NBH-Non-biogas Households

It can be noted from the above two tables that the production and consumption patterns of both biogas and non-biogas households were quite similar.

Mustard and potato, besides fruit and vegetables, were the major cash crops grown. A totals of 6575 kg of mustard and 4210 kg of potato were grown by 40 non-biogas households and the corresponding figures for 80 biogas households were 1901 and 7865 respectively. Fruits and vegetables were grown mainly for household consumption. However, one of the non-biogas households under study, sold 1000 kg of vegetables and another sold 1200 kg of fruits in a year. In similar manner, one biogas household in Chitawan sold 1500 kg of vegetables and another in Syangja sold 1300 kg of fruits.

3.3.4 Livestock Ownership

The sampled biogas owners owned a total of 432 livestock (buffaloes, cows, ox, horses etc.) at an average of 5.4 cattle per household. Among the total of 432 numbers, 314 were adults and 118 were calves. There were four households without livestock. Similarly, the average number cattle for non-biogas households was 6.2 cattle per household. Among the total of 248 cattle in non-biogas households, 180 were adults and 68 calves. The maximum share in both the cases was of buffalo. The total numbers of buffalo were 159 and 76 for biogas and non-biogas households respectively. The following two tables provide the details.

Table- 7: Total Nos. of Cattle Owned by Households

Variable	Biogas HHs	Non-biogas HHs
No. of HHs under Study	80	40
Total No. of Cattle	432	248
Mean	5.4	6.2
Minimum	0	0
Maximum	18	19
Std. Deviation	3.25	3.89

Table- 8: Distribution of Cattle among Households under Study

No. of Livestock	Biogas HHs	Non Biogas HHs
0	4	1
1	1	1
2	6	5
3	11	3
4	13	4
5	9	4
6	14	3
7	8	9
8	4	3
9	3	2
10	2	2
1!	1	0
12	1	0
13	I	0
14	0	1
16	1	1
18	1	0
19	0	1
Total	80	40

3.4 Educational Level

The literacy rate of the selected biogas households was found to be 88.68% (excluding infants up to 5 years of age) which was very much higher than the national average (49.6%). The corresponding figure for sampled non-biogas households was 86.92% The male and female literacy rates, excluding the children of 1-5 years, were found to be 94.88% and 82.56% respectively for biogas households and that for non-biogas households were 90.77% and 82.24% respectively. The following table shows the educational status of the sampled households.

Table-9: *Literacy Pattern of Households*

Particulars	Biogas HHs	Non-biogas HHs
Total Population	468	263
Male	232 (49.57%)	140(53.23%)
Literate Male	204 (94.88%)	118(90.77)
Female	236 (50.43%)	123(46.77%)
Literate Female	180(82.%%)	88 (82.24%)
Literacy Rate	88.68%	86.92%
No of Infants	35(7.48%)	26 (9.88%)

Information as provided in the above table indicates that the figures on literacy condition were quite similar in both the cases.

3.5 Comments on Socio-economic Characteristics of Households under Study

The selection of non-biogas households for the study was done keeping in view the fact that these households were socially and economically comparable to the average biogas households. All the facts on socio-economic characteristics as given above supported this argument. The average family size, ethnicity, land holdings, production and consumption pattern, livestock ownership, literacy pattern etc. were quite similar in both biogas and non-biogas households. In other words the figures were comparable. It is therefore expected that the study findings, too, were comparable.

4.0 OPERATION OF BIOGAS PLANTS

4.0 OPERATION OF BFOGAS PLANTS

4.1 Plant Feeding

4.1.1 Feeding Material

Cattle dung was the only feeding material in all the cases besides human excreta in toilet attached plants. Information on plant feeding has been given in Annex-5. It can be noted from the table that out of 80 plants 45 (56.25%) received feeding less than 80% of the prescribed quantity. The following table summaries the quantity of feeding material received by the plants under study.

Table-10: Quantity of Feeding Material

Feeding (% of Prescribed Quantity)	Plants	Percentage
Less than 25%	4	5.00
<25% but >40%	4	5.00
<40% but >60%	13	16.25
<60% but >80%	24	30.00
<80%but>110%	25	31.25
More than 110%	10	12.50
Total	**80**	**100.00**

The outcome of the study indicated that the whole quantity of dung produced in the stable was not collected and that collected was not wholly fed into the plant. It showed that out of the average theoretical available dung (calculated based upon number of cattle) of 40 kilograms, 36.87 kilogram (92.18%) was collected and 33.37 (83.43%) of theoretical available quantity and 90.51% of the collected dung was fed into the digester. The average feeding rate, thus was 4.77 kilogram per cubic meter volume of the digester, which was far less than the prescribed quantities of 6 and 7.5 kilogram in hills and terai respectively. The average feeding was 74.62% of the prescribed rate. Conclusively, the plants were underfed.

It is encouraging to note that some of the plant owners who did not own cattle collected dung from outside. Out of the 80 households under study, 24 of them collected dung from outside to feed into their plants.

4.1.2 Dung-water Ratio

The outcome of the study revealed that in majority of the plants (67.5%), the dung-water ratio was maintained to the prescribed rate of 1:1. However, 5% of the total plants were found to have the ratio more than 1:1.1 and another 27.5% had ratio less than 1: 0.9. In other words, 67.5% of the total , plants were *fed* with appropriate quantity of water; 5% of the plants were fed with lesser quantity of water than the prescribed rate and the remaining 27.5% plants received more water. Detail information on dung-water ratio has been given in Annex-5

4.1.3 Latrine Attachment

The terms of reference (ToR) provided to the consultant required at least 40% of the plant to be attached with latrines. Another criterion was that at least 2 plants out of the total 5 in each capacity in each study area be attached with latrine. In total 42 plants out of the sampled 80, were attached with latrines. The following table illustrates the details.

Table-! 1: Information on Latrine Attachment in Biogas Plant

Plant Size (cum)	Syangja		Nuwakot		Chitwan		Morang		Total	
	Attached	**Not Attached**	**Attached**	**Not Attached**	**Attached**	**Not Attached**	**Attached**	**Not Attached**	**Attached**	**Not Attached**
4	3	2	3	**2**	4	1	4	1	14	6
6	2	3	*2*	**3**	3	2	2	3	9	11
8	2	3	***2***	3	2	3	2	3	8	12
10	2	3	4	1	3	2	2	3	11	9
Total	**9**	**11**	**11**	**9**	**12**	**8**	**10**	**10**	**42**	**38**

The following table shows the relation between latrine attachment and quantity of dung fed into digester. It can be seen from the table that there exists a relationship between these two parameters. Out of the total 45 plants which received less than 80% of the prescribed feeding, 27 (60%) were attached with latrines. Similarly, 7 out of the 8 plants that received feeding less than 40% of the prescribed rate have latrines attached to them. In other words, the owners believed that when latrine was attached to the plant, lesser quantity of dung than prescribed would be sufficient.

Table-12: Relation between Latrine Attachment and Dunn Feeding -^

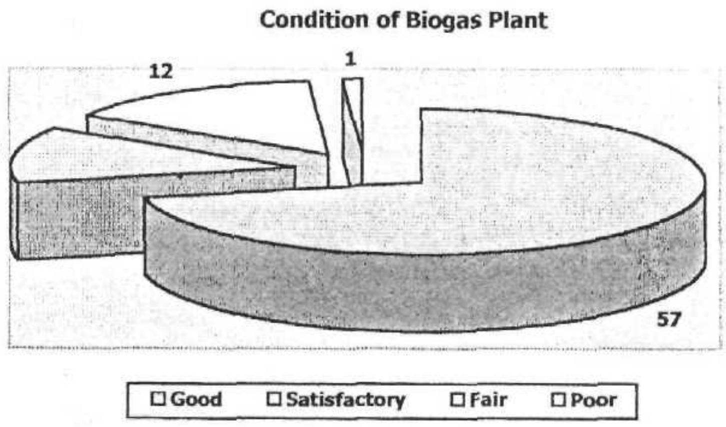
Feeding (% of Prescribed Quantity)	Latrine Attachment		
	Attached	Not Attached	Total
Less than 25%	3	1	4
<25% but >40%	4	0	4
<40% but >60%	8	5	13
<60% but >80%	12	12	24
<80%but>ll0%	10	15	25
More than 110%	5	5	10
Total	**42**	**38**	**80**

The co-relation coefficient of latrine attachment to biogas plant and dung feeding was calculated to be -0.2145. The negative value indicated that less dung was fed into latrine attached plant. However, the coefficient of plant size and dung feeding was positive (0.412). The positive value indicated that quantity of dung fed into digester was directly proportional to the plant capacity. In other words, bigger sized plants were receiving greater quantity of dung.

4.2 Biogas Plant Performance

4.2.1 Condition of Biogas Plant

Prior to the commencement of the study, all the plants sampled for the study were inspected in detail and any defects there in were repaired and maintained. However, depending upon the respective plant owner's attitude to operate plant the condition also differed. Plants under study were categorised as good, satisfactory, fair and poor based upon their physical condition. The following pie-diagram shows condition Of the sampled plants.



Any defects in plants during the time of study were corrected on time. Tn most of the plants, the main gas valve, gas taps and rubber hose pipes were changed. In most of the plants in Chitwan and Nuwakot even the stoves and water drains were changed.

4.2.2 Gas Production

The total amount of gas production from biogas plants under study have been assessed in the following two manners:

- Based upon stove and light burning hours
- Based upon the meter readings

The monthly details of average stove and lamp burning hours in sampled biogas households have been given in Annex-5. Similarly, Annex-6 provides annual average gas production from each biogas plants based upon burning hours, meter readings and theoretical production based upon actual amount of dung-fed.

Because of some technical problems in gas meters, most of the gas meters installed in biogas plants did not work efficiently. The reading obtained from these meters were found to be unreliable. Therefore, while calculating the amount of gas production from biogas plant, the actual burning hours of biogas stove and lamp are used. The efficiencies of biogas plants have been calculated in two ways. The first one is gas production based upon actual burning hours versus theoretical expected production and the second one is gas production based upon actual burning hour versus theoretical expected production based upon actual amount of dung fed into the digester. The following table summaries efficiencies derived from both ways.

Table-13: Efficiency of Biogas Plants under Study

Efficiency	Based upon burning hour and theoretical production		Based upon burning hour and actual amount of dung fed	
	No. of Plant	Percentage	No. of Plant	Percentage
Less than 20%	0	0	0	0
20% to 40%	12	15.00	2	2.50
40.1% to 60%	25	31.25	9	11.25
60.1% to 80%	26	32.50	28	35.00
Above 80.1%	17	21.25	41	51.25
Total	**80**	**100**	**80**	**100**

It is worthy to note that none of the plants have efficiency less than 20%. Similarly, it is noteworthy that more than half of the total plants have efficiency more than 60% in the first case and more than 80% in the second case. These figures support the effects of underfeeding in one hand and proper functioning of biogas plants in the other. The lower efficiency rates in the first case are due to underfeeding and the higher efficiencies in the second case are results of good functioning of plants.

The details regarding the monthly total burning hours of stoves and lamps and the amount of gas production in biogas households have been given in Annex-5. The graphs provided *in* Annex-7, illustrates the average gas production in all four study areas. It can be noted from the graphs that 4 cum plants in Syangja, 6 cum plants in Nuwakot, 8 cum plants in Nuwakot and 10 cum plants in Morang are functioning better than other plants. The graph given in the following page illustrates average annual biogas production in four study areas. The following table illustrates the average gas production in four study areas:

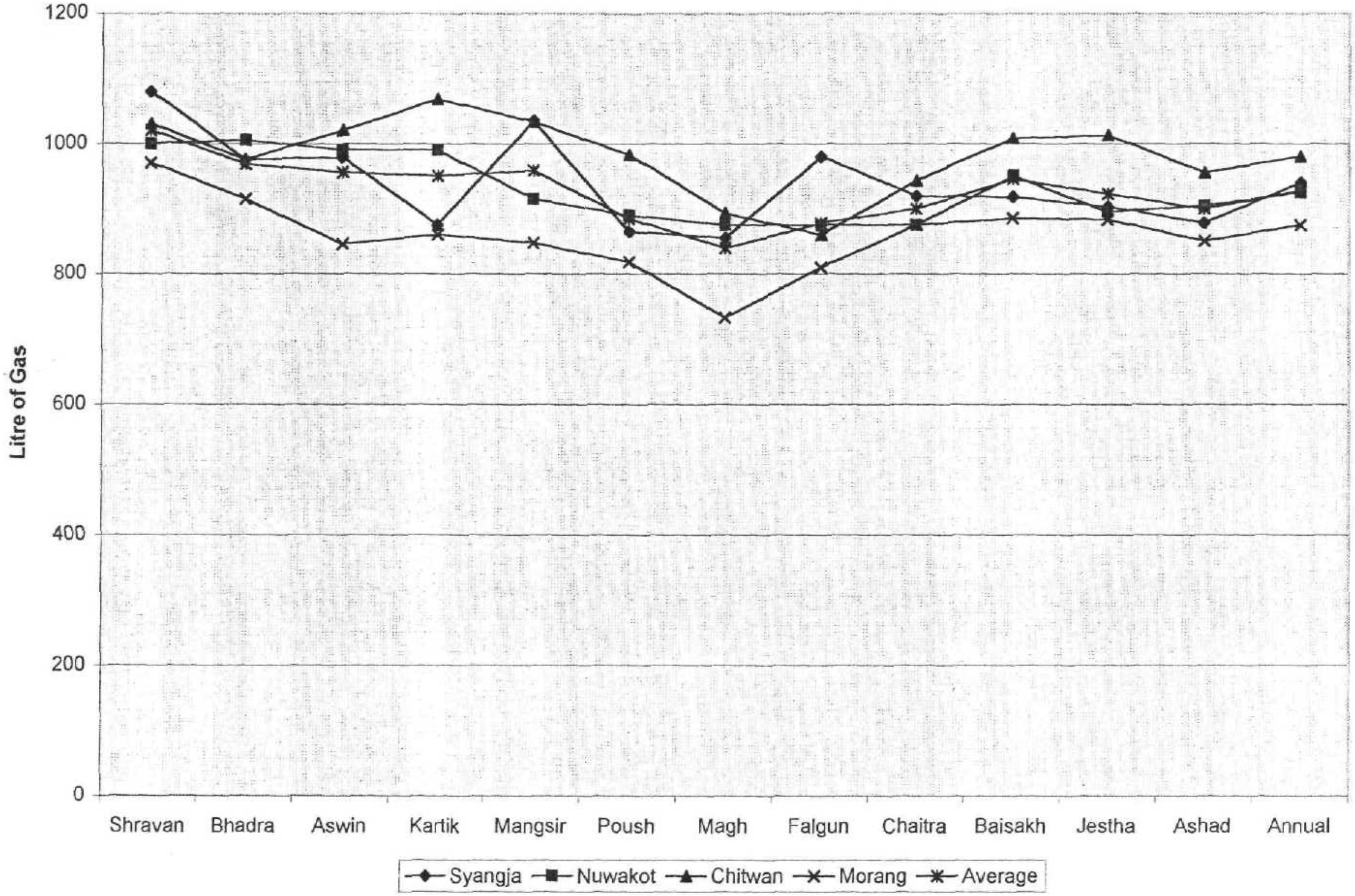
Table-14: Average Gas Production

Month	**Monthly Average Gas Production in Litres**				
	Morang	**Chitwan**	**Nuwakot**	**Syangja**	**Average**
Shravan (July/Aug.)	970	1030	1000	1080	1020
Bhadra (Aug./Sept.)	915	975	1005	975	968
Aswin (Sept./Oct.)	845	1020	990	978	955
Kartik (Oct./Nov.)	860	1068	990	875	950
Mangshir (Nov./Dec.)	847	1032	915	1035	957
Poush (Dec/Jan.)	817	982	890	865	885
Magh (Jan./Feb.)	732	892	875	855	840
Falgun (Feb./Mar.)	810	860	875	980	877
Chaitra (Mar./Apr.)	875	942	875	920	900
Baisakh (Apr./May)	885	1008	950	918	945
Jestha (May/June)	883	1013	895	903	923
Ashad (June/July)	850	955	905	878	900
Average	**875**	**980**	**925**	**940**	**928**

It is encouraging to note that the reduction in gas production during winter months (Magh, Falgun) was not too much. For example, 4 cubic meter capacity plant in Syangja produced 1055 litres of gas per day during the month of Shravan and the corresponding figure in Magh was 677.5. Similarly, the production figures in Nuwakot, Chitwan and Morang were 790, 775 and 438 litres respectively during Shravan and the corresponding figures were 665, 640 and 395 for Magh. The average production from this size of plant in all four sites was 770 litres in Shravan and 650 litres in Magh. It indicated that the reduction in gas production was only 15%.

The major cause of declination of gas production during winter was observed to be the higher differences of minimum and maximum temperatures inside digester during day and night times; but not the lower temperature. The outcome of the study revealed that the declination *in* production is not much in those plants where the temperature difference inside the digester during day and night

Annual Biogas Production



did not exceed by 5-6° centigrade. It indicated the need of minimising the gap between minimum and maximum temperatures inside the digester. This could be done by:

- Providing effective cover of top-filling over dome.
- Providing effective insulation of hey, straw etc. over the dome and outlet slabs of plant.
- Increasing the temperature of the feeding stock. This could be done by exposing the dung-water mix to solar radiation for about 3-4 hours by leaving the mix in the inlet chamber and by covering it with white plastic sheet.
- Lowering the gap of minimum and maximum by providing shades to biogas plants to avoid excessive sunlight during daytime and proper insulation to minimise the heat loss during night **time.**

4.2.3 Influence of Site Selection on Gas Production

Attempts were made to assess the influence of site selection on biogas production. First, the location of biogas plant from the house was considered and secondly, duration of direct sunlight into the biogas digester was also considered to examine if there were any relations between these two parameters and the gas production. The following two tables illustrate the co-relation between location of plant and gas production from those plants,

Tabie-15(a) &(b): Co-relation between Location of Plant and Gas Production

Direction of Plant from House	Plant Efficiency based upon burning hour and theoretical production					**Total**
	>20%	2CM0%	40.1-60%	60.1-80%	<80%	
East	0	4	8	9	10	**31**
West	0	4	6	7	3	**20**
North	0	1	9	7	3	**20**
South	0	3	2	3	I	**9**
Total	**0**	**12**	**25**	**26**	**17**	**80**

Direction of Plant from House	Plant Efficiency based upon burning hour and actual amount of dung fed					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
East	0	1	3	12	15	**31**
West	0	1	3	7	9	**20**
North	0	0	2	5	13	**20**
South	0	0	I	4	4	**9**
Total	**0**	**2**	**9**	**28**	**41**	**80**

It can be noted from the above tables that there is no major co-relation between the direction of plant from household and gas production. However, in the first case, it can be noted that 10 out of 31 plants located in the eastern direction have efficiency more than 80% which is not the case in other directions.

Similarly, attempts were made to draw relationship between gas production and duration of direct sun light into the biogas plants. The following two cross tables shows the outcome.

Table-16 (a) & (b): Relationship between Gas Production and Duration of Direct Sunlight into the Biogas Plants

Duration *of* direct sun light	Plant Efficiency based upon burning hour and theoretical production					**Total**
	>20%	20-10%	40.1-60%	60 1-80%	<80%	
1 hour	0	0	0	0	1	**1**
2 hours	0	0	0	2	0	**2**
3 hours	0	1	0	1	0	**2**
4 hours	0	L	4	6	3	**14**
5 hours	0	1	9	5	3	**18**
6 hours	0	2	5	4	2	**13**
7 hours	0	2	1	I	1	**5**
8 hours	0	2	4	6	3	**17**
More than 8 hours	0	1	2	1	4	**8**
Total	**0**	**12**	**25**	**26**	**17**	**80**

Duration of direct sun light	Plant Efficiency based upon burning hour and actual amount of dung fed					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
1 hour	0	0	0	0	1	**1**
2 hours	0	0	0	2	0	**2**
3 hours	0	0	0	1	1	**2**
4 hours	0	0	3	7	4	**14**
5 hours	0	0	1	5	12	**18**
6 hours	0	1	2	4	6	**13**
7 hours	0	1	0	2	2	**5**
8 hours	0	0	1	5	11	**17**
More than 8 hours	0	0	2	2	4	**8**
Total	**0**	**2**	**9**	**28**	**41**	**80**

It is noteworthy that 75% (13 out of the total 17) in the first case and 85% (35 out of 41) plants in the second case that have efficiency more than 80%, received direct sunlight for more than 5 hours a day. This indicated that although not very much, gas production was more in those plants, which received direct sunlight for longer duration. In contrary, one of the plants that had more than 80% efficiency in the both cases received direct sun light only for a hour and similarly, both the plants which received direct sun light for only two hours in a day, had efficiency in the range of 60 to 80%. This indicated that there is no major co-relationship between direct sunlight and plant efficiency.

4.2.4 Influence of Top Filling over Dome on Gas Production

It has been realised that top filling over dome helps in maintaining uniform temperature inside the digester, which is necessary for optimal gas production. This study also attempted to assess relationship between these two parameters. The following cross tables show the results:

Table-17 (a) & (b): Influence of Top Filling over Dome on Gas Production

Top-filling over dome	Plant Efficiency based upon burning hour and theoretical production					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
More than 40 cm	0	3	10	16	8	**37**
26 - 40 cm	0	4	8	6	7	**26**
10-25 cm	0	5	4	3	1	**12**
Less than 10 cm	0	0	3	1	1	**5**
Total	**0**	**12**	**25**	**26**	**17**	**80**

Top-filling over dome	Plant Efficiency based upon burning hour and actual amount of dung fed					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
More than 40 cm	0	**1**	4	11	21	**37**
26 - 40 cm	0	1	**1**	13	11	**26**
10-25 cm	0	0	2	3	7	**12**
Less than 10 cm	0	0	2	1	2	**5**
Total	**0**	**2**	**9**	**28**	**41**	**80**

From the above tables, it can be noticed that top filling over dome influenced gas production to some extent. In the first case, it can be seen that 88% (15 out of 17) plants that had efficiency more than 80%, had top filling more than 26 centimeter. Similarly, out of 41 plants that had efficiency more than 80%, 32 plants (78.05%) had more than 26 cm top filling over dome. The 2 plants that had efficiency more than 80% but top filling less than 10 cm, were having some sort of insulation over dome and outlet. In one of them the users had used straw-heap and in the other, rich husk was used as insulation. It is, therefore, evident that the insulation over dome increases the gas production.

4.2.5 Influence of Latrine Attachment on Gas Production

Details on latrine attachment lo the biogas digester have been given under clause 3.1.3. Details on latrine attachment and gas production could be referred to Annex-6. The following cross tables show the relation between latrine attachment and gas production.

Table-18(a) & (b): Influence of Latrine Attachment on Gas Production

Latrine Attachment	Plant Efficiency based upon burning hour and theoretical production					**Total**
	>2G%	20-40%	40.1-60%	60.1-80%	<80%	
Attached	**0**	7	13	13	9	**42**
Not Attached	**0**	5	12	13	8	**38**
Total	**0**	**12**	**25**	**26**	**17**	**80**

Latrine Attachment	Plant Efficiency based upon burning hour and actual amount of dung fed					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
Attached	0	1	1	16	24	**42**
Not Attached	0	1	8	12	17	**38**
Total	**0**	**2**	**9**	**28**	**41**	**80**

The above tables illustrate that plant efficiency increases with the latrine attachment. Although no major co-relation is seen in the first case, the second table indicates significant relation. Out of the 41 plants that had efficiency more than 80%, 24 of them had latrine attached Similarly, out of 11 plants that had efficiency less than 40%, 9 of them had no latrine attached. The influence of latrine attachment on gas production has further been described under heading 4.2.7.

The co-relation coefficient of latrine attachment and gas production was 0.3235. Higher positive value of such co-efficient indicates that there is perfect positive co-relation between the two parameters. For example, in the case of co-relation co-efficient 1, one can assume that gas production and toilet attachment have perfect co-relationship. Gradual decrease in value indicates lesser co-relation. If co-relation co-efficient is 0, it is known that there is no relation between the two. In this case this value is positive, which indicates that gas production has been increased due to the attachment of latrines into the plants, however the increase is not much.

4.2.6 Influence of Dung-Water Ratio on Gas Production

It is also believed that dung-water ratio, in other words, total solids in feeding material also influences biogas production to a great extent. The outcome of the present study supports this very fact. The following cross table indicates co-relation between dung-water ratio and gas production.

Table-19 (a) & (b): Influence of Dung-Water Ratio on Gas Production

Dung-Water Ratio	Plant Efficiency based upon burning hour and theoretical production					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
Less than 0.9	0	5	5	8	4	**22**
0.9 to 1.10	0	7	18	16	13	**54**
1.11 to 1.5	0	0	1	2	0	**3**
More than 1.5	0	0	1	0	0	**1**
Total	**0**	**12**	**25**	**26**	**17**	**80**

Dung-Water Ratio	Plant Efficiency based upon burning hour and actual amount of dung fed					**Total**
	>20%	20-40%	40.1-60%	60.1-80%	<80%	
Less than 0.9	0	2	1	5	14	**22**
0.9 to 1.10	0	0	7	21	26	**54**
1.11 to 1.5	0	0	0	2	1	**3**
More than 1.5	0	0	1	0	0	**1**
Total	**0**	**2**	**9**	**2S**	**41**	**80**

It can be seen from the above tables that there is distinct co-relation between dung-water ratio and gas production. In the first case 13 plants out of the 17 whose efficiency exceeds 80% have dung water ratio in between 0.9 to 1.1. Similarly, in the second case both the plants, which have efficiency less than 40% have dung water ratio less than 0.9. It means that much or less water than the prescribed quantity of one litre per kg of dung, effects the gas production adversely. Gas production id maximum when dung-water ratio falls between 0.9 to I.I.

4.2.7 Gas Production per Kilogram of Dung

The study attempted to assess how much biogas is produced per kilogram of dung in all four study areas. The outcome of the study provided with an interesting scenario. The following table shows the results:

Table-20: <u>Gas Production per Kilogram of Dung</u>

Study Area	Biogas Production Per Kg of Duns (litre)		
	Latrine Attached	Latrine Not Attached	Average
Syangja	40	34	37
Nuwakot	33	33	33
Chitwan	38	30	35
Moran#	54	32	43
Average	43	33	38

The above table illustrates that the average gas production of 38 litre/kg of dung is very near to the assumed value of 40 litres/kg. However, this value is significantly less (33) in plants in which latrines were not attached.

The table indicates the influence of latrine attachment into the biogas plant. When latrines were attached the production significantly increased. This value was very much encouraging in Morang, where as no significant change was observed in Nuwakot.

There are certain factors that influence the quantity of gas production. Major factors are the average temperature per month and the difference of minimum and maximum temperatures in a day, water dung ratio, operation practices etc.

4.2.8 Average Gas Consumption by Stove and Lamp

It has been assumed that a GGC model gas stove consumes 300 to 350 litres of gas per hour and that a gas lamp consumes about 150 to 175 litres. The actual amount of gas consumption by these two devices has been calculated based upon the gas meter readings and actual burning hours of stove. Only one household used gas to burn lamp only and therefore the average burning hour has been taken from the consumption rate in that specific household.

The outcome of the study suggested that a biogas stove consumed a maximum of 443 litre and a minimum of 210 litres of gas per hour. The average figure is 290 litre. Similarly, in the case of lamp it is 166 litres per hour. The average figure in the case of biogas stove seems to be too low. The reason for this might be the non-functioning of gas mettes in some of the plants. During Held study it was observed that majority of the gas meters had problems in functioning. Hence, these figures are still debatable.

5.0 BIOGAS USE PATTERN

5.0 BIOGAS USE PATTERN

The efficiency of biogas plant is mainly determined by its size and daily feeding received by it. Another parameter to determine the efficiency is the size of dome, that is, the gas storage capacity of the plant. The GGC 2047 Model biogas plants are designed to be able to store 55 - 60% of the daily gas production based on a minimum feeding as per the assumed hydraulic retention time of 55 days for Terai regions and 70 days for the hilly regions of the country; and on the assumption that 40 litres of gas is produced from 1 kg of dung mixed to equal volume of water. The volume of digester and that of dome (gas storage tank) as per the present design of different capacity biogas plant is given below:

Table-21: Volume of Dome and Digester of GGC 2047Model Plants

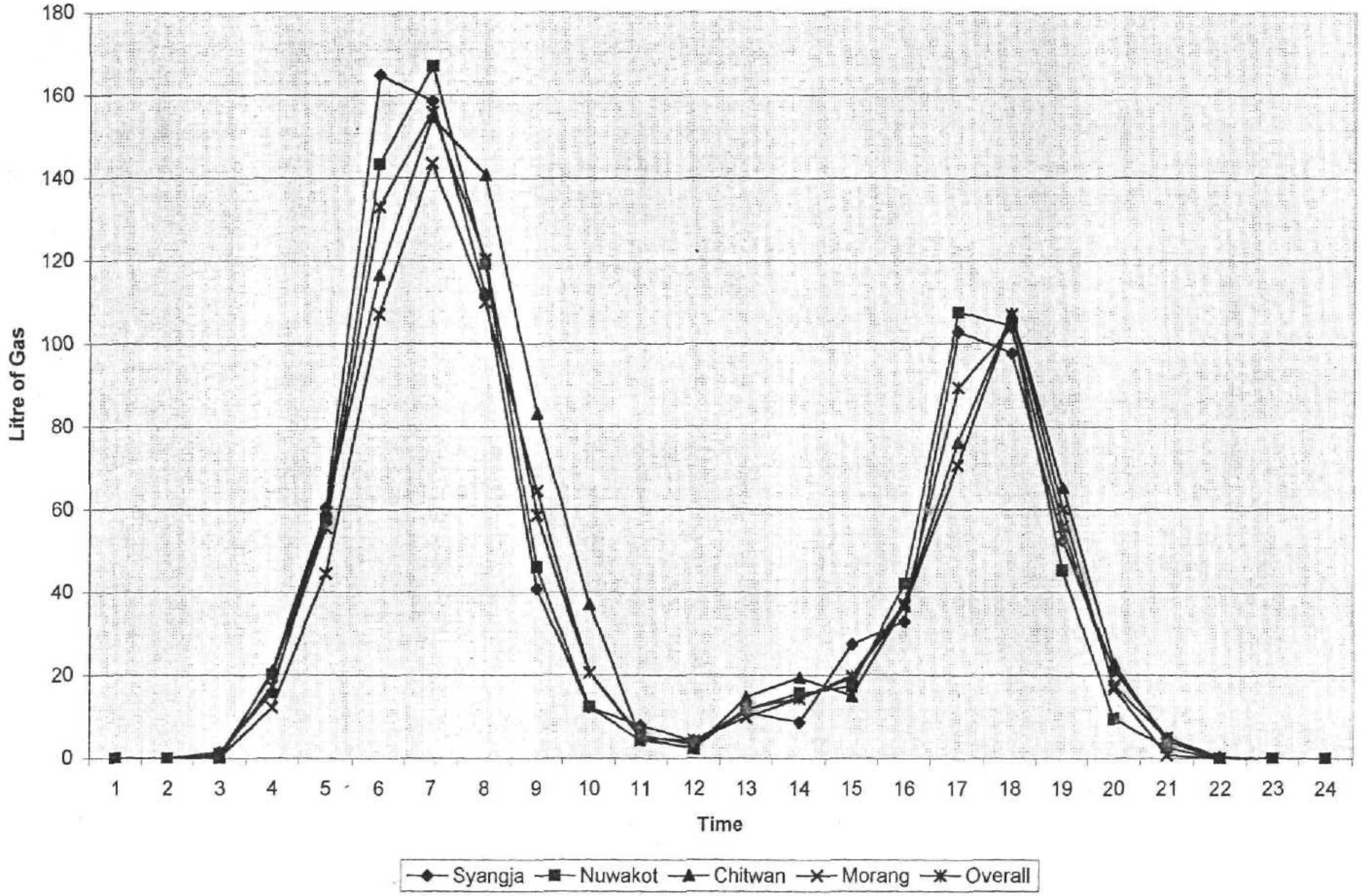
Plant Size (cum)	Digester		Dome		Expected Gas Production (litre)
	Volume (cum)	Percentage	Volume (cum)	Percentage	
4	2,81	70	1.21	30	960
6	4,30	71	1,75	29	1440
8	6.01	73	2.18	27	1920
10	7.00	69	3.1!	**31**	2400

It has been felt that the cost of biogas plant could be minimised if the gas storage capacity of plant is decided optimally. In other words, it was assumed that the presently size might be bigger than the required capacity and there might be possibilities of reducing this size of storage tank. The storage tank is constructed to store gas produced during lean hours so that it can fulfill the demand of peak hours. It is therefore necessary that the gas stored in the dome is enough to meet the demand during peak hours. Larger size of storage tank, although stores more gas, is over expenditure and therefore not necessary.

To decide on the optimal size of biogas plant, it is therefore, necessary to assess the actual biogas use pattern being practiced in the biogas households. Effort has been made to pin point the peak hour *ol"* gas use on the basis of stove on and off times in the morning, noon and evening. Ft is obvious that the gas use pattern may differ from place to place and from family to family depending upon several socio-economic characteristics. During the course of this study, the owners were provided with a format to record time of gas use preciously and correctly. The records, thus, kept by respective biogas households were daily checked by the Female Research Assistants appointed in each study area. Based upon the time recorded by these households, daily biogas use pattern was assessed. This analysis has been done month-wise for each study area.

The biogas use patterns in each study area have been depicted month-wise in the attached graphs given in Annex-8. The graph given in the next page illustrates average gas use pattern area-wise for the whole one year of study period. It can be noted from the graph that the average gas use pattern does not differ much in the four study areas. It may be because of quite similar socio-cultural conditions existing all over Nepal.

Biogas Use Pattern - Annual Average



The following table illustrates the average annual gas use pattern in four study areas and the average of all.

Table-22: *<u>Average Annual Gas-use Pattern</u>*

T1me O'c1ock	Ga8 U8e(1tr)				
	Syangja	Nuwakot	Chitwan	Morang	Average
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	2	1	0	0	1
4	16	20	21	12	17
5	60	58	60	45	56
6	165	143	117	107	133
7	159	167	155	144	156
8	112	119	141	126	120
9	41	46	83	74	59
10	12	12	37	21	21
11	8	4	5	5	6
12	4	3	2	4	3
13	11	12	15	10	12
14	9	16	19	15	15
15	28	17	15	19	20
16	33	42	37	37	37
17	103	108	76	71	89
18	98	104	107	107	104
19	53	45	65	60	56
20	21	10	23	17	18
21	5	3	4	1	5
Tota1	940	930	982	875	928

It can be seen from the above table that the peak hour of gas use falls in the range of 6 to 8 o'clock in the morning. From 10 p.m. to 4 a.m. no gas is used, which is the lean period. Similarly very little amount of gas is used in between 11 a.m. to 3 p.m. The general gas use pattern varies a bit during winter season. The graphs given in Annex- 8 illustrate it in detail.

6.0 USE OF BIOGAS AND CONVENTIONAL FUELS

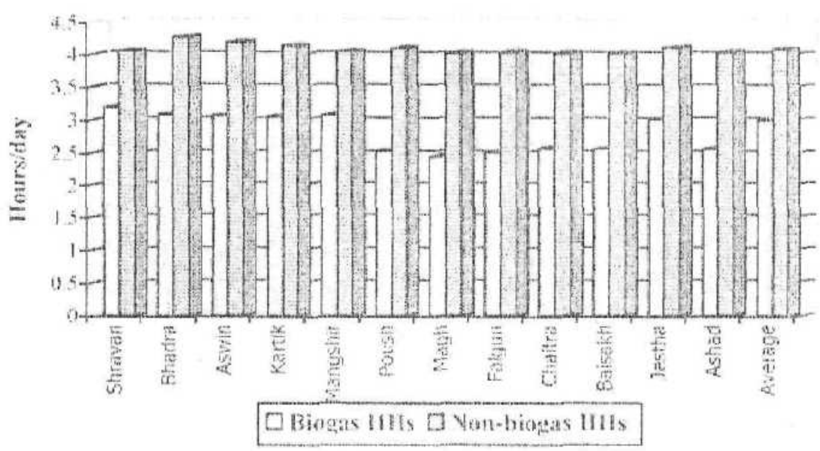
6.0 USE OF BIOGAS AND CONVENTIONAL FUELS

Data and information as regards the biogas stove and lamp burning hours; use of firewood, kerosene, agricultural residues, dung cake etc.; plant feeding and gas production etc. were analysed using computer software MS Excel, Access, SPSS PC+ and Harvard Graphics. The outcome of the analysis is presented hereafter.

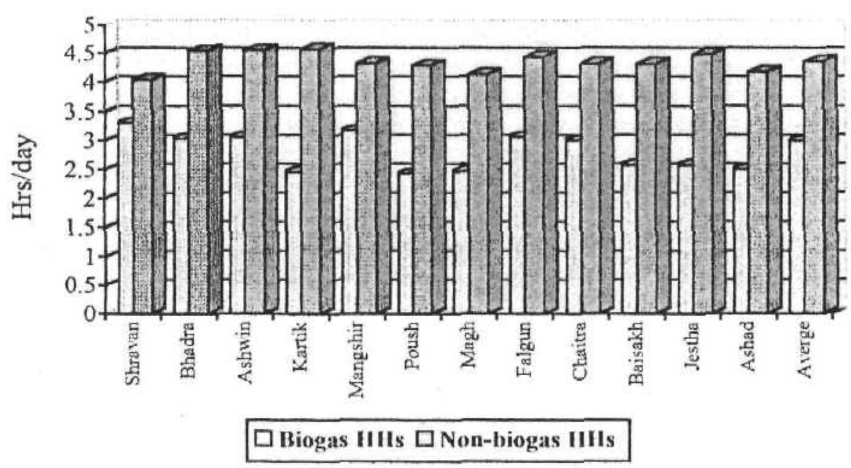
6.1 Cooking

The outcome of the study revealed that the average cooking time for biogas households under study was 3 hours 1 minute per day. The maximum and minimum figures were 2 hours 46 minutes (Magh) and 3 hours 19 minutes (Shravan) per day. Similarly, the average cooking time for non-biogas households was 4 hours 10 minutes. The minimum and maximum figures were 4 hours 03 minutes (Magh, Chaitra and Baisakh), and 4 hours 28 minutes (Bhadra). This indicates that considerable time (1 hour 9 minutes/day/hh in average) is saved after the installation of biogas plants, The following graph indicates the total time spend in cooking. The details on cooking have been shown in the table given in Annex-9. The following graphs illustrate some details.

