BIO-GAS: AN ALTERNATE ENERGY RESOURCE FOR SUSTAINABLE RURAL DEVELOPMENT

A THESIS SUBMITTED TO THE UNIVERSITY OF HYDERABAD IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE

DOCTOR OF PHILOSOPHY

IN

ECONOMICS

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DECLARATION

I hereby declare that the work embodied in this thesis entitled **"BIO-GAS: AN ALTERNATE ENERGY RESOURCE FOR SUSTAINABLE RURAL DEVELOPMENT"** has been carried out by me under the supervision of **Prof. V.B.N.S Madduri,** Department of Economics, School of Social Sciences, University of Hyderabad, Hyderabad, and is original. This thesis or a part of this has not been submitted for any other degree or diploma at the University or at any other Universities.

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ACKNOWLEDGEMENT

I take this opportunity to express my profound thankfulness and gratitude towards my supervisor Dr. V.B.N.S Madduri for his guidance and co-operation. I owe my allegiance to his wise, prudent and judicious guidance and for being a source of inspiration and encouragement to me. I must thank the Head, Department of Economics and all other faculty for generating an atmosphere congenial for academic pursuit.

I wish to express my thanks to the authorities of Bureau of Economics and Statistics, Govt. of A.P., NIRD, ASCI, CESS, NEDCAP, NISIET and staff of Hyderabad Central University (HCU) library for their kind co-operation and for helping me avail the information as well as Journals and publications needed for my work.

1 would like to sincerely thank Prof. K.S. Rao, Dr. G. U.K Rao, and Sri. Prasad Reddy of NISIET for their help in providing the necessary research material and Moral support. I owe special thanks to Sri. G.S. Murthy of NEDCAP, Andhara Pradesh for his intellectual advices and troubleshooting tips.

1 am grateful to all my classmates and friends Shiva, Kiran, Raji Reddy, Satyam, Madhu, Siddu, Naveen, Rama na, Rakesh, Sampath, Uma, Surendra, ACS, Malli, Madan, Varma, Rajender Reddy, Raju, Pillai, Madhubala, Madhavi, Prathibha, Saritha, Syamala, Sneha, and Jyostna for their co-operation and assistance in an earnest manner. I thank The Management & Principal of Vardhaman College of Engineering and my colleagues Sri. Venkat Ram Reddy, Dr. Mohan Rao, Ravi Kumar, Venkat Reddy, Venkaeshwer Reddy, Ravinder Reddy, Kiran, Mrs. Kavitha, Mrs. Kausar Saida,, Ms. Swapna, and Uma Shankar Reddy who have been a constant source of moral support and inspiration for this work.

I am thankful to my father Sri Pandari and uncles Mr. Laxmi Rajam, Mr. Shalaiah, Mr. Raja Ramesh, Mr. Ashok and Mr. Gopal from whom I learnt my social life and living. I acknowledge with grateful thanks the constant encouragement and support extended by my *family members throughout my work, Specially, my father and brother who have been extensively supporting me in this endeavor and will be happier than me with the completion of my thesis.*

Lastly, my wife Shalini deserves sincere thanks for her immense contribution towards helping me in my research work despite hectic routine of her education, household commitments and timely care of all my needs.

Nagar aju Path a

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A AI	Airports Authority of India
BEE	Bureau of Energy Efficiency
BOLT	Build-Own-Lease-Transfer
CEA	Central Electricity Authority
CBD	Convention on Biological Diversity
CPCB	Central Pollution Control Board
CNG	Compressed Natural Gas
CII	Confederation Of Indian Industries
DSM	Demand Side Management
EIA	Environmental Impact Assessment
EV	Electric Vehicles
ENVIS	Environmental Information System
FDI	Foreign Direct Investment
GAME	Global Energy Water Cycle Asian Monsoon Experiment
IREP	The Integrated Rural Energy Programme
1REDA	Indian Renewable Energy Development Agency
IGCC	Integrated coal gasification combined cycle technology the
IWT	Inland Water Transport
ICAO	International Civil Aviation Organization (ICAO
1CIM0D	International Centre for Integrated Mountain and Development
IUCN	International Union for Conservation of Nature and Natural Resources
IMD	India Meteorological Department
ICPC	**Indian** Centre for Promotion of Cleaner Technologies
IRS	**Indian** Remote Sensing
NCR	National Capital Region
JFM	Joint Forest Management
KVIC	Khadi and Village Industries Commission
LPG	Liquefied Petroleum Gas

MN'ES	Ministry of Non-Conventional Energy Sources
NHAI	National Highway Authority of India
MNP	Minimum Needs Programme
MLF	Multi Lateral Funding
NDDB	National Dairy Development Board
NPIC	National Programme on Improved Chulhas
NELP	New Exploration Licensing Policy
NCEPC	National Committee of Environmental Planning and Co-ordination
NEAC	National Environment Awareness Campaign
NRC	National Re-construction Corps schemes
NGO's.	Non-Governmental Organisations
NFAP	National Forestry Action Programme
NMNH	National Museum of Natural History
NNRMS	National Natural Resources Management System
NATMO	National Atlas and Thematic Mapping Organization
OGL	Open General License
OYWS	Own Your Wagon Scheme
ODS	Ozone Deleting Substances
PPA	Power Purchase Agreements
PCRA	Petroleum Conservation Research Association
REC	Rural Electrification Corporation Limited
RES	: Renewable Energy Sources
RSDO	Research Designs & Standards Organization
SADP	The Special Area Demonstration Programme
SPV	Solar Photo Voltaic
SEB	State Electricity Board
SPCB	State Pollution Control Boards
SDNP	Sustainable Development Networking Programme
TBU	Technical Back-up Units
TPES	: Total Primary Energy Supply
TPS	Thermal Power Station

UNFCCC	United Nations Framework Convention on Climate Change
VSAT	Very Small Aperture Terminals

UNITS AND TECHNICAL ABBREVIATIONS

Mega	: = M = 10^6
Giga	: = G = 10^9
Tera	: = T = 10^{12}
Peta	: = P = 10^{15}
GW	: Gigawatt
GWh	: Gigawatt hour
1 GWh	: = 3.6 Terajoules
MW	: Megawatt (electric)
MWh	: Megawatt hour
KW	: kilowatt
KWh	: kilowatt hour
t	: metric ton = tonne
c	: estimated data
c	: confidential data
x	: not applicable
1 TOE	: tonne of oil equivalent = 41.868 GJ = 107 kCal
TJ	: Terajoule (10^{12} joules)

Chapter – I

INTRODUCTION

1.0 INTRODUCTION

Energy is the most important component for economic development in a country. It plays a vital role in human welfare as all important activities of development are dependent on the use of energy. It is one of the indices of the measurement of prosperity in a country, which is often being used by the per capita energy consumption. Thus, one of the most important tasks of the country's planning process is to ensure that there is a sharp increase in the production of energy and its effective utilization to increase and its consumption pattern with respective to the forms of energy and sources also tends to change.

The main aim of the thesis is to elucidate the importance, viability and feasibility of solar application in the modern economy. Future, the importance of Biogas energy as a good means to control pollution and save conventional fuels is also dealt. The purpose here is to bring the importance and economic viability of biogas energy as a good alternate to the conventional energy sources which are costly and scarce in nature. Biogas energy applications can indeed be good alternate to meet the rural energy crisis and substitute the conventional sources like coal, petrol, and natural gas, etc. Emphasis is made on the accessibility and use as well as the knowledge of solar application in the present economy and an attempt is made to view the future prospects of the development of Biogas energy in various countries in various countries and various biogas applications.

1.1 METHODOLOGY

The use of biogas energy is nothing new; it has been used for time immemorial. But the fact is that all the biogas energy that is been used does not come into account or into the books. It is very difficult to calculate the actual amount of Biogas energy has region would be using. Similarly there are many such loopholes in the calculation of the use of Biogas energy. Only that biogas energy is considered that gets converted into some kind of useful energy in commercial sense. The data in this regard is not available in continuous manner as in some year more stress and development took place due to government policies and in some years it has been ignored.

A comparative study has been made with some solar application that has developed in India and in the rest of the world. A study has also been done as how much of conventional energy can be saved if these biogas applications would be used. Future an attempt is made to explain about the prospects of the future development. Attempts are also made to explain about the prospects of future development. Attempts are also make to explain the economic Payback period, ARR, NPV, IRR and Benefit -Cost ratio's. Calculations are done in this respect for Family Biogas plants. and study is made to understand the conventional energy saving by other Bio mass applications too. In total the aim of this dissertation is to explain the Biogas is and alternate for the Rural Energy Crisis. That is to say, molding of Biogas energy into useful form can give solution for the present rural energy crisis that the world is facing

1.2 IMPORTANCE OF ENERGY IN RURAL AREAS

Ability to do work is called Energy. Energy is the basic ingredient of all modern societies and its per capita consumption is regarded as a standard for advancement of a country. Energy is required to fulfill the basic needs of a human being like food, shelter, clothing, health, sanitation and education, etc.

In rural areas energy is mainly used for cooking , heating and lighting purposes. The energy demand for the cooking is the most common in rural household sector. Most of the rural households, are using firewood, vegetable and agricultural waste, dung cake for cooking purposes. On the other hand majority of the household use kerosene for lighting purposes.

Rural household sector uses with commercial and non-commercial forms of energy. The consumption of any particular type energy depends on various social and economic factors. In the rural areas, the majority part of the total energy consumption is accounted by non-commercial sources i.e., fuelwood, animal waste, agricultural waste and other bio-mass sources. The non-commercial sources are available to zero or negligible cost, it is an important sources of energy for the rural poor.

Fuelwood is an important fuel in the rural households. In the rural areas, 90% of the households development dependent on fuelwood. Energy is whatever form is used, it is vital for conducting daily activities in rural areas. For example, in agricultural pump sets, small scale and cottage industries, cooking etc.

1.2.1 Forms of Energy

Energy is found in different forms, such as light, heat, sound and motion. There are many forms of energy, but they can all be put into two categories, potential and kinetic.

1.2.1.1 Potential Energy

Potential energy is stored energy and the energy of position -gravitational energy. There are several forms of potential energy.

(i) ***Chemical*** *Energy* is energy stored in the bonds of atoms and molecules. It is the energy that holds these particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

(ii) *Stored Mechanical Energy is energy* stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

(iii) Nuclear Energy is energy stored in the nucleus of an atom-the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called fission. The sun combines the nuclei of hydrogen atoms in a process called fusion.

(iv) Gravitational Energy is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

1.2.1.2 Kinetic Energy

Kinetic energy is motion-the motion of waves, electrons, atoms, molecules, substances, and objects.

*(i) **Electrical** Energy* is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrons moving through a wire is called electricity. Lightning is another example of electrical energy.

(ii) Radiant Energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Solar energy is an example of radiant energy.

(iii) Thermal Energy, or heat, is the internal energy in substances-the vibration and movement of the atoms and molecules within substances. Geothermal energy is an example of thermal energy.

(iv) Motion Energy is the movement of objects and substances from one place to another. Objects and substances move when a force is applied according to Newton's Laws of Motion. Wind is an example of motion energy.

(v) Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate-the energy is transferred through the substance in a wave.

1..2.2 Conservation of Energy

To scientists, conservation of energy is not saving energy. The law of conservation of energy says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We change it from one form of energy into another. A car engine burns gasoline, converting the chemical energy in gasoline into mechanical energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

1.2.3 **Energy Efficiency**

Energy efficiency is the amount of useful energy you get from a system. A perfect, energy-efficient machine would change all the energy put in it into useful work—an impossible dream. Converting one form of energy into another form always involves a loss of usable energy.

In fact, most energy transformations are not very efficient. The human body is a good example. Your body is like a machine, and the fuel for your machine is food. Food gives you the energy to move, breathe, and think. But your body isn't very efficient at converting food into useful work. Your body is less than five percent efficient most of the time. The rest of the energy is lost as heat. You can really feel that heat when you exercise.

1.2.4 **Sources of Energy**

We use many different energy sources to do work for us. Energy sources are classified into two broad groups—renewable and non-renewable.

In the India, most of our energy comes from non-renewable energy sources. Coal, petroleum, natural gas, propane, and uranium are non-renewable energy sources. They are used to make electricity, to heat our homes, to move our cars, and to manufacture all kinds of products. These energy sources are called non-renewable because their supplies are limited. Petroleum, for example, was formed millions of years ago from the remains of ancient sea plants and animals. We can't make more petroleum in a short time.

Renewable energy sources include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable energy sources because they are replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity. Electricity is different from the other energy sources because it is a secondary source of energy. We have to use another energy source to make electricity.

Since the Non-conventional (Renewables) energy sources provide environment friendly non-polluting energy, it helps keep atmosphere and environment clean and safe. Moreover it is available locally, therefore it will reduce transmission costs losses. Their development and utilization will enhance rural development and will bring about a positive change in the life style of our rural folk.

1.3 DETERMINANTS OF RURAL ENERGY CONSUMPTION

The main determinants of the energy consumption in rural areas are, family size, farm size, income, landholdings etc. The family size influences least compared to al other. The season also an important variable in assessing bio-mass energy availability and utilization in different regions. Thus, with increases in income or farm sizes, the people switch-over from non-commercial to commercial forms of energy sources.

1.4 DATA TO BE USED IN THE STUDY

The main sources for such data collection are:

- Tata Energy Directory and Year Book, Published by Tata Energy Research Institute (TER1), New Delhi, Various Issues.
- Ministry of Non-Conventional Energy sources (MNE's) - State and Central government reports.
- NEDCAP - Non-Conventional Energy Development Corporation, A.P
- Economic Intelligence Service: India's energy sector, CMIE, Various Issues
- Economic Survey: Govt. of India, Ministry of finance, Economic Division, Various Issues.
- National accounts statistics: Statistical abstracts, Central Statistical Organization, Various Issues.
- National Sample Survey Organization reports (1970-2002)
- NCAER reports
- Sarvekshana - Various Issues

1.5 STRUCTURE OF THE THESIS

The thesis is divided into eight chapters. *Chapter - I: Introduction* including presentation of the study and structure of the thesis. *Chapter II:* ***Rural*** *Energy Crisis: An Empirical Analysis* deals with the Rural energy consumption patterns, Per capita income, Problems of Rural energy crisis and Alternatives of the Rural energy problem with the help of NSSO data regarding the energy consumption of different fuels in rural areas. *Chapter - III: Rural Energy in India:* deals with the Evolution of Rural energy or Renewable in India, Rural energy supply and demand, Rural energy development in

India, Impact of Rural energy on society - environment - natural resource base etc and finally it explains the Integrating Rural Energy with Rural Development. *Chapter - IV: Bio-gas Technology in India:* explains Evolution of Bio-gas Technology in India, Popular Bio-gas plants in India and Contribution of KVIC and NPBD for the development of Bio-gas Technology in India. *Chapter - V: Bio-gas plant - Technical feasibility: An overview* - the technological concepts, components, methodology, design and construction of bio-gas plants are discussed. *Chapter - VI: Bio-gas: A Sustainable Rural Energy Alternative* explains the role and benefits of energy, particularly Bio-gas (Renewable) energy in sustainable rural development with the help of different experts views and with the available date regarding the Energy Potential and Efficiency. *Chapter - VII: Economic Analysis* of Bio-gas plants in India with the help of Payback, and other discounted flow methods i.e , NPV, IRR and B:C ratio.

Chapter - II

RURAL ENERGY CRISIS: AN EMPIRICAL ANALYSIS

2.0 INTRODUCTION

Problems and issues pertaining to energy vary from one type of energy to the other and from one area to the other. Sources of energy are generally classified as commercial and traditional. Under commercial sources of energy such sources, as coal, coke, oil and natural gas and electricity are included, which traditional sources are understood to be consisting of such sources of energy like firewood, twigs and branches, agricultural residue and animal waste. Though, these sources are also strictly speaking commercial in nature as they are also bought and sold in the market if not totally at least partially, in general usage they are considered as traditional sources of energy,

Energy in the Indian rural sector is utilized in agriculture, households, rural handicrafts, transport and other sub-sectors. The rural sectors having a population of about 70%, consumes about 46.1% of the total National energy (20% Commercial & 80% Non-Commercial sources). The bulk of energy is consumed in the domestic sector (70%) followed by agriculture (25%) and others. The per capita energy consumption in the rural sector is 2.70 mil.k.cal/day, whereas it is 7.2 mil.k.cal/day in urban sector. (S. Giriappa:1984).

2.1 PER CAPITA ENERGY CONSUMPTIONIN IN RURAL AND URBAN AREAS

The energy demand in the households sector in 1982-83, as per information available with the energy supply organization, comprised 11.96 Twh of electricity, 5.19mt. of kerosene, 0.52 units of LPG and 1.73 mt of soft coke. The break up between rural and urban areas, however, is not available.

A comparison of the 18th (1963-64) and 28th (1973-74) Rounds of National Sample Survey (NSS) suggests that the average per capita consumption of energy has not changed significantly during this period. Curiously a conclusion of these surveys is that the per capita consumption in rural areas s higher than in the urban areas. The 28th round gives a figure of 349.61 kg per year in rural areas and 310.38 kg for urban areas, measured in coal replacement units. (Table.2.1)

The share of commercial and non-commercial energy in the rural areas is 20% and 80% respectively. The corresponding figures for urban areas are 49% and 51%, though not complete, explanation for this rather anomalous finding of higher per capita rural energy consumption lies in the relatively low efficiency of the energy using devices in the rural areas coupled with availability of free fuel which does not encourage economy of use.

From the NSS data (28th Round) There is variation of energy consumption according to Income. The lowest income group consumes hardly half the energy consumed by the highest income group. It would be noticed that according to these figures, the distribution is less skewed in the rural areas as compared with the urban areas. A substantial part of the fuel consumed in the rural areas is collected free of cost.

The level of useful energy consumption in the rural areas is very low, reflecting the pervasive poverty. The rural families depend even today primarily on the traditional fuels. A major portion of which is secured by private effort of individuals at a very low or even zero private cost. The bulk of the fuel requirement in the households sector is for cooking. Animal and human labour largely provide the energy input in agriculture, but energy for irrigation pumping is becoming increasingly significant. On account of depletion of suppliers of firewood, even traditional fuels are getting commercialized and they are rural poor find it difficult to meet their energy needs.

Rural energy demand will increase in parallel with the growing population. If, in addition, their level of living is to improve, the per capita consumption must also go up. Even for higher productivity in agriculture, the energy input has to go up.

Table 2.1

PER CAPITA ENERGY CONSUMPTIONIN IN RURAL AND URBAN AREAS

(1978-79)

	K.G (Coal replacement units)			
	Rural	%	Urban	%
Coal	3.68	1.05	17.82	5.74
Cock	4.37	1.24	21.85	7.03
Charocoal	0.13	0.04	2.61	0.84
Electricity	2.17	0.62	18.17	5.86
Kerosene	59.11	16.93	94.02	30.29
Firewood	239.11	68.45	141.16	45.48
Dung cake	29.06	8.31	10.06	3.24
F&L and others	11.78	3.36	4.69	1.52
Total	349.61	100.00	310.38	100.00

Source: Papers prepared for the Working Group on energy Policy, 1979

In order to sustain economic growth, the rural infrastructure has also to be strengthened. All of these will mean an ever-increasing demand for energy. How can we meet this demand in such a manner that the costs are with in the purchasing power of the people? It is clear in the next two or three decades, the traditional fuels, which will remain as the main sources of energy supply. The major trust has to be towards sustaining and augmenting fuelwood supplies through a vastly expanded programme of social and energy forestry.

Energy crisis attracted wide attention of the public policy makers in 1973 when there as an unusual oil price high and which put lot of strain on the economy of the developing countries. Acute shortage of commercial sources of energy and their bleak future prospects posed a real threat to the entire world. While, there was lot of concern initially about commercial energy crisis, gradually it dawned upon the policy makers and subject experts that the position regarding traditional sources of energy is also not very comfortable and that in fact this is one of the major day-to-day problems of the rural people who form the major portion of the total population. Rural people mainly depend upon the traditional sources of fuel like fuelwood, agricultural waste and animal waste. Domestic sector of the rural area accounts for more than 75% of total consumption. Owing to fast deforestation and dwindling supply of firewood and gradual commercialization of traditional fuel sources of fuel sources, it has become very difficult for the rural people to secure adequate energy supply at a cost, which is affordable by them. Majority of people, are compelled by their economic situation to cover long distances to gather fuelwood for their domestic requirements. It is not uncommon to find women and children spending 2 to 3 hours per day just in collecting fuel wood becoming more and more scarce the hardship and drudgery of collecting fuelwood has increased many times.

If on the one hand there is acute shortage of supply of energy to rural areas on the other hand there huge wastage of available energy due to inefficient energy gadgets used and enormous misuse of energy due to ignorance. In order to chide this huge waste, it is necessary to motivate the rural people to shift their choice for more fuel efficient heating and cooking devices than the devices presently used by them. It is also important to make the rural folk to aware of the dwindling energy sources or energy. It is essential to halt the indiscriminate feeling of trees; twigs and branches of living trees before it get too late and result in total deforestation.

2.2 STUDIES ON RURAL ENERGY

A major difficulty at rural energy problem is that even today, a clear picture of the pattern of rural energy (supply, demand and consumption etc.) is not available. There are a few macro and micro level studies, which have been carried out during the last 10-12 year in the field of energy.

Literature on energy is of recent origin. Infact, the problems pertaining to commercial sources of energy attracted the attention of the scholars and policy makers only in the early 70's of this century. The origin of global energy studies may be traced to the year 1952 with *Eugene and Scarlott* and later on other studies by ***Patnam and Darmstadter*** followed. The major theme of these studies related to the energy problems of the highly developed and industrialized countries especially belong to the OECD group of countries, studies pertaining to developing countries surfaced during early sixties.

In 1965, Govt. of India conducted a survey energy sources and brought out a report on energy situation pertaining to India. During mid and late 60's many studies were brought out in various developing countries of East Africa and South Asia, with main focus on fossil fuel and electricity. Energy requirement of important tertiary and secondary sectors were analysed in these studies. Problems pertaining to rural energy, traditional sources of energy did not surface significantly in any of these studies.

Energy crisis was mainly identified with petroleum crisis in the early seventies. While in the early sixties there were fringe references of rural energy sources, it was only in 1970's this aspect of energy crisis gained significance. However, there were no systematic studies to evaluate rural energy needs prior to 1970's. While most of the studies address to the problems of commercial source of energy, pricing of energy and such other issues, a few studies directed at examining the pattern of household energy consumption.

In 1976 *R. Revelle* conducted a study pertaining to rural energy consumption pattern in India. This study was based on secondary source of information and had an aggregative approach. Makhijani and Poole made an important contribution to the field of rural energy based on primary source of data These are important studies in the field of rural energy. However, as they have adopted a highly aggregative approach, they do not highlight the inter and intra regional variations in energy consumption. In fact for policy formulation, it is very important to catch the regional as well as seasonal variation of energy consumption pattern. As many studies reveal energy consumption has a positive relationship with the development and income level of a region.

According to study as quoted by TV. *Somasekhar* in 1975 the per capita energy consumption deferential between the United States of America and the rest of the World stood at 8:1 and is predicted to narrow down to a differential of 6.5:1 in 200 AD. The three regions of North America, Europe and USSR accounted for approximately 80% of the world energy consumption while Asia accounted for 14% and other accounted for the balance.

D. E. Earl had made an estimate of energy consumption in developed and developing countries. The per capita energy consumption in kilograms of coal equivalent was of the order 10,817 in the USA, 8,881 in Canada, 5,946 in Sweden and 5,143 in the UK. At the other end of the scale, Earl recoded 259 for Nepal, 274 for India, 291 for Sri Lanka and 304 for Madagascar.

Studies pertaining to household consumption of energy for various end uses like cooking, water heating, lighting, lifting water, space heating or cooling and other purposes like ironing, washing, cleaning and so on need to be studied at length, with relation to the changes in income level, overall development of the area, and availability of alternative sources of energy. Similarly, energy use on agricultural farms, in relation to cropping pattern, holding size and so on need to be studied in detain. In India some attempts were made to study energy problems at macro level. National Council of Applied Economic Research (NCAER) did some of the macro surveys regarding household energy consumption. The NCAER also conducted studies in different regions like Rural Energy Consumption in Northern India. Eastern India, and so on, NCAER also has conducted a detailed survey of consumption of kerosene in India.

The National Sample Survey organisation also carried out consumer expenditure survey (1977-78 and 1983), which provides data on household's energy consumption by income group at all India level and average energy consumption in different states. The survey does not provide State-wise date on energy consumption by income groups. The N.S.S. O data pertain to expenditure on energy by household classified according to average monthly total household expenditure group. However, detailed information about energy consumption by type and by end use by various income class, family size etc., are not available. Besides the above, a few major studies as Energy Survey of India Committee Study 1965, Fuel Policy Committee study (1974), Working Group on Energy Policy Study (1879), and Advisory Board on Energy Study 1985 have undertaken such studies.

2.3 THE PROBLEM OF CRISIS

Energy functions as factors of production, as a process of feedstock and as a consumer good. As an economy develops, its energy demand also tends to increase, and its consumption pattern in terms of energy forms and energy sources also tends to change (Veena; 1988).

Many studies revels that energy consumption has a positive relationship with the development and income level of traditional fuelwood and dung and agricultural wastes etc. The energy consumption varies from place to place and season to season. The dependency on various fuel sources depends on, and varies according to income level of households and the end use pattern.

Present and future energy needs in developing countries are generally different in urban areas from those in rural areas. In urban areas, the bulk of the energy used is commercial, which is itself largely made of petroleum products. The urban energy crisis is therefore best described as an oil crisis. Where the majority of the population still live, the largest energy consumption is of biomass in the form of fuelwood, animal dung and crop residue. Since the bulk of this energy supply is fuelwood. Which has become increasingly scarce, the rural energy crisis has been called the fuelwood crisis.

The shortage of supply of fuelwood (which is the main form of energy used in rural areas) is the energy crisis facing by the rural areas. These are mainly due to two things:

(i) Due to increase in demand, us result of increasing in population, the forests and other wood sources under severe pressure.

(ii) Due to relative increase in income or purchasing power, the increased consumption fuelwood, which is considered more efficient than crop wastes and other biomass fuels in rural areas.

Thus, with the increase in demand for food to satisfy the increasing in population, more forest areas are being brought under cultivation, thus worsening the fuelwood availability in the rural areas. The depleting sources of fuelwood on one side, and increasing demand on the other, are leading to the energy crisis in the rural areas.

This is so-called fuelwood crisis, which is mainly the result of ruinous exploitation and complete deforestation, did not occur suddenly. It proceeded continuously and unobserved over the course of time. In the beginning, small clearings emerged on the out-skirts of settlements, small patches, which then grew. Finally, joining together: wood supply came to an end in the surrounding settlements and eventually even in whole region, which had previously had a surplus of fuelwood. The fuelwood crisis or more broadly, the biomass was mainly caused by the following:

- Rapid growth of the rural population, and the resultant increased consumption fuelwood, or mass;
- Poverty of the rural population and the consequent lack of purchasing power to pay for and alternative fuel;
- Underestimation of the crisis and the over estimation of the means of containing it and
- Lack of or insufficient reforestation and/or aforestation.

These above all factors have resulted in a vicious cycle of resource depletion in rural areas in developing countries. This can be shown in Table 2.2.

Table 2.2

INCOME **AND** ENERGY CONSUMPTION **IN** RURAL **AND URBAN** AREAS

(1978-79)

Expenditure class Rs. Per month per capita	Index of total per capita energy consumption in	
	Rural	Urban
All expenditure classes together	100	100
0-21	66	48
21-28	80	61
28-43	90	82
43-75	100	96
Above 75	138	**125**

Source: Report of the Working Group on Energy Policy, 1979

As the declining wood yield of the forests could no longer meet the fuelwood requirements of the rapidly growing rural population, instead of planting new trees, the population began to cut them down without reforesting. This uncontrolled over exploitation caused extreme soil erosion and related impacts, thereby exacerbating the dramatic shortage of fuelwood, which has totally disappeared in some areas. With the increased shortage of fuelwood, which had till then been regarded as common property, the population searched for alternative found was to burn animal excrement dung cakes - and woody crop residues, such as cotton stalks, corn stalks and cored corn cobs. The increased burning of dung displaced its use as and organic soil conditioner or fertilizer and thereby downgraded soil fertility. Lower soil fertility brought about lower agricultural yields i.e reducing in food and fodder production with its ensuring consequences; a food crisis and a decrease in dung production.

In an attempt to compensate for the low yield achieved per unit of arable land, farmland was simply enlarged. As arable land could not be enlarged indefinitely, this expansion was at the expense of the forests woodlands, initially in the valleys and eventually on the mountain slopes. What followed was a dramatic contraction of forest land, resulting in increased soil erosion, so that even more forests and arable land were destroyed. The effects were, among other things, a shortage of biomass and food and an ecological crisis.

The decreasing agricultural yield also led to a reduction in the land used for fodder cropping and to decline in agricultural byproducts, so that altogether there was less fodder for the livestock. Livestock consequently produced less dung, which was needed both substitute for increasingly scarce fuelwood as an organic fertility, so that the drive intensified to create more farm land to compensate for the decreasing agricultural yield per unit. Equally less milk and meat were produced, so that the food shortage become increasingly acute.

These many vicious cycles (fuelwood crisis -leads to ecological crisis - which lends to food crisis), began with the apparently harmless shortage of fuelwood, but eventually spread to affect all rural activities. They highlight how serious the rural energy crisis and its consequences are: they threaten not only economic growth, but also the survival of the rural population in developing countries.

If the energy source to be substituted has no market price, as is often the case, for example with fuelwood and /or dung, the economic feasibility calculation can only be made on the basis of shadow prices or opportunity costs of the substituted energy sources, which are difficult to ascertain and verge, so that the outcome of the calculation in such cases is best with uncertainties.

Economic factors are important, therefore, but should not override the long-tem social and environmental value of disseminating renewable energy technologies. Where the concern is to satisfy the basis needs of the poorest section of the population, humanitarian criteria should replace economic ones. To ensure, however, that scarce capital is put to effective use, priority should be given to systems that constitute an improvement on traditional technologies. For example, if updates 'three-stone stoves' have been used, the population should be provided with better, more efficient stoves.

Where possible, a strategy for improving and securing energy supply should not be based on energy imports, but rather on self-sufficiency in energy. This self-reliance should not be confined to energy resources alone, but should also include the requisite technology and technology and technological infrastructure for the conversion and utilization of these energy resources. This means that, wherever possible, a renewable energy strategy for developing countries should avoid replacing or substituting the current heavy dependence on petroleum imports with a dependence on imports of capital intensive and highly sophisticated technical equipment.

2.4 ALTERNATIVES OF ENERGY CONSUMPTION IN RURAL AREAS

The Non-Commercial fuel is obtained form agro-waste, animal waste, firewood etc. Though non-commercial sources available at almost zero or negligible cost. Non-commercial fuels are in the nature of inferior goods; and tend to be substituted by commercial fuels as income level increases. Since non-commercial fuels are available at zero or negligible cost, it constitutes an important source of energy for poorer sections of the populations, especially in the rural areas. This is because a large majority of the rural population does not have enough purchasing power; they survive on non-commercial energy sources like firewood, dung-cake and agricultural wastes. Thus in rural areas, wood is the basic cooking fuel, and where it is scarce, dung and agricultural wastes are adopted.

With development, increase in incomes of the households, and an increase in population, the demand for energy increases almost exponentially. Energy consumption domestic or household sector depends mainly on increase in income and increase in family size. The *household energy source consists mainly of fuelwood, crop residues, animal dung and twigs and branches on the one hand and coal, kerosene, electricity and LPG on the other. Most of these sources of energy act as substitutes for one another, at one point or the other.*

The alternatives to fuelwood may be commercial, non-commercial or other potential fuels. Commercial fuels *like oil that is* petrol, diesel, kerosene, coal & coal products like briquettes, LPG, natural gas, propane, butane, electricity - hydro, thermal nuclear. The Non-commercial fuels can be divided into agricultural wastes, animal wastes, bio-gas, forest products, and shrubs, and the Potential sources of fuel (non-conventional) can be divided into solar-direct, solar electricity, fuel cells and solar cookers, wind energy, tidal energy, and geothermal energy.

Of the above listed alternatives, the viable and preferred sources of fuel for the rural household consumption are (he Non-commercial and Potential sources of fuel.

2.4.1 Commercial Sources of Energy

The commercial sources of fuels are not only non-renewable and almost near exhaustion. They form the foundation of the industrial structure, and most important, they have very high environmental costs attached to their usage and future development.

The most common usage of electricity at present is for lighting purposes. Cooking by electricity is rare in the rural areas, and even in the urban areas, it is very expensive to use electricity for cooking purposes. Also, cooing by electricity is rare in developing countries, and wherever it occurs, it is usually among the richer members of the region. Where it is adopted for cooling, it tends to replace or displaced gas or kerosene rather than fuelwood, and its direct impact on fuelwood demand in the reasonable near future is likely to be relatively minor.

In fact the major shift to kerosene is theoretically possible, does not imply that it is either feasible or desirable distribution systems completely precludes a significant shift to commercial fuels by rural consumers in the majority of the third world countries. The relative costs of cooking with different fuels might be expected to have an impact on the choice mix between the fuels by the customers.

2.4.2 Non-Commercial Sources of Energy

The alternatives of Non-commercial sources of energy are mainly four; i.e Improved Stoves, Agricultural Wastes, Animal Wastes, and Biogas.

2.4.2.1 Improved Stoves

Regarding non-commercial sources of alternative to fuelwood, most important and presently more feasible is introduction of improved stove, using fuelwood or twings and branches. It not only conserve the fuelwood, it also makes the cooking activity easier because of more efficient use of the fuel source then compared to the traditional stoves. It has been observed that on an average about 5% of fuelwood can be saved in the bigger cook stoves and about 10% in smaller ones (Tyagi and Bhat; 1985). But one major problem with the large scale adoption of the improved cook stoves is the cost involved, which needs periodical repairs or rebuilding, as most of the stoves are made mud, bricks and other locally available materials. Their relative non-flexibility ana larger labour time act as other constraints.

In order to encourage the women in the rural areas to use efficient improved chullhas / stoves in place of traditional stoves - thereby minimizing drudgery and health hazards. A centrally sponsored project on demonstration in Improved chullhas was implemented in the country from February 1984. Under the scheme, trainees are trained by master trainers in the art of constructing the improved chullhas. These trainees, on completion of their training are expected to construct chullhas for the beneficiaries in the villages ultimately making the entire village a 'Smokeless village'. The Government of India provides funds for this scheme at the rate of Rs. 10,000 per training course and subsidy of Rs. 50 per chullhas which are constructed outside the training classes.

2.4.2.2 **Agricultural** Wastes

The use of agricultural waste is dependent on agricultural production and its availability is seasonal. Apart from this, there are many other uses for the agricultural wastes, like it is an excellent fodder for the farm; animals, house making and some wastes are also used as fertilizers. Thus the use of agricultural wastes can best be limited to vocational use and fuel time dependence on it has a household fuel is neither possible nor feasible.

2.4.2.3 Animal Wastes

Animal wastes like cow dung is used on a large scale in the rural areas of India. It is also used to some extent in the poorer sections of urban areas also. Cow dung is not only a source of energy, it is also natural fertilizer. Cow dung cakes, though are a popular source of fuel in many areas, it is not an efficient fuel. The drawback of using cow dung cakes, as fuel is that its use deprives the farmer of a valuable natural fertilizer.

2.4.2.4 Bio-Gas

A device for utilizing the methane gas generated by the decomposition of organic matter like cow dung and the agricultural waste which are available in abundance in the countryside. The oil crisis of 1973 aroused keen interest about the potential of bio-gas as an alternative source of energy in the rural areas. Thus a biogas plants converts animal dung to produce both fuel and manure where as dung can be used either as manure or as dung cake for fuel.

The best alternative may be the usage of cow dung for the generation of biogas or gobar gas. This can be viable alternative for fuelwood in the rural areas, specially, as it usage as a source of fuel does not mean it cannot be used as a fertilizer. In fact, the by-product dung - out of the biogas plant is said to be better fertilizer source for the fields. The use of bio-gas can check the rate of deforestation, but the impact of promotion of bio-gas may increase the size of livestock population which in turn, needs more fodder is mainly derived from tree – leaves, branches cut form nearby trees or from local forests and other miscellaneous trees. Thus, even with the promotion and use of biogas, some amount of deforestation takes place. But bio-gas technology is a major alternative because it not only provides crop manure of a higher nutrient content, but also a very convenient fuel source, which can be used for cooking, heating and lighting purposes.

A bio-gas project being taken up must explore variables like the number of family members, size of land-holdings, livestock population, daily dung production, daily fuel wood consumption, the amount of dung used to produce bio-gas, consumption of kitchen fuel, if any, like kerosene.

Through it is a clean, efficient fuel, and it can be used for cooking lighting and gives manure for the fields, its high initial cost inspite of the subsidy given by the government, and its continuous operating costs make it unacceptable and in accessible to most of the rural households.

2.4.3 Potential Sources of Energy

These are still under development and as of now, not an economic prospect. But their development is underway, as they are all renewable sources of fuel and are by and large, non-polluting. Thus there will not be any adverse affect by their development and usage, but they are yet to be brought under usage on commercial scale. The energy from sun, sea tides and wind is considered as very useful source. Even these sources have make the people realize the importance of non-commercial and potential sources of energy, and its optimal utilization for meeting the growing needs of the people of the world in general and developing countries in particular.

Solar Energy of the potential sources of energy, solar energy is the most important. Though solar energy, is the most basic source of energy, its harnessing and use in the requires of recent origin. Solar energy used for lighting, drying, heating, and other uses from the earliest times, harvesting it and using the same even when sun is the source of energy, which is of interest here. The solar energy received by earth in a second is 10-17 joules. Which is equivalent to more than electricity generated in a month all over India, or eight days of sunshine is equal to the total availability source of energy **in the world put** together for a period of about one year.

Basically there are three ways of catching sun's rays used either for heating or for generating electricity:

a) By keeping of Solar Panel on the roof of house or building and storing as much as possible or converting these rays into electricity current.

b) Keeping water in insulated tubes is a good medium where is a lot of sunshine.

c) By Photovoltaic cells, where the cells generate energy because of chemical reaction, triggered on by the sunrays falling on the cell, filled with chemicals.

Other potential use of solar energy in households is by solar cookers. The solar cookers works on the reflector principle, where the sunrays are made to fall on **one** or a few mirrors and than they heat up the cookers and cook the dishes kept inside the cooker. Solar water heaters are mainly of two types thermosyphon systems and forced -flow systems.

Another use of solar energy is by solar battery. The battery is operated with semi-conductor crystals, which are quite similar to those use in transistors, wither of germanium of or silicon. An electric current is generated when sunlight strikes such a crystal. Solar power can be an ideal alternative to other commercial and non-commercial sources of energy because of its inexhaustive nature and also because there is a no shortage of the source in a tropical country like India.

Wind Power, Wind power, which can be developed as an alternative to fuelwood. Apart from generating electricity by wind miles, it can be used for various small uses like crop drying, irrigation, etc. This can be useful and free of pollution as long as **wind** of a particular velocity is available.

Tidal Energy or the sea tides are another source of energy, which is derived from tides, thus it can be called as Lunar Energy. But it is in an initial stage of development to provide available alternative to fuelwood.

2.5 CONCLUSION

In the rural parts of India, more than 75% of rural households depend on traditional sources of energy. Their income level is very low and lack of purchasing capacity, majority of households do not afford to buy fuel for their day-to-day use. Vast unemployment and acute poverty forces the rural poor to go on hunting for fuel. Small children of the age of 8 years and above also go to the forests or nearby grazing land, fallow land, and waste land in search of fuel. Men, Women and children, on an average daily spend about 3 hrs in fuel gathering and they walk about 4 to 5 kilometers in search of fuelwood.

Though, rural energy consumption pattern very much depends upon the socio-economic position of the villages and the households as the villages do not differ much in items of their socio-economic pattern, energy consumption pattern also do not very much among the villages. However, the quality consumed varies among the differentially developed villages and among different income and landholding class.

