THE POTENTIAL FOR BIOGAS PRODUCTION AND ITS UTILIZATION FROM LOCALLY AVAILABLE RESOURCES IN A TYPICAL INDIAN VILLAGE AREA: A PRELIMINARY ASSESSMENT

by

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ABSTRACT

This study presents a survey of demand and supply of biogas energy for cooking and lighting in a typical village area in India. Locally available animal manure and human night-soil as input materials for the generation of biogas are discussed and assessed in terms of their potential utilization as a future energy source.

An overview of the anaerobic digestion process, based on a literature review, has been presented in this study which could be aptly described as a "state of knowledge" assessment rather than a technology assessment.

This study also gives a preliminary analysis on the investment and benefit of biogas plants. Three sets of cost data for large, medium and small-scale plans for biogas plant operations indicate that the larger the scale of each system, the less will be the cost for the installation of the biogas plant. Although adoption of a biogas plant is economically beneficial, it is doubtful if villagers will be able to install these plants as a large initial investment is required for each of the three plans.

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Btu	British Thermal unit
Cal	Calorie
cm	Centimeter
C°	degree Celsius
ft^3	cubic feet
hr	hour
IARI	Indian Agricultrual Research Institute
J	Joule
Kcal	Kilocalorie
kg	Kilogram
KVIC	Khadi & Village Industries Commission
kWh	Kilowatt hour
L	Liter
Lb	Pound
m^3	Cubic Meter
MJ	Mega Joule
mm	Millimeter
NPK	Nitrogen, Phosphorus and Potassium
Rs	Rupee (The monetary unit of India)
TS	Total solids
VS	Volatile solids

GLOSSARY

Anaerobic	In the absence of air (oxygen)
Biodegradability	The characteristic of a substance that can be broken down by microorganisms.
Biogas	Results from the anaerobic decomposition of organic materials in a controlled environment and consists primarily of methane and carbon dioxide.
Biomass	The dry weight of living or dead matter, including stored food, present in a species population and expressed in terms of a given or volume of the habitat.
Calorie	A unit of heat energy, equal to the heat required to raise the temperature of 1 gram of water from 14.5 to 15.5 degree Celsius at a constant pressure of 1 standard atmosphere; equals to 4.19002 Joules.
Cellulose	The main polysaccharide in living plants, forming the skeletal structure of the plant cell wall.
Cereal	Any crop grown for its edible grain.
Chulha	Hindi word for oven.
Detention Time	The average time that a material remains in the digester for fermentation; generally calculated by dividing the total weight of material in the system by the weight removed per unit time (i.e. hour, day, or week).
Digester	A vessel used to contain the organic matter and other materials participating in the anaerobic process to produce biogass.
Digestion	The process of anaerobic decomposition of organic matter or liquefaction of organic waste materials by action of microbes.
Enzyme	Biological catalyst that facilitates the breakdown of complex organic molecules into simpler molecules.

Fermentation	The biological process by which organic matter is broken down by microorganisms; (see digestion).
Gobar	Hindi word for cow dung.
Grain	A collective term for the fruit of cereals.
Joule	The work done when the point of application of a force of 1N is displaced through a distance of 1m in the direction of the force (1J - 1Nm) is one Joule.
Kharif	Hindi word meaning summer season cultivation.
Methane	A colourless, odorless, flamable gas produced by decomposition of organic matter and used as fuel; consisting of one carbon atom and four hydrogen atoms (CH_4).
Organic Matter	Chemical compounds based on carbon chains or rings and also contain hydrogen with or without oxygen, nitrogen or other elements.
Night Soil	Human feces.
Rabi	Hindi word meaning winter season cultivation.
Sludge	Any semisolid waste from a chemical process.
Substrate	Material supplied for microbial action.
Straw	Stalks of grain after threshing.
Thermal Value	Heat produced by combustion, usually expressed in Calories per gram (cal/g) or British thermal units per pound (Btu/lb) or Joules per kilogram (J/kg).
Total solids	The weight of the solid matter remaining after drying to constant weight at 104°C; Total solid is composed of digestible organic matter (volatile solids) and indigestible residues.
Volatile solids	The portion of solids volatilized when material is heated at 550°C.
Zaid	Hindi word meaning pre-monsoon cultivation.

CHAPTER I

THE PROBLEM AND ITS SETTING

1.1 Introduction

Millions of people in the villages of some developing countries such as India light their homes with oil lamps and obtain heat for cooking by burning cow dung and dried leaves. These people use negligible quantities of petroluem products, yet the diminishing supply of these products has affected them severely. The shortage of fertilizers caused by a sharp increase in oil prices has affected food production, which is threatening these people with malnutrition and starvation. Millions of people who live in small villages and towns in Asia depend on kerosene for cooking and lighting. The scarcity of kerosene has resulted in great hardship for these people.

Shortage of liquid petroleum fuels in some developing countries has not involved lowering the thermostat or reducing highway speeds, rather the concern is whether the millions of villagers will have food to eat and fuel to cook it with. The uncertainity of energy supplies and a chaotic world monetary situation arising from high oil prices have thrown India's five-year plans into disarray. Many developing countries face similar circumstances.

The need for new approaches to the energy problem is apparent.

1.2 Problem Statement

1.2.1 The Problem of Depleting Fossil Fuels

In recent years, energy and energy conservation have become increasingly important factors in the every day life of all people throughout the world. The energy crisis has brought an increasing awareness that conventional fossil fuels are a depleting resource (Lapp, 1978).

The sharp increase in the price of crude oil affected by the oil producing countries has made the cost of oil imports prohibitive for developing countries who do not have oil. India's bill for crude and petroleum products went up from Rs. 3,325 million in 1973 to Rs. 11,091 million in 1974, to Rs. 11,467 million in 1975 to Rs. 13,480 million in 1976 and to Rs 16,018 million in 1977 (The Times of India Year-book, 1977 and 1979). Even with controls to maintain oil imports at minimum levels, the cost expected to continue to rise. Ample supplies of low cost energy are no longer available. As a result, keen interest has been focused on the conservation of existing energy and on the development of alternative sources, such as solar, tidal, geothermal, wind, nuclear and biomass. The recovery of energy from biomass has accordingly become a source that demands careful study.

1.2.2 The Problems of Electrical Power Distribution in Backward and Remote Areas in India.

Though biogas plants have been operated for several decades, their prominence in public discussion of energy and fertilizer use is a recent phenomenon. There are several reasons for the growing interest in these plants. Foremost among these is the recent oil crisis which has compelled a desperate search for alternative sources of energy. Even before the energy crisis in 1973, the acute power shortage commencing in late 1972 had exposed the weakness of Indian Energy Planning, an essential aspect of which was the dependence on hydro-electric and thermal power to the extent of 8.2% and 33.8%, respectively, of total energy consumption in India (Nambiar, 1973). The weakness of this approach is that hydro-electric power is dependent on the monsoons and thermal power is sustained by the movement of coal over long distances from area to area in the country.

These factors, which have led to the unfavourable economics of electrical power distribution to backward and remote areas, have been largely responsible for the slow progress of rural electrification. It has been estimated that only 32.7% of villages in India have been electrified as displayed in Table 1 (Eastern Economist, 1978, citing source from Central Electricity Authority, Government of India).

A recent survey completed by the United Nations Environment Program (UNEP) stated that "Villagers also have their "energy elites": 85% of the Indian villagers cannot afford electricity, even when it is supplied" (Uniterra, 1978). And yet, energy is an essential requisite for the progress of these villages and the country's overall development.

TABLE 1

Villages Electrified in States and Union Territories

Sl. No.	States/Union Territories	Total No. of villages (1961 Census)	Total No. of villages (1971 Census)	No. villages electrified ending March (1971 Census)	Villages electrified ending July 1976
1.	Andhra	27084	27221	10430	11654
2.	Assam	20565	21995	1359	1524(a)
3.	Bihar	67665	67566	13375	15407(b)*
4.	Gujarat	18584	18275	6026	6460
5.	Haryana	6669	6731	6731	6731
6.	Himachal Pradesh	13060	16916	6272	6778
7.	Jannu & Kashmir	6559	6503	1741(b)	1995(c)
8.	Karnataka	26377	26826	13730	14370
9.	Kerala	1573	1268	1182	1204
10.	Madhya Pradesh	70416	70883	11304	11984
11.	Maharashtra	35851	35778	18643	19454(d)
12.	Manipur	1866	1949	217	235(b)
13.	Meghalaya	4407	4583	185	261
14.	Nagaland	814	960	156	182
15.	Orissa	46466	46992	10128	11582
16.	Punjab	11947	12188	7717	12126(+)(d)
17.	Rajasthan	32241	33305	6326	7268
18.	Sikkim	460	215	5	11(b)
19.	Tamil Nadu	14124	15735	15416	15449
20.	Tripura	4932	4727	215	197
21.	Uttar Pradesh	112624	112561	30798	31982
22.	West Bengal	38454	22074	9257	10220
	Total (States)	362736	371251	171127	187073
1.	A & N Islands	399	390	55	64
2.	Arunachal Pradesh	2451	2973	58	58
3.	Chandigarh	31	26	26	26
4.	D & N Haveli	72	72	22	26
5.	Delhi	276	243	243	243
6.	Goa, Daman & Din	245	409	293	332
7.	Lakshadweep	10	10	9	9
8.	Mizoram	730	229	3	5(b)
9.	Pondicherry	388	333	333	333
	Total (Union Territories	4602	4685	1042	1098
	Total (all India)	567338	575936	172169	188169
	Percentage of Villages electrified			29.90	32.7

Notes *As per 1971 census

(a) Data as per 1961 census as details according to 1971 census not received so far.

(b) As on 28-2-1975.

(c) Figure provisional and under reconciliation.

(d) 62 villages have been declared as un-inhabited.

Source: Government of India, Central Electricity Authority, Commercial Directorate.

1.3 Research Objectives

The overall objective of this study is to develop a model which will give guidance to Indian villages that are considering the adoption of a new technology such as biogas plants to achieve self-sufficiency in their local energy demand, using locally available organic matters - animal manure and human night soil as inputs in biogas plants.

Cereal crop residues also contain significant amount of potential energy. While currently anaerobic fermentation of cereal crop residue is technically not possible, in future it may become technically feasible to use it in anaerobic digestion plants (biogas plants) to produce biogas, therefore, its quantity available in the study area will be estimated for future energy utilization.

The specific objectives of the study include:

1. To determine the energy demand in a typical Indian village for such purposes as cooking and lighting;
2. To estimate the supply of local energy inputs, such as cereal crop residues, human night soil and animal (cattle and buffalo) manure in a typical Indian village;
3. To present the technical, social and economic implications for Indian villages that have an objective to become self-sufficient in their local energy needs.

1.4 Delimitations

As a result of time and resource constraints, this study did not include these following considerations:

1. The laboratory experiments to assess the technical feasibility of biogas production;
2. The detail assessment of the quantity of fertilizer which is produced as a by-product from biogas plants;
3. The methods of distributing biogas to villagers from community biogas plant.

The study is limited to a discussion of the possibility of improving the standard of living of villagers by adopting new technology such as biogas production and utilizing locally available resources to produce bigas energy for their cooking and lighting needs.

1.5 The Importance of the Study

The study will assist the village level planners:

1. To understand the feasibility of any village to provide its energy needs, for cooking and lighting, using a locally available supply of energy inputs.
2. To assess the cost/benefits of the biogas plants in the area where sufficient residues are available to produce biogas for the village energy demand for cooking and lighting purposes.

Overall it is envisaged that large scale utilization of animal manure and to a certain extent night soil will lead simultaneously to the production of gaseous fuel and organic fertilizer with a corresponding reduction in the country's dependence on electricity/Kerosene for energy and imported fertilizer. Further, the utilization of these organic materials in biogas plants will improve health and sanitary conditions in the villages.

1.6 Study Area

The Naujheel Block* which is geographically located in the northern region of India, contains 147 villages (Figure 2). The typical village area, as a basic unit for this study was determined by making a summation and taking an average of the total area, human population, animal population and the number of households in 147 villages of the Naujheel Block.

A typical average village in Naujheel Block has a total geographical area of 244 hectares, of which 84% is under cultivation. The village has 98 households and a population of 794 persons. The village has 113 buffalo and 107 cattle. It is economically based on agriculture with about 76% of the working force engaged in agricultural activities. The major cereal crops grown in the village area

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*Naujheel Block, Mathura District, Uttar Pradesh,- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development (AVARD), Research and Development Unit, New Delhi.

include wheat, barley, sorghum, corn and rice. The total farm land area which is about 205 hectares is cultivated in three different seasons-Rabi (Winter season cultivation), Kharif (Summer season cultivation), and Zaid (Pre-monsoon season cultivation).

A detailed description of Naujheel Block, Mathura district is presented in the Chapter II of this practicum.

1.7 Research Methodology

All data relating to the study area were taken from a socio-economic survey of Naujheel Block* which contains a village-to-village investigation, therefore, a field inspection was not undertaken. The data basically related to biogas production were obtained from the Khadi and Village Industries Commission, Bombay, (an agency of Government of India), which has been working for many years on the biogas scheme. Other published literature from Canada and United States were also examined.

An average village with its area, number of households, and its human and animal population was determined by taking an average of area, households and population in 147 villages of Naujheel Block, Mathura district.

The energy demand, in terms of biogas needed for cooking and lighting in the typical average village (study area) was determined by making a summation of the per capital consumption of biogas for these purposes. The data for per

*Naujheel Block, Marthura District, Uttar Pradesh-A socio-Economic Survey, 1975 Published by the Association of Voluntary Agencies for Rural Development (AVARD), Research and Development Unit, New Delhi.

capita consumption of biogas used for cooking and lighting in rural India was provided by the Khadi and Village Industries Commission.

The supply of energy inputs for biogas plants such as animal (cattle and buffalo) manure and human night soil in such a village are determined by using the following steps:

The total animal and human population in the average typical village was determined by taking an average of 32,298 animals (cattle and buffalo) and 95,090 people in 147 villages of Naujheel Block. These average values were used to estimate the quantity of manure and night soil;

The standard rate of manure yield per animal per day, its availability and biogas production value per kilogram of manure were obtained from the Khadi and Village Industries Commission to estimate the total available quantity of manure and potential biogas production from it in the study area;

Similarly, the availability and average biogas yield value from human night soil were determined by using existing data from the Khadi and Village Industries Commission.

The quantity of cereal crop residues for future potential energy supply in the study area was estimated by the use of a ratio of grain to residue factor.

The quantity of cereal grains produced in the study area was estimated by taking an average of the total quantity of cereal grain produced per year in 147 villages of Naujheel Block.

CHAPTER II

DESCRIPTION OF MAUJHEEL BLOCK, MATHURA DISTRICT

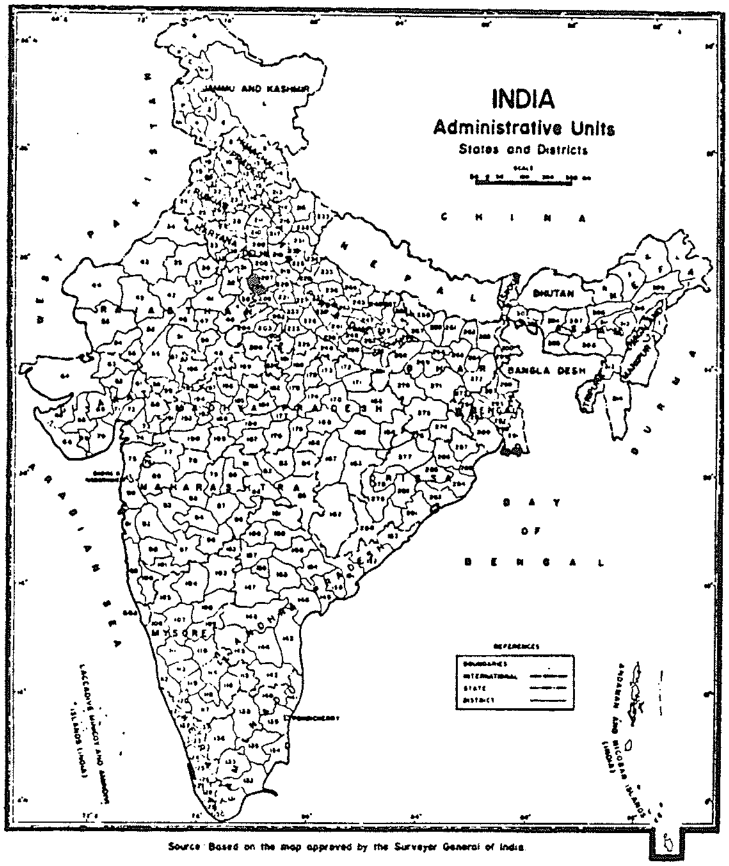
2.1 Location

Geographically, Naujheel block is located between N 27°40'-27°50' latitude and E 77°30'-77°50' longitude, about 97 kilometers northwest of Agra City. A block is an administrative unit within a district of a province in India. There are 314 districts in India. The province of U.P. (Uttar Pradesh) is the most populated province in India and also has the largest number of districts for any province in the country. Naujheel block comes under Mathura District (District Number 206) in U.P. province. Figure 1 shows the location of the Naujheel block in relation to the district, the province and the nation.