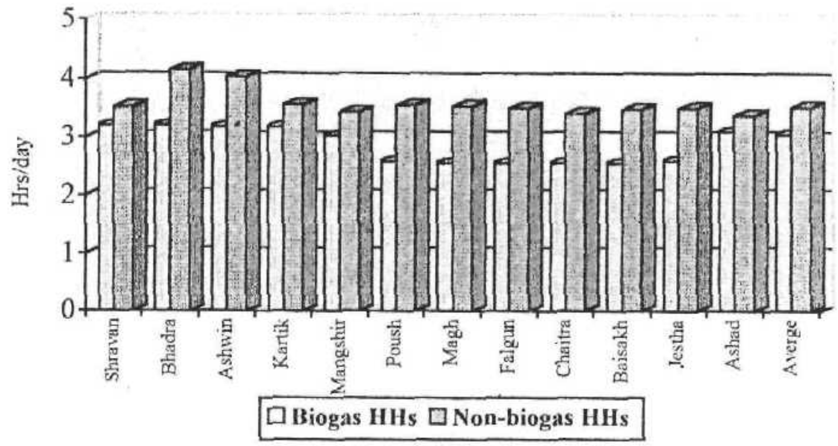
Total Time Used For Cooking



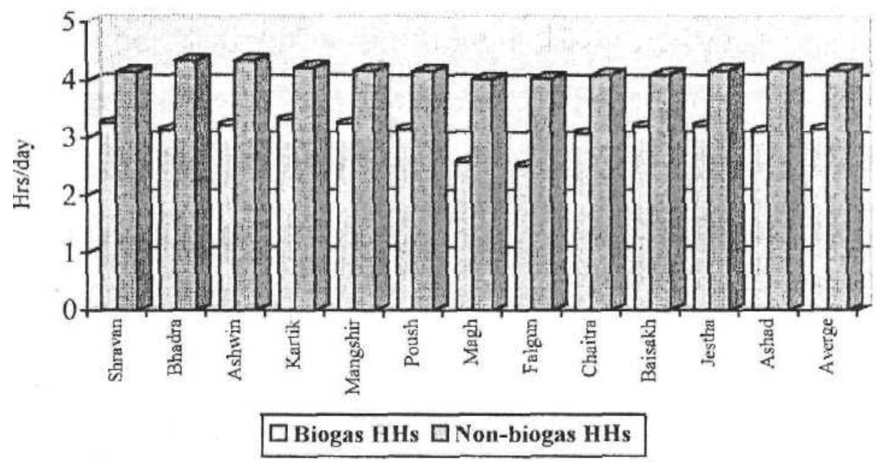
Time Used for Cooking - Syangja



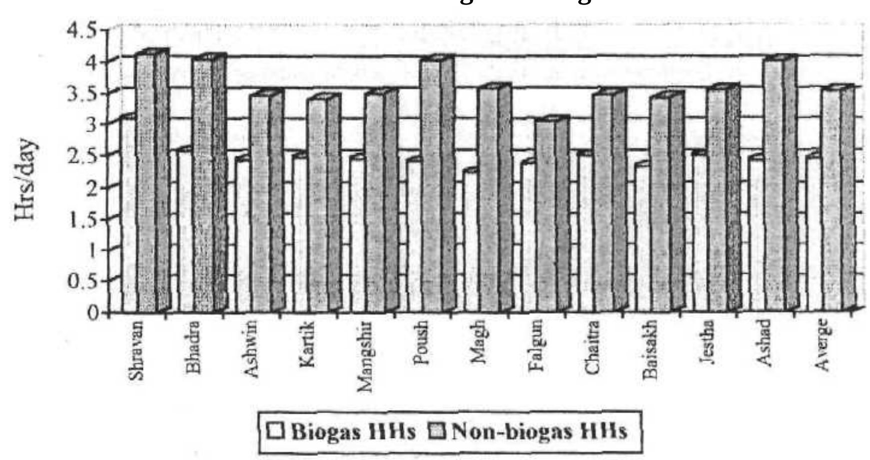
Time Used for Cooking - Nuwakot



Time Used for Cooking - Chitwan



Time Used for Cooking - Morang



The graphs given above show that a non-biogas households needed more than 4 hours time in all the four study areas to cook food where as the corresponding time for biogas households was about 3 hours. The average saving of time to cook due to the installation hence was found to be I hour 36 minutes, 48 minutes, 1 hour 3 minutes and 1 hour 9 minutes respectively for Syangja, Nuwakot, Chitwan and Morang respectively. The average time saving was 1 hour 9 minutes.

Attempts were also made to assess the relationship between average burning hours of stoves and family size. The following table presents the findings:

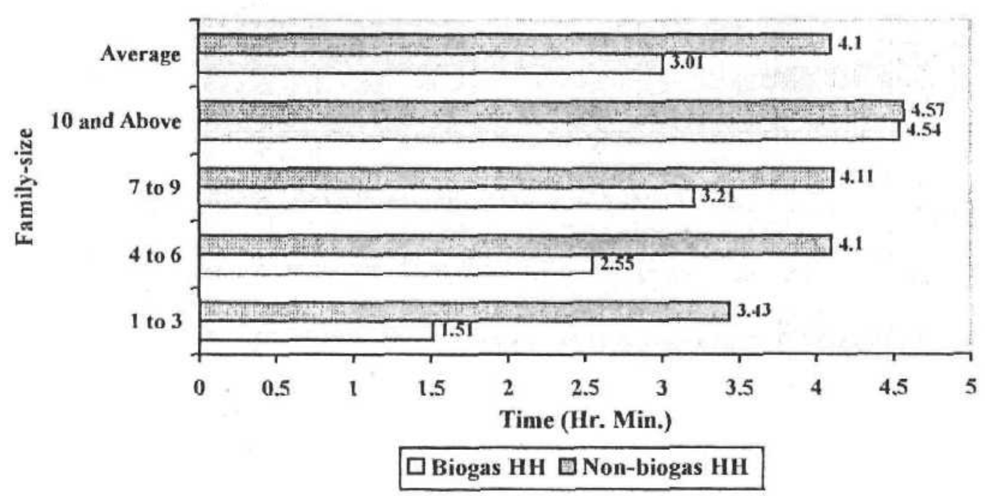
Table-23: *Relationship between Average Time Spent on Cooking and Family-size*

Family Size	Average Time Spent to Cook Food									
	Syangja		Chitwan		Nuwakot		Morang		Total	
	BH	NBH	BH	NBH	BH	NBH	BH	NBH	BH	NBH
1 to 3	2:54	4:05	2;19	NA	.1:31	3:29	0:59	NA	1:5!	3:43
4 to 6	3:04	4:22	3.00	4:17	2:32	4:09	3:18	3:.54	2:55	4:10
7 to 9	3:34	5:36	3:43	4:19	3:34	NA	2:29	3:47	3:21	4:11
10 &above	3:24	NA	5:28	NA	5:15	3:42	4:52	4:17	4:54	4:57
Average	3:00	4:36	3:15	4:18	3:05	3:53	2:45	3:54	3:01	4:10

Note: *BH Biogas HHs*
NBH - Non-biogas HHs

The following graph shows the average time needed to cook for households of different family-member compositions with and without biogas plant.

Family-size versus Average Time Spent on Cooking



The co-relation coefficient of total stove burning hour and family size was observed to be 0.7432. The positive relationship indicated that the total number of persons residing in households is one of the important governing factors for stove burning. The higher co-relation value indicated that as the family size increased, time for stove burning also increased.

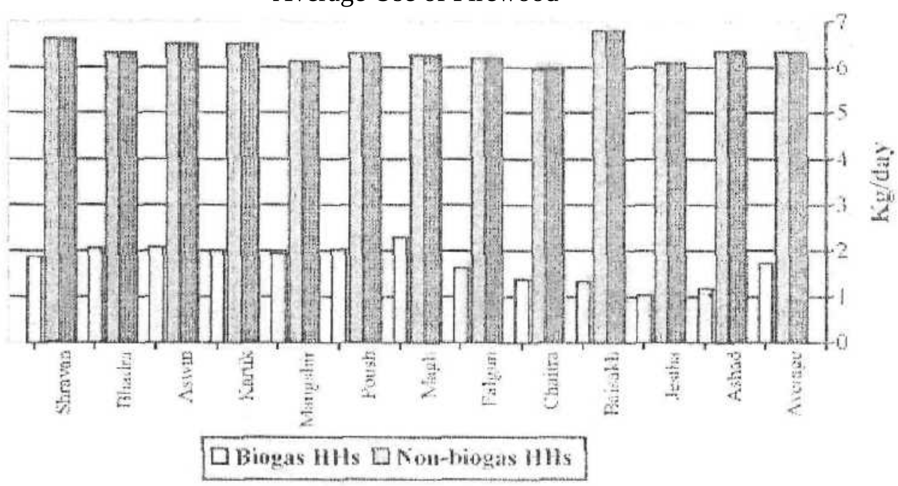
Similarly, the co-relation coefficient of total stove burning hour and total dung fed into biogas plant was 0.521. This indicated gas production was directly proportional to dung fed.

6.2 Use of Conventional Fuel

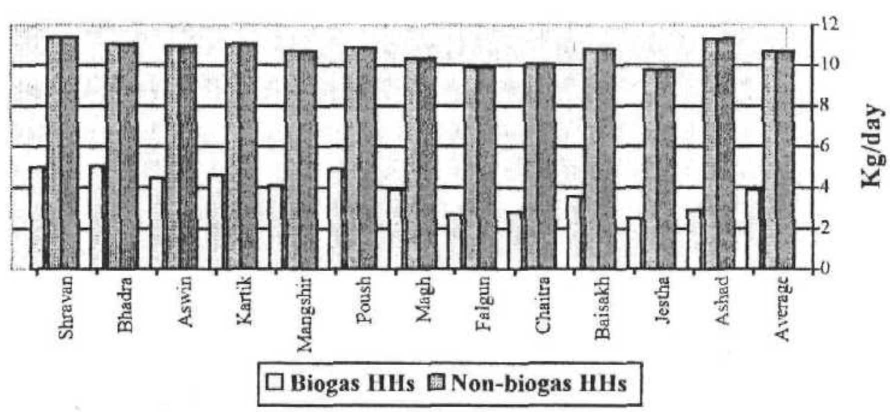
6.2.1 Fire Wood

The use of firewood for biogas households was found to be 1.61 kg (Chaitra) to 2.24 (Magh) kg per day. Non-biogas households used firewood in the range of 5.69 kg to 6.32 kg. In an average non-biogas households used 10.68, 5.03, 4.67 and 5.14 kg of firewood per day in Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 3.92, 0.89, 1.17 and 1.09 kg. The saving of firewood thus, was 6.76, 4.14, 3.5 and 4.05 kg per day respectively. The total saving of firewood was calculated to be 1668.30 kg per year per household. The following graphs illustrate the findings in detail:

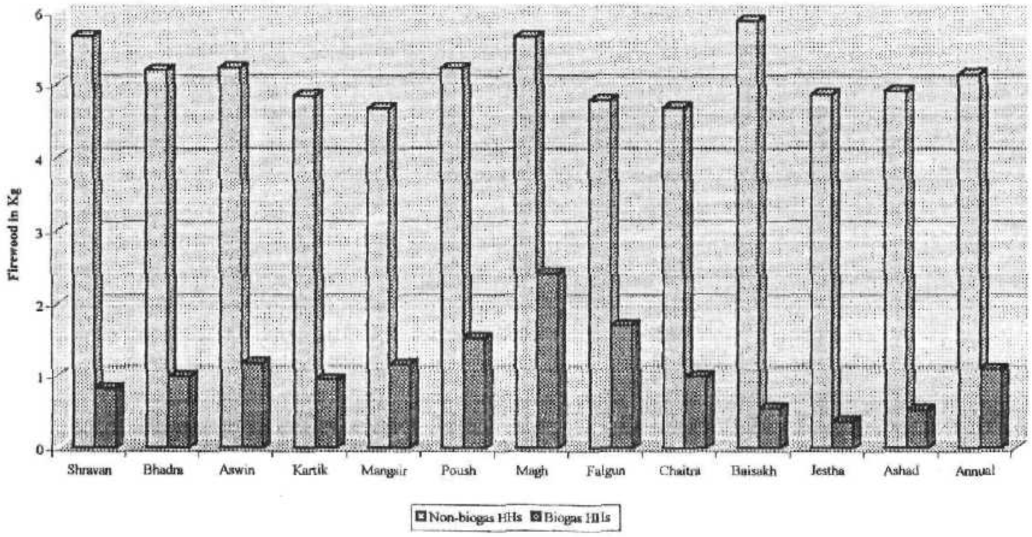
Average Use of Firewood



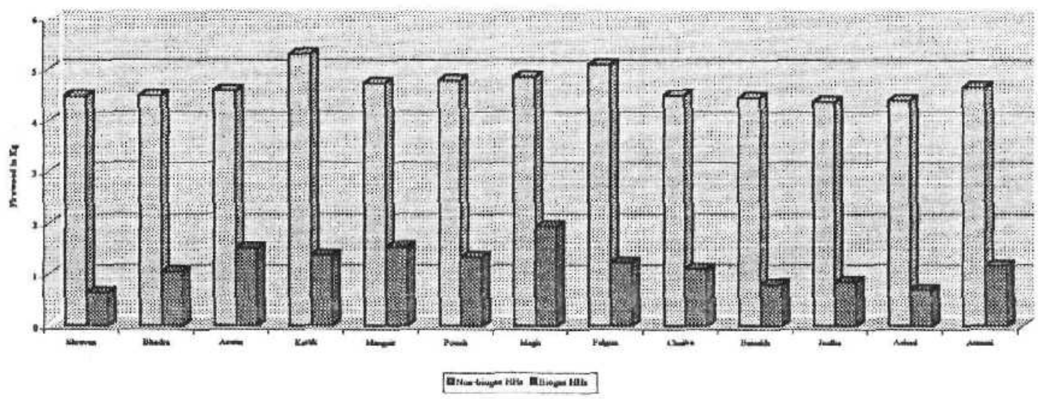
Average Use of Firewood - Syangja



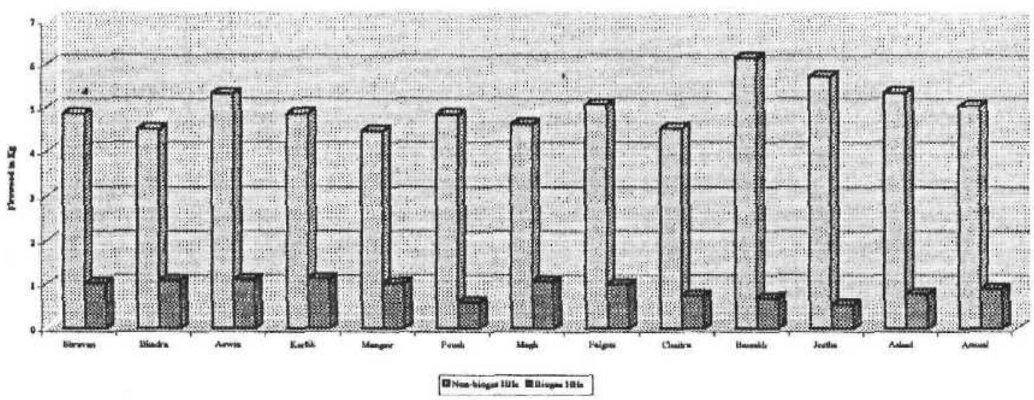
Average Use of Firewood – Morang



Average Use of Firewood-Chitwan



Average Use of Firewood – Nuwakot



Based upon the data on the saving of firewood, approximate area of forest saved per year because of the installation of biogas plants could be calculated using various empirical methods. Given the variety of fuel source systems and individual energy-use patterns, it is rather difficult to draw a direct relationship between biogas use and a positive impact on forest conservation. For example, when biogas is introduced as a substitute for the traditional fuels such as residues from agricultural and fodder crops or the dead wood from jungle, it usually has no significant impact on forest conservation but if it replaces the living trees as the fuel source, there will be more positive impacts as the first two do not require trees to be cut. Hence, as a method of conserving or preserving the forest, the direct benefits of biogas are less easily calculated However, after consultations with the family members in the sampled households for study, it was assumed that most of the recipients' family used to depend upon living trees to fulfil their energy needs prior to the installation of biogas plants. From this, the following hypothetical calculation, as practiced by AFPRO, assuming firewood received from one tree equivalents 11 cum of biogas, can be done to get biogas-forest relationship.

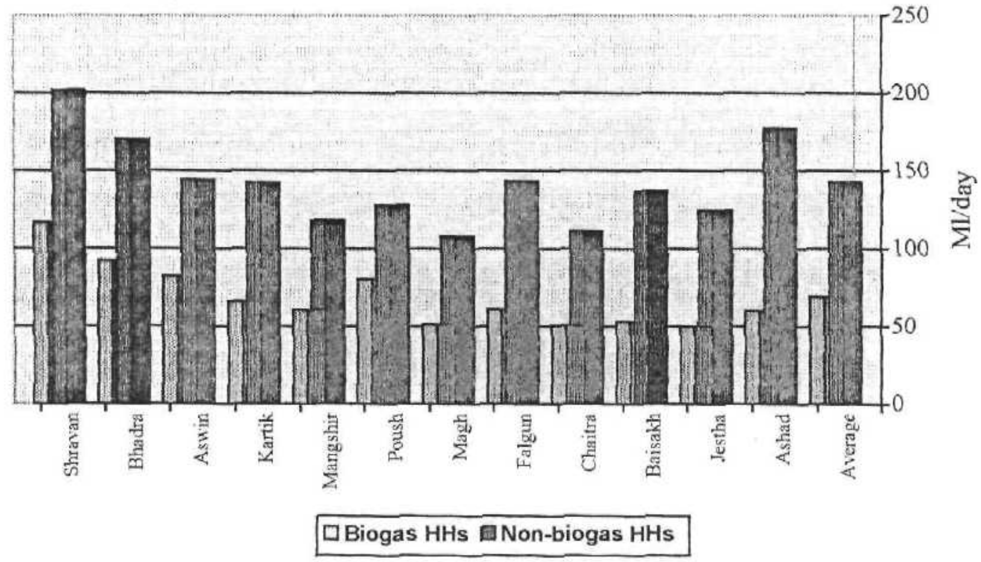
Saving of firewood per household per year	1668.3 kg
Equivalent quantity of biogas per household per year	417 cum
No. of trees saved per household per year	38
Equivalent area of forest	0.03 ha
	0.60 ropani

Such benefit calculation bears no specific relationship to the actual fuel-use patterns as the villagers solve their energy needs in a number of ways, simple conversions of the nature as shown above are simplistic and may be incorrect. Conclusively, it can be supposed that the installation of one biogas plant has saved a total of 0.03 hectares of forest and it has a very positive impact on checking forest depletion.

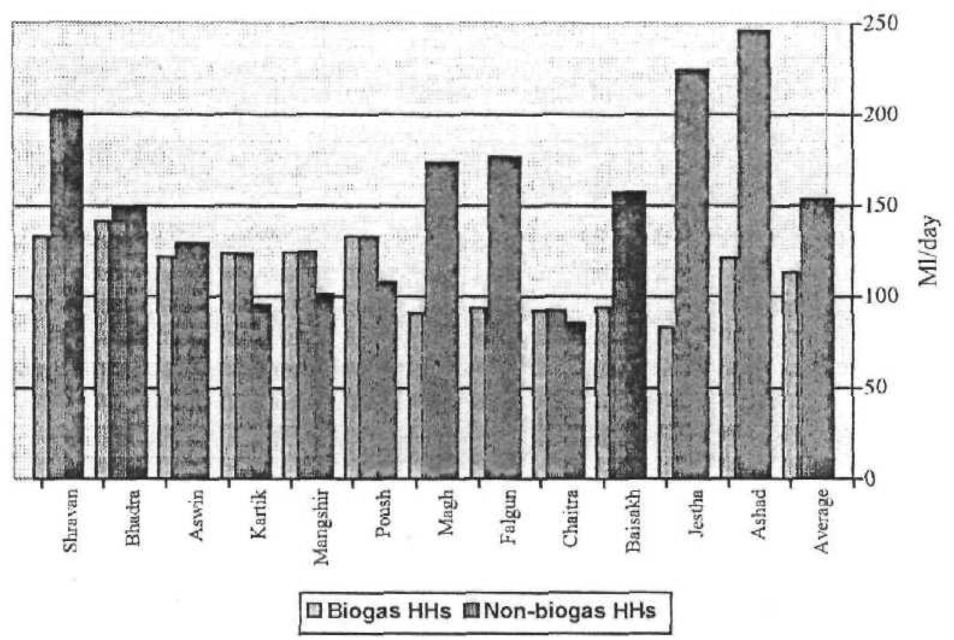
6.2.2 Kerosene

The outcome of the study indicated that an average of 49.21 (Magh) to 118.14 (Shravan) millilitre of kerosene was consumed by the biogas-households in a day where as the non-biogas households used 72.87 to 196.08 milliliters. In an average non-biogas households used 153.76, 141.85, 140.32 and 135.57 milliliter of kerosene per day in Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 113.64, 47.78, 81.22 and 35.62 milliliter. The savings of kerosene thus, were 40.12, 94.07, 59.10 and 99.95 milliliter per day respectively. The total saving was calculated to be 27 litres per year per households. The amount of saving seems not too encouraging. The reason is that the households under study used a little amount of kerosene for cooking and in most of the households biogas lamp was not installed. Details have been given below:

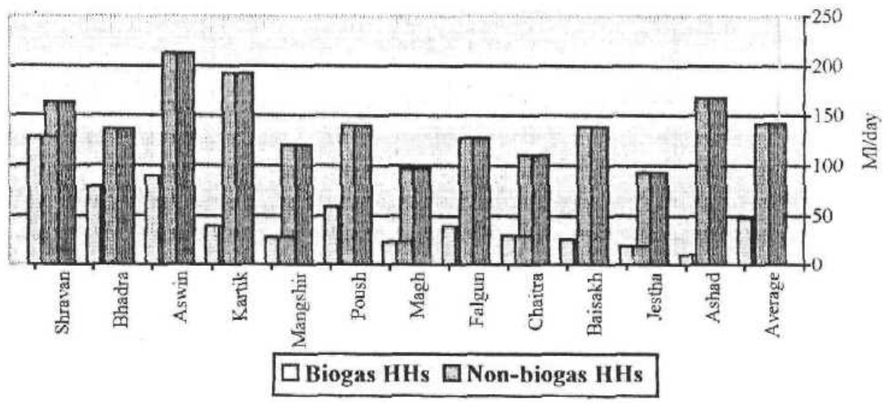
Average Quantity of Kerosene Used



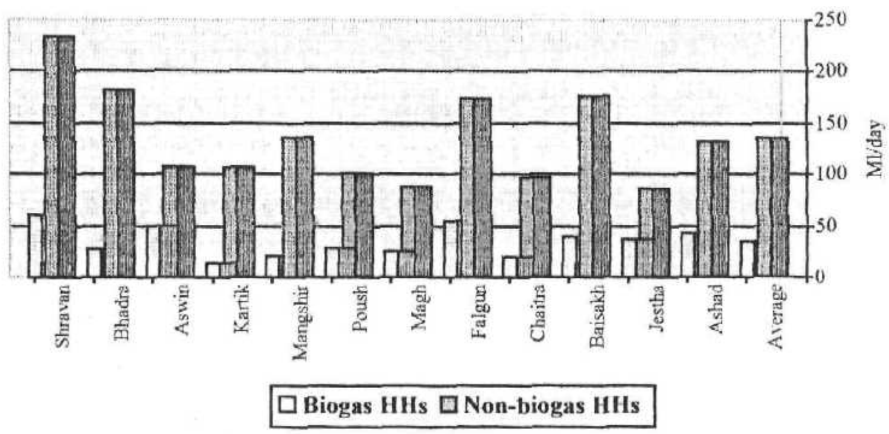
Average Quantity of Kerosene Used - Syangja



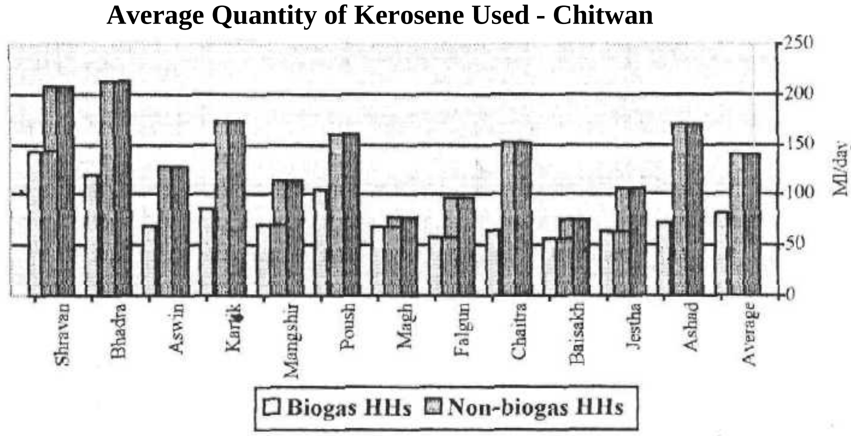
Average Quantity of Kerosene Used - Nuwakot



Average Quantity of Kerosene Used - Morang



Average Quantity of Kerosene Used - Chitwan



The above graphs indicate that kerosene use pattern differed from one ecological zone to another to a great extent. Similarly, the saving also differed a lot.

Attempts were made to collect information on co-relation between family-size and average use of firewood and kerosene in all the study areas. The following two tables summaries the findings.

Table-24: Average Use of Firewood and Kerosene (Non-biogas HHs)

Family Size	Syangja		Chitwan		Nuwakot		Morang		Average	
	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene
1U>3	H.00	92.16	NA	NA	5.51	146.88	NA	NA	5.78	131.58
4 to 6	11.05	155.4	4.7	148.33	4.71	138.49	4.94	137.49	6.34	145.45
7 to 9	10.78	179.08	4.59	108.34	NA	NA	5.72	140.26	6.84	142.19
10 & above	NA	NA	NA	NA	5.6	153.71	4.6	109.95	5.34	142.72
Average	10.68	153.76	4.67	140.32	5.03	141.85	5.14	135.57	6,35	142.78

Table-25: Average Use of Firewood and Kerosene (Biogas HHs)

Family Size	Syangja		Chitwan		Nuwakot		Morang		Average	
	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene	Firewood	Kerosene
1 lo 3	1.50	70.44	1.25	73.91	0.64	32.25	0.13	62.33	0.81	68.02
4 lo 6	4.10	106.70	1.06	60.02	1.32	52.20	1.29	26.51	2.04	64.66
7 to 9	5.14	174.55	0.55	86.38	0.38	47.68	1.45	41.78	1.44	73.97
10 & above	1.00	29.34	2.62	211.55	0.11	0.00	1.16	5.49	1.50	91.70
Average	3.92	113.64	1.17	81,22	0.89	47.78	1.09	35.62	1.73	68.89

From the above two tables, it can be noted that there is no specific co-relation between average use of firewood and kerosene and the family size.

6.2.3 Fodder Stem (Remains of Fodder)

The outcome of the study indicated that the households under study in all the four areas used very little quantity of the remains of fodder. The non-biogas households used 0.65, 0.2, 0.14 and 0.35 kg of fodder steins per day respectively in Syangja, Nuwakot, Chitwan and Morang. Similarly the biogas households used 0.17, 0.09, 0.03 and 0.08 kg of fodder stem per day per households in Syangja, Nuwakot, Chitwan and Morang respectively. The average figures were 0.33 and 0.09 kg respectively for non-biogas and biogas households respectively which gave an average saving of 0.24 kg per day per household. In total 87.60 kg of fodder stem was saved per year per household. The details have been given in Annex-9. The following table shows average use of fodder-stem:

Tabie-26: Average Use of Fodder-stem (Ks/day/HH)

Study Area	Non-biogas HH	Biogas HHs	Savings
Svangia	0.65	0.17	0.48
Nuwakot	0.20	0.09	0.11
Chitwan	0.14	0.03	0.M
Morang	0.35	0.08	0.27
Average	0.33	0.09	0.24

6.2.4 Dung-cake

As in the case of fodder stem, the use of dung-cake was also not very significant in all the four study areas. The use of dung-cake is widely practiced in terai zone. Although the study areas of Chitwan and Morang lied in this range, the use of dung-cake was very less in both the cases although it was higher than that in other two areas of Syangja and Nuwakot. It was observed that the use dung-cake was mostly practiced in pure Terai communities usually known as *Madhises.* It is rather discouraging that this community is yet to be penetrated by biogas programme. Out of the 40 households under study in Morang and Chitwan, only one household belonged to this community. This may be the reason for why the figures on use of dung-cake were quite insignificant.

The non-biogas households in Syangja, Nuwakot, Chitwan and Morang used 0.03, 0.26, 0.34 and 0.40 kg of dung-cake respectively where as the biogas households in Chitwan and Morang used 0.02 and 0.14 kg of dung-cake respectively. The biogas households in Syangja and Nuwakot did not use dung-cake. The average use of dung cake was observed to be 0.3 kg per day per HHs in non-biogas households and 0.04 in biogas households, which gave a total saving of 0.26 kg per day per household. Annex-9 shows the use of dung-cake in all four-study areas month-wise. Table-27 given below shows average use of dung-cake in biogas and non-biogas households under study:

Table-27: *Average Use of Dung-cake (Ks/day/HH)*

Study Area	Non-biogas	Biogas HHs	Savings
Syangja	0.03	0.00	0,03
Nuwakot	0.26	0.00	0,26
Chitwan	0.36	0.02	0.34
Morang	0.54	0.14	0,40
Average	0.30	0.04	0.26

6.2.5 Agricultural Residue

Maize-stalk, jute-stem, wheat-stem, rice-husk, *Khoya* and stems of some vegetables were the major agricultural residues burnt in study households. These items were used for both cooking or heating purposes. Although the amounts of such residues were not too much, these items were widely burnt.

The quantity of agricultural residues used differed from one study area to another. An average of 0.29, 1.96, 0.95 and 0.27 kg per day per households of these items were used in non-biogas households in Syangja, Nuwakot, Chitwan and Morang respectively. The corresponding figures for biogas households were 0.20, 0.06, 0.10 and 0.04 kg. The average quantities were 0.87 kg for non-biogas households and 0.10 kg for biogas households. The following table shows the average use of agricultural residues in biogas and non-biogas households. Monthly details have been given in Annex-9.

Table-28: *Average Use of Agricultural Residue (Ks/day/HH)*

Study Area	Non-biogas HH	Biogas HHs	Savings
Syangja	0.29	0.20	0.05
Nuwakot	1.96	0.06	1.90
Chitwan	0.95	0.10	0.85
Morang	0.27	0.04	0.09
Average	0.87	0.10	0.59

6.3 Saving of Conventional Fuel

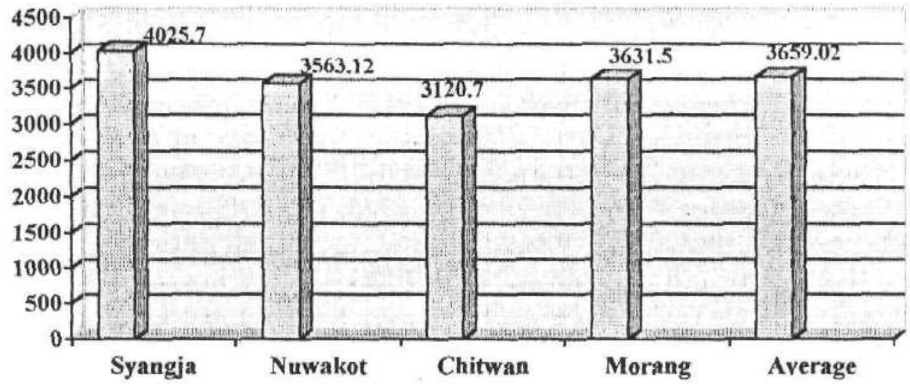
As described in clause 6.2 above, the use of conventional fuels in biogas and non-biogas households could be compared. The figures show that significant quantities of firewood and kerosene and considerable quantities of fodder-stem, dung-cake, and agricultural residues are saved after the installation of biogas plant. This could be quantified in monitory values. The following table provides the findings:

Table-29: Saving of Conventional Fuel

Particular	**Firewood (Kg)**	**Kerosene (ml)**	**Fodder-stem (Kg)**	**Dung-cake (Kg)**	**Agri-residue (Kg)**	**Saving per Year (Rs.)**
Syangja						
Quantity Saved/hh	6.76	40.12	0.48	0.03	0.05	
Rate per unit (Rs.)	1.5	0.015	0.5	0.75	0.5	
Saving/day (Rs.)/hh	10.14	0.6018	0.24	0.0225	0.025	
Saving/year (Rs.)/hh	3701.1	219.657	87.6	8.2125	9.125	
Total Saving (Rs.)/year/hh						**4025.70**
Nuwakot						
Quantity Saved/hh	4.14	94.07	0.11	0.26	1.9	
Rate per unit (Rs.)	1.75	0.014	0.5	0.75	0.5	
Saving/day (Rs.)/hh	7.245	1.31698	0.055	0.195	0.95	
Saving/year (Rs.)/hh	2644.425	480.6977	20.075	71.175	346.75	
Total Saving (Rs.)/year/hh						**3563.12**
Chitwan						
Quantity Saved/hh	3.5	59.1	0.11	0.34	0.85	
Rate per unit (Rs.)	2	0.0135	0.5	0.8	0.5	
Saving/day (Rs.)/hh	7	0.79785	0.055	0.272	0.425	
Saving/year (Rs.)/hh	2555	291.21525	20.075	99.28	155.125	
Total Saving (Rs.)/year/hh						**3120.70**
Morang						
Quantity Saved/hh	4.05	99.95	0.27	0.4	0.09	
Rate per unit (Rs.)	2	0.0135	0.5	08	0.5	
Saving/day (Rs.)/hh	8.1	1.349325	0.135	0.32	0.045	
Saving/year (Rs.)/hh	2956.5	492.50363	49.275	116.8	16.425	
Total Saving (Ks.)/year/hh						**3631.50**
Average						
Quantity Saved/hh	4.62	73.89	0.24	0.26	0.59	
Rate per unit (Rs.)	1.81	0.014	0.50	0.78	0.50	
Saving/day (Rs.)/hh	8.37	1.034	0.12	0.20	0.30	
Saving/year (Rs.)/hh	3056.42	377.58	43.80	73.55	107.68	
Total Saving (Rs.)/year/hh						**3659.02**

It can be noted that a significant amount of money is saved after the installation of biogas plant. The saving is maximum (Rs.4025.70/year/hh) and minimum (Rs.3120.70) in Chitwan. The following graph illustrates the savings:

Saving of Conventional Fuels



6.4 Replacement Value

As described in above headings, the use of conventional fuels differed a lot for biogas and non-biogas households in all the four study areas. Considerable quantities of these fuels were saved after the installation of biogas plants. Attempts were made to calculate the replacement value of biogas versus different cooking fuels based upon the conventional fuel saving. The outcome of the study showed the following replacement values:

Fuel Wood	:	3.7
Agricultural Waste	:	6.3
Dung Cake	:	7.5

While calculating the replacement value, agricultural wastes and remains of fodder have been termed as one item. These replacement values are just lower than the assumed values of 5, 9 and 10 respectively for fuel wood, agricultural waste and dung cakes. The reason for this deviation may be that the assumed values are based upon the sole use of a single type of fuel where as the actual figures are derived from the actual use of the respective fuel which may be combination of any two or more.

7.0 OPTIMUM BIOGAS PLANT SIZE

7.0 OPTIMUM BIOGAS PLANT SIZE

One of the major objectives of the research study was to determine the optimum size of biogas plant for the four ecological areas under consideration. Optimum biogas plant size has been calculated based upon:

- Availability of feeding material, in other words, quantity of dung produced
- Biogas Use Pattern, in other words, maximum capacity of storage tank needed to fulfil the demand of peak hours
- Average family size and required burning hours

7.1 Optimum Biogas Plant Size based upon Availability of Feeding Material

It is a simple fact that to operate biogas plant at optimal level, the feeding has to be supplied to the plant optimally. In other words, the size of plant should be decided in such a manner that the available fed-stock is sufficient for the operation of plant at the optimal level. The outcome of the study suggested that majority of the plants under study were under-fed, and hence, they were not operated optimally. Based upon the quantity of dung available, the optimum sizes of biogas plants for the four study areas are decided as given in the following table.

Tab/e-30: *Optimum Biogas Plant Size based upon Availability of Feeding Material (Puny)*

Study Area	**Dung Produced**	**Dung Available for Feeding***	**Retention Time**	**Recommended Size**
Syangja	37.58	33.822	70	**6**
Nuwakot	37.22	33.498	70	**6**
Chitwan	40.05	36.045	**55**	6
Morang	36.75	33.075	55	6
Average	**36.97**	**33.273**	**62.5**	**6**

*Assuming 10% wastage

It is interesting to note that the average quantity of dung available in all the four study areas did not differ much. Households in Chitwan produced an average of 40.05 kg of dung per day where as that in Morang was 36,75 kg. In all the cases, the recommended size of plant is calculated to be 6 cum based upon the average quantity of dung available and the hydraulic retention time of 70 days for hilly regions and 55 days for Terai regions.

7.2 Optimum Biogas Plant Size based upon Stove and Lamp Burning Hours

Attempts were also made to calculate optimum size of biogas plant for all the four ecological zones under study based upon stove and lamp burning hours for different types of family composition. The actual time of gas stove and lamp burning was been calculated and it was assumed that a plant constructed to meet the demand of biogas for that particular lime was of optimum capacity. The calculation has been done assuming 38 liters of gas was produced from one kg of dung. These values were assumed as per the findings of the study as stated in clause 4.2.7 above. The following table illustrates the optimum size of biogas plant as per the study findings in detail:

Table-31: Optimum Biogas Plant Size based upon Stove and Lamp Burning Hours

Family Size	Stove Burning Time (hr:min)	Lamp Burning Time (hr:min)	Gas Required (liter)	Dung Required (Kg)	Recommended Size of Plant (cum)
Syangja					
1 to 3	2:54	0	1015	28.2	4
4 to 6	3:04	0:08	1093.3	30.4	6
7 to 9	3:24	0:43	1297.5	32.4	6
10 & above	3:34	1:12	1428.3	35.7	6
Average	**3:00**	**0:16**	**1090**	**30.3**	**6**
Nuwakot					
1 to 3	1:31	0	530.8	14.7	4
4 to 6	2:32	0	886.7	24.6	4
7 to 9	3:34	0	1248.3	31.2	6
10 & above	5:15	0	1837.5	45.9	8
Average	**3:05**	**0**	**1079.2**	**30.0**	**6**
Chitwan					
1 to 3	2:19	0	810.8	22.5	4
4 to 6	3:00	0:04	1060.0	29.4	6
7 to 9	3:43	0	1300.8	32,5	6
10 & above	5:28	0	1913.3	47.8	8
Average	**3:15**	**0:01**	**1 140.0**	**31.7**	**6**
Morang					
1 to 3	1:15	0:34	522.5	14.5	4
4 to 6	2:29	0:05	881.7	24.5	4
7 to 9	3:18	0:01	1157.5	28.9	4
10 & above	4:52	0	1703.3	42.6	6
Average	**2:55**	**0:01**	**1023.3**	**28.4**	**4**

The above table illustrates that for a family having four or less members, 4 cum capacity plant was enough. Similarly, the average size of plant for Syangja, Nuwakot and Chitwan was 6 cum where as it was 4 for Morang. In other words, smaller sized plant was sufficient to fulfil demands in Terai regions in comparison to those in hilly regions, The biggest size needed was 8 cum capacity for families having more than 10 members *m* Chitwan and Nuwakot. The outcome of the study indicated that the presently adopted plant-sizes in most of the cases are bigger than actually needed.