The following are the major observations of this chapter:

- An increase in per capita income leads to an increase in the quantity of energy demand.
- Income increase, significantly influences the consumption pattern as:
  - People shift their demand from inferior type of fuel to superior type of fuel.
  - If, there is no shift in demand or shift is negligible along with an increase in Income, larger quantity of inferior type of energy consumed. (Energy Ladder: P.V.Prathibha - 2002)
- The end use pattern undergoes a change and the demand for energy for heating water increases.
- The rural people are not only using the traditional and very inefficient sources of energy, but also the cooking gadgets are out-moded and are very inefficient. There is considerable amount of energy loss due to inefficient cooking gadgets.

The depleting sources of fuelwood on one side, and increasing the demand on the other side are leading to the energy crisis in the rural areas. This crisis causes fuelwood crisis to ecological crisis, which leads to food crisis.

In order to reduce the rural energy crisis, there is need for formulating a comprehensive and integrated rural energy policy. To meet the rural energy problem, it is important to exploit, the locally available sources of energy. Simultaneously the technology in non-conventional energy systems should be constantly updated through intensive research and development efforts. It is equally important to educate and train the rural people in such devices through demonstrations.

The alternatives to fuelwood may be commercial, non-commercial, potential and other sources. The non-commercial and potential are viable and preferred sources of fuel for the rural household energy consumption. The next chapter considers the most viable source (Bio-gas) of energy considering the various socio, economic and other factors.

Chapter – III

RURAL ENERGY IN INDIA

3.0 INTRODUCTION

Energy is a critical input for economic growth and sustaining development processes. Over one-third of the world's population, largely consisting of the poor in rural areas of developing countries does not have access to electricity. It is estimated that a new power plant would need to be added every two days to meet the increasing global energy demand. This, however, is clearly an unsustainable proposition, and only emphasizes the urgent necessity for developing energy technologies that are environmentally sound, socially acceptable, and economically viable.

Lack of access to affordable energy is an important factor contributing to the relatively poor quality of life in rural areas of developing countries. The potential markets of the rural poor are characterized by a high demand for energy for purposes such as lighting, cooking, space heating in the domestic sector; water lifting and transportation in agriculture; and small and medium enterprises.

3.1 EVOLUTION OF RURAL ENERGY INDIA

3.1.1 Introduction

Biomass energy is the local energy available for meeting the minimum rural needs of cooking. Though the contribution of biomass sources in the overall energy scenario is gradually decreasing, it still contributes over 40% of the energy supply in the country. Sixty-five per cent of the biomass energy in the rural areas is apportioned to fuelwood, 20% to agricultural waste and 15% to cow dung. With the increasing use of commercial sources of energy there has recently been a substantial shift towards commercial sources. As such, the future projections for energy in India do not show a proportionate increase in the fuelwood consumption with the rising population. It is difficult at this stage to predict the shift in the fuel-mix but it is clear that shift is taking place. Also, in view of global energy policy considerations, the final form of energy is more important than the primary form. Therefore, there has been a major thrust on how fuelwood and other sources of energy can be converted into desirable form, thereby making the primary sources of energy of secondary importance. This change is gradual but quite perceptible.

The Government of India has focused attention on governance at the rural level through Panchayats, the body of elected members of the public. The Panchayats have also been assigned certain development tasks as laid down in the Eleventh Schedule of the Constitution of India. Social forestry and farm forestry, along with land improvement, implementation of land reforms, land consolidation and soil conservation, fuel and fodder, and non-conventional energy sources are the responsibility of the Panchayats.

It is necessary to have a look at the energy policy and rural energy planning efforts made in India, as well as the ongoing programmes, to consider how the biomass production can be better managed and regularised through local governance systems.

3.1.2 INDIAN RENEWABLE ENERGY SITUATION

In this section, Indian Renewable situation is examined with respect to its scope, potential, achievements and economics of renewable energy resources. Further this section deals with the Rural energy policy issues with the help of numerical and theoretical experiences

3.1.2.a Renewable Energy Scope

Today most of the world's energy is derived from conventional sources-fossil fuels as coal, oil, and natural gases. Electricity generated from fossil fuels such as coal and crude oil has led to high concentration of harmful gases as carbon-di-oxide, carbon-mono-oxide, sulphur-di-oxide etc in the atmosphere. Also the sources of fossil fuel in the earth are finite and will be depleted in few years. Most recent method to generate electric power is an atomic reactor. All these conventional sources of energy has caused more environmental damage then any other human activity.

Therefore, alternative sources of energy have become more important for the future world. The alternative sources of energy are called Renewable Energy System. A Renewable Energy System converts the energy found in Sunlight, Wind, Falling-water, Sea-waves, Geothermal heat, or Biomass into a form we can use such as heat or electricity. Most of the Renewable energy comes either directly or indirectly from Sun and Wind and can never be exhausted , therefore they called Renewable.

India receives 5000 trillion Kwh of Solar radiation per year. Most part of the country has 300 clear sunny days in a year. So in India alone it is possible to generate 20 MW Solar power per square kilometer area.

Renewable energy sources are environment friendly and reduces chemical , radioactive and thermal pollution. Renewable sources of energy such as Solar energy are economically feasible in small scale applications in remote areas or villages (where there is no electricity) or in large scale applications in areas where the resources are abundant.

The Renewable energy or the non-conventional energy sources are Sun, Wind, Falling-water, Sea-waves, Geothermal energy, method of co-generation etc. It is expected that 60% of all the energy will come from Renewable energy up to year 2070. The world Solar summit, world Solar Decade and the World Bank has recently allocated huge money to the projects dealing with Renewable Energy. World organizations as UNDP, UNISO, UNIDB etc US Department of energy (DOE) and National Renewable Energy Laboratory (NREL) .The European countries are doing lot of research work in Renewable Energy.

The Ministry of Non-Conventional Energy sources (MNES) created in 1992, a Nodal agency of the Government of India, relating to Renewable Energy. The several Renewable Energy sources are Solar Energy, Solar Photovoltaic System, Bio-gas Energy, Biomass

Energy, Wind Energy, Small Hydro Power, Geo Thermal Energy, Ocean Tidal Energy, Co-generation Energy etc

Today India has the World's largest programmes for Renewable Energy. Several Renewable Energy technologies have been developed and deployed in villages and cities of India. A Ministry of Non-Conventional Energy Sources (MNES) created in 1992 for all matters relating to Non-Conventional / Renewable Energy. It undertakes policy making, promotion, coordination of functions, R&D and technology development, intellectual property protection, human resources development and other matters relating to Renewable Energy. Government of India also created Renewable Energy Development Agency Limited (IREDA) to assist and provide financial assistance in the form of subsidy and low interest loan for Renewable Energy projects. India's achievement in the fields of Renewable Energy is very significant as shown in Table: 3.1.

There are 153 Energy Parks in India to educate people about Renewable Energy. India also provided technical guidance and help to many developing countries for construction of Non-Conventional energy equipments. Several Renewable Energy equipments and products as Solar Photovoltaic Systems, Wind Turbine Equipments, Thermal Applications, and Solar Cookers etc. have been exported. India ranks third largest producer in the world of Solar cells and Photovoltaic (PV) modules. In India alone thirteen projects of 940 kw total capacity have so far been installed in different states. A number of R&D projects on Renewable Energy technologies have been implemented at several Research, Scientific and Educational Institutions, National Laboratories, Government and Industrial organizations in India.

Ministry of Renewable Energy of India has taken major initiatives to encourage Private /Foreign Investments to tap energy from Renewable Energy sources. These initiatives include provision of Fiscal and Financial incentives, exemption from Excise duty, Sales tax and concessional customs duty in the imports of items used in Renewable Energy projects.

Table 3.1

The installed capacity (As on 31st March 1999), can be summarized as below

(in Units)

Biogas Plants	28.50 lakhs.
Improved Chulhas	300 lakhs.
Solar Heating System	4,50,000 sq.m.
Solar Photovoltaic System	329 mw.
Biomass Power	200 mw.
Wind Power	1025 mw.
Small Hydro Power	183.45 mw.
Solar Photovoltaic Power	1590 kw.
Solar Cookers	4,75,000.
Solar PV Pumps	2868.
Battery Operated Vehicles	217.

Source: Ministry of Non-conventional Energy Reports - ***2000-01***

3.1.2b. Renewable Energy Potential

With a strong industrial base and successful commercialization of technologies in wind, SPV, solar, thermal, small hydel, biogas and improved biomass stoves, India is in a position today to offer "state-of-the-art" technology to other developing countries and play a leading role in the global movement towards sustainable energy development.

India has a large potential for utilization of renewable energy. The scale over which potential can be economically exploited will depend largely on the technologies, financing and the strategies of implementation of renewable energy projects. According to the Ministry of Non-Conventional Energy sources, there exists a potential exploitation of the order of 80,000 MW. Break of this potential is presented in the table 3.2.

The Middle East Conflict of 1973 resulted in sharp increase in the prices of the vital inputs of agriculture, that is energy and fertilizer, thereby adversely affecting the economy of developing and developed nations. The only apparent benefit form this unfortunate conflict has been the creation of awareness, in both developing and developed countries of the value of organic wastes as inexpensive sources of energy and plant nutrients. Sometimes a dark could has a silver lining. So the present man-made energy crisis created by the action of a few countries is a blessing in disguise. It should be considered as an amber light - a warning prior to the real danger (Vandana S;2002)

Table 3.2

Renewable Energy Potential (As on 31st March 1999)

Sl. No	Sources / Technologies	Units	Approx. Potential	Achieved so far
1	Wind Power	MW	45,000	1,267
2	Small Hydro (upto 50 MW)	MW	15,000	**1,341**
3	Biomass Power	MW	19,500	35
4	Biomass Gasifiers	MW	--	~
5	Biomass Cogeneration	MW	--	273
6	Urban and Industrial Waste	MW	1,700	15.20
7	Solar Photovoltaics	MW	Not Known	65
8	Solar Thermal Applications	MW/Sq.	35	0.55
9	Solar Water Heating Systems	Sqm.	Not Known	5,25,000
10	Solar Cookers	Numbers	Not Known	4,96,000
11	Biogas Plants	Million	12	3.1
12	Improved Biomass Chulha	Million	120	33
13	Wind Pumps	Numbers	Not Known	670
14	Solar PV	Numbers	Not Known	3575

*Source: **MNEs;** December 2000-01*

3.1.2c Economics of Renewable Energy

There are several barriers to the adoption of renewable energy technologies, but opportunities exist to overcome them. The financial limiting greater deployment of renewable technologies. The essential barrier lies in the perceived risk associated with investing in renewable energy technologies, which is generally higher then competing conventional technologies, and the effects of this higher perceived risk on a technology's market:

- Capital markets generally perceive the deployment of emerging technologies as involving more risk than established technologies. The higher the perceived risk, the required rate of return demanded on capital.
- The perceived length and difficulty of the permitting process is an additional determinant of risk.
- The high front-end, or financing requirements of many renewable energy technologies often present additional cost-recovery risks for which capital markets demand a premium.

The following are opportunities to address these financial constraints:

- Low interest loans or loan guarantees might serve to reduce perceived investor risk.
- Tax credits for renewable energy technology production through the early, high risk years a project may provide another mechanism.
- Regulatory cost-recovery mechanisms, which today often favor low-initial-cost, fuel based technologies, can be modified to recognize life-cycle cost as a more appropriate determinant of cost effectiveness.
- Effective redistribution of government spending in research and development that more directly reflects the potential of renewable energy technologies.

Effective valuation of external environmental costs associated with conventional fossil-fuel power generation. In a straight economic accounting based on dollars per kilowatt of power generation, fossil fuel-fired facilities appear to be the option of least cost today. This method of accounting tends to neglect the environmental and social costs involved in producing electrical power by burning fossil fuels or using nuclear power. This form of economic analysis is in a relatively early form of development, yet has made great strides in recent years.

3.1.3 Need for Rural Energy Policy **in India**

India is the second most populous nation in the world and has extreme ecological diversity. 70% of the population in India, close to 700 million, still lives in the rural areas. Meeting their energy requirements in a sustainable manner continues to be a major challenge for the country. All most 75% of the total rural energy consumption is in domestic sector. For meeting their cooking energy requirements, villagers depend predominantly on biomass fuels like wood, animal dung and agricultural residues, often burnt inefficient traditional cook stoves. The main fuel for lighting in the rural households is kerosene and electricity. Irrigation is mainly through electrical and diesel pump sets, while the rural industries and the transport sectors rely primarily on animal power and to some extent on commercial sources of energy like diesel and electricity.

*India adopted short-, **medium-** and long-term energy planning processes in the country.* In the short term, the effort is to maximize returns from the assets already created in the energy sector, improving efficiency in production, transmission and end use; reducing energy intensity of different consuming sectors and initiating steps for meeting fully the basic energy needs of urban and rural households.

In the medium term, progressive substitution of petroleum products by coal, natural gas and electricity, accelerated development of renewable and promotion of R&D efforts on decentralized energy technologies based on renewable resources have been suggested.
In the long term, promotion of energy supply systems based largely on renewables and promotion of technologies of production, transportation and end use of energy, that are environmentally benign and cost effective, have been suggested though fuelwood, agro-

residue and cow dung are the main sources of fuel, only **the** use and availability of fuelwood can be planned and quantified. Primary data are available on fuelwood from field surveys, conducted by the National Sample Survey Organization (NSSOX National Council of Applied Economic Research (NCAER) and other research institutions and individuals.

Given the exploitation process of natural resources, this situation is likely to worsen in the years to come. Rural energy systems are further strained by the inability of people to shift to commercial fuels like electricity, LPG and kerosene because of low purchasing powers and limited availability. The subsides on electricity for agriculture and kerosene have also been a cause of concern for energy planners.

To reduce these problems, several efforts have been made both by governmental and non-governmental organizations in the form of national programmes for rural electrification and promoting renewable energy technologies like biogas, improved cookstoves, and solar cookers. However, in spite of the existence of these programmes for nearly tow decades, their impact on the rural energy scenario has been limited. Over the last few years, in line with economic liberalization, there have been efforts towards bringing about commercialization, implemented in the past two decades, in order to formulate a meaningful rural energy planning at national level.

3.2 RURAL ENERGY CONSUMPTION PATTERNS

Rural Energy consumption can be broadly classified into energy for domestic use, for agricultural use, use in Industry sector (small and medium enterprises) and Transport Sector.

3.2.1 Domestic Sector

The household sector accounts for nearly 75% of the energy used. Cooking accounts for almost 90% of the household energy use with the rest taken up by lighting and heating.

Biomass fuels provide 85-90% of the domestic energy and 75% of all rural energy. Among the commercial fuels, only kerosene is prominent being used mostly for lighting.

Given the geographical and ecological diversity in the country, the consumption pattern varies quite considerably as well; for example, the per capita consumption of fuelwood, for instance, ranges from 0.14 kg per day in Haryana to 1.31 kg per day in forest-rich Himachal Pradesh. The fuel-mix also varies from region to region depending on the resource endowments. Fuelwood consumption is high in states (for instance, all the North-Eastern states) where there is considerable foreste over, whereas dung cakes play an important role in states like Punjab and Haryana, which have little biomass cover. Crop residue is used in most areas as a backup fuel when other fuels are in shortage, such as West Bengal and Punjab.

Biomass fuels provide 85%-90% of the domestic energy (table 3.3) (Natarajan 1997). Cooking is the largest energy consuming end use. It accounts for nearly 90% of household energy; lighting and space heating consume the rest. Biomass (wood, animal dung, crop residue) in outdated, inefficient cook-stoves (10 per cent efficiency) is generally used for cooking, while inefficient devices fuelled by kerosene are used for rural lighting.

The Planning Commission estimates the fuelwood requirement at 180 million tonnes in 2001, a substantial increase from the actual consumption of 162 million tonnes in 1996 (Ninth Five-Year Plan: 1997-2002). Kerosene is used mainly for lighting. Considering that only a third of households even in electrified villages have electricity connections, it is estimated that there are 70-80 million households in the country that are not served by grid electricity.

Table 3.3

Energy Consumption in Rural Households: 1995-96

Energy fuel	Quantity (thousand tonnes)	Share (%) (useful kcal)	Quantity (thousand tonnes)	Share (%) (useful kcal)
Coal/soft coke	1,143	1.92	429	0.38
Kerosene	414	2.55*	1,103	4.44*
Dung cake	66,755	22.51	86,732	17.00
Firewood	—	—	—	—
Logs	20,109	11.95	57,956	32.49
Twigs	58,742	35.62	73,418	29.11
Crop waste	29,529	17.41	34,955	13.35
Others	—	1.03	—	—
Total	—	100.00	—	100.00

* *in thousand kilolitres*

Source: Natrajan I. *1997. Biomass energy: key issues* ***and priority needs. Paris: Organization for Economic Cooperation and Development.***

These homes are totally dependent on kerosene for lighting. An unreliable power supply, even to electrified homes, compels villagers to use kerosene lamps. According to the 50th round of the National Sample Survey (NSSO 1996), about 62% of rural households uses kerosene primarily for lighting (table 3.4). Only two per cent of rural households in India uses kerosene as the primary cooking fuel. The total kerosene consumption in India during 2000/01 was estimated at around 11.5 million tonnes out of which about 60% was for the rural areas. In spite of significant increases in the supply of commercial energy, the consumption of commercial fuels such as LPG is still negligible in the rural areas with only 1.3% of households using it for cooking (TERI 1998a).

TERI has found that grid-based rural electrification programmes in India are largely unaffordable and unreliable with an estimated cost of 12 500-30 000 dollars per village; this translates into 65-165 dollars per household per year, depending on the distance from the existing grid. With over 80 000 Indian villages still awaiting electrification, renewable energy technologies, such as solar lanterns, solar home lighting systems, solar water heaters, etc. can provide options that are more environmentally friendly, economically viable, and socially acceptable.

3.2.2 The Agriculture Sector

The agriculture sector is the second largest energy-consuming sector in rural India. In the agricultural sector, animate energy (human and draught power) accounts for more than one-third of the total energy consumed. Inanimate energy inputs are mainly in irrigation through diesel and electrical pump sets. There are an estimated 10 million electric and 6 million diesel pump sets in the country. Diesel for tractors used in tilling, harvesting, etc. is the other important energy source.

Table 3.4

Primary source of energy for lighting in Rural Households (%): 1988/89, 1993/94 and 2000/2001

	Kerosene			Electricity		
State /Year	**1988/89**	**1993/94**	**2000/2001**	**1988/89**	**1993/94**	**2000/2001**
Andhra Pradesh	59.07	50.5	41.6	38.20	**49.2**	52.6 '
Assam	84.70	84.6	78.3	9.10	**14.9**	21.3
Bihar	92.20	92.8	88.4	4.40	6.4	9.3
Gujarat	42.20	31.8	26.4	49.40	**67.5**	74.3
Haryana	41.60	23.5	19.1	57.20	74.6	82.4
Karnataka	60.10	44.9 -	31.6	35.80	54.5	66.3
Kerala	55.90	43.4	32.2	42.20	56.5	60.2
Madhya Pradesh	62.30	54.1	40.3	29.80	**44.9**	65.0
Maharashtra	50.70	41.1	33.4	45.90	**58.6**	60.3
Orissa	85.80	84.9	79.4	10.90	**14.6**	17.2
Punjab	23.80	11.0	10.2	71.40	87.3	90.3
Rajasthan	74.60	58.0	40.0	22.20	41.0	55.4
Tamil Nadu	53.20	45.7	38.3	43.20	54.0	58.3
Uttar Pradesh	89.10	81.0	74.2	9.30	17.7	22.1
West Bengal	91.10	88.2	85.3	5.80	11.2	19.8
All-India	**69.20**	**62.4**	**60.0**	**27.04**	**37.1**	**48.3**

Sources: National Sample Survey Organization.2001. Sarvekshana XX(4): S213 and S2S7. New Delhi: Department of Statistics, Ministry of Planning and Programme Implementation, Government of India.

Three activities in the sector account for most of the energy used: land preparation, harvesting and irrigation (water lifting and transportation). Irrigation is the most important end-use of energy. Animate energy (human and draught power) caters to over one-third of the total energy consumed (table 3.5). An estimated 15 million electric and 6 million diesel pumps are currently in operation in the agriculture sector of the country. Diesel oil and electricity are the major sources of energy for irrigation with the estimated demand for each being 8 MMT and 127 TWh, respectively in 2001/2002. The share of oil and electricity in the final energy consumption of the agricultural sector has increased steadily over the years (Figure 3.5). The sector accounts for 30% of the overall demand for electric power, mostly for water lifting, which is provided by the erratic grid power supply interspersed by human and animal power. An erratic and insufficient power supply reduces the efficiency of the electric pumps also affecting agricultural yield.

The country's population is slated to reach 1.4 billion by 2030, but with the restricted land area available for cultivation, agricultural production needs to grow, too. This can be achieved only by using innovative methods such as biotechnology, bio-fertilizers, bio-intensive pest control methods, and micro-irrigation. Villages would benefit greatly from a dependence on non-conventional modes of energy generation (renewable and energy efficient technologies).

3.2.3 The Industry and Commercial Sector

While small industries and commercial establishments (hotels, restaurants, shops, etc.) in rural areas (and in urban areas)consume significant quantities of biomass energy, reliable statistics are not available on the extent of consumption. Available evidence suggests a high level of fuelwood consumption and a growing demand. Most of these establishments are in the informal sector, would depend on diffused sources for fuelwood, and would have no proper records. Nonetheless, one estimate puts the figure of total fuelwood consumed in this sector at 6 million tonnes per annum

Table 3.5.

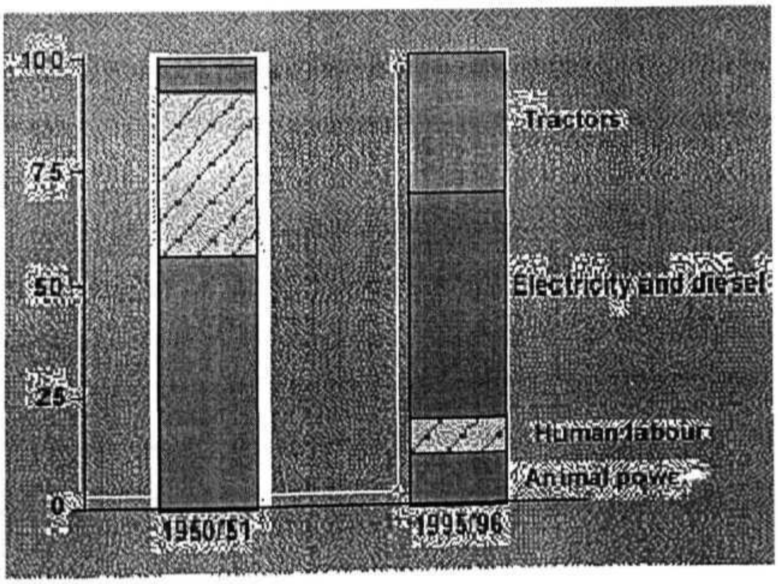
Contribution of various energy sources to farm power: 1991/92

Sources of **farm** power	Number (million)	Total (GW)	**Total** (%)
Human	-		
Male	149.20	8.95	7.32
Female	50.80	2.54	2.08
Draught animals	84.00	31.50	25.76
Tractors	1.30	29.10	23.80
Power tillers	0.09	0.54	0.44
Diesel engines	4.60	17.16	14.04
Electric motors	8.30	30.96	25.32
Combines	0.04	1.51	1.24

*Source: **TERI.** 1995.*

Fig: 3.5

Changes in relative share of different source of energy in **agriculture** over **time**



.The small-scale industry in India is characterized by gross inefficiency, which leads, in turn, to the consumption of large amounts of energy and adverse effects on the environment caused by high levels of pollutants generated at the source. The overall consumption of energy is low when compared to the rest of the energy requirement in the rural sector. The small enterprises sector is an important engine of the economy, stimulating the development of technical skills and providing employment to the local population. Rural industries such as small-scale foundries and brick kilns are energy-intensive and use fuel wood to fulfill their energy requirements. Cottage enterprises resort to grid electricity where it is available, though its use is restricted due to poor connectivity.

3.2.4 Transport Sector

The rural infrastructure in India in terms of metal led roads, access to markets, etc. is generally poor, with the majority of the people using non-motorized transport. However, the level of transport infrastructure, which depends on the level of prosperity of agriculture, is highly non-uniform across the country. Statistics on the energy consumption pattern in the rural transport sector are not generally available.

3.3 RURAL ENERGY SUPPLY AND DEMAND

The broad trends in supply and demand of various fuels including fuelwood, animal residues, crop residues and commercial fuels are outlined below.

3.3.1 Fuelwood

The average consumption of fuelwood at present is around 200 million tonnes per annum, with estimates ranging between 100 and 300 million tonnes. The per capita or per family consumption of fuelwood varies considerably across different regions and agro-climatic zones depending on the resource endowments and accessibility. Also most of the fuelwood consumed in the rural areas is collected in the form of twigs and branches, mainly by women and children, and not purchased.

On the supply side, it is estimated that the annual sustainable yield from different land sources is about 86 million tonnes -- 36 million tonnes from forests and the rest from other lands such as plantations, revenue lands, wastelands, etc.. Thus there is a wide gap between the demand and the sustainable supply. Of the total supply, forests contribute just about 32% of the total fuelwood while the rest comes from a variety of other sources.

Given the trend, the demand for fuelwood by the turn of the century is expected to top 300 million tonnes. At the present rate of supply, this will clearly result in further degradation of the biomass resource base, and containing this demand would be a major concern.

3.3.2 Animal residues

Animal waste in the form of dung cakes is an important fuel in the regions which are agriculturally prosperous but where the fuelwood supply is poor. The total current consumption of dung as fuel is about 100 million tonnes per annum. On the other hand, the total supply is about 200 million tonnes. However, most of the dung produced is used as manure in the fields, and diversion of its use for fuel has a large opportunity cost.

3.3.3 Crop residues

Crop residue is the least preferred of the biomass fuels because, being in loose form, the rate of combustion is high and difficult to control. As a consequence, it is also an inefficient fuel. However, this acts as a back-up fuel wherever there are scarcities of fuelwood, and is gaining prominence as the fuelwood availability is becoming difficult. It is estimated that about 100 million tonnes of non-fodder crop residue is produced and consumed as fuel in different parts of the country.

3.3.4 Commercial fuels

Kerosene and electricity are the other important fuels in the domestic sector, while diesel and electricity are prominent in agriculture. Presently about 10 million tonnes of kerosene and 8 billion units of electricity are consumed in the rural areas, and the demand is expected to go up to 12 million tonnes and 13 billion units respectively, by year 2006. Also, kerosene use for cooking will grow faster than kerosene for lighting, which is expected to be taken care of by electricity.

In the agricultural sector electricity demand is expected to grow sharply in the next two decades along with diesel, assuming that large-scale mechanisation would take place.

3.4 RURAL ENERGY DEVELOPMENT IN INDIA

Rural Development purse has never figured in the stated Energy Policy. Rural electrification is mainly perceived in the context of energy requirements to meet the irrigation needs of agriculture as part of the overall food security policy. Therefore, Rural Electrification PRIORITY was to provide assistance for transmitting energy to agricultural pump sets to increase the productivity of land. Household electrification came as a secondary or incidental issue. The whole definition of rural energy in the past was to provide one connection to a village which was primarily used to electrify agricultural pump sets. The Government of India changed the definition of village electrification recently to state that a village is considered as electrified if it provides electricity/power to all the habitations in the village. They consider the village as electrified if al least 10 to 20% of the inhabitants in the villages are provided with energy for lighting.

Consequently, the emphasis is not on energy and its use for rural development, but availability of electricity for certain segment of households, in the villages and hamlets.

The main issue is how do we bring rural development and bridge the gap between the power requirements for rural development and the energy policies of the government.

The Rural Electric Supply Technology (REST) mission launched by the Government of India hopes to make power available for the rural households but even the stated policy objectives do not cover the strategies to provide energy to the poorest of poor households in the rural areas. If we need to achieve sustainability in rural development with emphasis on livelihoods and the means of enhancing the economic well being of the poor households, it is necessary that affordable access to energy is provided to these households. The primary need is an integrated development strategy to use energy to improve health, education, nutrition and economic activities of the rural households. As such gender issues need to be addressed with adequate focus in the context of energy use. It is difficult to bring any meaningful integration between energy and rural development unless we take a integrated approach to development and energy end use.

The major programmes/schemes undertaken in these areas are as follows and are open for implementation in all States/UTs.

3.4.1 Rural Energy Programmes

- o National Programme on Improved Chullas
- o National Project on Biogas Development
- o Community, Institutional and Night Soil based biogas plants programme.
- o Rural Energy entrepreneurship and Institutional Development (REEID)
- o Women and Renewable Energy Development (WRED)
- o Biomass Production, conversion & utilisation programme
- o Biomass gasification programme.
- o Animal Energy Programme
- o Integrated Rural Energy Programme.

3.4.2 National Programme on Biogas Development (NPBD), Community, Institutional &Night-Soil based Biogas Plants (CBP/IBP/NBP) Programme and Research and Development on Biogas.

Biogas is a clean, unplugging, smoke and soot-free fuel, containing inflammable methane gas. It is produced from cattle dung, human waste and other organic matter in a biogas plant, through a process called "anaerobic digestion". The Indian biogas system mainly comprises of collection and processing of cattle dung, production and delivery of biogas and handling & application of digested slurry in agricultural fields. The State-wise estimated potential and achievement up to 2000-01 is presented in Table No. 3.6.

The biogas programme was started by the government of India in 1981-82 and comprised:

- National Project on Biogas Development (NPBD) for setting up of family type biogas plants
- Community, Institutional and Night Soil based Biogas Plants (CBP/IBP/NBP) Programme
- Research and Development on Biogas Production and Utilization Technology.

3.4.2.1 National Project on Biogas Development (NPBD)

It was started in 1981-82 with the objectives of:

- Providing fuel to rural households for cooking purposes
- Organic manure for application in agricultural fields
- Mitigating the drudgery of rural women
- Recycling human waste by linking toilets with biogas plants, thereby improving sanitation
- To provide easy and safe cooking gas for the rural families.
- To prevent pollution and forest degradation
- To protect the health of women and children by creating a Smoke-free kitchen.
- To help rural women devote this saving in time to more Productive pursuits
- To create additional employment by setting up of biogas **plants. In the ultimate** analysis, **to** create a clean, healthy and enterprising village.

Table: 3.6 NPBD (State-wise coverage of Estimated Potential up to 2000-01

Sl. No.	State / UT	Number of Plants		Percentage
		Est. Potential	Plants Installed	
1	Andhra Pradesh	1065600	308519	29
2	Arunachal Pradesh	7500	1142	15
3	Assam	307700	48059	16
4	Bihar	939900	119110	13
5	Goa	8000	3283	41
6	Gujarat	554000	343686	62
7	Haryana	300000	42120	14
8	Himachal Pradesh	125300	43354	35
9	Jammu & Kashmir	128500	1932	2
10	Karnataka	680000	306845	45
11	Kerala	150500	72339	48
12	Madhya Pradesh	1491200	192951	13
13	Maharashtra	897000	662120	74
14	Manipur	38700	1939	5
15	Meghalaya	24000	1859	8
16	Mizoram	2500	2376	95
17	Nagaland	6700	1477	22
18	Orissa	605500	171761	28
19	Punjab	411600	62708	15
20	Rajasthan	915300	66026	7
21	Sikkim	7300	2971	41
22	Tamil Nadu	615800	198838	32
23	Tripura	28500	1438	5
24	Uttar Pradesh	2021000	358311	18
25	West Bengal	695000	187266	27
26	A & N Islands	2200	137	6
27	Chandigarh	1400	97	7
28	Dadra & Nagar Haveli	2000	169	8
29	Delhi	12900	675	5
30	Pondichery	4300	539	13
	Total	**12049900**	**3204047**	**27**

Cumulative achievement

The total potential of 12 million biogas plants exists in the country.

The achievements so far indicate:

- 3.20 million rural families have benefited, indicating coverage of 27% of the total potential of biogas.
- About 3486 nightsoil-based and institutional biogas plants have been set up.
- Research and Development projects have been taken up to develop new designs and improve operational efficiency of the biogas plants. These plants have helped in saving 42 lakh tonnes of fuelwood and in producing 430 lakh tonnes of manure equivalent to 9.5 lakh tonnes of urea per year. In addition an estimated 5.5 million person-days of employment has been generated in rural areas.

Financial Assistance

The NPBD provides for Central Finance Incentives as detailed below:

(i) *Central Subsidy:* A fixed a mount is offered as Central subsidy depending upon the category of beneficiaries and the rural areas. The detail of Central subsidy are given in the below table: 3.7

(ii) *Turnkey Job Fee:* The rate of turnkey job fee was increased from Rs. 500 to Rs. 700 per plant during 20001-02 with a view to attracting more entrepreneurs, corporate bodies and NGOs. However, for the North Eastern Region States (excluding the plain areas of plain areas of Assam). Sikkim, Jammu and Kashmir, Himachal Pradesh, other notified hilly areas and Andaman and Nicobas Islands the turnkey jog fee is Rs. 800/-per plant.

(iii) *Household Toilet-linked Plants:* An additional Central subsidy of Rs. 500/- per plant is given for linking the cattle dung-based plant with a sanitary toilet, wherever feasible.

(iv) *Incentive **for** Saving Diesel:* Up to a maximum, of Rs. 2,500/- per plant is provided for a kit to modify a diesel engine to work as dual fuel engine and for one or two plastic or rubber balloons for transportation of gas.

(v) ***Toilet-linked** Plants in Schools:* A sum of 10,000/- or 70% of the total cost of a small capacity biogas plant tow toilets and a water storage tank is given for demonstration purpose to schools, especially girls schools in rural areas.

(vi) *Service Charge and Staff Support:* The rates of service charge are linked with a given target range allocated to states and agencies, expect in the North Eastern Region States, Sikkim and Jammu and Kashmir. Where full financial support is given for the staff sanctioned for the state headquarters and selected districts.

(vii) *Biogas Extension Centres (BECs):* A non-recurring grant of Rs. 10,000/- and a recurring grant of Rs. 20,000/- per year is given to **a** BEC fro systematically organizing user's courses in villages.

(viii) ***Training** Course:* Financial assistance is given for organizing different kinds of training courses as mentioned below Table: 3.8

Table 3.7

CBP/IBP/NBP Programme (Patterns of Central Financial Assistance)

(a) Central Subsidy

(ii) For Community and Institutional Biogas Plants

Plant Capacity (cu. m. of gas production per day)	Community Biogas Plant	Institutional Biogas Plants Goshatas / Pinjrapotes, Charitable Organizations / Government Institutions, Co-operaive Societies, Trusts or other Institutions tied to such bodies		Private and Profit making Institutions and others	
		for NE Region	Other States	for NE Region	Other States
Category	I	II (A)	II (B)	II (C)	II(D)
15	44000	85000	22000	70000	15000
20	44000	110000	22000	90000	15000
25	70000	135000	55000	112000	35000
35	70000	200000	55000	165000	35000
45	150000		95000		64000
60	170000		115000		76000
85	200000		140000		94000

Table 3.7

CBP/IBP/NBP Programme (Patterns of Central Financial Assistance) **(contd...)**

(ii) For Night – Night soil based Biogas Plants

(Amounts in Rupees)

Plant Capacity (cu.m.of gas production per day)	NE States		Other States	
	Institution	Community *	Institution	Community**
10 – 15	90,000	2.50,000	70,000	1,45,000
20 – 25	2,00,000	4,60,000	1,50,000	2,25,000
35	-	-	2,10,000	4,50,000
45	-	-	2,70,000	6,25,000

* CFA includes assistance for toilet sets, a dual fuel engine and a machine room.

** CFA includes assistance for a dual fuel engine and a machine room.

(b) Project Contingency

A project contingency amount is given for CBPs, IBPs and NBPs of upto 25 cubic metre capacity is 10% of the CFA with free operation and maintenance warranty for two years. In the case of NBPs of 35 to 60 cubic metres capacity, the amount of project contingency is 20% of the CFA with the provision of free operation and maintenance warranty for a minimum period of 20 years.

Table 3.8

National Project on Biogas Development (NPBD) - Training course

Course	**Duration**	**No. of Trainees per Course**	**CFA per Course**
Users	1 day	50-60	Rs. 1,000
Staff	2-3 days	10-15	**Rs. 5,000**
Refresher / Construction-cum-Maintenance	16 days	10	Rs. 19,000
Turnkey Workers	21 days	10	Rs. 38,500

(ix) Communication and Publicity: Assistance is given for communication and publicity work linked with target ranges to **State nodal departments and** agencies as mentioned below Table 3.9.

Table 3.9

National Project on Biogas Development (NPBD) - Communication and Publicity

Target Range	**Assistance**
Up to 1,000	Rs. 1.00 Lakh
1,001-10,000	Rs. 2.50 Lakh
More than 10,000	Rs. 5.00 Lakh

(x) *Biogas Development and Training Centres:* A sum of Rs. 10.00 lakh is **given to each Centre to meet the expenses of staff, contingency and training** courses.

3.4.2.2 Community and Institutional Biogas Plants Programme

It was initiated in 1982-83 with the scheme of setting up of night soil based plants in community toilet complexes being added in 1993-94. It was started with the objective of recycling the large quantity of cattle dung available in the villages for the benefit of the weaker sections of society as well. A total of 3,487 plants including 600 Night soil-based biogas plants (NBPs), had been installed upto 2000-01. The State -wise number for community, Institutional and Night soil-based biogas plants set up is given in A3. 3.4.2

The biogas generated is generally used to fuel requirements of motive power and electricity, in addition to meeting the cooking needs of the rural populace. Through the programme,

- Indigenously developed models of biogas plants, namely floating drum type and fixed dome Deenbandhu are being popularized.
- Central financial assistance, including Central subsidy, turn-key job fee, service charges or staff support, training and publicity support, etc are being provided.

Central Financial Incentives

Central financial assistance (CFA) is provided in fixed amounts which vary according to the type and the size of the plants and the category of institutions and areas (Table 3.7). During 2001-02, the pattern of CFA was rationalized in order to provide a higher CFA for biogas plants linked with community toilet complexes. The highest amount of CFA, which works out to about 90% of the estimated cost of the biogas plant, is given to the States in the North Eastern region. In addition, a project contingency amounts at the rate of 10% of the CFA is given to State nodal departments and agencies for providing technical and training support, including determining the feasibility, arranging trained masons, supervising construction work, etc. The amount of project contingency is higher, i.e 20% of the CFA for 35, 45 and 60 cubic metres capacity NBP, with the condition of providing free operation and maintenance warranty for a minimum period of 20 years.

3.4.2.3 Research and Development on Biogas

The trust areas of the biogas research and development activities are mentioned below: *Research and development on biogas* is taken-up in the identified thrust areas, such as:

- Studies in the field of microbiology, biochemistry and engineering for increasing the yield of biogas especially at low and high temperatures;
- Development of cost-effective designs of biogas plants;
- Development of designs and methodologies for utilization of biomass, other than cattle dung for biogas production;
- Reducing the cost of biogas plants by using alternative building materials and construction methodology; and
- Diversified use of digested slurry for value-added products.

3.4.3 National Programme on Improved Chulhas (NPIC)

The National Programme on Improved Chulha programme was started by Ministry of Non Conventional Energy Sources, Govt. of India, in 1984 as a demonstration programme. The demonstration programme became a national programme in 1985 due to its overwhelming popularity. It was initiated in 1986-87 with the following objectives:

- Fuel wood conservation;
- Eliminate / reduction of smoke;
- Reduction in drudgery of women and children from cooking in smoky kitechen and collection of fuel wood;
- Environmental upgradation and check on deforestation; and
- Employment generation in rural areas.

Fuel burning efficiency of an improved chulha is 20-50% whereas fuel burning efficiency of traditional chulha is only 5-10%. The chimney system and efficient burning in an improved chulha causes less smoke and harmful gases like carbon monoxide are released less in the kitchen. The multipot seats in an improved chulha reduce cooking time and make time available for other productive activities. Reduction of smoke means cleaner cooking operation and lesser blacking of the utensils. The National Programme on Improved Chulhas (New Models of Fixed-type Improved Chulhas developed during 2001-02) is shown in Table No: 3.10.

Achievement

The 3.39 over 7.00 Lakh Improved chulhas have been installed during the period of April to December 2001. The State-wise and Agency-wise achievement vis-à-vis the targets are given in Table No. 3.11.