Naujheel block consists of 147 villages. Figure 2 shows the boundaries of only 146 villages as in 1961, the block had only 146 villages. Since then one village had been subdivided so that the block now consists of 147 villages.

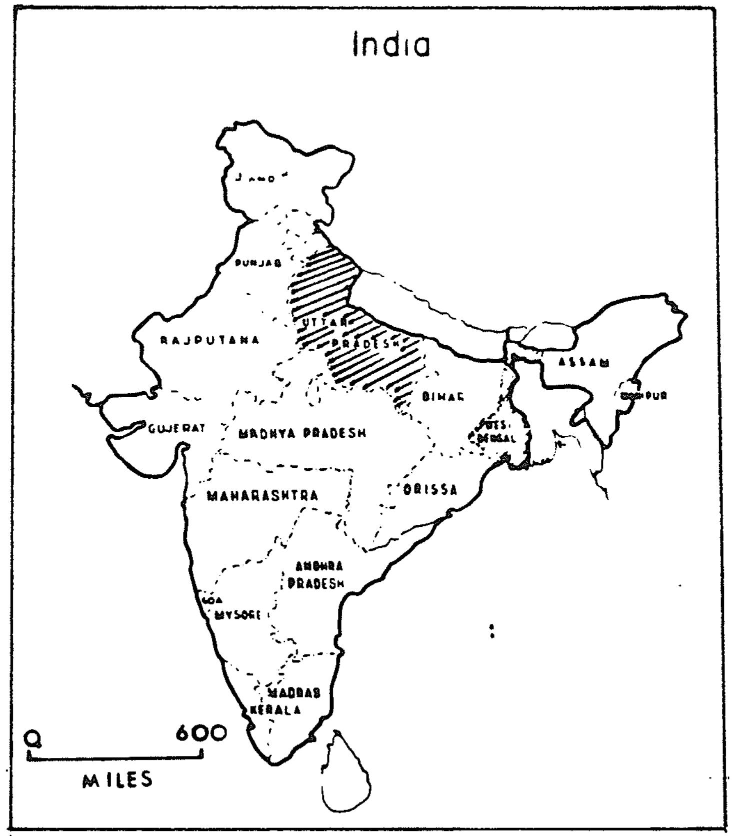
2.2 Climate

The climate of the area is monsoon-dominated, with yearly rainfall about 722 mm. Table 2 indicates that approximately 92% of the rainfall occurs between June and September which is characterized as the monsoon period. The summer months (March through mid June) are hot (the heat is intense in May and June) with the average



District No. 206-Mathura District

A



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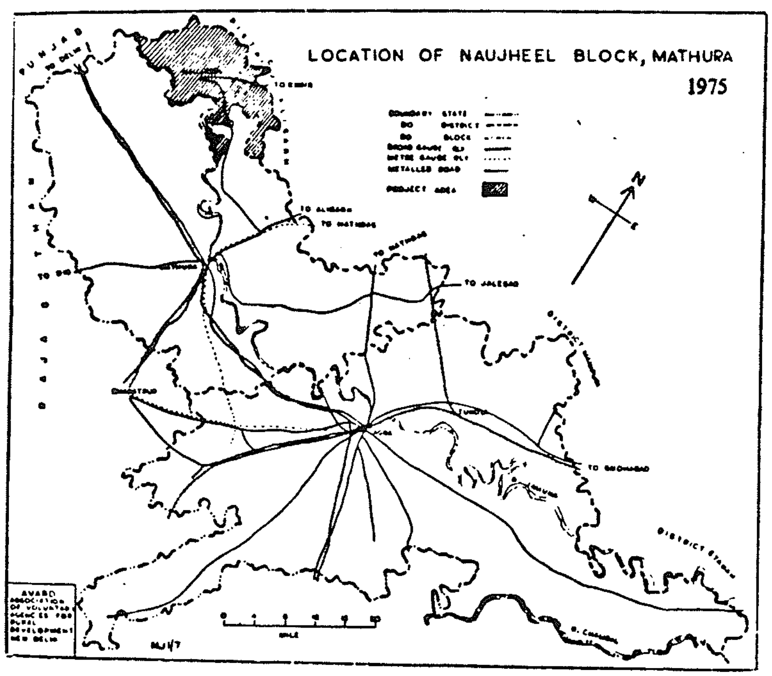

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FIGURE 1

LOCATION MAP OF NAUJHEEL BLOCK IN RELATION TO THE NATION (A), THE PROVINCE (UTTAR PRADESH) (B), AND THE DISTRICT (MATHURA) (C).

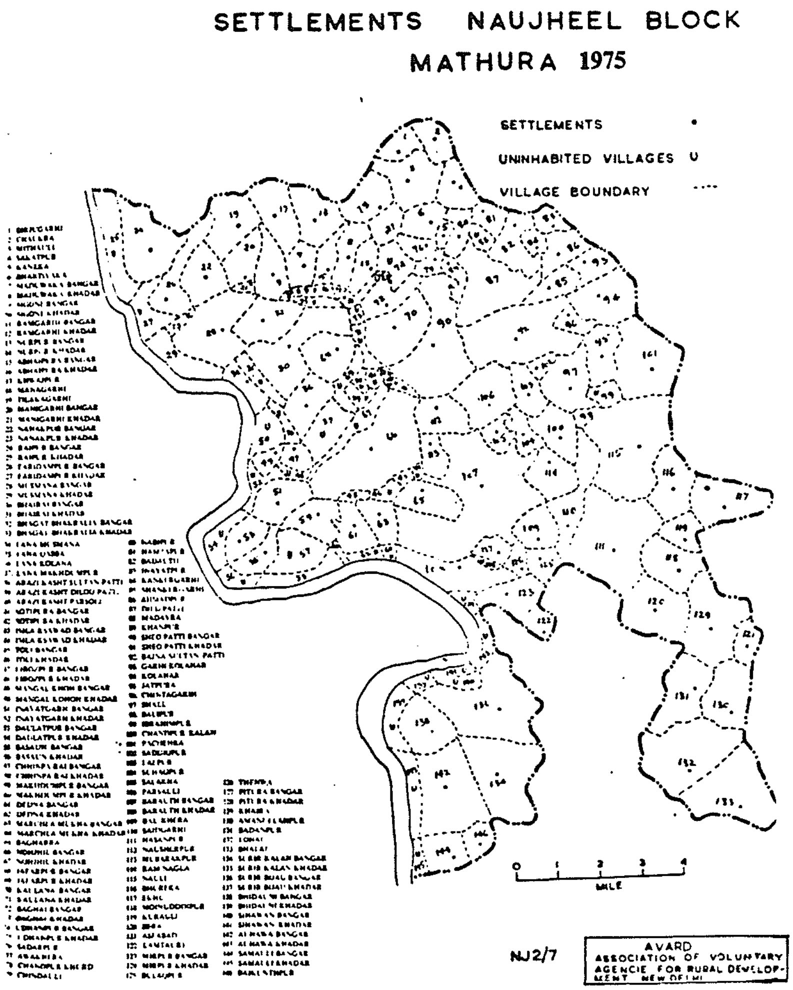


FIGURE 2

LOCATION MAP OF VILLAGES IN NAUJHEEL BLOCK

TABLE 2

MONTHLY RAINFALL IN NAUJHEEL BLOCK

(In mill-imetres)

Month/ Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Average Rainfall
January	22.1	9.7	4.1	-	0.8	-	-	21.5	-	4.2	11.0	6.6
February	27.0	15.5	-	-	12.2	6.4	-	6.6	3.0	67.0	14.0	13.7
March	-	14.0	8.4	-	6.3	-	38.6	4.0	-	20.0	1.0	8.3
April	4.6	1.3	12.4	-	4.8	-	0.4	-	10.4	3.0	6.4	3.9
May	-	11.9	19.0	0.5	2.5	34.6	-	-	26.2	65.2	15.1	15.9
June	4.1	11.7	55.1	5.6	1.5	112.1	11.6	34.0	25.4	45.2	175.2	43.7
July	142.4	139.6	35.5	320.7	121.6	66.7	222.8	320.2	]76.4	17.5	215.7	170.8
August	494.9	134.6	353.4	168.7	215.4	340.6	397.4	306.4	291.0	124.0	531.4	305.1
September	71.1	113.8	491.3	201.2	128.6	28.0	60.2	-	171.0	81.2	102.5	131.7
October	50.1	-	-	-	8.6	-	7.2	24.6	-	5.2	84.6	16.3
Nobember	6.6	-	10.9	-	-	0.8	-	-	-	-	-	1.6
December	-	7.1	12.2	-	1.0	-	33.2	-	-	-	-	4.8
TOTAL	822.0	459.2	1002.3	696.7	503.3	589.2	771.4	717.3	803.4	432.5	1156.9	722.4

Source: Naujheel Block, Matura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development (AVARD), New Delhi, India, p. 4.

mean temperature maximum and minimum being 42°C and 26°C respectively. The Winter period (December through February) is cool but rarely below freezing, with maximum and minimum mean temperature averages being 23°C and the minimum 7°C respectively.

The average relative humidity is less than 23 percent.

2.3 Soil

Naujheel block has two soil types which are locally called Bangar and Khadar. The Khadar soils are recent alluvium and the Bangar soils are older deposits (Figure 3). The rising ground water table and inadequate drainage has led to the deposit of salt in large areas of the block.

2.4 Land Use

The block has a total geographical area of 34857 hectares, of which approximately 84% is under cultivation. The area under forest is negligible (about 1.30% of the total geographical area) as the forests have over the years been cleared for firewood. The area under miscellaneous tree crops, culturable waste, fallow land and other use of land is given in Table 3.

The average size of land holding in the block is calculated to be 1.81 hectares and the per capita cultivated land comes to approximately 0.78 hectares (Naujheel Block, Mathura District, Uttar Pradesh-A Socio-Economic Survey, 1975).

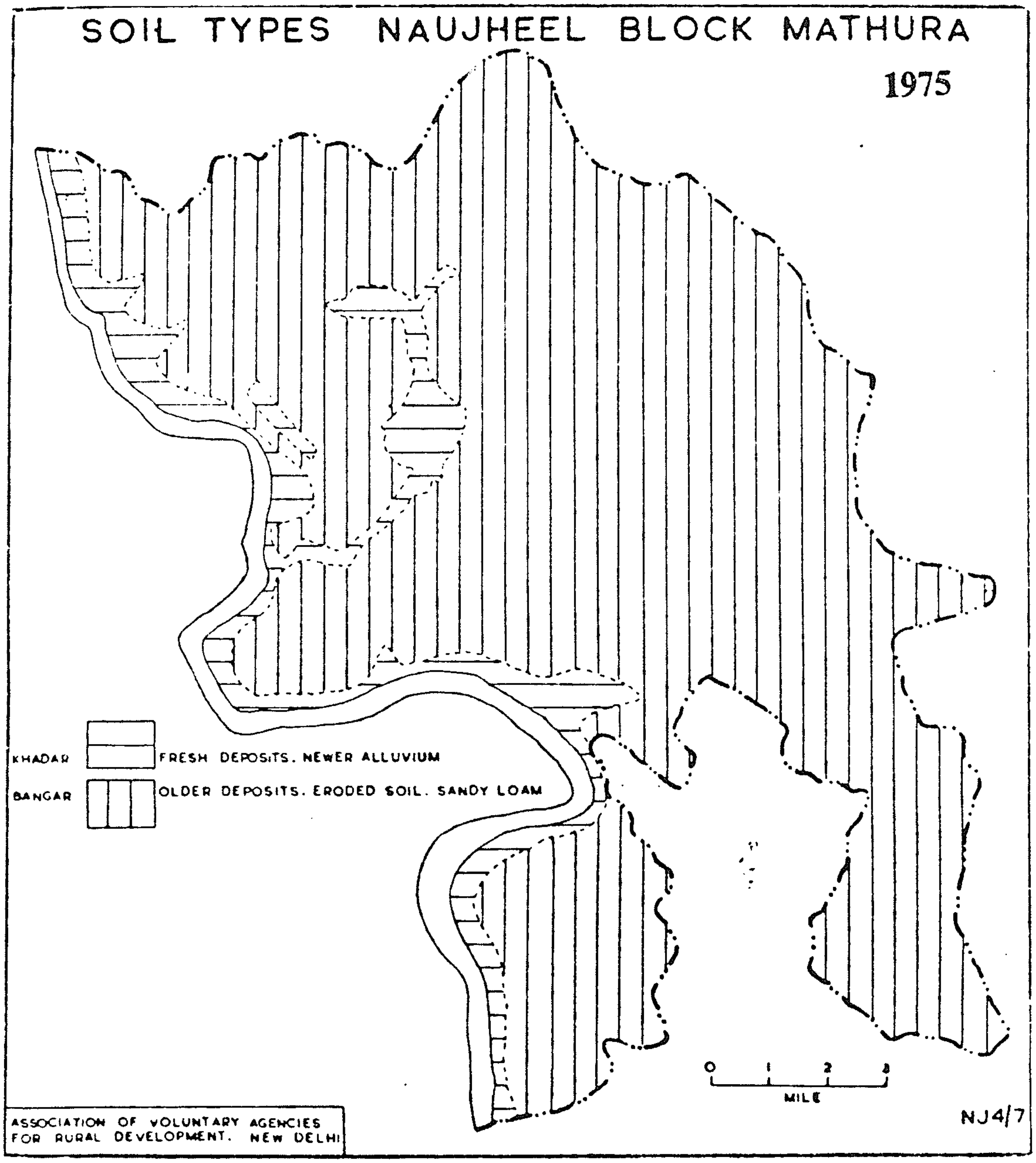


FIGURE 3

SOIL TYPES NAUJHEEL BLOCK, MATHURA

TABLE 3

LAND USE PATTERN OF NAUJHEEL BLOCK

Item	1972-73 Area in hectare	1972-73 Percent to total	1973-74 Area in hectare	1973-74 Percent to total	Percentage change 1973-74
Total geographical area	35888	100.00	35858	100.00	- 0.09
Forests	617	1.72	476	1.30	-22.77
Land put to non-agriculture use	2335	6.50	2365	6.60	+24.22
Permanent Pasture and common grazing land	19	0.05	63	0.17	+241.30
Miscellaneous tree crops and groves not included in the net area shown	38	0.11	25	0.07	-34.74
Culturable waste	963	2.68	782	2.18	-18.82
Fallow land other than current fallow	236	0.66	198	0.55	-15.95
Current fallow	1204	3.36	1176	3.28	- 2.38
Net area sown	29932	83.40	30094	83.93	+ 0.54
Area sown more than once	10867	30.28	11557	32.23	+ 6.35
Total area cropped per year	40799	113.68	41651	116.16	+ 2.09
Area irrigated	18004	50.17	18357	51.20	+ 1.96

Source: Naujheed Block, Mathura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development (AVARD), New Delhi, p. c.