7.3 Optimum Plant Size based Upon Volume of Gas Storage Tank and Outlet

7.3.1 Volume of Gas Storage Tank

Prior to deciding on maximum storage capacity needed to fulfil the demand of biogas in the peak hours it is necessary to see the biogas use pattern. The following tables show the calculation of maximum storage capacity of dome based upon the biogas use pattern in all the four study areas:

Table-32: Calculation of Volume of Gas Storage Tank (Dome) of Biogas Plant based upon Average Gas Production and Gas Use Pattern in Four Study Areas

Time (o'clock)	Gas Production Per hour (Ltr)	Cumulative Production (Ltr)	Gas Use (Ltr)	Cumulative Gas Use (Ltr.)	Gas Stored (Ltr)
22	38.7	38.7	0	0.0	38.7
23	38.7	77.3	0	0.0	77.3
24	38.7	1 16.0	0	0.0	116.0
1	38.7	154.7	0	0.0	154.7
2	38.7	193.3	0	0.0	193.3
3	38.7	232.0	1	1.0	231,0
4	38.7	270.7	17	180	252.7
5	38.7	309.3	56	74.0	235.3
6	38.7	348.0	133	207.0	141.0
7	38.7	386.7	\5b	363.0	23.7
8	38.7	425.3	120	483.0	-57.7
9	38.7	464.0	59	542.0	-78.0
10	38.7	502.7	21	563.0	-60.3
11	38.7	541.3	6	569.0	-27.7
12	38.7	580.0	3	572.0	8.0
13	38.7	618.7	12	584.0	34.7
14	38.7	657.3	15	599.0	58.3
15	38.7	696.0	20	619.0	77.0
16	38.7	734.7	37	656.0	78.7
17	38.7	773.3	89	745.0	28.3
18	38.7	812.0	104	849.0	-37.0
19	38.7	850.7	56	905.0	-54.3
20	38.7	889.3	18	923.0	-33.7
21	38.7	928.0	5	928.0	0.0

Gas Deficit - 348.7 ltr
Max. qty of gas accumulated = 252.7 ltr
Gas Deficit > Max. qty of gas accumulated
Minimum capacity of storage tank = gas deficit = 348.7 ltr
i.e. 37.60% of daily gas production

Therefore, the minimum storage capacity of biogas plant (volume of dome)
Shall be 38% of the digester volume.

Table-33: <u>Calculation of Volume of Gas Storage Tank (Dome) of Biogas Plant based upon average Gas Production and Gas Use Pattern in Syangja</u>

Time (o'clock)	Gas Production Per hour (Ltr)	Cumulative Production (Ltr)	Gas Use (Ltr)	Cumulative Gas Use (Ltr.)	Gas Stored (Ltr)
22	39.2	39,2	0	0.0	39.2
23	39.2	73.3	0	0.0	78.3
24	39.2	117.5	0	0.0	117.5
1	39.2	156.7	0	0.0	156.7
2	39.2	195,8	0	0.0	195.8
3	39.2	235.0	2	2.0	233.0
4	39.2	274.2	16	18.0	256.2
5	39.2	313.3	60	78.0	235.3
6	39.2	352.5	165	243.0	109.5
7	39.2	391.7	159	402.0	-10.3
8	39.2	430.8	112	514.0	-83.2
9	39.2	470.0	41	555.0	-85.0
10	39.2	509.2	12	567.0	-57.8
11	39.2	548.3	8	575.0	-26.7
12	39.2	587.5	4	579.0	8.5
13	39.2	626.7	11	590.0	36.7
14	39.2	665.8	9	599.0	66.8
15	39.2	705.0	28	627.0	78.0
16	39.2	744.2	33	660.0	84.2
17	39.2	783.3	103	763.0	20.3
18	39.2	822.5	98	861.0	-38.5
19	39.2	861.7	53	914.0	-52.3
20	39.2	900.8	21	935.0	-34.2
21	39.2	940.0	5	940.0	0.0

Max. qty of gas accumulated = 256.2 ltr
GflS Deficit =388 Ltr
Gas Deficit > Max. qty of gas accumulated
Minimum capacity of storage tank = gas deficit = 388 ltr
i.e. 41.28% of daily gas production

Therefore, the minimum storage capacity of biogas plant (volume of dome) Shall be 42% of the digester volume.

Table-34: Calculation of Volume of Gas Storage Tank (Dome) of Biogas Plant Bused upon Average Gas Production and Gas Use Pattern in Nuwakot

Time (o'clock)	**Gas Production Per hour (Ltr)**	**Cumulative Production (Ltr)**	**Gas Use (Ltr)**	**Cumulative Gas Use (Ltr.)**	**Gas Stored (Ltr)**
22	38.8	38.8	0	0.0	38.8
23	38.8	77.5	0	0.0	77.5
24	38.8	116.3	0	0.0	116.3
1	38.S	155.0	0	0.0	155.0
2	38.8	193.8	0	0.0	193.8
3	38.8	232.5	1	1.0	231.5
4	38.8	271.3	20	21.0	250.3
5	38.8	310.0	58	79.0	231.0
6	38.8	348.8	143	222.0	126.8
7	38.8	387.5	167	389.0	-1.5
8	38.8	426.3	119	508.0	-81.8
9	38.8	465.0	46	554.0	-89.0
10	38.8	503.8	12	566.0	-62.3
11	38.8	542.5	4	570.0	-27.5
12	38.8	581.3	3	573.0	8.3
13	38.8	620.0	12	585.0	35.0
14	38.8	658.8	16	601.0	57.8
15	38.8	697.5	17	618.0	79.5
16	38.8	736.3	42	660.0	76.3
17	38.8	775.0	108	768.0	7.0
18	38.8	813.8	104	872.0	-58.3
19	38.8	852.5	45	917.0	-64.5
20	38.8	891.3	10	927.0	-35.8
21	38.8	930.0	3	930.0	0.0

Gas Deficit =421 ltr
Max. qty of gas accumulated =250.3 ltr
Gas Deficit > Max. qty of gas accumulated
Minimum capacity of storage tank = gas deficit = 421 ltr
i.e. 44.16% of daily gas production

Table-35: Calculation of Volume of Gas Storage Tank (Dome) of Biogas Plant Based upon Average Gas Production and Gas Use Pattern in Chitwan

Time (o'clock)	Gas Production Per hour (Ltr)	Cumulative Production (Ltr)	Gas Use (Ltr)	Cumulative Gas Use (Ltr.)	Gas Stored (Ltr)
22	40.9	40.9	0	0.0	40.9
23	40.9	81.8	0	0.0	81.8
24	40.9	122.8	0	0.0	122.8
1	40.9	163.7	0	0.0	163.7
2	40.9	204.6	0	0.0	204.6
3	40.9	245.5	0	0.0	245.5
4	40.9	286.4	21	21.0	265.4
5	40.9	327.3	60	81.0	246.3
6	40.9	368.3	117	198.0	170.3
7	40.9	409.2	155	353.0	56.2
8	40.9	450.1	141	494.0	-43.9
9	40.9	491.0	83	577.0	-86.0
10	40.9	531.9	37	614.0	-82.1
11	40.9	572.8	5	619.0	-46.2
12	40.9	613.8	2	621.0	-7.2
13	40.9	654.7	15	636.0	18.7
14	40.9	695.6	19	655.0	40.6
15	40.9	736.5	15	670.0	66.5
16	40.9	777.4	37	7070	70.4
17	40.9	818.3	76	783.0	35.3
18	40.9	859.3	107	890.0	-30.7
19	40.9	900.2	65	955.0	-54.8
20	40.9	941.1	23	978.0	-36.9
21	40.9	982.0	4	982.0	0.0

Gas Deficit = 387.9 llr ,
Max. qty of *gas* accumulated = 265.4 ltr
Gas Deficit > Max. qty of gas accumulated
Minimum capacity of storage tank = gas deficit = 387.9 ltr
i.e. 39.51% of daily gas production

Therefore, the minimum storage capacity of biogas plant (volume of dome) Shall be 40% of the digester volume.

Table-36: Calculation of Volume of Gas Storage Tank (Dome) of Biogas Plant Based upon Average Gas Production and Gas Use Pattern in Morans.

Time (o'clock)	Gas Production Per hour (Ltr)	Cumulative Production (Ltr)	Gas Use (Ltr)	Cumulative Gas Use (Ltr.)	Gas Stored (Ltr)
22	36.46	36,46	0.00	0.00	36.46
23	36.46	72,92	0.00	0.00	72.92
24	36.46	109.37	0.00	0.00	109.37
1	36.46	145.83	0.00	0.00	145.83
2	36.46	182.29	0.00	0.00	182.29
3	36.46	218.75	0.00	0.00	218.75
4	36.46	255.21	12.00	12.00	243.21
5	36.46	291.66	45.00	57.00	234.66
6	36.46	328.12	107.00	164.00	164.12
7	36.46	364.58	144.00	308.00	56.58
8	36.46	401.04	126.00	434.00	-32.96
9	36.46	437.50	74.00	508.00	-70.50
10	36.46	473.95	21.00	529.00	-55.05
11	36.46	510.41	5.00	534.00	-23.59
12	36,46	546.87	4.00	538.00	8.87
13	36.46	583.33	10.00	548.00	35.33
14	36.46	619.79	15.00	563.00	56.79
15	36.46	656,24	19.00	582.00	74.24
16	36.46	692.70	37.00	619.00	73.70
17	36.46	729.16	71.00	690.00	39.16
18	36.46	765.62	107.00	797.00	-31.38
19	36.46	802.08	60.00	857.00	-54.92
20	36.46	838.53	17,00	874.00	-35.47
21	36.46	874.99	1.00	875.00	-0.01

Gas Deficit = 304 *ltr*
Max. qty of gas accumulated = 243.21 ltr
Gas Deficit > Max. qty of gas accumulated
Minimum capacity of storage tank = gas deficit = 304 ltr
i.e. 34.74% of daily gas production

Therefore, the minimum storage capacity of biogas plant (volume of dome) shall be 35% of the digester volume.

Now, the following table summarizes the findings on the maximum capacity of gas storage tank (dome) as calculated *in* the five tables given above,

Table-37: <u>Minimum Capacity of Gas Storage Tank</u>

Study Area	**Maximum Capacity of Gas Storage Tank**
Syangja	42% of daily gas production
Nuwakot	45% of daily gas production
Chitwan	40% of daily gas production
Morang	35% of daily gas production
Average	35% of daily gas production

The maximum capacity is, thus determined by the value in Nuwakot, which is highest of all the values. Therefore, the dome should be able to store 45% of the daily gas production to fulfil the demand of peak hours. Assuming that 38 liters of gas is produced from 1 kg of dung, which is the average value as per the outcome of this study; and the presently adopted hydraulic retention times of 55 days for the Terai and 70 for the hills; the capacity of dome in cubic meter could be calculated as given below:

Table-38: <u>Calculation of Volume of Storage Tank (Dome)</u>

Size (cum)	**Theoretical Gas Production (ltr)**	**Qty of Gas needed to be stored (45% of Theoretical) (ltr)**	**Gas in Dead Volume (100% of storage) (ltr)**	**Total qty of Gas to be stored (ltr)**	**Dome size (cum)**	**Existing Dome Size (cum)**	**Reduction in Volume of Dome (%)**
For Terai Regions							
4	1140	513	513	1026	1.03	1.21	15.21
6	1710	769.5	769.5	1539	1.54	1.75	12.06
8	2280	1026	1026	2052	2.05	2.18	5.87
10	2850	1282.5	1282.5	2565	2.57	3.11	17.52
For Hilly Regions							
4	912	410.4	410.4	820.8	0.82	1.21	32.17
6	1368	615.6	615.6	1231.2	1.23	1.75	29.65
8	1824	820.8	820.8	1641.6	1.64	2.18	24.70
10	2280	1026	1026	2052	2.05	3.11	34.02

It could be noted from the above table that a considerable amount of saving could be made from reduction of dome size based upon gas consumption pattern. Although the reduction in volume for Terai region is in the range of 6% to 18%, it is considerably higher for hilly regions, which fall in the range of 25 to 34%. In both the cases, maximum reduction could be done in 10 cum plants. The current design of the GGC 2047 model biogas plant could be redesigned based upon these data. It will not affect the uniformity of the current design from technical point of view.

7.3.2 Volume of Outlet (Displacement Chamber)

The outlet in biogas digester is constructed mainly to provide enough pressure to the gas stored in the dome so that it flows to point of use with required pressure. In other words, the size of outlet is governed by the storage capacity of the dome. As stated in 7.3, the presently adopted size of dome could be reduced. This also necessitates the reduction of outlet volume. The volume of outlet should be equal to or slightly more than the total volume of gas storage tank (dome) minus dead volume. In this case, the dead volume is assumed to be equal to the maximum quantity of usable gas needed to be stored in the dome. In other words, the volume of outlet should be equal to or slightly (say 10%) bigger than the volume of usable gas needed to be stored in the dome. The following table shows the recommended volume of outlet for different category of plants:

Tahle-39: *Calculation of Volume of Outlet (Displacement Chamber)*

Size (cum)	**Theoretical Gas Production (ltr)**	**Qty of Gas needed to be stored (45% of Theoretical) (ltr)**	**Gas in Dead Volume (100% of storage) (ltr)**	**Outlet Size (cum)**	**Existing Outlet Size (cum)**	**Reduction in Volume of Outlet (%)**
For Terai Regions						
4	1140	513	513	0.57	0.84	31.00
6	1710	769.5	769.5	0.85	1.08	21.57
8	2280	1026	1026	1.13	1.44	21.32
10	2850	1282.5	1282.5	1.42	1.53	7.25
For Hilly Regions						
4	912	410.4	410.4	0.45	0.84	46.31
6	1368	615.6	615.6	0.68	1.08	36.85
8	1824	820.8	820.8	091	1.44	36.60
10	2280	1026	1026	1.13	1.53	25.95

As in the case of volume of dome, the volume of outlet could also be decreased by a considerable quantity. The percentage of decrease ranges from 7% to 32% in Terai regions and 26 to 46% in the hilly regions. The current design of the GGC 2047 model biogas plant could be redesigned based upon these data. It will not affect the uniformity of the current design from technical point of view.

7.3.3 Plant Volume

Based upon the outcome of the study as described in clause 7.3.1 and 7.3.2, the volume of biogas plant can now be decided. The following table shows the recommended optimum size of biogas plants.

Table-40: *Calculation of Plant Volume*

Size (cum)	Digester Volume (cum)	Dome size (cum)	Plant Volume (cum)	Existing Plant Volume (cum)	Reduction in Plant Volume (%)	Outlet Size (cum)	Reduction in Volume of Outlet (%)
For Terai Regions							
4	2.81	1.03	3.84	4,02	4.48	0.57	31.90
6	4.30	1.54	5,84	0,05	3.47	0.85	21,57
8	6.01	2.05	8.06	8.19	1.59	1.13	21.32
10	7.00	2.57	9.57	10.11	5.34	1.42	7.25
For Hilly Regions							
4	2.81	0.82	3.63	4.02	9.70	0.45	46.31
6	4.30	1.23	5.53	6.05	8.60	0.68	36.85
8	6,01	1.64	7.65	8.19	6.59	0.91	36.60
10	7.00	2.05	9.05	10.11	10.48	1.13	25.95

The above table indicates that the volume of biogas plant could slightly be reduced to operate it optimally. Although, the decrease in volume of dome and outlet is of significant magnitude, the reduction in overall plant volume is not too significant, especially in the case of Terai regions. However, the reduction in dome and outlet volume would reduce the cost of plant to a considerable extent.

7.4 Benefit-Cost Analysis

The cost benefit analysis of different sized biogas plant in the four study areas has been done with the following major assumptions:

- Economic life-span period of biogas plant is 10 years.
- Cost of plant construction is as per AEPDF quotation for the fiscal year 2057/57 (1999/00) and is same for all the study areas irrespective of their location.
- O & *M* cost is constant for all years.
- Quantity of gas produced is 38 liters/kg of dung per day (as per the study outcome).
- Annual income from plant includes saving on firewood, kerosene, dung-cake, agricultural-residues and remains of fodder. It does not include added nutrient value of slurry and other social or health or environmental impacts.
- The opportunity costs of investment, subsidy amount and interest on loan are not considered.

The following table summarizes outcome of the analysis:

Table-41: Benefit - Cost Analysis

Plant Size (cum)	Investment Cost (Rs.)	O&M cost (Rs.)	Total Expenditure (Rs.)	Daily Gas Production (ltr)	Production in 10 years (cum)	Cost/cum (Rs.)	Annual Income (Rs.)	Total Income in 10 years (Rs.)	B/C Ratio
Syangja									
4	19875	3000	22875	938	3423.70	6.68	4069.08	40690.80	1.78
6	23590	3000	26590	790	2883.50	9.22	3427.05	34270.51	1.29
8	27730	5000	32730	955	3485.75	9.39	4142.83	41428.27	1.27
10	31010	5000	36010	1095	3996.75	9.01	4750.15	47501.52	1.32
Nuwakot									
4	19875	3000	22875	710	2591.50	8.83	2726.09	27260.94	1.L9
6	23590	3000	26590	1010	3686.50	7.21	3877.96	38779.65	1.46
8	27730	5000	32730	985	3595.25	9.10	3781.98	37819.75	1.16
10	31010	5000	36010	995	3631.75	9.92	3820.37	38203.71	1.06
Chitwan									
4	19875	3000	22875	675	2463.75	9.28	2269.91	22699.06	0.99
6	23590	3000	26590	815	2974.75	8.94	2740.70	27407.01	1.03
8	27730	5000	32730	1080	3942.00	8.30	3631.85	36318.49	1.11
10	31010	5000	36010	1365	4982.25	7.23	4590.25	45902.54	1.27
Morang									
4	19875	3000	22875	405	1478.25	15.47	1584.87	15848.68	0.69
6	23590	3000	26590	718	2620.70	10.15	2809.72	28097.17	1.06
8	27730	5000	32730	1015	3704.75	8.83	3971.95	39719.53	1.21
10	31010	5000	36010	1270	4635.50	7.77	4969.83	49698.33	1.38

Table-41 given above indicates that alt the plants were financially viable in Syangja. It was encouraging to note that the cost per cubic metre of biogas generation was only Rs.6.68 for 4 cum plant in comparison to Rs. 9.39 for 8 cum plant. The C/B ratio was very high (1.78) for 4 cum plant and that for 8 cum plant was 1.27. Conclusively, 4 cum plants were most cost-effective in Syangja.

Similarly, for Nuwakot too, all the plants had B/C ratio more than 1 and 6 cum capacity plant was most cost-effective. The cost of biogas generation was highest (Rs.9.92/cum) for 10 cum plant and lowest (Rs.7.21/cum) for 6 cum plant. However, for Chitwan, 4 cum plants had C/B ratio less than 1, which indicated that the owners are not receiving benefit to the expected extent. Biogas plants of other capacity had C/B ratio more than 1. The cost of biogas generation fell in the range of Rs.7.23/cum for 10 cum plant to Rs.9.28/cum for 6 cum plants.

It was rather discouraging to note that the plants of 4 cum capacity were not functioning well in Morang. The cost of biogas generation was Rs.15.47/cum for this type of plants, which were very much higher than that for other capacity plants. The C/B ratio hence was very low (0.69) for 4 cum plants. However, for biogas plants of 6, 8 and 10 cum capacity, C/B ratio and cost per/cum of biogas were 1.06, 1.21, 1.38 and Rs.10.15, Rs.8.83 and Rs.7.77 respectively. In other words, 10 cum capacity plants were most cost-effective.

The main reason for bad performance of 4 cum capacity plants in Chitwan and Morang was observed to the insufficiency of feeding materials. In both the cases, these plants were heavily underfed.

7.5 Limitations of Benefit-Cost Analysis

Based on the construction costs and the yield of gas only, a financial analysis based on market prices has been carried out. This type of analysis is useful in determining the rates of return for a particular biogas plant and can help in evaluating the various technical options available to satisfy specific end-uses, such as cooking and lighting. However, this type of financial analysis is fairly narrow in its scope since it uses market prices rather than "shadow" prices, which reflect the true economic worth to society of the inputs and outputs of the plant. In addition, this financial analysis does not incorporate "secondary" benefits, e.g. improved public health, reduced reliance on imported fossil fuels, reduced deforestation etc. These benefits are difficult to quantify, but nevertheless are extremely important in assessing the technology. These latter factors are incorporated in a social analysis (social cost-benefit). However, it is strongly recommended that the social analysis be used by concerned agencies like BSP to assess the viability of biogas since it most accurately reflects the effect of the project on the fundamental objectives of the whole economy.

The actual construction cost of a digester is relatively easy to assess, although at some periods during the year unskilled labour costs may be virtually negligible since it is virtually idle. Determining plant life (depreciation) is difficult since there is still little information available, and assumptions vary between 10 and 25 years. However, depending on the discount rate, a life of more than about 15 years will have little impact on benefit-cost ratios. Obviously, different parts of the plant will have different lives, and these should be assessed accordingly.

Maintenance cost can also vary considerably depending on the design and appliances used. For example, a 'Santosh' gas tap requires considerable attention and maintenance than a GGC gas tap. Also, while land costs can contribute significantly to overall costs, except in those areas where land is abundantly available. In this case even the most densely settled village land can be treated as zero cost item since the quantities involved are quite small. Finally, the labour involved in collecting the feed, e.g. manure, agricultural residues, mixing it with water and feeding it to the digester has to be evaluated. However, in many cases this time is minimal and is often equivalent to the labour required to collect the biomass for traditional uses, e.g. as a fuel or manure. Hence, in many cases this cost can be neglected.

Evaluating the quantifiable benefits of a biogas plant is also fraught with many difficulties. The output of a plant consists of two streams: gas and slurry. Valuation of the gas depends on three complex considerations: the quantity and composition of the gas; the mix of end-uses, and the price, type and burning efficiency of another substitute fuel, e.g. firewood, kerosene, LPG, dung-cakes, electricity etc. The first factor depends entirely on the feedstock and process design parameters. However, the mix of end-uses determines what fuels may be used for calculating replacement costs. Finally, since the price and burning efficiency of substitutable fuels varies considerably, this factor can radically alter the value of biogas from the plant.

The benefits from the slurry depend on whatever it is used as a fertiliser/soil conditioner, an animal feed, a feed to fish ponds or to grow algae, water hyacinth etc. The value of the slurry in increasing crop yields depends strongly on the handling procedures used and hence the fate of nitrogen. In some cases this increase may be equivalent to spreading the biomass directly on the land without digestion and hence no benefits should be claimed. If the slurry is used to reefed animals then the benefits from the slurry could be considerably greater than from the gas. Considerable care should be exercised in evaluating the benefits from the slurry, and these should be related to an original quantity of biogas.

8.0 LABORATORY ANALYSIS OF DUNG AND SLURRY

8.0 LABORATORY ANALYSIS OF DUNG AND SLURRY

Laboratory analysis of raw dung prepared for feeding into digester after mixing with water and digested slurry coming out of biogas plant was done to measure the digestion of dung in the biogas plant in relation to feeding (hydraulic retention time) and temperature by identifying the total solids (TS) and volatile solids (VS) content.

To determine the Total Solids content, a known amount of sample was transferred into a previously weighed crucible and dried at 105-110 degree centigrade for 24 hours. Similarly for volatile solids estimation, dried sample obtained after total solids estimation was ignited in a muffle furnace at 550 ±50 degree centigrade for four hours and cooled in a desiccators to take constant weight.

The following is the flow-diagram of activities in the laboratory;

Take 25-50 gm of sample in a tarred evaporating dish

↓

Evaporate to dryness on a water bath

↓

Dry at 105-110°C for one hour

↓

Cool in a desiccators "and take constant weight

↓

Ignite the residue over a gas burner

↓

Transfer to the residue over a gas burner

↓

Transfer to a muffle furnace for ignition at 550 ± 50°C

↓

Cool in a desiccators and take constant weight

Now,

% of total solids = $\frac{(A\text{-}B1 \times 100}{C\text{-}B}$

% of Volatile Solids = $\frac{(A\text{-}D) \times 100}{A\text{-}B}$

where,

A = Wt. of dried residue + dish, mg.
B = Wt. of dish
C = Wt. of wet sample + dish, mg. and
D = Wt. of residue + dish after ignition, mg.

The samples of dung and slurry were collected from the respective plants three times in a year-during the months of October 1998, February 1999 and June 1999. The results of laboratory analysis have been given in the following table.

Table-42: lab Analysis of Dung and Digested Slurry Taken from Sampled Plant

ID	Name of Plant Owner	District	Pt. Size (m3)	First Sample (October, 1998)									% of Volatile Solid Remained in Slurry
				Dung			Slurry				Feeding		
				TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)	TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)	Tem (o C)	Dung (Kg)	Water (Ltr)	
1	Ganesh Acharya	Morang	4	11.56	76.09	40.51	7.08	67.06	7.57	19	35	36	18.69
2	Sashi P. Siwakoti	Morang	4	10.23	80.30	23.36	0.20	14.63	4.68	20	5	9	20.03
3	Nabin Adhikari	Morang	4	7.86	76.77	31.81	0.26	72.36	4.91	20	10	12	15.44
4	Tikaram Chapagain	Morang	4	5.16	67.92	27.53	0.62	51.49	3.89	20	20	22	14.14
5	Ram Devi Dahal	Morang	4	9.11	79.66	24.03	6.24	59.51	4.24	19	5	8	17.64
6	Netra P. Neupane	Morang	6	6.19	78.52	32.98	4.60	70.18	6.82	19	40	42	20.66
7	Durgadevi Katuwal	Morang	6	15.04	76.48	46.83	9.49	63.06	8.35	19	24	24	17.84
8	Lalit Tamang	Morang	6	12.90	79.45	39.89	7.83	63.32	6.94	18	23	25	17.40
9	Tara Nath Chapagai	Morang	6	6.78	76.19	33.35	5.03	66.54	6.75	18	35	35	20.24
10	Yam Nath Mahatara	Morang	6	10.68	78.17	31.93	5.03	66.54	5.43	19	36	45	17.00
11	Dinesh Khanal	Morang	8	11.73	73.38	40.73	3.55	60.53	5.90	20	25	26	14.49
12	Purna B. Shrestha	Morang	8	9.47	78.90	45.45	7.67	68.89	9.41	20	60	55	20.70
13	Dambar B. Shrestha	Morang	8	9.14	68.23	34.00	4.50	64.80	6.36	18	45	45	18.69
14	Hari P. Dahal	Morang	8	8.10	77.30	34.92	6.69	66.48	7.21	20	46	50	20.64
15	Pushpa Lal Acharya	Morang	8	11.86	63.21	34.76	8.18	75.83	8.11	19	42	45	23.32
16	Pushpa Timsina	Morang	10	10.09	80.78	33.60	0.96	89.05	5.86	18	26	30	17.43
17	Bishnu Shrestha	Morang	10	7.82	74.64	23.79	10.40	59.03	5.65	20	35	55	23.75
18	Bisheshwor Dhakal	Morang	10	7.87	74.21	36.96	6.93	59.73	7.47	20	40	40	20.23
19	Tilak P. Dhakal	Morang	10	8.19	66.12	28.51	6.05	72.24	6.65	18	50	55	23.33
20	Harischandra Acharya	Morang	10	11.96	81.14	43.87	7.56	70.13	8.20	19	60	60	18.70
21	Mithu Sharma	Syangja	4	9.10	79.60	21.92	8.20	68.20	4.66	16	20	30	21.26
22	Tulsi Roka	Syangja	4	9.30	83.50	31.12	7.90	47.40	5.07	17	30	35	16.28
23	Rudra B. Roka	Syangja	4	5.60	82.90	31.10	7.20	77.00	7.68	17	35	35	24.70
24	Chhetra B. Roka	Syangja	4	8.50	84.30	40.87	1.80	33.20	3.31	20	30	30	8.10
25	Suman Raj Giri	Syangja	4	8.20	74.70	33.08	4.90	65.50	6.26	17	25	25	18.94
26	Dhan Bdr. Roka	Syangja	6	8.70	77.20	30.14	9.10	72.60	7.18	15	40	40	23.83
27	Min B. Khadka	Syangja	6	5.40	83.80	27.06	2.50	73.20	5.07	15	40	40	18.75
28	Rupa Roka	Syangja	6	7.90	85.70	26.67	7.90	75.50	5.95	15	30	35	22.33
29	Man B. Roka	Syangja	6	5.70	82.10	24.86	1.50	67.50	4.09	16	30	35	16.44
30	Dil Bdr. Roka	Syangja	6	1.30	55.50	13.58	5.90	72.60	5.39	15	30	35	39.69
31	Hum Nath Padhya	Syangja	8	5.50	78.30	28.79	6.60	68.80	6.72	17	25	25	23.34
32	Hum Bdr. Thapa	Syangja	8	8.60	78.10	28.65	7.70	66.30	6.04	17	30	35	21.07
33	Dil Bdr. Thapa	Syangja	8	8.80	78.30	26.45	6.60	73.90	5.63	14	32	35	21.28
34	Ganesh B. Thapa	Syangja	8	4.70	77.90	23.10	6.90	78.10	6.21	14	34	35	26.90
35	Dil Kumari Timilsina	Syangja	8	8.90	81.30	15.09	8.40	77.70	3.50	15	15	30	23.16
36	Tarapati Sharma	Syangja	10	9.50	81.80	32.65	8.50	75.90	7.28	14	39	35	22.30
37	Ram B. Adhikari	Syangja	10	9.10	77.70	28.32	11.10	73.00	7.20	15	42	45	25.41
38	Tilak Ram Shrestha	Syangja	10	4.20	77.20	22.33	1.10	71.00	2.33	15	15	30	10.41
39	Khinapadam Devkota	Syangja	10	6.60	74.50	25.54	7.90	72.20	6.45	15	39	40	25.25

40	Keshav Raj Neupane	Syangja	10	9.20	78.20	35.89	7.30	77.40	8.02	17	48	45	22.34
41	Saligram Adhikari	Chitwan	10	5.30	76.70	34.33	0.60	55.70	4.74	22	55	60	13.79
42	Tanka P. Dhamala	Chitwan	10	8.50	76.40	44.39	5.90	66.20	8.70	21	70	65	19.60
43	Tulasi Ram Kandel	Chitwan	8	5.00	80.20	31.45	3.60	76.50	6.84	19	56	60	21.77
44	Sita Ram Karki	Chitwan	8	9.40	75.40	44.71	9.10	65.90	9.92	21	53	50	22.18
45	Goma Baniya	Chitwan	4	9.50	74.60	32.85	0.40	56.30	3.82	21	28	35	11.64
46	Narayan Adhikari	Chitwan	10	5.90	76.80	41.63	4.70	69.70	8.86	22	44	40	21.28
47	Tirtha Raj Paudel	Chitwan	6	8.10	79.40	38.69	4.30	74.10	7.51	18	32	30	19.40
48	Shyam P. Upadhyaya	Chitwan	4	8.70	74.90	34.30	4.70	66.40	6.34	19	28	30	18.49
49	Subindra K.C.	Chitwan	4	11.20	73.90	41.49	5.30	71.90	7.68	20	10	10	18.50
50	Ganesh Bdr. Shrestha	Nuwakot	6	5.40	76.90	30.56	6.60	63.60	6.89	17	41	40	22.55
51	Pushpa Nath Acharya	Nuwakot	8	7.00	85.60	34.42	6.90	65.20	6.91	17	42	40	20.07
52	Ramraja Sadula	Nuwakot	10	7.60	84.40	37.01	1.70	67.30	5.57	16	28	25	15.05
53	Tej Bdr. Adhilkari	Nuwakot	10	6.50	83.50	30.40	0.80	55.60	3.79	16	60	60	12.47
54	Pinggong Galane	Nuwakot	10	7.50	82.60	28.11	4.00	68.60	5.04	16	36	40	17.93
55	Khop Maya Dhabala	Nuwakot	10	6.40	77.20	34.76	0.50	41.00	3.36	19	31	30	9.67
56	Netra Bdr. Chhetri	Nuwakot	10	9.60	82.70	34.11	6.50	66.90	6.32	16	39	40	18.52
57	Manjushree Chapagai	Chitwan	10	5.40	67.00	28.35	1.70	60.60	5.06	20	69	75	17.85
58	Chabilal Adhikari	Chitwan	6	5.60	75.20	33.51	4.40	67.30	7.04	20	39	40	21.00
59	Prem Pd. Dhabala	Chitwan	6	6.10	77.00	42.82	3.70	68.20	8.38	20	37	30	19.58
60	Madhab Dhungana	Chitwan	6	6.00	75.50	33.94	6.00	65.20	7.44	20	34	35	21.91
61	Tul Raj Upreti	Chitwan	6	4.20	80.00	27.49	4.90	66.20	5.97	19	26	30	21.73
62	Harinarayan Adhikari	Chitwan	8	7.90	75.20	34.14	4.60	65.40	6.40	19	42	45	18.76
63	Ram Maya Kandel	Chitwan	8	7.50	78.40	29.55	6.30	68.80	6.22	19	50	60	21.04
64	Dharma Pun	Chitwan	8	7.90	79.60	38.28	6.50	64.90	7.61	19	36	35	19.89
65	Surat Bdr. Chitrakar	Nuwakot	6	4.60	75.30	31.55	4.40	63.40	6.64	16	36	30	21.05
66	Ramkrishna Shrestha	Nuwakot	6	9.60	82.70	27.39	2.70	63.10	3.91	17	22	30	14.28
67	Bhakta Bdr. Shrestha	Nuwakot	6	6.90	78.40	32.53	5.40	72.80	6.99	18	40	40	21.48
68	Raj Kumar Jung Shah	Nuwakot	6	9.70	88.70	38.71	5.60	68.80	6.65	18	42	45	17.18
69	Paban Kumari Acharya	Nuwakot	8	10.70	83.60	37.61	17.20	70.10	10.44	17	44	45	27.76
70	Bhadra B. Pyakurel	Nuwakot	8	9.10	77.50	31.65	7.10	70.70	6.66	16	43	45	21.03
71	Sitaram Pyakurel	Nuwakot	8	7.80	75.40	31.60	6.30	70.30	6.84	17	40	40	21.65
72	Gopal Acharya	Nuwakot	8	9.10	74.40	33.40	6.90	68.60	7.00	18	33	35	20.96
73	Gopal Malakar	Nuwakot	4	5.30	84.50	31.17	9.20	71.50	8.00	18	29	30	25.65
74	Hari Bdr. Adhikari	Nuwakot	4	5.10	77.80	24.55	8.70	78.90	7.05	18	24	30	28.72
75	Gopal Shrestha	Nuwakot	4	10.60	85.60	39.35	6.30	77.80	7.56	17	36	36	19.22
76	Mukti Nath Gautam	Nuwakot	4	10.90	76.90	33.50	6.60	63.60	6.01	17	33	35	17.94
77	Khadka B. Adhikari	Nuwakot	4	10.20	82.60	30.26	6.50	74.50	5.91	18	30	40	19.52
78	Dil Bdr. Tamang	Chitwan	4	8.60	75.90	34.03	11.30	60.60	8.16	20	22	25	23.98
79	Nanda Pd. Rijal	Chitwan	4	7.00	78.90	38.25	3.10	67.20	6.75	20	30	30	17.64
80	Krishna Bdr. Gurung	Chitwan	10	12.30	39.40	32.98	6.40	79.70	8.98	20	25	25	27.23
Average			**7**	**8.08**	**77.33**	**32.74**	**5.69**	**66.84**	**6.45**	**18**	**35**	**37**	**19.70**

ID	Name of Plant Owner	District	Pt. Size (m3)	Second Sample (February, 1999)										% of Volatile Solid Remained in Slurry
				Dung			Slurry			Tem. (o C)	Feeding			
				TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)	TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)		Dung (Kg)	Water (Ltr)		
1	Ganesh Acharya	Morang	4	12.90	85.30	58.30	11.30	72.40	17.01	13	30	25		29.19
2	Sashi P. Siwakoti	Morang	4	6.10	81.40	36.80	5.30	75.90	11.35	13	10	10		30.84
3	Nabin Adhikari	Morang	4	18.20	78.50	68.67	8.10	74.80	15.91	14	12	10		23.17
4	Tikaram Chapagain	Morang	4	6.60	76.50	48.32	8.20	74.80	17.24	13	20	15		35.68
5	Ram Devi Dahal	Morang	4	10.30	66.40	23.53	8.00	65.50	7.14	13	5	8		30.36
6	Netra P. Neupane	Morang	6	6.80	74.50	35.09	6.10	68.50	10.81	13	35	35		30.80
7	Durgadevi Katuwal	Morang	6	8.50	76.40	39.85	4.30	75.40	10.98	14	25	25		27.56
8	Lalit Tamang	Morang	6	12.00	80.60	50.17	7.20	65.60	12.29	13	22	20		24.51
9	Tara Nath Chapagai	Morang	6	5.00	73.30	25.35	4.70	71.30	8.23	13	35	45		32.48
10	Yam Nath Mahatara	Morang	6	6.00	73.20	29.23	5.80	72.60	9.70	13	35	40		33.20
11	Dinesh Khanal	Morang	8	7.30	78.70	32.78	6.60	76.00	10.47	13	26	30		31.94
12	Purna B. Shrestha	Morang	8	8.40	75.90	37.55	8.10	74.40	12.38	14	55	60		32.95
13	Dambar B. Shrestha	Morang	8	6.10	61.40	28.59	3.80	59.60	8.26	13	43	45		28.89
14	Hari P. Dahal	Morang	8	6.40	77.60	32.17	11.60	70.40	12.71	13	45	50		39.51
15	Pushpa Lal Acharya	Morang	8	6.90	80.10	31.07	3.30	71.30	8.03	13	38	45		25.85
16	Pushpa Timsina	Morang	10	9.40	82.50	38.12	9.70	65.40	11.34	13	28	30		29.75
17	Bishnu Shrestha	Morang	10	7.70	84.30	36.01	6.30	67.50	9.80	13	36	40		27.21
18	Bisheshwor Dhakal	Morang	10	6.20	78.30	37.28	7.80	76.90	13.33	14	35	35		35.75
19	Tilak P. Dhakal	Morang	10	5.60	77.70	37.60	8.80	76.10	14.39	14	51	50		38.28
20	Harischandra Acharya	Morang	10	8.00	68.20	36.58	7.10	82.50	13.50	14	58	60		36.90
21	Mithu Sharma	Syangja	4	13.20	90.20	40.31	6.30	78.10	9.59	11	20	20		23.79
22	Tulsi Roka	Syangja	4	10.40	80.50	33.91	5.90	76.50	9.19	10	30	30		27.09
23	Rudra B. Roka	Syangja	4	6.90	82.70	33.30	6.80	77.80	10.71	12	35	35		32.18
24	Chhetra B. Roka	Syangja	4	6.20	78.40	31.04	4.40	57.50	7.61	12	28	30		24.50
25	Suman Raj Giri	Syangja	4	9.80	71.80	30.85	9.10	69.90	9.99	12	22	25		32.37
26	Dhan Bdr. Roka	Syangja	6	6.90	81.20	29.87	4.80	73.40	8.48	11	38	40		28.40
27	Min B. Khadka	Syangja	6	8.10	82.50	28.83	1.60	65.40	5.81	10	40	40		20.16
28	Rupa Roka	Syangja	6	7.00	75.20	26.66	5.90	67.50	7.92	10	30	30		29.72
29	Man B. Roka	Syangja	6	6.90	79.50	26.02	6.60	75.70	8.37	10	28	30		32.17
30	Dil Bdr. Roka	Syangja	6	8.30	80.60	27.82	6.60	75.60	8.36	10	28	30		30.06
31	Hum Nath Padhya	Syangja	8	10.20	78.40	35.37	6.60	70.50	9.58	10	22	20		27.09
32	Hum Bdr. Thapa	Syangja	8	8.60	79.60	30.95	6.30	76.00	9.17	11	32	35		29.64
33	Dil Bdr. Thapa	Syangja	8	8.90	76.30	30.35	6.00	68.70	8.39	10	30	30		27.64
34	Ganesh B. Thapa	Syangja	8	7.90	79.00	25.81	7.80	76.00	8.46	10	30	35		32.79
35	Dil Kumari Timilsina	Syangja	8	5.40	76.70	16.16	6.20	73.00	5.46	11	18	30		33.78
36	Tarapati Sharma	Syangja	10	8.20	83.90	32.05	4.40	73.40	8.27	10	35	35		25.80
37	Ram B. Adhikari	Syangja	10	6.70	79.40	27.52	7.20	73.10	8.97	11	40	45		32.60
38	Tilak Ram Shrestha	Syangja	10	8.90	85.40	26.42	5.90	65.40	6.52	11	15	20		24.69
39	Khinapadam Devkota	Syangja	10	8.80	82.50	31.81	3.70	56.50	6.38	10	35	35		20.04
40	Keshav Raj Neupane	Syangja	10	8.70	77.10	32.52	6.90	76.00	10.08	11	48	50		30.99