Benefits

An improved chulhas saves on an average about 375 kg of bio-fuel and 3 litres of kerosene per year under field conditions. Accordingly, the achievement of the target of 17.55 lakh of improved chulhas set for 2001-02 would result in a saving of about 6.58 lakhs tones of bio-fuels and 53 lakh litres of kerosene per year. Besides, an improved chulhas results in a saving of 45 minutes to one hour per family which would otherwise be spent on collecting and processing the fuel material, cleaning of utensils and cooking. The improved chulhas also helps in making the environment inside the kitchen smoke-free, thereby reducing the incidences of eye and lung diseases amongst women and children. The NPIC is also generating employment in the rural areas for women at the rate of 0.3 person day per chulha.

Table No: 3.10.

National Programme on Improved Chulhas (New Models of Fixed-type Improved Chulhas developed during 2001-02)

TBU	Model Name	Type of Model	Type of Fuel	Thermal Efficiency (in %)	Estimated cost per Chulha (Rs)
Indore	Jyoti	Simple-pot chulha made cement and tone power	Wood, agro-residues and dung-care	**21**	170
Indore	Ahilya	Simple-pot chulha made of clay and cement	Wood, agro-residues and dung-care	**20**	260
Katyani	Modified Kalyani coal chulha	Single pot bricks and lime	Coal	**42**	134
Sotan	High Attitude Metal Stove	3-pot Iron and steel	Wood	**21**	700
Gukwahati	Modified Sukhad	2-pot pottery liner brick and cement	Wood and Agri-residues	**25**	190
Gukwahati	Modified Aafavati	2-pot pottery liner brick and cement	Wood and Agri-residues	**25**	210

3.4.4 Rural Energy Entrepreneurship and Institutional Development (REEID)

The Rural Energy Entrepreneurship and Institutional Development, which was initiated in 2000-01, was continued with the following objectives:

- To promote local - level entrepreneurship in the rural energy sector;
- To strengthen the Entrepreneurship Development Centres in different states for providing training, management skills, support for project formulation, maintenance services and export management and consultancy.
- To organize entrepreneurship Awareness Camps in the teaching and technical institutions;
- To organize Entrepreneurship Development Programmes to promote rural energy micro-enterprises for manufacturing, marketing, servicing and exporting rural energy systems;
- To develop and promote linkages among rural energy entrepreneurs, renewable energy industries, financing institutions including IREDA and State nodal departments and nodal agencies;
- To involve non-governmental organizations in promoting, facilitating and establishing rural energy enterprises; and
- To develop and disseminate entrepreneurship manuals, guides, etc.

Table: 3.11:NationaI Project on Improved Chulhas (State-wise achievement 2001-02)

Sl. No	State/UT/Agency	Annual Target		April to December 2001	
		No. of Villages	No. of Chulhas	Target No. of Chulhas	Achievement No. of Chulhas
1	Andhra Pradesh	800	175000	87500	34824
2	Assam	300	12500	6250	32
3	Bihar	80	6000	3000	2178
4	Chattisgarh	150	15000	7500	-
5	Gujarat	490	105000	52500	48928
6	Goa	20	4000	2000	1510
7	Haryana	300	60000	30000	28482
8	Himachal Pradesh	6	1000	500	510
9	Jammu & Kashmir	100	30000	15000	-
10	Jharkand	100	16000	8000	-
11	Karnataka	300	60000	30000	32179
12	Kerala	200	40000	20000	20443
13	Madhya Pradesh	10	1500	750	-
14	Maharashtra	540	86000	43000	16071
15	Manipur	100	5000	2500	1231
16	Meghalaya	100	5000	2500	-
17	Mizoram	150	5000	2500	-
18	Nagaland	150	5000	2500	1660
19	Orissa	700	200000	100000	138636
20	Punjab	250	35000	17500	-
21	Rajasthan	150	30000	15000	6234
22	Sikkim	100	5000	2500	4096
23	Tamil Nadu	300	60000	30000	45312
24	Tripura	200	18000	9000	4157
25	Uttar Pradesh	800	150000	75000	52384
26	Uttaranchal	40	2000	1000	154
27	West Bengal	1300	325000	162500	191086
28	A & N Islands	8	1200	600	841
29	Dadra&Nagar Haveli	5	500	250	-
30	Delhi	12	2000	1000	-
31	Lakshwadeep	2	300	150	-
32	Pondichery	15	4000	2000	1435
33	KVIC Mumbai	1970	260000	130000	65517
34	Aiwc, New Delhi	220	25000	12500	2448
35	Thiruvanantapuram	50	5000	2500	-
	Total	10018	1755000	877500	700348

Central Financial Assistance (CFA)

CFA is given for the organization of one-day Entrepreneurship Awareness Camps **at the** rates of Rs. 10,000 per camp and Entrepreneurship Development Programme at the rate of Rs. 0.50 lakh to Rs. 1.00 lakh per programme for a duration of about 4 **to** 5 weeks. Also, core organizational support up to Rs. 10.00 lakh s non-recurring grant and Rs. 5.00 lakh per year as recurring grant is given to R&D, teaching and management institutions. A grant of Rs. 1.00 lakh is given for establishing a Rural energy Entrepreneurs and consumers facilitation counter. Besides, REEID provides for partial financial support to entrepreneurs for acquiring technology, getting quality certification from the Bureau of Indian Standards (BIS), preparing bankable projects, etc. Provision has also been made for organizing market surveys, studies on financial and socio-economic analysis of renewable energy systems, preparation and distribution of good practices manuals for fostering entrepreneurship among the rural youth.

3.4.5 Women and Renewable Energy Development

The 'Women and Renewable Energy Development' (WRED) programme was started to train and empower women in the promotion, marketing, utilization and management of renewable energy system and devices. In all, 125 Sales and Servicing Outlets and 150 Renewable Energy Women Self-Help Groups have been sanctioned. The scheme was started in 2000-01 with the following objectives:

- Establishment of renewable energy sales and servicing outlets managed by women at the local level;
- Organization of women self-help groups to arrange construction and maintenance servicing of improved chulhas, biogas plants, solar lanterns, solar cookers, etc. besides undertaking energy plantations in waste lands for fuel wood production and organizing annual maintenance contracts for renewable energy systems, etc.;
- Imparting of training in the construction, operation, repair and maintenance of various kinds of renewable energy systems relevant for women;

- Reorganization of entrepreneurship and research capabilities among women through awards and certificates of merit;

Central Financial Assistance

The Scheme provides for CFA to the tune of Rs. 20,000/- for establishing a renewable energy sales and servicing outlet (KliSSO) in rural areas managed by a women self-help group or a women entrepreneur. Besides a grant of Rs. 10.000/- is given to serve as a revolving fund to self-help groups for arranging maintenance servicing of renewable energy devices and systems. For training of women in renewable energy technologies, courses are organized in villages through educational institutions and grass root NGOs. The duration of the Orientation and Training Course (OTC) is about five days and a CFA of Rs. 15,000/- per course is given.

3.4.6 Integrated Rural Energy Programme

The IREP aims at developing planning and institutional capabilities to formulate and implement micro level energy plans and projects for promoting the most cost-effective mix of energy options for use in rural areas. The objectives of the programme are to

- Provide for minimum domestic energy needs
- Provide the most cost effective mix of energy sources for meeting the requirements of sustainable agriculture and rural development with due environmental considerations
- Ensure people's participation in the planning and implementation of IREP plans and projects through various micro-level institutions
- Develop and strengthen mechanisms and co-ordination arrangements for linking micro-level planning for rural energy with state and national level for energy and economic development.

The centre and state provide financial, technical and training support for the IREP programme, which is being implemented in 724 blocks in the country against the 860 blocks sanctioned during 2001-02. With this about 16% of the total number of the Blocks in the country have been covered under IREP. State-wise cumulative number of blocks sanctioned for the preparation and the implementation of IREP plants and projects information is given in the Table No.3.12

3.5 IMPACT OF RURAL ENERGY

In this section, the impact of Rural Energy on Society & Environment, Natural Resource base, Women & children and Global impacts are explained with reference to the rural energy fuel.

3.5.1 On Society and Environment

As is evident, the energy demand, especially that of biomass fuels is going to increase substantially which could only raise the gap between the demand and the sustainable supply. This would have a deteriorating effect on the resource endowment apart from other manifestations which are briefly discussed here.

3.5.2 On Natural Resource base

It is an established fact that forests and other public lands in India, given the pressures of high population growth rate, are in various stages of degradation severely affecting their carrying capacity. One of the major casualties of this situation is fuelwood which is becoming scarce in several parts of the country. Though no direct correlation between deforestation and rural energy use has been established -- demand for agricultural land, and industrial and commercial requirements are considered the principal causes -- there is evidence that where the land is already degraded, fuelwood extraction could exacerbate the process. With domestic households as well as rural industries using increasing quantities of fuelwood, this situation could only worsen in the future.

Table: 3.12

Integrated Rural Energy Programme
State-wise Cumulative Number of Blocks **Sanctioned– 2001-02**

Sl.No.	State / UT	Number of Blocks
1	Andhra Pradesh	32
2	Arunachal Pradesh	10
3	Assam	21
4	Bihar	48
5	Chhitisgar	22
6	Goa	5
7	Gujarat	25
8	Haryana	38
9	Himachal Pradesh	45
10	Jammu & Kashmir	28
11	Jarkhand	8
12	Karnataka	42
13	Kerala	44
14	Madhya Pradesh	63
15	Maharashtra	37
16	Manipur	15
17	Meghalaya	18
18	Mizoram	11
19	Nagaland	25
20	Orissa	45
21	Punjab	40
22	Rajasthan	38
23	Sikkim	4
24	Tamil Nadu	21
25	Tripura	6
26	Uttar Pradesh	94
27	Uttaranchal	21
28	West Bengal	34
29	A & N Islands	5
30	Chandigarh	1
31	Dadra & Nagar Haveli	1
32	Dao & Daman	1
33	Delhi	5
34	Lakshadeep	1
35	Pondichery	6
	Total	860

3.5.3 On Women and Children

As mentioned earlier, fuel collection in rural areas is mostly done by women, except in some cases of head loading, which puts a heavy burden on them. This is particularly so in the hilly areas where women also have to participate in all other productive activities. As fuelwood becomes scarce, women are forced to spend more time and walk long distances to collect fuelwood. This extra burden affects the quality of life substantially as it cuts into the time and attention women could pay to their children's education and health, and other household activities. Several micro level studies conducted in different ecological settings, indicate that distances up to 10 km are covered in the process expending 5 to 6 hours per day.

Pollution due to biomass burning is a major factor that affects the quality of life in a major way. Burning of biomass in inefficient cookstoves is one of the major causes of chest and lung related health problems among rural women and children. This problem would be particularly severe in a scarcity situation where households may be forced to switch to inferior fuels such as fuelwood fron. shrubs, roots and weeds, and crop residue in loose form.

3.5.4 Global Impacts

Biomass energy consumption, apart from local environmental effects, also has serious impact on climate change due to emissions of greenhouse gases. The process of degradation and depletion of forests — which results in loss of natural sinks that could absorb carbon emissions ~ and biomass burning, have been identified as significant contributing factors to the greenhouse effect. In India it is estimated that of the 68.3 million tonnes of carbon released annually due to biomass burning, fuelwood accounts for 82.3%. Thus, it is important to take this potential contribution into account in the issue of sustainable biomass use.

3.6 INTEGRATING RURAL ENERGY WITH RURAL DEVELOPMENT

The other imperative is to integrate rural energy with other development factors such as health, education, infrastructure and financing. As we saw, electrification does not automatically yield economic development and rural people will not automatically adopt woodfuel forestry. This section will explore how the requirement for integrated development may be met and what the institutional implications are. However, in order to discern how government and non-government institutions could better integrate the various elements required for rural energy development, first we must see what institutions are currently at work

3.6.1 Institutional arrangements for rural energy planning

In India, predominantly an agrarian economy, the government has sought to increase rural people's cash and therefore their ability to make the transition to modern fuels by intervening in setting the procurement price for cereals. Hence when the government raises prices, food and goods consumers subsidise rural energy development. As part of its Integrated Rural Energy Programme, India has also developed technical back-up units at the state and district level for devices such as biogas plants, improved woodstoves and solar cookers. A national training centre has been set up in Delhi and regional training and R&D centres are already set up in a substantial portion of districts. (Ramani et al (1993).

5.6.2 Institutional coordination

As has been stated time and again, energy does not cause rural development but it can act as a catalyst when other development factors are already present. Thus, to be most effective, certain forms of energy, for example grid-based electricity, should only be introduced into rural areas after or along with a series of other development inputs or infrastructural components. While centralised co-ordination of the planning effort is still necessary at the national level, this should focus primarily on seeking consensus on policy decisions, establishing common guidelines for planning at the decentralised level and mobilising the necessary human resources and finance. Much of the planning effort, in particular the aspects of energy needs identification, resource assessment and technology choice, should be decentralised to the level of local government and other local agencies.

An important task of the agency entrusted with rural energy planning co-ordination at the national level would be to establish links between the planning for decentralised renewable energy systems and that for centralised energy systems. Specific attention should be given to rural electrification, to ensure that the plans and programmes of the electricity utilities are consistent with those for the diffusion of decentralised renewable energy systems.

In order to achieve this integration of energy and other factors in development it is essential that there be greater horizontal communication between all agencies involved in rural development. Presently, the lack of information exchange and horizontal co-operation, particularly between government agencies, inhibits the implementation of well-integrated programmes in many countries.

Many other rural development activities, or inputs, such as agriculture, transport, water supply, education and the provision of health care, all have their energy needs. The energy role of agriculture, both as a producer and consumer, must be integrated into both energy and agricultural plans. Bioenergy resulting from the energy conversion of residues and from purpose-grown energy plantations is a major source of rural fuel. However, it is very seldom that these ministries or departments co-ordinate or co-operate with the ministry of energy, or one another, to arrive at the most rational and integrated solution to their energy needs. It is possible that decentralisation of the rural energy planning process may help to achieve this. However, it is an important aspect that still needs to be addressed at the central government planning level, if optimal use of a country's development resources is to be achieved.

5.6.3 Decentralization and integration

The principles of decentralization and integration should be the starting point in all areas of rural energy development effort.

Sustainable forestry: Participatory management of natural forests and woodlands and by extension agro-forestry, is probably the most significant outcome of the new thinking. However, recommendations for action should take into account the existing human, financial and institutional resource constraints in developing countries. While joint forest management might seem like an easy and politically popular winner, there are many barriers to successful implementation. For participating communities they include the willingness:

- to co-operate with each other,
- to invest their labour and cash resources, and
- to organise for and learn new management skills.

Government, on the other hand, must be prepared to weaken greatly its own jurisdiction and authority over basic national resources. It thus requires from government:

- a strong commitment to more equitable land tenure or access to land and land-based resources,
- increased local accountability and community powers,
- openness to and policy support for the emergence of non-governmental organisations and private entrepreneurs, and
- willingness to explore many technical and administrative innovations, including the redistribution of tax revenues from the state to local communities.

In addition to the above obvious benefits, pilot projects have shown that the training of rural people is often needed in techniques of sustainable production, elementary management and, at later stages, marketing skills.

Better data: It is becoming clear that decentralisation of rural energy planning and its integration with other aspects of development has a number of advantages, particularly in assisting planners to formulate strategies and projects that more closely meet the needs of local communities. However, apart from the changes in attitude required, there are some further constraints that have to be dealt with in order for it to be effectively implemented.

One of the most important of these is lack of information. As a first step, a more comprehensive and reliable rural energy information system needs to be developed in many countries at all planning levels. In addition, it needs regular updating. It should include assessments of rural energy needs on an area basis, patterns and trends in traditional and commercial energy consumption, and economic, social and environmental indicators of rural development. Under conventional approaches substantial financial and human resource commitments would have to be made for the surveys necessary to capture the data, and for establishing information systems that could be accessed by the various agencies involved in rural energy development.

A further important lack of information is the one felt by rural people themselves. Although they know a great deal about traditional energy supplies and end-use options, very few of know about the potential of new technologies and modern fuels, making it difficult for them to contribute meaningfully to much of the planning process.

Better training: A further factor that constrains the effectiveness of decentralised planning is the lack of sufficiently skilled people to carry it out. While collecting data through schools could form the basis for improving these skills, it is necessary, in addition, to introduce higher level training of planners. Such efforts have already begun in China, where university-level courses in rural energy planning have been initiated. The Chinese have shown willingness to share this experience with other countries, and this could provide the starting point for a plan of action to improve rural energy planning skills in developing countries.

Local agencies need to be provided with adequate human resources and skills to develop and implement decentralised rural energy plans and programmes. Explicit policies and strategies are needed to ensure the involvement of rural communities, interested non-governmental organisations and the private sector in the planning and programming process. Particular attention should be paid to the role of women in these processes. In building these skills, it is important to move away from the still common approach of having foreign experts move into energy planning departments to produce national rural energy master plans. Technical assistance of this type does nothing to help build national capacity and often only results in the demoralisation of nationals employed in these planning departments. It would surely be more effective for such technical assistance to be structured so as to be short-term to provide instead a mentoring of nationals responsible for the planning. In addition, where skills are lacking in a country, by linking with universities and other training institutions, and using both their faculty staff and students to assist in the planning process, the longer term sustainability of national energy planning capacity could be greatly enhanced.

Rural Credit: A crucial aspect of rural development integration must be the widening of credit facilities to include the financing of energy technologies. The provision of affordable financial services for rural people has long been a prime component of rural development strategics. Originally the approach focused on concessional loans to farmers. More recently, however, it has been replaced by much wider financing for rural activities, thus reducing the lending transaction costs. In addition, the integration of rural financial markets with general financial markets has resulted in the mobilizing of savings as the major capital resource for rural people, rather than the previous reliance on concessional donor or government funds.

A number of barriers at the multilateral, bilateral, national government and village level serve to distort capital markets away from energy technologies. Capital needs to be mobilized to form an investment pool able to be leveraged to provide improved small-scale energy supplies on a large scale. A new approach to risk and return is needed, in which public sector capital becomes subject to more commercial discipline than in the past and private sector capital accepts possibly longer lead times to realize its returns. With such help from the public and private sectors, the savings poor people themselves can make as they substitute more efficient energy forms for inefficient, expensive traditional ones can potentially help develop and disseminate the technologies that would significantly improve their welfare and livelihoods.

3.7 CONCLUSION

In most developing countries, the largest contribution to the establishment of the national energy infrastructure comes from governments, either through national funds themselves or through international loans. Donor inputs normally contribute significantly in the pre-investment phases, critically influencing the design of the projects and programmes. It is clear that many opportunities for co-operation exist in the rural energy sector, and it is also apparent that communications gaps are all too common.

- Amongst donors and other external development agencies, sector or project work and recommended solutions may be driven by agendas established *a priori* by a particular aid or development agency, without much cross-fertilization and exchange of experience.
- Between donors and governments, there is still not sufficient recognition of the fact that any drive for radical policy change and new approaches can only succeed with a genuine meeting of the minds. Short of that, pro forma compliance, with what are often seen by recipient governments as externally imposed conditions, breeds only frustration on all sides.
- Between governments and the people, conflicts arise when it is perceived that the former have lost touch with the needs of the common people. This is especially so with the rural population with their traditional ways of life.

In all the above cases, if governments were better equipped with well-defined development agendas, most of these communication problems would be avoided. However, other agencies or organisations can play a role in improving communication.

Another vital area for greater co-ordination and co-operation is in the stimulation of research and development for the rural energy sector. The quality of energy services proposed for rural areas often falls far short of those provided in urban areas. There is a clear need for research and development effort on technologies suitable for rural energy supply and use, and there are a couple of specific areas that could be addressed in the short term.

Bringing electricity to all households should also be given high priority. This would require far more research and development on two fronts. First, energy-efficient, decentralised and reliable small-scale power sources need to be developed that can deliver a level of energy service equivalent to that enjoyed by those connected to the grid. These systems should also be designed to operate in conditions of skills scarcity. Second, research and development is required to reduce the costs of grid-based electrification. Some possible avenues were noted. It is apparent that there is still significant potential for greater reductions in cost, without loss of amenity.

Finding the resources for this research and development is in itself a challenge. Support from international aid agencies may be desirable in some instances, while co-operative programmes, mounted and funded by strategic groupings of developing countries, might be better in others. Collaboration with industrialized countries should be considered in all instances.

Chapter –IV

BIO-GAS TECHNOLOGY IN INDIA

4.0 INTRODUCTION

The gas produced by decomposition of organic waste is called Biogas. Biogas is rich with CH_4 (Methane) and when bunt produces energy, which can use for heating, lighting etc. It satisfies several criteria of appropriateness - meets a basic need as cooking fuel; makes optimal use of local resources such as cow dung and other organic wastes; helps to develop indigenous growth using local skills and technologies; provides relief from drudgery; and leads to environmental improvement. Scientifically, biogas plants only either of these is possible. The realization, its undoubted potential, led to the promotion of biogas plants in a major way in the late 1970's as an answer to the growing fuel crisis. Today India has the second largest programme in the world after China.

Biogas technology is one of the most appropriate options for meeting the growing energy needs of the rural areas in India. Biogas is a clean and convenient fuel for cooking and lighting in the households; it can supply motive power for irrigation and small industries, and the effluent slurry, a by-product, can be used as organic manure. More importantly, biogas makes use of local resource - cattle dung - in an environmentally and economically viable manner. In addition to dung, biogas can also be produced using other organic matter like human waste. It is for these reasons that biogas has gained popularity in India and is, the largest and most prominent of all the rural renewable energy programmes implemented by the government.

4.1 EVOLUTION OF BIOGAS TECHNOLOGY IN INDIA

Biogas technology has a long history in India, stretching from the early 20:th century to today. The bulk of installed units have, however, been constructed within the last 15 years, and this process was initiated only when a number of designs, considered practical and appropriate for dissemination, were available. There was also a political foundation for propagating a large-scale diffusion programme administered on a national level. The Milestones in the Evolution of Biogas Technology in India can seen in Table: 4.1.

Table4.1: Milestones in the Evolution of Biogas Technology in **India**

1897	Biogas used for lighting at Matunga leper asylum, Bombay.
1937	Commissioning of Dadar sewage purification plant, Bombay.
1946	The first biogas plant designed by N.V Joshi at Indian Agricultural research Institute, Delhi.
1952	Development of the floating dome model, Grama Laxmi III by Jashbai Patel.
1961	Establishment of Gobar Gas Research Station at Ajitmal bye Planning Research and Action division, Government of Uttar Pradesh.
1962	Khadi and village industries commission's entry into the field of biogas technology.
1977	Development of Janatha Model Biogas Plant by PRAD.
1981	Launching of National Project of Biogas Development.
1982	Transfer of National Project of Biogas Development to the Department of Non-conventional energy sources and inclusion of biogas in the Prime Minister's 20-point programme.
1984	Development of low cost Deenbandhu design by Action for Food.
1985	Initiation of large National Programme relying on subsidies, multi organization and multi-design approach.
1985-92	Improving designs, improving the organization and results from dissemination.
1992-02	Decrease in subsidies, new structures of dissemination and extension.

4.2 HISTORICAL PHASES OF BIOGAS DEVELOPMENT IN INDIA

The history of biogas introduction is here divided into a number of phases, which are defined by occurrences and changes in society and programme developments:

4.2.1 Phase – I: Early history of Biogas Technology (up to 1950's)

The early years of biogas research and development can be said to start in the 1920's, even though some work had been done previously with biogas technology for sewage treatment. In places such as the Indian Agricultural Research Institute (IARI) near Delhi, research on biogas technology was carried out. In Poona, near Mumbay (Bombay) Professor N. V. Joshi, who had earlier been at the IARI, worked with, among other things, designing a new biogas model which he managed and later patented (Chawla 1986; Singh 1996). One of the main research interests during this period was to better understand the process and conditions needed to get an efficient anaerobic fermentation process. What on the other hand lacked at the time was a practical design of the digester that could be used by farmers. Another problem was to find reasons to implement it. Initially the attraction of the technology laid in the possibility to improve the utilisation of available manure as fertiliser, whereas the gas was seen as a by-product (Singh 1974). The use of dried dung cakes as fuel instead of using it as manure was also a factor encouraging further biogas technology development *(Singh 1996)*.

During this lime basically agricultural researchers were responsible for the development of the technology and it was considered important by the involved people to develop an indigenous Indian biogas design (Moulik 1990b). In the late 1940's a social worker within the Khadi and Village Industry Commission (KVIC), Mr Jashbhai Patel, started to work on developing a biogas design that was different from the designs that had been developed thus far. His design was constructed with the digestion chamber placed below the ground instead of above ground. Another new feature was that the gasholder and the reactor were made into one unit saving both space and material. Further innovations of this design were the continues flow system and automatic overflow when loading. It was also equipped with a scumbreaker that should prevent scum to enter the gaspipes (Singh 1974). The first unit of this type was installed at Osmania University, Hyderabad, in 1950 (United Nations 1984). The design was called *Gramalakshmi*. *Grama* meaning rural in Hindi and *Lakschmi* is the Goddess of wealth and prosperity in the Hindu religion. There is also a notion of the word *Grama* towards the Gandhian movement of rural development. The installation of the first *Gramalakshmi* unit constitutes the end of the first period. Biogas technology had until then been more or less a mere research issue, but now an Indian design that could be disseminated in rural areas had been developed. It was, however, still far from being affordable to rural farmers.

4.2.2 Phase - II: Development of practical design (1950V1972)

During the period from early 1950's to 1972, biogas technology was slowly attracting more attention, still mainly from agricultural researchers. Most important though, it was further developed and experiences on operation of units under practical conditions were being collected. A very small number of units were constructed and this took place in certain regions such as Maharashtra and in the vicinity of Delhi.

The work of Mr. Patel continued during the fifties and other institutions such as the Rama Krishna Mission in Calcutta and Khadi Pratisthan Sodepur in West Bengal did also develop new designs (Chawla 1986). Experience began to be accumulated from these projects. Indications were that biogas technology faced problems when integrated into the livelihood systems of the farmers.

A project implemented by 1AR1 in the mid 1950's is discussed in an article by M. A. Idnani (1964). The project had installed twelve biogas plants in twelve different villages free of cost to the farmer. The first period of time after installation the operation was satisfactory but then the units started to malfunction. The reason for this is argued in the article to be traditions of living, and the means to overcome this is suggested to be education.

The reason for the farmer to adopt biogas technology is argued by Mr Idnani to be the benefits that would be the results from operation. The improved situation should thereafter give other farmers incentives to install and invest in their own plants. This can be seen in contrast to the experience gained, which did *not* lead to other people finding it attractive enough to use. The strategy of building a number of plants in each village in order to reach a critical mass, as is exemplified in the citation, seems to have formed the main strategy in India since the beginning of the diffusion process. KVIC included dissemination of biogas technology in its programme in 1961, and this was a result of earlier field trials. The aim of including diffusion of the technology in KVIC's work plans was to spread it nation-wide (KVIC 1976; United Nations 1979). The Planning Research and Action Division (PRAD) of Uttar Pradesh took further national initiatives through the establishment of the research station in Ajitmal. This research station was later to become known as the Gobar Gas Research Station and one of the influential persons here was Mr Ram Bux Singh. There were few signs of a rural energy crises at this time and within the rural energy field the main goal was electrification. The electrification of rural India took its start by the creation of the Rural electrification programme in 1950/51 (Sinha *et al.* 1991a).

The national development goals at this time were to bring India into development through industrialisation. The rationalisation of the agriculture became central, since it accounted for the largest part of India's national income. A programme called Intensive Agricultural District Programme had been running since the early 60's. This programme was targeted to special areas and the aim was to get India self sufficient in grains which was seen as best done through intensified agricultural practice by certain farmers. During 1965-67 there were severe drought/famines in the northern parts of India, which acted, as alarm clocks for many politicians that the agricultural sector had to be modernized.

The so-called *green revolution* was initiated and through the introduction of High Yield Varieties (HYV) and chemical fertilisers an industrialisation of the Indian agriculture could take it starts in 1965. The High Yield Varieties Programme was initiated soon after. The main breakthrough for the green revolution in India came at the end of the 60's when the HYV of Mexican wheat and HYV of Taiwan and Philippine rice were introduced (Wolpert

1993). The first harvests from these new varieties, displaying the possibilities that came along with modern agriculture, came in 1966 (Brass 1990).

The green revolution emerged during a period of time when the oil price was low and the food scarcity was seen as the major threat of the future. The result was that the new farming practices and technologies were more energy intensive and relied (indirectly) to a higher degree on oil (Kumar *et al.* 1977). The oil price began to gain increasing importance through among other things the close link to chemical fertilizer production. Along with this efficiency aspects of the agriculture were given priority before the equity aspects Natarajan 1987). Small and marginal farmers were not actually involved in the two major agriculture rationalisation programmes. It was considered that the new technologies and practices of the green revolution should trickle out to these so-called non-progressive farmers. (Kaviraj 1986; Taylor 1999).

4.2.3 Phase-Ill: Increased interest for biogas in the shade of crisis (1972-1975)

The Prime Minister Mrs. Indira Gandhi had a different strategy to development than her predecessors during the 50's and 60's. Indira Gandhi believed that technological self-reliance was the key for maintaining India's political independence towards the international community (Natarajan 1987). This strategy was to a large extent in line with what biogas technology apparently could offer. Poverty alleviation was another issue that was high on her political agenda.

In 1973 the Organisation of Petroleum Exporting Countries (OPEC) announced a cutback in oil production which was followed by the October 1973 Middle East War. The result from this was a quadrupling of the crude-oil international prices during the period 1973 to 1974. Oil and fertilisers accounted for 21% of the import to India by value in 1973, in 1974 this figure had increased to 35% (Moulik 1989). All of this happened at the end of the fourth five years plan when the fifth was already a draft. It can also be pointed out that during this time there were attempts made to establish a national energy policy.

The industrialization and promotion of the green revolution in agriculture made drastic cuts in commercial energy consumption and chemical fertilizers impossible both from an economic and political point of view. The government was forced to take measures against the rising import bill. Industries had to initiate energy management programmes aiming at reducing wasteful use of resources. These programmes did not fall out very well as the response from the industry was instead of implementing energy saving measures, to install captive diesel generators, as there were subsidies available for these investments. Hence, little energy savings were made (Moulik 1989). The Indian Government also took policy measures regarding, among other things, transportation. The working lives of coal-fired locomotives were extended; the electrification of the railway was at the same time encouraged. Gasoline prices were tripled.

Small and medium farmers' dependence on commercial fuels was low and thus they were not affected directly to such a great extent. But prices on commodities in general increased giving indirect effects. Due to the increasing prices all of a sudden 50% of the population could be found below the so-called poverty line (Hettne 1979). For the rural population, where many were subsistence farmers, the changes might not have been that important. But the important thing was that the country of India became poorer from global point of view, and that caused the government to take further actions to meet the problematic economic situation and further push for development. As a measure against the rising oil import bill, the Government of India requested increased research on alternative renewable energy sources. This was a crucial step for the diffusion of biogas technology. Resources and attention, on a totally different scale than earlier, were given to the technology.
Still there was no infrastructure to implement larger biogas technology extension programmes. Skills needed to construct the units were, for example, not widely available. The high investment cost attached to the technology was considered another major obstacle for wide dissemination. Moulik *et al.* (1975) argued strongly for subsidies to compensate the farmers.

The end of the period is represented by two separate events. Firstly, the initiation of the All India Co-ordinated Biogas Programme (AICBP) which came to existence in 1975.

Secondly, another energy crisis was "discovered", the so-called fuel wood crisis. This energy crisis was supposed to hit the rural poor people and gained great international attention. All of a sudden the discussions of biogas technology became two-folded. Firstly to the increasing national oil import bill and secondly the fuel-wood crisis. Biogas could be a solution to both.

4.2.4 Phase-IV: Getting in start position for nation-wide programme (1975-1980)

By 1975 it was considered that there existed a well-tested technology and an infra-structure for carrying out nation-wide dissemination. AICPB was created with the aim to install 1.5 million biogas units by 2001 (Moulik 1989). IST was the main initiator but many organisations and institutions were involved, such as the IARI, PRAD, and the Indian Institute of Management (IIM). The main responsibility for the implementation of the programme was, however, held by KVIC.

In the meantime, there had been almost 7 million biogas units constructed in China during the period between 1973-78 (Qui *et al.* 1990). In China political attention had been given to biogas since the 50's and the practice was argued by the rulers to be well adopted to the livelihood systems of rural farmers and the political intention of the party. The main feedstock was pig manure and indications are that the main emphasis of the Chinese programme was to provide a good fertiliser, rather than the Indian emphasis that had more and more turned to the energy aspects of biogas technology. One of the lessons from China was that diffusion of the technology to a very large number of households was possible.

In 1978 the Gobar Gas Research Station in Ajitmal, Uttar Pradesh, came up with a prototype of a new design called *Janata* biogas plant, meaning public or people in Hindi. The *Janata* design was similar in several ways to the Chinese fixed dome design, but one notable difference was there. The *Janata* design was not equipped with a manhole on the top of the digester, which was a common feature of Chinese designs. The manhole on the top made it possible to use other feedstock than manure, as feedstock that floated on top of the slurry could be lifted out. Floating biomass inside the digester can cause blockage of gas pipes as well as the digester volume is not used efficiently with reduced gas production as a result. The main advantage seen in the *Janata*- over the KVIC design, was the reduced cost for construction.

But why had not the *Janata* design, which was similar to the well-known fixed dome type that had been spread extensively in China since the 50's, been introduced earlier to the Indian biogas scene? There is no clear answer to this, but the drive to develop an indigenous Indian design had been strong since the start of biogas development in India. The KVIC design or Indian type of digester was long assumed to be better than the Chinese type from a technical point of view due to among other things the constant gas pressure. Also K.VIC as the main body for extension of biogas technology in India was of course interested in disseminating their own model. The relation between India and China were not very good at this time. It had among other things resulted in war in 1962. These are some reasons to why transfer of technology from China could be problematic. Anyhow, by 1980 approximately 90,000 units had been installed of which only a small number were of the *Janata* type (Sarkar 1982; Ellegård *et al.* 1983).

Texts and articles on biogas production and utilisation began to be produced *en masse* and also spread publicly during this period 41 . Biogas technology was seen as a potential alternative energy source that could be beneficial for rural people and contribute to solving the energy crisis that India was facing. But there were some authors that argued that the technology, however well adapted, could not be seen as a general solution in rural areas as there were conditions to be met such as the need of capital investments. The general ideas were however that some of these conditions could be solved through technical development and then make biogas an important energy source for rural areas. It is quite clear that the main argument of biogas technology became more and more centered on the energy aspect.
Towards the end of this period, 1975-1981, the biogas programme was integrated into the Government of India's 20-point program. The 20-point programme was launched the first time some weeks after the emergency had been declared on June 26, 1975. The programme promised to bring down prices, called for land reforms, the removal of the system of bonded labour, design laws declaring minimum wages. The programme had been a populistic

response to the situation that existed at the time of the emergency (Hællquist *et al.* 1977; Hettne 1979; Brass 1990; Wolpert 1993)

4.2.5 Phase-V: Biogas Technology crash programme **initiated (1981-1985)**

The integration of the biogas programme into the 20-point programme made it a national development goal. As a response to this, the Government of India in 1981/82 launched an extension and development programme called National Programme for Biogas development (NPBD). The Ministry of Agriculture was only to implement the programme. NPBD still exists and the goal, as it is presented today, is:

...providing clean and cheap source of energy in rural areas, producing enriched organic manure for supplementing the use of chemical fertilisers, improving sanitation and hygiene and remov-ing drudgery of women (MNES 1996).

Soon after the launch of the NPBD the responsibility for the programme was taken over by the Department of Non-Conventional Energy Sources (DNES) which had been created in September 1981 under the Ministry of Power (Sinha· 1994). The already strong emphasis on energy was now settled as the programme was handled by a Department involved in renewable energy technologies (RET) *(Singh. 1996).* The other aspects of the technology, such as the fertiliser and health benefits, were still acknowledged as important features though. The NPBD was the main RET programme within DNES, followed by the National Programme on Improved Chulha (NPIC). NPBD held about 50% of the department's total budget.

The programme was designed to encourage the construction and dissemination of biogas technology mainly through:

- *Direct support* in the form of subsidy to the beneficiary if installing an approved biogas design. A turnkey fee is given to organisations, corporate bodies and approved entrepreneurs who construct biogas plants with a 3-year warranty.

- *Indirect support* in the form of training courses for users, turnkey worriers/ masons and representatives for organisations, and through support for communication and publicity activities.

In 1984 AFPRO introduced their new biogas design called *Deenbandhu* biogas plant meaning "friend of the poor" in Hindi 44 . This design was approved for inclusion in the NPBD by the DNES in July 1986 (Singh *et al.* 1987). The *Deenbandhu* design was claimed to cut the cost of installations even fcrther. Actually it was not a new design, but rather a further development of the *Janata* type. The cost reduction was due to the use of some standardised pipes and a different construction technique. The design got a breakthrough, as it soon became the most popular design within the NPBD. When Indira Gandhi was assassinated on October 31 1984, the Prime Minister post was taken over by Rajiv Gandhi, her son. Rajiv Gandhi believed that a more technology and market oriented development strategy than his mother had advocated could modernise and develop India (Gupte 1992; Wolpert 1993; Tully *et al.* 1996).

The four years that had passed from the integration of biogas development in the 20- point programme as well as the initiation of the NPBD had resulted in a large number of installed units, about 400,000. The technology as such had proved itself as a potential rural technology, and resources allocated in the national budget for RET implementation and extension were increased. However the increased number of annually installed biogas plants made it important which an efficient extension organisation to implement the program. Moreover, the importance of high quality construction was identified as an important factor for successful implementation of biogas units. This leads into the next phase where the NPBD programme was revised to some extent and steps were taken to meet the problems of malfunctioning and non operational plants.

4.2.6 Phase-VI: Reforming the crash programme (1985-1992)

During the period between 1985 and 1992, 160-200 000 biogas units were installed annually. This can be compared to the earlier annual installations between 1980 and 1984 of less than 90,000. Many of the units that were constructed soon after installation fell into disrepair or were simply abandoned. One of the measures taken by the DNES to meet this was to encourage autonomous bodies and entrepreneurs to take part in the implementation of the NPBD.

From the mid 80's a category of biogas extension worker acquired escalating importance for the dissemination under the NPBD. These, so-called Turnkey worker (TKW), were people (men) trained for construction of biogas plants. The profit for the TKW in the biogas venture was the government turnkey fee that was available for the trained and approved entrepreneurs. NGOs and other Institutions could also act as extension bodies, provided trained personal was available. Thus a transition to rely more on NGOs and TKWs for the extension work happened. A person constructing a biogas plant required special skills and training. Training was needed to an even higher extent in the case with the fixed dome types than with floating domes. Construction of the fixed-dome plant is done with bricks, plaster, and concrete, materials that are non-plastic which can cause cracks in the dome if the construction is not carried out properly. The cracks can be microscopic, but still cause gas to leak out. The inside of the dome is due to this painted with thick paint (which is plastic). A further measure was to advocate high quality construction materials to be used for the plants.

During the period between 1985 and 1992 the resources for RET diffusion and development in general was enlarged manifold. Comparing the budget allocation for New and Renewable Sources for Energy (NRSE) in 1988/89 (Rs 830x10 6 in 1981/82 prices) with that of 1980/81 (Rs 40x10 6 in 1981/82 prices), the amount of resources allocated to this sector is enlarged by a factor 20. Other energy sectors did not experience the same spectacular rise in budget allocation 45 . NRSE stood, however, only for a very small part of **the** total **net** budget.

For the NPBD this meant that a brave new goal was set to install 12 million units by 2001 (Sinha *et al.* 1990; Sinha *et al.* 1991b). This would mean that the total estimated national potential for biogas would have been met by this time. The international oil price was still a factor of central concern to the Government. Between November 1985 and end of April 1986 an inverse oil price shock lowered the price on oil. Due to rapid increase in consumption of foremost kerosene and diesel the easing of public expenditures that could have been the result of decreased oil price did not happen (Moulik 1989). As time passed by, less interest was given to small-scale biogas technology from the international actors (donor organisations, international development agencies) with some exceptions. Dhussa *(1996)* argued that reasons for this could be that biogas technology had gone from the research and development phase to the extension and dissemination phase, a phase that attracted less international attention. On the other hand the many disappointing experiences yielded from international and Indian biogas extension programmes in the early 80's certainly played a role. Indications from China at this time told that perhaps more than 50% of their biogas units had broken down or were not in operation (Kristoferson *et al.* 1986b)48 . The implementation of the NPBD went on. Large numbers of units were installed and the strategy of heavy direct subsidies to the households for the investment, along with turnkey fees made the foundation. The state development organisation as well as both NGOs and TKW, who could make an income through installation of biogas units, carried out more a more of the extension work.