2.5 Socio-Economic Infrastructure

The Naujheel Block is an agricultural region, where 76.41% of the inhabitants are engaged in agricultural activities (Table 4). The total population of the Block is 95,000 persons, 51,353 males and 43,737 females. The sex-ratio is 852 females per 1,000 males. The entire population is considered rural. The density of population in the block is 265 persons per square kilometer, which is higher than the all-India density, which is about 167 persons per square kilometer.

In the block, crops are grown in three different seasons - Kharif (Summer), Rabi (Winter) and Zaid (Pre-monsoon). The major Rabi crops are wheat and barley with 30% and 9% of the total cropped area respectively. The major Kharif crops grown in the area are Bajra (local name for sorghum), maize (corn) and mixed cropping of leguminous crops with 13, 10 and 7% of the local cropped area respectively. The major Zaid (Pre-monsoon) crops include spices, tobacco and vegetables, with only 1% of the total cropped area.

Animal husbandry is practiced as an important subsidary occupation by villagers in the block. The total number of buffalo (water buffalo), cattle, sheep, goats, hens and pigs in the block are displayed in Table 5.

Although agriculture is the most important activity in the block, about 6% of the total workers are engaged in household and other than household industry. Some of the important cottage industries are Molasses making, Flour milling, Carpentry, Handloom and Pottery (Table 6). Figure

TABLE 4

OCCUPATIONAL DISTRIBUTION OF THE TOTAL WORKING FORCE IN NAUJHEEL BLOCK

Occupation	Number	% to total worker
1. Cultivators	16,316	62.48
2. Agricultural Labourer	3,634	19.93
3. Livestock, Fishing	617	2.36
4. Mining Quarrying	4	0.02
Primary Sector	20,571	78.79
5. Household Industry	1,332	5.10
6. Manufacturing other than Household Industry	294	1.12
7. Construction	124	0.47
Secondary Sector	1,750	6.69
8. Trade and Commerce	821	3.14
9. Transportation, Storage and Communication	224	0.86
10. Other services	2,747	10.52
Teritiary Sector	3,792	14.52
TOTAL WORKERS	26,113	100.00

Source: Naujheel Block, Mathura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi, p. 11.

TABLE 5

LIVESTOCK WEALTH OF NAUJHEEL BLOCK

Type of Animal	Number of Animals (Year: 1974)
1. Bullocks	11,533
2. Cows	5,022
3. Buffaloes (Water)	1,721
4. She-Buffaloes (Water)	14,022
5. Sheep	2,511
6. Goats	2,657
7. Hens	1,624
8. Pigs	1,182

Source: Naujheel Block, Mathura District, Uttar Pradesh-A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi, p. 8.

4 displays the infrastructure of the block.

According to the 1971 Census, only 21.96% of the total population in the block are literate (Table 7). The block has 88 primary schools, 10 middle schools, 6 high schools and 4 colleges. Although the block has small shopping facilities, the block has neither storage facilities nor a regulated market for agricultural commodities. Local farmers go outside of the block for purchase and sale of agricultural goods. Transportation facilities in the block are in very poor condition, as only 12 villages are connected by concrete roads. As for communications, the block has only one Post Office and 17 Sub Post Offices. There are no telegraph or telephone facilities.

Only 21 out of 101 inhabited villages in the block have been electrified. Table 8 classifies some un-electrified villages in the block by distance from the nearest transmission line.

TABLE 6

COTTAGE INDUSTRIES IN THE NAUJHEEL BLOCK

Year: 1974-1975

Type of Industry	No. of Unit	No. of persons employed
Flour Mill	59	117
Oil Crushing	29	51
Black Smithy	49	77
Carpentry	74	124
Handloom	40	100
Cloth Printing	6	14
Leather Industry	29	49
Basket Making	19	34
Pottery	40	79
Molasses Making	41	190
Gold Smithy	10	12
Thread Making	22	41
Stone Carving	10	32
Cement Tile Making	1	8
Ice Candy Making	1	3
TOTAL	430	931

Source: Naujheel Block, Mathura District, Uttar Pradesh-A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi, p. 39.

TABLE 7

CHANGE IN LITERACY

Population	Literate Population 1961	Literate Population 1971	Percentage of Literates to total Population 1961	Percentage of Literates to total Population 1971	Percent change 1961-1971
Male	13,111	18,353	30.81	35.74	+39.98
Female	1,539	2,524	4.21	5.77	+64.00
TOTAL	14,650	20,877	18.51	21.95	+42.51

Source: Naujheel Block, Mathura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi, p. 13.

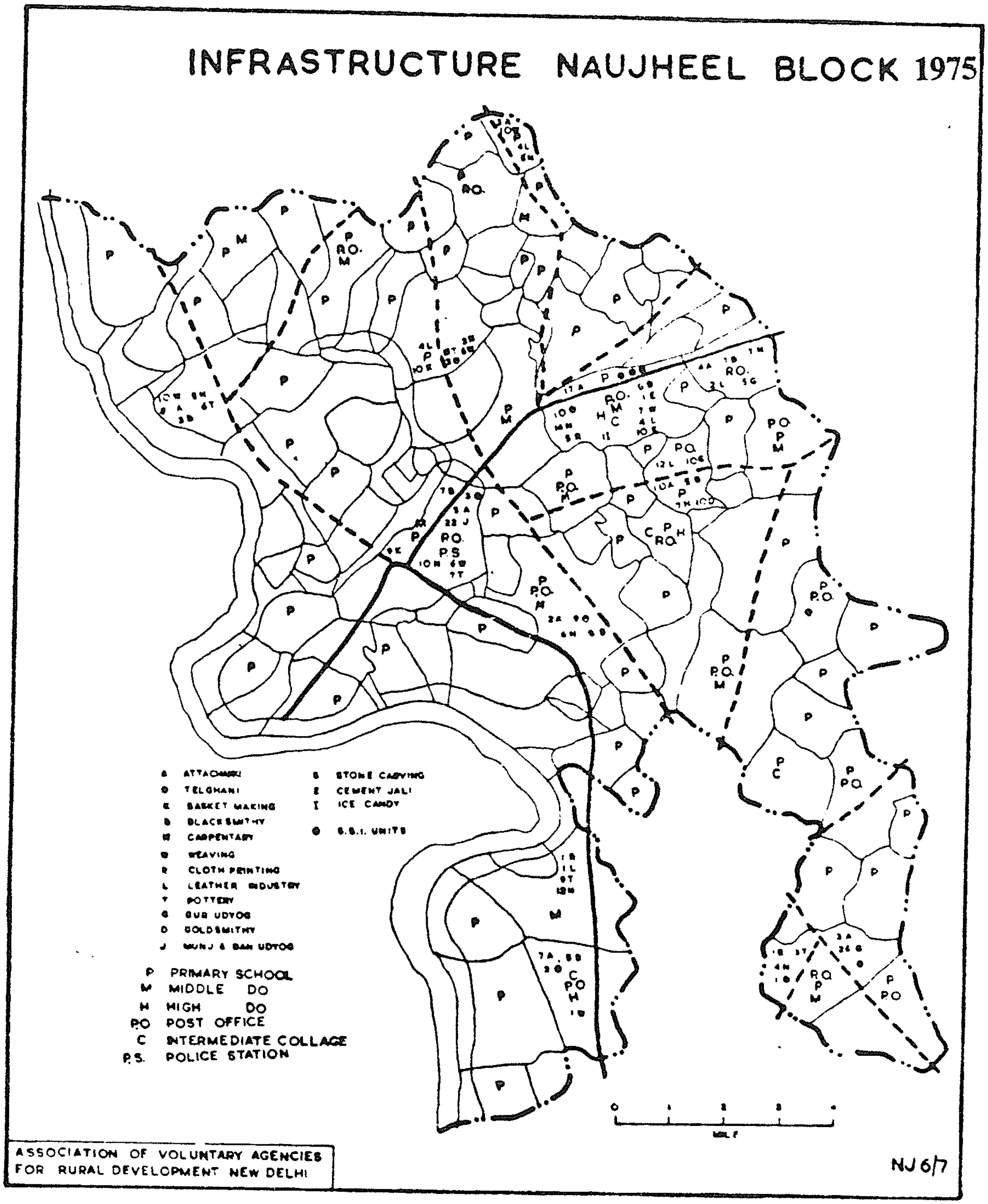


FIGURE 4

INFRASTRUCTURE NAUJHEEL BLOCK

TABLE 8

UN-ELECTRIFIED VILLAGES BY DISTANCE

FROM THE NEAREST TRANSMISSION LINE

Distance (in Kilometers)	Number of Villages
Up to 2	29
3 - 5	16
6 - 10	9
11 - 15	7

Note: Information for remaining villages is not available.

Source: Naujheel Block, Mathura District, Uttar Pradesh-A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi, p. 17.

CHAPTER III

REVIEW OF THE LITERATURE

Heat energy from dry organic materials can be obtained by direct burning. Pound for pound, they contain about one-half of the heat energy of anthracite coal. But when some of these materials are converted to biogas by anaerobic bacteria, they are contained in a slurry and the biogas produced is convenient to use for such purposes as cooking and heating. By-product from agricultural production containing organic matter, particularily animal manure is excellent input material for producing biogas. Successful economic recovery and utilization of this energy will reduce the dependency on high-cost petroleum fuels (Lapp, 1977).

By using various technologies (direct combusion, pyrolosis, anaerobic digestion, etc.) different forms of energy such as heat, steam, electricity, methane and methanol can be extracted. Biogas is produced by digesting organic materials such as animal manure and human night soil. Biogas can be used to supply heat, generate electricity or operate internal combustion engines (Argue, 1978).

Anaerobic digestion of organic materials produces a large quantity of biogas, which ranges between 60-70% methane (CH_4) and a balance of 30-40% carbon dioxide (CO_2).

One of the most important factors which influence the rate of biogas production is temperature. Although biogas production is possible throughout the 0 to 60° range, production declines rapidly as temperature drops below 20°C and increases above 55°C (Lapp, 1978). Thus in cold climates, some of the biogas produced will be needed to keep the digester tank warm. The amount of gas required to keep the tank warm will depend on outside air temperature, temperature of the input materials, size of the tank and tank insulation.

Farm-scale anaerobic digesters were used by many European farmers during and after World War II, and recently thousands of anaerobic digesters have been installed and operating successfully in warm climatic regions of Asia.

In Germany, during and immediately after the World War II, the diminishing energy supply led farmers and engineers to develop their own sources of energy by using "Bihugas Plants (biological human and gas plant), (Tietjeen, 1977).

In France, the attempt was made during the World War II to solve the problems of energy shortage on the farms by installing several small farm-scale digesters (Tietjeen, 1977). It has been reported that in France by 1952 there were around 1,000 installations (Singh, 1972).

In Taiwan, methane generator plants have proved quite successful and Taiwanese farmers have installed 7,500 digesters using hog dung and chicken droppings as raw materials (Po, 1973). It has been reported that the number of biogas plants of varying capacities has reached 4.3 million units in the People's Republic of China and 24,000 units in Korea (Lapp, 1977).

In India, biogas plants have reached a prominent place in rural development programs. The high cost of oil, and other reasons such as inadequate distribution of electrical power and shortage of firewood, have caused decentralized energy production to become an attractive proposition. It has been reported that gas plants of 14 different capacities ranging from 2 to 140 m^3 are available, and 59,919 plants are in operation in India (Gobargas on the March, 1979).

In India, the first biogas plant was developed at the Indian Agricultural Research Institute (IARI), in 1937. Later in 1961 the Khadi and Village Industries Commission (KVIC) pursued this program and put to test the first plant. In the development of biogas plants in India, a number of individuals and institutions have played a key role during its different stages of development (Srinivasan, 1975).

Experimentation Stage (1937-1950): During the experimentation stage, the credit for building the first experimental anaerobic digester goes to S. V. Desai of IARI. Work with this digester made the data on anaerobic digestion of cattle dung available for the first time in India. The result of Desai's work was published in 1945. In 1946 N.V. Joshi also from IARI, took out a patent for a cattle dung digester. This digester was essentially similar to the apparatus used by Desai for his experiments, except for the feed pipe. Instead of being on top in the digester as used by Desai, the feed pipe was connected near the bottom of the digester by Joshi. Joshi offered a family sized digester which produced about 20 cubic feet ($0.57m^3$) of biogas per day for a cost of Rs. 1800. Three bigger digesters were set up at Walchand Nagar, which subsequently failed due to the foaming of the digesting cow dung that burst open the flat roof.

Though the plants of Desai and Joshi did not produce a practical digester they proved that the farmer could obtain fuel for his household from manure.

During this period two other workers, Y. N. Kotwal, Superintendent of the Dadar Sewage Purification Station, and his assistant in Bombay, set up a small experimental digester. Their work too revealed that when urine was added to the cattle dung it fermented rapidly and gave more gas per unit of cattle dung. It was also found, addition of greater amounts of urine accelerated the fermentation so much that the fermenting cattle dung slurry tended to foam over the digester. They did not however, attempt to design a practical plant for anaerobic digestion of cattle dung.

Pilot-Plant Stage (1950-1959): During the pilot-plant stage, Jashbhai Patel made the first big break-through in the manufacture of a practical plant. Patel named his plant "Gramlaxmi" gas plant and patented it in 1951. This particular type of gas plant constructed at a cost of Rs 1800 and delivered about 200 ft^3 ($5.7m^3$) of gas a day. Patel made many changes in the plant originally designed by Desai. For the first time the digester with a cylindrical gas holder as cover was used. This gas plant was demonstrated in the

KVIC exhibition at Hyderabad in 1953.

Swami Vishwakarmanaud (1951-1952) and Satish Chandra Das Gupta (1953) both working separately introduced a cheap digester made of split bamboos. Their main interest was to bring working models of the gas plant within economical reach of the poor farmer.

Indian Agricultural Research Institute (IARI) Scientists also renewed their activity. They built two plants having gas holders as covers on the digesters in 1952-1953. They undertook more elaborate work on digestion and made available useful information to other workers in the field.

Though the experimentation was still going on, many agencies undertook to introduce cow dung gas plants. The Planning Research and Action Institute, Lucknow undertook to construct 200 "gobar" gas plants in U.P. under the leadership of Ram Bux Singh.

By the year 1955-56, gobar (cow dung) gas activity was increasing with the cheap IAIR design which used the main features of gas plants designed by Jashbhai Patel. Cheapness of construction was the main driving force of this design. Most of the IARI and other government projects working with design came to a grinding halt by 1958-59, and the enthusiasm subsided for the time being.

The Field Stage (1960 to the Present): The causes for the failure of those gas plants were mainly due to the fact that in their eagerness to attain cheapness, some essential points of gas plant construction were overlooked. Some of the problems were as follows:

1. In most places, a gas plant claimed to produce 2.83 m^3 (100 ft^3) of gas per day was constructed, without reference to the needs of the family or to the availability of cattle dung.
2. In villages cheap tin burners, designed without regard for technical efficiency, were used for cooking. They consumed a lot more gas per person. In most places gas would be exhausted before the cooking was over. Other means of cooking had to be used right in the middle of cooking. This daily irritation resulted in leaving the gas plant unused.
3. The gas holder of the plant, guided either by three or four guides with only one pulley on each guide could never be kept in a balanced position. The gas holders tilted badly, giving very uneven supplies of gas and often interrupting the gas supply altogether. The housewife had to go to the plant in the middle of cooking and set right the gas holder to resume the gas supply.
4. Inefficient burners made from empty cigarette and shoe polish tins worked at less than 30% efficiency and the flame temperature was also very low which took too long a time to cook.

Many of these defects were due to faulty supply systems as well as inefficient appliances for the use of gas. So in the next stage of development, along with the improvement of the digester attention was also paid to the designing of proper stoves and burners.