41	Saligram Adhikari	Chitwan	10	6.30	68.80	31.37	5.80	65.40	9.97	13	52	55	31.77
42	Tanka P. Dhamala	Chitwan	10	11.90	77.50	52.24	6.10	67.20	12.64	14	67	60	24.19
43	Tulasi Ram Kandel	Chitwan	8	7.40	89.40	40.45	5.90	78.00	11.60	13	58	60	28.69
44	Sita Ram Karki	Chitwan	8	9.60	87.50	41.80	5.50	45.00	7.56	13	55	58	18.09
45	Goma Baniya	Chitwan	4	7.70	74.20	29.12	0.30	41.70	3.77	13	24	30	12.95
46	Narayan Adhikari	Chitwan	10	8.30	79.80	35.73	2.40	63.10	7.48	13	42	45	20.92
47	Tirtha Raj Paudel	Chitwan	6	4.30	65.50	19.90	4.10	72.70	7.18	13	22	30	36.07
48	Shyam P. Upadhyaya	Chitwan	4	4.30	60.20	19.56	0.80	52.80	4.58	12	28	35	23.42
49	Subindra K.C.	Chitwan	4	4.80	52.40	11.32	0.40	40.00	2.10	12	10	20	18.56
50	Ganesh Bdr. Shrestha	Nuwakot	6	7.30	71.80	26.39	4.30	55.80	6.36	11	39	45	24.12
51	Pushpa Nath Acharya	Nuwakot	8	9.60	65.00	32.21	5.80	58.80	8.49	12	38	38	26.35
52	Ramraja Sadula	Nuwakot	10	9.10	74.40	33.65	6.90	68.60	9.79	11	25	25	29.10
53	Tej Bdr. Adhilkari	Nuwakot	10	5.10	66.20	22.86	9.50	70.70	9.93	11	55	60	43.45
54	Pinggong Galane	Nuwakot	10	9.30	72.00	32.37	7.80	67.80	9.88	12	37	40	30.52
55	Khop Maya Dhabala	Nuwakot	10	4.50	59.30	18.66	5.60	73.90	7.83	12	30	40	41.99
56	Netra Bdr. Chhetri	Nuwakot	10	9.40	71.50	32.09	7.70	63.10	9.32	12	37	40	29.04
57	Manjushree Chapagai	Chitwan	10	6.80	63.60	29.80	6.30	65.50	10.01	13	61	65	33.60
58	Chabilal Adhikari	Chitwan	6	5.80	83.50	31.56	5.10	56.70	7.77	14	42	50	24.61
59	Prem Pd. Dhabala	Chitwan	6	6.30	85.70	37.00	2.60	65.50	8.35	14	37	40	22.57
60	Madhab Dhungana	Chitwan	6	7.60	70.20	30.86	1.70	66.80	7.26	14	30	35	23.53
61	Tul Raj Upreti	Chitwan	6	8.40	72.70	37.01	3.30	66.70	9.08	13	25	25	24.54
62	Harinarayan Adhikari	Chitwan	8	4.00	62.80	21.65	5.20	67.50	8.23	13	40	50	38.01
63	Ram Maya Kandel	Chitwan	8	9.00	80.40	40.43	1.10	55.00	6.60	13	46	45	16.32
64	Dharma Pun	Chitwan	8	8.30	43.10	26.96	4.30	68.50	9.75	13	37	37	36.17
65	Surat Bdr. Chitrakar	Nuwakot	6	6.50	75.00	26.85	6.30	66.80	8.29	12	30	35	30.85
66	Ramkrishna Shrestha	Nuwakot	6	6.90	77.60	23.06	6.10	56.90	6.07	12	21	30	26.31
67	Bhakta Bdr. Shrestha	Nuwakot	6	8.60	79.50	34.72	4.10	69.80	8.65	12	40	40	24.92
68	Raj Kumar Jung Shah	Nuwakot	6	8.90	76.60	34.60	7.00	72.10	10.35	12	40	40	29.92
69	Paban Kumari Acharya	Nuwakot	8	8.40	76.80	32.33	7.10	62.20	8.99	12	48	50	27.81
70	Bhadra B. Pyakurel	Nuwakot	8	9.30	69.20	32.71	9.00	64.50	10.49	12	38	40	32.06
71	Sitaram Pyakurel	Nuwakot	8	9.50	76.50	36.71	6.30	67.60	9.93	12	44	45	27.05
72	Gopal Acharya	Nuwakot	8	9.70	84.90	41.08	5.30	68.40	9.89	13	30	30	24.06
73	Gopal Malakar	Nuwakot	4	7.10	72.30	30.85	5.90	64.90	9.13	12	29	30	29.58
74	Hari Bdr. Adhikari	Nuwakot	4	7.10	72.30	29.61	5.90	64.90	8.76	12	23	25	29.58
75	Gopal Shrestha	Nuwakot	4	7.00	68.80	30.21	1.00	56.30	6.03	12	35	35	19.95
76	Mukti Nath Gautam	Nuwakot	4	8.10	78.00	29.45	7.90	68.80	9.10	11	27	30	30.89
77	Khadka B. Adhikari	Nuwakot	4	7.70	75.60	29.65	0.40	48.30	4.42	11	29	30	14.90
78	Dil Bdr. Tamang	Chitwan	4	6.90	70.90	26.03	6.90	78.20	9.40	14	18	25	36.11
79	Nanda Pd. Rijal	Chitwan	4	8.00	79.20	38.37	2.40	64.60	8.33	14	29	30	21.71
80	Krishna Bdr. Gurung	Chitwan	10	7.30	81.30	35.05	9.40	69.40	11.69	13	23	25	33.35
Average			**7**	**7.91**	**75.55**	**32.29**	**5.76**	**67.54**	**9.22**	**12**	**34**	**36**	**28.54**

ID	Name of Plant Owner	District	Pt. Size (m3)	Third Sample (June, 1999)									% of Volatile Solid Remained in Slurry
				Dung			Slurry			Tem. (o C)	Feeding		
				TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)	TSC (%)	VSC (% of TSC)	Expected Gas Prod. (Litre/kg)		Dung (Kg)	Water (Ltr)	
1	Ganesh Acharya	Morang	4	11.25	92.00	44.01	9.60	54.20	8.10	27	38	37	18.40
2	Sashi P. Siwakoti	Morang	4	8.56	89.23	36.83	5.61	58.36	6.42	26	16	16	17.43
3	Nabin Adhikari	Morang	4	8.24	83.50	39.01	4.20	61.57	6.88	35	10	12	17.64
4	Tikaram Chapagain	Morang	4	6.28	87.61	35.84	5.34	51.18	6.23	28	20	20	17.38
5	Ram Devi Dahal	Morang	4	10.05	79.98	26.13	6.33	57.25	4.76	30	5	8	18.22
6	Netra P. Neupane	Morang	6	8.72	91.23	39.06	5.18	51.16	5.94	27	30	30	15.22
7	Durgadevi Katuwal	Morang	6	11.26	78.84	40.44	5.74	61.00	7.18	28	20	20	17.74
8	Lalit Tamang	Morang	6	12.15	87.56	42.81	7.25	61.74	7.56	27	20	20	17.66
9	Tara Nath Chapagai	Morang	6	7.58	81.43	33.30	4.57	53.14	5.64	26	35	35	16.95
10	Yam Nath Mahatara	Morang	6	9.65	82.19	36.64	5.57	54.42	6.17	27	34	35	16.83
11	Dinesh Khanal	Morang	8	10.47	86.23	44.51	5.21	49.67	6.49	30	35	35	14.58
12	Purna B. Shrestha	Morang	8	9.69	86.98	39.18	7.12	41.58	5.95	27	60	60	15.20
13	Dambar B. Shrestha	Morang	8	8.90	75.23	36.87	4.47	41.87	5.28	28	38	37	14.31
14	Hari P. Dahal	Morang	8	7.86	87.48	36.75	8.00	54.35	7.28	27	40	40	19.81
15	Pushpa Lal Acharya	Morang	8	9.79	89.98	40.20	4.56	57.34	6.18	27	34	34	15.38
16	Pushpa Timsina	Morang	10	10.56	87.97	35.45	10.18	62.99	7.65	28	21	25	21.59
17	Bishnu Shrestha	Morang	10	8.54	89.69	28.38	7.85	50.41	5.12	29	31	45	18.03
18	Bisheshwor Dhakal	Morang	10	8.45	87.75	37.66	7.88	56.36	7.39	27	30	30	19.62
19	Tilak P. Dhakal	Morang	10	7.46	79.90	32.03	8.74	51.58	6.93	26	48	49	21.65
20	Harischandra Acharya	Morang	10	9.98	85.00	39.69	7.98	60.39	7.87	27	58	57	19.84
21	Mithu Sharma	Syangja	4	11.25	93.36	40.52	10.44	48.27	7.26	23	22	20	17.92
22	Tulsi Roka	Syangja	4	10.63	94.55	34.81	8.43	43.33	5.37	22	40	40	15.43
23	Rudra B. Roka	Syangja	4	7.45	93.37	32.28	6.90	46.81	5.34	23	30	30	16.55
24	Chhetra B. Roka	Syangja	4	7.59	91.74	30.96	5.82	32.14	3.89	25	32	36	12.56
25	Suman Raj Giri	Syangja	4	9.87	87.00	35.05	8.86	43.89	6.05	24	41	41	17.25
26	Dhan Bdr. Roka	Syangja	6	8.85	91.11	33.40	7.21	63.74	6.56	23	36	36	19.64
27	Min B. Khadka	Syangja	6	8.53	93.26	35.01	3.56	46.81	4.43	24	40	40	12.65
28	Rupa Roka	Syangja	6	8.20	81.28	31.47	6.96	60.14	6.51	24	30	30	20.69
29	Man B. Roka	Syangja	6	6.99	91.70	33.37	6.58	49.37	5.76	26	33	35	17.27
30	Dil Bdr. Roka	Syangja	6	8.78	89.25	31.34	6.67	52.00	5.35	24	32	35	17.07
31	Hum Nath Padhya	Syangja	8	10.85	86.32	29.66	7.14	52.60	4.97	23	30	35	16.77
32	Hum Bdr. Thapa	Syangja	8	9.63	89.45	35.39	7.45	54.26	6.27	24	26	26	17.73
33	Dil Bdr. Thapa	Syangja	8	9.33	85.76	28.56	7.82	58.96	5.64	23	35	40	19.74
34	Ganesh B. Thapa	Syangja	8	7.68	86.34	24.64	7.59	45.36	4.38	23	32	40	17.77
35	Dil Kumari Timilsina	Syangja	8	4.25	71.28	20.27	4.10	64.45	4.45	22	30	36	21.95
36	Tarapati Sharma	Syangja	10	10.94	92.36	30.79	8.58	45.41	4.93	23	34	40	16.02
37	Ram B. Adhikari	Syangja	10	8.57	87.14	36.25	9.43	48.78	7.13	26	34	34	19.66
38	Tilak Ram Shrestha	Syangja	10	7.89	81.47	29.84	6.75	50.91	5.56	23	25	25	18.65
39	Khinapadam Devkota	Syangja	10	9.11	87.93	40.07	6.64	48.81	6.56	28	40	40	16.37
40	Keshav Raj Neupane	Syangja	10	9.86	84.82	43.09	6.21	51.40	7.07	30	50	50	16.40

41	Saligram Adhikari	Chitwan	10	10.41	95.28	35.36	9.69	40.15	5.67	24	56	60	16.03
42	Tanka P. Dhamala	Chitwan	10	11.78	91.28	44.99	10.14	41.53	7.38	24	70	60	16.40
43	Tulasi Ram Kandel	Chitwan	8	9.97	90.64	37.63	9.51	43.57	6.51	25	60	60	17.29
44	Sita Ram Karki	Chitwan	8	8.97	92.57	44.23	7.52	41.25	6.76	24	50	40	15.28
45	Goma Baniya	Chitwan	4	9.99	82.14	35.35	1.24	42.19	3.46	25	20	20	9.78
46	Narayan Adhikari	Chitwan	10	7.85	87.41	35.35	5.56	61.08	6.60	26	45	45	18.68
47	Tirtha Raj Paudel	Chitwan	6	6.49	80.14	29.03	4.17	52.17	5.01	24	30	30	17.25
48	Shyam P. Upadhyaya	Chitwan	4	8.17	81.24	31.42	3.76	48.72	4.63	28	30	35	14.73
49	Subindra K.C.	Chitwan	4	8.84	79.95	31.93	5.59	64.45	6.34	24	20	20	19.85
50	Ganesh Bdr. Shrestha	Nuwakot	6	8.74	87.46	30.01	7.84	47.19	5.27	24	40	45	17.55
51	Pushpa Nath Acharya	Nuwakot	8	10.41	88.19	35.14	7.54	49.68	5.84	24	39	40	16.62
52	Ramraja Sadula	Nuwakot	10	9.47	84.49	36.72	4.68	56.69	5.95	26	30	30	16.20
53	Tej Bdr. Adhilkari	Nuwakot	10	8.47	86.64	44.08	7.85	48.27	7.97	27	59	50	18.07
54	Pinggong Galane	Nuwakot	10	8.58	84.58	32.22	5.59	53.36	5.48	25	33	35	16.99
55	Khop Maya Dhabula	Nuwakot	10	7.38	79.96	30.96	5.03	45.53	4.99	27	32	35	16.10
56	Netra Bdr. Chhetri	Nuwakot	10	9.63	86.95	38.91	6.69	53.98	6.71	28	48	50	17.26
57	Manjushree Chapagai	Chitwan	10	8.24	88.84	41.87	6.98	51.47	7.40	24	75	60	17.68
58	Chabilal Adhikari	Chitwan	6	6.56	84.35	28.96	5.59	54.49	5.42	23	40	40	18.71
59	Prem Pd. Dhabala	Chitwan	6	7.48	87.89	34.99	4.69	59.96	6.20	26	35	35	17.71
60	Madhab Dhungana	Chitwan	6	8.64	81.16	30.66	5.49	56.43	5.51	23	30	30	17.98
61	Tul Raj Upreti	Chitwan	6	8.54	84.18	32.65	8.46	48.96	6.26	24	25	25	19.16
62	Harinarayan Adhikari	Chitwan	8	6.48	79.54	31.27	5.48	58.85	6.41	26	50	50	20.49
63	Ram Maya Kandel	Chitwan	8	9.32	93.46	36.05	3.59	51.63	4.77	27	40	45	13.23
64	Dharma Pun	Chitwan	8	8.90	71.43	34.74	5.26	56.81	6.65	28	35	35	19.14
65	Surat Bdr. Chitrakar	Nuwakot	6	6.65	85.56	30.65	5.42	56.89	5.76	24	31	31	18.79
66	Ramkrishna Shrestha	Nuwakot	6	7.84	81.24	31.01	5.28	67.53	6.44	24	22	22	20.77
67	Bhakta Bdr. Shrestha	Nuwakot	6	9.85	92.27	37.92	7.85	41.85	5.79	25	34	34	15.28
68	Raj Kumar Jung Shah	Nuwakot	6	10.45	90.15	39.65	8.74	38.72	6.12	26	38	38	15.44
69	Paban Kumari Acharya	Nuwakot	8	10.83	89.94	40.11	10.20	43.35	7.01	26	41	41	17.47
70	Bhadra B. Pyakurel	Nuwakot	8	10.14	84.74	34.80	9.98	48.47	6.75	24	38	38	19.38
71	Sitaram Pyakurel	Nuwakot	8	8.86	87.15	25.94	8.81	61.19	5.53	23	32	40	21.33
72	Gopal Acharya	Nuwakot	8	10.18	92.28	33.66	7.79	58.34	6.10	24	32	35	18.12
73	Gopal Malakar	Nuwakot	4	6.90	89.04	31.56	5.51	57.71	5.79	26	32	35	18.35
74	Hari Bdr. Adhikari	Nuwakot	4	7.85	84.21	31.80	7.54	69.68	7.36	24	21	21	23.16
75	Gopal Shrestha	Nuwakot	4	9.79	89.07	37.76	6.67	47.46	5.89	28	31	34	15.61
76	Mukti Nath Gautam	Nuwakot	4	10.20	91.70	30.14	7.63	53.73	5.18	23	30	35	17.17
77	Khadka B. Adhikari	Nuwakot	4	9.75	89.76	32.57	5.86	42.27	4.49	24	32	35	13.78
78	Dil Bdr. Tamang	Chitwan	4	8.54	78.58	23.56	7.81	71.60	5.73	29	25	40	24.32
79	Nanda Pd. Rijal	Chitwan	4	9.83	87.08	32.52	8.84	46.61	5.78	26	30	35	17.78
80	Krishna Bdr. Gurung	Chitwan	10	11.49	74.14	39.35	8.45	68.79	8.88	28	30	30	22.57
Average			**7**	**9.00**	**86.32**	**34.74**	**6.81**	**52.51**	**6.08**	**26**	**35**	**36**	**17.50**

Table-42 given above illustrates the expected amount of gas production from the dung water mix (feeding) and digested slurry. The calculation is based upon the quantity of feeding, total and volatile solid content and the temperature. However, the actual amount of gas production depends upon various other factors besides these. Therefore, in absence of other information a concrete decision could not be made. However, the results of analysis may provide general scenario on the functioning of plants in different seasons.

The outcome of the analysis showed that the expected quantity of gas production from dung differed from one season to another. The figures are 32.74 litres per kg of dung during October, 32.29 litres per kg of dung during February and 34,74 litres per kg of dung during June. The average expected production, therefore, is 33.26 litres per kg of dung.

Another important finding is that the % of volatile matter presented in slurry also differs from one season to another. During July-Oct 19.70% of the volatile matter is left in slurry. The figures for November-February and March-June are 28.54% and 17.50% respectively. These figures suggest that the digestion is affected during the winter season months (November-February).
However, this type of practice to compare the rate of digestion is not common. As it is understood, that the digested slurry sample may not represent the nature and quality of the dung sample taken in the same day. Due to some turbulence of slurry inside the digester, laminar flow of slurry is not possible. Therefore, the slurry sample may also contain undigested part of the feeding. Therefore, the data obtained before digestion and after the digestion are not actually comparable.

9.0 CONCLUSION

9.0 CONCLUSION

Increasing population and depleting non-renewable energy resources are posing a serious threat to the low-income developing world in the endeavour to attain better standards of life. Nepal is not an exception in this regard. Living standards are co-related with energy consumption. Most of the developing countries including Nepal, have very low per capita consumption of energy which is one of the indications of sub-standard living condition. These countries appear to be below the subsistence thresholds in terms of commercial energy consumption. The reason for such condition is unaffordable commercial energy costs and lack of capital to exploit non-conventional energy resources. Though little late it may be, it is worthy that His Majesty's Government has shown interest to exploit renewable energy resources available in the country. Realising its importance and simplicity in installation and operation and maintenance many households in the remote and semi-urban areas of Nepal are attracted towards biogas technology. Installation of more than 70,000 biogas digesters with in a short period of time is a clear indication that the technology is widely appreciated by the users.

To safeguard the interest of farmers and make biogas technology more cost-effective and affordable to marginal population it is imperative that some research studies be carried out to explore possibilities to reduce the cost by further improving the presently adopted design. Till now the government subsidy is being provided to only one type of plant design - the GGC 2047 Model type, which is improved version of Chinese Fix Dome plant. The effectiveness of keeping only one plant design has been large in terms of imposing quality and making quality control less complicated and cost-effective. It is, therefore, necessary that this type of design is made most cost-effective and affordable. It has been realised that plant cost can not or only marginally be reduced per unit without compromising on present quality norms. However, the cost of the generated biogas can be brought down by using the plant more efficiently and effectively. To explore these possibilities the present research study on **'Optimum Biogas Plant Size, Daily Biogas Use Pattern and Conventional Fuel Saving'** was conducted.

The final outcomes of the study are very encouraging. It has explored various possibilities of cost reduction. It has also provided answers to various unanswered questions such as whether latrine attachment really helps in increasing the plant efficiency; whether top-filling over dome helps in maintaining temperature inside the digester during winter season; whether site selection and direct sunlight over biogas plant have any influence over plant functioning; whether the existing plants are operated optimally; whether the presently adopted size of dome and outlet is correct; and so on. The study has also generated reliable primary data and information on the actual savings on conventional fuel for average biogas households in various ecological zones in Nepal by comparing the quantity used in biogas and non-biogas households having quite similar socio-cultural conditions. As the study was carried out in all four ecological zones, viz. Hilly, Mid-Hilly, Inner Terai (semi-plain area) and Terai (Plain) Regions representing altitude ranges of above 800m, 500-600m, 200-400m and below 200m respectively, it provided clear picture of the whole country. Moreover, the complete one-year cycle of the study period has helped in assessing the functioning of plant and fuel use pattern for different seasons. Conclusively, the duration of study, extended nature of the study area, incorporation of biogas plants of different-size and involvement of the users intensively during the whole period of the study has made the outcome of the study reliable and factual.

The main outcome of the study is that there are possibilities of reducing the size of gas storage tank (dome) and outlet (displacement chamber). Similarly, there are possibilities to jump into smaller sized biogas plant from the presently adopted one to achieve the same magnitude of benefits that is being received from existing plants of bigger sizes. This, in one hand will reduce the investment cost and in the other, will help in optimal operation of plants. Major complications in biogas plants that are encountered due to under-feeding or over-sizing, such as entry of slurry in pipeline etc, could be eliminated to a great extent.

The outcome of the study would help in convincing actors involved in the sector like biogas construction companies, banks, and farmers to construct appropriate size of biogas plant given the availability of feeding material (dung). The outcome of the study could also be used to draw up stricter quality norms regarding size-selection that are acceptable for all the actors involved. Finally, it is expected that the outcome of the study fulfil the expected objectives of the study.

The non-functioning of gas metres and damaging of temperature meters were serious drawback on the research. As a result number of findings are affected. The Chinese company that supplied the gas meter is a new company and it was understood that the types of gas meters used in the research were not tested earlier in any locations. Therefore, their serviceability and durability were not proven in advance. Similarly, temperature meters were imported without spare dipping chords. There were every chances of damaging of the chord as it was dipped in slurry time and again to measure the temperature. Because of the wear and tear, these chords stopped functioning with in five or six months. Spare chords were not available during then. The research have learnt lesson that if the tools and equipment are to be imported, they have to be of high standard and should have proven track records.

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10.0 REFERENCES

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ANNEXES

Annex-1
General Information of sampled Households

Annex-l(a) : General Information of Sampled Biogas House

S.N.	Name of Plant Owner	District	VDC/Municipality	Ward No.	Plant Size
1	Ganesh Acharya	Morang	Indrapur	4	4
2	Sashi P. Siwakoti	Morang	Indrapur	3	4
3	Nabin Adhikari	Morang	Indrapur	7	4
4	Tikaram Chapagain	Morang	Kerabari		4
5	Ram Devi Dahal	Morang	Baniganu	9	4
6	Netra P. Neupane	Morang	Indrapur	4	6
7	Durgadevi Katuwal	Morang	Indrapur	4	6
8	Lalit Tamang	Morang	Kerabari	9	6
9	Tara Nath Chapagai	Morang	Kerabari	2	6
10	Yam Nath Mahatara	Morang	Belbari	1	6
11	Dinesh Khanal	Morang	Indrapur	3	8
12	Purna B. Shrestha	Morang	Indrapur	6	8
13	Dambar B. Shrestha	Morang	Indrapur	6	8
14	Hari P Dahal	Morang	Indrapur	2	11
15	Pushpa Lal Acharya	Morang	Indrapur	4	3
16	Pushpa Timsina	Morang	Indrapur	3	10
17	Bishnu Kumari Shrestha	Morang	Indrapur	2	10
I8	Bisheshwor P. Dhakai	Morang	Indrapur	4	10
19	Tilak P. Dhakai	Morang	Indrapur	4	10
20	Harishchandra Acharva	Morang	Indrapur	4	10
21	Mithu Sharma	Syangja	Putalibazar	1	4
22	Tulsi Roka	Syangja	Putalibazar	10	4
23	Rudra B. Roka	Syangja	Putalibazar	10	4
24	Chhetra B. Roka	Syangja	Putalibazar	10	4
25	Suman Raj Giri	Syangja	Putalibazar	9	4
26	Dhan Bdr. Roka	Syangja	Putalibazar	10	6
27	Min 11. Khadki	Syangja	Arjun Chaupari	2	6
2S	Rupa Roka	Syangja	Putalibazar	10	6
29	Man B. Roka	Syangja	Putalibazar	10	6
30	Dil Bdr. Roka	Syangja	Putalibazar	10	6
31	Hum Nath Padhya	Syangja	Putalibazar	1	8
32	Mum Bdr. Thapa	Syangja	Karandada	1	8
33	Dil Bdr. Thapa	Syangja	Putalibazar	12	8
34	Ganesh B. Thapa	Syangja	Putalibazar	12	8
35	Dil Kumari Timilsina	Syangja	Putalibazar	12	8
36	Tarapati Sharma	Syangja	Putalibazar	2	10
37	Ram B. Adliikuri	Syangja	Arjun Chaupari	4	10
38	Tilak Ram Shresiha	Syangja	Putalibazar	2	10
39	Khina Padam Devkota	Syangja	Arjun Chaupari	5	10

40	Keshav Raj Neupane	Syangja	Putalibazar	10	10
41	Saligram Adhikari	Chitwan	Birendranagar	3	10
42	Tanka P. Dhabala	Chitwan	Bachhyauli	8	10
43	Tulasi Ram Kandd	Chitwan	Birendranagar	4	8
44	Sit a Ram Karki	Chitwan	Bachhyauli	9	8
45	Goma Baniya	Chitwan	Mangalpur	7	4
46	Nrayan Adhikari	Chitwan	Bachhyauli	9	10
47	Tirtha Raj Paudel	Chitwan	Birendranagar	4	6
48	Shyam Pd. Upadhyaya	Chitwan	Bharatpur	8	4
49	Subindra K.C.	Chitwan	Mangalpur	7	4
50	Ganesh Bdr. Shrestha	Nuwakot	Bidur	9	6
51	Pushpa Nath Acharya	Nuwakot	Bidur	5	8
52	Ramraja Sadula	Nuwakot	Bidur	6	10
53	Tej Bahadur Adhilkari	Nuwakot	Kha Bha	5	10
54	Pinggong Ghalenee	Nuwakot	Bidur	8	10
55	Khop Maya Dhabala	Nuwakot	Bidur	8	10
56	NetraBdr. Chhetri	Nuwakot	Bidur	6	10
57	Manjushree Chapagai	Chitwan	Khairani	7	10
58	Chabilal Adhikari	Chitwan	Bachhyauli	9	6
59	Prem Pd. Dhabala	Chitwan	Khairani	2	6
60	Madhab Dhunyana	Chitwan	Khairani	2	6
61	Tul Raj Upreti	Chitwan	Birendranagar	4	6
62	Hari Naravan Adhikari	Chitwan	Bachhyauli	9	8
63	Ram Maya Kandel	Chitwan	Khairani	8	8
64	Dharma Pun	Chitwan	Birendranagar	2	8
65	Surai Bdr Chitnikar	Nuwakot	Bidur	4	6
66	Ram Kiishna Slirestha	Nuwakot	Bidur	9	6
67	Bhakta Bdr. Shrestha	Nuwakot	Bidur	9	6
68	Raj Kumar Jung Shaha	Nuwakot	Kha Bha	5	6
69	Paban Kumari Acharya	Nuwakot	Bidur	5	8
70	Bhadra B. Pyakuref	Nuwakot	Bidur	9	8
71	Sitaram Pvakurel	Nuwakot	Bidur	9	8
72	Gopal Acharya	Nuwakot	Bidur	5	8
73	Gopal Malakar	Nuwakot	Bidur	3	4
74	Hari Bahadur Adhikari	Nuwakot	Bidur	9	4
75	Gopai Shresiha	Nuwakot	Bidur	9	4
76	Mukti Nath Gautam	Nuwakot	Bidur	9	4
77	Khadka B. Adhikari	Nuwakot	Bidur	9	4
78	Dil Bdr. Tamang	Chitwan	Mangalpur	7	4
79	Nanda Pd. Rijal	Chitwan	Khairani	2	4
80	Krishna Bdr. Gurung	Chitwan	Birendranagar	4	10

Annex-l (b) : General Information of Sampled Non-Biogas House

S.N.	Name of Plant Owner	District	VDC/Municipality	Ward No.
1	Bhawani Shankar Dahal	Morang	Indrapur	4
2	Bhawani Prasad Dahal	Morang	Indrapur	2
3	Bhupendra K.C.	Morang	Indrapur	2
4	Hari Kumar Pradhan	Morang	Indrapur	2
5	Shiva P. Dhakal	Morang	Indrapur	4
6	Ram B. Ghimire	Morang	Indrapur	4
7	Kamal P. Dahal	Morang	Indrapur	4
8	Bishnu P. Kaile	Morang	Indrapur	4
9	Devi P. Neupane	Morang	Indrapur	4
10	Madhav P. Ojha	Morang	Indrapur	4
11	Thaneshwor Sapkota	Syangja	Putalibazar	1
12	Ujeli Khadka	Syangja	Putalibazar	10
13	Kul Bdr. Paudel	Syangja	Putalibazar	2
14	Rishiram Sharnia	Syangja	Putalibazar	6
15	Ishwori Roka	Syangja	Putalibazar	10
16	Pampha Roka	Syangja	Putalibazar	10
17	Parbati Roka	Syangja	Putalibazar	10
I8	Maiva Aryal	Syangja	Putalibazar	10
19	Kopila Nepal	Syangja	Thuladihi	8
20	Krishma Giri	Syangja	Putalibazar	9
21	Jagan Nath Khanal	Chitwan	Bachhyauli	8
22	Dharma Raj Paudel	Chitwan	Birendranagar	5
23	Ram Chandra Paihak	Chitwan	Birendranagar	4
24	Balram Pathak	Chit wan	Kathar	4
25	Bishnu Pd. Piithak	Chitwan	Kathar	4
26	Kham Raj Pathak	Chitwan	Birendranagar	4
27	Bir Bdr. Karki	Chitwan	Bachhyauli	8
2S	Bhoka Chaudhari	Chitwan	Khairani	1
29	Shova Sapkoia	Chitwan	Khairani	2
30	Kedar Prasad Adhikari	Chitwan	Bachhyauli	4
31	Sunita Sadaula	Nuwakot	Bidur	6
32	Chini Maya Kumai	Nuwakot	Bidur	6
33	Hari Pd. Joshi	Nuwakot	Bidur	6
34	Debaki Paneai	Nuwakot	Bidur	4
35	Januka Kumal	Nuwakot	Bidur	6
36	Man Kumari Pakurei	Nuwakot	Bidur	9
37	Ram Bdr Bhadari	Nuwakot	Tupche	9
38	Dacha Mijar	Nuwakot	Bidur	9
39	Parbati Bhandari	Nuwakot	Bidur	9
40	Sarashoti Khadka	Nuwakot	Bidur	9

Annex-2
Information of Family-size and Literacy

Annex-2(a); Information on Family-size and Literacy (Biogas Households)

S.N.	Family In	Family Out	Total	Literate Male	Illiterate Male	Literate Female	Illiterate Female	Infant Male	Infant Female
1	4	0	4	2	1	1	0	1	0
2	4	0	4	2	1	1	0	1	0
3	7	0	7	2	0	5	0	0	0
4	2	0	2	1	0	1	0	0	0
5	2	0	2	0	0	1	1	0	0
6	4	0	4	2	0	2	0	0	0
7	7	0	7	2	1	2	2	0	1
8	4	0	4	2	0	1	1	0	1
9	2	0	2	1	0	1	0	0	0
10	5	0	5	3	0	1	1	0	1
11	6	0	6	4	0	2	0	0	0
12	8	0	8	4	1	2	1	1	0
13	5	0	5	3	0	1	1	0	0
14	7	0	7	3	0	4	0	0	0
15	6	0	6	3	1	1	1	1	0
16	4	0	4	2	0	2	0	0	0
17	5	0	5	3	0	1	1	0	0
18	5	0	5	1	0	2	2	0	2
19	5	0	5	3	0	2	0	0	0
20	11	0	11	5	0	4	2	0	2
21	6	0	6	3	0	3	0	0	0
22	4	0	4	2	0	2	0	0	0
23	6	1	7	3	1	2	1	0	0
24	4	0	4	3	0	1	0	0	0
25	3	0	3	2	0	0	1	0	0
26	4	0	4	3	0	0	1	0	0
27	10	4	14	4	1	7	2	1	0
28	5	0	5	4	0	1	0	0	0
29	7	1	8	4	1	3	0	1	0
30	5	1	6	4	0	1	1	0	0
31	5	1	6	3	0	3	0	0	0
32	3	1	4	2	0	2	0	0	0
33	5	0	5	3	0	2	0	0	0
34	5	2	7	3	0	4	0	0	0
35	4	1	5	2	0	3	0	0	0
36	6	0	6	3	0	2	1	0	0
37	6	1	7	4	0	2	1	0	0
38	5	0	5	2	0	2	1	0	0

39	8	0	8	2	2	2	2	1	1
40	7	1	8	5	0	3	0	0	0
41	12	0	12	6	0	5	1	0	0
42	10	4	14	5	2	5	2	1	1
43	9	0	9	3	0	6	0	0	0
44	7	2	9	3	1	3	2	1	1
45	4	0	4	2	0	2	0	0	0
46	4	0	4	1	1	1	1	1	1
47	4	0	4	2	0	2	0	0	0
48	3	0	3	1	0	1	1	0	1
49	5	0	5	2	1	2	0	1	0
50	9	0	9	2	2	4	1	1	0
51	8	1	9	4	0	4	1	0	1
52	5	0	5	4	0	1	0	0	0
53	7	0	7	2	1	2	2	0	1
54	4	0	4	2	0	1	1	0	0
55	5	0	5	2	1	1	1	0	0
56	10	1	11	5	1	2	3	1	1
57	5	0	5	2	0	2	1	0	0
58	4	0	4	2	0	1	1	0	1
59	4	0	4	2	0	2	0	0	0
60	6	0	6	3	0	3	0	0	0
61	8	0	8	2	2	3	1	1	0
62	4	0	4	2	0	2	0	0	0
63	4	0	4	1	0	3	0	0	0
64	6	0	6	2	0	4	0	0	0
65	8	0	8	2	0	5	1	0	0
66	4	0	4	2	0	2	0	0	0
67	7	0	7	2	1	3	1	1	0
68	5	0	5	2	0	3	0	0	0
69	7	0	7	2	1	3	1	0	0
70	6	0	6	3	0	3	0	0	0
71	5	0	5	2	0	2	1	0	0
72	7	0	7	2	1	3	1	0	0
73	6	0	6	3	1	1	1	0	0
74	5	0	5	2	0	2	1	0	0
75	7	0	7	2	0	4	1	0	0
76	5	0	5	1	0	1	3	0	2
77	6	0	6	4	1	0	1	1	0
78	3	0	3	1	1	1	0	1	0
79	3	0	3	1	0	1	1	0	0
80	4	0	4	2	0	2	0	0	0

Annex-2(b); Information on Family-size and Literacy (Non-biogas Households)

S.N.	Family In	Family Out	Total	Literate Male	Illiterate Male	Literate Female	Illiterate Female	Infant Male	Infant Female
1	8	0	8	5	0	1	2	0	0
2	9	0	9	3	1	4	1	1	1
3	4	1	5	2	0	2	1	0	1
4	5	0	5	3	0	2	0	0	0
5	5	0	5	2	1	2	0	1	0
6	5	0	5	2	0	2	1	0	1
7	5	0	5	2	0	3	0	0	0
8	5	0	5	4	0	1	0	0	0
9	7	0	7	3	0	1	3	0	0
10	11	0	11	4	1	5	1	1	1
11	4	3	7	3	0	3	1	0	0
12	8	5	13	7	0	6	0	0	0
13	3	4	7	2	1	2	2	1	1
14	5	0	5	2	1	2	0	1	0
15	4	0	4	3	0	1	0	0	0
16	5	1	6	5	0	1	0	0	0
17	6	0	6	4	0	2	0	0	0
18	9	0	9	3	1	3	2	1	2
19	6	0	6	2	1	3	0	1	0
20	5	0	5	2	0	1	2	0	2
21	4	2	6	4	0	2	0	0	0
22	5	0	5	2	0	2	1	0	1
23	7	0	7	4	0	1	2	0	0
24	6	0	6	3	0	3	0	0	0
25	5	3	8	4	0	4	0	0	0
26	6	0	6	1	1	3	1	1	0
27	7	1	8	4	1	3	0	1	0
28	5	0	5	1	1	3	0	0	0
29	5	0	5	3	2	0	0	0	0
30	5	0	5	3	0	2	0	0	0
31	4	0	4	2	0	2	0	0	0
32	14	0	14	2	4	4	4	1	2
33	5	0	5	1	1	2	1	0	0
34	5	0	5	2	0	2	1	0	1
35	10	1	11	2	2	3	4	0	2
36	5	0	5	3	0	0	2	0	1
37	4	0	4	3	0	0	1	0	0
38	10	0	10	5	2	2	1	0	0
39	6	0	6	2	0	3	1	0	0
40	3	2	5	4	1	0	0	0	0

Annex-3
Production and Consumption of Four Major Cereals

Annex-3(a): Production and Consumption of Four Major Cereals (Biogas Households)