Two events make-up the transition from this period to the next. First, the economic crisis, which came to the surface in 1991 and led to, among other things, what is referred to the economic liberalisation of the Indian economy in 1992 (Kurien 1996). One of the results was that the Government of India was forced to drastically cut in fiscal expenditures. Second the transformation of the DNES into an own ministry, Ministry for Non-conventional Energy Sources (MNES).

4.2.7 Phase-VII Uncertainties but continues dissemination (1992-2000)

In July 1992 DNES was transformed into a ministry called Ministry for Non-Conventional Energy Sources (MNES) The supply strategy that had been applied in the work when it was a department was still holding. In July 1993 this strategy was slowly transformed in order to try to pursue a more end-use oriented approach (Sinha 1994). MNES assignments were varying from biogas research and development, improved *chulha* extension and development over mini hydro and solar photovoltaic (PV) power to more institutional assignments such as the Indian Renewable Energy Development Agency (IREDA) (MNES 1996). The NPBD was still the largest project and constituted for about half of the budget. The ministry is divided into six groups relating to different aspects of RET:

- *Power group:* wind power, small hydro-, biomass-, and solar power
- *Rural energy group:* household biogas, improved *chulhas*, community biogas
- *New technology group:* hydrogen energy, chemical sources of energy, tidal en-ergy, wave energy
- *Urban and industrial group:* energy from urban and industrial waste
- *Solar energy group:* solar water heaters, solar cookers, PV programme; small, and medium size
- Administration and co-ordination group

4.3 BIOGAS PROGRAMME IN INDIA

Biogas is a very important renewable resource of energy produced form the organic materials like cattle dung, human waste and different types of biomass. It is a very clean and smokeless domestic fuel. The main advantages that , the pressure on fuel wood reduces, improves sanitation and environmental conditions, reduces the incidence of eye and lung diseases. The technology that is available is of low cost and simple, mostly useful in **the** rural areas, where all the required materials for the plant are available.

It is one of the most appropriate options for meeting the growing energy needs of the rural areas in India. Biogas is a clean and convenient fuel for cooking and lighting in the households; it can be supply motive power for irrigation and small industries, and the effluent slurry, a by product, can be used as organic manure. More importantly, biogas make use of a local resource - cattle dung in an environmentally benign and economically viable manner. In addition to dung, biogas can also be produced using other organic matter like human waste. It is for these reasons that biogas has gained popularly in India and is, perhaps, the largest and most prominent of all rural renewable energy programmes implemented by the government (Ramana P V: 1991)

4.3.1 Role of KVIC

The KVIC developed standard designs for capacities varying from 3 cu. M to 14 cu. m of gas output per day. It also evolved efficient gas burners and an engine to run on biogas. Five regional centers were set up to purse research and dissemination work. KVIC trained several educated, rural youth in plant construction and arranged for subsides and loans from the government. With these efforts, KVIC could install about 7000 plants of varying sizes all over the country by 1974. During this period, the PRAD (Planning Research and Action Division) of Uttar Pradesh government also established the Gobar Gas Research Station in 1961 at Ajitmal, Etawah district. But it was only in 1974 that biogas become an issue of public interest when policy makers as well as scientists realized that it could be a major energy option for rural areas in view high oil import bills and growing deforestation.

Based on 1961 livestock census, it was estimated that biogas could generate nearly 195 billion kwh of energy annually equivalent to 24 billion liters of kerosene and 236 mt of manure with a nitrogen content of 3.5 mt. It was calculated that the dung available in could support 18.75 million family biogas plant (1.7 cu.m average capacity) and 560 000 community plants (142 cu.m average capacity). The two committees set up by the government to formulate the energy policy, the fuel Policy Committee (1974) and the Working Group on energy Policy (1979) felt that biogas was the most promising alternative energy source for household sector and made suggestions for its promotion.

The central government had initiated a field dissemination programme in 1974 which the assistance of KVIC and by 1979080, over 80,000 individual plants were installed in several parts of the country. Encouraged by the promise shown by the technology, the Sixth five Year Plan envisaged setting up one million family-sized plants and hundred community plants during the plan period.

4.3.2 Role of NPBD

The main objectives of NPBD are:

- To provide energy in clean, unpolluted form;
- To make available enriched fertilizer as a by product for supplementing and optimizing the use of chemical fertilizers;
- To reduce pressure on dwindling fuelwood suppliers and to prevent indiscrimination;
- To eliminate the smoke-filled cooking environment, reduce drudgery, and prevent eye diseases; and
- To bring about an improvement in rural sanitation.

In keeping with the aim of disseminating biogas technology, the Ministry of Agriculture launched the NPBD (National Project on Biogas Development) in late 1981 with an outlay of Rs. 50 crores. After a few months the programme was transferred to the a DNES (Department of Non-conventional Energy Sources) and the onus of policy making shifted to the CASE (Commission on Alternative Sources of energy). Biogas got a further fillip when it was included in the Prime Minister's 20-point programme.

The Ministry adopted a decentralized multi-agency and multi-model implementation strategy for NPBD. At the state level, the programme is implemented through a nodal agency (Council for Science and Technology, energy Development Agency, etc.) which is primarily responsible for achieving targets, managing finances, monitoring, etc. Other agencies involved in implementation at the district level and below are several government goodies such as district Rural Development Agency (DRDA), Block Development Office (BDO), Local entrepreneurs, rural non-governmental organizations (NGOs), Gram

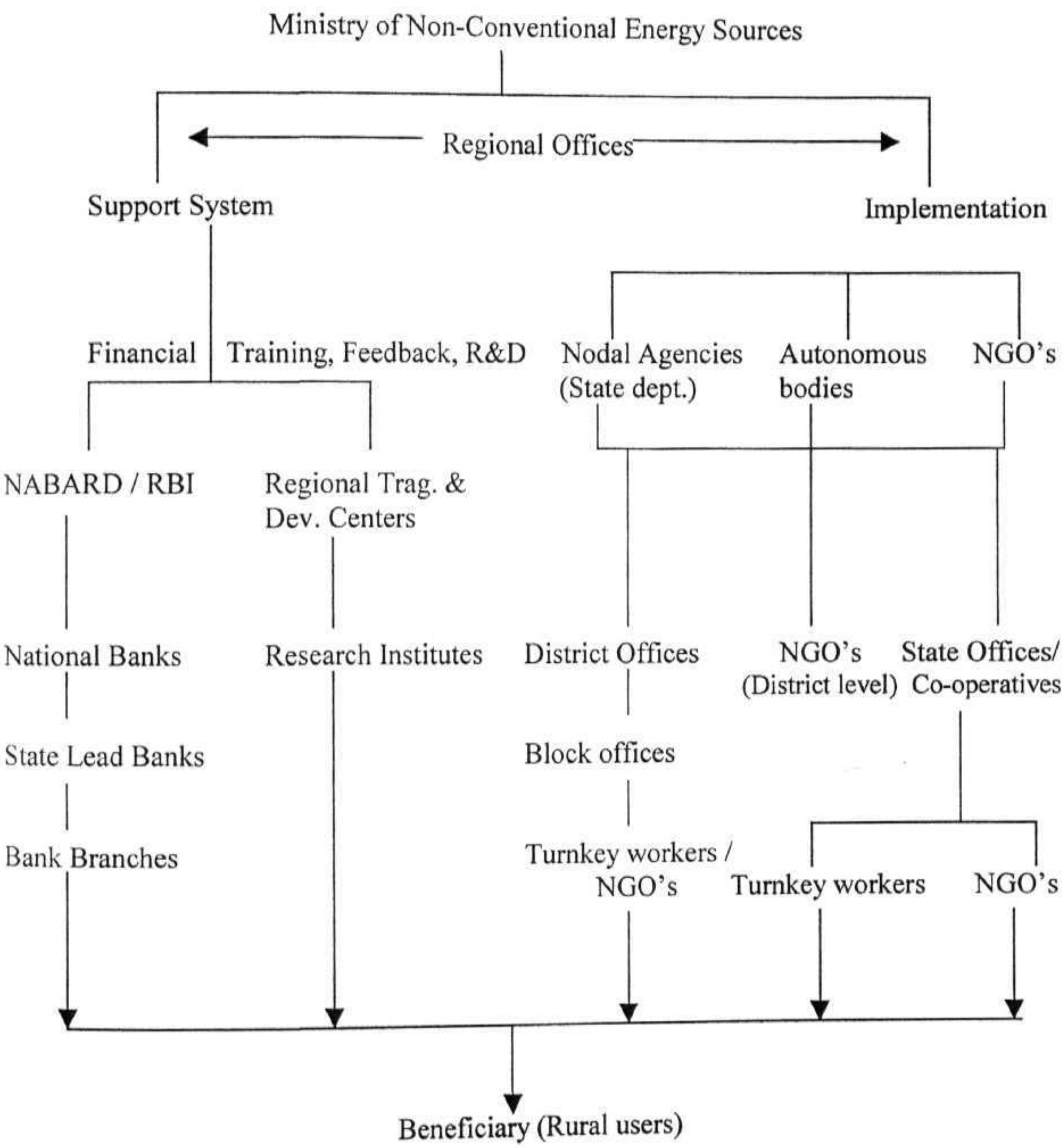
Panchayats, dairy cooperatives, etc. further, the National Banks are also involved in the programme by providing soft loans to beneficiaries to partially meet the costs of construction.

By the end of the plan period, NPBD not only achieved, but exceeded its target by installing 3,43,930 plants. Evaluation survey commissioned by DNEs reported an average success rate of 85%. In addition, 106 community plants were set up against a target of 100 plants . Enthused by this success, the Seventh Plan had an ambitious target of installing 1.5 million family biogas plants and 1200 community biogas plants, extending the programme to cover all the districts. However, the target number was once again lowered because of low budget allocation of Rs 177 crore instead of Rs 300 crore as originally envisaged. Not withstanding, 8,93,908 plants were set up against a target of 7,31,150 plants.

Thus, at the end of Seventh Plan, approximately 1.33 million family biogas plants were operational under the NPBD (Table:4.2). Biogas has literally reached every book and corner of the country, even remote regions, such as, Arunachal Pradesh, Andamnan Islands, and Dadra and Nagar Haveli. In terms of numbers, Maharastra acconts for a tlargest number of pants (3,70,702) representing 30% of the total, followed by Uttar Pradesh with 1,80,806 plants (15%) . A notable feature of NPBD in Uttar Pradesh has been the preponderance of Janata model plants, Denbandhu design also gained popularly in Uttar Pradesh. The other leading states are Tamil Nadu, Gujarat, Andhra Pradesh and Karnataka.

All though biogas has been a success in several states, its presence is merely a token in the North-east and the Himalayan region. Among the smaller states and union territories, only Goa has installed about 1500 plants with the remaining setting up less than 500 plants each. Difficult terrain and high transportation costs coupled with lack of trained manpower have rendered the dissemination of biogas in the remote and hilly regions difficult. To tackle such problems, DNES increased subsidies in these areas and tried to involve local NGOs in the programme. This has resulted in some improvement in the last couple of years. An organisational chart of the NPBD is displayed in below Figure 4.1, in this structure, the government development workers are no longer present. Many local NGOs can support

Figure 4.1
Organisational structure of the NPBD



their other development programmes through biogas extension work as they are also entitled to the turnkey fees. It seems that people and organisations have experienced problems in obtaining the subsidies and turnkey fees when the installment had been done. The reasons given are slow handling of the cases and a low confidence in the technology from the bank's branches (Dutta *et al.* 1997).

It should also be noted that at the bottom of the structure the *users* are found, but the directions of the arrows indicates that there is little feedback from this group to other parts of the NPBD structure. This is of course not totally so. As part of the NPBD there is continues monitoring of the progress from the different bodies, carried out by themselves or in some cases by autonomous bodies.

The concepts of both sustainable development and rural employment became increasingly linked to biogas technology in the 1990's. Biogas technology has fitted into the sustainable development discussion through among other things making the energy system in India less dependant on fossil-based energy. Other examples is that biogas is found in discussions and suggestions for sustainable energy solutions for India (Raja: 1997).

Rural employment generated through biogas extension work had gained growing attention from the late 80's. In 1965 about 25% of the rural households in India received their major income from wages, in 1988 this percentage had increased to 40% (Ghosh *et al.* 1992). The figures are rough estimates on a trend that indicates that an increasing portion of the rural households and people have to rely more on wages for their livelihood. To many of these wage-dependant households there are no possibilities to cultivate any land, as there is no land available. The formal sector of manufacturing and service do not expand in correspondence to the available excess workers (EIU 1993). One possibility is to do casual labour or to migrate to urban areas. Another way is to work in household industry and informal sector services, work that is insecure and paid with low salaries. Rural employment schemes have become increasingly important within national development, but many of the schemes implemented have not reached their aims due to lack of resources, lack of local decision making and low usability of the products produced (Ghosh: 1992).

In 1996 there were a total of seven biogas designs approved by the MNES. Besides the KVIC, *Janata* and *Deenbandhu* there were the *Pragrati* design, KVIC design with reinforced plastic dome, KVIC design with ferrocement dome and the *FLXI*-design. One of the striking features at the end of this period is that biogas technology should after nearly 20-years as a government subsidised programme begin to act as a commercial venture *(Dhussa 1996; Kishore 1996; Moulik 1996).* This puts the end of the transition period between 1992 to 1996 and we find ourselves at the present time.

4.4 TODAY AND THE FUTURE

Against an estimated potential of 12 million family type biogas plants over 2.9 millions family type biogas plants has been installed in the country up to December 1999. The table 4.6 shows state-wise achievements up to December 1999.

According to Dhussa *(1996)* there is quite a substantial difference between the different state boards on how much they want to push for biogas technology, i.e. how large targets they want to fulfil. This has resulted in a quite large spread between the different states concerning numbers of installed biogas plants. Maharashtra is without comparison the state with largest numbers of constructed biogas plants, covering almost 1/3 of the total number of installed plants. It can be noted that KVIC has it headquarters in Mumbai (Bombay) situated in Maharashtra and this organisation has been one of the leading actors in the development and diffusion of biogas technology. Uttar Pradesh, Gujarat, Tamil Nadu, and Andhra Pradesh follow Maharashtra in number of installed units. There are a number of small states that have not installed that many number of plants, among which we can find for example Bihar, Nagaland, Tripura (MNES 1996). However it should be noted that within these states there might be pockets where an organisation, or TKW, have implemented a relatively high density of biogas plants. The potential for biogas might further on not be that large in every region.

Table: 4.2

Number of family bio-gas plants installed (state-wise) under NPBD

S.No	State / UT	Number of Biogas plants Installed		
		1974–81	1989–90	2000-01
1	Andhra Pradesh	2854	92106	308519
2	Arunachal Pradesh	0	26	1142
3	Assam	75	8632	48059
4	Bihar	9826	68415	119110
5	Goa	0	1449	3283
6	Gujarat	9185	102093	343686
7	Haryana	10277	28406	42120
8	Himachal Pradesh	0	20823	43354
9	Jammu & Kashmir	0	710	1932
10	Karnataka	7799	73824	306845
11	Kerala	1587	25055	72339
12	Madhya Pradesh	3652	40953	192951
13	Maharashtra	11933	382635	662120
14	Manipur	0	339	1939
15	Meghalaya	0	167	1859
16	Mizoram	0	591	2376
17	Nagaland	0	124	1477
18	Orissa	622	49029	171761
19	Punjab	5612	20414	62708
20	Rajasthan	409	35273	66026
21	Sikkim	0	364	2971
22	Tamil Nadu	6565	134078	198838
23	Tripura	0	114	1438
24	Uttar Pradesh	27883	208698	358311
25	West Bengal	2413	42888	187266
26	A & N Islands	0	98	137
27	Chandigarh	0	77	97
28	Dadra & Nagar Haveli	470	603	1169
29	Delhi	51	629	675
30	Pondichery	0	447	539
	Total	101213	1339051	3205047

Table: 4.2.a Number of family bio-gas plants installed (Andhra Pradesh -District wise) under NPBD

Sl.No	District	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	Total
1	Adilabad	225	300	450	400	357	360	150	800	2000	713	752	1100	7607
2	Anantapur	108	351	702	846	810	772	700	780	920	1290	1224	500	9003
3	Chittoor	420	433	539	430	475	416	500	350	820	1000	1000	1200	7583
4	Cuddapah	104	151	150	225	275	175	300	250	118	307	600	500	3155
5	East Godavari	569	618	591	1066	1074	915	1640	500	550	751	603	200	9077
6	Guntur	1100	1203	1350	1500	1138	685	302	575	405	500	650	300	9708
7	Karimnagar	815	1009	1355	1503	980	525	1150	1417	1200	850	903	600	12307
8	Khammam	1479	1791	3000	2147	2150	1110	2203	2901	1170	846	1225	1459	21481
9	Krishna	1349	1130	1302	1503	1566	1132	1600	800	1125	1509	915	100	14031
10	Kurnool	70	200	400	350	275	175	200	300	810	668	180	130	3758
11	Mahabubnagar	300	414	628	524	501	302	550	521	456	701	1050	800	6747
12	Medak	159	152	300	400	564	531	750	1142	1200	825	801	801	7625
13	Nalgonda	1505	1601	3030	2803	2755	1750	2010	2400	2250	2571	3024	3249	28948
14	Nellore	350	500	550	550	500	320	400	300	390	340	580	270	5050
15	Nizamabad	515	665	489	578	500	295	438	350	113	1700	2004	1896	9543
16	Prakasam	330	430	500	666	292	307	670	1016	694	700	574	140	6319
17	Rangareddy	152	400	442	542	550	361	400	500	251	201	201	100	4100
18	Krikakulam	905	861	1045	1320	1180	627	700	1133	1188	969	909	639	11476
19	Visakhapatnam	430	450	350	100	250	158	75	535	416	500	306	100	3670
20	Vizayanagaram	150	250	600	300	548	159	525	500	500	650	567	225	4974
21	Warangal	518	957	1300	2029	1692	2097	2500	2080	1550	533	1172	1116	17544
22	West Godavari	891	403	558	629	781	270	800	812	343	91	402	169	6149
	Total	**12444**	**14269**	**19631**	**20411**	**19213**	**13442**	**18563**	**19962**	**18469**	**18215**	**19642**	**15594**	**209855**
	Growth Rate		**0.1279**	**0.2731**	**0.0382**	**-0.0624**	**-0.4293**	**0.2759**	**0.0701**	**-0.080838**	**-0.0139**	**0.0727**	**-0.2596**	

The shift from subsidised national programme to commercialisation of biogas technology will put the technology to the test. There are very few if any biogas units that have not been subsidised in any way. There is also very little grassroots movement regarding innovation and development of the technology. The diffusion and extension process has thus far been a question not so much for the user as is indicated in the NPBD structure (Figure 4.3). When biogas technology has to compete with other technologies and bear its own costs, the comparison to other energy options will seem increasingly important and the users (or households) demands on sound and appropriate technology solutions will become a central concern. The services that can be obtained from biogas technology and whether or not people see these services as important in relation to other concerns are questions that have to be raised.

4.4.1 Problems of the future

We have come this far in the history of biogas diffusion and development in India without touching so much upon one of the most difficult question, i.e. the results. It has been mentioned that during the first part of the NPBD, 1981-85, quite some problems of malfunctioning plants existed. Further on we have touched upon some of the difficulties that were confronted in China with their massive propagation and diffusion of biogas during the 70's. NPBD is continuously monitored in respect to progress of the programme and, similar is the case with more or less all biogas projects.

In a major study carried out in 1992 by the National Council for Applied Economic Research (NCAER) an estimate of the use of biogas plants installed between 1985/86 to 1989/90 was made. 3,600 villages spread in 251 districts and 27,000 units were monitored. It was found that on a national level *66%* of the units were in use while there were significant regional variations (Ravindranath *et al.* 1995). A similar study carried out on plants set up during the period of 1992/93 to 1994/95 covering 5,165 plants in 727 villages in 18 states found that 87% were in use (MNES 1996). It should be noted however that these surveys only consider units that are not older than four years.

Another survey of the functionality of installed plants can be found referred to in Dutt and Ravindranath (1993). A survey of 4,108 biogas plants in Maharashtra showed that 36% of them were working. The reasons given for why the plant was not in working condition was 3% said it was due to technical failures. Other reasons given were; 29% lack of dung and in 16% there were difficulties in keeping a good process. In most cases, 52%, there was just a lack of interest in the technology from the respondents.

The NPBD has existed for more than 15 years, and it is surprising that the above information does not already exist. An estimate of the cost of the NPBD in 1992 was that the Government of India had spent Rs 3 billion on the project (Lichtman 1992). In respect to other power and conventional energy related programmes this is quite small amount of money, but it is the major non-conventional energy programme implemented in India. It is moreover noteworthy that the point of departure is with all clarity from the energy aspect and that biogas is argued to be "the best decentralised energy source" (Drat of Nineth Plant; GOI 2000).

There is one big difficulty involved in what the Government of India is planning to do; quantification of fuelwood saving. Today it seems more and more clear that there is only very small, if any direct correlation between on the one hand fuelwood saving in rural domestic sector and deforestation on the other (Agarwal 1985a; Leach *et al.* 1988; Ravindranath *et al.* 1995). Hence introduction of biogas technology will have no, or a very small effect on deforestation. The issue at stake is quantification of the benefits implies that there are benefits to quantify.

We can assume that there will be a number of new surveys carried out regarding biogas technology in the years to come. One of the major tasks then will be to quantify the achievements from the NPBD. First thing here is to find out what the results really are. Questions relating to if the biogas units are in use or not will be insufficient. Information on the performance of the different units will also be required. As of today there is very little information on the actual performance in terms of amount of produced gas and quality and amount of effluent. Some exceptions exist, like for example Teri's surveys in Dhanawas, but these only concern a small number of plants. A number of different laboratory and controlled tests have also been carried out, but there has not been any survey, to my knowledge, with a large number of plants looking at the actual performance over a longer time span and in different geographic zones.

4.5 POPULAR BIOGAS PLANTS IN INDIA

There are two well-tested and field-worthy designs of biogas plants. They are:

1. Floating gas holders type (KVIC type Gobar gas plant) - (Fig. 4.5) and
2. Fixed home type (Janatha Biogas plant) - (Fig. 4..6) During the last ten years, five new models have been developed, field-tested and approved for extension. These models are as follows:
3. Floating gas holder type plant having digester made of angle iron and polythene sheet called the 'Gandesh Model'.
4. Floating gas holders type plant having digester made of pre-fabricated fibrocement segments.
5. Floating gas holder type plant having gas her made of fibre glass reinforced plastic.
6. A plant having conical shaped base and shell shaped digester made with a provision of a gas holder, called 'Pragati Model' (Fig. 4.7)
7. Fixed dome model dispensing with the shuttering work for construction of dome portion, called the 'Deenabahdhu Model' (Fig. 4.8)

Hydraulic retention periods have been standardized for different areas according to temperature zones as indicated below:

Zone	Mean Temperature during Winter months (°C)	Recommended retention period for a biogas plant (days)
I	More than 20	30
II	15-20	40
HI	10-15	55
IV	Less than 10	Not Suitable

Biogas plants in vogue in India are primarily semi-continuous fermentation type. The most common feedstock is cattle dung. Night-soil, poultry-droppings, excreta of other livestock, etc, can also be used in these designs with much problem. Solely night soil based biogas plants (Fig-4.9) are also becoming popular. Some farmers have been operating fixed dome plants on a mixture of cattle dung and organic refuse colleted from kitchen. The common sizes of plants vary from 1 to 10 m^3 / gas productin per day at an ambient temperature of 25 to 30°C. The smallest one cu m capacity plant requires 25 kg. Dung collectable form 1-2 cattle heads.

Trust areas of Research and Development were identified in 1984-85 for short-term (2-3 years) and long-term (5 years) duration projects. About 40 institutions have been selected to work on various aspects of the Trust areas. Board areas covered under the on-going research projects are;

- Optimisation and standardization of plant design and process for alternative and mixed feeds for biogas generation
- Development, testing and standardization of alternate materials for construction of biogas plants with consequent reduction in unit cost.
- Field evaluation, testing and demonstration of promising results of research through pilot / experimental plants.
- Development of techniques for sustaining gas production during colder months.
- Improved methods for handling and application of manure as organic fertiliser.
- Development of engine to work on 100 per cent sewage gas for power generation.
- Extract of biogas form landfill and it utilization.

Fig: **4.5**

Floating Gas Holder Type Bio-gas Plant (KVIC Model)

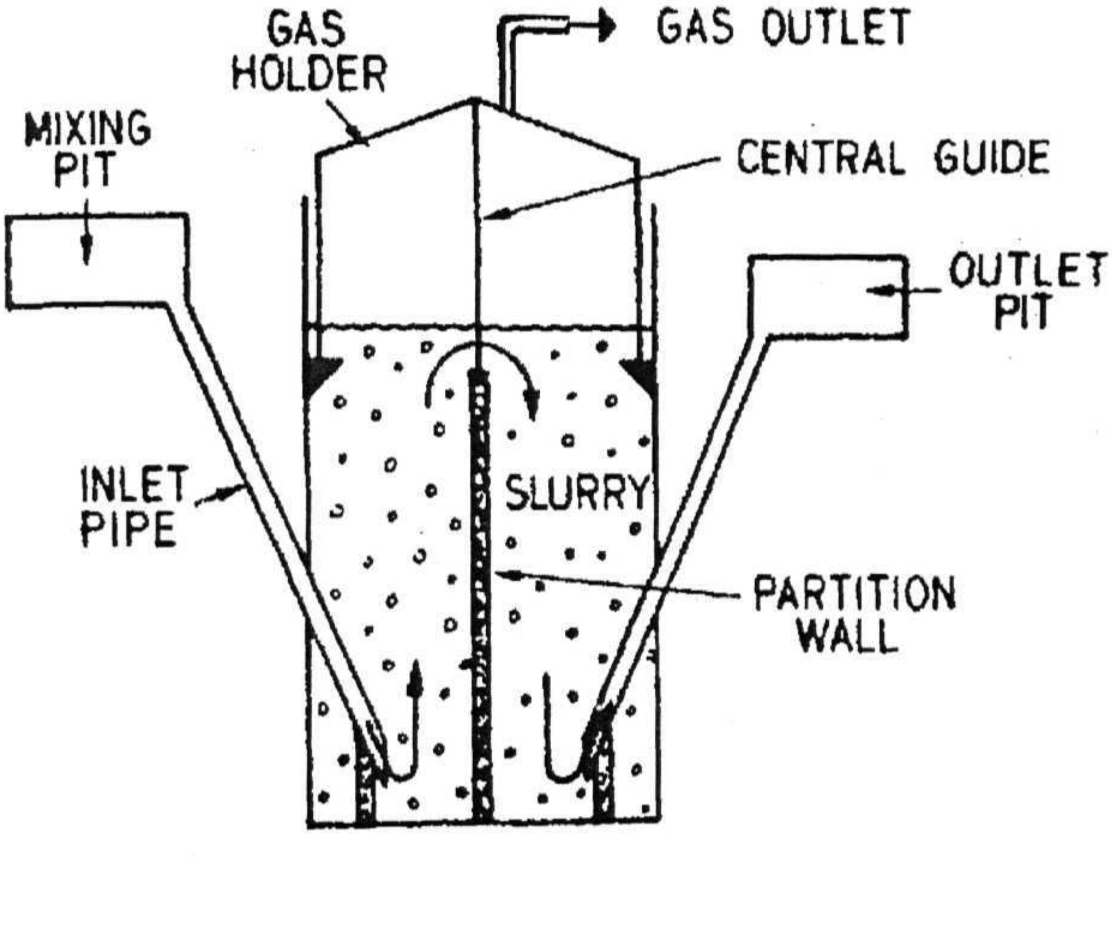


Fig: 4.6

Fixed Dome Type Bio-gas Plants (Janata Type)

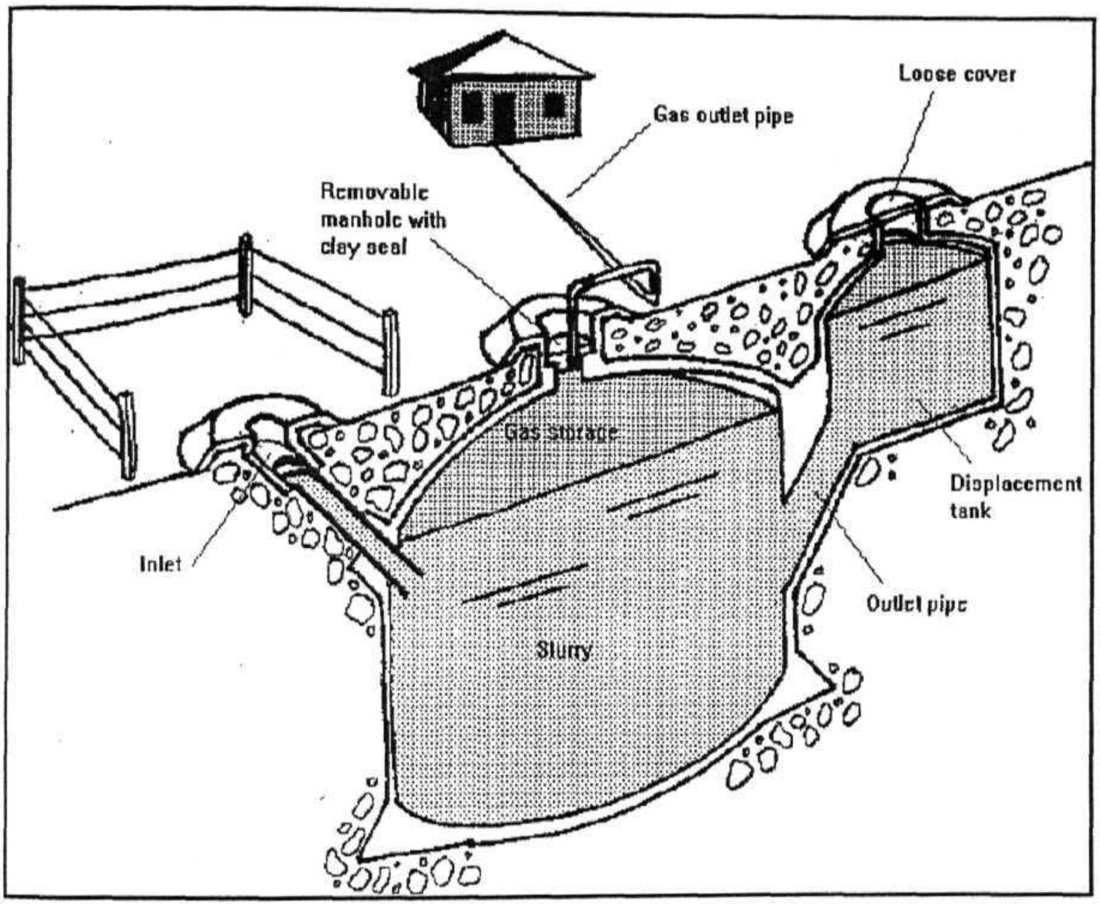


Fig: 4.7

Pragati Model

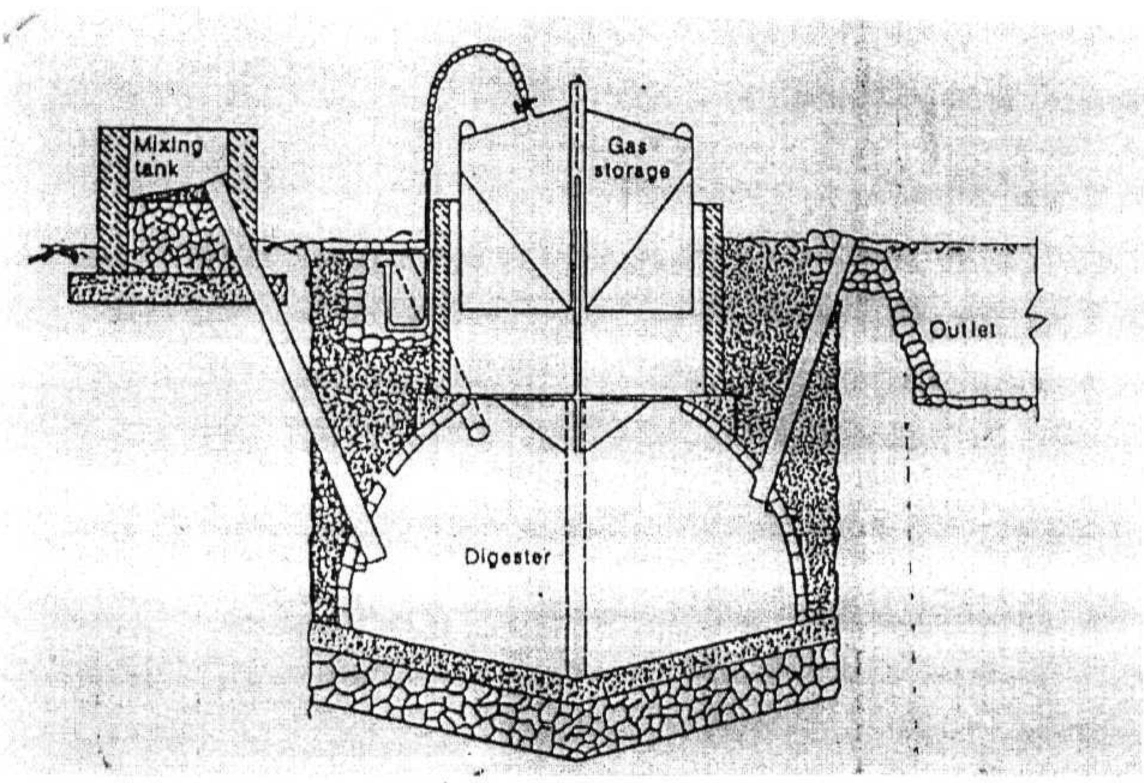


Fig: 4.8

Deenbandhu Model

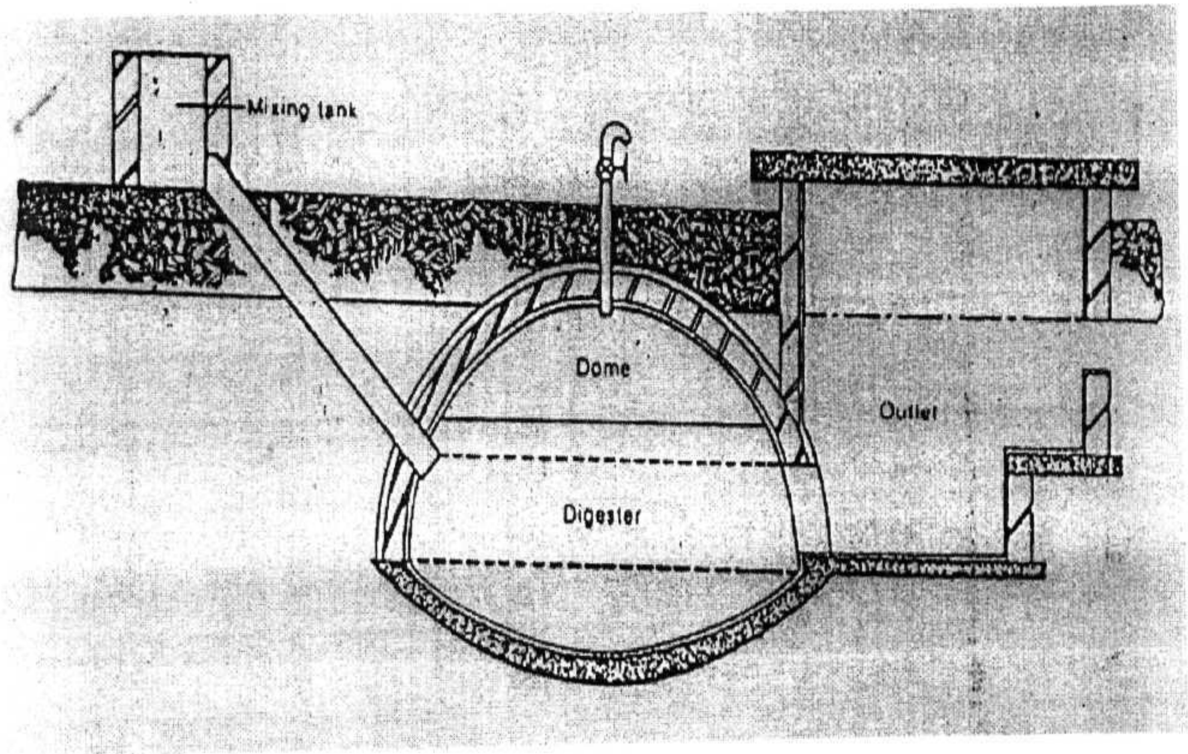
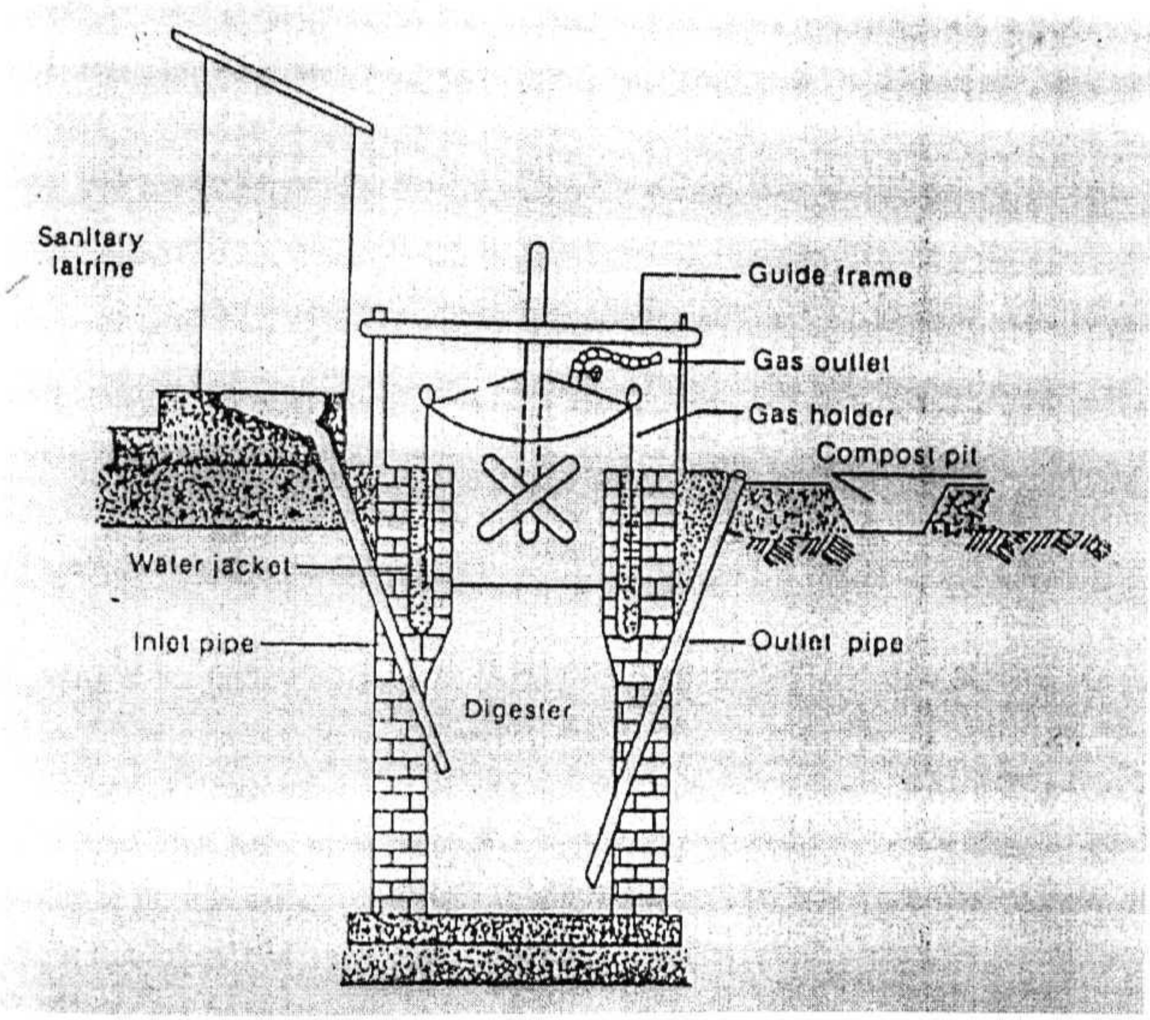


Fig: 4.9

Sanitary Latrine with Bio-gas plant



4.6 CONCLUSION

If biogas technology can stand up to its potentials it can, probably, make a real difference for rural people. At present little is known of the performance in general nation-wide and over a longer time span. As of today one of the major constraints to further interest in the technology is its history, as strange as it might sound. During the 80's there were many people involved in the extension and dissemination of biogas technology. The experiences from this time were often disappointments. The projects ended in failures and aims not reached. Much of information on biogas available is based on the experiences made in the 80's. Today many of the international organisations, with some exceptions, are hesitant of further work with biogas. The strong dependence on state subsidies can be seen as an indication that the technology cannot live on its own merits. Today the policy seems to be to slowly phase out the direct subsidies, which could be a step in the right direction to make the technology prove its merits. It is not clear that letting biogas technology compete on market terms will bring about increasing numbers of installed units. One important factor is whether or not this technology will compete on the same terms as for example LPG or kerosene, which have subsidized prices.