In 1961, the Khadi and Village Industries Commission included a biogas plant development scheme in its program. KVIC undertook development and research work at Kora Kendra, Bombay where biogas burners (with 60% thermal efficiency), biogas lamps and biogas engines were designed and developed. KVIC also improved the earlier designs of biogas plants, taking considerations which follow into account:

1. Each gas plant must be designed to suit the available quantity of raw material;
2. Attempt to prevent the often noticed scum formations on the surface of the digester;
3. The plant design must minimize operation and supervisory attention.

Accordingly, KVIC designed and started manufacturing biogas plants of different capacities ranging from 2 to 140 m^3, to suit the availability of dung and quantity of gas requirement.

Improvement in the design of gas holders helped in the adjustment of pressure for the gas to flow and burn satisfactorily in the stoves and lamps.

With these modifications the design was ready for introduction into villages on a large scale.

Further, to promote the use of biogas plants, KVIC decided to provide financial and technical aid to users.

These steps put the introduction of biogas plants on an organized basis and helped to accelerate the movement in the country. Designs of biogas plants used in India are also suitable for operation in other tropical countries in Africa and Asia. The Khadi and Village Industries Commission has given biogas technology to a number of countries in Africa and Asia including: Botswana, Iran, Iraq, Nepal, Tanzania, Sri Lanka and Somalia (Gobar Gas- Retrospects and Prospects, 1978).

Other institutions in India besides KVIC, where extensive research and development work is in progress related to problems connected with biogas technology are the Indian Agricultural Research Institute, Planning and Action Research Institute, National Environmental Research Institute, Central Building Research Institute, Gobar Gas Research Station, and the Indian Institute of Science.

Although farm scale biogas plants have been operated in Europe, Asia, and Africa, its development for energy production in North America was largely neglected until recently because other less costly sources of energy were readily available. In North America, the research and development work has just entered the pilot plant stage, but it is being done in many places. Among the most prominent are: The University of Manitoba, The University of Illinois, University of Hawaii, Cornell University, Columbia University, Institute of Gas Technology, Chicago, Agricultural Research Service, United States Department of Agriculture, Biomass of Colorado Inc., Denver, and the Biomass Energy Institute Inc., Winnipeg. Much of this recent work is summarized in the following publications:

The Proceedings of the 1971 International Symposium on Livestock Waste Management, (American Society of Agricultural Engineers, 1971); the Proceedings of the 1973 International Biomass Energy Conference, (Biomass Energy Institute, 1973); the Proceedings of the 3rd (1975) International Symposium on Livestock Wastes (American Society of Agricultural Engineers 1975); and in the Proceedings of the 1975 Cornell Agricultural Waste Management Conference (Jewell, 1975).

This literature review has demonstrated that there are valuable data available regarding the anaerobic fermentation process and the technology of biogas plant construction. However, it is significant to note that although the technology of biogas production exists, and is accepted by Indian villagers, its large scale utilization and potential have not been assessed to date.

CHAPTER IV

BIOGAS ENERGY DEMAND IN STUDY AREA

4.1 Village Life-Style

The Indian village is usually a cluster of houses around which the small plots of the farmland are spread. The houses generally have two or more rooms and are made of sun-baked brick coated with a plaster of mud. Occasionally there are houses of fire-baked brick plastered with cement belonging to wealthier people. The houses are often built wall-to-wall, forming a cluster, and narrow unpaved lanes run crookedly through the village. Only in the villages which have been influenced by community projects does one find paved lanes or lanes with gutters. During the rainy season the lanes are muddy, but inside the house, the floor is swept clean and belongings neatly kept. The animal of the household--cattle or buffalo live in the walled courtyard beside the house.

Nearly 80% of India's population lives in 575,936 villages, with agriculture as their main occupation. The inhabitants of a village besides farmers, include black-smiths, carpenters, barbers, washermen, priests, goldsmiths, weavers and heardsmen as artisans. Villagers may, moreover, belong to a single tribe, or may differ from one another in a single tribe, or may differ from one another in 'caste' or religious persuasion. Division of society on the basis of caste is a peculiar social phenomenon existing throughout the entire Indian territory. The Hindu community incorporates four castes, Brahmins (priests/teachers) the top rank, then Kshatriyas (warriors), Vaisyas (merchants) and Shudras (laborers). A caste is again divided into many sub-castes. These castes differ among themselves in the sense that they have unequal share of advantages and disadvantages in social, economic and political life depending on their ranks in the caste hierarchy. One remarkable characteristic of the Muslim community in India is its quasi-caste character. The caste system though foreign to Islam has entered the Muslim social system to some extent because of constant contact with the Hindus (Dube, 1955).

The social organization of rural India revolves around a tightly integrated extended family or a larger kinship unit. All village co-operative activities centre around the family household rather than the individuals. In the family households, certain jobs are specified for men and others for women, while some other activities are either jointly undertaken or are interchangeable between men and women. The women are responsible for day to day domestic work, while men take charge of agricultural activities with the help of draft animals, such as ploughing, threshing, water lifting from wells and transportation of grains. However, women also participate with men in other agricultural activities such as weeding, transplanting and harvesting. The job of cutting trees for firewood is generally reserved for men. Women with the help of children gather cow dung and crop residues to make cow dung-cakes- a main fuel source for cooking. However, women from higher socio-economic status are less likely to participate in agricultural work than others. There are several reasons for this, such as status (a person of high status should not allow his women to work) and economic change (rising man/land ratios, e.g. migration into the prosperous village, means that the better-off should make room for those who need to work for subsistence).

Traditionally the Indian village has been managed and administered by the Gram Panchayat (village council). The members of the village council are elected every five years. The village council is villager's working committee, available when they need help with their problems. The most important post in the village is considered that of President of the village council, who is responsible for collecting taxes due to the council and keeps records of all money spent by the council. It is the village council's President's duty to report immediately to the block development officer if any epidemic strikes the village. The President of the council is expected to attend any block or district meeting, and is usually given an opportunity to present the needs of the village.

For agricultural purposes bullocks are generally preferred by the villagers, and, therefore, cows in rural India are primarily maintained for the production of male progeny, rather than for milk. The she-buffaloes on the other hand are considered to be better dairy animals than cows. The male-buffaloes are used as draft animals in some wet paddy areas where they are more efficient than the bullocks. Each

Indian farmer needs at least two bullocks or buffaloes to plow the field at the proper time of the year. When the monsoons arrive, draught animals cannot be shared because all farmers need them at precisely the same time; sowing must be done quickly during the first showers and harvesting begun when the grain matures. Besides ploughing, these animals are also used for several other purposes such as carrying manure to fields, lifting water from wells by means of a pulley system, and driving sugarcane crushers and oil-seed presses. It has been estimated that these draught animals supply over 60% of the power needs of farms in India (Bhatia, 1977).

4.2 Energy consumption pattern in the villages of India

The life-styles, occupations and energy needs of people in the villages, small towns and big metropolitan cities are different, and so are their energy problems. The rural population in India derives about 90% of its energy needs from "non-commercial" sources, such as fire-wood, dried animal dung, vegetable waste, and only 10% from commercial sources usually coal and kerosene. By contrast the urban population consumes about 90% of the energy derived from commercial energy sources.

The principal energy needs in the villages are:

(a) for cooking;

(b) for lighting (household and community);

(c) for agriculture - irrigation, grain transport and storage;

(d) for small scale cottage-industries.

The villagers in rural India fulfull these agricultural energy needs, to the extent that they can, primarily by the power of human and draft animals - almost all the labour for the fields, including the energy required to provide water for irrigation. Fire-wood, dried cow dung and vegetable waste are the primary cooking fuels and kerosene is commonly used by the villagers to fuel small oil-lamps for lighting.

Those familiar with life-style in the villages of India know that the needs of people who live in them are simple and include: energy to cook the meals, light the home at night, run local community centers and small-scale industries (Unitera, 1978). These energy needs could be fulfilled by developing simple technologies to harness locally available sources of energy at reasonable costs, and in a more efficient way than is being used at present. The present pattern of non-commercial energy use in villages is certainly unwelcome from the environmental and economic points of view. As the felling of trees to obtain fuel leads to deforestation, soil erosion, desertification and flooding; and it has been stated that only 23% of the country is under forest cover (and the figure has declined over the years), whereas the figure should be around at least 35% (Yearbook, 1979). The burning of cow-dung cakes in open-fired stoves means a loss of fertilizer, an increase in health hazard for housewives (because of the soot and smoke produced by these stoves). Moreover the average efficiency with which these fuels are burnt in an open-fired stove is only 11 percent (Gobar Gas- Why and How, 1979).

The data for the energy consumption pattern in the villages of Naujheel block for cooking and lighting are not available. The kind of village-by-village studies for biogas energy consumption data that are needed do not yet exist. But some suggestive observations emerge from the following information given by the Khadi and Village Industries Commission (Gobar Gas- Why and How, 1979):

Biogas Consumption in rural India

For Cooking: 0.2286 m^3 per day per person

For Lighting: 0.1274 m^3/lamp of 100 Candle Power

The above information on biogas energy consumption pattern in rural India has been used in this study to estimate the total biogas energy requirements in the study area.

4.2.1 Cooking

Since the per capita biogas consumption for cooking is 0.2286m^3 per day, 794 villagers in the study area would need 181.50m^3 of biogas per day. As there are 98 family households with an average of 8 persons per family, each family in the village would require about 1.85m^3 of biogas per day for cooking purposes.

2.2.2 Lighthing

For lighting, the 98 households in the village would consume 12.48m^3 of biogas per hour at night on the basis that each family uses one lamp of 100 Candle Power consuming $0.127m^3$ of biogas.

4.3 Results and Discussion

The total quantity of biogas required by 794 villagers in the study area, for cooking and lighting consumption, as calculated in the preceding sections was $194m^3$ per day and $70810m^3$ per year.

It has been assumed in this study that each family in the study area uses only one lamp having one mantle with a 100 Candle Power rating and lights it only for one hour per night. The consumption quantity of biogas for lighting would increase by $0.1274m^3$/1amp per additional hour. Therefore, for additional use of lighting, this factor should be taken into consideration.

CHAPTER V

BIOGAS ENERGY SUPPLY IN STUDY AREA

5.1 Biogas Production

When biological substances undergo anaerobic digestion in a controlled environment, biogas is produced. This gas is mainly a mixture of methane and carbon dioxide. The non-volatile solids left behind as a slude retain all the nitrogen, phosphorous and potasium originally present and can therefore be used as an organic fertilizer.

The anaerobic digestion in the biogas plant consists of two main steps. The first step involves conversion of the complex biological substances into simple organic acids; and the second step involves gasification of acids into biogas. Each of these steps is handled by separate families of bacteria, and it is the methanogenic bacteria concerned with the gasification step which require the anaerobic conditions.

A detailed description of anaerobic digestion process is presented in Chapter VII.

The main emphasis in India has been on the anaerobic digestion of 'Gobar' (Hindi word for cow-dung); hence it is known in India as Gobar gas. The fermentation, however, also proceeds with human night soil.

To discuss the potential of biogas production in any area, it is necessary to have exact information on the human and cattle population, the daily yield of night soil and dung, the biogas yield per unit weight of dung and night soil.

5.1.1 Energy Conversion Factors

The conversion factors given in Table 9 and Table 10 show the comparison of energy content of various fuels and replacement values of various fuels respectively. These values of different fuels have been used in estimating the potential energy available from the anaerobic digestion system.

5.1.2 Estimation of Total Quantity of Animal Manure and human night-soil available

The manure yield from various animal depends on the breed, weight of the animal, the feed, and whether the animal is stable-bound or freely grazing.

The manure yield values from cattle and buffalo in the study area are not available. However, the Khadi and Village Industries Commission, which has been working on the biogas program in India for decades has determined the average availability of manure for biogas production from the average weight of cattle and buffalo. The Khadi and Village Industries Commission has also estimated the availability of night soil per person per day. The figure, which has been used in this study to estimate the total quantity of animal manure and human night-soil is displayed in Table 11.

As shown in the Table 11, 2765 kg (1695 kg and 1070 kg from buffalo and cattle respectively) of manure from 113 buffalo and cattle is expected to be available per day for its potential use in the biogas plant operation. Further

TABLE 9

COMPARISON OF VARIOUS FUELS

Fuel	Unit	Energy Content Kilo-Calories	Energy Content Mega-Joules	Mode of Burning	Thermal Efficiency (%)	Effective Heat Kilo-Calories	Effective Heat Mega-Joules
Biogas (60 to 65% CH_4)	m^3	4,713	20.0	In Standard Burner	60	2,828	12.0
Kerosene	L^{-1}	9,122	38.2	Pressure Stove	50	4,561	19.1
Fire Wood	kg^{-1}	4,708	19.7	In Open Stove	17.3	814	3.4
Cow-Dung Cakes	kg^{-1}	2,092	8.7	In Open Stove	11	230	0.9642
Charcoal	kg^{-1}	6,930	29.0	In Open Stove	28	1,940	8.1
Soft Coke	kg^{-1}	6,292	26.3	In Open Stove	28	1,762	7.3
Butane	kg^{-1}	10,882	46	In Standard Burners	60	6,529	27.6
Furnace Oil	L^{-1}	9,041	38	In Water tube boiler	70	6,781	28.5
Coal Gal	m^3	4,004	16.7	In Standard Burner	60	2,402	10.0
Electricity	kWh^{-1}	860	3.6	Hot Plate	70	602	2.5

Source: Gobar Gas- Why and How, 1979, Published by the Khadi and Village Industries Commission, Bombay, India, p. 14.

TABLE 10

REPLACEMENT VALUES OF VARIOUS FUELS

Name of fuel	Unit	Biogas $1 m^3$	Kerosene 1 Litre	Fire-wood 1 kg	Cowdung Cakes 1 kg	Charcoal 1 kg	Soft coke 1 kg	Butane 1 kg	Furnace Oil 1 litre	Coal Gas $1 m^3$	Electricity 1 kWh
Biogas	m^3	1.0	1.613	0.288	0.081	0.686	0.623	2.309	2.398	0.849	0.213
Kerosene	Litre	0.620	1.0	0.178	0.050	0.425	0.386	1.431	1.487	0.527	0.132
Firewood	kg	3.474	5.603	1.0	0.283	2.383	2.165	8.210	8.330	2.951	0.740
Cow-dung cakes	kg	12.296	19.830	3.539	1.0	8.435	7.640	28.387	29.483	10.443	2.617
Charcoal	kg	1.458	2.351	0.420	0.119	1.0	0.908	3.365	3.495	1.238	0.310
Soft coke	kg	1.605	2.589	0.462	0.130	1.101	1.0	3.705	3.848	1.363	0.342
Butane	kg	0.433	0.699	0.125	0.035	0.297	0.270	1.0	1.039	0.368	0.089
Furnace Oil	Litre	0.417	0.673	0.120	0.034	0.286	0.260	0.963	1.0	0.354	0.089
Coal gas	m^3	1.177	1.899	0.339	0.096	0.808	0.734	2.788	2.832	1.0	0.251
Elect-ricity	kWh	4.698	7.576	1.352	0.382	3.223	2.927	10.846	11.264	3.990	1.0

For equivalents read vertical columns.

Source: Gobar Gas- Why and How, 1979, Published by the Khadi and Village Industries Commission, Bombay, India, p. 15.

TABLE 11

ESTIMATED QUANTITY OF ANIMAL MANURE AND NIGHT-SOIL AVAILABLE

Source of Manure or Night-Soil	Total Number of Animal or person in the study area	Availability of Manure or Night-Soil per day per Animal or person	Total Quantity of Manure or Night-Soil available per day	Total Quantity of Manure or Night-Soil available per year
Buffalo	113	15 kg *	113 x 15=1695 kg	618675 kg
Cattle	107	10 kg *	107 x 10=1070 kg	390550 kg
Human	794	400 grams**	794 x 400 grams = 317.6 kg	115924 kg

Sources: * Gobar Gas- Why and How, 1979, Published by the Khadi and Village Industries Commission, Bombay, India, p. 13.

** Gobar Gas- Retrospects and Prospects, 1978, Published by the Khadi and Village Industries Commission, Bombay, India, p. 6.

it is estimated that from 794 persons in the study area (village) about 317.6 kg of night-soil would be also available for the fermention in the biogas plant to produce biogas.