S.N.	Paddy Produced	Paddy Consumed	Maize Produced	Maize Consumed	Wheat Produced	Wheat Consumed	Millet Produced	Millet Consumed
1	1600	1000	80	400	200	200	0	0
2	1600	1600	40	40	0	0	0	0
3	8000	2000	800	600	0	160	0	0
4	2000	880	360	360	1600	600	0	0
5	2000	1000	200	200	400	400	0	0
6	2400	1400	160	560	200	80	0	0
7	1600	2000	40	160	200	280	0	0
8	2400	1200	160	240	200	40	0	0
9	2000	880	360	360	1600	600	0	0
10	3000	1400	400	200	0	0	0	0
11	800	1600	80	400	40	320	0	0
12	4800	3200	200	280	1200	600	0	0
13	2400	1600	200	200	800	200	0	0
14	6000	3200	0	0	160	160	0	0
15	1000	1400	40	340	320	320	0	0
16	760	1600	0	0	0	0	0	0
17	3600	2400	400	400	80	80	0	0
18	8000	4000	200	200	200	40	0	0
19	5200	1600	160	160	400	240	0	0
20	2400	2400	400	400	1000	400	0	0
21	0	500	20	100	0	100	0	0
22	200	1200	0	0	0	0	0	0
23	800	800	320	320	40	40	400	400
24	1600	1600	240	240	120	120	240	240
25	400	640	320	320	80	80	360	360
26	1200	1200	480	480	0	0	480	480
27	1600	1600	800	800	520	520	600	600
28	280	280	400	400	280	280	400	400
29	800	800	240	240	40	40	240	240
30	1400	1400	280	280	240	240	280	280
31	560	560	280	280	80	80	120	120
32	1000	1480	160	160	80	80	160	160
33	920	920	200	200	40	40	200	200
34	600	1200	280	580	160	160	160	160
35	600	720	160	200	80	80	75	75
36	360	1160	160	360	0	0	160	160
37	1400	1400	400	400	200	200	25	25
38	1200	1200	130	130	90	90	0	0
39	1400	1400	240	240	130	130	50	30

40	2800	2800	200	200	120	120	200	200
41	2400	2000	200	440	120	120	0	0
42	2000	1600	200	200	400	200	0	0
43	3000	1700	0	0	0	0	0	0
44	1400	1400	150	150	200	200	0	0
45	1500	1400	0	0	200	200	0	0
46	800	1200	0	0	100	150	0	0
47	1600	1600	100	100	150	150	0	0
48	1200	400	200	0	0	0	0	0
49	800	1200	200	200	150	150	0	0
50	1200	1200	80	80	0	0	560	280
51	1000	1000	400	320	120	120	120	0
52	800	800	400	400	0	0	120	120
53	0	40	320	320	0	0	320	40
54	40	1000	0	0	0	0	0	50
55	1000	800	0	0	0	0	80	80
56	2000	2000	800	800	200	120	280	80
57	1600	1500	300	300	150	150	0	0
58	1000	1200	200	200	0	0	0	0
59	0	1200	0	200	0	200	0	0
60	1200	1200	200	200	500	100	0	0
61	2000	1400	200	200	0	0	0	0
62	400	600	100	200	0	0	0	0
63	600	1000	100	100	150	150	0	0
64	1000	1000	40	40	0	0	0	50
65	1680	1680	480	480	280	280	280	280
66	600	600	160	160	120	120	80	80
67	1200	1200	120	200	160	160	0	0
68	1000	1000	400	200	320	120	0	0
69	1000	1000	280	280	0	0	0	0
70	600	1080	200	200	120	120	0	0
71	1400	1400	120	320	0	0	40	0
72	1200	800	400	400	0	0	120	120
73	880	880	0	0	0	0	0	0
74	1120	1240	80	480	80	80	0	0
75	600	800	80	80	80	80	0	0
76	1200	1200	80	320	0	0	0	0
77	600	600	160	640	200	200	0	0
78	200	500	50	100	40	40	0	40
79	800	800	0	0	0	100	0	0
80	1600	1200	0	0	0	0	0	50

Annex-3(b): Production and Consumption of Four Major Cereals (Non-biogas Households)

S.N..	Paddy Produced	Paddy Consume	Maize Produced	Maize Consume	Wheat Produced	Wheat Consume	Millet Produced	Millet Consume
1	2000	2000	80	80	200	200	0	0
2	2800	2400	1400	800	600	200	0	0
3	1600	1400	160	360	0	10	0	0
4	1800	1400	240	160	400	40	0	0
5	4000	1600	200	200	400	160	0	50
6	2400	1600	80	80	480	240	0	0
7	2000	1200	400	400	600	80	0	0
8	5000	3200	400	400	280	280	0	0
9	1200	1600	40	40	280	120	0	0
10	2000	2000	120	120	200	80	0	0
11	400	1600	80	80	0	20	100	100
12	1600	2000	400	500	200	200	500	400
13	800	1200	80	200	30	100	30	30
14	400	1200	200	200	50	50	320	300
15	400	300	120	120	0	0	125	125
16	500	500	250	250	0	10	160	160
17	700	700	400	400	160	160	0	0
18	1200	1200	200	200	120	120	240	200
19	1000	2000	400	400	100	100	90	90
20	40	1000	80	150	0	0	120	100
21	2800	1600	800	400	280	80	0	0
22	850	850	100	100	100	100	0	0
23	7500	1600	300	300	0	0	0	0
24	1200	1200	1600	800	0	25	0	0
25	2400	1600	600	400	0	0	0	0
26	1200	1200	50	50	0	0	0	0
27	3200	1200	400	200	1200	80	0	0
28	800	800	0	50	0	0	0	0
29	4000	2000	1000	100	0	0	0	0
30	1200	1200	400	400	0	25	0	0
31	400	600	50	50	0	0	250	250
32	400	1400	1000	1000	0	0	300	200
33	800	800	125	125	0	0	90	90
34	800	1200	0	480	0	40	0	0
35	0	600	480	480	0	0	200	350
36	1400	1200	300	325	0	0	125	80
37	1800	1000	400	320	250	160	500	100
38	700	1400	300	500	120	200	0	100
39	440	500	125	125	160	160	0	0
40	550	550	50	50	80	80	0	0

Annex-4
Information on Plant Feeding

Information on Plant Feeding _

ID	Name of Plant Owner	District	Pt. Size (m3)	Available Dung (Theoretical) (Kg)	Dung Collected (Kg)	Dung Fed (Kg)	Water Fed (Ltr)	Dung Water Ratio	Feeding Required (Kg)	% Feeding	Dung Collected from Outside	Latrine Attached
1	Ganesh Acharya	Morang	4	20	39.26	35.17	36.7	0.96	30	117.23	Yes	No
2	Sashi P. Siwakoti	Morang	4	0	4.76	4.57	4.49	1.02	30	15.23	Yes	Yes
3	Nabin Adhikari	Morang	4	100	9.18	8.6	13.64	0.63	30	28.67	No	Yes
4	Tikaram Chapagain	Morang	4	0	19.94	18.72	19	0.99	30	62.40	Yes	Yes
5	Ram Devi Dahal	Morang	4	20	1.64	1.63	1.52	1.07	30	5.43	No	Yes
6	Netra P. Neupane	Morang	6	15	40.86	40.15	41.4	0.97	45	89.22	Yes	No
7	Durgadevi Katuwal	Morang	6	24	24.99	22.11	23.33	0.95	45	49.13	No	Yes
8	Lalit Tamang	Morang	6	20	19.65	18.33	21.07	0.87	45	40.73	No	Yes
9	Tara Nath Chapagai	Morang	6	27	37.23	32.75	34.6	0.95	45	72.78	No	No
10	Yam Nath Mahatara	Morang	6	60	38.62	34.85	41.22	0.85	45	77.44	No	No
11	Dinesh Khanal	Morang	8	43	28.15	25.34	26.21	0.97	60	42.23	No	No
12	Purna B. Shrestha	Morang	8	89	63.94	59.33	58.97	1.01	60	98.88	No	No
13	Dambar B. Shrestha	Morang	8	72	42.83	42.19	42.74	0.99	60	70.32	No	Yes
14	Hari P. Dahal	Morang	8	45	46.73	46.73	47.49	0.98	60	77.88	No	No
15	Pushpa Lal Acharya	Morang	8	20	42.59	39.05	39.54	0.99	60	65.08	Yes	Yes
16	Pushpa Timsina	Morang	10	0	9.51	8.4	10.66	0.79	75	11.20	Yes	Yes
17	Bishnu Shrestha	Morang	10	39	38.1	33.5	52.51	0.64	75	44.67	No	Yes
18	Bisheshwor Dhakal	Morang	10	53	41.32	39.23	40.17	0.98	75	52.31	No	No
19	Tilak P. Dhakal	Morang	10	32	51	50.79	52.79	0.96	75	67.72	Yes	No
20	Harischandra Acharya	Morang	10	75	60.63	60.41	57.78	1.05	75	80.55	No	No
21	Mithu Sharma	Syangja	4	18	20.5	19.89	27.8	0.72	24	82.88	No	Yes
22	Tulsi Roka	Syangja	4	35	36.78	32.34	32.95	0.98	24	134.75	No	No
23	Rudra B. Roka	Syangja	4	44	39.27	35.52	35.81	0.99	24	148.00	No	Yes
24	Chhetra B. Roka	Syangja	4	42	37.37	29.41	30.65	0.96	24	122.54	No	Yes
25	Suman Raj Giri	Syangja	4	28	28.33	24.3	25.77	0.94	24	101.25	No	No
26	Dhan Bdr. Roka	Syangja	6	42	40.1	36.96	38.12	0.97	36	102.67	No	No

ID	Name of Plant Owner	District	Pt. Size (m3)	Available Dung (Theoretical) (Kg)	Dung Collected (Kg)	Dung Fed (Kg)	Water Fed (Ltr)	Dung Water Ratio	Feeding Required (Kg)	% Feeding	Dung Collected from Outside	Latrine Attached
27	Min B. Khadka	Syangja	6	87	39.89	38.97	39.67	0.98	36	108.25	No	Yes
28	Rupa Roka	Syangja	6	59	39.89	30.86	30.86	1.00	36	85.72	No	No
29	Man B. Roka	Syangja	6	47	39.69	30.08	33.74	0.89	36	83.56	No	Yes
30	Dil Bdr. Roka	Syangja	6	42	36.79	31.48	31.85	0.99	36	87.44	No	No
31	Hum Nath Padhya	Syangja	8	105	27.81	32.2	20.34	1.58	48	67.08	No	Yes
32	Hum Bdr. Thapa	Syangja	8	47	38.68	31.57	32.55	0.97	48	65.77	No	No
33	Dil Bdr. Thapa	Syangja	8	81	41.37	32.24	35.41	0.91	48	67.17	No	No
34	Ganesh B. Thapa	Syangja	8	42	37.73	34.94	35.54	0.98	48	72.79	No	No
35	Dil Kumari Timilsina	Syangja	8	45	33.52	14.1	39.1	0.36	48	29.38	No	Yes
36	Tarapati Sharma	Syangja	10	30	38.76	38.36	34.52	1.11	60	63.93	Yes	Yes
37	Ram B. Adhikari	Syangja	10	32	42.78	41.29	43.66	0.95	60	68.82	Yes	Yes
38	Tilak Ram Shrestha	Syangja	10	32	34.54	14.76	53.49	0.28	60	24.60	No	No
39	Khinapadam Devkota	Syangja	10	20	41.09	39.17	39.33	1.00	60	65.28	Yes	No
40	Keshav Raj Neupane	Syangja	10	74	45.95	46.46	45.09	1.03	60	77.43	No	No
41	Saligram Adhikari	Chitwan	10	76	55.79	52.68	59.71	0.88	75	70.24	No	No
42	Tanka P. Dhamala	Chitwan	10	94	69.6	69.24	61.12	1.13	75	92.32	No	Yes
43	Tulasi Ram Kandel	Chitwan	8	43	56.29	55.43	56.36	0.98	60	92.38	Yes	No
44	Sita Ram Karki	Chitwan	8	51	52.46	52.28	50.98	1.03	60	87.13	No	Yes
45	Goma Baniya	Chitwan	4	0	29.52	25.7	32.73	0.79	30	85.67	Yes	Yes
46	Narayan Adhikari	Chitwan	10	42	41.05	40.9	41.79	0.98	75	54.53	No	No
47	Tirtha Raj Paudel	Chitwan	6	20	39.81	30.07	31.36	0.96	45	66.82	Yes	Yes
48	Shyam P. Upadhyaya	Chitwan	4	20	30.08	26.57	24.22	1.10	30	88.57	Yes	Yes
49	Subindra K.C.	Chitwan	4	0	11.64	8.66	9.41	0.92	30	28.87	Yes	Yes
50	Ganesh Bdr. Shrestha	Nuwakot	6	56	43.31	39.82	39.22	1.02	36	110.61	No	No
51	Pushpa Nath Acharya	Nuwakot	8	75	39.5	38.84	39.81	0.98	48	80.92	No	Yes
52	Ramraja Sadula	Nuwakot	10	44	26.68	25.27	29.6	0.85	60	42.12	No	Yes
53	Tej Bdr. Adhikari	Nuwakot	10	39	59.6	59.66	61.47	0.97	60	99.43	Yes	No
54	Pinggong Galanee	Nuwakot	10	20	40.14	36.11	37.2	0.97	60	60.18	Yes	Yes

ID	Name of Plant Owner	District	Pt. Size (m3)	Available Dung (Theoretical) (Kg)	Dung Collected (Kg)	Dung Fed (Kg)	Water Fed (Ltr)	Dung Water Ratio	Feeding Required (Kg)	% Feeding	Dung Collected from Outside	Latrine Attached
55	Khop Maya Dhamala	Nuwakot	10	20	39.77	31.86	30.12	1.06	60	53.10	Yes	Yes
56	Netra Bdr. Chhetri	Nuwakot	10	75	40.07	39.84	40.49	0.98	60	66.40	No	Yes
57	Manjushree Chapagai	Chitwan	10	74	67.95	68	63.1	1.08	75	90.67	No	Yes
58	Chabilal Adhikari	Chitwan	6	42	41.06	38.8	41.83	0.93	45	86.22	No	Yes
59	Prem Pd. Dhamala	Chitwan	6	20	35.18	26.81	28.37	0.95	45	59.58	No	No
60	Madhab Dhungana	Chitwan	6	15	33.63	26.79	32.02	0.84	45	59.53	Yes	Yes
61	Tul Raj Upreti	Chitwan	6	35	25.73	20.97	26.1	0.80	45	46.60	Yes	Yes
62	Harinarayan Adhikari	Chitwan	8	42	41.5	39.11	43.36	0.90	60	65.18	No	No
63	Ram Maya Kandel	Chitwan	8	48	48.96	48.88	65.3	0.75	60	81.47	No	No
64	Dharma Pun	Chitwan	8	35	34.98	26.29	35.49	0.74	60	43.82	No	Yes
65	Surat Bdr. Chitrakar	Nuwakot	6	44	35.17	27.89	28.43	0.98	36	77.47	No	No
66	Ramkrishna Shrestha	Nuwakot	6	42	21.55	21.33	27.8	0.77	36	59.25	No	Yes
67	Bhakta Bdr. Shrestha	Nuwakot	6	46	39.36	38.55	38.92	0.99	36	107.08	No	No
68	Raj Kumar Jung Shah	Nuwakot	6	42	41.22	40.67	41.47	0.98	36	112.97	No	No
69	Paban Kumari Acharya	Nuwakot	8	45	43.79	40.95	45.21	0.91	48	85.31	No	Yes
70	Bhadra B. Pyakurel	Nuwakot	8	28	42.87	41.48	44.36	0.94	48	86.42	Yes	No
71	Sitaram Pyakurel	Nuwakot	8	39	39.66	34.67	37.55	0.92	48	72.23	No	No
72	Gopal Acharya	Nuwakot	8	15	32.35	29.12	29.49	0.99	48	60.67	Yes	No
73	Gopal Malakar	Nuwakot	4	30	28.82	26.5	28.67	0.92	24	110.42	No	Yes
74	Hari Bdr. Adhikari	Nuwakot	4	24	24.61	23.05	32.71	0.70	24	96.04	No	Yes
75	Gopal Shrestha	Nuwakot	4	35	36.14	32	36.84	0.87	24	133.33	No	No
76	Mukti Nath Gautam	Nuwakot	4	15	32.45	27.06	27.28	0.99	24	112.75	Yes	No
77	Khadka B. Adhikari	Nuwakot	4	35	39.67	29.77	34.66	0.86	24	124.04	No	Yes
78	Dil Bdr. Tamang	Chitwan	4	0	21.23	18.52	25.66	0.72	30	61.73	Yes	Yes
79	Nanda Pd. Rijal	Chitwan	4	34	31.67	29.13	32.45	0.90	30	97.10	No	Yes
80	Krishna Bdr. Gurung	Chitwan	10	50	32.8	23.86	41.61	0.57	75	31.81	No	No
Average			**7**	**40**	**36.87**	**33.37**	**36.33**	**0.92**	**47**	**74.62**		

Annex-5
Production of Biogas based upon Burning Hours of Lamp of Stove

Average Gas Production Based upon Stove & Lamp Burning Hour

Shrawan

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:24	2:35	2:38	1:18	2:30	0:14	0:00	0:00	0:19	0:08	1055	775	790	438	770
6	2:44	3:04	3.14	3:08	3:02	0:18	0:00	0:00	0:16	0:08	865	920	970	980	930
8	3:28	3:46	3:52	3:37	3:41	0:00	0:00	0:00	0:00	0:00	1010	1130	1160	1085	1105
10	4:15	4:17	3:34	4:32	4:09	2:28	0:11	0:00	0:00	0:27	1645	1313	1070	1360	1313
Total	3:21	3:25	3:20	3:10	3:19	0:30	0:02	0:00	0:08	0:10	1080	1030	1000	970	1020

Bhadra

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:37	2:28	2:22	1:18	2:11	0:15	0:00	0:00	0:28	0:10	823	740	710	460	680
6	2:29	2:48	3:22	2:40	2:50	0:17	0:00	0:00	0:21	0:09	788	840	1010	853	873
8	3:49	3:21	3:46	3:36	3:38	0:00	0:00	0:00	0:00	0:00	1145	1005	1130	1080	1090
10	4:07	4:20	3:55	4:14	4:09	1:33	0:09	0:00	0:00	0:18	1468	1323	1175	1270	1290
Total	3:04	3:14	3:21	2:57	3:09	0:22	0:02	0:00	0:12	0:09	975	975	1005	915	968

Aswin

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:16	2:26	2:26	1:12	2:20	0:09	0:00	0:00	0:24	0:08	1003	730	730	420	720
6	2:27	2:50	3:00	2:32	2:42	0:28	0:00	0:00	0:26	0:13	805	850	900	825	843
8	3:36	3.47	3:50	3:11	3:36	0:00	0:00	0:00	0:00	0:00	1080	1135	1150	955	1080
10	3:14	4:31	3:55	3:57	3:58	1:05	0:10	0:00	0:00	0:13	1133	1380	1175	1185	1223
Total	3:06	3:23	3:18	2:43	3:07	0:19	0:02	0:00	0:12	0:08	978	1020	990	845	955

Kartik

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:59	2:29	2:16	1:13	2:14	0:00	0.00	0:00	0:27	0:06	895	745	680	433	685
6	2:20	2:54	3.45	2:11	2:48	0:36	0:00	0:00	0:15	0:12	790	870	1125	693	870
8	2:29	4:00	3:32	3:19	3:20	0.00	0:00	0:00	0:00	0:00	745	1200	1060	995	1000
10	3:20	4:44	3:37	4:23	4:06	1:05	0:12	0:00	0:00	0:14	1163	1450	1085	1315	1265
Total	2:46	3:32	3:18	2:47	3:06	0:18	0:03	0:00	0:10	0:08	875	1068	990	860	950

Mangshir

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:17	2:37	2:29	0:51	2:15	0:10	0:00	0:00	0:32	0:10	1010	785	745	335	700
6	2:26	2:42	3:25	2:00	2:38	0:18	0:00	0:00	0:07	0:06	775	810	1025	617.5	805
8	3:02	4:03	3:01	3:04	3:18	0:00	0:00	0:00	0:00	0:00	910	1215	905	920	990
10	3:34	4:17	3:19	5:03	4:06	1:12	0:14	0:00	0:00	0:16	1250	1320	995	1515	1270
Total	3:18	3:25	3:03	2:45	3:08	0:18	0:03	0:00	0:09	0:07	1035	1032.5	915	847.5	957.5

Poush

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:29	2:14	2:30	1:05	2:04	0:09	0:00	0:00	0:22	0:07	767.5	670	750	380	637.5
6	2:22	2:32	3:01	2:06	2:30	0:19	0:00	0:00	0:00	0:04	757.5	760	905	630	760
8	2:27	3:33	3:02	2:59	3:00	0:00	0.00	0:00	0:00	0:00	735	1065	910	895	900
10	3:11	3:41	3:17	4:34	4:03	1:55	0:14	0:00	0:00	0:17	1242.5	1140	985	1370	1257.5
Total	2:43	3:15	2:58	2:41	2:54	0:20	0:03	0:00	0:05	0:06	865	982.5	890	817.5	885

Magh

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:12	2:08	2:13	1:09	2:07	0:07	0:00	0:00	0:20	0:06	677.5	640	665	395	650
6	2:06	2:17	2:56	1.50	2:25	0:12	0:00	0:00	0:03	0:03	660	685	880	557.5	732.5
8	2:07	3:05	2:57	3:07	3:04	0:00	0:00	0:00	0:00	0:00	635	925	885	935	920
10	3:29	4:18	3:05	3:31	3:37	0:26	0:13	0:00	0:00	0:07	1110	1322.5	925	1055	1102.5
Total	2:47	2:57	2:55	2:24	2:46	0:08	0:03	0:00	0:05	0:04	855	892.5	875	732.5	840

Falgun

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:22	2:05	2:20	1:15	2:08	0:18	0:00	0:00	0:29	0:11	755	625	700	447.5	667.5
6	2:38	2:24	3:15	2:02	2:35	0:17	0:00	0:00	0:02	0:04	832.5	720	975	615	785
8	3:19	2:51	2:56	3:14	3:05	0:00	0:00	0:00	0:00	0:00	995	855	880	970	925
10	3:52	4:06	3:07	4:02	3:46	0:38	0:09	0:00	0:00	0:14	1255	1252.5	935	1210	1165
Total	3:07	2:51	2:55	2:38	2:52	0:18	0:02	0:00	0:08	0:07	980	860	875	810	877.5

Chaitra

Plant Size	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
Cum	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:22	2:02	2:35	1:31	2:12	0:10	0:00	0:00	0:00	0:02	1035	610	775	455	665
6	2:49	2:34	2:59	2:11	2:31	0:07	0:00	0:00	0:04	0:04	862.5	770	895	665	765
8	3:16	3:00	3:07	3:52	3:23	0:00	0:00	0:00	0:00	0:00	980	900	935	1160	1015
10	2:38	4:56	3:58	4:07	4:13	0:22	0:07	0:00	0:00	0:07	845	1497.5	1190	1235	1282.5
Total	3:01	3:08	2:55	2:50	2:58	0:06	0:01	0:00	0:10	0:04	920	942.5	875	875	900

Baisakh

Plant Size Cum	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:09	1:57	2:11	0:55	2:03	0:22	0:00	0:00	0:19	0:10	1000	585	655	323	640
6	2:28	2:48	3:37	2.08	2:45	0:00	0:00	0:00	0:07	0:02	740	840	1085	658	831
8	3:27	3:43	3:03	3:36	3:27	0:00	0:00	0:00	0:00	0:00	1035	1115	915	1080	1036
10	2:47	4:54	3:50	3:58	3:52	0:31	0:10	0:00	0:00	0:10	913	1495	1150	1190	1186
Total	2:58	3:20	3:10	2:54	3:06	0:11	0:03	0:00	0:06	0:06	918	1008	950	385	945

Jestha

Plant Size Cum	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:12	1:59	2:18	0:55	2:06	0:13	0:00	0:00	0:40	0:13	993	595	690	375	663
6	2:20	2:47	3:42	2:20	2:47	0:00	0:00	0:00	0:14	0:03	700	835	1110	735	844
8	3:10	4:09	2:53	3:51	3:30	0.00	0:00	0:00	0:00	0:00	950	1245	865	1155	1054
10	3:18	4:30	3:02	4:11	3:45	0:06	0:11	0.00	0:00	0:04	1005	1378	910	1255	1136
Total	2:58	3:21	2:59	2:50	3:02	0:05	0:03	0:00	0:13	0:05	903	1013	895	883	923

Ashad

Plant Size Cum	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	2:55	1:57	2:06	0:56	1:58	0:19	0:00	0:00	0:38	0:13	923	585	630	375	625
6	2:31	2:48	3:38	2:19	2:49	0:00	0:00	0:00	0:12	0:03	755	840	1090	725	853
8	3:06	3:52	3:25	3:22	3:26	0:00	0:00	0:00	0.08	0:02	930	1160	1025	1030	1036
10	2:49	4:08	2:56	4:15	3:32	0:26	0:01	0:00	0:00	0:06	910	1243	880	1275	1075
Total	2:50	3:11	3:01	2:43	2:57	0:11	0:00	0:00	0:14	0:06	878	955	905	850	900

Whole Year

Plant Size Cum	Average Stove Burning Hours				Total	Average Light Burning Hours				Total	Total Quantity of Gas Use (Lit.)				Total
	Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang		Syangja	Chitwan	Nuwakot	Morang	
4	3:02	2:15	2:22	1:07	2:10	0:11	0:00	0:00	0:28	0:09	938	675	710	405	673
6	2:31	2:43	3:22	2:18	2:43	0:14	0:00	0:00	0.11	0:06	790	815	1010	718	830
8	3:11	3:36	3:17	3:23	3:22	0:00	0.00	0:00	0:00	0:00	955	1080	985	1015	1010
10	3:19	4:28	3:19	4:14	3:51	0:40	0:10	0:00	0:00	0:11	1095	1365	995	1270	1183
Total	3:00	3:15	3:05	2:50	3:02	0:16	0:02	0:00	0:10	0:07	940	980	925	875	928

Annex-6

Gas Production based upon Burning Hours, Meter Reading and Dung-fed

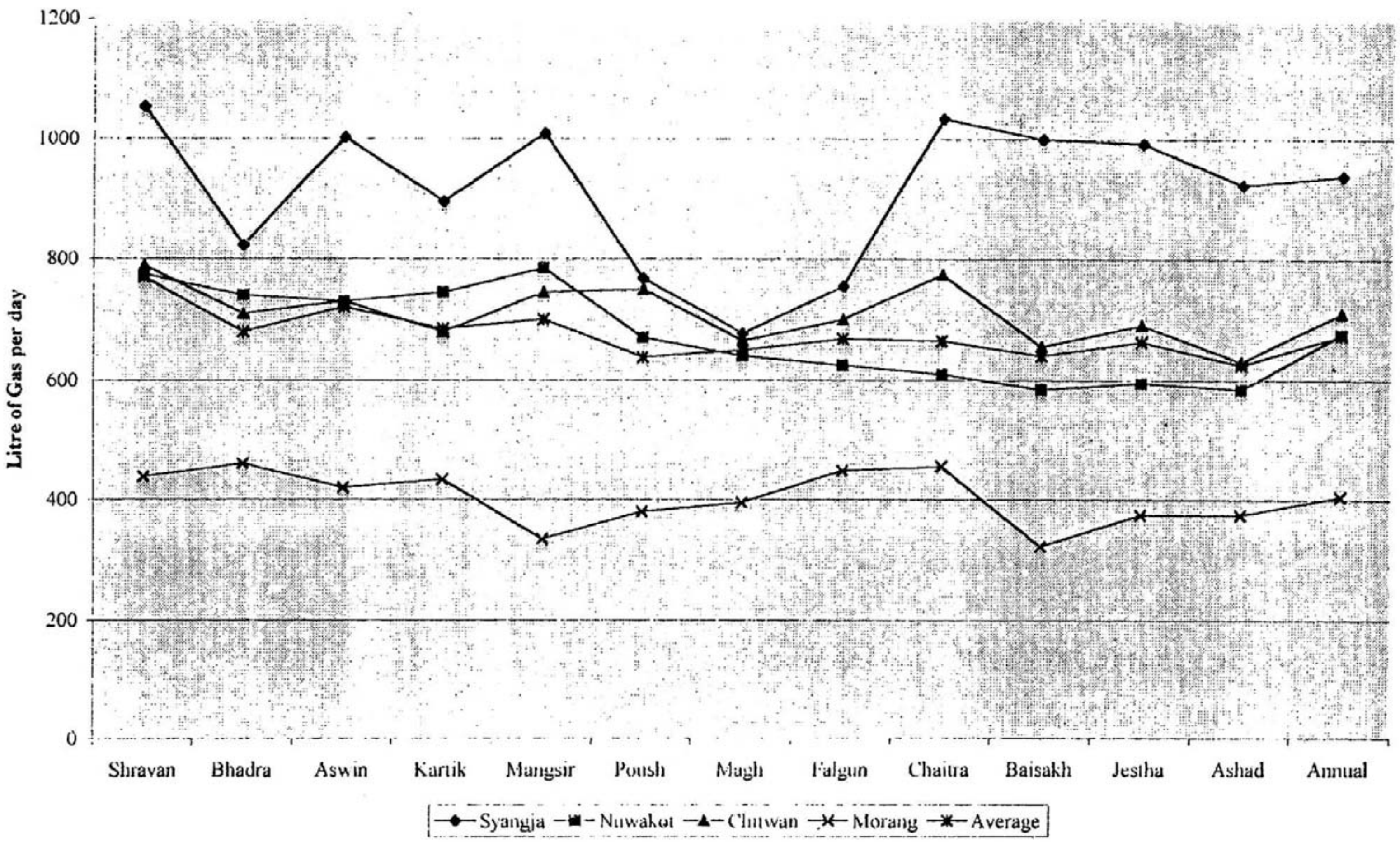
Gas Production based upon Burning Hours, Meter Reading and Dung-fed

ID	Name of Plant Owner	District	Pt. size	Gas Production (Litre)				Toilet Attached	Plant Efficiency	
				Therotical Production	As per Burning Hr	As per Meter Reading	As per Dung-fed		As per Burnig Hr. & Th. Prod.	As per Burning Hr. & Dung-fed
1	Ganesh Acharya	Morang	4	1200	758	575	1407	No	63.19	53.90
2	Sashi P. Siwakoti	Morang	4	1200	583	239	183	Yes	48.61	319.11
3	Nabin Adhikari	Morang	4	1200	317	250	344	Yes	26.41	92.12
4	Tikaram Chapagain	Morang	4	1200	463	153	749	Yes	38.61	61.88
5	Ram Devi Dahal	Morang	4	1200	292	321	65	Yes	24.31	447.35
6	Netra P. Neupane	Morang	6	1800	951	758	1606	No	52.82	59.20
7	Durgadevi Karuwal	Morang	6	1800	642	587	884	Yes	35.65	72.55
8	Lalit Tamang	Morang	6	1800	772	544	733	Yes	42.87	105.25
9	Tara Nath Chapagai	Morang	6	1800	490	558	1310	No	27.22	37.40
10	Yam Nath Maharara	Morang	6	1800	1337	943	1394	No	74.26	95.89
11	Dinesh Khanal	Morang	8	2400	1103	537	1014	No	45.94	108.77
12	Purna B. Shrestha	Morang	8	2400	1628	1687	2373	No	67.81	68.58
13	Dambar B. Shrestha	Morang	8	2400	1095	1268	1688	Yes	45.63	64.89
14	Hari P. Dahal	Morang	8	2400	916	1151	1869	No	38.16	49.00
15	Pushpa Lal Acharya	Morang	8	2400	1178	860	1562	Yes	49.10	75.44
16	Pushpa Timsina	Morang	10	3000	700	488	336	Yes	23.33	208.33
17	Bishnu Kumari Shrestha	Morang	10	3000	2123	1374	1340	Yes	70.78	158.46
18	Bisheshwor P. Dhakal	Morang	10	3000	1336	1223	1569	No	44.53	85.13
19	Tilak P. Dhakal	Morang	10	3000	1540	1376	2032	No	51.33	75.80
20	Harishchandra Acharya	Morang	10	3000	1703	1680	2416	No	56.78	70.49
21	Mithu Sharma	Syangja	4	864	613	500	796	Yes	70.89	76.99
22	Tulsi Roka	Syangja	4	864	731	550	1294	No	34.59	56.50
23	Rudra B. Roka	Syangja	4	864	1546	784	1421	Yes	178.92	108.80
24	Chhetra B. Roka	Syangja	4	864	1353	827	1176	Yes	156.54	114.97
25	Suman Raj Giri	Syangja	4	864	939	322	972	No	108.70	96.62
26	Dhan Bdr. Roka	Syangja	6	1296	595	475	1478	No	45.91	40.25
27	Min B. Khadka	Syangja	6	1296	1430	921	1559	Yes	110.34	91.74
28	Rupa Roka	Syangja	6	1296	1038	726	1234	No	80.12	84.12
29	Man B. Roka	Syangja	6	1296	788	643	1203	Yes	60.76	65.45
30	Dil Bdr. Roka	Syangja	6	1296	793	389	1259	No	61.21	63.00
31	Hum Nath Padhya	Syangja	8	1728	998	649	928	Yes	57.73	107.49
32	Hum Bdr. Thapa	Syangja	8	1728	1091	841	1263	No	63.13	86.38
33	Dil Bdr. Thapa	Syangja	8	1728	1056	934	1290	No	61.10	81.87
34	Ganesh B. Thapa	Syangja	8	1728	1266	942	1398	No	73.25	90.57
35	Dil Kumari Timilsina	Syangja	8	1728	1173	789	564	Yes	67.85	207.89
36	Tarapati Sharma	Syangja	10	2160	1402	1140	1534	Yes	64.89	91.35
37	Ram B. Adhikari	Syangja	10	2160	1091	858	1652	Yes	50.50	66.05
38	Tilak Ram Shrestha	Syangja	10	2160	659	455	590	No	30.52	111.65
39	Khina Padam Devkota	Syangja	10	2160	1598	972	1567	No	74.00	102.01
40	Keshav Raj Neupane	Syangja	10	2160	1774	1117	1858	No	82.14	95.47
41	Saligram Adhikari	Chitwan	10	3000	1814	1260	2107	No	60.47	86.09
42	Tanka P. Dhamala	Chitwan	10	3000	2018	2069	2770	Yes	67.28	72.87

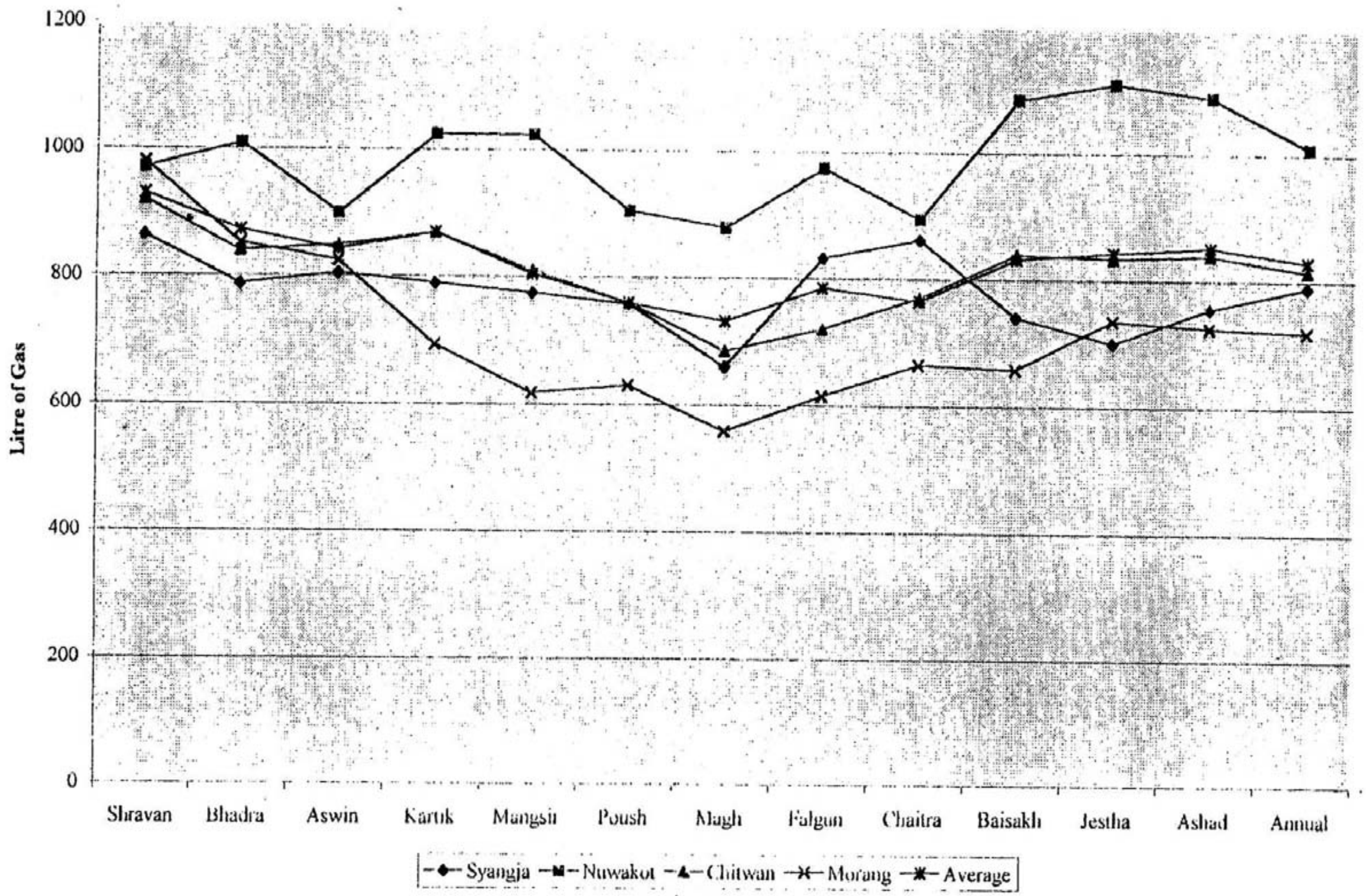
ID	Name of Plant Owner	District	Pt. size	Production				Toilet Attached	Plant Efficiency	
				Therotical Production	As per Burning Hr	As per Meter Reading	As per Dung-fed		As per Burnig Hr. & Th. Prod.	As per Burning Hr. & Dung-fed
43	Tulasi Ram Kandel	Chitwan	8	2400	1750	1620	2217	No	72.92	78.93
44	Sita Ram Karki	Chitwan	8	2400	1517	1914	2091	Yes	63.19	72.53
45	Goma Baniya	Chitwan	4	1200	735	705	1028	Yes	61.25	71.50
46	Narayan Adhikari	Chitwan	10	3000	1293	1091	1636	No	43.11	79.05
47	Tirtha Raj Paudel	Chitwan	6	1800	1412	741	1203	Yes	78.43	117.37
48	Shyam Pd. Upadhyaya	Chitwan	4	1200	700	295	1063	Yes	58.33	65.86
49	Subindra K.C.	Chitwan	4	1200	770	535	346	Yes	64.17	222.29
50	Ganesh Bdr. Shrestha	Nuwakot	6	1296	770	761	1593	No	59.41	48.34
51	Pushpa Nath Acharya	Nuwakot	8	1728	1202	959	1554	Yes	69.54	77.35
52	Ramraja Sadula	Nuwakot	10	2160	1009	750	1011	Yes	46.72	99.84
53	Tej Bahadur Adhikari	Nuwakot	10	2160	1639	1057	2386	No	75.89	68.69
54	Pingjong Galanee	Nuwakot	10	2160	531	437	1444	Yes	24.58	36.75
55	Khop Maya Dhamala	Nuwakot	10	2160	793	385	1274	Yes	36.73	62.25
56	Netra Bdr. Chhetri	Nuwakot	10	2160	1838	1238	1594	Yes	85.07	115.30
57	Manjushree Chapagai	Chitwan	10	3000	1896	1983	2720	Yes	63.19	69.70
58	Chabilal Adhikari	Chitwan	6	1800	828	752	1552	No	46.02	53.37
59	Prem Pd. Dhamala	Chitwan	6	1800	869	779	1072	Yes	48.29	81.05
60	Madhab Dhungana	Chitwan	6	1800	986	763	1072	Yes	54.77	92.00
61	Tul Raj Upreti	Chitwan	6	1800	642	643	839	No	35.65	76.50
62	Hari Narayan Adhikari	Chitwan	8	2400	974	1051	1564	No	40.59	62.27
63	Ram Maya Kandel	Chitwan	8	2400	1003	942	1955	Yes	41.81	51.32
64	Dharma Pun	Chitwan	8	2400	1056	664	1052	No	43.99	100.40
65	Surat Bdr. Chitrakar	Nuwakot	6	1296	1289	964	1116	Yes	99.47	115.56
66	Ram Krishna Shrestha	Nuwakot	6	1296	1202	781	853	No	92.72	140.84
67	Bhakta Bdr. Shrestha	Nuwakot	6	1296	1470	835	1542	No	113.43	95.33
68	Raj Kumar Jung Shah	Nuwakot	6	1296	1143	591	1627	Yes	88.22	70.28
69	Paban Kumari Acharya	Nuwakot	8	1728	1085	955	1638	No	62.79	66.24
70	Bhadra B. Pyakurel	Nuwakot	8	1728	1103	1308	1659	No	63.80	66.45
71	Sita ram Pyakurel	Nuwakot	8	1728	910	1151	1387	No	52.66	65.62
72	Gopal Acharya	Nuwakot	8	1728	1429	904	1165	Yes	82.71	122.70
73	Gopal Malakar	Nuwakot	4	864	869	583	1060	Yes	100.60	82.00
74	Hari Bahadur Adhikari	Nuwakot	4	864	980	588	922	No	113.43	106.29
75	Gopal Shrestha	Nuwakot	4	864	1091	496	1280	No	126.25	85.22
76	Mukti Nath Gautam	Nuwakot	4	864	455	354	1082	Yes	52.66	42.04
77	Khadka B. Adhikari	Nuwakot	4	864	764	718	1191	Yes	88.45	64.17
78	Dil Bdr. Tamang	Chitwan	4	1200	776	602	741	Yes	64.65	104.73
79	Nanda Pd. Rijal	Chitwan	4	1200	951	720	1165	No	79.24	81.60
80	Krishna Bdr. Gurung	Chitwan	10	3000	974	913	954	Yes	32.47	102.07
Average			7	1806	1080	841	1330		59.80	81.17