Looking at the history of biogas technology, many of the aspects that were taken up to advocate the technology in the past are still seen as valid arguments for the technology. The argument that biogas technology would meet the problems of deforestation is still seen as a valid point, even found in the Ninth Five Year plan. The same goes for the allegedly good quality of the effluent as a fertiliser and soil conditioner. We could call these 'dogmas of biogas technology' and they are similar to development narratives. During the years biogas technology has fit in the main stream development ideas. Biogas could be used for rural development in the 70's and also fit perfectly in the integrated rural development ideas. When eco-development came along biogas was adopted as a perfect technology to achieve the desired aims. From the appropriate technology side biogas technology can be seen as an almost perfect technology, easy to use and with high benefits, locally manageable and profiting the rural households. In the late 80's and 90's when biogas technology could be seen as means to implement sustainable development. Research on various aspects of biogas technology has throughout the history been carried out, but it was often hard to transfer to any practical use on the grassroots level. Technical innovation, like coming up with new designs, was basically done outside the conventional research institutions. The *Deenbandhu* model, for example, was an APPRO innovation, and KVIC model was the innovation of Mr Patel and later taken up by KVIC. Even though there is one part of the NPBD, which is devoted to research, little seems to have come out of it. There is definitely a need for new innovations and designs within the field. Today basically one design, the *Deenbandhu,* is disseminated throughout the whole country. It is a 'one design fits all' type of approach.

Development of biogas technology has to a large extent been initiated by a group of highly educated scientist with backup from research and development infrastructure (Moulik 1985). This seems still valid to some extent. Life in rural areas has changed during the years that biogas technology has been diffused, but little notice has been taken of this. In all the applications where biogas teclinology could fit it is mainly the potential benefits that have been considered. But I would argue that there exist few linkages between the potential benefits and practical experiences from biogas technology. Most of the argumentation relies on theoretical cause and effect considerations, which might not at all be valid in reality. Biogas can provide positive results if managed correctly, but it is not an automatic or mechanical process.

Chapter – V

BIOGAS PLANT - TECHNICAL FEASIBILITY: AN OVER VIEW

5.0 INTRODUCTION

Biogas technology is a complete system in itself with its set objectives (cost effective production of energy and soil nutrients), factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors. Brief discussions on each of these factors or subsystems are presented in this section.

Biogas is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and low amount of other gases as shown in Table 5.1.

Table 5.1

Composition of biogas

Substances	Symbol	Percentage
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1 -2
Water vapour	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

Source: Yadav and Hesse 1998

Biogas is about 20 percent lighter **than air and** has **an ignition temperature in the** range of 650 **degrees** to **750** degrees C. **It** is **an** odourless **and colourless gas that burns with** clear blue flame **similar to that of LPG** gas (Sathianathan, 1975). **Its calorific value** is **20** Mega Joules (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove.

5.1 COMPONENTS OF A BIOGAS SYSTEM

This section focuses on Methanogens and Methanogens to explains the components and their utilization in bio-gas process is explained.

5.1.1 Methanogenic Bacteria or Methanogens

These are the bacteria that act upon organic materials and produce methane and other gases in the process of completing their life-cycle in an anaerobic condition. As living organisms, they tend to prefer certain conditions and are sensitive to micro-climate within the digester. There are many species of methanogens and their characteristics vary.

The different methane forming bacteria have many physiological properties in common, but they are heterogeneous in cellular morphology. Some are rods, some cocci, while others occur in clusters of cocci known as sarcine. The family of methanogens (Methanobacteriacea) is divided into following four genera on the basis of cytological differences (Alexander, 1961):

- A. Rod-shaped Bacteria

    (a) Non-sporulating, Methanobacterium
    (b) Sporulating, Methanobacillus

- B. Spherical

    (a) Sarcinae, Methanosarcina
    (b) Not in sarcinal groups, Methanococcus

A considerable level of scientific knowledge and skill is required to isolate methanogenic bacteria in pure culture and maintain them in a laboratory. Methanogenic bacteria develop slowly and are sensitive to a sudden change in physical and chemical conditions. For example, a sudden fall in the slurry temperature by even 2o C may significantly affect their growth and gas production rate (Lagrange, 1979).

5.1.2 Biodigesters

The biodigester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the biodigester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size. Construction of this structure forms a major part of the investment cost. Some of the commonly used designs arc *Floating drum digester, Fixed dome digester, Deenbandhu model, Bag digester and Plug flow digester*

5.2 ANAEROBIC FILTER

This type of digester was developed in the 1950's to use relatively dilute and soluble waste water with low level of suspended solids. It is one of the earliest and simplest type of design developed to reduce the reactor volume. It consists of a column filled with a packing medium. A great variety of non-biodegradable materials have been used as packing media for anaerobic filter reactors such as stones, plastic, coral, mussel shells, reeds, and bamboo rings. The methane forming bacteria form a film on the large surface of the packing medium and are not carried out of the digester with the effluent. For this reason, these reactors are also known as "fixed film" or "retained film" digesters (Bioenergy Systems Report, 1984).

5.3 BIOGAS AND SOME TECHNICAL CONSIDERATIONS

5.3.1 Gas Production potential of various types of dung

Any biodegradable organic material can be used as inputs for processing inside the biodigester. However, for economic and technical reasons, some materials are more preferred as inputs than others. If the inputs are costly or have to be purchased, then the economic benefits of outputs such as gas and slurry will become low. Also, if easily available biodegradable wastes are used as inputs, then the benefits **could** be of two folds:

- Economic value of biogas and its slurry; and

• Environmental cost avoided in dealing with the biodegradable waste in some other ways such as disposal in landfill.

One of the main attractions of biogas technology is its ability to generate biogas out of organic wastes that are abundant and freely available. The cattle dung that is most commonly used as an input mainly because of its availability. The potential gas production from some animal dung is given in Table 5.2.

Table 5.2

Gas Production potential of various types of dung

Types of Dung	**Gas Production Per Kg Dung (m3)**
Cattle (cows and buffaloes)	0.023 - 0.040
Pig	0.040 - 0.059
Poultry (Chickens)	0.065-0.116
Human	0.020 - 0.028

Source: Guidebook on Biogas Development, 1994

In addition to the animal and human wastes, plant materials can also be used to produce biogas and bio-manure. For example, one kg of pre-treated crop waste and water hyacinth have the potential of producing 0.037 and 0.045 m3 of biogas, respectively. Since different organic materials have different bio-chemical characteristics, their potential for gas production also varies. Two or more of such materials can be used together provided that some basic requirements for gas production or for normal growth of methanogens are met. Some characteristics of these inputs which have significant **impact on the** level of gas production are described below.

5.3.2 C/N Ratio of Organic Materials

The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen (C/N) ratio. A C/N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion. If the C/N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over carbon content of the material. As a result, gas production will be low. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia (NH4). NH4 will increase the pH value of the content in the digester. A pH higher than 8.5 will start showing toxic effect on methanogen population.

Animal waste, particularly cattle dung, has an average C/N ratio of about 24. The plant materials such as straw and sawdust contain a higher percentage of carbon. The human excreta has a C/N ratio as low as 8. C/N ratio of some of the commonly used materials are presented in Table 5.3.

Materials with high C/N ratio could be mixed with those of low C/N ratio to bring the average ratio of the composite input to a desirable level. In China, as a means to balance C/N ratio, it is customary to load rice straw at the bottom of the digester upon which latrine waste is discharged.

5.3.3 Dilution and consistency of Raw Materials

Raw materials may be obtained from a variety of sources - livestock and poultry wastes, night soil, crop residues, food-processing and paper wastes, and materials such as aquatic weeds, water hyacinth, filamentous algae, and seawood different problems are encountered with each of these wastes with regard to collection, transportation, processing, storage, residue utilization, and ultimate use. Residues from the agricultural sector such as spent straw, hay, cane trash, corn and plant stubble, and bagasse need to be shredded in order to facilitate their flow into the digester reactor as well as to increase the efficiency of bacterial action. Succulent plant material yields more gas than dried matter does, and hence materials like brush and weeds need semi-drying. The storage of raw materials in a damp, confined space for over ten days initiates anaerobic bacterial action that, though causing some gas loss, reduces the time for the digester to become operational.

Before feeding the digester, the excreta, especially fresh cattle dung, has to be mixed with water at the ratio of 1:1 on a unit volume basis (i.e. same volume of water for a given volume of dung). However, if the dung is in dry form, the quantity of water has to be increased accordingly to arrive at the desired consistency of the inputs (e.g. ratio could vary from 1:1.25 to even 1:2). The dilution should be made to maintain the total solids from 7 to 10 percent. If the dung is too diluted, the solid particles will settle down into the digester and if it is too thick, the particles impede the flow of gas formed at the lower part of digester. In both cases, gas production will be less than optimum. A survey made by BSP reveals that the farmers often over dilute the slurry.

For thorough mixing of the cow dung and water (slurry), GGC has devised a Slurry Mixture Machine that can be fitted in the inlet of a digester. It is also necessary to remove inert materials such as stones from the inlet before feeding the slurry into the digester. Otherwise, the effective volume of the digester will decrease.

5.3.4 Volatile solids

Production of biogas is inefficient if fermentation materials are too dilute or too concerted, resulting in, low biogas production and insufficient fermentation activity, respectively. Experience has shown that the raw-material (domestic and poultry wastes and manure)ratio to water should be 1:1, i.e., 100 kg of excrete to 100 kg of water. In the slurry, this corresponds to a total solids concentration of 8-11 per cent by weight. (S. N. Ghosh: 1977)

The weight of organic solids burned off when heated to about 538 degrees C is defined as volatile solids. The biogas production potential of different organic materials, given in Table 5.2, can also be calculated on the basis of their volatile solid content. The higher the volatile solid content in a unit volume of fresh dung, the higher the gas production. For example, a kg of volatile solids in cow dung would yield about 0.25 m^3 biogas.

Table 5.3

C/N Ratio of some organic materials

Raw Materials	**C/N Ratio**
Duck dung	8
Human excreta	8
Chicken dung	10
Goat dung	12
Pig dung	**18**
Sheep dung	19
Cow dung/ Buffalo dung	24
Water hyacinth	25
Elephant dung	43
Straw (maize)	60
Straw (rice)	70
Straw (wheat)	90
Saw dust	above 200

Source: Karki and Dixit, 1994

5.3.5 Digestion

Digestion refers to various reactions and interactions that take place among the methanogens, non-methanogens and substrates fed into the digester as inputs. This is a complex physio-chemical and biological process involving different factors and stages of change. This process of digestion (methanization) is summarized below in its simple form. The breaking down of inputs that are complex organic materials is achieved through three stages as described below:

Stage **1: Hydrolysis**

The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, proteins and inorganic materials. Large molecular complex substances are solubilized into simpler ones with the help of extracellular enzyme released by the bacteria. This stage is also known as polymer breakdown stage. For example, the cellulose consisting of polymerized glucose is broken down to dimeric, and then to monomeric sugar molecules (glucose) by cellulolytic bacteria.

Stage 2: Acidification

The monomer such as glucose which is produced in Stage 1 is fermented under anaerobic condition into various acids with the help of enzymes produced by the acid forming bacteria. At this stage, the acid-forming bacteria break down molecules of six atoms of carbon (glucose) into molecules of less atoms of carbon (acids) which are in a more reduced state than glucose. The principal acids produced in this process are acetic acid, propionic acid, butyric acid and ethanol.

Stage **3: Methanization**

The principle acids produced in Stage 2 are processed by methanogenic bacteria to produce methane. The reactions that takes place in the process of methane production is called Methanization and is expressed by the following equations (Karki and Dixit, 1984).

CH3COOH Acetic acid	-->	CH4 Methane	+	CO2 Carbon dioxide		
2CH3CH2OH Ethanol	+	CO2 Carbon dioxide	-->	CH4 Methane	+	2CH3COOH Acetic acid
CO2 Carbon dioxide	+	4H2 Hydrogen	-->	CH4 Methane	+	2H2O Water

The above equations show that many products, by-products and intermediate products are produced in the process of digestion of inputs in an anaerobic condition before the final product (methane) is produced. Obviously, there are many facilitating and inhibiting factors that play their role in the process. Some of these factors are discussed below.

5.3.6 **pH Value**

The low pH inhibits the growth of the methanogenic bacteria and gas generation and is often the result of overloading. A successful pH range for anaerobic digestion is 6.0 -8.0, efficient digestion occurs at pH near neutrality. The pH in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria are very sensitive to pH and do not thrive below a value of 6.5. Later, as the digestion process continues, concentration of NH4 increases due to digestion of nitrogen which can increase the pH value to above 8. When the methane production level is stabilized, the pH range remains buffered between 7.2 to 8.2.

5.3.7 **Temperature**

The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35° C. When the ambient temperature goes down to 10° C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25 degrees to 30 degrees C. Proper insulation of digester helps to increase gas production in the cold season. When the ambient temperature is 30 degrees C or less, the average temperature within the dome remains about 4 degrees C above the ambient temperature

5.3.8 Loading rate

The size of the digester depends upon the loading, which is determined by the influent solids content, retention time, and the digester temperature. Optimum loading rates vary with different digesters and their sites of location. Higher loading rates have been used when the ambient temperature is high. In general, the literature is filled with a filled with a variety of conflicting loading rates. In practice, the loading rates should be an expression of either:

(a) The weight of Total Volatile Solids (TVS) added per day per unit volume of the digester, or
(b) The weight of TVS added per day per unit weight of TVS in the digester.

Loading rate is the amount of raw materials fed per unit volume of digester capacity per day. In Nepalese conditions, about 6 kg of dung per m3 volume of digester is recommended in case of a cow dung plant (BSP, 1992). If the plant is overfed, acids will accumulate and methane production will be inhibited. Similarly, if the plant is underfed, the gas production will also be low.

Retention time: Retention time (also known as detention time) is **the** average period that **a** given quantity of input remains in the digester to be acted upon by the methanogens. In a cow dung plant, the retention time is calculated by dividing the total **volume** of the digester by the volume of inputs added daily. Other factors such as **temperature,** dilution, loading rate, etc., influence retention time. At high temperature **bio-digestion** occurs faster, reducing the time requirement. A normal period for the digestion of dung would be tow to four weeks.

Toxicity: Waste and biodegradable residues are often accompanied by a variety of pollutants that could inhibit anaerobic digestion. Potential toxicity due to ammonia can be corrected by remedying the C/N ratio of manure through the addition of shredded bagasse or straw, or by dilution. Common toxic substances are the soluble salts of copper, zink, nickel, mercury, and chromium. On the other hand, salts of sodium, potassium, calcium, and magnesium may be stimulatory or toxic in action, both manifestations being associated with the cation rather than the anionic portion of the salt. Pesticides and synthetic detergents may also be troublesome to the process.

Mineral ions, heavy metals and the detergents are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of mineral ions (e.g. sodium, potassium, calcium, magnesium, ammonium and sulphur) also stimulates the growth of bacteria, while very heavy concentration of these ions will have toxic effect. For example, presence of NH4 from 50 to 200 mg/1 stimulates the growth of microbes, whereas its concentration above 1,500 mg/1 produces toxicity. Similarly, heavy metals such as copper, nickel, chromium, zinc, lead, etc. in small quantities are essential for the growth of bacteria but their higher concentration has toxic effects. Likewise, detergents including soap, antibiotics, organic solvents, etc. inhibit the activities of methane producing bacteria and addition of these substances in the digester should be avoided. Although there is a long list of the substances that produce toxicity on bacterial growth, the inhibiting levels of some of the major ones are given in Table 5.4.

Slurry: This is the residue of inputs that comes out from the outlet after the substrate is acted upon by the methonogenic bacteria in an anaerobic condition inside the digester. After extraction of biogas (energy), the slurry (also known as effluent) comes out of digester as by-product of the anaerobic digestion system. It is an almost pathogen-free stabilized manure that can be used to maintain soil fertility and enhance crop production. Slurry is found in different forms inside the digester as mentioned below:

- a light rather solid fraction, mainly fibrous material, which float on the top forming the scum;
- a very liquid and watery fraction remaining in the middle layer of the digester; - a viscous fraction below which is the real slurry or sludge; and
- heavy solids, mainly sand and soils that deposit at the bottom.

There is less separation in the slurry if the feed materials are homogenous. Appropriate ratio of urine, water and excrement and intensive mixing before feeding the digester leads to homogeneous slurry.

Use of biogas: Of the outputs of biogas, the gas is valued for its use as a source of energy and the slurry for its fertilizing properties (soil nutrients). Energy content of biogas can also be transformed into various other forms such as mechanical energy (for running machines) and heat energy (for cooking and lighting) depending on the need and availability of the technology. Some of the common uses of biogas are : cooking, lighting, refrigeration and running internal combustion engine.

5.4 METHANE (BIOGAS) FROM ANAEROBIC DIGESTERS

Methane is a gas that contains molecules of methane with one atom of carbon and four atoms of hydrogen (CH_4). It is the major component of the "natural" gas used in many homes for cooking and heating. It is odorless, colorless, and yields about 1,000 British Thermal Units (Btu) [252 kilocalories (kcal)] of heat energy per cubic foot (0.028 cubic meters) when burned. Natural gas is a fossil fuel that was created eons ago by the anaerobic decomposition of organic materials. It is often found in association with oil and coal.

The same types of anaerobic bacteria that produced natural gas also produce methane today. Anaerobic bacteria are some of the oldest forms of life on earth. They evolved before the photosynthesis of green plants released large quantities of oxygen into the atmosphere. Anaerobic bacteria break down or "digest" organic material in the absence of oxygen and produce "biogas" as a waste product. (Aerobic decomposition, or composting, requires large amounts of oxygen and produces heat).

Table 5.4

Toxic level of various inhibitors

Inhibitors	Inhibiting Concentration
Sulphate (SO_4^{--})	5,000 ppm
Sodium Chloride or Common salt (NaCl)	40,000 ppm
Nitrate (Calculated as N)	0.05 mg/ml
Copper (Cu^{++})	100 mg/1
Chromium (Cr^{+++})	200 mg/1
Nickel (Ni^{+++})	200 - 500 mg/1
Sodium (Na^{+})	3,500 - 5,500 mg/1
Potassium (K^{+})	2,500 - 4,500 mg/1
Calcium (Ca^{++})	2,500 - 4,500 mg/l
Magnesium (Mg^{++})	1,000 -1,500 mg/1
Manganese (Mn^{++})	Above 1,500 mg/l

Source; The Biogas Technology in China, BRTC, China (1999)

Anaerobic decomposition occurs naturally in swamps, water-logged soils and rice fields, deep bodies of water, and in the digestive systems of termites and large animals. Anaerobic processes can be managed in a "digester" (an airtight tank) or a covered lagoon (a pond used to store manure) for waste treatment. The primary benefits of anaerobic digestion are nutrient recycling, waste treatment, and odor control. Except in very large systems, biogas production is a highly useful but secondary benefit.

Biogas produced in anaerobic digesters consists of methane (50%-80%), carbon dioxide (20%-50%), and trace levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen, and hydrogen sulfide. The relative percentage of these gases in biogas depends on the feed material and management of the process. When burned, a cubic foot (0.028 cubic meters) of biogas yields about 10 Btu (2.52 kcal) of heat energy per percentage of methane composition. For example, biogas composed of 65% methane yields 650 Btu per cubic foot (5,857 kcal/cubic meter).

5.4.1 Digester Designs

Anaerobic digesters are made out of concrete, steel, brick, or plastic. They are shaped like silos, troughs, basins or ponds, and may be placed underground or on the surface. All designs incorporate the same basic components: a pre-mixing area or tank, a digester vessel(s), a system for using the biogas, and a system for distributing or spreading the effluent (the remaining digested material).

There are two basic types of digesters: batch and continuous. Batch-type digesters are the simplest to build. Their operation consists of loading the digester with organic materials and allowing it to digest. The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated.

In a continuous digester, organic material is constantly or regularly fed into the digester. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material. Unlike batch-type digesters, continuous digesters produce biogas without the interruption of loading material and unloading effluent. They may be better suited for large-scale operations. There are three types of continuous digesters: vertical tank systems, horizontal tank or plug-flow systems, and multiple tank systems. Proper design, operation, and maintenance of continuous digesters produce a steady and predictable supply of usable biogas.

Many livestock operations store the manure they produce in waste lagoons, or ponds. A growing number of these operations are placing floating covers on their lagoons to capture the biogas. They use it to run an engine/generator to produce electricity.

5.4.2 The Digestion Process

Anaerobic decomposition is a complex process. It occurs in three basic stages as the result of the activity of a variety of microorganisms. Initially, a group of microorganisms converts organic material to a form that a second group of organisms utilizes to form organic acids. Methane-producing (methanogenic) anaerobic bacteria utilize these acids and complete the decomposition process.

A variety of factors affect the rate of digestion and biogas production. The most important is temperature. Anaerobic bacteria communities can endure temperatures ranging from below freezing to above 135° Fahrenheit (F) (57.2° Centigrade [C]), but they thrive best at temperatures of about 98°F (36.7°C) (mesophilic) and 130° F (54.4°C) (thermophilic). Bacteria activity, and thus biogas production, falls off significantly between about 103° and 125°F (39.4° and 51.7°C) and gradually from 95° to 32°F (35° to 0° C).

In the thermophilic range, decomposition and biogas production occur more rapidly than in the mesophilic range. However, the process is highly sensitive to disturbances such as changes in feed materials or temperature. While all anaerobic digesters reduce the viability of weed seeds and disease-producing (pathogenic) organisms, the higher temperatures of thermophilic digestion result in more complete destruction. Although digesters operated in the mesophilic range must be larger (to accommodate a longer period of decomposition within the tank [residence time]), the process is less sensitive to upset or change in operating regimen.

To optimize the digestion process, the digester must be kept at a consistent temperature, as rapid changes will upset bacterial activity. In most areas of the United States, digestion vessels require some level of insulation and/or heating. Some installations circulate the coolant from their biogas-powered engines in or around the digester to keep it warm, while others burn part of the biogas to heat the digester. In a properly designed system, heating generally results in an increase in biogas production during colder periods. The trade-offs in maintaining optimum digester temperatures to maximize gas production while minimizing expenses are somewhat complex. Studies on digesters in the north-central areas of the country indicate that maximum net biogas production can occur in digesters maintained at temperatures as low as 72°F (22.2°C).

Other factors affect the rate and amount of biogas output. These include pH, water/solids ratio, carbon/nitrogen ratio, mixing of the digesting material, the particle size of the material being digested, and retention time. Pre-sizing and mixing of the feed material for a uniform consistency allows the bacteria to work more quickly. The pH is self-regulating in most cases. Bicarbonate of soda can be added to maintain a consistent pH, for example when too much "green" or material high in nitrogen content is added. It may be necessary to add water to the feed material if it is too dry, or if the nitrogen content is very high. A carbon/nitrogen ratio of 20/1 to 30/1 is best. Occasional mixing or agitation of the digesting material can aid the digestion process. Antibiotics in livestock feed have been known to kill the anaerobic bacteria in digesters. Complete digestion, and retention times, depend on all of the above factors.

5.4.3 Producing and Using Biogas

As long as proper conditions are present, anaerobic bacteria will continuously produce biogas. Minor fluctuations may occur that reflect the loading routine. Biogas can be used for heating, cooking, and to operate an internal combustion engine for mechanical and electric power. For engine applications, it may be advisable to scrub out hydrogen sulfide (a highly corrosive and toxic gas). Very large-scale systems/producers may be able to sell the gas to natural gas companies, but this may require scrubbing out the carbon dioxide.

5.4.4 **Using the Effluent**

The material drawn from the digester is called sludge, or effluent. It is rich in nutrients (ammonia, phosphorus, potassium, and more than a dozen trace elements) and is an excellent soil conditioner. It can also be used as a livestock feed additive when dried. Any toxic compounds (pesticides, etc.) that are in the digester feedstock material may become concentrated in the effluent. Therefore, it is important to lest the effluent before using it on a large scale.

5.4.5 Economics

Anaerobic digester system costs vary widely. Systems can be put together using off-the-shelf materials. There are also a few companies that build system components. Sophisticated systems have been designed by professionals whose major focus is research, not low cost. Factors to consider when building a digester are cost, size, the local climate, and the availability and type of organic feedstock material.

In the India, the availability of inexpensive fossil fuels has limited the use of digesters solely for biogas production. However, the waste treatment and odor reduction benefits of controlled anaerobic digestion are receiving increasing interest, especially for large-scale livestock operations such as dairies, feedlots, and slaughterhouses. Where costs are high for sewage, agricultural, or animal waste disposal, and the effluent has economic value, anaerobic digestion and biogas production can reduce overall operating costs. Biogas production for generating cost effective electricity requires manure from more than 150 large animals.

5.5 FACTORS THAT INFLUENCE THE SELECTION OF A PARTICULAR DESIGN OR MODEL OF A BIOGAS PLANTS

This section mainly concentrates on the Economic factors, Simple design, Utilization of local materials, Durability, suitability types of inputs and their frequency of using are discussed.

5.5.1 Economic Factors

An ideal plant should be as low-cost as possible (in terms of the production cost per unit volume of biogas) both to the user as well as to the society. At present, with subsidy, the cost of a plant to the society is higher than to an individual user.

5.5.2 Simple design

The design should be simple not only for construction but also for operation and maintenance (O&M). This is an important consideration especially in a country like Nepal where the rate of literacy is low and the availability of skilled human resource is scarce.

5.5.3 Utilization of local materials

Use of easily available local materials should be emphasized in the construction of a biogas plant. This is an important consideration, particularly in the context of Nepal where transportation system is not yet adequately developed.

.5.5.4 Durability

Construction of a biogas plant requires certain degree of specialized skill which may not be easily available. A plant of short life could also be cost effective but such a plant may not be reconstructed once its useful life ends. Especially in situation where people are yet to be motivated for the adoption of this technology and the necessary skill and materials are not readily available, it is necessary to construct plants that are more durable although this may require a higher initial investment.

5.5.5 Suitable for the type of inputs

The design should be compatible with the type of inputs that would be used. If plant materials such as rice straw, maize straw or similar agricultural wastes are to be used, then the batch feeding design or discontinuous system should be used instead of a design for continuous or semi-continuous feeding.

5.5.6 Frequency of using inputs and outputs

Selection of a particular design and size of its various components also depend on how frequently the user can feed the system and utilize the gas.

5.6 CONSTRUCTION OF A BIOGAS PLANT

The Construction of a biogas system requires the services of a project designer experienced with these systems. Designing involves selecting a location; calculating the size of the digesters and the gas holder; and determining the labor, materials, and tools needed for construction. The products of the design process are:

- a location map,
- design drawings of the system, and
- a detailed materials list.

These products will be given to the construction foreman prior to construction. This technical note describes how to design a biogas system.

5.6.1 Materials Needed

Measuring tape - To obtain accurate field Information for a location map.

Ruler - To produce a location map.

General requirements

A biogas system requires a constant and large supply of manure. A system serving one family needs the daily manure production of either lo-15 pigs, two or three horses, or two cows.

All components of a biogas system must be gas-tight. Gas leaks are dangerous because certain mixtures of methane gas and air are explosive. Therefore, the design, construction, and operation of these systems should be undertaken only by experienced or carefully trained personnel. There are a number of types of biogas systems. One design requires at least two digesters to ensure continuous gas production. While one digester is producing gas, the other can be emptied of digested material and reloaded with fresh manure and water.

Some components of the system may be built but some must be purchased. The digesters and the floor and walls of the gas holder are generally made from reinforced concrete and usually are built on the site. However, the gas holder is typically circular and requires special construction skills to build. Components which must be purchased include the metal cover for the gas holder, guide wheels, guide posts, gas pipes, valves, petcocks, and fixtures used to burn the gas. These items make a biogas system relatively costly.

The gas holder and digesters are designed to be Installed partially underground. This is done for ease of loading and maintenance, while allowing a portion of the system to be exposed to sunlight. In temperate climates, this kind of installation helps keep the temperature in the digester more uniform.

5.6.2 Selecting a location

The system should be located:

- Alongside the stable, pig sty, or other manure source to avoid excessive handling of manure,
- Near the dwelling to minimize the amount of gas piping,
- In an unshaded area to make use of the maximum available heat from the sun.

When a location has been selected, draw a location map similar to Figure 5.1 and give It to the construction foreman.

5.6.3 Calculating Size

The size of the system depends on the desired volume of daily gas production. The volume of the gas holder should equal one day's gas production, with a minimum size of $2m^3$. Table 1 provides approximate quantities of gas required for some domestic activities.

When the dimensions of the digesters have been determined, prepare a design drawing similar to Figure: 5.3 and give it to the construction foreman.

The digesters and the gas holder, not including the cover, are made from reinforced concrete. The thickness of the concrete is summarized in Table 5.5. Add this information to Figures 5.2 and 5.3.

5.6.4 Determining Labor, Materials, and Tools

The primary labor requirement is a construction foreman familiar with these systems. An experienced pipe fitter is needed to install the gas pipes. At least one worker should have some experience with reinforced concrete. Unskilled labor can be used for making excavations, mixing concrete, and hauling materials.

The floating cover for the gasholder is made from sheet iron 2-3m thick, reinforced with angle iron or cross-braces. Because of its strict design specifications, it must be purchased unless an exceptionally skilled sheet metal worker can be found.

Table 5.5

Concrete Thick nesses

Feature	Thickness
Digester:	
Walls	175 mm
Floor '	175 mm
Top	150 mm
Gas Holder:	
Walls	150 mm
Floor	250 mm

Gas pipes are 12-25 mm in diameter and are made from copper or galvanized iron. Valves and petcocks are placed at key control points along the gas lines. To determine the amount of pipe needed, and the number of valves, petcocks, and pipe-fittings, prepare a drawing similar to Figure 4 showing the layout of the system.

Fixtures are needed to burn the methane gas. These are generally purchased. Materials for reinforced concrete include cement, sand, gravel, water, reinforcing material, and materials to build forms.

Tools needed include picks and shovels for excavation; hammer and saw for building forms; trowel for working concrete; wrenches, hacksaw, and threading tool for installing gas pipes, and a device for checking leaks.

In summary, give the construction foreman a location map in Figure 5.1, design drawing in Figure 5.2 and 5.3, a system layout in Figure5.4, and a materials list in Table 5.3. are shown below.

Fig: 5.1

Location Map

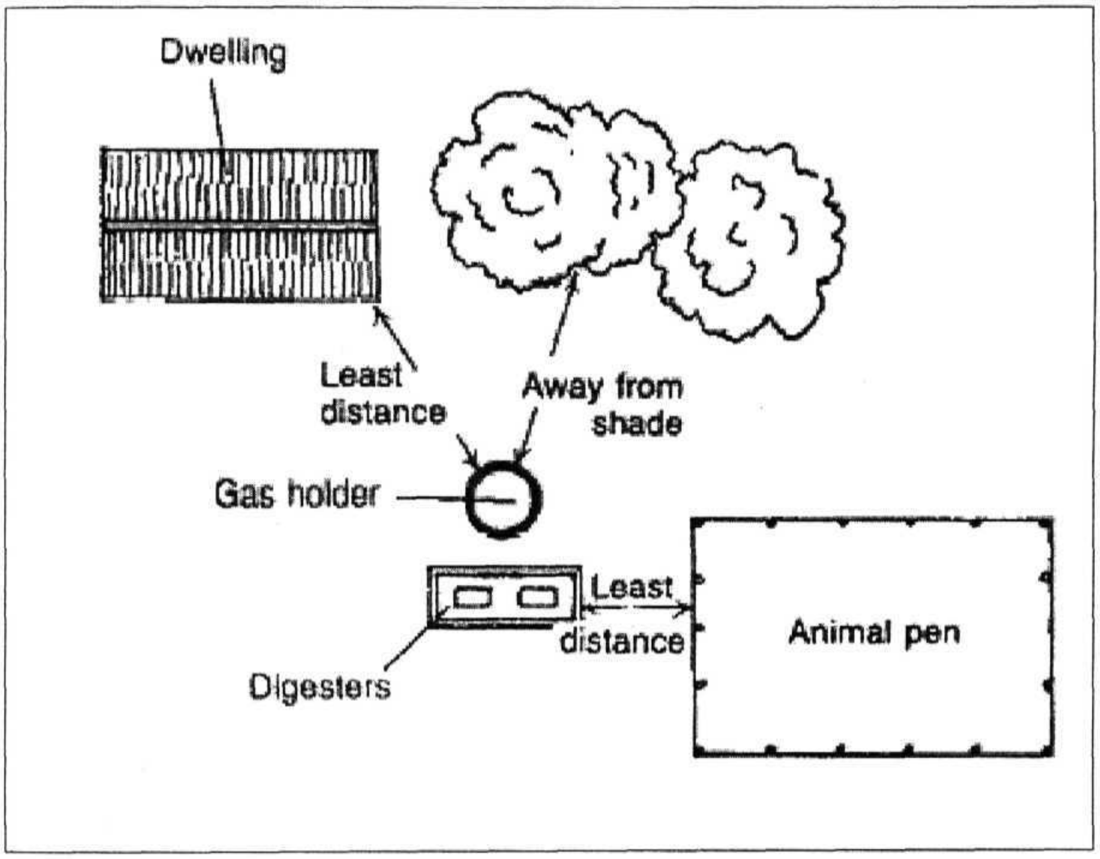


Fig: 5.2

Design of Gas Holder

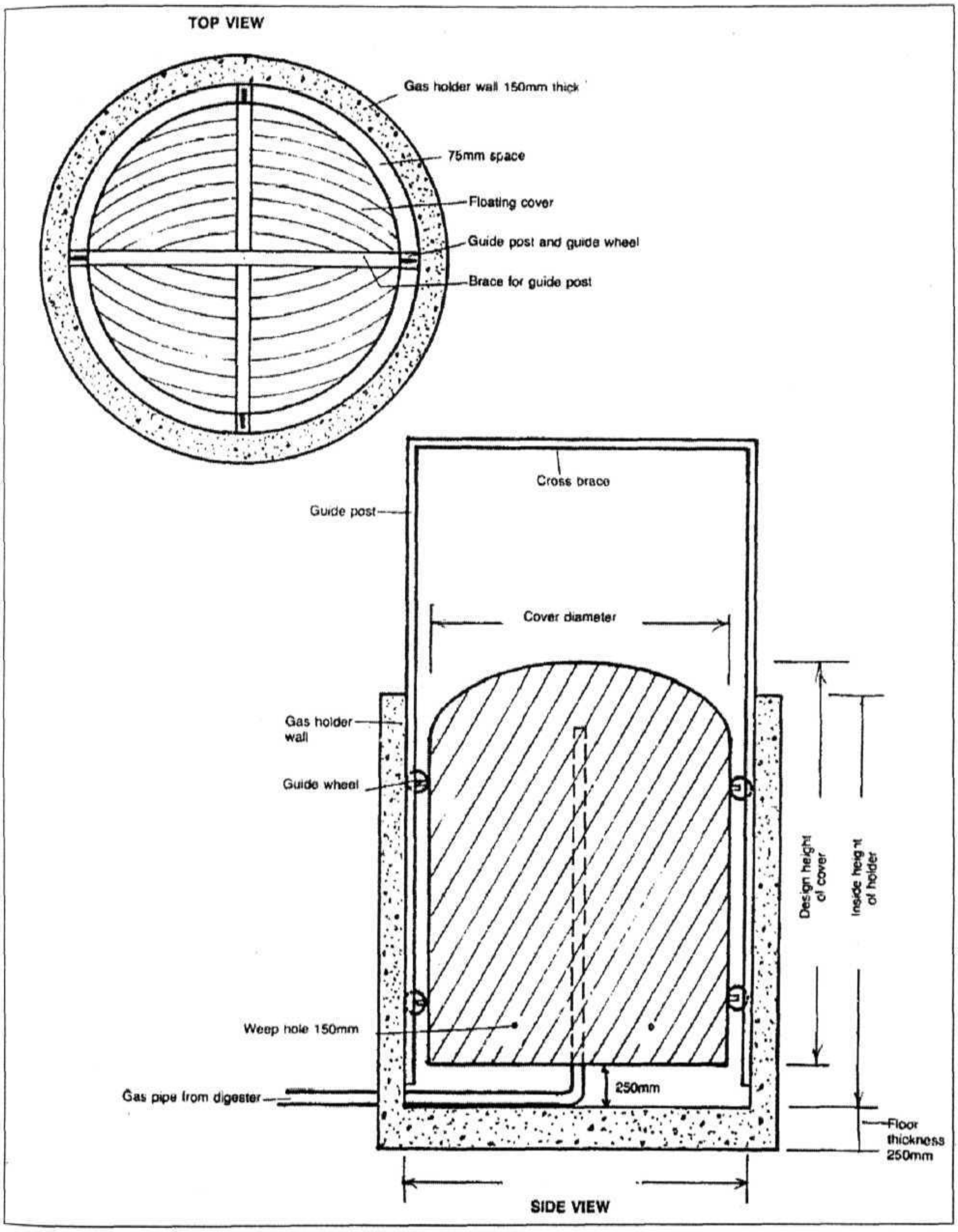


Fig: 5.3

Design of Digesters

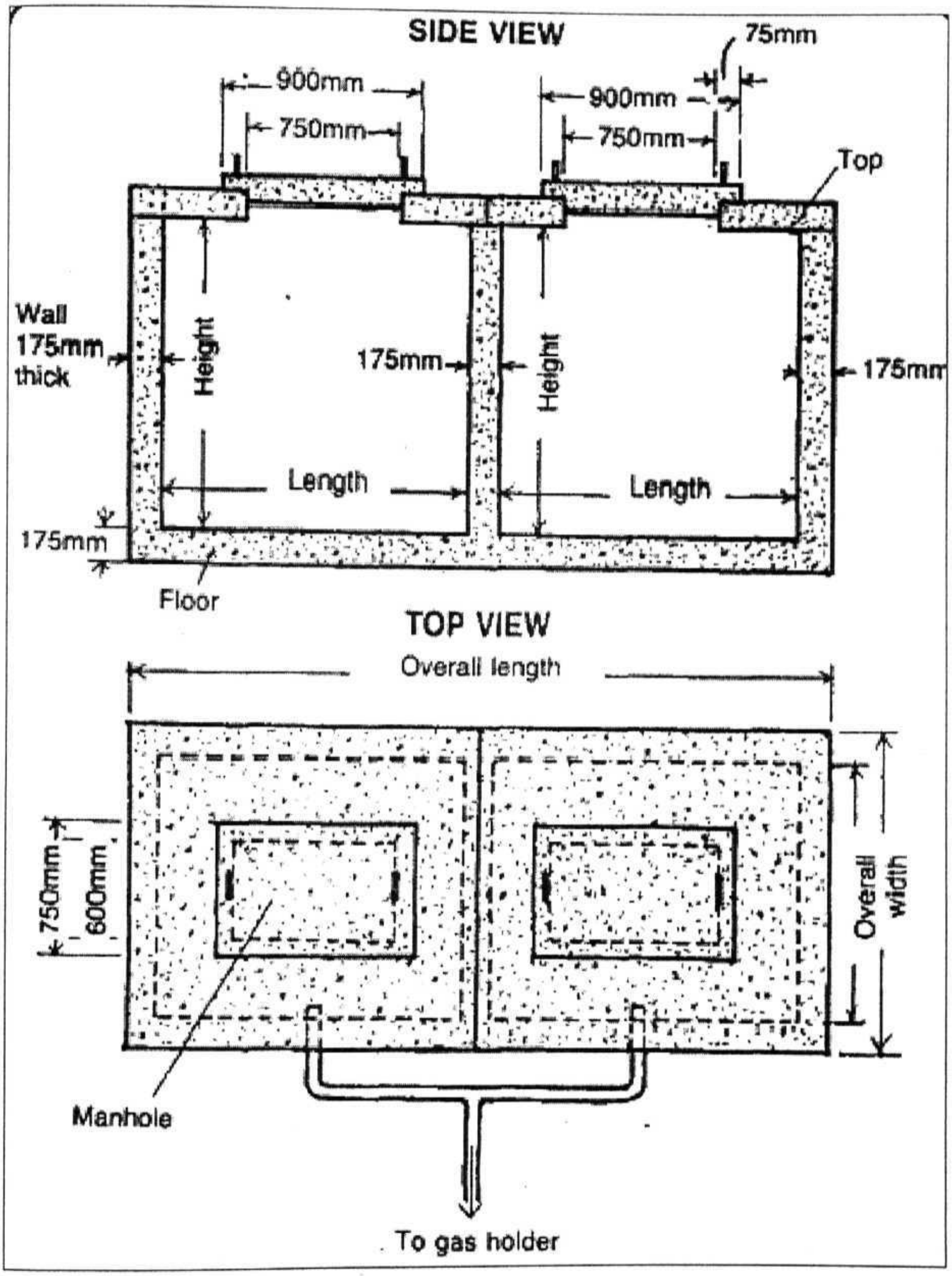
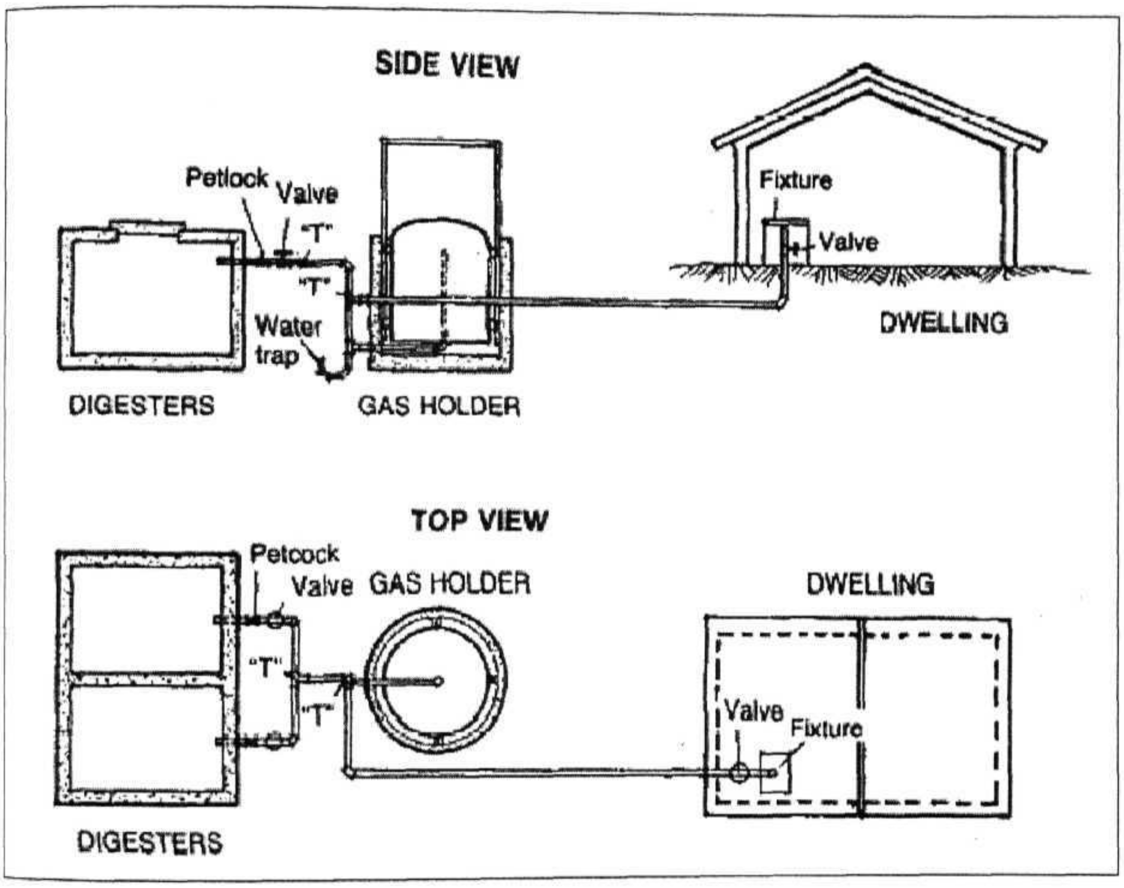


Fig: 5.4

Typical Gas Pipe Arrangement



5.7 CONCLUSION

Biogas production is limited by environmental conditions such as the need for warm temperatures and availability of water and dung. In cooler or drought-prone regions, or in villages with insufficient cattle, projects have failed. These and other problems relating to construction and maintenance have been compounded by institutional factors that obstruct most renewable energy projects. As an essentially decentralized energy strategy, biogas has suffered from a far too centralized and top-down planning approach. Across-the-board implementation policies have led to the construction of plants in areas unsuited to biogas production; plants that suffered from technical difficulties were abandoned when project technicians failed to follow up. And although the government introduced many financial incentives such as subsidies and tax benefits to encourage biogas use, conventional fuels like diesel, kerosene and LPG are also highly subsidized in rural areas, so there is little incentive to make the switch.