5.1.3 Estimation of Total Quantity of Biogas Recovered from Animal Manure and Human Night-Soil

The production of biogas from organic materials, such as animal manure and night-soil by the anerobic digestion system depends on various factors such as the nature of raw materials, temperature, loading rate, alkalinity, retention time, nutrients and seeding. These factors which are essential for the successful operation of an effective biogas generator have been discussed in detail in Chapter VII of this practicum.

By considering these factors, the Khadi and Village Industries Commission has determined the average value of biogas production from animal manure and human night-soil under Indian climatic conditions. It has been estimated by the Khadi and Village Industries Commission that 1 kg of cattle dung (20 to 25% of dry solids) yields 0.0368 m^3 of biogas and 1 kg of night-soil produces 0.0707 m^3 of biogas (Gobar Gas-Petrospects and Prospects, 1978). Assuming these figures, the total quantity of biogas produced from 2765 kg (1695 kg buffalo dung + 1070 kg cattle dung) of dung available per day in the study area from 113 buffalo and 107 cattle, was estimated to be 102 m^3 of biogas. A further, 22 m^3 of biogas per day would be generated from the 317.6 kg of night-soil available per day from 794 persons living in the study area (village), assuming that latrines are connected to the biogas plants.

Therefore, a total quantity of 124 m^3 of biogas can be generated per day from animal manure and night-soil available from 113 buffalo, 107 cattle and 794 persons living in the study area (village). The quantity of biogas produced from animal manure and night-soil in the study area are summarized in Table 12.

5.2 Results and Discussion

From the proceeding section it is clear that the village (study area), from its sources would be able to supply only 124 m^3 of biogas whereas the total demand for biogas in the village is about 194 m^3. As a result present available supply is only enough to fulfill 64% of the total demand of biogas energy for cooking and lighting in the village. To fulfill the remaining 36% of biogas energy demand in the village, the quantity of raw materials will have to be increased in order to produce the remaining 70 m^3 of biogas. Another approach to increase the quantity of biogas, to a certain extent, is the need for further research on pretreatment techniques with available resources, that would improve the biodegradability of the locally available raw material such as cereal crop residue, and thus improve the efficiency of biogas production.

TABLE 12

ESTIMATED QUANTITY OF BIOGAS AVAILABLE

Source	Total Number in the study area	*Total Quantity of Manure or Night-Soil available per day	*Total Quantity of Manure or Night-Soil available per year	**Biogas yield per kg. of Manure/Night-Soil	Total Quantity of Biogas produced per day	Total Quantity of Biogas Produced per year
Buffalo	113	1695 kg	618675 kg	0.0368 m^3	62.376 m^3	22767.24m^3
Cattle	107	1070 kg	390550 kg	0.0368 m^3	39.376 m^3	14372.24m^3
Human	794	317.6 kg	115924 kg	0.0707 m^3	22.45432m^3	8195.8268m^3
TOTAL					124.20632m^3	45,335.306m^3

Sources: * Figure from Table 13

** Gobar Gas-Restrospects and Prospects, 1978, Published by the Khandi and Village Industries Commission, Bombay, India, p. 6.

CHAPTER VI

CEREAL CROP RESIDUES AS POTENTIAL ENERGY SUPPLY FOR FUTURE

6.1 Residue Coefficients

Cereal crop residue coefficients vary with such factors as yielding variety, thickness of planting, productivity of soil, climatic variations from season to season and cultural practices from location to location. Cereal crop residue coefficients data is not available for India. However, Table 15 shows the data on residue coefficients for major cereal crops which were determined by individual crop experts and forwarded by Dr. Robert Yeck of the Agricultural Research Service of the U. S. Department of Agriculture (Poole, 1975). Since in the U. S., more improved varieties of cereal crop are sown than in India, it has been assumed in this study that the ratio of residue will be more rather than less in India than in U. S., as generally improved varieties of cereal crops yield more grain than residues. Therefore, in estimating the quantity of cereal crop residue in the study area, data displayed in Table 13 has been used in this study.

6.2 Estimation of Total Quantity of Cereal Crop Residue Available

Cereal crop productivity varies with high yielding varieties of seeds, local variety of seeds, irrigated and unirrigated land. The average yield of crops per hectare

TABLE 13

RESIDUE COEFFICIENTS FOR MAJOR CEREAL CROPS

Crop	Residue Co-efficients Mass Dry Residue: Mass Harvested Crop
Wheat	1.50: 1.00
Oats	1.50: 1.00
Barley	1.25: 1.00
Rye	1.70: 1.00
Corn (Maize)	0.85: 1.00
Rice	0.85: 1.00
Sorghum	0.85: 1.00

Source: Poole, A., 1975, "The Potential for Energy Recovery from Organic Wastes", in Williams, R. H. (ed.), The Energy Conservation Papers, Ballinger Publishing Co., Cambridge, Mass., p. 238.

(considering high yield variety of seeds, local variety of seeds, irrigated and unirrigated land) has been used in this study to determine the total crop production in the study area which is shown in Table 14.

The cereal grain yields per unit area in Naujheel block are poor compared to the all-Indian average. For example, the all-India average for wheat and rice yields are 1,338 kg and 1,877 kg per hectare respectively (Times of India Yearbook, 1979), whereas in the study area it is only 344 kg and 364.5 kg per hectare (Table 14).

The Naujheel Block has a geographical area of 35,877 hectares, out of which 84% of the area is under cultivation. Since three crops are grown per year, in the same land, the total cropped area is 115 percent (41,178 hectares) of total geographical area (35,857 hectares). The major cereal crops grown in this area include Wheat, Sorghum, Barley, Corn and Rice. These cereal crops cover about 72% (28,825 hectares) of total geographical area. Other important crops grown in this area are sugarcane, pulses, fodder and cotton.

A summary of the area, yields and productions of cereal crop residues in the Naujheel block and in an average typical village is shown in Table 15 and 16 respectively. Not all of the cereal crop residue estimated would be available for use as a future energy input. The Rice Straw has been excluded from the total amount of cereal residue, as its amount available is negligible in the study area and its

TABLE 14

PRODUCTIVITY OF LAND IN NAUJHEEL BLOCK

Crop	High Yield Variety Irrigated	High Yield Variety Unirrigated	Local Variety Irrigated	Local Variety Unirrigated	Average
1. Wheat	526	283	364	202	344
2. Barley	445	364	364	202	344
3. Sorghum	283	---	202	162	215
4. Corn (Maize)	284	---	---	---	284
5. Rice	405	---	324	---	364.5

Source: Naujheel Block, Mathura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi.

TABLE 15

ESTIMATED QUANTITY OF CEREAL CROP RESIDUES AVAILABLE IN NAUJHEEL BLOCK

No.	Description	Unit	Cereal Crops				
			Wheat	Barley	Sorghum	Corn	Rice
1.	Area Under Cultivation[1]	Hectare	13,013	5,271	7,178	4,159	304
2.	Grain Yield[1]	kg/Hectare	344	344	215	284	364.5
3.	Grain Production[1]	kg	4,476,472	1,813,244	1,543,270	1,181,156	110,808
4.	Residue:Grain Ratio[2]	Mass Dry Residue:Mass Harvested Crop	1.50:1.00	1.24:1.00	0.85:1.00	0.85:1.00	0.85:1.00
5.	Residue/Unit area[2]	kg/hectare	516	430	183	241	310
6.	Total Quality of Cereal Crop Residue	kg	6,714,708	2,266,530	1,313,574	1,002,319	94,240

Source: [1]Naujheel Block, Mathura District, Uttar Pradesh- A Socio-Economic Survey, 1975, Published by the Association of Voluntary Agencies for Rural Development, New Delhi.

[2]Poole, A., 1975, "The Potential for Energy Recovery from Organic Wastes" in Williams, R. H. (ed.), The Energy Conservation Papers, Ballinger Publishing Co., Cambridge, Mass., p. 238.

TABLE 16

ESTIMATED QUANTITY OF CEREAL CROP RESIDUES AVAILABLE IN TYPICAL VILLAGE AREA*

			Cereal Crops				
No.	Description	Unit	Wheat	Barley	Sorghum	Corn	Rice
1.	Area Under Cultivation[1]	Hectare	89	36	49	28	2
2.	Grain Yield[1]	kg/hectare	344	344	215	284	364.5
3.	Grain Production	kg	30616	12384	10535	7952	729
4.	Residue:Grain[1] Ratio	Mass Dry Residue:Mass Harvested Crop	1.50:1.00	1.25:1.00	0.85:1.00	0.85:1.00	0.85:1.00
5.	Residue/Unit[1] area	kg/hectare	516	430	183	241	310
6.	Total Quantity of Cereal Crop Residue	kg	45,994	15,489	8,955	6,759	620

7. Total Quantity of Cereal Crop Residue (Excluding Rice Residue) 77,188 kg.

8. Total Quantity of Cereal Crop Residue (excluding Rice) available (75% of No.7) 57,891 kg

*A Typical Village was determined by taking an average of 147 villages in Naujheel Block. Therefore, data are based on Table 17. [1]Figure from Table 17.

also used as cattle feed with other forage crops. Residues from other cereal crops, for example, wheat Sorghum, Barley and Corn are brittle, thick and stemmy in nature, therefore, it is difficult if not impossible to be digested by livestock. Because of this problem, residues from wheat, Sorghum, barley and corn are generally not used as cattle-feed, but are sometimes used in making cowdung cakes by mixing with cowdung, for fuel, and the rest are burned in the open field. Unlike western agriculture practice, cereal crops are not ploughed back into the soil in India, as in the same field another crop is sown just after the first harvest. Therefore, except for a small quantity of cereal crop residues being used for fuel with cowdung cakes, these are generally considered as a problem by farmers in India.

It has been assumed that 75% of the total quantity of crop residue (77,188 kg) from wheat, sorghum, barley and corn will be available for converting into useful potential energy use in the future in the study area.

6.3 Results and Discussion

Table 16 illustrates that only 57,891 kg of cereal crop residue per year is available for potential use in the future in the typical village area. Cereal crop residue has a higher heat value of 5,000 to 6,500 Btu per pound (McGinnis, 1973). If an average value of 6,000 Btu/lb or 13.93 MJ/kg could be used, then the energy content of cereal crop residue available in the village (study area) would be about 806422MJ per year or 2209.37MJ per day. In comparison with the total biogas energy consumption demand for the village, which is about 194 m^3 per day (which is equivalent to 4337.37MJ), the energy content value of cereal crop residue available in the study area is about 51% (2209.37MJ) of the 194 m^3 of biogas consumption.

CHAPTER VII

TECHNICAL AND SOCIO-ECONOMIC CONSIDERATIONS

7.1 Technical Aspects

The technical aspects of biogas plant operation for the production of biogas has been discussed under the following sections of the Anaerobic Digestion Process, Digester Design Example and Construction Materials for Biogas Plants:

7.1.1 Anaerobic Digestion Process

A Biogas plant is a device for conversion of the digestable organic matter, in a particular animal manure into combustible biogas (consisting primarily of methane and carbon dioxide) and effluent which can be used as organic fertilizer. This is achieved by subjecting the material to anaerobic digestion. Anaerobic digestion is a biological process during which the organic matter is decomposed by anaerobic bacteria. Anaerobic digestion depends upon two groups of bacteria which thrive in the absence of oxygen. The first of these groups of bacteria is called the "acid formers". The acid formers convert biodegradable organic compounds such as fats, carbohydrates and proteins, into simple organic compounds such as acetic acid, propionic acid, carbon dioxide and hydrogen. The second of these bacteria, the methanogenic bacteria, converts simple organic compounds made by the acid formers into methane and carbon dioxide.

The acid forming group comprises both faculative and obligate anaerobic bacteria. They are generally capable of rapid reproduction and are relatively insensitive to change in environment. Their role in the digestion process is to convert the incoming materials into a form which can be used by methanogenic bacteria.

The methanogenic bacteria have more demanding environmental requirements. These bacteria are extremely sensitive to the presence of oxygen. Most of these bacteria grow quite slowly. The quantity and quality of the biogas produced by the anaerobic fermentation process are affected by the following several factors.

7.1.1.1 Temperature

Although it has been reported that biogas production is possible throughout the 0 to 60°C range, the methanogenic bacteria are severely limited below 20°C and above 55°C (Lapp et al. 1978). Anaerobic digestion occurs most rapidly at two temperature ranges, namely, Mesophilic range: 20°C - 45°C and Thermophilic range 45°C. Precise limits to these ranges have not been established. Although digestion proceeds more rapidly in the thermophilic range, the mesophilic range is generally preferred. A sudden temperature fluctuation affects the performance of the bacteria in this process. It has been suggested that temperature of an operating digester should not fluctuate much more than

±2°C (Sparling 1973).

7.1.1.2 pH

The term pH denotes the acidity and alkalinity of the substrate. The optimum range is between 7.0 and 8.5 (Lapp *et al*. 1978). Animal manure usually has sufficient alkalinity, which functions as a buffering agent to prevent the pH from dropping to a level which will inhibit the methanogenic bacteria. Low concentrations of alkalinity however, may cause the methanogenic bacteria to cease activity due to organic acid accumulation. If the alkalinity is too low, because of acid accumulation the pH of digester will drop. It has been suggested that a drop in pH concentration can be counteracted with the addition of alkalinity in the form of lime (Sparling 1973).

7.1.1.3 Loading Rate

Loading rate is expressed as the weight of volatile solids added per day per unit of digester capacity. It has been reported that the loading rate should not exceed 6 kg of VS per day per m^3 of digester operating at or below 35°C (Lapp *et al*. 1978).

7.1.1.4 Detention Time

Detention time is the length of period that volatile solids remain in an anaerobic digester for digestion.
In a continuous-feed system, the detention time or retention

time can be defined in terms of solids retention time (SRT) as the quantity of total solids in the digester divided by the quantity of total solids removed per day. It can also be defined in terms of hydraulic retention time (HRT) as the digester volume divided by the volume of daily feed. Hydraulic retention times usually vary from 10 to 30 days, depending on the temperature (Lapp et al.1975). In KVIC's design in India, this period is about 45 to 55 days (Gobar Gas Retrospects and Prospects, 1978).

7.1.1.5 Volatile Solids

Volatile solids are that portion of the total solids that are organic in composition. It has been reported that generally less than 50% of the volatile solids are destroyed by the biological organisms in process, therefore gas production can be expressed either in terms of the volume of gas produced per unit weight of volatile solids added or in terms of volatile solids destroyed (Lapp et al.1975).

7.1.1.6 Total Solids Concentration

Generally the optimum total solids concentration in an anaerobic digester is considered to be 7 to 9. Since the solid content of fresh manure is in the range of 5-25%, dilution may be required.

7.1.1.7 Seeding

Although methanogenic bacteria are found in manure, it may take several weeks for them to multiply. The time required for active digestion to begin can be reduced by seeding (addition of actively digesting material to new digester).

7.1.1.8 Nutrient Balance

All organisms require a supply of nutrients, particularly nitrogen, phosphorus and potassium (NPK). Fortunately, in animal manure these nutrients (NPK) are adequately present for bacteria. Occasionally, however, the ammonia concentration may become so high that it is toxic to the anaerobic bacteria. Therefore, in certain situations the balance between certain nutrients may need adjustment.

7.1.1.9 Mixing

Mixing of digester contents helps the digestion process as it establishes a uniform contact between bacteria and their substrate, assists in preventing scum formation and facilitates the release of the biogas produced. Mixing can be accomplished either by mechanical stirring or gas re-circulation.

7.1.2. Digester Design Example

An anaerobic digester can be regarded as providing a source of energy, fertilizer or feed, and as a method of waste treatment in agriculture. The exact type and purpose of the digester, and therefore, the type of associated installation, vary by location. Different types of digesters have been designed in countries such as India, People's Republic of China, Taiwan, Germany, United States of America, Canada and some other countries in Asia and Africa depending on different specific situations.