Annex-7
Graphical Representation of Gas Production

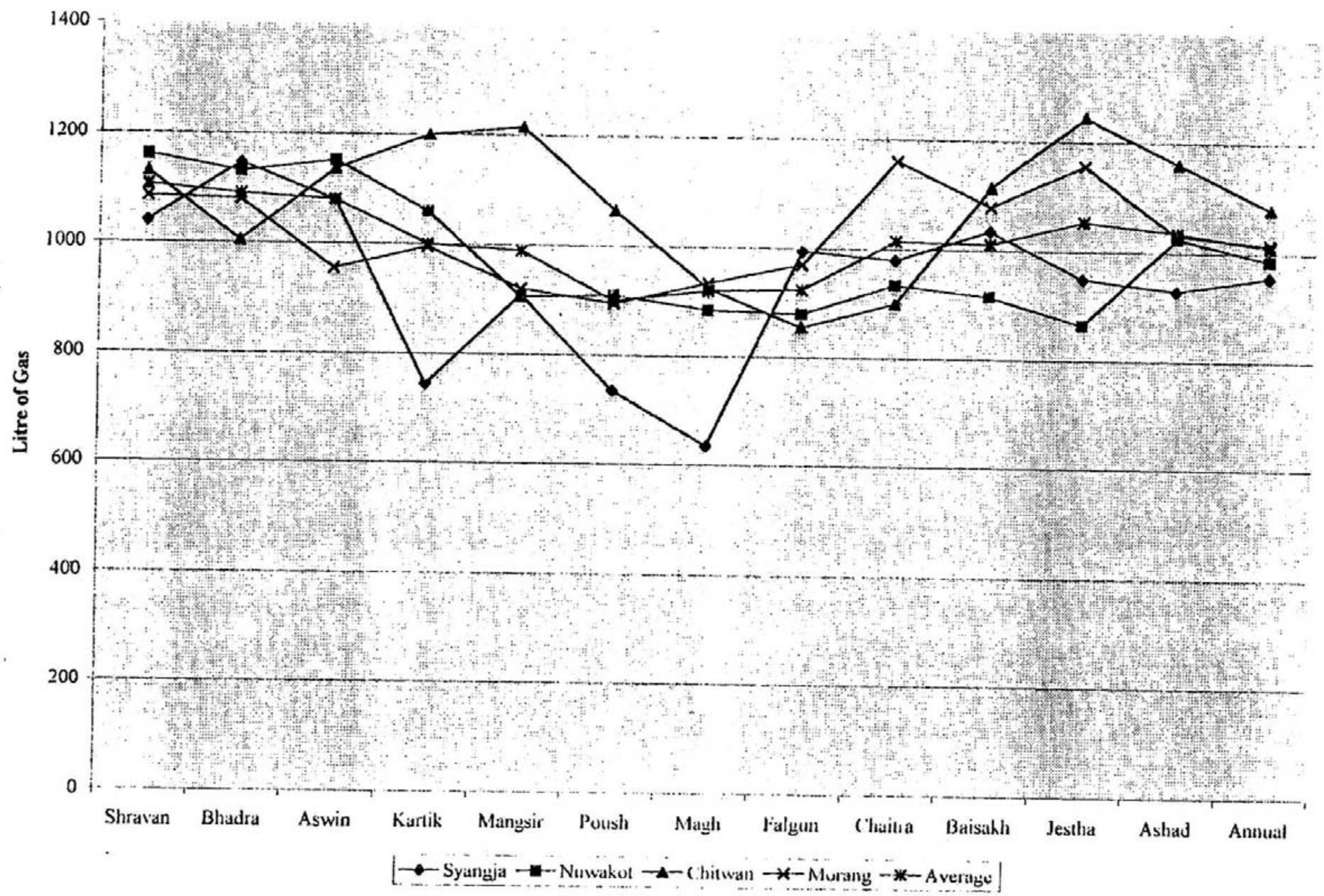
Average Biogas Production – 4 cum Plant



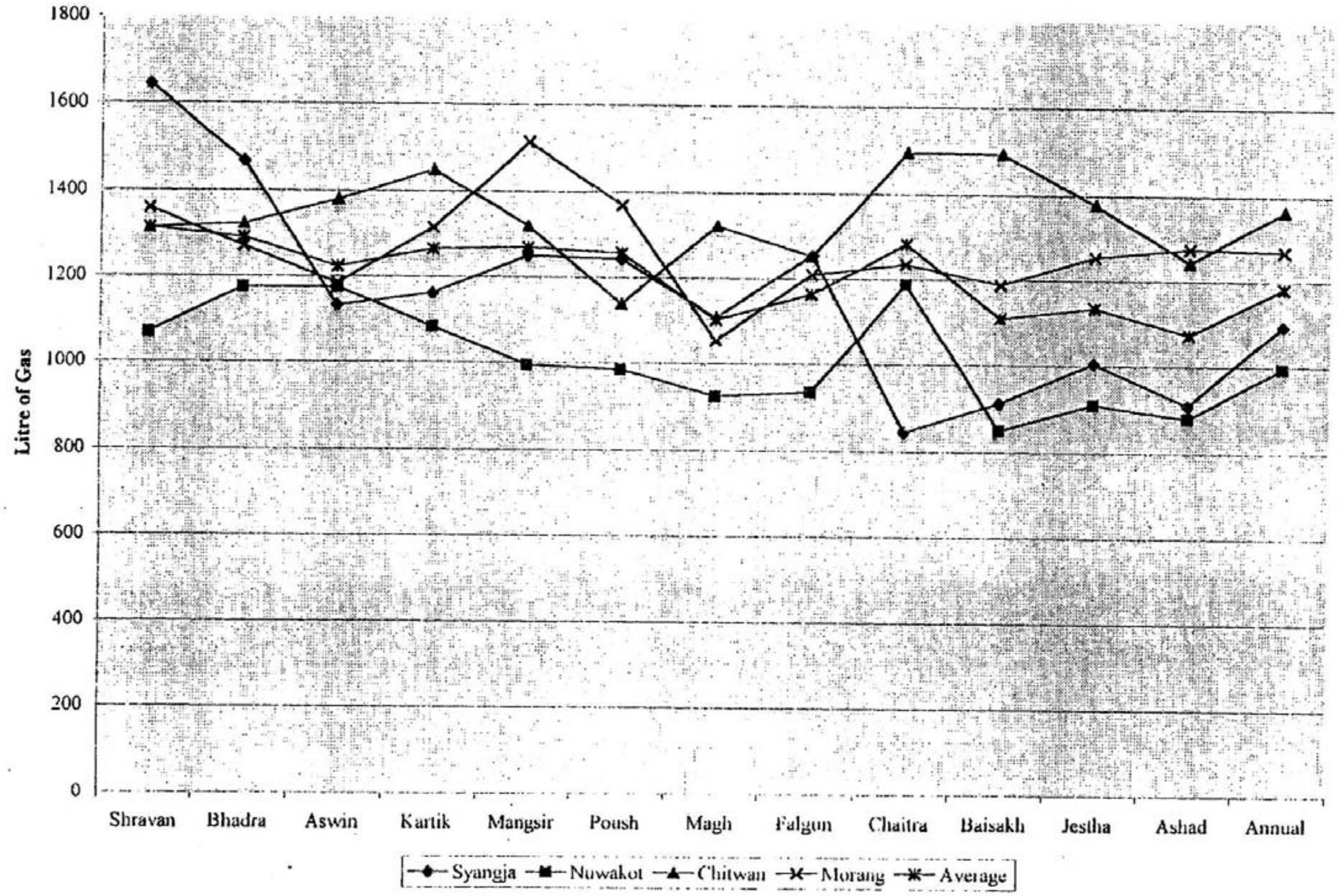
Average Biogas Production – 6 cum Plant



Average Biogas Production – 8 cum Plant



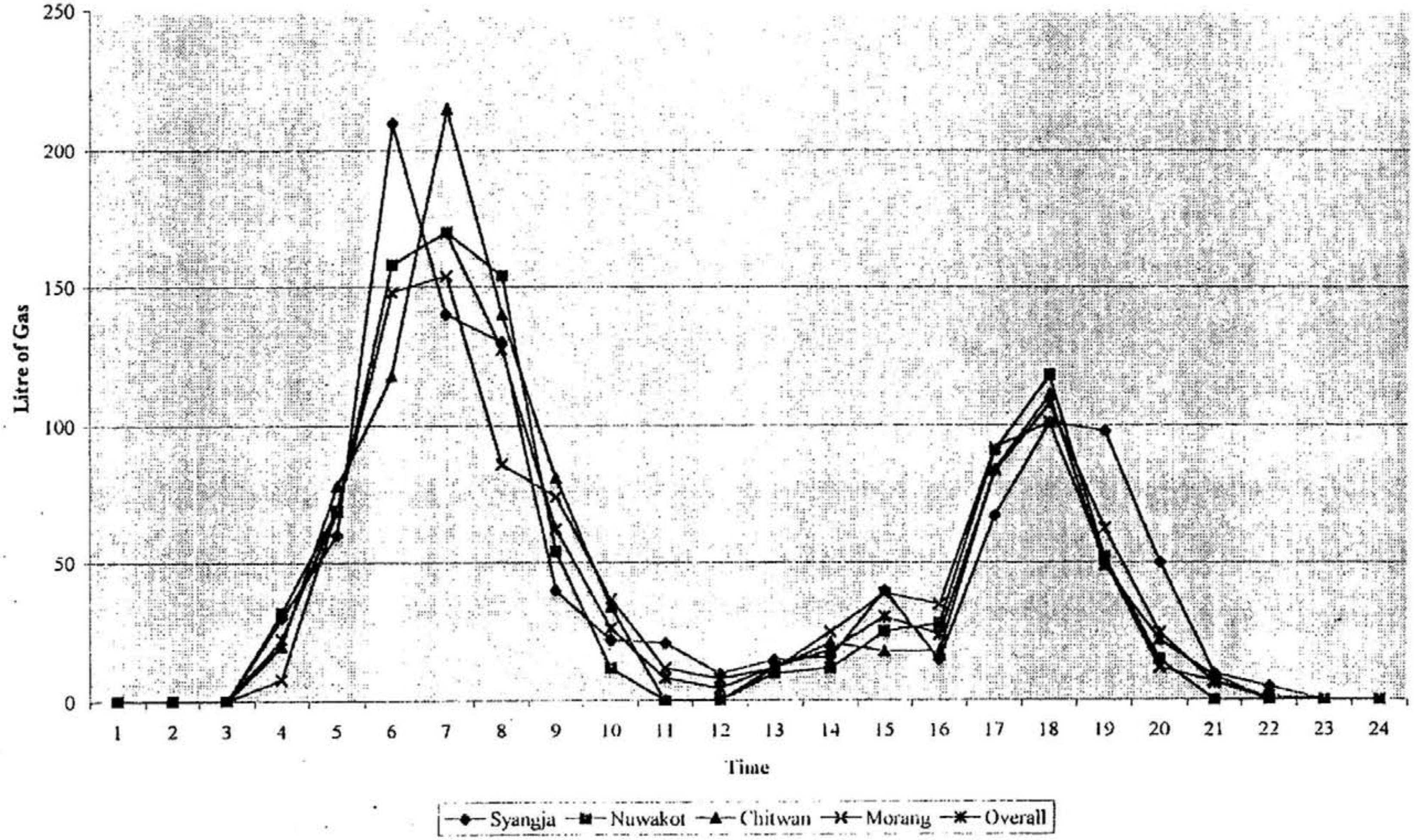
Average Biogas Production – 10 cum Plant