The goal of India's biogas program is to construct digesters for the 12 million rural Indian households that have enough cattle to maintain a regular supply of dung. Depending on family size, this would mean a regular supply of fuel for 60 to 85 million people. In a largely agrarian nation where rural electrification is limited and commercial fuels make up only 11 percent of rural energy use, biogas could go a long way toward improving the energy and environmental future. And given the broad availability of dung, crop residues, and other organic wastes, biogas could do the same elsewhere. Along with other renewable technologies like photovoltaics, biogas could help form the foundations of a decentralized energy strategy in many developing countries.

Chapter-VI

BIOGAS: A SUSTAINABLE RURAL ENERGY ALTERNATIVE

6.0 INTRODUCTION

Energy is a primary input in the production of goods and services. The role of energy in contributing towards human welfare has increased in stature along with industrialization and the organized development of service sector or modern society. The far reaching changes in the form of energy and their respective shares in supporting human activities. Various attempts have been made since early 1980s and it also incorporate in energy planning activities. 'In the Energy Crisis' perception of the 1970s, the negative effects on the rural subsistence economy, deforestation effects and impressive 'National Fuel Gaps' between supply and demand predominated. Remedies for the rural fuel wood problems were thought to be relative simple: biogas production from different kinds of wastes, more tress in the form of every plantation, better stoves for rural families, tapping of energy stored in wind, water and solar energy conversion for heating are widely being studied.

Biogas is a cheap source of energy because it is manufactured from natural products Œ animal dung and human waste. In developing countries, such as China, India and Nepal, biogas is used widely as a source of energy. A biogas digester offers many benefits: it provides a good form of sanitation, it generates a useful fuel product and it produces a regular supply of nitrogen-enriched fertiliser for the garden.

6.1 ROLE OF ENERGY IN SUSTAINABLE RURAL DEVELOPMENT

The term "Sustainable Development" has comes to indicate a process by which development occurs without harmful side effects to the environment.

"Development that meets the needs of the present without compromising the ability of future generations to meet their own ***needs." (Bruntland*** *Definition: 1987)*

A definition from which it is possible to infer two quite different meanings:

- *That the stock of natural capital in particular must be left intact for the next generation.* In other words, the depletion of non-renewable resources must stop so that natural capital in particular is not further depleted. In policy terms this would mean putting a stop to all activities which exploited a non-renewable resource e.g, mining, activities which depleted the ozone layer, activities which affected future generations - for instance, the production of radio-active waste.

- *That the aggregate stock of manufactured and natural capital must not decline between one generation and the next.* In other words, there can be trade-offs between man-made and natural capital; the depletion of natural capital is justified so long as there is investment in a natural or manufactured alternative and the aggregate stock is retained. In policy terms this means the oil stock can be depleted so long as it is replaced by investment in another asset which allows future generations the same quality of life and choice, for example, as was supplied by oil to the present one. But this interpretation is also problematic:

*"Sustainable Development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable **development** (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable. ("* **FAO: 1989)**

Sustainable development involves more than growth. It requires a change in the content of growth to make it less material- and energy intensive and more equitable in its impact. These changes are required in all countries as part of a package of measures to maintain the stock of ecological capital, to improve the distribution of income, and to reduce the degree of vulnerability to economic crises.

6.1.1 The Economists' view on Sustainable Rural Development

Sustainable Development is important to distinguish it from other related concepts - those of economic growth, sustainable economic growth, and economic development.

Economic growth: an increase over time in the level of real Gross National Product (GNP) per capita. This does not mean that the growth observed at any one point in time is "sustainable" however.

Sustainable economic growth: when real GNP increases over time and the increase is not threatened by feedback from biophysical impacts (pollution, resource problems) or from social impacts (social disruption). This is a fairly narrow view, which implies that as long as economic growth is not hindered by environmental factors and as long as GNP is increasing then this is acceptable.

Economic development: a wider concept than the above. "Development" incorporates notions of:

- An increase in peoples' quality of life, particularly the poorest. Increasing incomes would be a major factor here;
- Advances in skills and knowledge, capability and choice;
- Advance in civil rights and freedoms, e.g. independence from domination, rights to political representation.

This definition, however, does not include ideas about environmental sustainability. **Environmental economists** have brought to the attention of conventional economists ideas about defining growth in different ways, incorporating the value of environmental assets and the importance of maintaining essential ecological services and natural capital. The following definitions are fairly representative of those now put forward by environmental economists:

"Sustainable economic development involves maximising the net benefits of economic development, subject to maintaining the services and quality of natural resources over time." *(Pearce et al., 1987)*

"Sustainable economic development ... refers to the optimal level of interaction between three systems - the biological, the economic and the social - through a dynamic and adaptive process of trade-offs". *(E.* ***Barbier, 1989)***

6.1.2 Sustainability and Rural Development

In order to gain additional insights into the relationship between energy consumption and social conditions in general, and particularly the situation of women, we asked a number of leading specialists around the world are concentrated mainly on the following aspects:

- The level of energy use necessary for meeting basic human needs and achieving sustainable human development;
- How the lack of energy, and its inefficient use, constitute obstacles to improve living standards; and
- How such obstacles can be removed, either by improving the efficiency of energy use or by using new, environmentally benign sources of energy,

Carlos Suárez, along the lines of the classical work conducted at the *Bariloche Foundation* more than twenty years ago on the Latin American World Model, plots the Human Development Index (HDI), as a function of commercial energy consumption with results rather similar to the ones.

Srilatha Batliwala and Daniel Kammen review, in their respective papers, the costs of obtaining energy services in rural areas, and highlight the fact that the poor pay a much higher price for the energy they need than any other sector of society since energy is used very inefficiently. In *Batliwala's words:* "In the face of inadequate inanimate energy and a lack of access to efficient technologies of energy use, the poor are forced to depend on their own labour, on animal power, and biomass energy resources, to meet their survival needs."

In developing countries the situation is completely different. Biomass plays a major role as a non-commercial fuel in the residential sector and is widely used as a commercial fuel in other sectors, whereas the use of modern forms of energy is still limited. It is estimated that, by 1980, 14% of global energy and 35% of energy used in developing countries was derived from biomass. Since 1980 the total amount ob biofuels have not been widely substituted for oil **(M.M. Gowen; 1989)**

In addition to the low levels of energy consumption, there may be other reasons why the issue of sustainable energy use is less articulated in developing countries:

- Their interest in the concept of sustainable development in general is much less then in the industrialized world.
- Countervailing powers in the form of non-governmental organizations have little democratic access to power.
- Technologies tend to follow their own dynamics.

6.2 ROLE OF RURAL ENERGY IN SUSTAINABLE RURAL DEVELOPMENT

Rural energy development on the one hand has effectively increased energy supply in rural areas tlirough development of new or renewable energy resources, and on the other hand has helped to meet the goal of energy saving by introducing related techniques. At the same time, the development and utilization of new or renewable energy resources in rural areas have facilitated the use of high quality energy.

6.2.1 Promoting rural economic development and social progress

Close integration of rural energy development with production and poverty eradication has strongly supported the implementation of "three-high" (high yield, high efficiency and high quality) agriculture project.

Now large scale development and use of new and renewable energy resources has made it possible to supply large quantity of clean and good-quality energy to farmers for cooking and bathing or for their electrical appliances. As a result, farmers' living standard has been improved.

6.2.2 Promoting sustainable agricultural development

Development of rural energy has not only made contribution to energy supply in rural areas but also played an irreplaceable role in ecological environment protection in rural areas. Due to the establishment of fuelwood plantations, afforestation campaigns and small watershed management, we have witnessed a rising forest coverage, better protected grass slopes and well controlled water and soil erosion. Great efforts to introduce energy saving techniques to farmers have resulted in reduced emission of pernicious gases like CO_2 and SO2, thus helping to protect rural ecological environment. By biogas use in rural areas and integrated use of agricultural wastes, we have greatly increased the application of highly efficient organic fertilizer, improved soil fertility and promoted sustainable agricultural development.

6.2.3 Future Outlook for Rural Energy Development

Along with rural economic development and the improvement of people's living standard, especially the mushrooming of rural and township enterprises, the demand by Rural India for large quantity of quality energy is rising. At the same time, the close integration of rural energy development with farm production and rural economic development has led to profound change in rural energy development, which plays an increasingly important role in agricultural development, rural economic development and the improvement of ecological environment and the life of farmers. It has not only become an important solution to the problems of energy shortage in rural areas but also served as a major means in promoting "three-high" agriculture, rural economic development, poverty alleviation and ecological environment improvement. To this end, it is necessary to make the following efforts for further rural energy development:

Careful planning to identify priorities: Rural India is faced with problems such as limited energy resources, low efficiency in utilization and serious waste. It is very important then to follow the principle of "emphasizing both development and conservation", pay attention to resource saving and integrated use, and cut improper use or consumption. Local governments are required to identify their priorities in the light of local conditions. Areas with great potentials in energy resources should be given top priority and those with less potentials should focus on better use of existing energy resources.

Better collaboration and integration of demonstration and extension: Rural energy development involves different sectors and industries. In order to promote the development of rural energy resources, all the relevant sectors should, under the unified leadership of the government, work in better collaboration and give full play to their own strong points under overall planning and proper division of work.

Multiple funding sources and more investment: Rural energy development should follow the principle of "users' investment as the main supplemented by state support" so as to give full play to initiatives of all sectors and mobilize financial resources from multiple channels.

Attracting foreign investment, technology and human resources and engaging in international cooperation: It is necessary to attract internationally advanced applicable technology and products related to rural energy development, such as biomass / biogas energy transformation technology, photo voltaic technology and wind energy technology, in order to help upgrade our rural energy development to a higher level and push forward the advancement of rural energy science and technology.

Promoting development of energy industry: We should correctly handle the relationship between rural energy enterprises and rural energy development under the principle of mutual promotion. The development of rural energy enterprises should meet the needs of rural energy development and follow the market economic mechanism in order to achieve economic benefits, which in turn serves to promote rural energy development as a whole.

6.2.4 The Need for Sustainable Rural Development in India

Today India, a country with more than a billion people, faces the challenge of achieving growth and development in a sustained manner. Economic growth and development call for huge capacity additions in the energy infrastructure of the country. The challenge is in achieving the developmental objectives without adversely impacting the environment, natural resources, wild life and climatic conditions. Presently, fossil fuels, mainly coal and oils are being used in the commercial sector while biomass is being used in an inefficient manner in domestic and rural sectors. However, limitations of fossil fuels are all too obvious. Coal reserves will last a little over 200 years and the oil reserves would have dried up much before that. There is a need for a shift in our national energy strategy. More compelling than the diminishing reserves are the environmental reasons. Today, development based on commercial fuels with current rates of pollution and deterioration in natural resource base is not sustainable. Threat from GHG (green house gas) has caused worldwide concern. Kyoto Protocol, agreed at the Conference of Parties to the Framework Convention to Climate Change, in December 1997, is an indicator of global resolve to address this concern. In India electric power generation is the largest source of GHG emissions and accounts for 48% of the carbon emitted. These concerns point towards more rational energy use strategies. Perhaps, renewable energy based technologies, functioning in a sustainable manner are the way forward.

In a country as vast as India, Renewable energy is seen as an effective **option** for ensuring access to modern energy services. Dwindling fossil fuels, the **impact** of **oil** imports on foreign exchange reserves and the national energy security **concerns are additional** stimulants for greater thrust on renewable energy.

Thus, the energy use, as practiced today, is indeed a serious obstacle to development and to the improvement of living standards. It is also clear that improved energy end-use efficiency and increased **use** of renewable sources of energy would go a **long** way **in** solving the energy problems of developing countries like India.

6.3 UNIDO'S APPROACH TO "RURAL ENERGY"

UNIDO aims to help its clients in developing countries to solve two fundamental problems by de-linking economic growth and increased use of energy and by reducing the environmental damage that occurs with expanded energy use. UNIDO's overall work on energy has two components:

- Development of technical cooperation projects and programmes and
- Carrying out global forum activities, including the preparation of studies and organizing international conferences to discuss the pertinent issues of the sector.

Technical cooperation projects and programs formulate energy policies aiming at reducing green house gases (GHG) and therefore climate change; increase energy efficiency on both the supply and demand side, and promote the application of renewable (alternative) energies.

In its resolution GS.9/Res.l, entitled "Medium-Term Programme Framework, 2002-2005, the General Conference emphasizes UNIDO's mandate in the area of energy for sustainable development and urges to devote particular attention to "giving special emphasis to initiatives, in coordination with other relevant actors and stakeholders, providing access to modern and efficient energy services for the poorest, with the goal of contributing to the international development targets" Within UNIDO's energy programme, major attention is focused on rural energy needs for development. UNIDO's competence and potential in this area has been recognized within the UN System and for the Third UN Conference on Least Developed Countries, LDC III, UNIDO was the Lead Agency for the Special Energy Session. As a result of LDC III, UNIDO is developing programmes that address the International Development Target to halve the number of people living in extreme poverty by 2015 with special emphasis on renewable energy for the poor.

The target groups for UNIDO's "Rural Energy Strategy" are those parts of the population of developing countries that are either too poor, or too isolated to attract private sector energy-related investments. UNIDO also addresses the "rural energy" issue in the countries with economies in transition. Some of those countries, UNIDO has already identified large areas of populated land that are not connected to any grid system. Recent examples of UNIDO projects designed for such areas are "Off-grid wind energy project" in Romania and "Rural geothermal heat and power project" in Tomsk Region of the Russian Federation.

In defining its target group and its approach to rural energy, UNIDO is in full agreement with the intergovernmental consensus that enhanced international cooperation is needed to bring energy services to those currently without access to modern energy. These un-served populations are not attracting private sector activity, since they do not constitute a market that can generate adequate return on investment. There is global consensus that international cooperation, strong national commitments and public funding are initially needed to build basic energy service delivery structures. UNIDO is committed to fashion its cooperation projects so as to facilitate the "take-over" by the private sector at the earliest possible stage of market development. UNIDO is of the view that once viable energy markets have emerged, international organizations should not falsify the private sector competition.

It is equally understood and has been demonstrated through programs on every continent that while the very poor cannot afford the up-front costs of energy-related installations - they are capable and willing to pay for energy services. UNIDO therefore makes a point of doing energy cooperation in such a way as to promote income generation and productive uses so that the poor can better afford the energy services they desire.

Through its rural energy projects and programmes UNIDO promotes the **productive (income generating) uses** of energy for rural development (industrialization) and poverty alleviation. In addition, UNIDO's energy programmes cover **capacity building** activities related to renewable energy technology and the assembly and manufacture of energy equipment and structures in developing countries.

UNIDO's energy programs would work with the **renewable sources of energy** (solar, mini-hydro, wind, biomass) most suitable to a given situation, taking into account the natural endowment of a region, the development priorities of the national government and the uitability of different energy sources for different applications. An interesting application ofPV solar energy to information and communication technologies (ICTs) for rural areas isdescribed below. A mini-hydro power plant is planned for rural areas with water resources in Mali. A biomass energy project has been designed in Tanzania to convert the harmful waste of sisal plant processors to biogas. In Indonesia, UNIDO implemented a micro-wind energy project aiming at local manufacture of an appropriate wind mill.

An important programme component is renewable powered information and communication technologies (ICTs) for rural areas. Power supply is a precondition for the operation ofICTs and is therefore not possible in areas without electricity. ICTs offer major opportunities for economic development and income generation in rural areas as well as many social benefits. These programmes based upon solar energy systems are particularly appropriate for Sub Saharan African countries and rural areas of many Asian countries.

6.4 BIOGAS: A SUSTAINABLE RURAL ENERGY

Biogas, a mixture containing 55-65 per cent of methane, 30-40 per cent of carbon-di-oxide and the rest being the impurities (H_2, H_2S and some N2), can be produced from the decomposition of animal, plant and human waste. "Like a lamp in a dark room, the use of gobar gas could bring brightness, necessary fuel and comfort to the rural masses. Cleanliness that is a part of the bargain also stands to improve the scene in the rural areas".

In view of the food crisis (energy crisis) and the environmental pollution, in recent years biogas technology has attracted wide attention. China and India are in the forefront of the development and promotion of the technology. Current Chinese Programmes for biogas development aim at intensifying the Research and Development programmes and streamlining the diffusion campaigns to insure proper communication between Research and Development Personnel and extension workers. Next to China India has the largest biogas development programmes. The Planning commission Working Group on Energy Policy stated enthusiastically, "Biogas plants constitute the most promising alternative energy technology in the household sector". The country's energy needs are large. Yet the gobar gas plant will meet at least the needs of rural India. This simple innovation could certainly eliminate indiscriminate felling of trees and shrubs in the country side for fuel and thus same the country from the consequent ecological hazards.

Biogas means social benefits for women and children. Women and children are the big winners in India where every year 200,000 families turn away from the traditional fireplace and have a biogas plant installed to provide energy for cooking and lighting. A smoke-free and as-free kitchen means women are no longer prone to lung and throat infections and can look forward to a longer life expectancy. In rural areas, where there is generally no electricity supply, the introduction of biogas has given women a sense of self-worth and time to engage in more activities outside the home. Dung is no longer stored in the home but is fed directly into the biogas plant, along with toilet waste. As a result, standards of hygiene have improved, and the vegetable patch has gained a top quality fertilizer that guarantees a better crop.

More than two million biogas plants have been built in India so far. Almost 200,000 permanent jobs have been created for the male bread-winners of Indian families. With a potential market for 30 plants attached to households with 3 cattle or more, the social and environmental advantages of biogas are only just being to be explored.

6.4.1 Role of Women in Biogas Programme

In the rural areas, women have traditionally shouldered the responsibility of managing the domestic energy requirements for managing the domestic energy requirements for their families. They thus have an intrinsic and symbiotic relationship with the surrounding natural resource system. Cooking fuels are derived predominantly from biomass resources like wood, crop residue and animal dung. In most parts of the country, these are collected from forests, wastelands and other community-owned lands, agricultural fallow, and homesteads. Children carry out firewood collection by women and occasionally.

Women **are** generally the ones that clean the cattle sheds i.e **manage the fresh manure. They** are further on the ones that collect the water and mix it with **dung to make the input to the** digester. Biogas technology have been introduced in India to supply an alternative domestic fuel for cooking, women normally do the cooking. This means that the operation and management of the biogas unit is a gendered issue.

Biogas units are normally described as being installed in a household. The decision to make larger investment, such as the case of investing in a biogas unit, in rural areas is usually taken by the man in the household, or by the men in co-operation (Mencher 1989; Young 1992; Agarwal 1997). On the other hand the women (including girls) of the household are the main persons responsible for the household domestic chores relating to water collection (for the domestic use), cooking and collection or preparation of fuel (CSE 1985; Jain 1996; Kulshreshtha *et al.* 1996). When there is a biogas unit installed in a household, the women will become the main managers and users of it.

The technology has the potential, however, to bring a number of improvements to the situation of the women, something which is acknowledged. But as often is the case with unpaid domestic work of the women and children, it is not visible in the discussion on development and economics (Benería 1992; Evans 1992; Elson 1995; Jain 1996; Chambers 1997). For the case of biogas technology the gender aspect of for example the work load and resource utilisation has been more or less invisible. In most contemporary development projects the aspect of gender is considered. One example is the APPRO biogas project (Turner *et al* 1994; Dutta *et al.* 1997).

There are several constraints in involving women in government programmes. These are:

- Traditional gender roles within family;
- Low level of economic independence of women;
- Educational constraints leading to lack of access to information, skills, and technical expertise; and
- Prejudices among extension workers which prevalent them from interacting with women.

There are also some regional variations in social dynamics, which influence the participation of women. For example, women in South India enjoy more freedom in the society than those in Northern States like Uttar Pradesh and Bihar. The primary constraint in engaging women, as biogas staff is that there is extensive travel involved in the programme. Given the present status of the public transport system in rural areas, mobility for women staff is a serious constraint.

The AFPRO-CHF network emphasis the involvement of women in the biogas programme. In response to this requirement, NGO's / any other programme implementers have tried to involve women in two ways:

(i) By employing women staff as motivators; and

(ii) By involving village women in the programme.

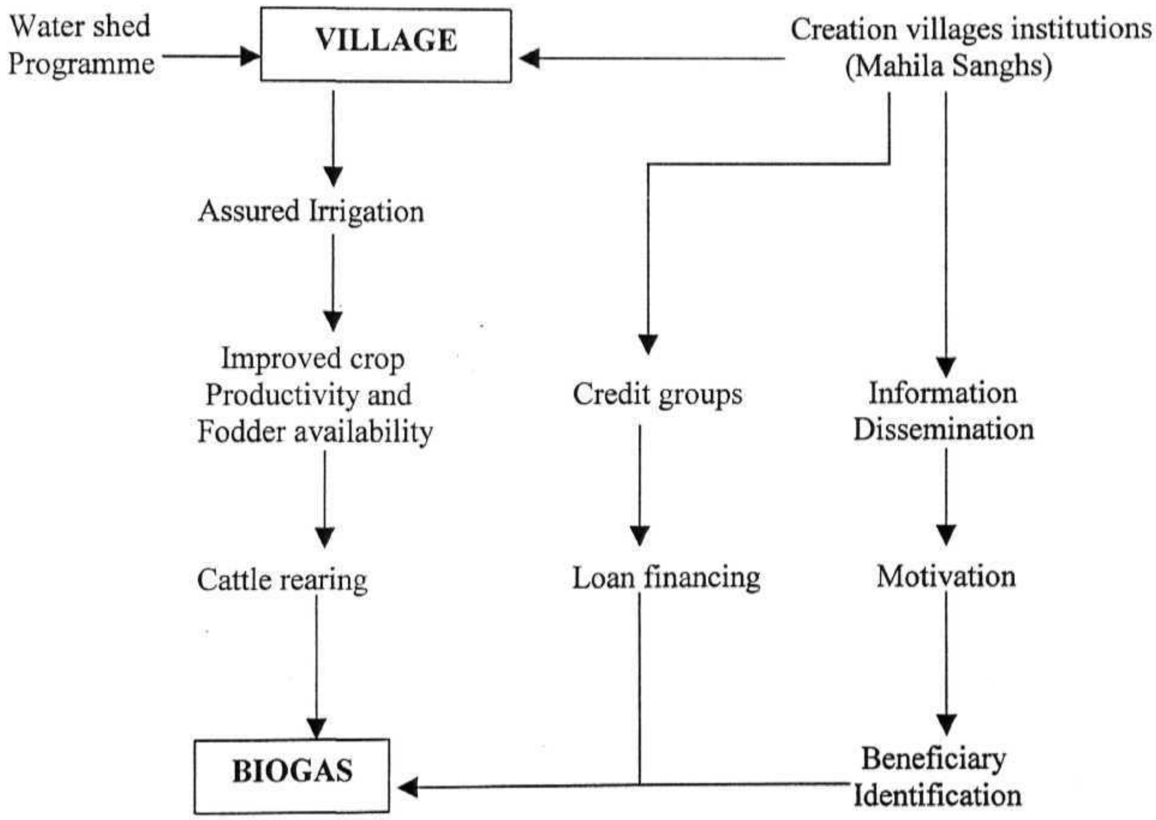
In light of this divergence between the potential and actual role of women in the biogas programme and the experiences of the network NGOs in this respect, it is found that:

- Motivation is most effective when local villages can be used for motivating other to adopt the technology; and
- Involvement of women would be high if undertaken through village-level institutions. However, instead of creating new institutions, focus should be utilizing existing institutions like mahila mandals and gram panchayats.

The network NGOs have integrated other activities with biogas to a certain degree. However, till now, the integration has been restricted only some stages of biogas programme implementation. While institutions like Mahila sangh have actively participated in pre-construction activities like motivation, beneficiary identification and financing, their involvement in the post-construction phase has been minimal. The lies a great potential for the NGOs to involve these groups in follow-up maintenance of the installed biogas plants. The linkages between biogas, women's development and watershed management programme are shown in fig. 6.1 :

Fig: 6.1

Frame work for programme integration



Thus from the analysis of various literature of the past, it can be seen that though women are the primary users of biogas they have only a marginal role in the implementation process. While all the NGOs emphasized the need to involve women at every stage of the programme, the situation at the field level is vastly different.

The below table 6.1, lists out the various activities in which women can participate effectively as users and implementation of the programme, and compares this with present situation.

6.4.2 Benefits from the Biogas Plants

Promoted as an appropriate rural energy technology for several decades in India, the application of biogas technology in rural areas lies mainly in the fact that it enables an effective utilization of a locally available resource. For the rural poor, this technology provides a clean and convenient fuel at a low cost, being environmentally benign at the same time. Today, the benefits of biogas technology are well understood by the rural masses. Benefits accrue at the Individual level as well as at the community and National level.

6.4.2.1 Individual Level

A biogas plant is an important source of organic manure for the farmer. The sludge constitutes good quality manure free from weed seeds, foul smell and pathogen. The content of major plant nutrients in the digested slurry is shown in the below table: 6.4

Table: 6.1 Role of Women in Biogas Programme

Role of Wo men in	Desired role	Existing situation
Planning	Decision-maker for adopting the Technology And selecting appropriate site for biogas plant.	The decision to install a biogas plant is taken by men except in cases where women have been involvement Through village based institutions in motivation.
Construction	Need to be aware of the type, quality and quantity of material used for construction.	The women are completely unfamiliar with the construction on related aspects such as material requirement, technique used, etc.
Operation and maintenance	As primary users, women should be familiar with: * the functioning of the biogas plant; * proper method of feeding dung and water; * the procedure for removing water from the pipe line; * method of cleaning stove components like knobs and burner; and * minor repairs like replacement of washer, teak etc.	Except for operating the stove, they have incomplete information on all major aspects related to operation and maintenance.
Role of women **Staff** as Motivators	Should have a through knowledge of the **technical** and related aspects like functioning of a biogas plant and advantages of the technology	Are generally poorly infonned due to lack of adequate training

Source: Ministry of ***Non-conventional*** *Energy Sources '2000-01*

Table:6.2

Nutrient content in the Digested Slurry

Plant Nutrient	Digested Slurry (%)	**Farm Yard Manure** (%)
Nitrogen (N)	1.5-2.0	0.5-1
Phosphorous (P_2O_5)	1.0	0.5-0.8
Potash (K_2O)	1.0	0.5-0.8

Source: Biogas Technology and Utilisation (A Practical Hand Book)

Digested slurry has been found useful for raising fish. Common crop fry and fingerlings fedl on a mixture of rise barn and digested slurry (1:3) showed faster growth.

Biogas had higher thermal efficiency when compared to kerosene, firewood, cow-dung, wood and charcoal as shown in table 6.3.

Table: 6.3

Thermal Efficiency of Different fuels

Name of Fuel	Thermal Efficiency (%)
Gobar gas (m^3)	60
Kerosene (litre)	50
Firewood (kg)	17.3
Cow-dung Cake (kg)	11
Charcoal (kg)	29

Source: Khadi Gramodyog, June 1986.

Biogas has the potential of doubling the fuel efficiency of the resource materials like dung and even quadrupling the efficiency as compared to three stone fire very much common among the rural poor.

6.4.2.2 Community Level

Biogas being a clean fuel does not cause air pollution. It also helps to improve sanitation. Since the digested slurry remains free from foul smell, mosquitoes and flies do not breed in the digested slurry which are the important agents of spreading diseases.

Biogas is new source of fuel fro mechanization of agriculture and village industries. It can be used for running diesel and petrol engines. According to a reputed manufacturer diesel engines which can be operated with duel fuels (diesel plus biogas) 80% of the diesel requirements (apparently energy - wise) can be saved using full supplier of biogas along with 0.2 litre of diesel per hour (Vandana S;2002)

6.4.2.3 National Level

Biogas helps to same foreign currency, which is spent on kerosene and chemical fertilizers. Researchers have estimated that 5 lack biogas plants will have 750 million litres of kerosene per year and provide 12 million tones of organic manure. It helps in reducing the need for expensive energy distribution in rural areas. Due to inefficient distribution, system almost 20 per cent of the powers is lost during transmission. "The poor maintenance and operation of the thermal plants is mainly responsible for the present power crisis plaguing the country" was the impression of the three members Sixth Finance Commission gathered during its tour of the country.

Biogas system would help in preventing the denuding of forests in a careless manner by the villagers for firewood requirements. Today, deforestation being a serious threat to environment n large parts of the country, as it is followed by the danger soil erosion and several other ecological imbalances.

A summary of the above-described benefits from biogas technology is displayed in **a** matrix Table 6.4.

Table: 6.4

Benefits from Bio-gas technology

	Individual Level	Community Level	National Level
Energy replacement of commercial fuel	Reduced spending	Reduce transportation and need for infra structure	Improve Balance of Payments
Energy replacement of Non-commercial fuel	Less time spent on collecting fuel	Environmental impact	Reduced cost for afforestation
Fertilizer, if manure not used prior	Reduced spending on fertilizers	Reduce transportation and need for infra structure	Improve BOP
Health	Improved health	Increased labour availability and equality	Reduced spending on health care
Development	Convenient fuel	Create employment	Sustainable rural development
Economy	n.a	n.a	**n.a**

Source: Human Ecology Reports Series 2000-1

6.4.3 General Benefits

The benefits of the biogas are manifold. It provides a good form of sanitation, it generates a useful fuel product and it produces a regular supply of nitrogen-enriched fertiliser for the garden.

6.4.3.1 As a Sanitation System

As sanitation system the biodigester holds many health advantages:

- The safe disposal of human fasces reduces diseases related to poor sanitation, such as cholera and other diarrhoreal diseases, or diseases related to groundwater pollution.
- 99% of bacteria dangerous to people (pathogens) are killed in the process of producing biogas.
- The environment is generally improved, as people do not defecate in the bush, and cow dung is systematically collected and processed.

6.4.3.2 As a Useful Fuel Product

The use of biogas in the household has many benefits. It provides:

- free gas for cooking
- improved social conditions in the form of hours of labour saved. Collecting wood and making fires for cooking can take many hours of labour per day, depending on the availability of wood.

6.4.3.3 Biogas as a cooking fuel

- Biogas provides clean, smoke-free energy for cooking. When biogas is burnt, there is no smoke and soot. No fire-markings are left on pots and walls. Pots are easier to clean than pots that are heated over wood- fuels. Health problems are reduced because of the absence of smoke and soot.
- Biogas is convenient. Based on the effective heat produced, a 2 m^3 biogas plant could replace, in a month, the fuel equivalent of 26 kg of liquid petroleum (LP) gas, 37 litres of paraffin, 88 kg of charcoal, 210 kg of fuel wood, or 740 kg of animal dung.
- Biogas is cheap. Biogas is cheaper than LP gas, and is only fractionally more expensive than paraffin. Commercial fuels like paraffin and LP gas have severe supply constraints in the rural areas.
- Biogas is easy to use and saves time in the kitchen. The biogas stove has an efficiency of about 55%, which is comparable to that of an LP gas stove.
- Biogas improves the quality of life in the household. Women's workload in cooking and collecting firewood is reduced.

6.4.3.4 Biogas as a fuel for lighting

- Biogas can be used for lighting, through a specially designed mantle.
- Biogas can partially replace fuel to run internal combustion engines for water pumping, or for small industries like flour mills, saw mills, oil mills etc.
- Biogas digesters can also be used to produce electricity via a generator fuel cell.

6.4.3.5 As a Source of Fertilizer

- The liquid fertiliser is easily absorbed by the soil, and produces healthy crops. It is a better fertilizer for the soil than raw cow dung, because it has more available nitrogen. It can be directed straight onto gardens, or can be transported easily in a wheelbarrow or in buckets, and applied directly along furrows.
- Dried manure from the biogas digester is an equally good source of enriched fertiliser for the garden, resulting in better quality crops.

6.4.3.6 Environmental advantages of Biogas

Biogas has many advantages as a source of energy for the rural areas.

- Using biogas instead of firewood helps reduce i.e. green house gas emissions. This means that less methane gas and carbon dioxide enters the air, making it cleaner and healthier.
- Using biogas instead of firewood means that trees are not cut down, and forests are not destroyed, which can result in increased soil erosion.
- The environment is kept clean and hygienic. Cow dung is systematically collected.
- Dung is often burned directly as a fuel, or applied as a fertiliser to gardens. However, the processing of cattle or human dung in a biogas digester provides a better quality gas and liquid manure than raw dung. Biogas provides nearly three times more useful energy than dung directly burnt, and also produces nutrient-rich manure.

6.4.3.7 Qualitative and Quantitative Social and Economic benefits

- Biogas digesters can be installed in remote areas at low lifetime costs. With the cheaper digesters, families can save up to Rs. 5 per day if they replace LP gas with biogas.
- Labour is saved, as wood does not have to be collected and chopped, and fires prepared for cooking.
- Biogas provides a source of fuel, and the potential to generate income.

6.5 CONCLUSION

Thus, The use of biogas has brought about significant improvements in the quality of life of users. It has affected about 30-40% savings in fuel, reduced the workload and drudgery for women, and generated employment in the rural areas. But, the perceptions of the beneficiaries are mixed. Although most users rate the benefits of fuel and time saving high, the perceptions regarding quality of biogas slurry have not always been positive. This biogas programme has been successful in reducing pressure on biomass resources by shifting the dependence of the communities. This is particularly true for the countries (i.e India) where fuelwood is scarce.

Ostensibly 84 percent of Indian villages are connected to the electrical grid, but only 27 percent of their inhabitants actually had access to power in 1991, according to R.K. Pachauri of the Tata Energy Research Institute in New Delhi. That means 435 million people, more than half of India's population, lack electricity. And 80 percent of rural India faces difficulties in obtaining sufficient cooking fuel. Biogas bypasses these shortages and transmission problems by providing a decentralized and locally-controlled fuel supply from a readily available material.

Generating biogas also makes sense in the Indian cultural context. All products of the cow, including dung (or "gobar" in Hindi) are considered purifying agents by Hindus, according to O.P. Joshi, a sociologist at the H.C. Mathur Institute of Public Administration in Rajasthan. In the classical Indian epic, the Mahabharata, says Joshi, "gobar is described as the living place of Lakshmi, the goddess of wealth." Traditionally in India, dung is collected and fashioned into dung-cakes, to be burned directly as fuel or composted for fertilizer. Dung accounts for over 21 percent of total rural energy use in India, and as much as 40 percent in certain states.

Usually, dung used for one purpose is lost to the other, but biogas provides a means to both ends. It exploits the caloric content of the waste, while retaining the nutrients as fertilizer - and on both counts, it is more efficient than traditional methods. Direct burning only captures about 11 percent of the dung's energy value, but biogas generation has a 45 to 60 percent efficiency. In other words, biogas captures approximately 5 times as much energy as does direct burning. And the by-product slurry has twice the nitrogen content of composted dung because open-air composting allows much of the nitrogen to escape in the form of volatile compounds. The slurry also releases its nutrients more readily than composted dung. And unlike decomposing dung, it is odorless and does not attract flies or mosquitoes.