An anaerobic digester is basically a container designed to hold the input material and the culture of micro-organisms. It must be airtight, must permit the loading and unloading of materials, and it must have a means of collecting the gas produced. The structures meeting these requirements can range from a used oil drum buried in the ground to a sophisticated structure with pumps, heating coils, insulation and automatic input and output handling equipment (Figure 5).

The simplest design structure is the batch digester (Figure 6). Organic material is placed in the container and the container is sealed.

As the digestion process proceeds, the inputs separate into biogas, scum, supernatant, digested solids and undigestible solids. When the digestion process is complete, the residual contents are removed and the container is filled with fresh organic matter.

The scum consists of undigestible materials that float to the top. The supernatant is a liquid material situated next to the scum. The sludge in solids include residue such as sand and dirt which entered the digester and settled to the bottom. Most digesters have some means of mixing the materials to eliminate the various layers.

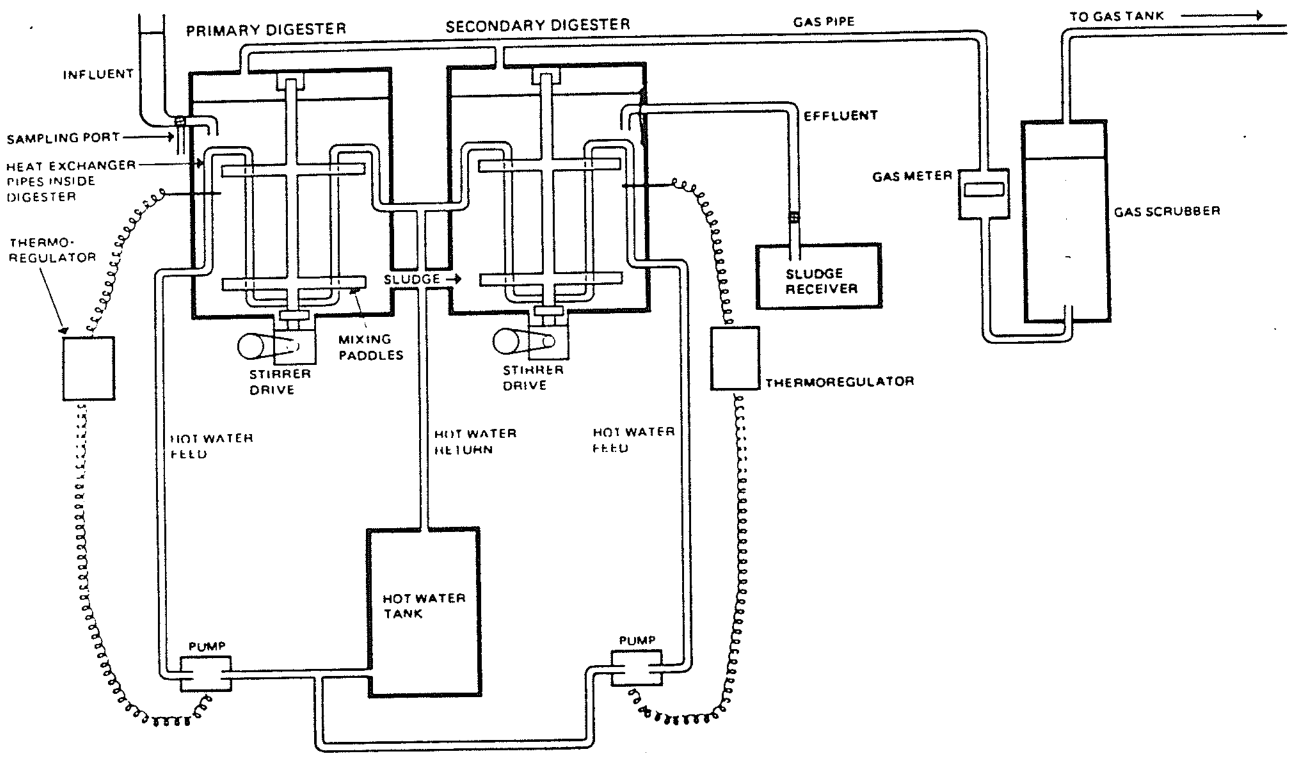


FIGURE 5

SCHEMATIC DIAGRAM OF EXPERIMENTAL LIVESTOCK WASTE DIGESTER

Source: Lapp, M. M. et al., 1974, Methane Production from Animal Waste, Published by Canada Department of Agriculture, Government of Canada, Publication No. 1528, Ottawa, pp. 6-7.

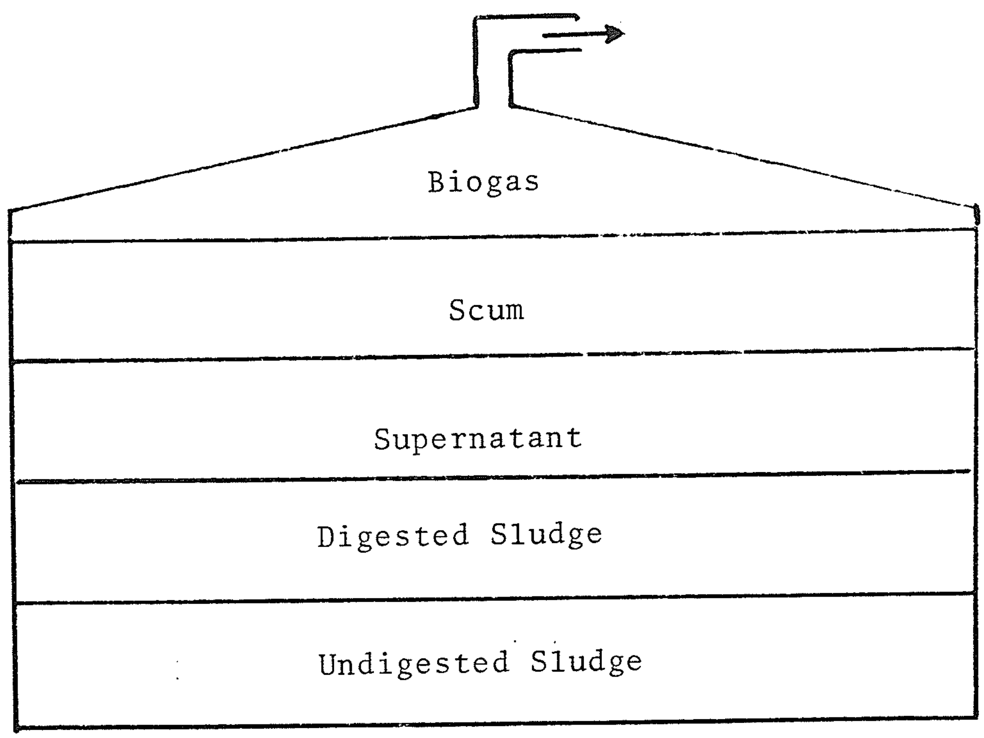


FIGURE 6

SIMPLE BATCH DIGESTER

This type of digester is considered unsatisfactory for use.

One simple modification of the batch digester is the batch load process. This process consists of operating two batch digesters simultaneously (Figure 7). As one unit operates and produces gas, the other is unloaded and fed. Thus, one unit is in operation at all times. This arrangement permits a more continuous use of inputs and supply of outputs.

Daily-fed or continuous flow digesters constitute a fundamental change in design of digesters. This procedure eliminates the irregularity in gas production associated with the batch digester.

One form of the continuous flow digester is the plug flow or displacement design (Figure 8). In this process, input materials are placed in one end of a longitudinal digester and spent materials are forced out the other end. If there is no mixing in the digester the input materials digest as it moves from one end of the tank to the other.

The completely mixed or anaerobic contact process is another continuous flow modification, with or without partitioning, has been popular in India, because of its reliability. This process is designed to retain the biologically active population in the digester while removing the spent effluent (Figure 9). The effluent from the digester is fed into a settling tank where the biologically active solids are separated and fed back into the digester.

All biogas plants used in India consist of the following main parts:

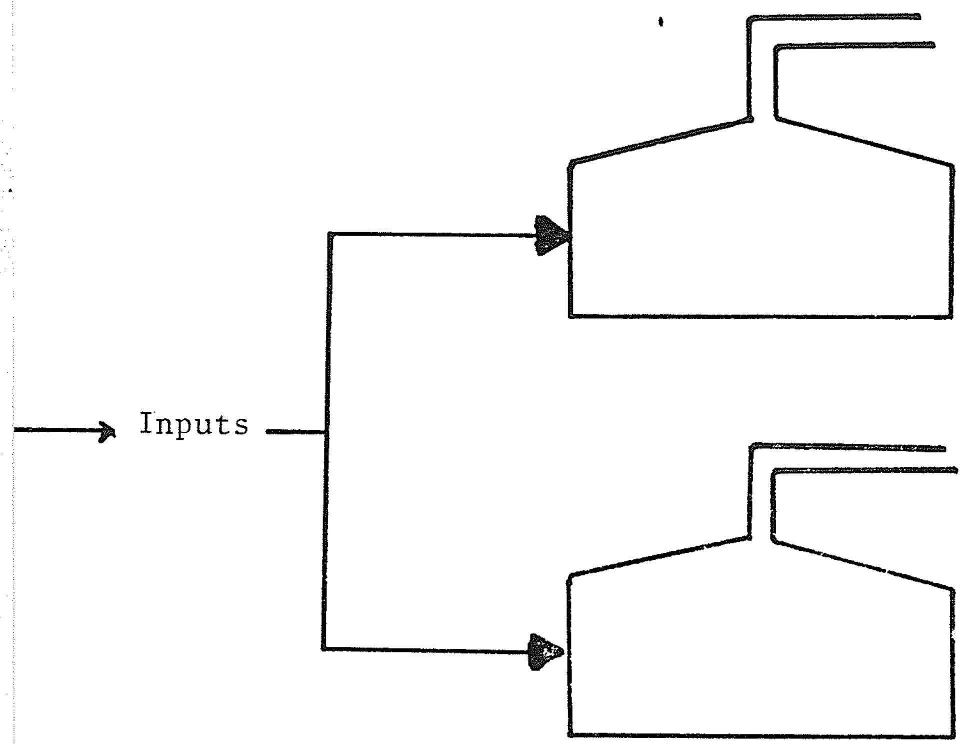


FIGURE 7

BATCHLOAD PROCESS

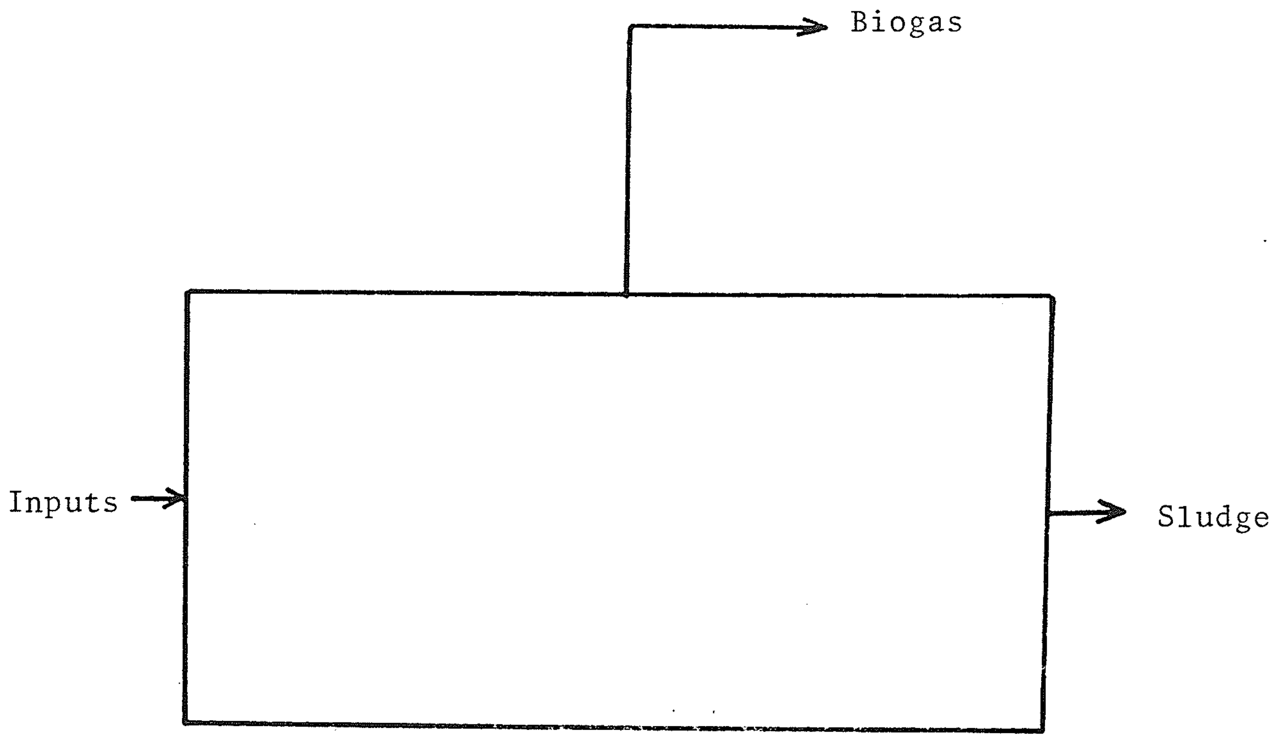


FIGURE 8

PLUG FLOW DISPLACEMENT DIGESTER

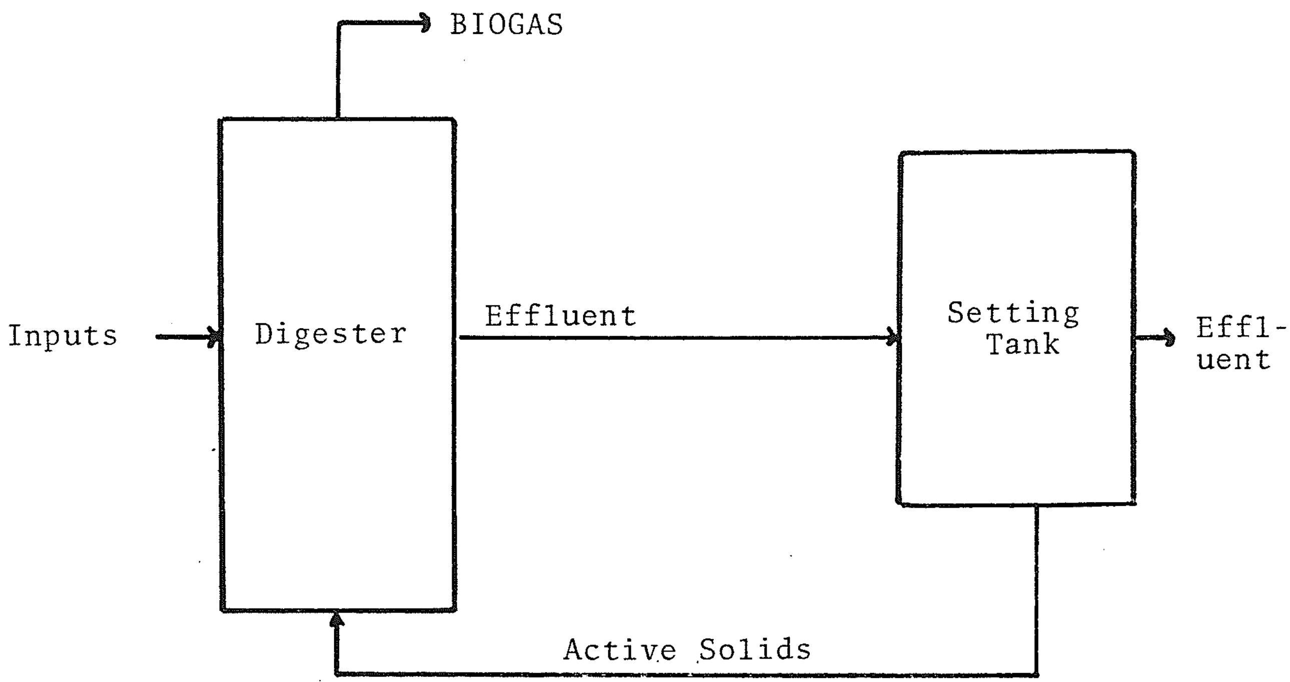


FIGURE 9

ANAEROBIC CONTACT PROCESS

Digestion tank: The volume and dimension of a digestion tank depend on the specific situation such as volume dung, the amount of gas produced per unit weight of dung and retention period. It has been recommended that size of digestion tank should be 2.75 times the volume of gas produced per day (Gobar Gas--Retrospects and Prospects, 1978).