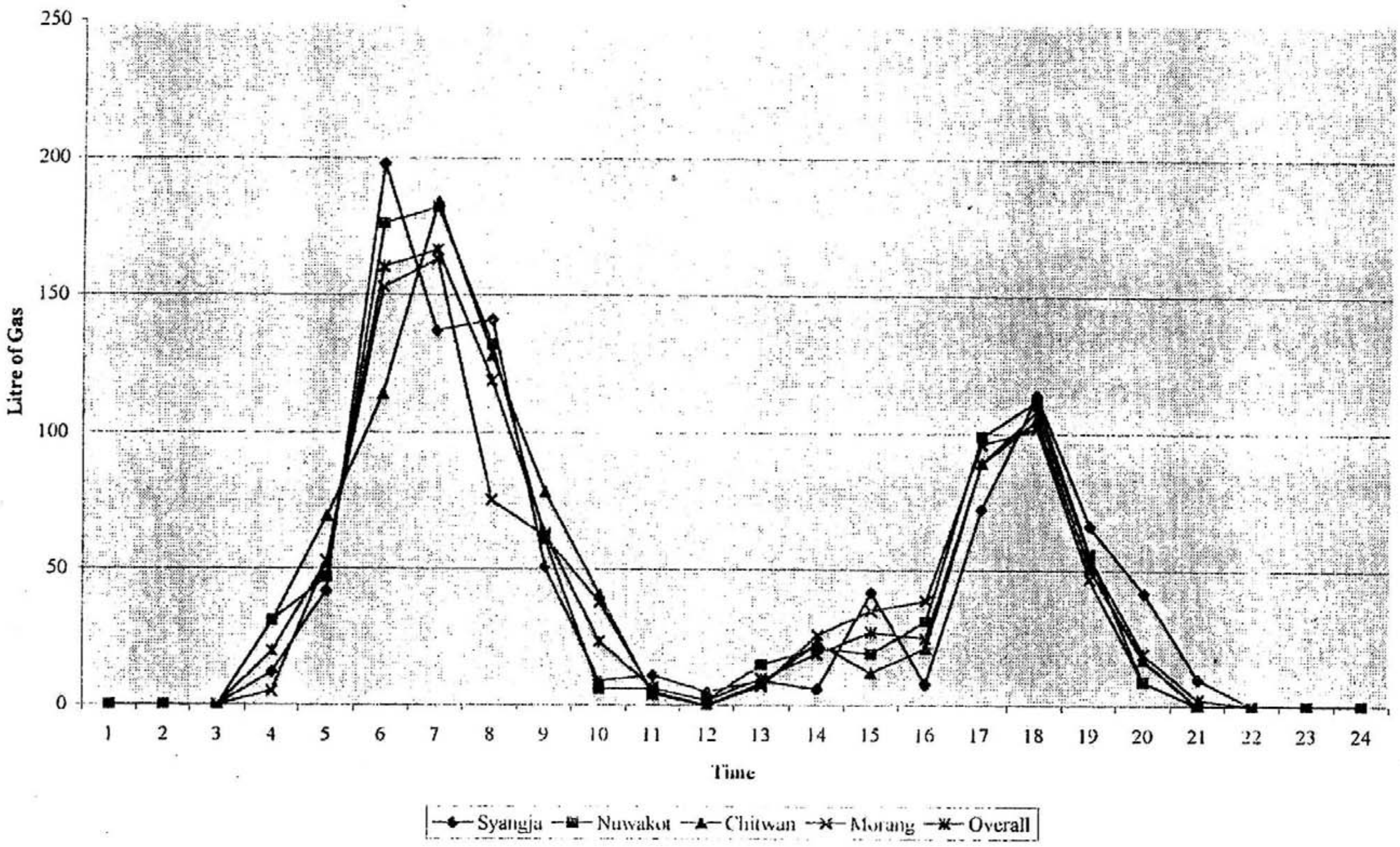
Annex-8

Graphical Representation of Gas Use Pattern

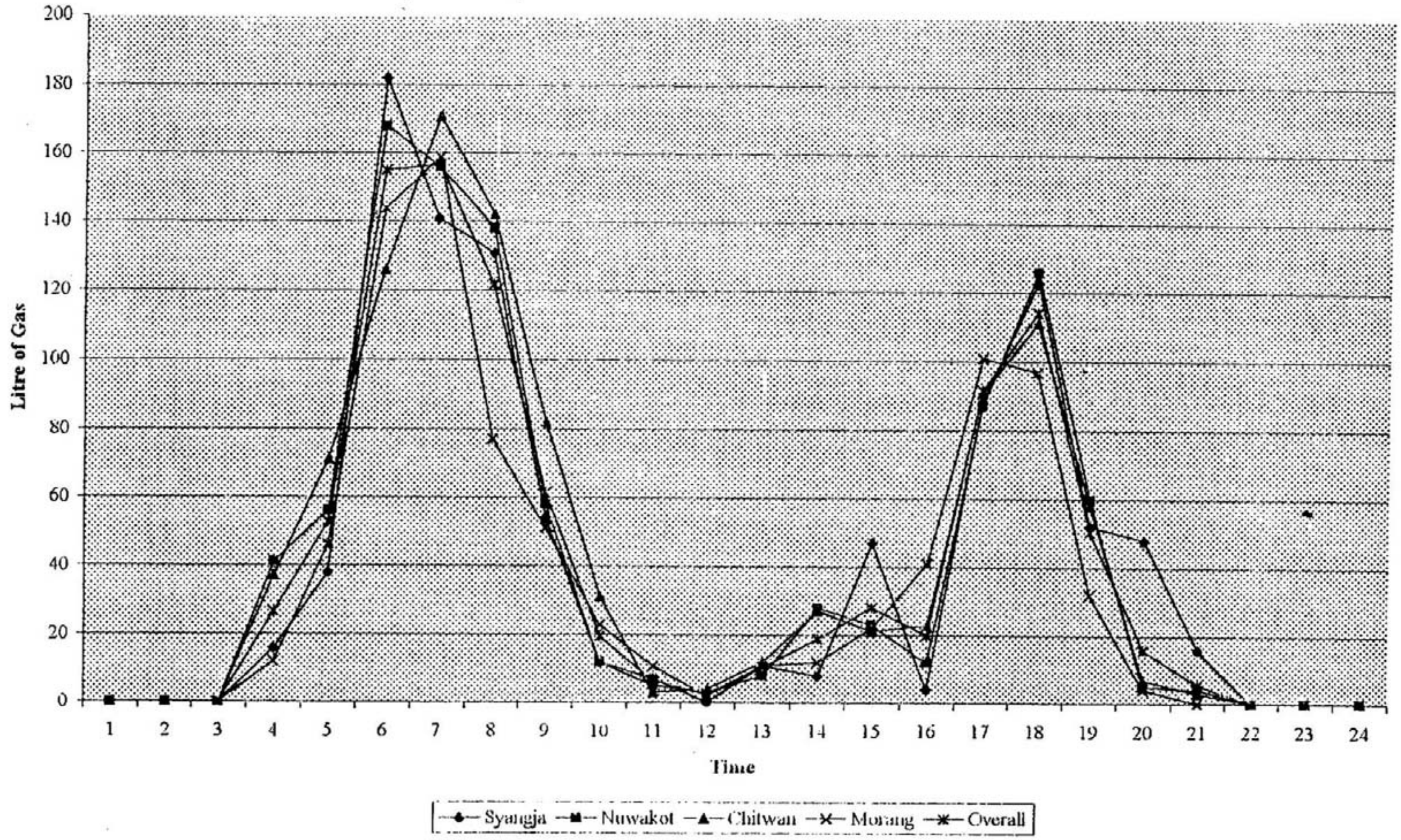
Biogas Use Pattern - Shravan



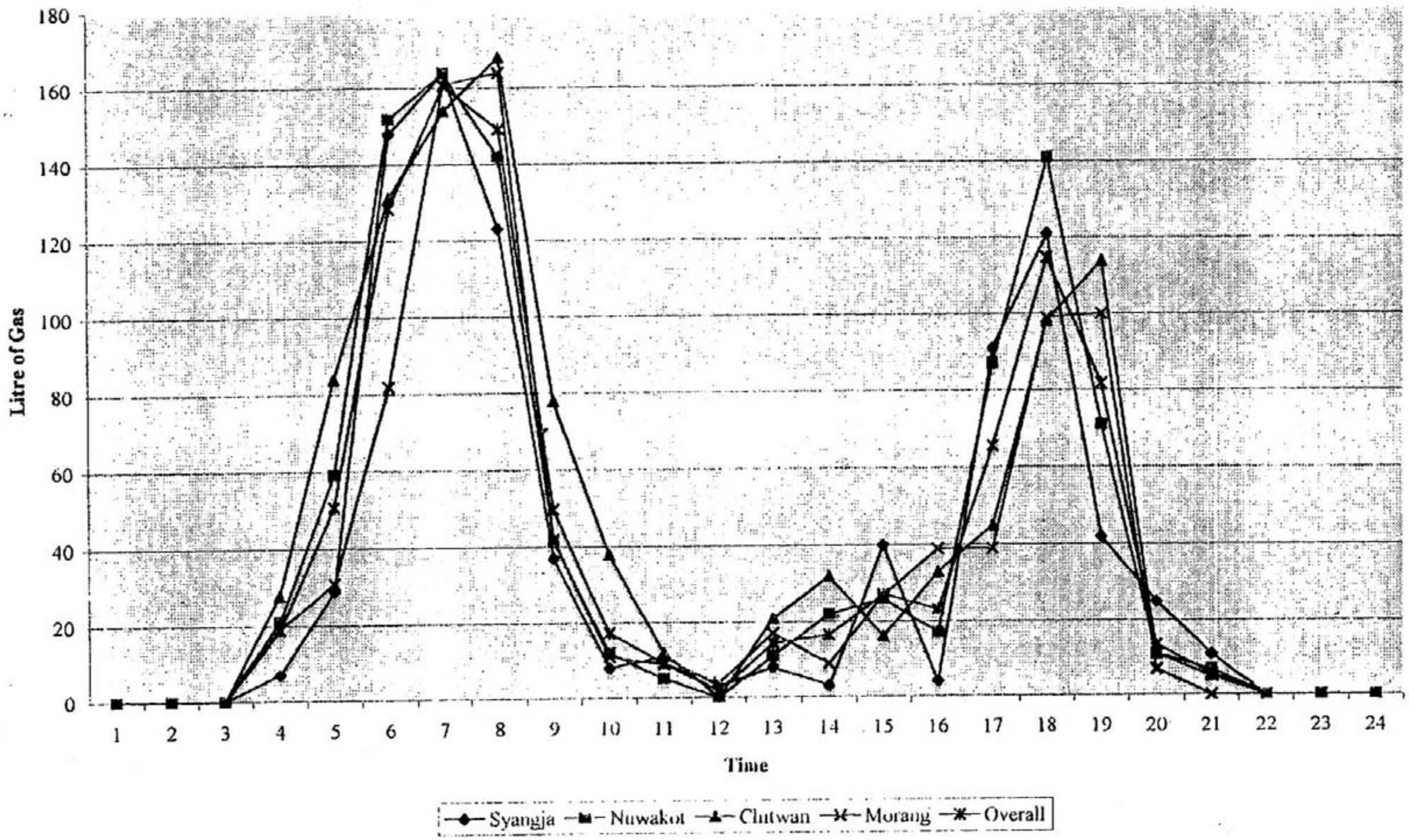
Biogas Use pattern – Bhadra



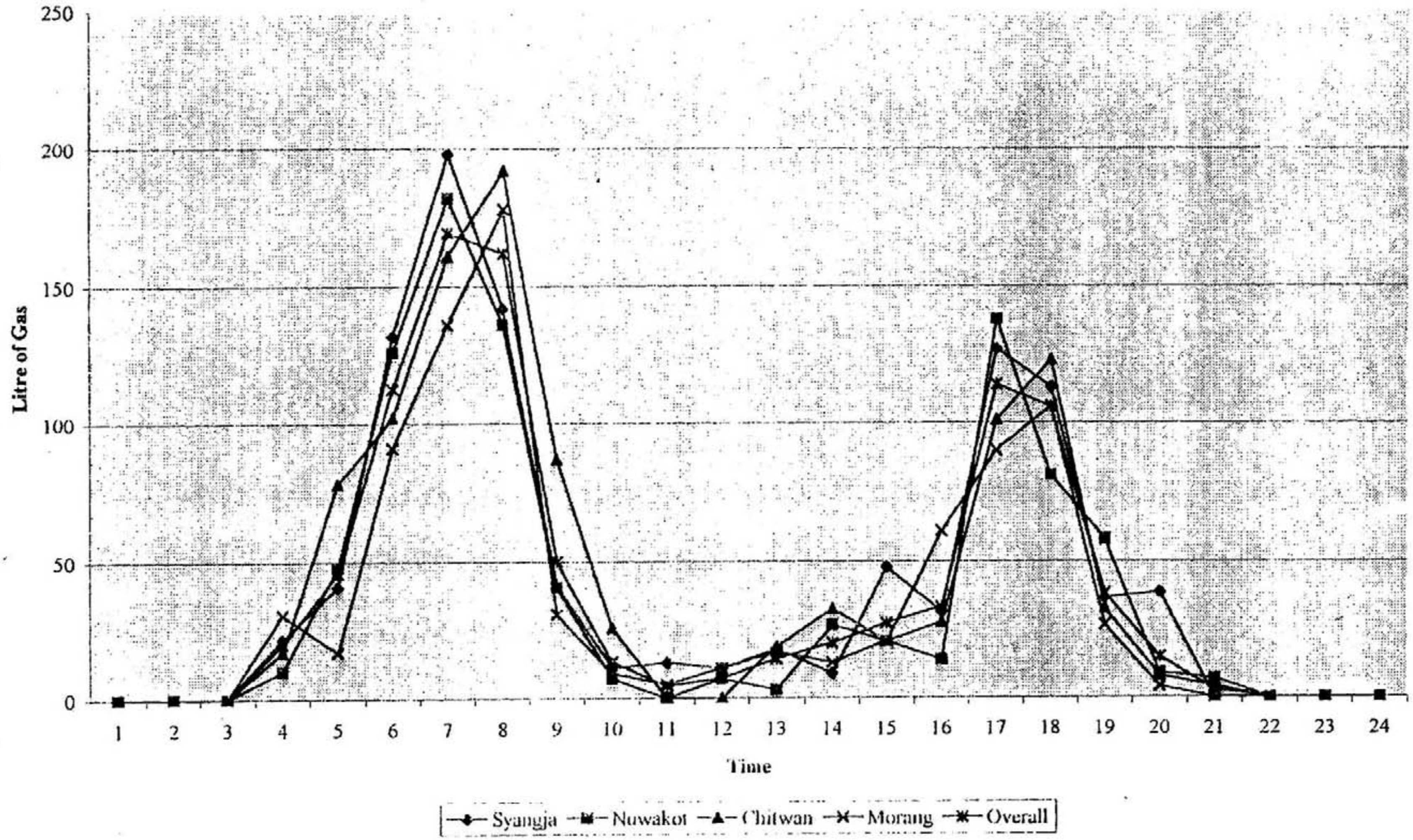
Biogas Use Pattern – Ashwin



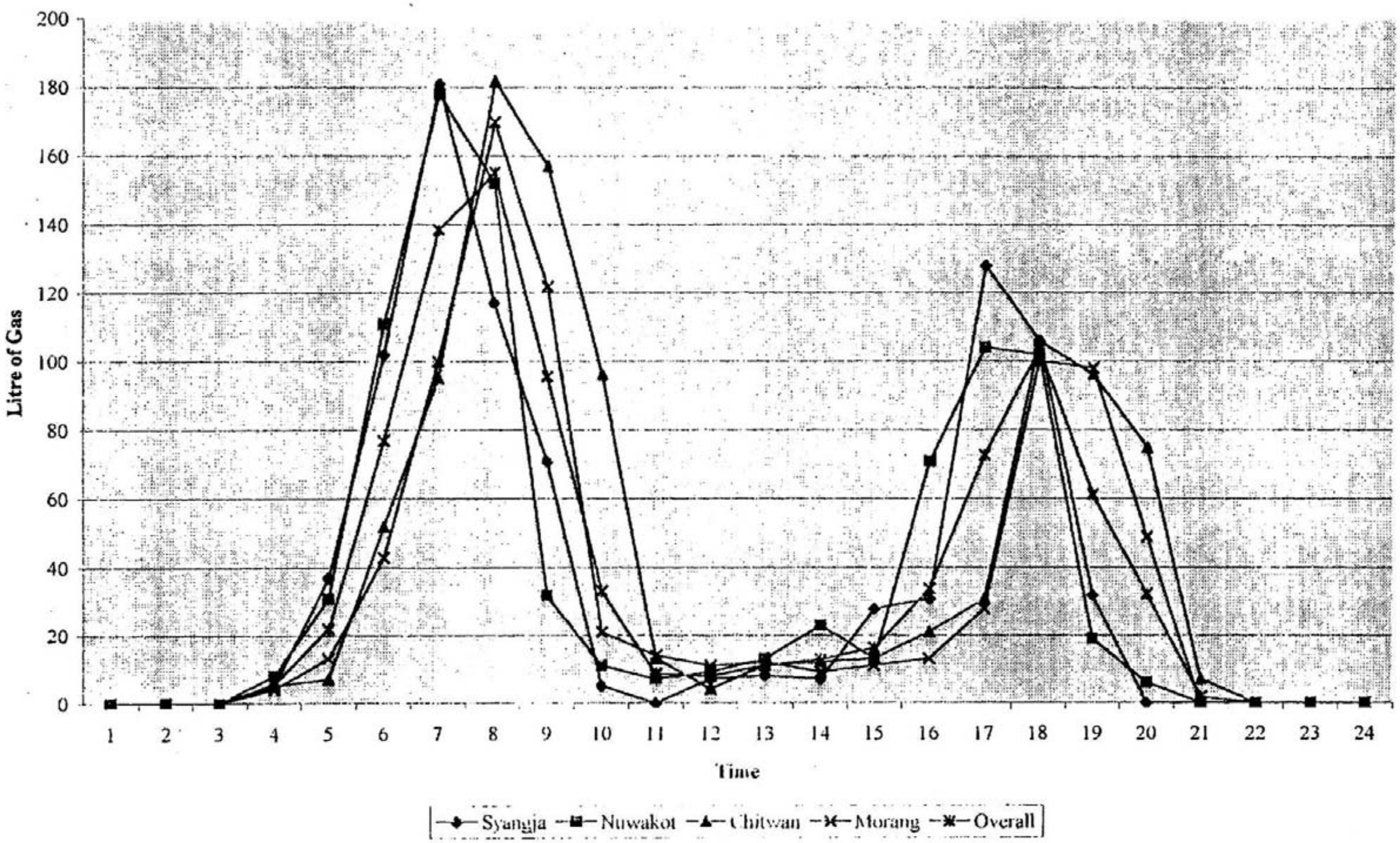
Biogas Use Pattern – Kartik



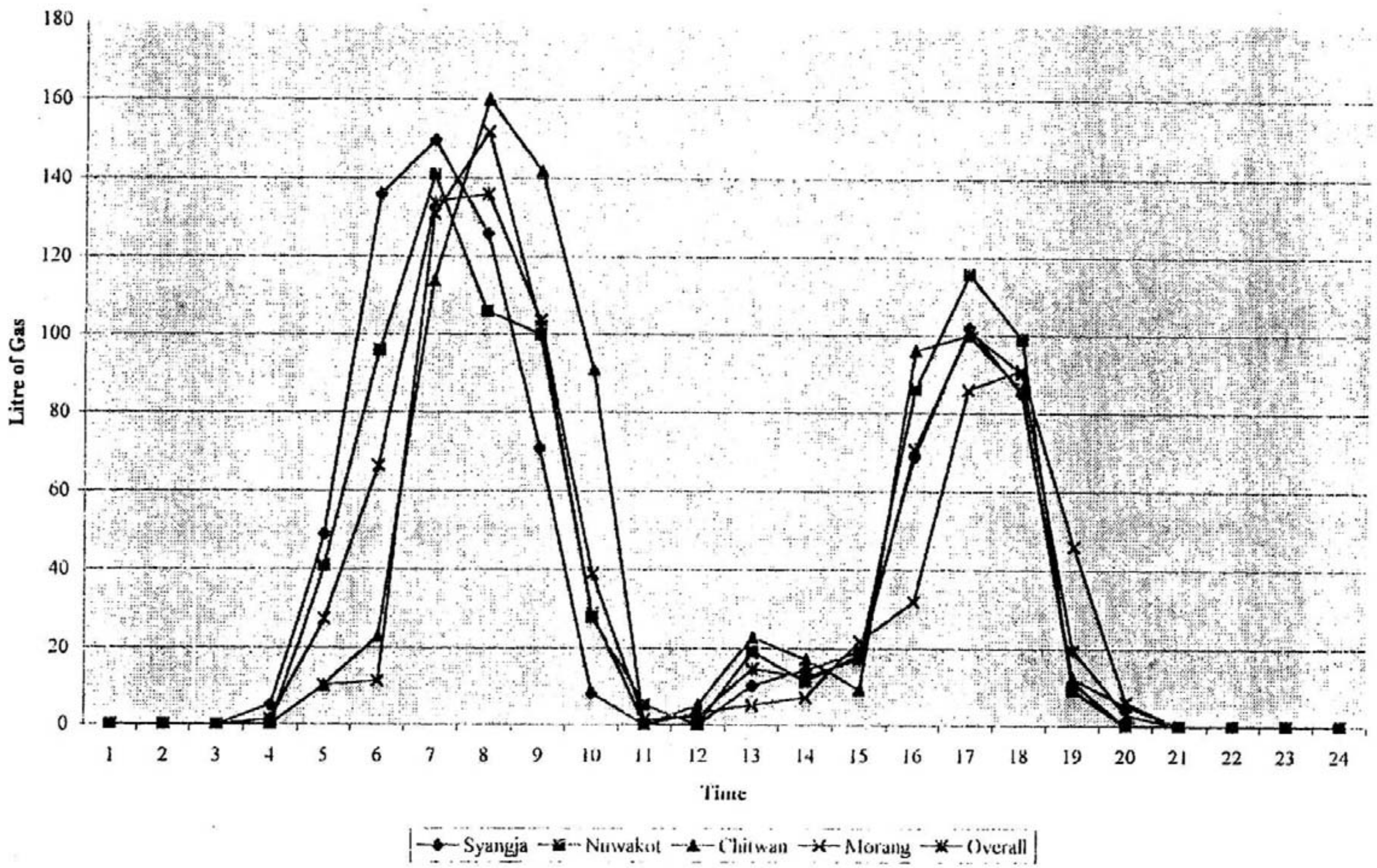
Biogas Use Pattern - Mangshir



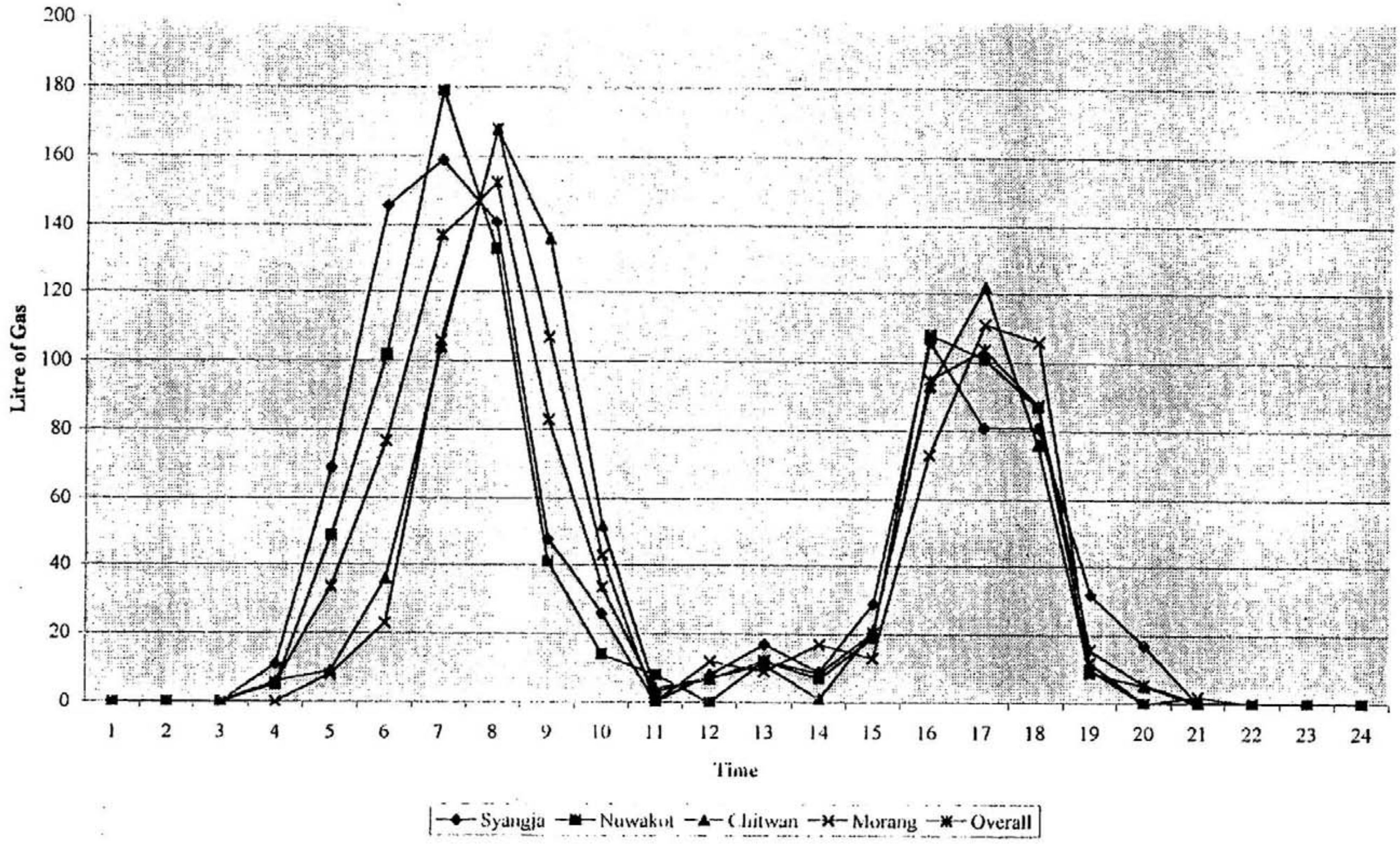
Biogas Use Pattern – Poush



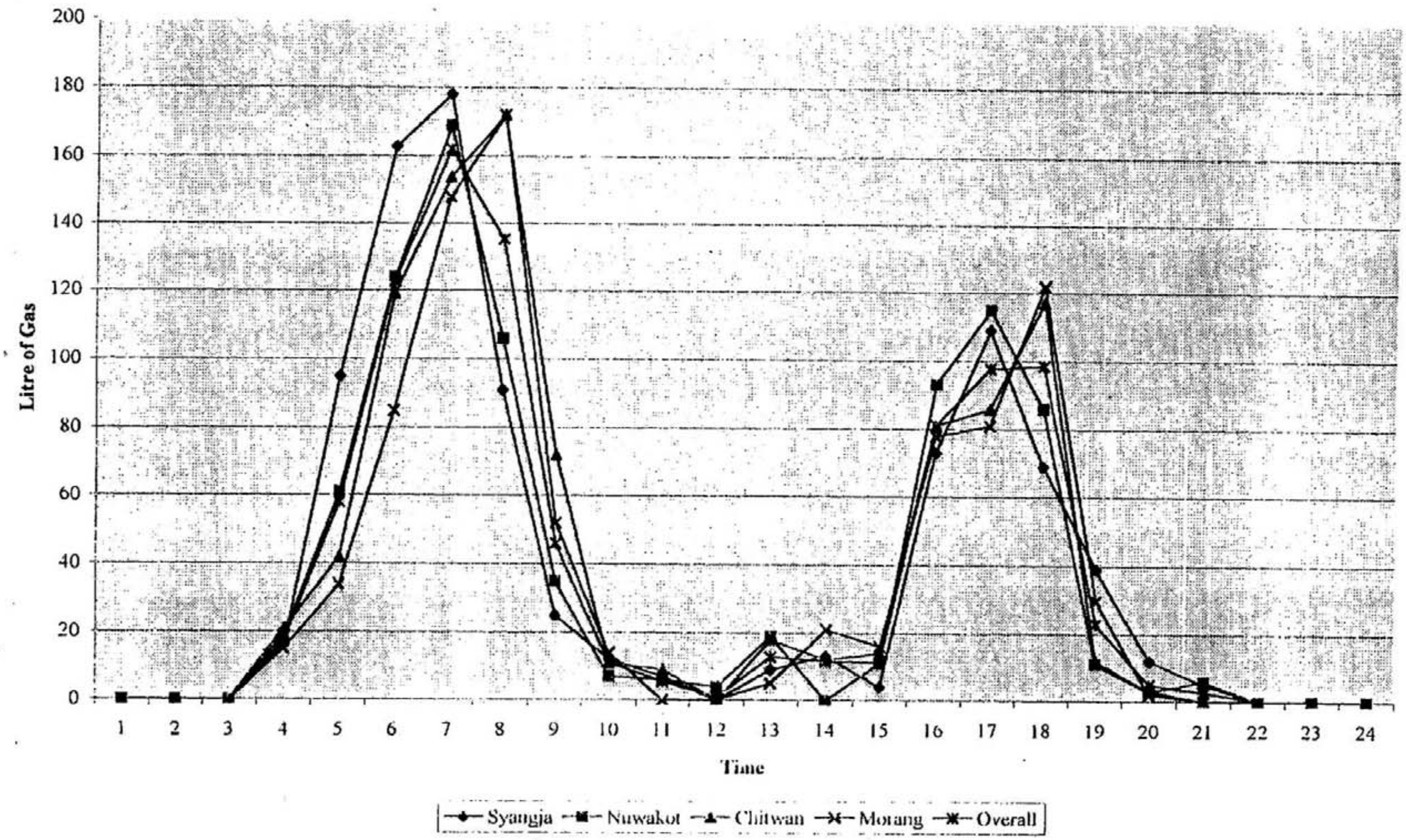
Biogas Use Pattern – Magh



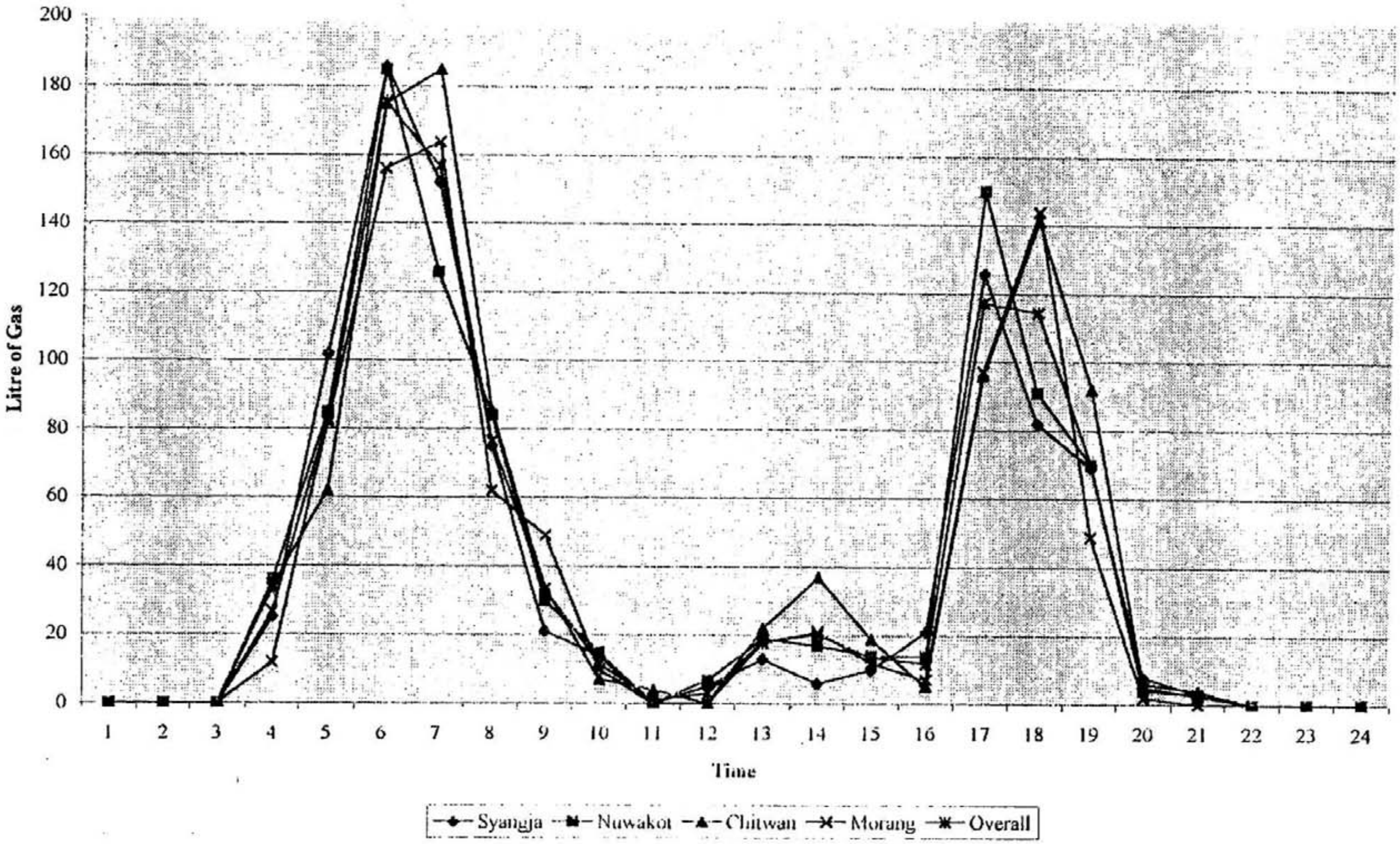
Biogas Use Pattern – Falgun



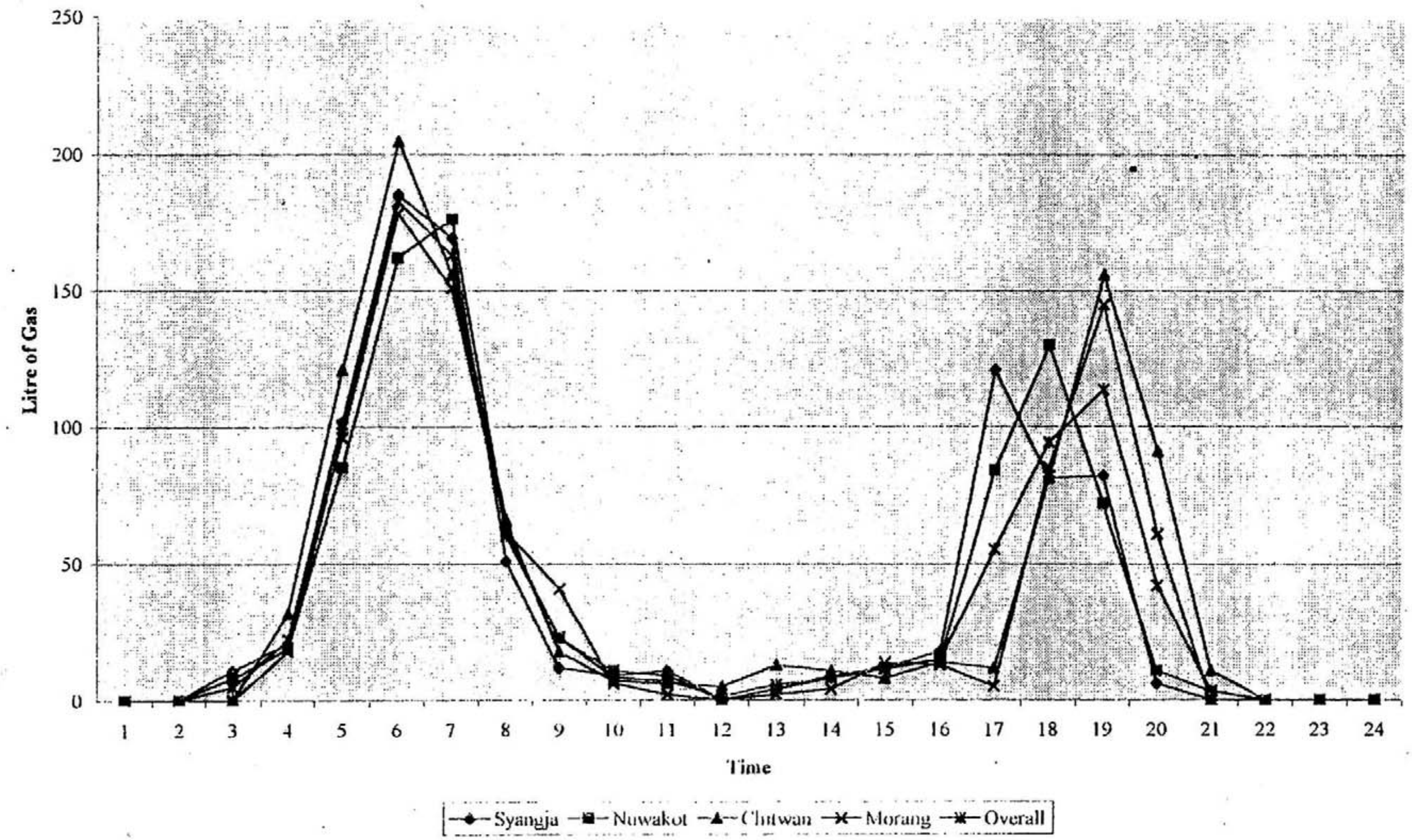
Biogas Use Pattern – Chaitra



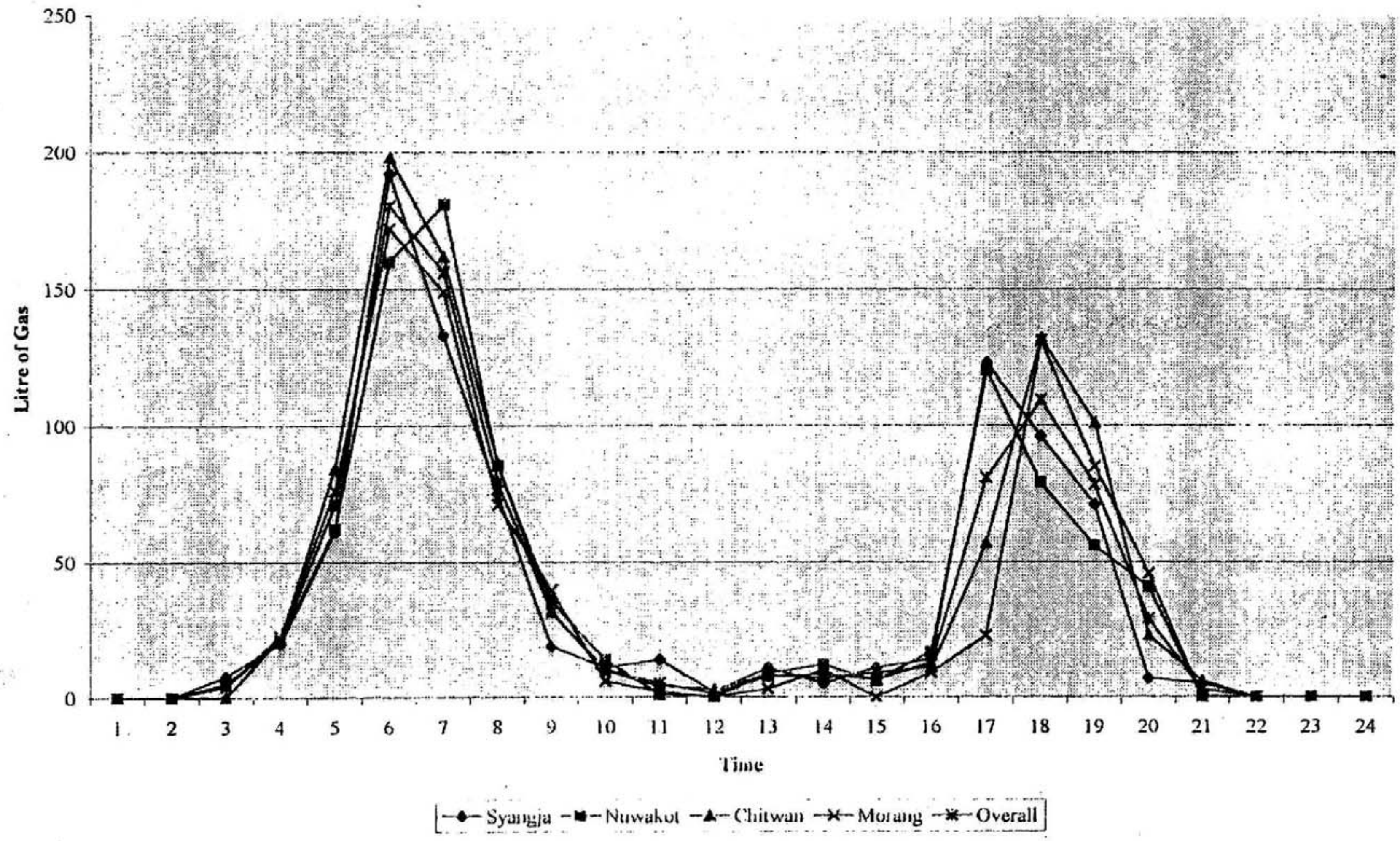
Biogas Use Pattern – Baishakh



Biogas Use Pattern – Jestha



Biogas Use Pattern – Ashad



Annex-9
Conventional Fuels Saving

TRADITIONAL FUEL SAVING AFTER THE INSTALLATION OF BIOGAS PLANT

Month/ District	Cook-Stove (Hr:Min)			Firewood (KG)			Kerocene (millilitre)			Fooder stem (KG)			Dung-cake (KG)			Agri-residue (KG)		
Shravan																		
District	NBH	BH	Saving	NBH	BH	Saving	NBH	BH	Saving	NBH	BH	Saving	NBH	BH	Saving	NBH	BH	Saving
Syangja	4:04	3:31	0:33	11.39	4.98	6.41	201.74	133.38	68.36	1.11	0.35	0.76	0.00	0.00	0.00	0.18	0.05	0.13
Nuwakot	3:53	3:20	0:33	4.86	1.01	3.85	162.89	128.04	34.85	0.13	0.00	0.13	0.24	0.00	0.24	10.33	0.21	10.12
Chitwan	4:15	3:25	0:50	4.49	0.64	3.85	207.89	143.69	64.20	0.03	0.01	0.02	0.31	0.00	0.31	4.63	0.03	4.60
Morang	4:13	3:10	1:03	5.67	0.82	4.85	233.85	60.69	173.16	0.37	0.00	0.37	0.21	0.00	0.21	0.17	0.07	0.10
Average	4:06	3:19	0:47	6.62	1.87	4.75	201.83	116.69	85.14	0.41	0.09	0.32	0.19	0.00	0.19	3.78	0.06	3.72
Bhadra																		
Syangja	4:55	3:04	1:51	11.04	5.05	5.99	149.13	141.47	7.66	0.81	0.31	0.50	0.00	0.00	0.00	0.33	0.30	0.03
Nuwakot	4:16	3:21	0:55	4.51	1.09	3.42	136.17	79.06	57.11	0.05	0.20	-0.15	0.08	0.00	0.08	0.63	0.10	0.53
Chitwan	4:33	3:14	1:19	4.50	1.05	3.45	213.81	119.78	94.03	0.05	0.03	0.02	0.21	0.00	0.21	0.41	0.02	0.39
Morang	4:05	2:57	1:08	5.20	0.99	4.21	181.77	28.46	153.31	0.23	0.04	0.19	0.32	0.00	0.32	0.33	0.09	0.24
Average	4:28	3:09	1:19	6.32	2.05	4.27	170.20	92.36	77.84	0.28	0.14	0.15	0.15	0.00	0.15	0.43	0.13	0.30
Ashwin																		
Syangja	4:56	3:06	1:50	10.93	4.47	6.46	129.68	122.30	7.38	0.92	0.18	0.74	0.00	0.00	0.00	0.15	0.19	-0.04
Nuwakot	4:04	3:18	0:46	5.32	1.10	4.22	212.33	86.43	125.90	0.17	0.21	-0.04	0.11	0.00	0.11	0.74	0.13	0.61
Chitwan	4:34	3:23	1:11	4.60	1.53	3.07	128.04	68.77	59.27	0.03	0.01	0.02	0.45	0.00	0.45	0.64	0.10	0.54
Morang	3:46	2:43	1:03	5.23	1.17	4.06	107.86	50.16	57.70	0.40	0.00	0.40	0.32	0.00	0.32	0.11	0.05	0.06
Average	4:20	3:07	1:13	6.52	2.07	4.45	144.43	81.92	62.51	0.38	0.10	0.28	0.22	0.00	0.22	0.41	0.12	0.29
Kartik																		
Syangja	4:58	2:46	2:12	11.04	4.62	6.42	95.47	123.86	-28.39	1.00	0.28	0.72	0.04	0.00	0.04	0.18	0.34	-0.16
Nuwakot	3:57	3:18	0:39	4.86	1.12	3.74	192.46	40.00	152.46	0.19	0.11	0.08	0.09	0.00	0.09	0.67	0.07	0.60
Chitwan	4:23	3:32	0:51	5.30	1.38	3.92	174.82	85.92	88.90	0.06	0.01	0.05	0.44	0.00	0.44	0.43	0.07	0.36
Morang	3:41	2:47	0:54	4.85	0.94	3.91	107.05	14.17	92.88	0.41	0.11	0.30	0.65	0.00	0.65	0.07	0.07	0.00
Average	4:15	3:06	1:09	6.52	2.01	4.51	142.51	65.76	76.75	0.42	0.13	0.29	0.30	0.00	0.30	0.34	0.14	0.20
Mangshir																		
Syangja	4:33	3:18	1:15	10.68	4.10	6.58	101.26	124.74	-23.48	0.87	0.28	0.59	0.00	0.00	0.00	0.80	0.21	0.59
Nuwakot	3:44	3:03	0:41	4.47	1.01	3.46	120.07	28.50	91.57	0.09	0.06	0.03	0.63	0.00	0.63	1.45	0.05	1.40
Chitwan	4:18	3:25	0:53	4.74	1.55	3.19	113.69	69.83	43.86	0.05	0.03	0.02	0.17	0.00	0.17	0.72	0.31	0.41
Morang	3:50	2:45	1:05	4.68	1.16	3.52	136.62	21.52	115.10	0.46	0.09	0.37	0.26	0.00	0.26	0.49	0.11	0.38
Average	4:06	3:08	0:58	6.14	1.93	4.21	117.91	60.34	57.57	0.37	0.11	0.26	0.26	0.00	0.26	0.86	0.17	0.69

Month/ District	Cook-Stove (Hr:Min)			Firewood (KG)			Kerocene (millilitre)			Fooder-stem (KG)			Dung cake (KG)			Agri-rsidue (KG)		
Poush																		
Syangja	4:29	2:43	1:46	10.84	4.91	5.93	107.97	133.32	-25 35	0.42	0.19	0.23	0.19	0.00	0.19	0.74	0.30	0.44
Nuwakot	3:56	2:58	0:58	4.85	0.58	4.27	140.04	59.17	80 87	0.17	0.10	0.07	0.16	0.00	0.16	1.25	0.08	1.17
Chitwan	4:17	3:15	1:02	4.80	1.35	3.45	160.85	104.13	56 72	0 00	0.03	-0.03	0.36	0.00	0.36	0.85	0.45	0.40
Morang	4:03	2:41	1:22	5.23	1.53	3.70	101.12	29.05	72.07	0.42	0.16	0.26	0.46	0.00	0.46	0.35	0.06	0.29
Average	4:11	2:54	1:17	6.31	2.02	4 29	127.99	80.10	47 89	0 25	0.12	0.13	0.29	0 00	0.29	0.80	0.22	0.58
Magh																		
Syangja	4:14	2:47	1:27	10.35	3.89	6 46	174 00	90.93	83 07	0 60	0.14	0.46	0.04	0.00	0.04	0.40	0.25	0.15
Nuwakot	3:55	2:55	1:00	4.62	1.06	3 56	96.91	24 18	72.73	0.26	0 13	0.13	0.19	0.00	0.19	0.83	0.03	0.80
Chitwan	4:05	2:57	1:08	4.87	1.94	2 93	77.34	68.16	9 18	0 08	0 06	0.02	0.50	0.00	0.50	0.59	0.20	0.39
Morang	3:58	2:24	1:34	5.66	2 42	3.24	88.30	25.86	62 44	0.72	0 17	0.55	0.68	0.00	0.68	0.43	0.00	0.43
Average	4:03	2:46	1:17	6.27	2 29	3 98	107.42	51.31	56 11	0.41	0.12	0.29	0.36	0 00	0.36	0.57	0.11	0.46
Falgun																		
Syangja	4:44	3:07	1:37	9.88	2.69	7.19	176.81	93.73	83.08	0.31	0.03	0.28	0.02	0.00	0.02	0.18	0.23	-0.05
Nuwakot	3:51	2:55	0:56	5.07	0.99	4.08	127.27	40.00	87.27	0.10	0.09	0.01	0.16	0.00	0.16	0.32	0.00	0.32
Chitwan	4:04	2:51	1:13	5.10	1.24	3.86	96.27	57.78	38.49	0.19	0.09	0.10	0.10	0.00	0.10	0.86	0.06	0.80
Morang	3:04	2:38	0:26	4.79	1.70	3.09	174.01	55.09	118 92	0.44	0.10	0.34	0.28	0.00	0.28	0.34	0.00	0.34
Average	4:05	2:52	1:13	6.21	1.63	4.58	143.59	60.79	82 80	0.26	0.08	0.18	0.14	0.00	0.14	0.43	0.07	0.36
Chaitra																		
Syangja	4:32	3:01	1:31	10.05	2.86	7.19	85.69	92.58	-6 89	0.67	0.12	0.55	0 02	0.00	0.02	0.09	0.26	-0.17
Nuwakot	3:42	2:55	0:47	4.53	0.73	3.80	110.53	30.05	80.48	0.20	0.08	0.12	1.00	0.00	1.00	6.62	0.00	6.62
Chitwan	4:10	3:08	1:02	4.51	1.10	3.41	152.98	64.17	88 81	0.05	0.04	0.01	0.49	0.00	0.49	0.36	0.01	0.35
Morang	3:48	2:50	0:58	4.69	0.99	3.70	96.70	20.00	76 70	0.26	0.18	0.08	1.63	1.10	0.53	0.28	0.00	0.28
Average	4:03	2:58	1:05	5.95	1.38	4.57	111.43	50.66	60.77	0.30	0.11	0.19	0.83	0.28	0.55	1.83	0.06	1.77

7

Month/ District	Cook-Stove (Hr:Min)			Firewood (KG)			Kerocene (millilitre)			Fooder-stem (KG)			Dung cake (KG)			Agri-rsidue (KG)		
Baisakh																		
Syangja	4:32	2:58	1:34	10.77	3.58	7.19	157.57	94.00	63 57	0.36	0.05	0.31	0.07	0.00	0.07	0.43	0.19	0.24
Nuwakot	3:49	2:55	0:54	6.16	0.67	5.49	139.03	25.85	113 18	0.20	0.06	0.14	0.18	0.00	0.18	0.36	0.00	0.36
Chitwan	4:11	3:20	0:51	4.46	0.79	3 67	75.45	55.97	19.48	0.07	0.00	0.07	0.36	0.20	0.16	0.77	0.01	0.76
Morang	3:43	2:34	1:09	5.88	0.55	5.33	176.52	40.26	136 26	0.16	0.03	0.13	0.72	0.30	0.42	0.23	0.00	0.23
Average	4:03	2:57	1:06	6.81	1 34	5.47	137.08	53.00	84 08	0.20	0.04	0 16	0.34	0.13	0.21	0.45	0.05	0.40

Month/ District	Cook-Stove (Hr:Min)			Firewood (KG)			Kerocene (millilere)			Fooder-stem (KG)			Dung-cake (KG)			Agri-rsidue (KG)		
Jestha																		
Syangja	4:48	2:58	1:50	9.75	2.52	7.23	221.67	83.28	141 39	0.26	0.03	0 23	0.00	0 00	0.00	0.00	0.09	-0.09
Nuwakot	3:51	2:59	0:52	5.73	0.53	5.20	93.06	19.48	73.58	0.73	0 05	0.68	0.10	0.00	0.10	0.27	0.00	0.27
Chitwan	4:18	3:21	0:57	4.39	0.85	3.54	165.50	63.00	42.50	0.48	0.00	0.48	0.40	0.00	0.40	0.35	0.00	0.35
Morang	3:56	2:50	1:06	4.87	0.37	4.50	86.13	37 16	48.97	0.17	0.02	0.15	0.45	0.00	0.45	0.12	0.00	0.12
Average	4:12	3:02	1:10	6.10	1.03	5.07	124.86	49.93	74 93	0.41	0 02	0.39	0.25	0.00	0.25	0.19	0.02	0.17
Ashad																		
Syangja	4:18	2:50	1:28	11.28	2.95	8.33	246.20	121.39	124.81	0.40	0.00	0.40	0.00	0.00	0.00	0.07	0.08	-0.01
Nuwakot	3:39	3:01	0:38	5.35	0.77	4.58	167.54	10.89	156 65	0.12	0.03	0.09	0.24	0.00	0.24	0.31	0.00	0.31
Chitwan	4:21	3:11	1:10	4.41	0.70	3 71	170.81	71.72	99 09	0.58	0.00	0.58	0.48	0.00	0.48	0.75	0.00	0.75
Morang	4:02	2:43	1:19	4.91	0.53	4.38	132.29	42.97	89.32	0.24	0.11	0.13	0.23	0.00	0.23	0.33	0.00	0.33
Average	4:05	2:57	1:08	6.36	1.19	5 17	177.45	60.15	117.30	0.33	0 04	0.29	0 25	0.00	0.25	0.37	0.02	0.35
OVERALL																		
Syangja	4:36	3:00	1:36	10.68	3.92	6.76	153.76	113.64	40.12	0.65	0.17	0.48	0.03	0.00	0.03	0.29	0.20	0.05
Nuwakot	3:53	3.05	0:48	5.03	0.89	4.14	141.85	47.78	94.07	0.20	0 09	0.11	0.26	0.00	0.26	1.96	0.06	1.90
Chitwan	4:18	3:15	1:03	4.67	1.17	3.50	140.32	81.22	59.10	0.14	0.03	0.11	0.36	0.02	0.34	0.95	0.10	0.85
Morang	3:54	2:45	1:09	5.14	1.09	4.05	135.57	35.62	99.95	0.35	0.08	0.27	0.54	0.14	0.40	0.27	0.04	0.09
Average	4:10	3:01	1:09	6.35	1.73	4.62	142 78	68.89	73.89	0.33	0.09	0.24	0.30	0.04	0.26	0.87	0.10	0.59
Average			419.75			1686.30			26969.85			87.60			94.90			215.35

Note:

NBH: Non-biogas Households (households without biogas plant)

BH : Biogas Households (households with biogas plant)