In addition to the slurry's nutrient recycling function, the gas itself has important environmental benefits. It offers an ecologically sustainable alternative to fuel wood, which currently provides over half of India's rural household energy. Biogas can help check deforestation; in the 1980s, for instance, when biogas technology was introduced into villages near the Gir Lion Sanctuary in Gujarat, woodcutting within the Sanctuary dropped substantially. And since the conversion process in the digester is anaerobic (it occurs in the absence of oxygen), it destroys most of the pathogens present in dung and waste, thereby reducing the potential for infections like dysentery and enteritis

The burning of traditional fuels like dung cakes or wood releases high levels of carbon monoxide, suspended particulates, hydrocarbons, and often, contaminants like sulfur oxides. (Dung contains traces of hydrogen sulfide, which is converted to sulfur oxides on combustion.) Exposure to these fumes in unwanted cooking spaces increases the risk of respiratory disease. According to a study sponsored by the World Health Organization, Indian women cooking over firewood were inhaling as much of the carcinogen benzopyrene - a combustion by-product of wood - as they would by smoking 20 packs of cigarettes a day. Because it is a gas, biogas burns much more efficiently than these solid fuels. It leaves very few contaminants, although it is true that biogas releases small quantities of sulfur oxides. Biogas offers perhaps the most environmentally benign method for tapping the solar energy stored in bio-mass. It's a renewable and decentralized alternative to the other methane-based fuel, natural gas, which is commonly used in cities.

Chapter - VII
ECONOMIC ANALYSIS

7.0 INTRODUCTION

There is an increased recognition, in both developing and industrial countries, of the need for technical and economic efficiency in the allocation and exploitation of resources. Systems for the recovery and utilization of household and community wastes are gaining a more prominent place in the world community. Today, a new environmental agenda is emerging, which is now forcing itself on the attention of policy-makers and the public at large. Its concerns are both practical and urgent: they address the survival of human, animal and plant populations over vast sections of our globe.

Today's issues arise from the spread of deserts, the loss of forests, the erosion of soils, the growth of human populations and industrialized animal husbandry, the destruction of ecological balances, and the accumulation of wastes. As a result, the politics needed to meet present and future challenges require a new vision and new diplomacy, new leadership and new policies. In a world that is daily more complex and economically interdependent, the economic and security interests of the Developing Countries must be understood in a broader, global context.

These acute, relatively new problems of the world stem from either poverty and excessive population growth, in the Developing Countries, or from the careless and excessive use of natural resources in the Developed Countries; with more cumulative impact on the poor countries than on the rich. While many of these problems have been recognized for some time, they demand a new policy agenda for the world. The emergence of such a new approach has been accompanied by the growing realization that the goals of environmental conservation and economic growth in both developing and industrial countries are more complementary than often depicted. A.W. Clausen, President of the World Bank, has stressed these relationships: "There is increasing awareness that environmental precautions are essential for continued economic development over the long run. Conservation, in its broad sense, is not a luxury for people rich enough to vacation in scenic parks. Rather, the goal of economic growth itself dictates a serious and abiding concern for resource management".

Necessary goals are to achieve economic and environmental benefits through sustainable projects for resource recovery and utilization, and programs for Developing Countries. The use of anaerobic digestion in an integrated resource recovery system in Developing Countries is important to solve both ecological and economic problems.

The problem of energy crisis in India in recent yeas assumed greater magnitude both in Industry and Agriculture with rise in Oil prices. At the present rate f exploitation, the non-renewable sources of energy like oil and natural gas reserves would be depleted in near future. Hence, an increased dependence on renewable sources of energy like Solar, Wind and Biogas would be inevitable. The large scale introduction of Biogas plants, wherever technology feasible, not only serves as an alternative source of energy but also improves the quality and quantity of farmyard manure.

The present study was taken in Nizamabad district of Andhra Pradesh in order to estimate the cost of installation of biogas plants and the problem faced by them in their adoption. The findings of this study are of immense use of farmers, financing institutions and extension agencies that are actively involved in the popularization of biogas plants in rural area.

7.1 EXPERIENCE OF ECONOMIC EVALUATION IN OTHER COUNTRIES

Bhavani (1976) gave a composite estimate based on uses of dung for both fuel and fertilizer. She concluded that "it is obvious that the whole economics of biogas plants depend on the proportion of cow dung which is used as fertilizer before the introduction of biogas plants". Therefore the price of dung must be taken as fertilizer and as cakes. This assumption does not improve the economics of biogas plants, rather the reverse, **for** it means that the replacement costs of the biogas plant output should be valued in the same way as the dung input. In practice, most Indian farm households are not able to afford the investment anyway, and for the few that can, the assumption of **a market value** for **dung** is reasonable

According to a survey by Moulik et al. (1975) for KVIC system, the major item of expense was the gas holder. Survey evidence suggests that access to technical assistance is **a** major determinant of plant performance, and yet social benefit-cost studies rarely consider this **as** a cost item. The development of Biogas Offices for helping the farmers maintain the plants was a key in the special rural development in both China and India. Marchaim, during his tour in China (1990), found that most families expressed their thanks to the extension biogas officers. He concludes in study that, the poor maintenance has been said to be the single most important cause of plant failure in the digesters' design, particularly the failure to paint the gas holder to avoid corrosion.

Several other reviews of cost benefit studies of biogas have been published, notably Barnett (1978), Sanghi (1979), Mukherjee and Arya (1980), ESC AP (1981), de Lucia and Bhatia (1980), Mazumdar (1982), Gunnerson and Stuckey (1983), Wellinger et al. (1988), Zhijine (1988), de Poli et al. (1988).

Evidence on household and community plants from other countries is extremely scarce and provides little additional knowledge that might resolve some of the uncertainties that the Indian studies have raised. Only a few of the studies available were based on actual user experience. Rahman (1976) gives a breakdown of costs and benefits of a modified Indian design used in Bangladesh, without any firm conclusion on its economic viability. However, with a net annual operating profit of Tk.581, and an initial construction cost of Tk.7,600, only very low interest rates on a loan for construction would make the plant financially viable.

Of three **Nepalese** desk studies based on Indian design (three **cubic meter)** plants, only Berger (1976) estimated a positive benefit-cost ratio **(1.67:1), while Pradhan (n.d.) and** Pang (1978) argued that construction cost reductions were **critical if biogas was to be financially feasible** for any but the richer farmers.

In Thailand, an empirical study of Indian design plants by Prasith-raithsint et al. (1979) found that household plants on average had a payback period of 5 years. No other estimates of economic worth were calculated. No benefits were claimed for the slurry, as this we" not used by plant owners. The high cost of plant-, a lack of technical know-how, the availability of other fuels, and the shortage of dung were the main reasons given by the 94.5% of current nonusers who said they did not want a plant.

A desk study by Roeser (1979) of two household plants in Honduras showed that the economic viability of the pants depended critically upon the relative time spent on dung and firewood collection. At low dung collection times, the larger plant (360 ft^3) was viable. The smaller plant (180 ft^3) was viable only when cooking, rather than lighting, was the use adopted. However, in the absence of subsidized kerosene for lighting, use of biogas for lighting was viable at low dung collection and preparation times. He recommended further study before diffusing biogas, and drew attention to the importance of comparing the use of a biogas plant for cooking with the use of an improved stove. If the fuel efficient "Lorena" stove could reduce firewood collection time to one hour per day, the use of biogas for cooking was not as profitable to the household as use of the stove.

Tarrant (1977) undertook a comprehensive evaluation of the use of a community plant for generation of electricity in Debarek, Ethiopia. He concluded, using three different measures of social worth, that the project was viable at current oil prices (the fuel used to value biogas), but that the project was not financially viable. However, the detailed figures provided on financial and social costs and benefits suggest that a subsidy to cover the financial deficit would still leave the project socially viable. He concluded that more detailed field evidence was required on three critical parameters; electricity demand projections, slurry transport costs, and the value of dung, to firm up the estimates presented.

7.2 ECONOMIC ANALYSIS OF BIOGAS PLANTS IN INDIA

For economic analysis, biogas facilities can be broadly divided into two categories:

1. Those in which there is a significant economic cost associated with the handling and disposal of organic feed stocks from ecological and environmental aspects, and
2. Those in which this cost is negligible. Examples of the first area include sewage disposal, agro-industrial waste treatment, and manure disposal from intensive livestock farming. The second category includes household and community scale plants in rural communities.

With the implementation of more legislation in Developed Countries concerned with environmental and ecological aspects of handling wastes, most industrialized countries already have experience in handling and disposing wastes, but as yet there are only very few cases where data on which to base relevant economic analyses exist. However, the few studies do provide some preliminary indication of economic justification.

Data on different economic aspects of biogas plants in rural areas are accumulating for fertilizer and for fuel uses, which were both commonly, obtained from the same source material, but are now handled differently. Most of the economic data and analyses come from the Chinese and Indian biogas programs, but other countries are catching up.

One of the forces behind renewable energy technology R & D, including biogas, has been the need to eliminate deforestation by using substitutes for traditional firewood. This secondary benefit creates two problems for analysis: the first is the one of its measurement and evaluation, and the second is one of comparing biogas with other energy technologies that have a different, and commonly smaller array of secondary benefits like improved health etc.

The economic feasibility and financial viability of biogas plants depends on whether output in the form of gas and slurry can substitute for fuels, fertilizers or feeds which were previously purchased with money. If so, the resulting cash savings can be used to repay the capital and maintenance costs, and the plant has a good chance of being financially viable.

However, if the output does not generate a cash inflow, or reduce cash outflow, then plants lose financial viability. Finally, if broader social criteria are used to evaluate biogas, conclusions will be more favorable than a strictly financial analysis. Social viability is difficult to evaluate because of problems in valuing secondary benefits.

7.2.1 Analysis of economic feasibility for biogas construction

The anaerobic fermentation process is an important measure for the solution of fuel shortage in rural area, as well as an important measure for using biomass resources efficiently; for accelerating a common development of agriculture, forestry, husbandry, aquaculture and secondary production; for improving agricultural profitability; for protecting the environment and for good rotation in agricultural production. It is also an important measure for improving and the quality of life, and for the achievement of modernization in rural areas.

One important point for the popularization of a technology is to examine its economic benefits. If profitability is higher, a condition for rapid popularization is available. If economic benefit is low, it is difficult to popularize the technology. The factor of environmental protection is not popularly acceptable, but can be popularized by preferential economic policies, such as in credit and tax.

The production of biogas from cow dung / biomass by fermentation techniques requires the construction of a biogas pit and a complete system for gas storage, distribution and utilization. Raw materials, labour, etc. for constructing the equipment make up the capital investment of biogas production and utilization. For combined biogas pits, costs for the building of toilets and pigsties need not be included, but the costs of renovating existing toilets for excrement collection should be included.

Economic evaluation of small scale or individual biogas plants requires measuring and valuing the fertilizer and fuel output, then comparing the gross value of output with the costs of plant construction and operation to arrive at a benefit-cost ratio or other index of value.

It is also necessary to include in periodic costs for the maintenance of biogas equipment. The cost of labour and material for managing and maintaining the biogas pits are also included here in the annexure 7.8 and 7.9 for 1 cu.m and 2 cu.m respectively.

Production and utilization of biogas are beneficial in many ways. They have both direct and indirect economic benefits and social benefits. The direct economic benefit of biogas as a fuel, in place of firewood and coal, is a reduction in fuel expenses. Compared with kerosene lamps, biogas lamps not only reduce the cost of fuel, but also increase light level and improve living quality. Compared with direct burning of stalks, biogas produced from biomass fermentation increases the quantity of organic manure which can be sold to production teams, increasing the direct benefit to farmers.

Biogas production also has many indirect benefits, which sometimes play a very important role in biogas development. For instance, crop stalks, when no longer burned, may be used as animal fodder, increasing the income from animal husbandry, while still providing raw material for biogas production. Farmers can use the time saved from firewood collection for additional production, and thereby increase their income; fermentation effluent can be used as fodder to raise fish, mushrooms and earthworms, and as protein fodder for poultry. Compared with kerosene lamps, biogas lamps improve lighting conditions, making it possible for farmers to embroider, weave and tailor after dark. An investigation of Haian County, in Jiangsu Province, shows that it is the latter benefit that has made farmers actively demand the development of biogas.

Furthermore, biogas development brings about social benefits in many respects. For example, the quantity of animal protein supplied to the society may increase as a result of a reduction of direct burning of stalks and development of animal husbandry. As the problem of fuel for the farmer's daily use is solved, trees are protected and forests are developed. The protection of trees and increase in vegetation areas can reduce soil erosion and improve ecologic balance. The increase in organic manure can result in using less chemical fertilizer, improving soil and increasing production. Environmental improvement in rural area reduces illness and builds up people's health. Besides, in regions where biogas is used to generate electricity, cultural, recreation and spare time study conditions can also be improved. Although these benefits are very important for the whole society, they are often not of direct economic benefit to investors in biogas installation, and it is impossible to calculate them accurately in monetary terms. We will not, therefore, consider these benefits in the following economic feasibility analysis.

7.2.2 Computation of Returns (Project Returns)

The annual returns included the value of the fuel saved and sludge manure obtained per annum. The value of the fuel saved includes the value of the firewood, kerosene, electricity and commercial cooking gas. The value of the firewood, kerosene, electricity and commercial cooking gases was determined based on the market price prevailing in the study areas.

7.2.3 Computation of Costs (Project Costs)

The annual costs of biogas gas plants were computed by adding the annual maintenance cost (variable cost) and annual fixed costs. The annual costs were computed with out subsidy.

The annual maintenance cost computed by adding the cost actually incurred on labour used for feeding the dung, dung feed to the plant, painting, repairs and replacement.

The annual fixed cost was computed by adding interest on total investment and depreciation on various component parts or Investment of the plant.

Thus, total annual cost(TC) was worked out by adding the annual maintenance cost (M) and fixed costs(F) and it is represents as follows:

$$TC = M + F$$

7.2.4 Net Annual Energy Capacity

Net Annual Energy capacity is the quantity of energy generated, expressed in kilowatt-hour (KWH) per unit of gobar gas in one year's time. It is worked out by using the formula given Reddy, et al (1973).

$$E = 1080.4246 \ KWH / cu.M.$$

Where,

E = Net annual energy capacity.

Generating cost of biogas energy is the cost incurred to produce one KWH energy from biogas plant. It is also called energy rate. It is computed by using the following formula:

$$e = \frac{A_c \ x \ 100}{1080.4246 \ x \ Q} \ paisa \ per \ KWH$$

Where,

e = energy rote of biogas at 60 per cent thermal efficiency

A_c = annual cost of biogas plant (Rs.)

Q = Capacity of the plant (cu. m)

7.2.5 Energy cost of **Alternative Fuels**

The per unit cost of the Kerosene, Firewood, LPG and Electricity was worked out based on the market price of these fuels prevailing in the study area during the period of survey.

7.3 EVALUATION OF INVESTMENT IN BIOGAS PLANTS: TRADITIONAL AND DISCOUNTED CASH FLOW MEASURES

The investments in Biogas plants were evaluation using the traditional and discounted cash flow techniques. The techniques has the advantage that future variable cash flows are reduced to a single sum at one pint of time, thereby facilitating comparisons between various alternatives. The most widely accepted techniques used in estimating the cost-returns of investments projects can be grouped under two categories, i.e. Traditional Methods and Discounted Cash flow Methods.

7.3.1 Traditional Methods

The following are some of the important traditional methods of capital budgeting are used to appraise the long-term investment proposals. They are Payback period method and Average Rate of Returns method.

7.3.1.1. Payback Period Method

The payback period method is the simplest method of evaluating investment proposals. Payback period represents the number of years required to recover the original investment. The payback period is also called payout or payoff period. This period is calculated by dividing the cost of the project by the annual earnings after tax but before depreciation. Under this method the projects are ranked on the basis of the length of the payback period-, A project with the shortest payback period , the less risky the investment is. The payback period can be calculated as follows:

a. **When annual cash inflow is constant**

$$\textit{Payback Period} = \frac{\textit{Original cost of the Project}}{\textit{Annual Cash Inflow}}$$

b. When annual cash inflows are not constant

$$\text{Payback Period} = LY + \frac{\text{Original cost of the Project} - \text{AACI of lower year}}{\text{AACI of upper year} - \text{AACI of lower year}}$$

Where,

AACI - Accumulate Annual Cash Inflow

7.3.1.2 Average / Accounting Rate of Return (ARR) Method

This method, based on accounting profit, take into account the earnings expected from the investment over the entire lifetime of the asset. The projects are ranked in order of the rate of returns. The project with the higher rate of return is accepted. Average rate of return is found out by dividing the average income after depreciation and taxes, i.e., the accounting profit, by the average investment.

$$ARR = \frac{\text{Average Annual Earnings}}{\text{Average Investment}} X\,100$$

Where,

The *Average* ***Annual earnings*** is the total of anticipated **annual** earnings after depreciation and tax divided by the number of years.

The *Average investment* is

i. If there is no salvage (scrap) value, the average investment
= ½ (total investment)

b. When annual cash inflows arc nut constant

$$Payback\ Period = LY + \frac{\text{Original cost of the Project} - \text{AACI of lower year}}{\text{AACI of upper year} - \text{AACI of lower year}}$$

Where,

AACI - Accumulate Annual Cash Inflow

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$$ARR = \frac{\text{Average Annual Earnings}}{\text{Average Investment}} X\ 100$$

Where,

The *Average Annual earnings* is the total of anticipated annual earnings after depreciation and tax divided by the number of years.

The *Average investment* is

i. If there is no salvage (scrap) value, the average investment

= ½ (total investment)

ii. If there is scrap value the average investment

= ½ (total investment - scrap value) + scrap value

iii. if there is additional working capital the average investment

= ½ (total investment - scrap value) + additional working capital

7.3.2 Discounted cash flow Methods

The following three are important techniques or methods of Discounted techniques of capital budgeting, which arc helpful in long-term investment proposals. They are i.e., Benefit-Cost ratio, Net Present Worth and Internal Rate of Returns.

7.3.2.1 Benefit-Cost (B:C)Ratio

This is also called as Profitability Index method. The *B:C* ratio is the ratio of discounted cash flows (project benefits) to discounted cash outflows (project costs. It must be unity or more for the project to be considered economically viable. The discounted rate used was the opportunity cost of capital. The general model of B:C ratios is specified as follows:

$$\text{B:C Ratio} = \frac{\sum_{t=1}^{T} B_t(1+i)^{-t}}{\sum_{t=1}^{T} C_t(1+i)^{-t}}$$

Where,

B_t = Benefits (in rupees) obtained in the year 't'

C_t = Costs (in rupees) incurred in the year 't'

T = Economic life period of the Biogas plant

i = Discount rate

7.3.2.2 Net Present Value (NPV) or Net Present Worth (NPW) Method

The NPV method takes into consideration the time value of money. The cash flows of different years are valued differently and made comparable in terms of present values. For this, the net cash inflows of various periods are discounted using required rate of return which is predetermined. Taking into consideration the scrap value, if the present value of as cash inflows exceeds the initial cost of the project, the project is accepted otherwise rejected. If the two project proposals giving NPV, the project with the higher NPV is selected. In computing the NPV, the difference between the Present value of Benefit and Cost stream are considered. The general model of NPV is as follows:

$$NPV = \sum_{t=1}^{T} B_t(1+i)^{-t} - \sum_{t=1}^{T} C_t(1+i)^{-t}$$

The decision algorism in the framework of this model of project evaluation is that as long as the NPV is positive, the investment activity in question is economically justifiable. The NPV gives the same results as the B:C ratio.

7.3.2.3 Internal Rate of Return (IRR) Method

The IRR for an investment proposal is that discount rate which equates the present value of cash inflows with the present value of cash outflows of an investment. In other words, it is the discount rate which makes the difference between NPV of cash inflow and Outflow equal to zero. It represents the average earning capacity of an investment from the project. The IRR is suggested to be a very dependable criterion for evaluating the profitability of different projects. When compared the IRR with a required rate of return, if the IRR is more than required rate of return then, the project is accepted else rejected. **In** the case of more than one project with IRR more than required rate of return, the one which gives the highest IRR rate is selected.

The IRR is not a predetermined rate, rather it is to be found out by trial and error method. It implies that one has to start with a discounting rate to calculate the present value of cash inflows. If the obtained present value is higher than the initial cost of the investment one has to try with a higher rate. Likewise if the present value of the expected cash inflow obtained is lower than the present value of cash outflow, a lower rate is to be taken up. The process is continued till the net present value becomes zero. Thus the IRR is said to be the rate which gives the NPV of the proposed project is zero. As this discount rate is determined internally, this method is called Internal Rate of Returns method. The model is specified as follows:

$$IRR = \sum_{t=1}^{T} B_t(1+i)^{-t} - \sum_{t=1}^{T} C_t(1+i)^{-t} = 0$$

or

$$IRR = L + \frac{P1 - Q}{P1 - P2} X \; D$$

Where,

i = the internal rate of return

L = Lower discount rate

P1 = Present value of earnings at lower discount rate

P2 = Present value of earnings at higher discount rate

Q = Actual Investment

D = Difference in rate of return

7.4 COST - BENEFIT ANALYSIS

Biogas is a promising non-conventional energy and it is a better energy from polluting waste, clean and efficient, eco-friendly, money saver, time saver, minimizes expenditure, producing enriched bio-manure as by product for increasing productivity and soil conservation. The cost and returns of the 1 cu.m and 2 cu.m are computed with the help of a technical data regarding total cost and price of different fuels i.e., fuel wood, Kerosene, LPG and Electricity etc., are shown in appendix.

Table: 7.4.1

Cost of the Project

I	Fixed Cost	1 cu. m (in Rupees)	2. cu.m (in Rupees)
	a. Investment cost of depreciable value	265.00	360.00
	b. Interest on Investment @ 12%	636.00	864.00
	Total Fixed Cost	**901.00**	**1224.00**
II	**Variable Cost**		
	a. Cost of man hour in feeding	1277.50	1277.00
	b. Cost of Cattle dung	912.50	1825.00
	c. Maintenance cost	100.00	100.00
	Total Variable Cost	**2290.00**	**3202.50**
III	**Total Cost (FC + VC)**	**3191.00**	**4426.50**

Table 7.4.2

Returns of the Project

Sl.No.	Particulars	1 cu.m Money Measurement Value (Rs.)	2 cu.m Money Measurement Value (Rs.)	Non-monetary Value
1	Electricity charges (lighting)	600.00	900.00	-
2	Value of bio-manure produced	4562.00	9125.00	-
3	Fuel wood	744.60	1489.20	-
4	Kerosene	2190.00	4380.00	
5	LPG – commercial cooking gas	3240.00	6480.00	-
6	Electricity	2518.50	5021.00	-
7	Health incremental value	-	-	Infinity
8	Environmental preservation	-	-	Infinity
9	Family bondage	-	-	Infinity
10	**Total Returns**			
	In the case of Fuel wood (1+2+3)	**5906.60**	**10,764.60**	**Infinity**
	In the case of Kerosene (1+2+4)	**7353.00**	**14405.00**	**Infinity**
	In the case of LPG (1+2+5)	**8402.00**	**16505.00**	**Infinity**
	In the case of Electricity (1+2+6)	**7680.50**	**15046.50**	**Infinity**

7.4.2 Net **Saving s of** Project

The net savings of different fuels for 1 cu.m and 2 cu.m are shown in Table 7.4.3.1 and 7.4.3.2 respectively.

Table: 7.4.3.1

Net savings / **annum / family (1. cu.m)**

Sl. No	**Fuel**	**Annual Revenue**	**Annual** Cost	**Annual Savings** *	**Payback period** (Years)
1	Fuel wood	5906.60	3191.00	2715.60	1.95
2	Kerosene	7352.00	3191.00	4161.00	1.27
3	LPG	8402.00	3191.00	5211.00	1.01
4	Electricity	7680.50	3191.00	4489.00	1.18

* Net Annual savings = Annual savings + Infinity value on health and environment values.

Table: 7.4.3.2

Net **savings / annum / family** (2 cu.m)

Sl. No	Fuel	Annual Revenue	Annual Cost	**Annual Savings** *	**Payback period** (Years)
1	Fuel wood	11509.20	4426.50	7082.70	1.01
2	Kerosene	14405.00	4426.50	9978.50	0.72
3	LPG	16505.00	4426.50	12078.50	0.59
4	Electricity	15046.00	4426.50	10619.50	0.67

* Net Annual savings = Annual savings + Infinity value on health and environment values.

7.4.4 Results and Analysis

The above capital budgeting methods were computed based on the project cost and returns obtained frrm the sample beneficiaries of the plant. The discounted measures, viz., Benefit-Cost ratio (B:C ratio), Net Present Worth (NPW) and Internal Rate of Returns(IRR) Method for 1 cu.m. and 2 cu.m are presented in below table: 7.4.4

Table: 7.4.4

The Discounted Measure Values of B:C Ratio, NPW **and IRR**

Name **of** the **Fuel**	1 cu.m plant			**2 cu.m plant**		
	B:C Ratio	NPW (in Rs.)	IRR (in %)	B:C Ratio	**NPW** (in Rs.)	**IRR** (in %)
Fuel wood	4.36	17820.61	22.50	8.37	53102.10	41.03
Kerosene	6.68	30126.75	23.85	11.79	77756.94	42.64
LPG	8.37	39066.45	24.34	14.28	95636.34	43.32
Electricity	7.21	32919.34	24.03	12.55	83214.42	42.88

7.5 ECONOMIC ANALYSIS

The Economic analysis of bio-gas plants explains the Installation cost, Average Annual Costs and Discounted cash flow measures of Bio-gas plants of 1 cu.m and 2 cu.m.

7.5.1 The Installation cost of Biogas Plants

The Installation costs of 1 and 2 cu.m plants are 5,400 and 7,300 respectively, When the plants are installed without subsidy. It is observed form Annexure 8 and 9, which the cost of digester and gasholder alone amounted to about 90% of the total cot of the installation of the plants.

7.5.2. Average Annual Costs and Returns

The average annual costs were Rs. 3191.00 and Rs. 4426.50 for 1 and 2 cu. m size plants, when subsidy is excluded in the computations. As the subsidy is uncertain i.e. it varies between the region, caste and others. As indicated in table 7.4.1, the operating cost are very low for the both plants.

The annual returns for 1 and 2 cu.m plants are presented in table 7.4.2. The annual returns consisted of the value of fuel displaces and sludge manure. The total annual returns of different fuels for 1 cu.m are Rs. 5906.60, Rs. 7352.00, Rs. 8402.00 and Rs. 7680.00 **for** Fuelwood, Kerosene, LPG and Electricity respectively. For 2 cu.m are Rs. 11509.20, Rs. 14405.00, Rs. 16505.00 and Rs. 15046.00 for Fuelwood, Kerosene, LPG and Electricity respectively.

It is interesting to note that among the fuels, the value of LPG is saved was the major items and it amounted to Rs. 5211.00 and Rs. 12078.50 for 1 and 2 cu.m respectively.

7.5.3 **Discounted** Cash **Flow (DCF) measures for** Biogas **Plants**

The DCF measures were computed based on the project costs and revenues obtained from the sample beneficiaries. The DCF measures, viz, B.C ratio, NPW and IRR for 1 and 2 cu.m plants are presented in table 7.4.4.

The DCF measures were highest when the returns were assessed by valuating the Fuelwood, Kerosene, LPG and Electricity saved at actual price / producers price and subsidy is not included, this is presented in table 7.4.4 for 1 cu.m andl 2 cu.m plants. The study revels that DCF measures for 2 cu.m plant were higher then that of 1 cu.m plant. This is because the annual returns of 2 cu.m plants were grater than that of 1 cu.m plant.

7.6 ECONOMIC ANALYSIS OF COMMUNITY BIOGAS PLANTS IN INDIA

The economic feasibility and financial viability of community scale plant" is limited by similar considerations as household units, although economies of scale will tend to make them a better prospect financially. However, it appears that the primary barriers to diffusion are not economic or technical, but rather social and organizational. Since the benefits from a community plant can be shared by poorer households that would not be able to afford the investment and operating cost of household units, community plants may be more socially viable than the smaller units.

The introduction of large scale (greater than 40 ma) plants for use by rural communities has been prompted by two important considerations. First, the alternative of a household plant is not an option for most Indian households. Only 5% of the cattle-owning households have the minimum 5 animals needed to provide feedstock (Prasad et al., 1974), and perhaps even fewer could bear the additional cash outlay involved in the substitution of biogas for firewood and dung, previously collected by family labour. Second, economy of scale is one of a number of potential techno-economic advantages of community over household plants, though this partly offset by the larger volumes of dung required at one site, and in the greater organizational requirements.

Two community plants have been evaluated in some detail; one at Fateh Singh Ka Purwa in Uttar Pradesh by Bahadur and Agarwal (n.d.), Ghate (1979), and Bhatia and Niamir (1979), and one in Xubadthal, Gujarat by Maulik (1982). Evaluating community plants has the same drawback as in household units, of valuing input and output, so it is not surprising that three evaluations of the Uttar Pradesh plant arrived at three different economic benefit-cost ratios; 1.14:1, 1.54:1 and 0.6:1. Moulik's (op. cit.) financial analysis of the Gujarat plant did not include a final estimate of financial viability, but it was evident from current performance that the profit from plant operation would not meet the loan and interest payments due. Other analyses agreed that the plant was not financially viable, though Ghate (op. cit.) suggested that at least part of the deficit on the costs of cooking, lighting and water supply (from a biogas powered tube well) could be met through a surplus generated by the dual fuel engine used for crop processing.

Financially nonviable plants can be justifiably supported through state subsidies, if overall analysis is sufficiently positive. The basis for an accurate economic benefit-cost analysis is still lacking, however, one important difference from the analysis of household plants is the greater variety of possibilities for the use of gas from a community plant. Gas availability varied in the Fateh Sing] Ka Purwa plant from below 1900 ft^3 /day in winter, to above 2700 ft in summer (Bhatia and Niamir, op. cit.). This gas was used for cooking, a generator to supply lighting and to power a tube well, and a dual fuel engine running a flour mill, a thresher and a chaff cutter. The proportion of gas distributed to these different end uses has been considered to be a critical determinant of both the financial and social worth of the plant because both market and shadow prices of the gas will vary. An alternative approach to economic evaluation assumes the highest value use until the demand is met, then the next, etc. This higher use(s) requires a unique fuel characteristic with unique replacement value. The combination of end uses that will maximize benefits depends upon the assumptions used to value gas put to different end uses.

In their social analysis, all three studies used the shadow price of soft coke or coal to value biogas in cooking. They arrived at three different estimates: 11.6, 15 and 38.3% as the share of cooking in the total benefits. Bhatia and Niamir (op. cit.) also used the price of dung and firewood to value biogas in cooking, giving a second estimate of 63% of total benefits from this end use. In this second estimate, dung was valued using the shadow price of imported fertilizer. Under this assumption over half of the total benefits were due to the use of dung for fertilizer, instead of for cooking which is now carried out using biogas. Since cooking uses about 60% of the gas, these widely differing percentages (11.6 to 63%) can be used to support a case for or against the use of biogas for cooking in preference to other end uses. Different initial investment and operating costs will also affect the calculation). Financial analysis of the value of different end uses was less equivocal; non-cooking uses, particularly substitution for diesel fuel, are better.

What these ambiguous results demonstrate is the inability of social and financial analysis to determine policy in the absence of a strategic energy policy framework. The possible deforestation and loss of agricultural output associated with the use of firewood and dung has to be evaluated in conjunction with the foreign exchange costs of diesel imports in the case above, but this is only one example of the types of valuation implicit in all energy policy decisions. A second, and equally crucial limitation, is the difficulty analysts face in incorporating secondary benefits. Some, such as health benefits, are extremely difficult to quantify, while others, such as improved community spirit through a successful biogas program, are impossible. In the community programs discussed above, a variety of secondary benefits were acknowledged by participants as being very important to their perception of the value of biogas plants. This was particularly true of women who benefited from improved kitchen conditions, and savings on cooking time.

The technology evaluated in the above studies was an expensive KVIC design. In a Southern Indian village a community plant is being built to meet the specific village energy requirements, and financial viability is possible (Lichtman, 1983). It is worth noting, however, that both the plants discussed above were also financially viable on paper. A second, and critical feature of the Southern Indian program is the involvement of the villagers in the planning of the biogas plant. In both the plants discussed above the chief reasons for their difficulties were organizational, rather than economic or technical. Moulik in the Gujarat study, and Bahadur and Agarwal, in the Uttar Pradesh study, provide detailed descriptions of numerous organizational and operational problems that were related to village social structure, and the relationship between the villagers and the implementing agency. All the authors of these studies agree that the solution of such social problems with community plants requires the involvement of users from the very first stages of planning.

7.7 CONCLUSION

Bio-gas is more than a renewable energy technology. As a comprehensive rural development tool, it allows villages to meet fundamental needs using local resources. It is a labor-intensive technology, and therefore a significant source of employment, especially for village women who collect the dung and sell the slurry, and for the rural laborers who construct and maintain the plants. Some family biogas digesters even support small-scale enterprises, by providing electricity for agricultural and cottage industries. Community digesters encourage collective responsibility and local participation in decision-making. The role that women play in the operation enhances their social standing. Biogas also helps ease the traditional burdens of women and girls, by reducing the amount of time they have to spend collecting fuel-wood. And with the advent of biogas-powered pumps, it also reduces the time spent fetching water.

A biogas digester with a 1& 2 cu.m capacity plants - enough to meet the cooking needs of a family of four and eight respectively- costs approximately Rs. 5400 & Rs.7300 for 1 & 2 cu.m respectively. The costs of inputs are minimal assuming the household has a water supply and at least five cows - the minimum necessary to supply the digester. Yet despite government subsidies that run as high as 85 percent of total costs, start-up expenses can seem formidable to fanners, whose participation in the cash economy is often limited. But in this thesis, while computing the cost and returns of the project, the subsidies are not considered because it always varies and the subsidies are differently determined.

Thus, this chapter is mainly deals with the economic analysis of bio-gas plants with the help of capital budgeting techniques i.e Payback method, NPV, IRR and Cost-benefit methods. The results are showing positively in the case of bio-gas to other alternatives of rural energy. With the above results we can say that the next generation can depend on bio-energy (bio-gas)for meeting all the energy needs. The world can be saved from future energy crisis by bio-energy and its appliances.

Chapter – VIII
POLICY RECOMMENDATIONS

8.0 SUMMARY

Since its inception, biogas has established itself as a technology with great potential which could exercise major influence on the energy scene in rural areas. Yet the experience so far shows that the field level performance has not matched the expectations because of various factors. Hence, there is a need to take serious steps that could translate the high potentional into high performance.

This study is undertaken to understand the prospects of Non-conventional sources, particularly the biogas. The idea behind is to bring the uses and applications of biogas energy sources to the limelight and show that they can be very much useful if there are any energy crises (Rural) and they can also be good alternates in the future and can reduce the pressure on the fossil fuels. Though these sources are developing al a slow rate, still, there is a hope to have a bright future for these sources. The Biogas energy has developed as early as 4th century or even before, and their use was not widely recognized or appreciated till the recent years.

There are only few studies have done in this area. The developed countries have understood the importance of these resources and so took interest in their development. The developing and underdeveloped countries also need to understand the importance of this Non-conventional energy resource.

In the economic analysis, we notice that simple biogas plant involving low investment, quick returns and a short pay back period offers the highest economic benefit, but it requires much maintenance and renewal work, while its management is complex.

Centralized biogas supply systems are an important method of supplying energy for living in a modernized rural area in the future. At present, however, its economic benefit is low. It is necessary to study new fermentation processes, to increase its economic benefit.

The present study also revealed that the adopters were getting most of these intangible benefits. If quantitative estimation of these benefits were made, the profitability of gas plants would have still increased and the cost for unit of energy decreased.

There was unanimous option among the adopters about the cleanliness the residence, utensils and comfort in cooking due to use of biogas. Most of them felt that cooking with biogas was really a comfort even when compared to electricity or commercial cooking gas, let alone fuel wood, because of the regular supply and hazards. These findings also confirm the findings of previous studies by Sathianathan, 1975; Bhatia, 1977; Patcl1980; Guldager,1980.

Thus, the widespread adoption of Biogas plants would go a long way in meeting the rural energy needs, conserving the forest resources, safeguarding the nutrient value of dung and thereby bringing agricultural prosperity of the nation.

8.1 POLICY ISSUES, RECOMMENDATIONS AND SUGGESTIONS

Non-Conventional is still in immature and primary stages of development. But if these energy sources have to be proved to are good alternatives for the new millennium. Then it is very much necessary that some serious steps have to be taken by the central and state government for their development. These sources have high potentiality, but as they are not used to their optimal level, much of these sources are wasted. Some times they also remain to be under or unused. The remedy for this problem is to develop the technology and popularize it in such a way that even the layman can understand its importance. To develop the technology the government has to play the major role. It has to either import the technology or develop it by opening research centers. It might be difficult to the Third World Developed countries to follow to second path. So, far these countries importing is better. This does not mean that these countries should totally depend on the imported technology, rather it means that these countries must import the technology and then try to develop it in their own country, The main problems in this area are that, most of the countries are unaware about the developments taking place in this field. By educating the common public, they become aware of the developments around them and automatically understand the need and importance of non-conventional sources for the present conditions of scarce energy and excess demand for the conventional sources. Due to lack of education and technical know how these problems take root in the developing and third world countries. So, the only way to make the country walk in the path of developing these sources is by making the common people aware of the present energy crisis and further educating them to understand the hopeful bright prospects of these sources. These sources can be proved the alternate and can also be a remedy for the energy crisis in the coming years. The main measure that a country or an institute can take to develop these sources is to develop the technology, as it is the only way to have improvements in this area. By doing so the costs come down and people would be will to opt these Non-conventional collectors, rather than conventional resources.

Based on the performance of the programme, the strengths and weaknesses of the strategies, *the following suggestions and Recommendations have been made:*

- A need-based approach should be adopted rather than a target-oriented one. This can be achieved only through integrating the plan for biogas development into an overall energy plan for a particular region or ecosystem instead of deciding targets in isolation. Such energy plans could then be integrated at a higher level for policy making, budget allocation, etc.
- In order to make the biogas available to poor who actually need it, low-cost designs must be developed.
- The efforts in research and development should be expedited to produce alternative feed-stocks, building materials, etc. Special thrust should be given to micro biology of biogas to develop bacteria that could work at low temperatures, with low water consumption, so that biogas cold be used all over the country uniformly.

- To improve the performance of the project itself, effective feedback systems need to be developed and special attention paid to training masons, user education, and so on.
- Efforts should be made to promote biogas in urban, semi-urban areas through the use of sewage and solid wastes.
- Promoting the technological level and developing improved, pragmatic, and efficient cook stoves and biogas digesters by depending on scientific and technological progress.
- Strengthening training activities to set up a contingent of a sufficient number of qualified technicians nationwide.
- Developing rural energy industry and sales- service systems, which could coordinate with the market system (Ex: China) and promote the development of biogas digesters.
- Focus on streamlining the repair and maintenance strategies
- Improve the awareness level of Biogas users.
- Streamline an simplify the financial mechanisms
- Undertake capacity building for the NGOs in other technological interventions in rural energy
- Integrate biogas with other developmental programmes at the policy level.
- Focus Research and Development on cost reduction, and alternative feed-stock's.
- Subsidies and tax concessions must be given to encourage their use in commercial and non-commercial organizations.
- These sources must be popularized among the public in such a way that even an uneducated villager can understand the use and implementation of these energy sources.

Thus, with the above suggestions and recommendations there is a hope to develop and use biogas (Non-conventional energy source) in the next millennium, in a more intense manner.

8.2 LIMITATIONS OF THE STUDY

The study has its own bottlenecks. If a critical evaluation is undertaken the problems might be get highlighted. The main problem is none availability of reliable data of all the years (particularly related to biogas) and of all the sources concerned. Even the literature found is either too old or repeated, as nothing new improvements have taken place in this Held. So, one cannot find many books concerning this topic. In recent years, there as been significant development in lining bio-gas as an alternate to conventional forms of energy with special reference to rural energy programme. The dissertation identifies the Chinese model and examine the Cost-Benefit Ratio's to further bio-gas applications, while applying benefit- cost analysis, there are difficulties in measuring the direct and indirect effects. There is a need to combine primary data with secondary data in examining the discounted methods i.e, NPV, IRR and Profitable Index Ratio.