The digesting tank is usually constructed of reinforced concrete and generally built below ground level. Although they are also built above ground level, in India the digestion tank is usually below ground (Figure 10). The depth and diameter of digestion tank varies with the size of the gas plant and quantity of material to be fed in. A partition wall in the middle of the tank divides it into two semi-circle compartments. Two slanting cement pipes reach the bottom of the well on either side of the partition wall and have their opening on the surface of the ground by the side of the top of the well. One pipe serves as the input and the other as the output. The mixture of dung and water is introduced through the inlet pipe and as the tank fills up, an equal quantity of dung slurry flows out through the outlet pipe. The partition wall in the tank stops short of the top of the wall and thus remains submerged in the dung slurry. The digestion tank is so designed that it can hold 50 days of material. Initially it is filled up so that whenever any material is put up from one side an equal quantity goes out from the other side.

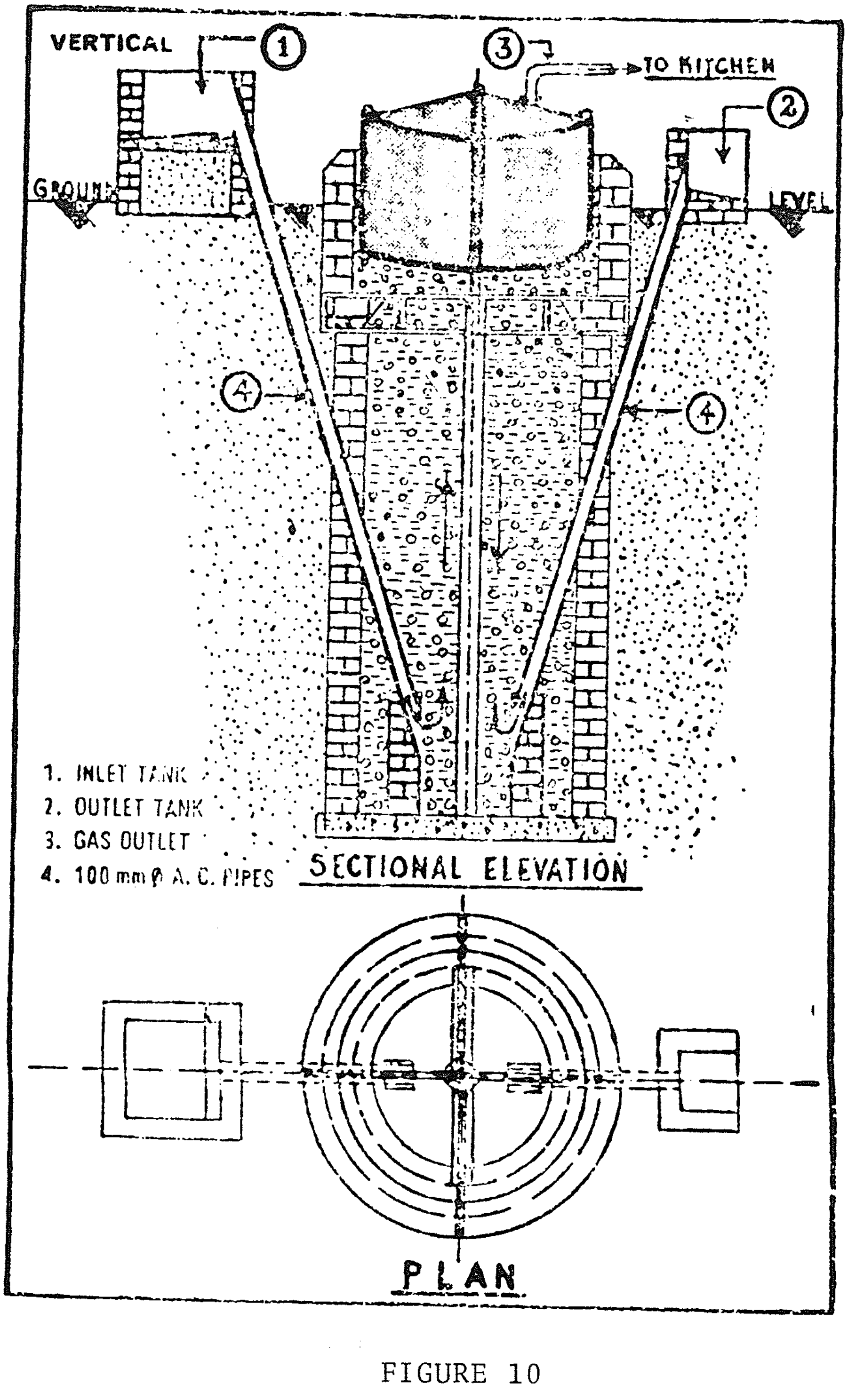


FIGURE 10

TYPICAL FEATURES OF BIOGAS PLANT USED IN INDIA

Source: Gobar Gas Why and How, 1979, Published by the Khadi and Village Industries Commission, Bombay, India, p. 16.

Gas Holder: It is a drumlike structure constructed of mild-steel sheet which fits like a cap on the mouth of the digestion tank. It dips into the slurry and rests on a ledge built inside the digestion tank for this purpose. The drum collects the gas which bubbles out from the dung slurry in the digester. As the gas collects on top of the slurry the drum rises and the accumulated gas flows out through the gas pipe. Through this pipe, the gas can be led to the kitchen for cooking purposes or can be used for gas for lighting whenever required. Normally the gas holders are designed taking into account distribution of the use of gas during the day and night to arrive at storage capacity.

The gas which accumulates inside the drum is under pressure equivalent to the weight of the drum. The weight of the gas holder is designed to give a pressure of about 9.38 cm water column i.e. 900 kg/m^2 of the circular area of the holder (Gobar Gas - Retrospects and Prospects 1978). The pressure is reported to be sufficient to provide pressure for the kitchen stove and gas lamp.

Gas Appliances: To utilize the maximum heat of any cooking fuel, it is necessary to have an efficient burner or oven. KVIC has designed and developed burners for biogas utilization in different capacities, ranging from 9.22 to 1.13 m^3 per hour, having thermal efficiently estimated to be 60% (Gobar Gas - Retrospects and Prospects, 1978). Different designs of burners are shown in Figure 11.

Similarily gas lamps are also available with one to three mantels. Each mantel consumes 0.07 m^3 biogas per hour and gives a light intensity approximately equivalent to a 40 watt bulb.

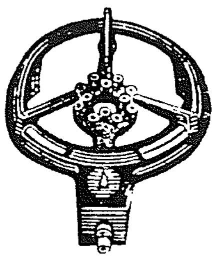
7.1.3 Construction Materials for Biogas Plants

The materials required for constructing biogas plants of 100 ft^3 or 2.83 m^3 gas per day and 3000 ft^3 or 85 m^3 gas per day producing capacities are listed in Table 17 and Table 18 respectively, as reported by the Khadi and Village Industries Commission.

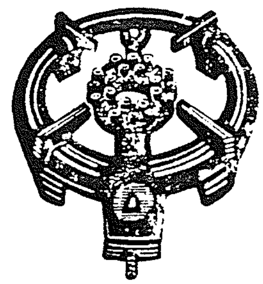
Although in India, three different types of biogas plant designs are known which were developed by the Indian Agricultural Research Institute, Ram Bux Singh of Gobar Gas Research Station, Ajitmal, and the Khadi and Village Industries Commission, the latter design is the most extensively used. It has been reported that by 1978 a total of 59,919 biogas plants of different capacities had been installed in different parts of India by the Khadi and Village schematic diagram of biogas plants of 100 ft^3 (2.83 m^3) and 3000 ft^3 (85 m^3) gas per day capacities are illustrated in Figure 12 and Figure 13 respectively. The gas holders of these two respective capacities are shown in Figure 14 and 15.

The other two types of biogas plant designs,

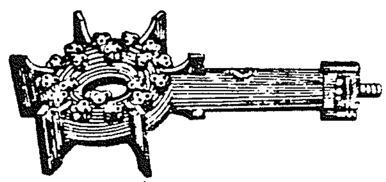
KVIC APPROVED BURNERS MADE BY GASCRAFTERS, BOMBAY



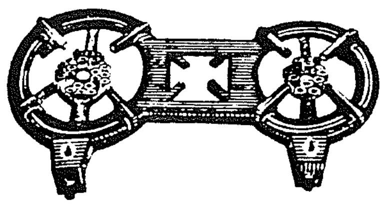
GOBAR GAS DELUX BURNER
225 Litres/Hr.
This is the smallest of Gobar gas burners using 225 Liters/Hr. (8 Cft/Hr.) of Gobargas. It burns with an intensity equal to half that of a kerosene pressure stove.



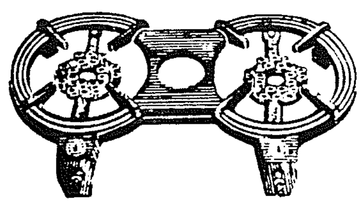
This is similar to 3 a, but bigger in size. The gas consumption being 450 liters (16 Cft) per hour.



GOBAR GAS ANGITTI BURNER
1130 Liters/Hr.
This burner uses 1130 Liters/Hr. (40 Cft/Hr.) of Gobar Gas. This burner is useful for community kitchen of hostels and institutions. It can also be used for industrial heating.



GOBAR GAS DOUBLE DELUX BURNER
This set is a combination of two burners. Each of them will use 450 Liters/Hr. (16 Cft/Hr.) of Gobar Gas and burns with an intensity equal to to that of a kerosene pressure stove.



GOBAR GAS DOUBLE-DELUX-BURNER
(ECONOMY-SIZE)
This set is a combination of two burners out of which one will use 450 liters/Hr. (16 Cft/Hr.) and the other will use 225 Liters/Hr. (18 Cft/Hr.) of gobar gas.

FIGURE 11

DIFFERENT DESIGNS OF BIOGAS BURNERS

Source: Personal Communication with the Director of Gobar Gas Scheme, the Khadi and Village Industries Commission, Bombay, India.

TABLE 17

LIST OF MATERIALS REQUIRED FOR A 100 ft/2.83m^3 GAS PER DAY BIOGAS PLANT

		Vertical	Horizontal
I.	Materials required for Construction of Digester:		
1.	Bricks	2,900	2,800
2.	Sand	100 ft^3 (2.83m^3)	100 ft^3 (2.83 m^3)
3.	Stone-chips 3/4"	25 ft^3 (.70m^3)	3/4" 25 ft^3 (.70 m^3) 1/2" 10 ft^3 (.28 m^3)
4.	Cement	15 bags	20 bags
5.	A.C. Pipe 4" diameter	19 Rft.	20 Rft.
6.	M.S. Rods 1/2" dia. (for horizontal gas plant only) M.S. Rocs 3/8"	-	120 Rft. 80 Rft.
II.	Materials required for Central Guide Frame:		
1.	1 1/4" x 1 1/4" x 1/4" Angle Iron	39 Rft	
2.	2" dia. G.I. or M.S. Pipe	6 Rft	
3.	9" x 9" and 1/4" thick plates	2	
4.	1/2" dia. 1 1/4" long bolts with nuts	16	
III.	Materials required for gas holder		
1.	1 1/4" x 1 1/4" x 1/4" Angle Iron	65 Rft	
2.	M.S. or G.I. or W.I. pipe 3" dia.	3'-6'	
3.	9" dia. and 1 1/4" thick flange plates	9	
4.	Flats 1 1/2" and 1/4"	12	
5.	Gas outlet pipe flange 1" dia.	1	
6.	G.I. Bend 1" dia.	1	
7.	Heavy duty gate valve 1" dia.	1	
8.	Nipple 1" dia.	1	
9.	Coping or Socket 1" dia.	1	
10.	3 metre 1" Reinforced rubber pipe with 1" adapters and rubber washer at both ends	1	
11.	12 gauge M.S. Sheets (3'x6')	3	

Source: Personal Communications with the Director of Gobar Gas Scheme, the Khadi and Village Industries Commission, Bombay, India.

TABLE 18

LIST OF MATERIALS REQUIRED FOR A 3,000 ft^3 or $85m^3$ BIOGAS PER DAY BIOGAS PLANT

I.	Materials required for construction of digester:	
	1. Bricks	48,000 Nos.
	2. Sand	1,300 ft^3 ($36.80m^3$)
	3. Cement	239 Bags
	4. Stone Chips 3/4"	325 ft^3 ($9.20m^3$)
	5. A. C. Pipe	50 Rft
II.	Materials required for Central Guide Frame:	
	1. Internal dia G.I. Pipe, Welded with 12 x 12 x 1/4 Flange Plate	24 Rft.
III.	Materials required for Gas Holder	
	1. Angle Iron 3" x 3" x 5/16"	650 Rft.
	2. 6" Intl. Di. G.I.M.S. or W.I. Pipe	8' - 4"
	3. 4-6" dia flange for 6" pipe, 5/16" thick	2
	4. Flats 3" x 1/2"	65 Rft.
	5. Gas outlet pipe flange 2"	1
	6. G. I. Bend 2" dia.	1
	7. Heavy duty gate valve 2"	1
	8. Nipple 2"	1
	9. Coupling or Socket 2"	1
	10. 10 Metre 2" Polthene connector with 2" adopted and Rubber washer at both ends	1
	11. 10 guage M.S. Sheets (8'-4')	23

Source: Personal communication with Director of Gobar Gas Scheme, Khadi and Village Industries Commission, Bombay, India.

developed by the Indian Agricultural Research Station, Ajitmal, have not been tried out on a sufficiently extensive scale in India.

7.2 Social Aspects

In India there is a considerable uniformity in the way energy is used by the villagers, regardless of the disparity of the socio-economic status. Most of the villagers burn cow dung and vegetable matters for cooking but the collection of these materials varies with the socio-economic status of the villagers. Very few of the women and children from a high socio-economic household, for instance, collect fire-wood and cattle dung, but many women and children from the low socio-economic group have to do so. In fact, one of the main sources of income to many villagers in Indian society is through the collection of dung and preparation of cow dung cakes for sale as fuel to high economic groups in villages (Tribune, New Delhi, 1974). It is expected that the installation of biogas plants by the high socio-economic group would result in an increasing tendency to have stable-bound cattle in order to augment the collection of dung and urine. This would deprive the poorer sections in rural society of cheap source of fuel for their energy needs and a source of income. A similar problem is likely to arise for families who do not own cattle.