Annex-10
Details on Monthly Gas Production

Biogas Production Based upon Average Burning Hours of Stove and Light

Burning Hours

ID	Owner	District	Plant Size	Avg. (Shravan 055- Ashad 056)			Shravan-055			Bhadra-055			Ashoj-055			Kartik-055			Mangsir-055		
				Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)
1	Ganesh Acharya	Morang	4	2:10	0:00	758.33	2:09	0:00	752.50	1:55	0:00	670.83	2:07	0:00	740.83	2:16	0:00	793.33	2:06	0:00	735.00
2	Sashi P. Siwakoti	Morang	4	1:40	0:00	583.33	1:28	0:00	513.33	2:28	0:00	863.33	1:25	0:00	495.83	1:53	0:00	659.17	0:57	0:00	332.50
3	Nabin Adhikari	Morang	4	0:52	0:04	316.89	1:30	0:00	525.00	1:17	0:00	449.17	1:41	0:00	589.17	1:11	0:00	414.17	0:40	0:00	9833.33
4	Tikaram Chapagain	Morang	4	0:00	2:19	463.33	0:00	1:54	380.00	0:00	2:18	460.00	0:00	2:01	403.33	0:00	2:17	456.67	0:00	2:40	533.33
5	Ram Devi Dahal	Morang	4	0:50	0:00	291.67	1:11	0:00	414.17	0:59	0:00	344.17	0:50	0:00	291.67	0:46	0:00	268.33	0:31	0:00	180.83
6	Netra P. Neupane	Morang	6	2:43	0:00	950.83	3:05	0:00	1079.17	2:34	0:00	898.33	2:47	0:00	974.17	2:51	0:00	997.50	2:41	0:00	939.17
7	Durgadevi Katuwal	Morang	6	1:50	0:00	641.67	2:05	0:00	729.17	1:08	0:00	396.67	1:48	0:00	630.00	1:52	0:00	653.33	2:04	0:00	723.33
8	Lalit Tamang	Morang	6	1:58	0:25	771.67	2:39	1:06	1147.50	2:30	0:22	948.33	1:54	0:45	815.00	1:29	0:32	625.83	1:34	0:16	601.67
9	Tara Nath Chapagai	Morang	6	1:24	0:00	490.00	2:29	0:00	869.17	3:02	0:00	1061.67	2:53	0:00	1009.17	0:57	0:00	332.50	0:18	0:00	105.00
10	Yam Nath Mahatara	Morang	6	3:32	0:30	1336.67	5:16	0:14	1890.00	4:04	1:25	1706.67	3:19	1:24	1440.83	3:52	0:43	1496.67	3:25	0:20	1262.50
11	Dinesh Khanal	Morang	8	3:09	0:00	1102.50	2:29	0:00	834.17	3:13	0:00	1125.83	2:25	0:00	845.83	3:25	0:00	1195.83	2:59	0:00	1044.17
12	Purna B. Shrestha	Morang	8	4:39	0:00	1627.50	5:44	0:00	2006.67	5:08	0:00	1796.67	4:46	0:00	1668.33	4:44	0:00	1656.67	4:28	0:00	1563.33
13	Dambar B. Shrestha	Morang	8	3:06	0:03	1095.00	4:38	0:00	1621.67	3:39	0:00	1277.50	3:23	0:00	1184.17	3:07	0:00	1090.83	2:43	0:00	950.83
14	Hari P. Dahal	Morang	8	2:37	0:00	915.83	2:32	0:00	886.67	3:13	0:00	1125.83	2:32	0:00	886.67	2:39	0:00	927.50	2:19	0:00	810.83
15	Pushpa Lal Acharya	Morang	8	3:22	0:00	1178.33	2:48	0:00	980.00	2:46	0:00	968.33	2:48	0:00	980.00	2:41	0:00	939.17	2:54	0:00	1015.00
16	Pushpa Timsina	Morang	10	2:00	0:00	700.00	2:33	0:00	892.50	2:07	0:00	740.83	1:20	0:00	466.67	2:12	0:00	770.00	4:15	0:00	1487.50
17	Bishnu Kumari Shrestha	Morang	10	6:04	0:00	2123.33	5:55	0:00	2070.83	6:50	0:00	2391.67	6:46	0:00	2368.33	6:01	0:00	2105.83	6:23	0:00	2234.17
18	Bisheshwor P. Dhakal	Morang	10	3:49	0:00	1335.83	4:16	0:00	1493.33	3:41	0:00	1289.17	3:05	0:00	1079.17	3:42	0:00	1295.00	3:28	0:00	1213.33
19	Tilak P. Dhakal	Morang	10	4:24	0:00	1540.00	3:54	0:00	1365.00	4:01	0:00	1405.83	3:43	0:00	1300.83	5:39	0:00	1977.50	5:34	0:00	1948.33
20	Harishchandra Acharya	Morang	10	4:52	0:00	1703.33	6:00	0:00	2100.00	4:29	0:00	1569.17	4:52	0:00	1703.33	4:22	0:00	1528.33	5:37	0:00	1965.83
21	Mithu Sharma	Syangja	4	1:45	0:00	612.50	1:15	0:00	437.50	1:14	0:00	431.67	2:55	0:00	1020.83	1:35	0:00	554.17	0:00	0:00	0.00
22	Tulsi Roka	Syangja	4	2:03	0:04	730.83	4:03	0:00	1417.50	2:41	0:00	939.17	1:37	0:00	565.83	2:25	0:00	845.83	1:26	0:00	501.67
23	Rudra B. Roka	Syangja	4	4:25	0:00	1545.83	5:29	0:00	1919.17	3:47	0:00	1324.17	4:57	0:00	1732.50	5:03	0:00	1767.50	5:09	0:00	1802.50
24	Chhetra B. Roka	Syangja	4	3:25	0:47	1352.50	3:21	1:13	1415.83	2:49	1:16	1239.17	2:53	0:49	1172.50	2:24	0:00	840.00	3:23	0:40	1317.50
25	Suman Raj Giri	Syangja	4	2:41	0:00	939.17	2:54	0:00	1015.00	2:33	0:00	892.50	3:58	0:00	1388.33	3:32	0:00	1236.67	3:10	0:00	1108.33
26	Dhan Bdr. Roka	Syangja	6	1:42	0:00	595.00	2:23	0:00	834.17	2:10	0:00	758.33	1:46	0:00	618.33	1:44	0:00	606.67	1:30	0:00	525.00
27	Min B. Khadka	Syangja	6	3:24	1:12	1430.00	2:45	1:32	1269.17	3:07	1:29	1387.50	3:54	2:21	1835.00	3:31	3:00	1830.83	3:44	1:31	1610.00
28	Rupa Roka	Syangja	6	2:58	0:00	1038.33	3:10	0:00	1108.33	2:46	0:00	968.33	2:53	0:00	1009.17	2:39	0:00	927.50	3:02	0:00	1061.67
29	Man B. Roka	Syangja	6	2:15	0:00	787.50	2:42	0:00	945.00	2:00	0:00	700.00	1:56	0:00	676.67	1:46	0:00	618.33	2:08	0:00	746.67
30	Dil Bdr. Roka	Syangja	6	2:16	0:00	793.33	2:39	0:00	927.50	2:24	0:00	840.00	1:49	0:00	635.83	2:00	0:00	700.00	1:48	0:00	630.00
31	Hum Nath Padhya	Syangja	8	2:51	0:00	997.50	3:46	0:00	1318.33	4:54	0:00	1715.00	4:21	0:00	1522.50	1:57	0:00	682.50	2:12	0:00	770.00
32	Hum Bdr. Thapa	Syangja	8	3:07	0:00	1090.83	3:51	0:00	1347.50	3:28	0:00	1213.33	3:36	0:00	1260.00	2:02	0:00	711.67	2:38	0:00	921.67
33	Dil Bdr. Thapa	Syangja	8	3:01	0:00	1055.83	2:59	0:00	1044.17	3:31	0:00	1230.83	2:16	0:00	793.33	2:01	0:00	705.83	2:49	0:00	985.83
34	Ganesh B. Thapa	Syangja	8	3:37	0:00	1265.83	3:30	0:00	1225.00	3:17	0:00	1149.17	4:06	0:00	1435.00	2:48	0:00	980.00	4:02	0:00	1411.67
35	Dil Kumari Timilsina	Syangja	8	3:21	0:00	1172.50	3:17	0:00	1149.17	3:53	0:00	1359.17	3:40	0:00	1283.33	3:31	0:00	1230.83	3:00	0:00	1050.00
36	Tarapati Sharma	Syangja	10	3:50	0:18	1401.67	3:55	0:58	1564.17	4:22	0:15	1378.33	3:44	0:18	1366.67	2:51	0:00	997.50	3:27	0:00	1207.50
37	Ram B. Adhikari	Syangja	10	2:43	0:42	1090.83	3:31	1:23	1507.50	3:06	1:07	1308.33	3:19	1:03	1370.83	2:56	0:55	1210.00	4:19	0:50	1677.50
38	Tilak Ram Shrestha	Syangja	10	1:53	0:00	659.17	2:56	0:00	1026.67	1:28	0:00	513.33	1:47	0:00	624.17	1:33	0:00	542.50	2:36	0:00	910.00
39	Khina Padam Devkota	Syangja	10	4:34	0:00	1598.33	3:05	0:00	1079.17	2:58	0:00	1038.33	3:47	0:06	1344.17	4:45	0:00	1662.50	4:46	0:00	1668.33
40	Keshav Raj Neupane	Syangja	10	3:51	2:08	1774.17	5:22	5:04	2891.67	4:53	3:25	2392.50	2:38	1:52	1295.00	4:14	2:20	1948.33	6:55	2:47	2977.50
41	Saligram Adhikari	Chitwan	10	5:11	0:00	1814.17	5:05	0:00	1779.17	6:29	0:00	2269.17	6:20	0:00	2216.67	6:11	0:00	2164.17	3:46	0:00	1318.33
42	Tanka P. Dhakala	Chitwan	10	5:46	0:00	2018.33	5:04	0:00	1773.33	5:00	0:00	1750.00	4:39	0:00	1627.50	6:11	0:00	2164.17	5:02	0:00	1761.67
43	Tulasi Ram	Chitwan	10	5:00	0:00	1750.00	5:00	0:00	1750.00	4:25	0:00	1545.83	5:52	0:00	2053.33	6:36	0:00	2310.00	5:49	0:00	2035.83
44	Sita Ram Karki	Chitwan	10	4:20	0:00	1516.67	3:58	0:00	1388.33	3:40	0:00	1283.33	4:25	0:00	1545.83	4:40	0:00	1633.33	6:47	0:00	2374.17
45	Goma Baniya	Chitwan		2:06	0:00	735.00	2:54	0:00	1015.00	2:50	0:00	991.67	2:48	0:00	980.00	2:50	0:00	991.67	4:34	0:00	1598.33
46	Narayan Adhikari	Chitwan	10	3:32	0:52	1293.33	2:54	0:55	1198.33	2:38	0:45	1071.67	3:39	0:51	1447.50	3:06	1:02	1303.33	2:50	1:12	1231.67
47	Tirtha Raj Paudel	Chitwan	4	4:02	0:00	1411.67	4:38	0:00	1621.67	4:26	0:00	1551.67	4:20	0:00	1516.67	4:48	0:00	1680.00	3:07	0:00	1090.83
48	Shyam Pd. Upadhyaya	Chitwan	4	2:00	0:00	700.00	2:29	0:00	869.17	2:06	0:00	[illegible]	2:21	0:00	822.50	2:02	0:00	711.67	4:33	0:00	1592.50
49	Subindra K.C.	Chitwan	4	2:12	0:00	770.00	2:21	0:00	822.50	2:37	0:00	915.83	1:36	0:00	560.00	2:12	0:00	770.00	2:08	0:00	746.67
50	Ganesh Bdr. Shrestha	Nuwakot	6	2:12	0:00	770.00	2:28	0:00	863.33	2:34	0:00	898.33	2:20	0:00	816.67	2:33	0:00	892.50	2:00	0:00	700.00
51	Pushpa Nath Acharya	Nuwakot	8	3:26	0:00	1201.67	3:43	0:00	1300.83	3:56	0:00	1376.67	3:19	0:00	1160.83	3:42	0:00	1295.00	2:29	0:00	869.17
52	Rammja Sadula	Nuwakot	10	2:53	0:00	1009.17	3:39	0:00	1277.50	3:38	0:00	1271.67	2:45	0:00	962.50	2:39	0:00	927.50	3:22	0:00	1178.33
53	Tej Bahadur Adhikari	Nuwakot	10	4:41	0:00	1639.17	4:40	0:00	1633.33	5:44	0:00	2006.67	5:28	0:00	1913.33	5:07	0:00	1790.83	2:41	0:00	939.17
54	Pinggong Galane	Nuwakot	10	1:31	0:00	530.83	2:28	0:00	863.33	2:06	0:00	735.00	2:05	0:00	729.17	2:26	0:00	851.67	4:28	0:00	1563.33
55	Khop Maya Dhabala	Nuwakot	10	2:16	0:00	793.33	2:04	0:00	723.33	3:07	0:00	1090.83	3:36	0:00	1260.00	2:55	0:00	1020.83	2:18	0:00	805.00
56	Netra Bdr. Chhetri	Nuwakot	10	5:15	0:00	1837.50	4:57	0:00	1732.50	5:02	0:00	1761.67	5:38	0:00	1971.67	5:00	0:00	1750.00	2:23	0:00	834.17
57	Manjushree Chapagai	Chitwan	10	5:25	0:00	1895.83	5:18	0:00	1855.00	4:38	0:00	1621.67	4:58	0:00	1738.33	4:56	0:00	1726.67	4:46	0:00	1668.33
58	Chabilal Adhikari	Chitwan	6	2:22	0:00	828.33	2:54	0:00	1015.00	2:30	0:00	875.00	2:24	0:00	840.00	2:07	0:00	740.83	4:45	0:00	1662.50
59	Prem Pd. Dhabala	Chitwan	6	2:29	0:00	869.17	3:00	0:00	1050.00	2:33	0:00	892.50	2:22	0:00	828.33	2:23	0:00	834.17	2:05	0:00	729.17
60	Madhab Dhungana	Chitwan	6	2:49	0:00	985.83	2:55	0:00	1020.83	2:31	0:00	880.83	2:42	0:00	945.00	2:53	0:00	1009.17	2:11	0:00	764.17
61	Tul Raj Upreti	Chitwan	6	1:50	0:00	641.67	1:52	0:00	653.33	1:54	0:00	665.00	2:21	0:00	822.50	2:21	0:00	822.50	2:41	0:00	939.17
62	Hari Narayan Adhikari	Chitwan	8	2:47	0:00	974.17	3:06	0:00	1085.00	2:59	0:00	1044.17	3:01	0:00	1055.83	2:26	0:00	851.67	1:59	0:00	694.17
63	Ram Maya Kandel	Chitwan	8	2:52	0:00	1003.33	2:30	0:00	875.00	2:09	0:00	752.50	2:18	0:00	805.00	2:50	0:00	991.67	2:40	0:00	933.33
64	Dharma Pun	Chitwan	8	3:01	0:00	1055.83	4:17	0:00	1499.17	3:32	0:00	1236.67	3:19	0:00	1160.83	3:30	0:00	1225.00	2:41	0:00	939.17
65	Surat Bdr. Chitrakar	Nuwakot	6	3:41	0:00	1289.17	2:53	0:00	1009.17	2:11	0:00	764.17	2:13	0:00	775.83	4:21	0:00	1522.50	3:34	0:00	1248.33
66	Ram Krishna Shrestha	Nuwakot	6	3:26	0:00	1201.67	3:22	0:00	1178.33	4:27	0:00	1557.50	3:12	0:00	1120.00	4:00	0:00	1400.00	3:28	0:00	1213.33
67	Bhakta Bdr. Shrestha	Nuwakot	6	4:12	0:00	1470.00	4:56	0:00	1726.67	4:39	0:00	1627.50	4:22	0:00	1528.33	4:26	0:00	1551.67	3:44	0:00	1306.67
68	Raj Kumar Jung Shaha	Nuwakot	6	3:16	0:00	1143.33	2:29	0:00	869.17	2:53	0:00	1009.17	2:54	0:00	1015.00	3:26	0:00	1201.67	4:12	0:00	1470.00
69	Paban Kumari Acharya	Nuwakot	8	3:06	0:00	1085.00	4:10	0:00	1458.33	3:37	0:00	1265.83	3:16	0:00	1143.33	3:07	0:00	1090.83	2:07	0:00	740.83
70	Bhadra B. Pyakurel	Nuwakot	8	3:09	0:00	1102.50	4:10	0:00	1458.33	4:06	0:00	1435.00	4:37	0:00	1615.83	3:58	0:00	1388.33	2:44	0:00	956.67
71	Sita rani Pyakurel	Nuwakot	8	2:36	0:00	910.00	3:01	0:00	1055.83	3:28	0:00	1213.33	3:51	0:00	1347.50	2:50	0:00	991.67	2:52	0:00	1003.33
72	Gopal Acharya	Nuwakot	8	4:05	0:00	1429.17	4:19	0:00	1510.83	3:42	0:00	1295.00	4:09	0:00	1452.50	4:01	0:00	1405.83	3:59	0:00	1394.17
73	Gopal Malakar	Nuwakot	4	2:29	0:00	869.17	2:30	0:00	875.00	2:20	0:00	816.67	2:32	0:00	886.67	2:03	0:00	717.50	2:54	0:00	1015.00
74	Hari Bahadur Adhikari	Nuwakot	4	2:48	0:00	980.00	3:17	0:00	1149.17	3:11	0:00	1114.17	3:11	0:00	1114.17	2:46	0:00	968.33	2:56	0:00	1026.67
75	Gopal Shrestha	Nuwakot	4	3:07	0:00	1090.83	3:16	0:00	1143.33	2:59	0:00	1044.17	3:18	0:00	1155.00	3:20	0:00	1166.67	2:55	0:00	1020.83
76	Mukti Nath Gautam	Nuwakot	4	1:18	0:00	455.00	1:51	0:00	647.50	1:12	0:00	420.00	1:09	0:00	402.50	1:08	0:00	396.67	1:25	0:00	495.83
77	Khadka B. Adhikari	Nowakot	4	2:11	0:00	764.17	2:18	0:00	805.00	2:04	0:00	723.33	2:00	0:00	700.00	2:03	0:00	717.50	2:16	0:00	793.33
78	Dil Bdr. Tamang	Chitwan	4	2:13	0:00	775.83	1:56	0:00	676.67	2:07	0:00	740.83	2:35	0:00	904.17	2:39	0:00	927.50	2:48	0:00	980.00
79	Nanda Pd. Rijal	Chitwan	4	2:43	0:00	950.83	3:13	0:00	1125.83	2:40	0:00	933.33	2:49	0:00	985.83	2:44	0:00	956.67	3:20	0:00	1166.67
80	Krishna Bdr. Gurung	Chitwan	10	2:47	0:00	974.17	3:02	0:00	1061.67	2:57	0:00	1032.50	2:54	0:00	1015.00	3:11	0:00	1114.17	2:40	0:00	933.33

ID	Poush-055			Magh-055			Falgun-055			Chitra-055			Baisakh-056			Jestha-056			Ashad-056			Prod./cub.m (Litre)
	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	Stove (hr:min)	Light (hr:min)	Avg. Prod. (Litre)	
1	2:13	0:00	775.83	2:02	0:00	711.67	2:23	0:00	834.17	2:35	0:00	904.17	2:16	0:00	793.33	2:18	0:00	805.00	1:47	0:00	624.17	189.58
2	1:58	0:00	688.33	2:14	0:00	781.67	2:14	0:00	781.67	2:09	0:00	752.50	1:15	0:00	437.50	1:14	0:00	431.67	1:00	0:00	350.00	145.83
3	0:42	0:00	245.00	0:50	0:00	291.67	0:35	0:00	204.17	0:40	0:00	233.33	0:33	0:00	192.50	0:06	0:50	201.67	0:41	0:00	239.17	79.22
4	0:00	1:50	366.67	0:00	1:42	340.00	0:00	2:36	520.00	0:00	3:02	606.67	0:00	1:36	320.00	0:00	2:37	523.33	0:00	3:09	630.00	115.83
5	0:33	0:00	192.50	0:36	0:00	210.00	1:00	0:00	350.00	0:40	0:00	233.33	0:35	0:00	204.17	0:58	0:00	338.33	1:16	0:00	443.33	72.92
6	2:12	0:00	770.00	2:17	0:00	799.17	2:40	0:00	933.33	2:43	0:00	950.83	3:02	0:00	1061.67	2:55	0:00	1020.83	2:42	0:00	945.00	158.47
7	2:06	0:00	735.00	1:31	0:00	530.83	1:38	0:00	571.67	1:42	0:00	595.00	1:45	0:00	612.50	2:00	0:00	700.00	2:18	0:00	805.00	106.94
8	1:42	0:00	595.00	1:23	0:15	534.17	1:58	0:15	731.67	2:07	[illegible]	814.17	2:07	0:21	810.83	2:12	0:28	863.33	2:03	0:15	767.50	128.61
9	1:32	0:00	536.67	1:20	0:00	466.67	0:34	0:00	198.33	0:38	[illegible]	9821.67	0:54	0:00	315.00	1:13	0:00	425.83	1:07	0:00	390.83	81.67
10	2:58	0:00	1038.33	2:38	0:00	921.67	3:20	0:00	1166.67	3:45	[illegible]	1312.50	2:55	0:17	1077.50	3:21	0:43	1315.83	3:24	0:46	1343.33	222.78
11	3:14	0:00	1131.67	3:23	0:00	1184.17	3:11	0:00	1114.17	3:53	0:00	1359.17	3:49	0:00	1335.83	2:45	0:00	962.50	3:12	0:00	1120.00	137.81
12	3:55	0:00	1370.83	4:12	0:00	1470.00	4:19	0:00	1510.83	5:22	0:00	1878.33	2:15	0:00	787.50	5:44	0:00	2006.67	5:04	0:00	1773.33	203.44
13	2:52	0:00	1003.33	2:26	0:00	851.67	2:41	0:00	939.17	2:45	0:00	962.50	3:18	0:00	1155.00	3:35	0:00	1254.17	2:06	0:42	875.00	136.88
14	2:41	0:00	939.17	2:45	0:00	962.50	2:25	0:00	845.83	2:30	0:00	875.00	2:34	0:00	898.33	2:38	0:00	921.67	2:30	0:00	875.00	114.48
15	2:12	0:00	770.00	2:50	0:00	991.67	3:35	0:00	1254.17	4:43	0:00	1650.83	4:26	0:00	1551.67	4:35	0:00	1604.17	3:59	0:00	1394.17	147.29
16	4:17	0:00	1499.17	0:56	0:00	326.67	1:30	0:00	525.00	1:15	0:00	437.50	1:07	0:00	390.83	1:05	0:00	379.17	1:30	0:00	525.00	70.00
17	5:56	0:00	2076.67	4:55	0:00	1720.83	5:57	0:00	2082.50	5:55	0:00	2070.83	5:39	0:00	1977.50	6:32	0:00	2286.67	5:57	0:00	2082.50	212.33
18	3:12	0:00	1120.00	3:06	0:00	1085.00	3:14	0:00	1131.67	4:05	0:00	1429.17	4:51	0:00	1697.50	4:42	0:00	1645.00	4:24	0:00	1540.00	133.58
19	4:15	0:00	1487.50	3:57	0:00	1382.50	5:13	0:00	1825.83	4:58	0:00	1738.33	3:32	0:00	1236.67	3:56	0:00	1376.67	4:14	0:00	1481.67	154.00
20	5:09	0:00	1802.50	4:40	0:00	1633.33	4:16	0:00	1493.33	4:21	0:00	1522.50	4:39	0:00	1627.50	4:41	0:00	1639.17	5:13	0:00	1825.83	170.33
21	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	153.13
22	1:45	0:00	612.50	2:40	0:00	933.33	1:25	0:00	495.83	2:00	0:00	700.00	1:42	0:00	595.00	2:00	0:00	700.00	0:55	0:43	470.83	182.71
23	2:55	0:00	1020.83	3:03	0:00	1067.50	4:51	0:00	1697.50	4:51	0:00	1697.50	4:22	0:00	1528.33	4:24	0:00	1540.00	4:06	0:00	1435.00	386.46
24	3:40	0:36	1403.33	3:31	0:28	1334.17	3:52	0:56	1540.00	3:16	0:32	1250.00	3:56	1:28	1670.00	3:50	0:54	1521.67	4:06	0:30	1500.00	338.13
25	1:38	0:00	571.67	1:33	0:00	542.50	2:34	0:00	898.33	2:24	0:00	840.00	2:35	0:00	904.17	2:35	0:00	904.17	2:37	0:00	915.83	234.79
26	1:14	0:00	431.67	1:23	0:00	484.17	1:41	0:00	589.17	1:29	0:00	519.17	1:47	0:00	624.17	1:37	0:00	565.83	1:36	0:00	560.00	99.17
27	3:55	1:35	1487.50	3:26	1:02	1408.33	3:21	1:26	1459.17	3:51	0:38	1474.17	2:40	0:00	933.33	3:06	0:00	1085.00	3:35	0:00	1254.17	238.33
28	2:43	0:00	950.83	2:57	0:00	1032.50	3:15	0:00	1137.50	3:25	0:00	1195.83	3:28	0:00	1213.33	2:42	0:00	945.00	2:35	0:00	904.17	173.06
29	2:25	0:00	845.83	3:22	0:00	1178.33	2:42	0:00	945.00	2:10	0:00	758.33	2:02	0:00	711.67	1:52	0:00	653.33	2:01	0:00	705.83	131.25
30	1:36	0:00	560.00	1:56	0:00	676.67	2:10	0:00	758.33	3:13	0:00	1125.83	2:22	0:00	828.33	2:26	0:00	851.67	2:48	0:00	980.00	132.22
31	1:38	0:00	571.67	2:14	0:00	781.67	2:33	0:00	892.50	2:35	0:00	904.17	2:39	0:00	927.50	2:45	0:00	962.50	2:34	0:00	898.33	124.69
32	2:20	0:00	816.67	2:50	0:00	991.67	3:03	0:00	1067.50	2:50	0:00	991.67	3:33	0:00	1242.50	3:35	0:00	1254.17	3:30	0:00	1225.00	136.35
33	3:13	0:00	1125.83	4:13	0:00	1475.83	3:20	0:00	1166.67	3:02	0:00	1061.67	3:26	0:00	1201.67	3:12	0:00	1120.00	2:11	0:00	764.17	131.98
34	3:03	0:00	1067.50	3:43	0:00	1300.83	3:36	0:00	1260.00	3:50	0:00	1341.67	3:59	0:00	1394.17	3:42	0:00	1295.00	3:45	0:00	1312.50	158.23
35	2:00	0:00	700.00	2:34	0:00	898.33	4:04	0:00	1423.33	4:02	0:00	1411.67	3:38	0:00	1271.67	2:35	0:00	904.17	3:31	0:00	1230.83	146.56
36	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	0.00	140.17
37	2:13	0:46	929.17	2:55	0:51	1197.50	2:08	0:28	840.00	2:14	0:18	841.67	2:01	0:11	742.50	3:16	0:06	1163.33	2:15	0:21	857.50	109.08
38	1:02	0:00	361.67	0:40	0:00	233.33	0:55	0:00	320.83	1:24	0:00	490.00	2:09	0:00	752.50	2:13	0:00	775.83	1:45	0:00	612.50	65.92
39	7:23	0:00	2584.17	3:10	0:00	1108.33	4:54	0:00	1715.00	4:46	0:00	1668.33	4:25	0:00	1545.83	4:44	0:00	1656.67	4:14	0:00	1481.67	159.83
40	4:09	3:05	1969.17	4:04	3:05	2040.00	5:36	2:49	2523.33	3:02	0:35	1178.33	2:34	1:52	1271.67	3:00	0:20	1116.67	3:03	1:23	1344.17	177.42
41	6:08	0:00	2146.67	4:15	0:00	1487.50	4:11	0:00	1464.17	4:54	0:00	1715.00	4:55	0:00	1720.83	4:25	0:00	1545.83	4:11	0:00	1464.17	181.42
42	7:17	0:00	2549.17	6:03	0:00	2117.50	5:00	0:00	1750.00	6:51	0:00	2397.50	7:09	0:00	2502.50	6:34	0:00	2298.33	3:49	0:00	1335.83	201.83
43	5:04	0:00	1773.33	3:04	0:00	1073.33	2:22	0:00	828.33	3:20	0:00	1166.67	5:33	0:00	1942.50	5:57	0:00	2082.50	5:58	0:00	2088.33	218.75
44	4:48	0:00	1680.00	4:06	0:00	1435.00	3:56	0:00	1376.67	3:39	0:00	1277.50	4:24	0:00	1540.00	4:57	0:00	1732.50	4:48	0:00	1680.00	189.58
45	2:02	0:00	711.67	1:34	0:00	548.33	0:55	0:00	320.83	1:33	0:00	542.50	1:54	0:00	665.00	1:37	0:00	565.83	1:22	0:00	478.33	183.75
46	3:24	1:37	1423.33	3:15	1:11	1374.17	3:08	0:48	1256.67	3:12	0:09	1120.00	3:06	0:52	1258.33	3:29	0:58	1412.50	3:19	0:09	1190.83	129.33
47	3:27	0:00	1207.50	3:10	0:00	1108.33	3:02	0:00	1061.67	3:42	0:00	1295.00	4:14	0:00	1481.67	4:04	0:00	1423.33	3:54	0:00	1365.00	235.28
48	1:58	0:00	688.33	1:44	0:00	606.67	1:59	0:00	694.17	1:52	0:00	653.33	1:32	0:00	536.67	1:55	0:00	670.83	1:51	0:00	647.50	175.00
49	1:50	0:00	641.67	1:56	0:00	676.67	2:23	0:00	834.17	2:17	0:00	799.17	2:16	0:00	793.33	2:29	0:00	869.17	2:28	0:00	863.33	192.50
50	1:05	0:00	379.17	1:13	0:00	425.83	1:44	0:00	606.67	2:34	0:00	898.33	2:32	0:00	886.67	2:21	0:00	822.50	2:29	0:00	869.17	128.33
51	3:24	0:00	1190.00	3:08	0:00	1096.67	3:15	0:00	1137.50	3:08	0:00	1096.67	3:05	0:00	1079.17	3:10	0:00	1108.33	3:56	0:00	1376.67	150.21
52	3:03	0:00	1067.50	3:07	0:00	1090.83	2:53	0:00	1009.17	3:01	0:00	1055.83	2:19	0:00	810.83	2:16	0:00	793.33	2:32	0:00	886.67	100.92
53	4:17	0:00	1499.17	4:10	0:00	1458.33	4:42	0:00	1645.00	4:43	0:00	1650.83	4:17	0:00	1499.17	4:36	0:00	1610.00	3:56	0:00	1376.67	163.92
54	1:11	0:00	414.17	0:50	0:00	291.67	0:58	0:00	338.33	0:59	0:00	344.17	0:58	0:00	338.33	0:59	0:00	344.17	0:50	0:00	291.67	53.08
55	2:09	0:00	752.50	1:49	0:00	635.83	1:52	0:00	653.33	1:58	0:00	688.33	1:47	0:00	624.17	1:47	0:00	624.17	1:48	0:00	630.00	79.33
56	5:45	0:00	2012.50	5:28	0:00	1913.33	5:11	0:00	1814.17	5:08	0:00	1796.67	4:49	0:00	1685.83	5:32	0:00	1936.67	5:37	0:00	1965.83	183.75
57	4:26	0:00	1551.67	5:24	0:00	1890.00	5:55	0:00	2070.83	6:55	0:00	2420.83	6:28	0:00	2263.33	5:14	0:00	1831.67	6:05	0:00	2129.17	189.58
58	2:16	0:00	793.33	2:13	0:00	775.83	2:05	0:00	729.17	2:14	0:00	781.67	2:21	0:00	822.50	2:28	0:00	863.33	2:44	0:00	956.67	138.06
59	2:09	0:00	752.50	2:22	0:00	828.33	2:34	0:00	898.33	2:15	0:00	787.50	2:32	0:00	886.67	2:40	0:00	933.33	2:48	0:00	980.00	144.86
60	2:58	0:00	1038.33	2:31	0:00	880.83	2:40	0:00	933.33	2:44	0:37	1080.00	3:16	0:00	1143.33	3:01	0:00	1055.83	2:56	0:00	1026.67	164.31
61	1:52	0:00	653.33	1:09	0:00	402.50	1:42	0:00	595.00	1:52	0:00	653.33	1:37	0:00	565.83	1:42	0:00	595.00	1:39	0:00	577.50	106.94
62	2:34	0:00	898.33	3:02	0:00	1061.67	2:19	0:00	810.83	2:47	0:00	974.17	2:38	0:00	921.67	3:11	0:00	1114.17	2:40	0:00	933.33	121.77
63	2:30	0:00	875.00	2:47	0:00	974.17	3:08	0:00	1096.67	3:03	0:00	1067.50	3:27	0:00	1207.50	3:38	0:00	1271.67	3:27	0:00	1207.50	123.42
64	2:45	0:00	962.50	2:25	0:00	845.83	2:30	0:00	875.00	2:14	0:00	781.67	2:32	0:00	886.67	3:03	0:00	1067.50	2:29	0:00	869.17	131.98
65	3:41	0:00	1289.17	3:26	0:00	1201.67	3:31	0:00	1230.83	4:20	0:00	1516.67	4:51	0:00	1697.50	4:38	0:00	1621.67	4:35	0:00	1604.17	214.86
66	2:33	0:00	892.50	3:40	0:00	1283.33	3:15	0:00	1137.50	2:31	0:00	880.83	3:28	0:00	1213.33	3:36	0:00	1260.00	3:31	0:00	1230.83	200.28
67	4:48	0:00	1680.00	3:28	0:00	1213.33	4:21	0:00	1522.50	3:34	0:00	1248.33	3:41	0:00	1289.17	3:59	0:00	1394.17	3:54	0:00	1365.00	245.00
68	2:56	0:00	1026.67	2:52	0:00	1003.33	3:25	0:00	1195.83	3:49	0:00	1335.83	3:34	0:00	1248.33	3:58	0:00	1388.33	3:40	0:00	1283.33	190.56
69	2:49	0:00	985.83	2:41	0:00	939.17	2:48	0:00	980.00	3:15	0:00	1137.50	2:56	0:00	1026.67	2:52	0:00	1003.33	3:33	0:00	1242.50	135.63
70	2:30	0:00	875.00	2:49	0:00	985.83	2:18	0:00	805.00	2:24	0:00	840.00	2:29	0:00	869.17	2:35	0:00	904.17	3:05	0:00	1079.17	137.81
71	2:25	0:00	845.83	2:13	0:00	775.83	2:11	0:00	764.17	2:11	0:00	764.17	2:21	0:00	822.50	1:55	0:00	670.83	1:59	0:00	694.17	113.75
72	4:03	0:00	1417.50	3:56	0:00	1376.67	4:14	0:00	1481.67	3:42	0:00	1295.00	4:24	0:00	1540.00	3:52	0:00	1353.33	4:32	0:00	1586.67	178.65
73	3:29	0:00	1219.17	3:38	0:00	1271.67	2:46	0:00	968.33	2:07	0:00	740.83	2:14	0:00	781.67	2:04	0:00	723.33	1:16	0:00	443.33	217.29
74	2:41	0:00	939.17	2:49	0:00	985.83	2:41	0:00	939.17	2:33	0:00	892.50	2:29	0:00	869.17	2:33	0:00	892.50	2:24	0:00	840.00	245.00
75	2:37	0:00	915.83	3:03	0:00	1067.50	2:59	0:00	1044.17	3:04	0:00	1073.33	2:55	0:00	1020.83	3:23	0:00	1184.17	3:27	0:00	1207.50	272.71
76	1:31	0:00	530.83	1:52	0:00	653.33	1:03	0:00	367.50	1:11	0:00	414.17	1:12	0:00	420.00	1:03	0:00	367.50	1:03	0:00	367.50	113.75
77	2:12	0:00	770.00	2:14	0:00	781.67	2:09	0:00	752.50	2:02	0:00	711.67	2:07	0:00	740.83	2:24	0:00	840.00	2:24	0:00	840.00	191.04
78	2:24	0:00	840.00	2:10	0:00	758.33	2:10	0:00	758.33	2:11	0:00	764.17	1:48	0:00	630.00	2:00	0:00	700.00	1:48	0:00	630.00	193.96
79	2:58	0:00	1038.33	3:18	0:00	1155.00	2:57	0:00	1032.50	2:16	0:00	793.33	2:13	0:00	775.83	1:55	0:00	670.83	2:18	0:00	805.00	237.71
80	2:08	0:00	746.67	2:26	0:00	851.67	2:20	0:00	816.67	2:46	0:00	968.33	2:51	0:00	997.50	2:49	0:00	985.83	3:17	0:00	1149.17	97.42

ToR Conventional Fuel Saving (replacement value biogas vs conventional fuel), Daily Gas Consumption Pattern and Optimum Plant Size (efficiency measurement).

1. <u>Introduction</u>:

The biogas Support Programme (BSP) is a joint programme of His Majesty's Government of Nepal (HMG/N), the German Financial Co-operation (KfW) and the Netherlands Development Organization (SNV/N) in co-operation with the Agricultural Development Bank of Nepal ADB/N), Nepal Bank Limited (NBL), Rastriya Banija Bank (RBB) and recognized Biogas Companies.

The overall objective of BSP Phase-Ill, which started in March '97, is to further develop and disseminate biogas as an indigenous, sustainable energy source in the rural areas of Nepal. More specific objectives of the programme are:

- to develop a commercially viable, market oriented biogas industry
- to increase the number of quality, small(er)-sized biogas plants with 100,000
- to ensure the continued operation of all biogas plants installed under BSP
- to conduct applied research and development on construction, appliances and slurry
- to maximise the benefits of the operated biogas plants, particularly the use of slurry
- to strengthen and facilitate establishment of institutions for the continued and sustained development of the biogas sector.

According to the implementation document, one of the main benefits of the biogas plant construction is assumed to be:
Reduction in the rate of deforestation and environmental deterioration by substituting fuel wood, agricultural waste, dung cakes and kerosene to meet the energy demand of the rural population.

The assumed minimum savings per average biogas household per year are:

fuel wood	1700 kg
agricultural waste	720 kg
dung cakes	400 kg
kerosene	50 litres

In this regard the following replacement values for different cooking fuels have been used:

Fuel:	Unit:	Caloric value per unit (M J)	Efficiency of stove (%)	Replacement value wood (rounded)
Biogas	m3	19	55	N/A
Fuel wood	kg	17	12.5	1:5
Agricultural, waste	kg	12	10	1:9
Dung cakes	kg	10	10	1:10

To achieve the targeted increase in plant construction, the plants themselves will have to be as cost effective as possible. Plant cost can not or only marginally be reduced per plant unit. However, the cost of the generated gas can be brought down by using the plants more efficiently. Thereby biogas can become more competitive with conventional energy sources. In this regard a study needs to be undertaken on the efficiency (read optimum plant size) of biogas plants. The outcome of this study can be used to a: convince actors in the sector like companies and banks to construct the appropriate size of plant given the availability of dung and b: to draw up stricter quality norms regarding size selection.

The efficiency of biogas plants is largely depending on size and feeding. However, the efficiency is also determined by the gas storage capacity of the plant. The plants are presently designed to be able to effectively store 55-60% of the daily (24 h) gas production based on a minimum dung feeding and 40 litres/kg gas production. These design parameters are, again, based on assumptions.

2. Study Aim:

2.1 Conventional Fuel Savings

In order to verify the relevant assumptions and monitor the relevant indicators of the implementation document for phase III:

- To obtain reliable data regarding the actual savings on conventional fuel for an average biogas household in the Mils and the terai,
- To obtain reliable data regarding the replacement value of biogas vs conventional cooking fuels.

2.2 Optimum Plant Size

In order to facilitate the implemented in maximising the benefits of the plant for the users:

- To determine which plant volume is most efficient (cost effective) given average annual temperature and daily feeding and considering a economical life-span period of 10 years and a energy value of dung of Rs. 8 per 25 kg,

2.3 Daily Gas Consumption Pattern

In order to be able to make changes to the design to make it more in line with the daily needs of the user:

- To collect accurate data regarding the daily gas consumption patterns for different family compositions, climate zones and seasons.

3. Specific Objectives:

More specifically the study has the following objectives:

3.1 to measure and compare the amounts of fuel wood, agricultural waste, dung cakes and kerosene used by rural household with and without biogas

3.2 to calculate the average replacement value of biogas as compared to traditional cooking fuels

3.3 to provide a clear indication which plant volume is most suitable given a certain dung availability and climate condition

3.4 to measure the digestion of dung in the biogas plant in relation to feeding (HRT) and temperature by identifying the total solids (TS) and volatile solids (VS) content of raw dung as well as digested slurry.

3.5 to come to a more efficient and reliable plant design by identifying the actual needed effective gas storage capacity for the average family and plant size by measuring the daily gas consumption patterns

3.6 to measure the influence of site selection and top filling on the gas production, particularly in wintertime.

4. <u>Activities:</u>

For both terai and hill districts two study areas will be selected. The minimum elevation must be 800 meters above sea level for the hill study areas. All four areas will have a high biogas penetration. By working in cluster areas the observation work will be facilitated while the influence of dung quality on the measurements will be minimised. In each area 5 plants each of 4, 6, 8 and 10 m3 have to be identified for observation purposes. Two out these 5 plants per volume must have an attached toilet in use. These plants will have to be in use for at least 6 months. The families using the plants will have to be screened to assess if they are willing and capable to cooperate for one year in the study. Likewise per study area 10 non-biogas household need to be identified who are socially and economically comparable to the average biogas household.

At the identified biogas households, gas meters are to be installed. These meters will be provided by SNV/BSP. Besides a gas meter the biogas households will be equipped with a suitable barrel to measure the daily dung and water feeding of the plant. All co-operating households will be provided with a weighing scale for measuring traditional fuel consumption.

The following measurements have to be carried out and accurately recorded for a one year period:

	What:		How:	By whom:	Frequency:
A	Trade, fuel	- kg	weighing scale	farmer	daily
B	Water	- volume	barrel	farmer	daily
C	Dung	- volume - composition	barrel sample	farmer laboratory	daily monthly
D	Slurry	- volume - composition	barrel sample	farmer cons./ laboratory	N/A (A+B) monthly
E	Dig. slurry	- composition	sample	cons./laboratory	monthly
F	Gas use	- volume - hours	gas meter clock	Farmer farmer	Daily Daily
G	Digester temperature	: - degrees C	dig. thermometer	consultant	weekly

As will be clear from the above table, a great deal of work will have to be carried out by the user of the plant and the households used for comparison. Careful guidance and monitoring of these families through daily visits is therefore essential. For this reason a (female) person hired by the consultant must be permanently present in each of the four cluster areas. To give this person the necessary guidance and to monitor the progress of the study, the study co-ordinator will have to visit each area at least once a month. Furthermore, at each study area a training must be conducted for study participants to make them aware of the need for accuracy and to train them on the use of the measuring tools and on reporting. For co-operating families a remuneration of Rs. 50/week must be made available.

The gathered data will have to be listed, analysed and reported after a measuring period of 1, 3, 6, 9 and finally 12 months. Also the reports must contain possible observations and/or problems which can influence the proceeding or outcome of the study.

5. Time Schedule:

The identification of participating households should start within one week after the acceptation of the proposal. Within one month after the acceptation all the preparations like training of participants, installation of gas meters and other measuring equipment must be completed and then measurements started. The final draft report is to be submitted within 3 weeks after completion of the fieldwork,

6. Reporting:

The consultant must present clearly written progress reports as outlined under 4. Up on completion of the study, a clearly written and well founded report covering the whole study period is to be presented. Five copies of both draft and final report (including a summary in Nepali) will be submitted as well as one loose leaf final copy to enable SNV/BSP to make extra copies. In addition, computer files containing raw and processed data in excel will be submitted.

7. Budget:

The budget required by the consultant excluding hardware but including the services of a well reputed laboratory for sample analysis and the remuneration for participating households, will not exceed NRs. 1,200,000 (One million two hundred thousand rupees only).

8. Submission of proposal

A number of well reputed consultant agencies will be invited to submit proposals for this assignment. To elaborate further on the ToR, SNV/BSP invites all candidate agencies to a information and discussion gathering before February 10, 1998. The proposal has to be submitted to SNV/BSP before February 23, 1998. The proposal should contain a clear description of objectives, working method, proposed interview and observation forms, work schedule, expected results and detailed breakdown of the budget. In addition, the CV.'s of the persons selected to participate in the survey indicating their function and an overview of comparable activities done in the past has to be given. Suggestions to improve the design, execution and/or results of the study will be highly appreciated.

9. Acceptance of proposal

All rights are with SNV/BSP to approve or disapprove the proposal. The consultant will be notified within 5 working days after the closure of the submission period. The consultant can be asked for modifications in the proposal before approval whenever the need might arise.

10. Agreement

If the proposal is approved, an agreement will be signed between SNV/BSP and the consultant. After signing, 20% of the total budget will be paid to the consultant. Further 15% will be paid after submission and acceptance of the quarterly reports. The remaining budget will be paid within one week after approval of the final report by SNV/BSP.

10. Contact person

The contact person for further information is Mr. Jan Lam, Biogas Engineer of SNV/BSP.

Annexed: Listing of biogas plant build in potential study areas in the past three years.

Comments Draft Final Report

Research Stud/ on Optimal Biogas Plant Size
Daily Biogas Consumption Pattern

& Conventional Fuel Saving

I) EXECUTIVE SUMMARY

a) It is agreed that the finding of the study are comparable and relevant.
b) Plants are in general underfed (74.62% feeding). 30% of the farmers collect dung from outside. These findings are accepted. It is recommended drastic action is taken top increase the feeding %.
c) 27.5% of the plants receive more water thus affecting the gas production. This data is acceptable.
d) 27.5% of the plants have a toilet connection. Subsequently these plants receive less feeding. This information is acceptable.
e) The efficiency calculation shows different figures for the theoretical / actual amount of dung fed. Conclusion is missing.
f) A 15% reduction of gas production in the cold is acceptable. Request for recommendations to improve this gas production.
g) What is the increase in gas production % wise of plants receiving direct sunlight for a longer duration?
h) Figures about top filling are acceptance. Conclusion? *(...%* of plants with top filling have better efficiency)
i) The co-relation coefficient of 0.3235 requires an explanation.
j) The gas production of 38 liter/kg seems acceptable. I would like to indicate in the report the limitations on this value, (area, eve temp per month, water: dung ratio, etc) \
k) Debatable gas use of the stove is debatable. Can be accepted.
I) Gas patterns are accepted,
m) On stove burning: # of persons residing in the household is one of the important governing factors for stove burning" Can that be explained?
n) Saving of 1668.3 kg wood per household year is acceptable.
   (1) Can an equivalent in Ha be provided?
   (2) How much wood does a biogas household annually on average use?
o) Biogas families save 27lt kerosene per year per household. How much kerosene does a biogas household annually on average use?
p) Biogas households save 87.6 kg of fodder stem per day. Explanation required?
q) Biogas households on average use 13% of dung cakes. Is this seasonal or year round observation?
r) What is the composition of the agricultural residue used by households? Is it used for cooking only or heating?
s) The average saving on cooking fuels is Npr 3659.02. Is it possible co have a specification in NPs here per type of fuel?
t) The recommended plants size of 6 cum is acceptable,
u) For smaller families 4 cum is sufficient. This is acceptable.
v) Dome volume in Terai can be reduced by 6 - 18%. Dome volume in hills can be reduced by 25% - 34 %. In case it is decided to reduce the dome volume by 20-25% in the hills, can a recommendation be included how it will affect the uniformity of the current design from a technical point of view. What are the real savings?
w) Volume of the dome can be reduced. %. In case it is decided to reduce the outlet volume by 26-46% in the hills, can a recommendation be included how it will affect the uniformity of the current design from a technical point of view. What are the real savings?

2) INTRODUCTION

a) 1.7.1 The non -functioning of gas meters is a serious drawback on the research. As a result a number of findings are debatable. However the findings presented in the report are accepted under this condition.
i) The damaging of the temperature meters is accepted.
ii) On both cases what recommendation can be made to present future mishaps?

3) ToR

a 3.4 to measure the digestion of dung in the biogas plant in relation to feeding (HRT) and temperature by identifying the total solids (TS) and volatile solids (VS) content of raw dung as well as digested slurry.

i) This part of the ToR did not receive the accuracy it deserves. Conditions are accepted but recommendations for improvement are missing in the report.