The dissertation has done sufficiently to bridge this gap, but there is potential to undertake micro level studies are need to see the feasibility of the bio-gas plants in India. The main sources of data is through TEDDY, DNES, MNES, CMIE and various research organizations and publications. The data that is provided in them is not continues and it does not totally satisfy the purpose of the dissertation. Moreover, the biogas energy is an old technique but this type of energy is recently developed, the scope of study is restricted.

8.3 CONCLUSIONS

- Problems caused due to modification brought in the design specification at the local level.
- The reasons for disfunctionality is were mainly non-technical. The most common reason is fluctuation in the cattle holding and hence, hung availability. Very few plants had constructional defects.
- Seasonal variation in gas production due to lack of temperature control and poor insulation of the plant.

- Major percentage of the biogas plants were found in use.
- Inefficient designing of gas appliances.
- The awareness regarding usage aspects was low among the biogas plant users. The most common problem was that of underfeeding.
- Lack of awareness due to illiteracy.
- Lack of financial resources or capacity to borrow loans from financing institutions.
- Defective contraction by untrained or improperly trained masons.
- Delayed sanction and disbursement of bank loans.

8.4 CHALLENGE OF BIO-GAS PLANTS

The vast range of problems indicated in this, shows clearly that their solution can only come from advanced scientific and engineering inputs and from a multi-disciplinary Research and Development effort. Such capabilities lie today in the major scientific and technological institutions which must therefore take up the challenge. Unfortunately, it is precisely such instructions which have thus far ignored the science and technology of bio-gas generators.

This was not always the case. As far back as 1923 (over half a century ago) a classic paper on the fermentation of cellulosic wastes was published form the Indian Institute of Science, Bangalore. The introduction to this paper shows clearly the motivation of the authors to contribute to the energy problem. Indian work continued to be in the forefront until around 1952, the designs of various types of small bio-gas plants were first accomplished in this country.

Then, for some odd reason, for two decades bio-gas plants were denied the type of attention that they needed and deserved. Was this due to large influx of foreign-trained scientists who used western criteria to influence the choice of Research and Development problems?

During this long period of neglect, institutions like the KVIC and Indian Agricultural Research Institute per severed with their interest in bio-gas fully justified by the logic of the oil crisis.

The time has now come for major Research and Development institutions to contribute their share. To discharge that responsibility, they must realize that there are as many scientific and technological challenges in the fermentation of dung as in the fission of nuclei. Or, will these institutions wait till bio-gas technology become fashionable in the west, as it will soon become?

8.5 FUTURE RESEARCH POSSIBILITIES OR SCOPE OF THE STUDY

- Comparison of social costs and benefits of bio-gas plants and rural electrification.
- Comparison of social costs and benefits of small number of large size biogas-plants vs a large number a small-size plants, taking into account economies of scale and village demography.
- Methodology and techniques for routine decision-making regarding optimum location(s), size(s) and number of bio-gas plants in a particular village depending upon its cattle and human population, distribution of houses etc.
- Technology of the collection, and if necessary preparation, of various fermentable materials other than dung - poultry wastes, agricultural cellulosic wastes, eg. Bagasse, cannery wastes, etc.
- Design of latrines from the point of view of aesthetics, hygiene and non-manual introduction of human wastes into bio-gas plants.
- Study of the fermentation chemistry and microbiology with emphasis on the choice and management of micro-organisms for optimum methane production.
- Optimum of fermentation process for villages where water is scarce, i.e., development of "drier" processes, and water re-circulation systems.
- Development of cell-free enzyme processes for methane production.
- Research and development on alternative lining (polythene, creosote, earthwork, etc.) for the digester.

- Study of safety hazards and design of safety procedures for plant operation and for handling and storage of methane.
- Study of fortification of bio-gas fertilizer with chemical fertilizers.
- Methods of storage of bio-gas including compression into cylinders, materials of contraction of containers, eg. Balloons.
- Design and development of methane engines to drive electricity generators and vehicles.
- Study of the loss of fermentable solids into the sludge as a function of various factors.

A3. 3.13 NATIONAL PROGRAMME ON IMPROVED CHULHAS (RATES OF CENTRAL SUBSIDY DURING 2001-2002)

Type of Chulha	Amount of Central Subsidy per Chulha
Durable Fixed-type Chulha with Chimney (i) NE Region States and Sikkim • Other States	 Rs. 270/- Rs. 80/-
Portable Chulha • NE Region States and Sikkim • Islands and notified Hilly and Desert areas • SC/ST Beneficiaries in other states / UTs	 Rs. 135/- Rs. 75/- Rs. 50/-
High Attitude Chulha • NE Region States and Sikkim • Jammu & Kashmir, UP, HP and Hilly districts of West Bengal	 Rs. 450/- 50% of the cost subject to Max. Rs. 250

A3. 3.4.2 CBP/IBP/NBP PROGRAMME (STATE-WISE NUMBER OF PLANTS INSTALLED UP TO 2000-01.

SI. No.	State / Union Territory	Number of Plants Installed
1	Andhra Pradesh	112
2	Assam	2
3	Bihar	38
4	Goa	21
5	Gujarat	156
6	Haryana	51
7	Himachal Pradesh	7
8	Jammu & Kashmir	4
9	Jarkhand	1
10	Karnataka	53
11	Kerala	103
12	Madhya Pradesh	116
13	Maharashtra	448
14	Manipur	4
15	Meghalaya	4
16	Nagaland	7
17	Orissa	39
18	Punjab	634
19	Rajasthan	62
20	Tamil Nadu	224
21	Uttar Pradesh	1254
22	Uttaranchal	31
23	West Bengal	61
24	Delhi	54
25	Pondichery	1
	Total	3487

A7.1 TECHNICAL DATA

Sl.No.	Item	Details
1	Rate of Interest	12%
2	Life of Biogas Plant	20 years
3	Cost of Fuel wood	Rs. 600 / MT
4	Cost of Kerosene	Rs. 10 / kg.
5	Cost of LPG	Rs. 270 / cylinder
6	Cost of Electricity	Rs. 1.50 / unit
7	Cost of dung	Rs. 100 / MT or 0.10 / kg.
8	Cost of dry manure	Rs. 2 / Kg.
9	Quantity of cow dung produced	10 kgs / head (approximately) Gas production is 0.036 cu.m
10	Dry manure	Will be 25% of Wet Dung

A7.2 COMPARATIVE AVAILABILITY OF NUTRIENTS IN BIOGAS SLURRY AND FARM YARD MANURE (F.Y.M.)

S. No.	Type of Manure	Time of decomposition	Loss in quantity during process	Available		
				N	P	K
1	Biogas slurry	1 -2 months	7-10%	1.175%	1.10%	1.0%
2	Farm yard manure (composted under cover)	3-4 months	20-25%	0.9%	0.75%	0.75%
3	Farm yard manure composting	4-6 months	45%	0.75%	0.60%	0.60%

A7.3 COMPARISON OF VARIOUS FUELS

Sl. No	Name of Fuel	Calorific value (Kilo-cal.)	Mode of Burning	Thermal efficiency (%)	Effective heat (Kilo-calories)
1	Gobar Gas (M^3)	4713	In standard Burner	60	2828
2	Kerosene (litre)	9122	Pressure Stove	50	4561
3	Firewood (Kg.)	4708	In open chullha	17.3	814
4	Cow-dung cake (kg.)	2092	-do-	11	230
5	Charocoal (kg.)	6930	-do-	28	1940
6	Soft coke (kg.)	6292	-do-	28	1762
7	Butane / LPG (kg.)	10882	In standard Burner	60	6529
8	Furnace oil (litre)	9041	In water tube boiler	75	6781
9	Coal gas (M^3)	4004	In standard Burner	60	2402
10	Electricity (kwh.)	860	Hot plate	70	602

A7.4 POTENTIAL GAS PRODUCTION FROM DIFFERENT FEED STOCKS

S. No.	Type of feed stock	Gas yield per kg. (Cu.m)	Normal feed availability per animal per day kg (wet weight)	Gas yield per day (Cu.m)
1	Cow dung	0.036	10.0	**0.36**
2	Buffalo dung	0.036	15.0	**0.54**
3	Camel dung	0.056	6.0	**0.336**
4	Horse dung	0.045	10.0	**0.45**
5	**Sheep dug**	0.042	1.0	**0.042**
6	**Pig (Approx. 50** kg)	0.08	2.25	**0.18**
7	Chicken (Approx 2 kg)	0.062	0.18	**0.011**
8	Human excreta	0.07	0.40	**0.28**

A7.5 NUMBER OF CATTLE REQUIRED FOR DIFFERENT CAPACITY OF PLANTS AND FAMILY SIZES

S. No.	Size of plant (m3)	Amount of wet dung required daily (kg)	Approximate no. of cattle required	Approximate family size	Estimate cost of Denabandhu Model
1	1	**25**	2-4	**1-4**	**5,300**
2	2	**50**	4-5	**5-8**	**7,200**
3	3	**75**	6-8	**9-12**	**8,200**
4	4	**100**	**9-10**	**13-16**	**NA**
5	6	150	11-15	17-22	**NA**
6	8	200	13-16	23-26	**NA**
7	10	250	17-20	27-32	**NA**

A7.6 HEATING VALUE OF VARIOUS FUEL USED FOR COOKING AND THEIR REPLACEMENT

S. No.	Name of fuel	Heating value	Replacement value
1	Biogas	4713 K Cal/cu. M	1.0 m3
2	Electricity	860 K Cal/cu. M	4.968 Kwh
3	Fuel wood	4700 K Cal/cu. M	3.414 kg
4	Coal	6930 K Cal/cu. M	1.458 Kg
5	L P Gas	10882 K Cal/cu. M	0.433 Kg
6	Dung Cake	2092 K Cal/cu. M	12.296 Kg
7	Kerosene oil	9122 K Cal/cu. M	0.620 litre

A7.7 **QUANTITIES OF** BIOGAS REQUIRED FOR **DIFFERENT APPLICATIONS**

S. No.	Use	Specification of Appliances	Quantity of Gas Required
1	Cooking	2" Burner, 0.33 cu. M/hr 4" Burner, 0.47cu. M/hr 6" Burner, 0.64 cu. M/hr (@ 55-60% eficiency)	**0.3** cu. **M.** per day per person
2	Lighting	100 Candle power lamp	**0.15** cu.m per hr.
3	Motive Power	75-80% replacement of diesel in dual fuel engine	**0.50** cu.m per **bhp** hour

A7.8 COST ESTIMATE OF 1 CU.M DEENBANDHU BIOGAS PLANT (FOR 40 DAYS HRT)

Item	Unit	Rate (approx) Rs	Quantity	Cost (Rs)
Bricks (I Class)	nos	1.20	750	937.50
Cement	bag	1.65	8	1320.00
Stone chips of 1/2 size	cft	12	30	360.00
Sand (Coarse + Fine)	cft	Lump sum		300.00
GI Pipe 3/4 diameter with sockets	30 cm	Lump sum		30.00
AC pipe 6 diameter	ft	20	6	120.00
Iron bars (6mm diameter for outlet tank cover	kg	20	6	120.00
PVC / HDPE pipe	Mtrs.	25	12	300.00
Bio gas stove and gate value, water remover	Cft.	Lump sum		614.00
Labour charges for pit digging	days	50	5	250.00
Labour charges for construction	days	50	7	350.00
Master Masons charges		Lump sum		500.00
Local transport & Miscellaneous charges		Lump sum		150.00
Total				**5351.50**

A7.9 COST ESTIMATE OF 2 CU.M DEENBANDHU BIOGAS PLANT (FOR 40 DAYS HRT)

Item	**Unit**	**Rate (approx) Rs**	**Quantity**	Cost **(Rs)**
Bricks (I Class)	nos	1.20	1000	1200.00
Cement	bag	1.65	14	2310.00
Stone chips of 1/2 size	cft	10	**40**	400.00
Sand (Coarse + Fine)	cft	Lump sum		400.00
GI Pipe 3/4 diameter with sockets	**30** cm	Lump sum		30.00
AC pipe 6 diameter	ft	20	6	120.00
Iron bars (6mm diameter for outlet tank cover	kg	20	7	140.00
PVC / HDPE pipe	Mtrs.	25	12	300.00
Biogas stove and gate value, water remover	Cft.	Lump sum		614.00
Labour charges for pit digging	days	50	6	300.00
Labour charges for construction	days	50	10	500.00
Master Masons charges		Lump sum		700.00
Local transport & Miscellaneous charges		Lump sum		250.00
Total				**7264.00**

A7.10 PRESENT VALUE **OF RE.** 1

Years	5%	6%	8%	10%	12%	14%	15%	16%	18%	20%	22%	24%	25%	28%	30%
1	0.952	0.913	0.926	0.909	0.893	0.877	0.870	0.862	0.847	0.833	0.820	0.806	0.800	0.781	0.769
2	0.907	0.890	0.857	0.826	0.797	0.769	0.756	0.743	0.718	0.694	0.672	0.650	0.640	0.610	0.592
3	0.864	0.840	0.794	0.751	0.712	()0.675	0.658	0.641	0.609	0.579	0.551	0.524	0.512	0.477	0.450
4	0.823	0.792	0.735	0.683	0.636	0.592	0.572	0.552	0.516	0.482	0.451	0.423	0.410	0.373	0.350
5	0.784	0.747	0.681	0.621	0.567	0.519	0.497	0.476	0.437	0.402	0.370	0.341	0.328	0.291	0.269
6	0.746	0.705	0.630	0.564	0.507	0.456	0.432	0.410	0.370	0.335	0.303	0.275	0.262	0.227	0.207
7	0.711	0.665	0.583	0.513	0.452	0.400	0.376	0.354	0.314	0.279	0.249	0.222	0.210	0.170	0.159
8	0.677	0.627	0.540	0.467	0.404	0.351	0.327	0.305	0.266	0.233	0.204	0.179	0.118	0.139	0.123
9	0.645	0.592	0.500	0.424	0.361	0.308	0.284	0.263	0.225	0.193	0.167	0.144	0.134	0.108	0.094
10	0.614	0.558	0.463	0.386	0.322	0.270	0.247	0.227	0.191	0.162	0.137	0.116	0.107	0.085	0.073
11	0.585	0.527	0.429	0.350	0.287	0.237	0.215	0.195	0.162	0.135	0.112	0.094	0.087	0.066	0.056
12	0.557	0.497	0.397	0.319	0.257	0.208	0.187	0.168	0.137	0.112	0.092	0.076	0.069	0.032	0.043
13	0.530	0.469	0.368	0.290	0.229	0.182	0.163	0.145	0.116	0.093	0.075	0.061	0.055	0.040	0.033
14	0.505	0.442	0.340	0.263	0.205	0.160	0.141	0.125	0.099	0.078	0.062	0.049	0.044	0.032	0.025
15	0.481	0.417	0.315	0.239	0.183	0.140	0.123	0.108	0.084	0.065	0.051	0.040	0.035	0.025	0.020
16	0.458	0.394	0.292	0.218	0.163	0.123	0.107	0.093	0.071	0.054	0.042	0.032	0.028	0.019	0.015
17	0.436	0.371	0.270	0.198	0.146	0.108	0.093	0.80	0.060	0.045	0.034	0.026	0.023	0.015	0.012
18	0.416	0.350	0.250	0.180	0.130	0.095	0.081	0.069	0.051	0.038	0.028	0.021	0.018	0.012	0.009
19	0.396	0.331	0.232	0.164	0.116	0.83	0.070	0.060	0.043	0.031	0.023	0.017	0.014	0.009	0.007
20	0.377	0.312	0.215	0.149	0.104	0.073	0.061	0.051	0.037	0.026	0.019	0.014	0.012	0.007	0.005

A7.ll PRESENT VALUE OF **RE.1** RECEIVED ANNUALLY FOR N YEARS.

Years	5%	6%	8%	10%	12%	14%	15%	16%	18%	20%	22%	24%	25%	28%	30%
1	0.952	0.943	0.926	0.909	0.893	0.877	0.870	0.862	0.847	0.833	0.820	0.806	0.800	0.781	0.769
2	1.859	1.833	1.783	1.736	1.690	1.647	1.646	1.605	1.566	1.528	1.492	1.457	1.440	1.392	1.361
3	2.723	2.676	2.577	2.487	2.402	2.322	2.283	2.246	2.174	2.016	2.042	1.981	1.952	1.868	1.816
4	3.546	3.465	3.312	3.170	3.037	2.914	2.855	2.798	2.690	2.589	2.494	2.404	2.362	2.241	2.166
5	4.330	4.212	3.993	3.791	3.605	3.433	3.352	3.274	3.127	2.991	2.864	2.745	2.689	2.532	2.346
6	5.076	4.917	4.623	4.335	4.111	3.889	3.784	3.685	3.498	3.326	3.167	3.020	2.951	2.759	2.643
7	5.786	5.582	5.206	4.868	4.564	4.288	4.160	4.039	3.812	3.605	3.416	3.242	3.161	2.937	2.802
8	6.463	6.210	5.747	5.335	4.968	4.639	4.487	4.344	4.078	3.837	3.619	4.421	3.329	3.076	2.925
9	7.109	6.802	6.247	5.759	5.328	4.946	4.772	4.607	4.303	4.031	3.786	3.566	3.463	3.184	3.019
10	7.722	7.360	6.710	6.145	5.650	4.216	5.019	4.833	5.494	4.192	3.923	3.682	3.571	5.269	3.092
11	8.306	7.887	7.139	6.495	5.937	5.453	5.234	5.029	4.656	4.327	4.035	3.776	3.656	3.335	3.147
12	8.863	8.384	7.536	6.814	6.194	5.660	5.421	5.197	4.793	4.439	4.127	3.851	3.725	3.387	3.190
13	9.394	8.853	7.904	7.103	6.424	5.842	5.583	5.342	4.910	4.533	4.203	3.912	3.780	3.427	3.223
14	9.899	9.295	8.244	7.367	6.628	6.002	5.724	5.468	5.008	4.611	4.265	3.962	3.824	3.459	3.249
15	10.380	9.712	8.559	7.606	6.811	6.142	5.847	5.575	5.092	4.675	4.315	4.001	3.859	3.483	3.268
16	10.838	10.106	8.851	7.824	6.974	6.265	5.954	5.669	5.162	4.730	4.357	4.033	3.887	3.503	3.283
17	11.274	10.477	9.122	8.022	7.120	6.373	6.047	5.749	5.222	4.775	4.391	4.059	3.910	3.518	3.295
18	11.690	10.828	9.372	8.201	7.250	6.467	5.128	5.818	4.273	4.812	4.419	4.080	3.928	3.529	3.304
19	12.085	11.158	9.614	8.365	7.366	6.550	6.198	5.877	5.316	4.844	4.442	4.097	3.442	3.539	3.311
20	12.462	11.470	9.818	8.514	7.469	6.623	6.259	5.929	5.353	4.870	4.660	4.110	3.954	3.546	3.316

BIBLIOGRAPHY

Adelman, M.A., "Comment on: R.W. Bentley, "Global oil & gas depletion", *Energy Policy 30 (2002) 189-205" Energ Policy. 31, No. 4 (2003): 389-390.*

Agarwal, A, (1998): Myths about forest depletion. *Down to Earth,* Vol.7, No.1, pp29-42

Agarwal, **Anil,** (1984), The Cooking Energy Crisis, it's Impact on Environment and Human Needs, *Institute of Management, Ahmedabad.*

Amartya Sen, (1975), On Economic Equality, *Oxford University Press Delhi.*

Anderson, T., **Doig,** A., Rees, D. and **Khennas,** S., Rural Energy Services: A handbook for sustainable energy development. ITDG Publishing, 1999.

Assime Kopoulos. V., and Domenikos.H.G., Consumption Preference Structure of Greek Household., *Energy Economics, July 1991.*

ASTRA **(1981),** Alternative and Traditional Energy Sources for the Rural Areas of the Third world.

Bailey, D.G.B. (1976) " The Bio-Gas System: serious Energy Source or Environ - mental Fad" *Natural Resource Forum (1): 55 - 62.*

Bajpal.A.D.M., (1994), Global Energy Consumption: Concentration and the Determinants, Indian Economic Journal, Vol. 41, (4), PP. 64-78.

Banerjee, S, (1996): The Enemy Within: *Down to Earth.* Vol.5, No.4, pp27-32.

Barnelt.A., Bell.M. and Haffman.K., (1982), Rural Energy and Third World: A Review at Social Science Reserch and Technology Policy, Pergamon Press, Oxford.

Barnet, A., L. Pyle S. K. Subramaniam (197 8). Biogas Technology in the Third World. Ottawa, Ontario, *International Development Research Council.*

Behl, HM, Vimal, OP, (Eds.) (1985): *Procs. National Seminar Cum Workshop: Bio Energy Education.* Ajmer, pp31-42.

Benarjee.R., (1977), Model for Energy Planning, *Economic and Political Review, April 27th.*

Bhatia, R, (1990): Diffusion of renewable energy technologies in developing countries: A case study of biogas engines in India. *World Development,* Vol.18, No.4, pp575-590.

Bhatia, R. (1977) "Economic Appraisal of Bio-Gas units in India, Framework for Social Benefit Cost Analysis." *Economic and Political Weekly 12 (33-34): 1503- 1518.*

Bhatia.R., (1975), Energy and Rural Development in India, I.E.G. University of Delhi.

Bhattacharya.D., (1984), Energy Consumption It's Stated and Implied Meaning, Energy

Biswas, W. K. and N. J. D Lucas (1997) "Economic Viability of Biogas Technology in a B. Bangladesh Village." *Energy Journal 22 (8): 763-770.*

Bowonder.B., and Ravi shanker.K., (1983), Energy use in Rural areas at India. (Hyderabad).

Bowonder.B., Prakash Rao., N., Das Gupta.B., and Prasad. (1985), Energy use in Eight Rural Communities in India, *World Development, Vol., 13, PP. 1263-1286.*

Chand, AD, Murthy, N, (1988): District level management system for biogas programme. *Economic and Political Weekly.* Vol.23, No.22, ppM80-M84.

Chand, AD, Natarajan, U, (1987): Management information system for biogas development. *Economic and Political Weekly.* Vol.22, No.48, ppM153-M160.

Chandra Shekhar, Shina, Ramana.P. Venkata and Veena Joshi.,, Rural Energy Planning in India: Designing Effecting Intervention Strategies, *Energy Policy, 1994, May, Vol 22, No.5, PP. 403-414.*

ChandraShekhar, D.M., B.V. Krishna Murti and S.R. **Ramaswamy** (1987), "Social Forestry in Karnataka, An Impact Analysis." *Economic and Political Weekly XX11(24): 935-941.*

Chawla, O.P. (1986). Advances in Biogas Technology, New Delhi, *Indian Council of Agricultural Research.*

Corveer and Klaus Enevoldsen, (1993), Wood in Rural Energy Planning : Issues and Strategies for Discussion, *Tata Energy Research Institute, December, Vol.3 No. 4, pp. 323-337*

Dahiya, A.K. and P. Vasudevan (1986). "Biogas Plant Slurry as and Alternative to Chemical Fertilizer." *Biomass 9: 67-74.*

Dandekar, H.(1980). "Gobar Gas Plants : How Appropriate are They?" *Economic and Political Weekly XV(20):887-893.*

Daxiong, Q, Shuhua, G, Baofen, L, Gehua, W, (1990): Diffusion and innovation in the Chinese biogas programme. *World Development,* Vol.18, No.4, pp555-563.

Desai. A.V., (ed)., (1990), Pattern of Energy use in Developing Countries, *Willey Eastern Limited, New Delhi.*

Desai.D., (1986), Energy - GDP Relationship and Capital Intensity in LDC, *Energy Economics, Vol.8 (2), PP. 113-117.*

Desai.V., (1982), Rural Energy Survey in India, *NCAER.*

Dunkerley.J., Macauley.M., Naimuddin.M., and Agarwal P.C., (1990), Consumption of Fuel Wood and Other Household Cooking Fuels in Indian cities, *Energy Policy, Vol. 18, No.1, January/February.*

Dunstass.R.H., and Schmidt. R.H., (1998) Structural Charges in Residential Energy Demand, *Energy Economics, Vol. 9 (1), pp.149-453.*

Dutt.G.S., (1978), Energy use in Rural and Urban India, Center for environmental studies, Princeston.

Dutta, S., I.H. Rehman, P.Mahotra and V.P. Ramana (1997). Biogas: **The Indian NGO** Experince, AFPRO-CHF Network Programme, New Delhi, *Tata Energy Research Institute.*

EIA (United States Energy Information Administration) (1999): *Country Profile: India.*

Ellen L. Hugen - Conmnwick, (1985), Mairoobi Household and their Energy Use: An Economic Analysis at Consumption Patterns, October, *Energy Economics, Vol. 7, No.4.*

Folley.G., (1992), Rural Electrification in the Developing World, *Energy Policy, Vol. 20 (1), pp. 145-252*

GATE (Deutsches Zentrum fur Entwicklungstechnologien)(1999): *Biogas technology in India.* Eschborn, Germany.

Gaur, A.C., S. Neelakantan and K.S. Dargan (1984). Organic Manures, *Indian Council of Agricultural Researchn New Delhi*

Geeta, GS, Jagadeesh, KS, Reddy, TKR, (1990): Nickel as an accelerator of biogas production in water hyacinth *(Eichhornia crassipes). Biomass* 21(1990) 157-161.

Gerald Teach, (1992), The Energy Transition, *Energy Policy, February, Vol.20, No.2.*

Ghate, P.B. (1979). "Biogas : A Decentralized Energy System, A **Pilot** Investigation Project." *Economic and Political Weekly XIV(27): 1132-1136.*

Girija Sharavan, (1987), Energy Use **in Rural Gujarat,** New **Delhi.**

Girippa.S., (1986), Rural Energy Crisis, *Himalayan publishing House.*

Gita Dendukuri, Energy use in Rural Households al Semi - Arid Region of Andhra Pradesh.

Gitonga, Stephen, Biogas Promotion in Kenya. Intermediate Technology Kenya, 1997.

Guldager, R. (1980). "Biogas as an alternative energy source." *ITCC Review(3):49-55*.

Gunnerson C. **G. and Stuckey D.** C, Anaerobic Digestion - Principles and Practices for Biogas Systems. World Bank Technical Paper No 49, The World Bank, 1986.

Gustavsson, M. (1995). Bio-gas and Development-A case study among tribal communities in Orissa India, Humanekologiska rapporter 23, Goteborg University, April.

Habig, C, (1985): Influences of substrate composition on biogas yields of methanogenic digesters. *Biomass*, 8 (1985) 245-253.

Hall, DO, Ravindranath, NH, (1994): Indian forest conservation and tropical deforestation. *Ambio*, Vol.23, No.8, pp521-523

Hall, DO, Rosillo-Calle, F, de Groot, P, (1992): Biomass energy: Lessons from case studies in developing countries. *Energy Policy.* Vol.20, No.1, pp62-73.

Haung. J. R., (1993), Electricity Consumption and Economic Growth : A Case Study of China, *Energy Policy Vol.21, (8), pp.717-720.*

Huescher. W. S., and Hommer E. **W.,** (1992), Energy for Sustainable Rural Development, *Energy Policy, June, Vol.20, NO.6.*

ICAR (1976). The Economics of Cow-Dung Gas Plants (A Report), *Indian Council of Agricultural Research, New Delhi, April.*

Iyenger. N.S., **Jsin. L.R., and Srinivasan.T.N.,** Economics of Scale in Household Consumption : A Case Study, *Indian Economic Journal Vol.15., Econometrics Annual, pp.465-477.*

Jain, D. (1996). "Valuing Work: Time as a Measure." *Economic and Political Weekly XXXI (43): WS46- WS57.*

Jawurek, HH, Lane, NW, Rallis, CJ, (1987): Biogas/petrol dual fuelling of SI engine for rural Third World use. *Biomass* 13 (1987) 87-103.

Johan Soussan., Evan Mercer.D., and Phil.O' Keeta., (1992), Fuelwood Policies for the 1990's, February, *Energy Policy, Vol. 20, NO. 2.*

Johansen, T.B. et al, Renewable Energy Sources for Fuels and Electricity. Island Press, Washington D.C., 1993.

Jones. D.W., (1990), Energy use and Fuel Substitution : Lessons Learned Application to Developing Countries, *Tata Energy Research Institute.*

Joshi., (1988), Rural energy Demand and Rate of Improved Chullas, Economic policy Issues, *Tata Energy Research Institute.*

Kadekodi, (1985), Derived Demand Elasticity in a multi sect oral frameworks, *Journal of Quantitative Economics.*

Kalia, AK, (1988):Development and evaluation of a fixed-dome plug flow anaerobic digester. *Biomass* 16 (1988) 225-235.

Karekezi, S. and Ranja, T., Renewable Energy Technologies in Africa. AFREPEN, 1997.

Kathteen and Abdulla, (1994), Energy Policies for Sustaining Development in Developing Countries, *Energy Policy, January, Vol.22, No.1.*

Kaviraj, S. (1986). "Indira Gandhi and Indian Politics." *Economics and Political Weekly XXI (38-39) : 1967 - 1708.*

Khandelwal, K.C and P.C. Maithani (1989). Manual of Biogas Plants, *Ministry of Non-conventional Energy Sources (MNES), Government of India, New Delhi.*

Khandelwal, K.C.(1990). Biogas Technology & Implementation Strategies-Indian Experience. *International Conference on Biogas-Technologies and Implementation Strategies, Pune, India.*

Kishore, V.V.N. (1987), Biogas Technology : Potential, Problems and Research needs symposium on Alternate Sources of Energy and their Industrial Applications, Nehru Centre, Bombay.

Kishore, V.V.N. and C.S. Sinha (1990). Biogas Technology in India : Status and Prospects. PACER Conference on the Role of Innovative Technologies in India's Power Sector, *Tata Energy Resource Institution, Delhi.*

Kishore, V.V.N., V.V.R. Rao and P. Raman (1986). Some Problems of Implementation of Biogas Technology in Rural Areas, *Tata Energy Resources Institute, Delhi.*

Kristoferson L. A., and Bokalders V., Renewable Energy Technologies - their application in developing countries. ITDG Publishing, 1991.

Kulshreshtha, A.C. and G. Singh (1996). "Domestic Production by Gender in the Framework of 1993 SNA." *Economic and Political Weekly XXXI(51) : 3330-3336.*

Kumar, A.N. Reddy and K.K. Prasad (1977). "Technological Alternatives **and** the Indian Energy Crisis." *Economic and Political Weekly 12(33-34) : 1465-1502.*

Kurien, C.T. (1996). Economic Reforms and the People. Delhi, Madhyam Books.

KVIC (1976). Gobar Gas, On the March, Bombay, Khadi & Village Industries Commission.

KVIC (1977). Gobar Gas, Why & How. Bombay, Khadi & Village Industries Commission.

KVIC (1993): *Khadi and V.I Commission and its Non-Conventional Energy Programmes.* KVIC, Bombay, India.

Leach, G, (1987): Household energy in South Asia. *Biomass* 12 (1987) 155-184.

Leach. G., (1992), The Energy transition. *Energy Policy, Vol. 20,(2). Pp116-123.*

Lewanhak, S, (1989): *The Revaluation of Women's Work.* Earthscan, London. P147.

Lichtman, RJ, (1983): *Biogas Systems in India.* VITA (Volunteers in Technical Assistance). Virginia, USA.

Maheshwar, D, Vimal, OP, Singh, KK, (1989): Biomass gasification in India - DNES activities. *Biomass* 18 (1989) 197-204.

Maikhuri, RK, Gangwar, AK, (1991): Fuelwood use by different tribal and non-tribal communities in north-east India. *Natural Resources Forum*, May 1991, pp 162-165.

Makhijani, A. (1977). "Energy Policy for Rural India." *Economic and Political Weekly 12(33-34) : 1451-1464.*
Management, PP. 16-22.

Maurice.F. Strong, (1992), Energy, Environment and Development, *Energy Policy, June. Vol. 2, No. 6.*

MNES (1990 - 02). Annual Reports, Ministry of Non-Conventional Energy Sources, *Government of India, New Delhi.*

Moulik, T.K. (1985). "The Biogas Programme in India and China." *AMBIO 14(4-5) : 288-292.*

Moulik, T.K. (1990). Diffusion of Biogas Technology : Strategies and Policies. *International Conference on Biogas-Technologies and Implementation Strategies, Pune, India.*

Moulik, T.K. and U.K. Srivastava (1975). Biogas Plants at the Village Level, Problems and Prospects in Gujarat, *Indian Institute of Management, Ahmedabad.*

Moulik, TK, (1981): Biogas: The Indian experience: Technical feasibility alone is no guarantee of success. *Unesco Courier.* No.7, pp33-34.

Nag, **KN, Mathur, AN, Ali, NM,** (1985): Energy from biomass: An economic analysis.

Nag, **KN, Mathur, AN, Chhabra, KK,** (1986): Adoption of biogas plants in rural and tribal villages of Udaipur. *Journal of Rural Development.* Vol.5, (5) pp553-560.

Nagaraju P (2000), Rural Energy Demand: An empirical analysis, *M.Phil Dissertation University of Hyderabad, Hyderabad.*

Narauan.S., (1985), Pricing of Coal: The Indian Experience, *Energy Management, pp.199-208.*

Natarajan, (1979), Domestic Fuel Survey, Special Reference : Kerosene, *NCAER, Vol. 1&2.*

NCAER (1975) Domestic Fuels in India, *Asia Publishing House, New Delhi*

NCAER (1992). Evaluation survey of household biogas plants set up during 1984-85 **and** 1985-86, *National Council for Applied Economic Research, New Delhi.*

Nesmith, C, (1991): Gender, trees and fuel; social forestry in West Bengal, India. *Human Organisation.* Vol.50, No.4, pp337-348.

NSSO (1997). Energy Used by Indian Households, 410/2, National Sample Survey Organization, Department of Statistics, *Government of India, New Delhi.*

Parikh, Kirit.S (1980), Second Indian Studies, *The Mac Millar Company of India Limited.*

Rajvanshi, A.K. (1995). " Energy Self-Sufficient Talukas : A Solution to National Energy Crisis." *Economic and Political Weekly XXX(51) : 3315-3319.*

Ramaiah P. (1986), The Energy Demands Elasticity in **Relation** to **GDP,** A **Relevant** Indicator, *Energy Economics, Vol. 8 (1), pp 29-38,*

Ramana, P.V., N.Hazarika, S. Dutta and N. Kukrety (1991). Biogas Technology, A promise for the Future. *Tata Energy Resources Institute, New Delhi.*

Ramana, P.V., S. **Dutta** and N. Hazarika (1994a). Biogas, A source of Rural Employment, *Tata Energy Research Institute*, New Delhi.

Ramana, P.V., S. Dutta and N. Hazarika (1994b). Managing the Biogas Programme, *Tata Energy Research Institute, New Delhi.*

Ramesh Bhatia, Energy Demand Analysis in Developing Countries : *A Review, Economic Journal, Vol.8, Special LDC Issue.*

Ranadc, DR, **Ycolc,** TY, Godbolc, SH, (1987): Production of biogas from market wastc. *Biomass*, **13** (1987) 147-153.

Ravindranath, N. H. and Hall, D. **O.**, Biomass, Energy and the Environment: A Developing Country Perspective from India. Oxford University Press, 1995.

Reddy A.K.N. (1981), Alternative and Traditional Energy Sources for the Rural Areas of the Third World.

Reddy A.K.N., (1982), Rural Energy Consumption pattern - *A Field Study Biomass, pp.22 5-280.*

Reddy, A.K.N. and B.S.Reddy (1983) "Energy in a Stratified Society, Case Study of Firewood in Bangalore." *Economic and Political Weekly (October 8) : 1757-1770.*
Reddy, **Amulya** K.N. (1982), Rural Energy Consumption Pattern - *A Field Study Biomass,pp.253-280.*

Reddy, **KR,** D'Angelo, EM, (1990): Biomass yield and nutrient removal by water hyacinth (*Eichhornia crassipes)* as influenced by harvesting frequency. *Biomass,* 21 (1990)27-42.

Report of the Working Group of Energy Policy : *Government of India (1979)*

Revelle, R, (1976): Energy use in rural India. *Science,* Vol.192, 4 June 1976, pp969-975.

Ronala Copar, (1980), The Energy - Economy Connection, *Journal of Business Economics, September, Vol.15.*

Ruchen, C, (1981): The development of biogas utilisation in china. *Biomass* 1 (1981) 39-46.

Sandra **Hutton.,** (1984), Domestic Fuel Expenditure : An Analysis of Three National Surveying, *Energy Economics, Vol.6, No.1,pp : 52-58.*

Sasse, L, **Kellner, C, Kimaro,** A, (1991): *Improved Biogas Unit for Developing Countries.* (GATE) Deutsches Zentrum fur Entwicklungstechnologien. Eschborn, Germany.

Sharma, SK, Mishra, IM, Sharma, MP, Saini, JS, (1988): Effect of particle size on biogas generation from biomass residues. *Biomass* 17 (1988) 251-263.

Shravan. G., (1984), Cooking Fuels in Rural North Gujarat, *Energy Management, July - September, Vol.8(3).*

Singh, A, (1988): Socio-economic problems of community biogas plants in Punjab. *Journal of Rural Development,* Vol.7 (5) pp591-599.

Singh, **R,** (1985): Biogas: A source of energy for rural people. In: **Behl, HM, Vimal, OP,** (Eds.) (1985): *Procs. National Seminar cum Workshop: Bio Energy Education.* Ajmer, pp56-61.

Sinha, C.S. and V.V.N. Kishore (1991b). "Bio-fuel Conversion Process and Technologies." *TIDE, TERI InformationDigest on Energy 1(1) : 1-24.*

Sodhiya, HC, Jain, KK, (1988): Rural energy crisis and biogas technology. *Journal of Rural Development.* Vol.7, (4) pp427-432.

Soren **Sen.** B., (1991), Renewable Energy, A Technical Overview, *Energy Policy, May, Vol.19, No.4,pp.386=391.*

Subramaniam, M. (1994). "Designing Wood-Fired Cooking stoves : Where is the woman?" *Economic and Political Weekly XXIX (May 14) : 1176-1179.*

Sudhakar, K, Gusain, PPS, (1991): *Rural Energy Planning in Sikkim.* Society for Development Alternatives. New Delhi.

Tata, (1998): *Tata Energy Data and Directory Yearbook, 1997/8.* Tata Energy Research Institute, New Delhi.

TERI (1998). TERI Energy Data Directory & Year book 1998/99, *Tata Energy Research Institute, New Delhi.*

Tim Jackson, (1992), Renewal Energy's Summary Paper for the Renewable Series, September, Vol.20, No.9, pp.480-494

Van Buren, A., (1984), Commercialization of Fuelwood in Developing Countries. *Energy Planning and Management in Developing Countries, Bain and Nee., (ed).*

Varun Vidyarthi, (1980). Biogas Technology Development and Extension in India : An Overview, Discussion Paper, Appropriate Technology Development Association, Lucknow, December.

Varun Vidyarthi, (1985), Renewable Energy Development Alternatives : Village Experience and indicators for Policy, *Economic and Political Weekly, November, Vol.XX, Nos.45, 46, 47.*

Vernier, SC, Misra, PN, (1987): Biomass and energy production in coppice stands of *Sesbania sesban* (Linn.) Merrill under high density plantation on marginal lands of Banthra. *Biomass* 11 (1987) 309-313.

Vijayalakshmi V. (1985). Biogas Technology, An Information Package, Information Packages, Tata Energy Documentation and Information Centre, *Tata Energy Re-search Institute (Teri).*

WEBLIOGRAPHY

www.ad-nett.org

www.eia.doe.gov

www.forumforthefuture.org.uk

www.gate.gtz.de/isat/at_info/biogas/AT_biogas.html

www.ias.unu.edu/proceedings/icibs/mainpage/prog.htm.

www.ireda.nic.in

www.mnes.nic.in

www.nrel.gov

www.redp.org.np

www.renewingindia.org

www.stem.se/energitillforsel/altenerwfe.html

www.teriin.org

www.undp.org

www.worldbank.org

www.worldenergy.org