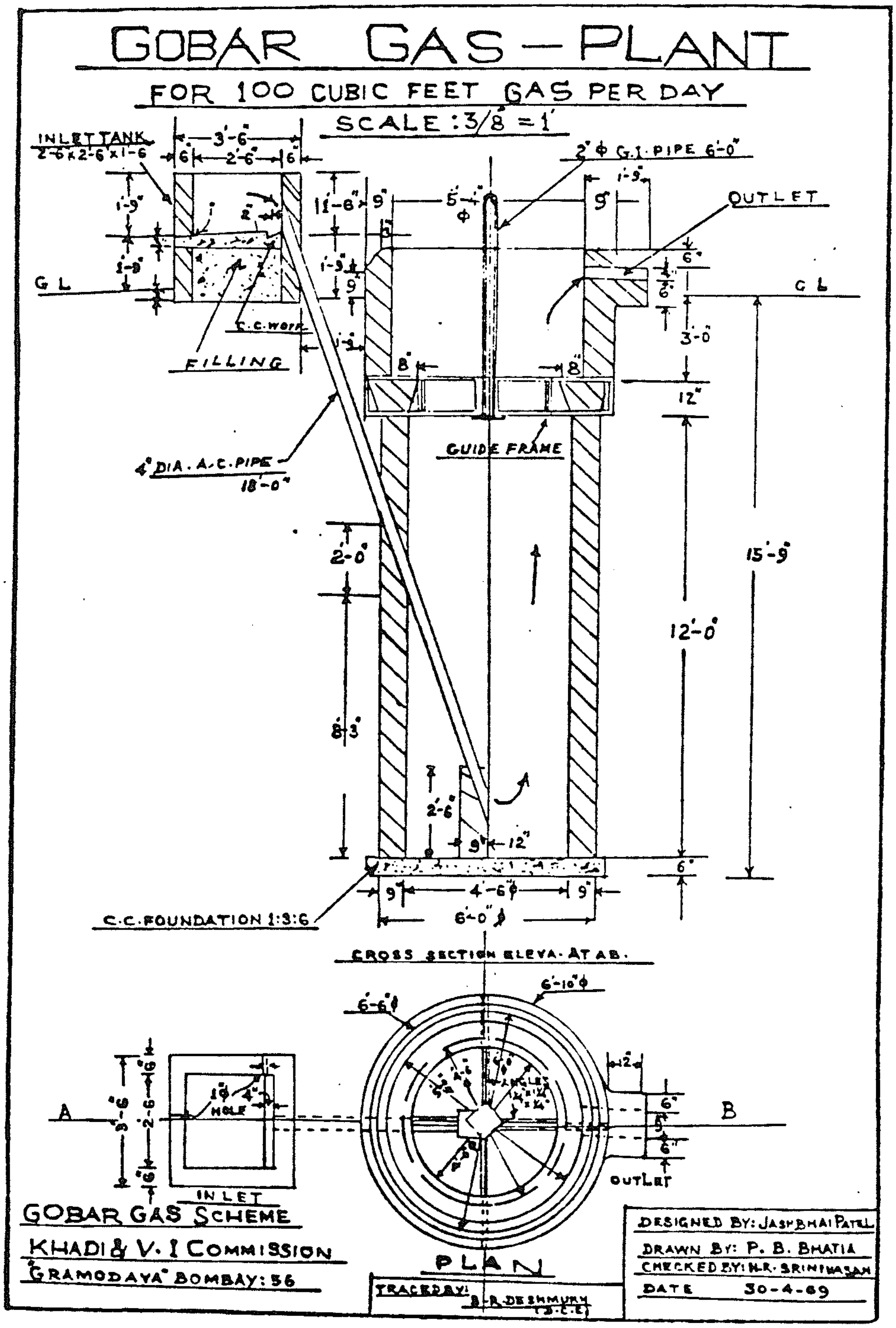


FIGURE 12

SCHEMATIC DIAGRAM OF 100 CUBIC FEET PER DAY CAPACITY BIOGAS PLANT

Source: Personal Communication with Director of Gobar Gas Scheme, Khadi and Village Industries Commission, Bombay, India.

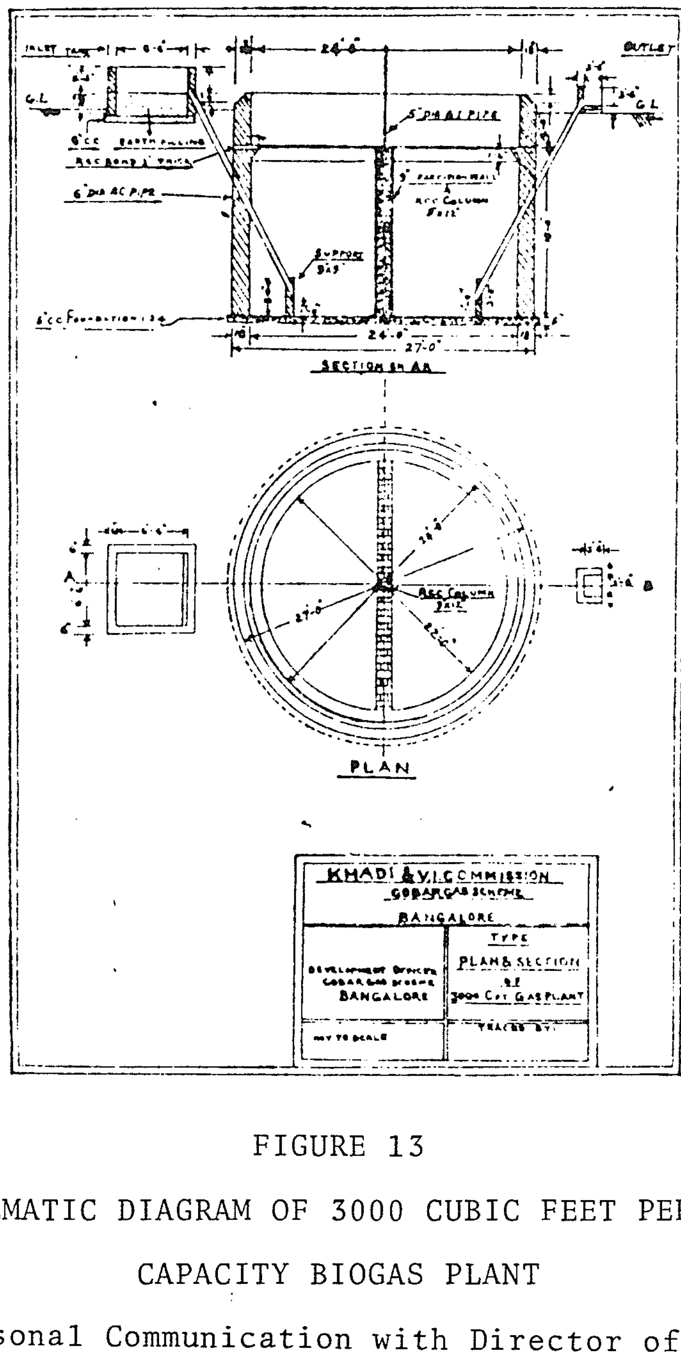


FIGURE 13

SCHEMATIC DIAGRAM OF 3000 CUBIC FEET PER DAY

CAPACITY BIOGAS PLANT

Source: Personal Communication with Director of Gobar Gas Scheme, Khadi and Village Industries Commission, Bombay, India.

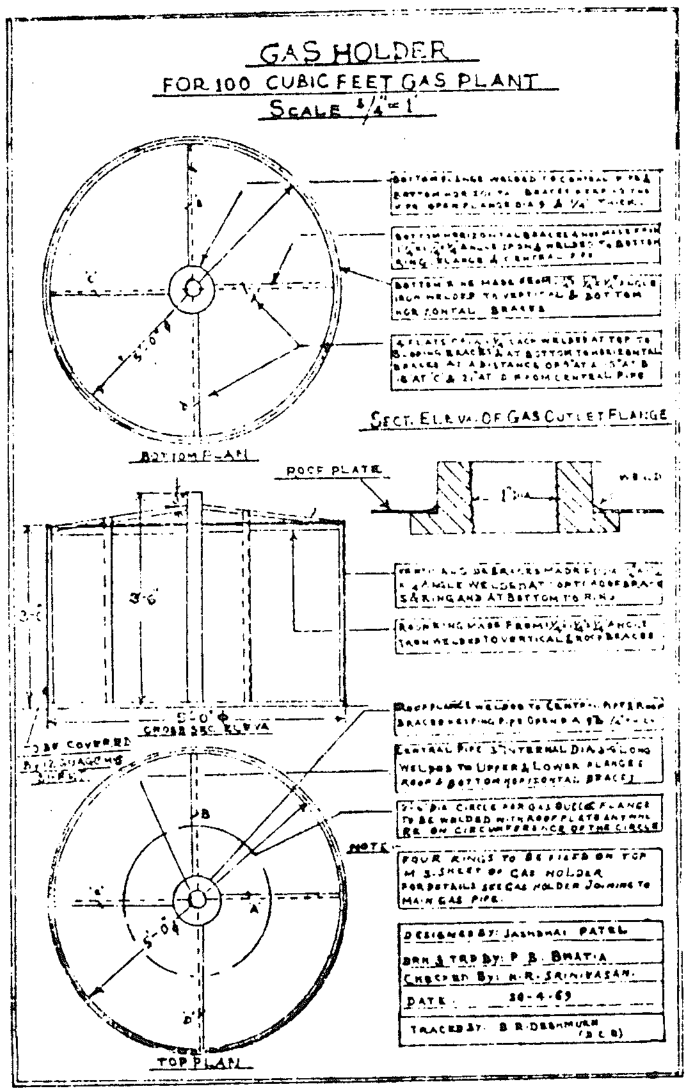


FIGURE 14

DIAGRAM OF GASHOLDER FOR 100 CUBIC FEET PER DAY

CAPACITY BIOGAS PLANT

Source: Personal Communication with Director of Gobar Gas Scheme, Khadi and Village Industries Commission, Bombay, India.

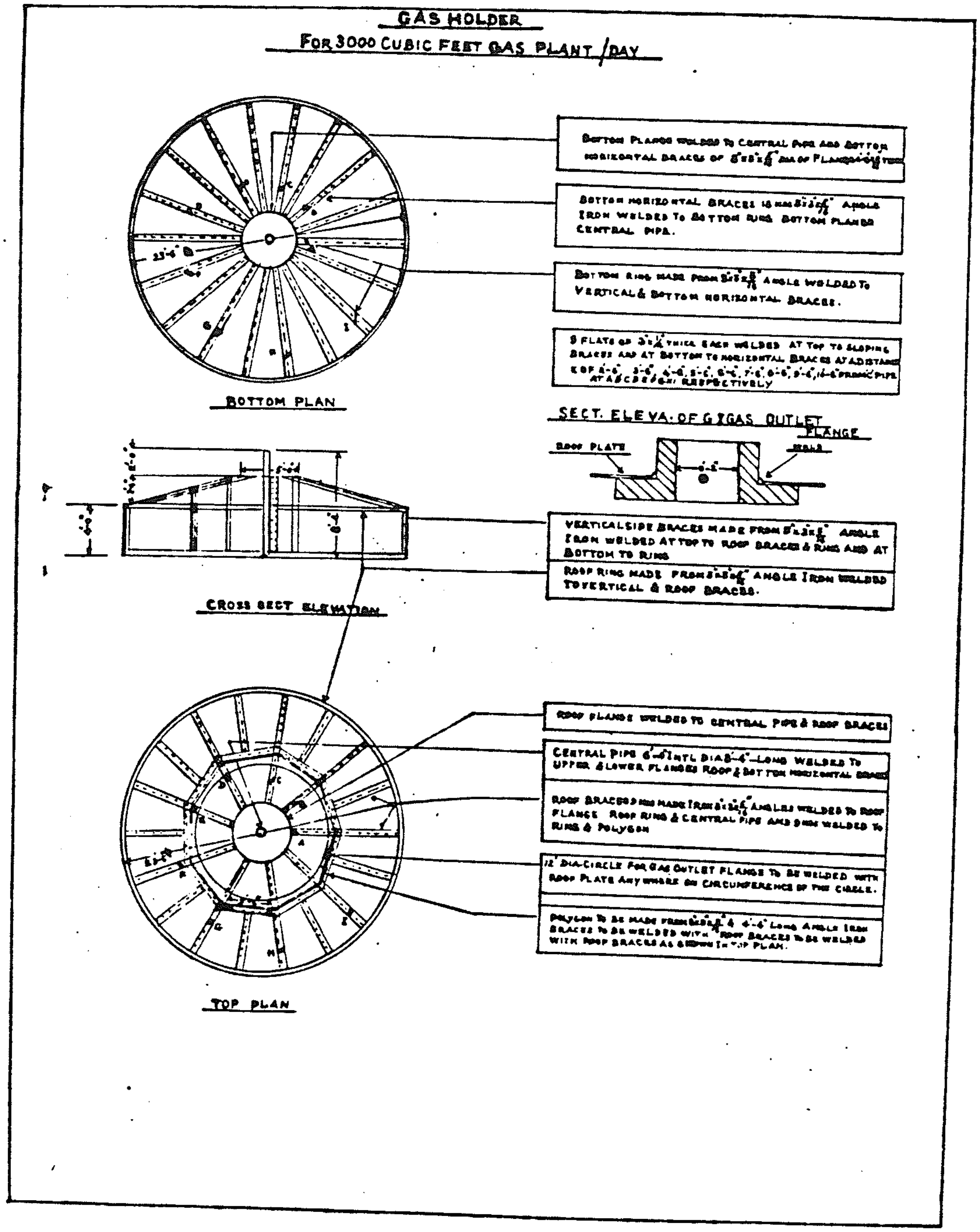


FIGURE 15

DIAGRAM OF GAS HOLDER FOR 3000 CUBIC FEET PER DAY CAPACITY BIOGAS PLANT

Source: Personal Communications with Director of Gobar Gas Scheme, Khadi and Village Industries Commission, Bombay, India.

The effect of installation of biogas plants on the availability of fuels to other sections of the society has not yet been studied in detail. This would require a comprehensive survey of villages where these biogas plants have been installed.

There are several advantages associated with the use of biogas energy. The use of biogas as fuel for cooking and lighting would enhance cleanliness as well as improve the health systems in the village. It is expected that with the establishment of biogas plants in the village, housewives in the village area would be freed from the eye sore and eye-diseases resulting from the present systems of burning dung-cakes and vegetable matter which produce smoke and soot. It has been stated that odor, flies and mosquitoes which are inseparable with manure dumps are remarkably absent when a biogas plant is established, as the slurry of the biogas plant neither attracts fly or mosquite nor emits putrid odors (Gobar Gas on the March, 1979).

Another advantage of the use of biogas plant is that if villagers attach their family latrine unit to the biogas plant, such a system would not only contribute to the production of additional biogas as energy and slurry as fertilizer but will also play a major role in the improving village sanitation and general health programs. In India.

however, as in some other countries, because of the strong cultural taboos associated with the handling of human excreta (which do not exist in rural China to the same extent), the adoption of latrine-cum-biogas plants may be limited amongst certain groups in society. Many doubts have been raised regarding the social acceptability of such latrine-cum-biogas plants. Nevertheless, the best way forward would be to install such plants and assess their acceptability, particularly amongst the underprivileged group where this taboo does not exist. It is expected that with proper initiative and education, the villagers would overcome their initial objections to use latrine-cum-biogas plants.

7.3 Economic Aspects

At present only 64% of the total raw material supply is available in the study area for the total biogas demand. It is not possible to fulfill the demand for biogas unless the remaining 36% of the supply of biogas is provided in the study area. It is useful however, to consider the economic aspects of biogas plants, assuming that the remaining 36% of supply of biogas will become available in the future.

In India, biogas plants are available in 14 different sizes, ranging from capacities of 2 to 140 m^3 per day production capabilities. These biogas plants are manufactured by the Khadi and Village Industries Commission, which scrutinizes the proposals, surveys the sites and supervises the construction of plants on an individual basis. KVIC also gives assistance in the form of grants and arranges loans from the nationalized banks. The Federal Ministry of Agriculture gives a subsidy of 25% of the total cost for biogas plant of 2 to 3 m^3 capacity and a 20% subsidy for all the other sizes of gas plants. Different capacities of biogas plants and their cost, which decreases with the size of the plant, are shown in Table 19 (Gobar Gas - Why and How, 1979).

As the total demand for biogas in the village study area is 194 m^3 per day and the largest capacity of gas plant available is only of 140 m^3, the villagers would have to establish additional biogas plant(s) besides 140 m^3 capacity plant to achieve 194 m^3 of biogas per day.

To assess the possible benefit of biogas plants in the study area, three options could be considered as noted below:

PLAN A: Under this plan it is assumed that following three sizes of biogas plants - 10m^3, 45m^3 and 140m^3 (Table 19) would be constructed in the village to fulfill the demand of 194 m^3 of biogas production per day. As it can be seen in the Table 19, the cost of 10m^3, 45m^3 and 140m^3 biogas plants are Rs. 7,320, Rs, 24,890 and Rs. 67,500 respectively. Therefore, the total cost of these 3 plant sizes will be Rs. 99,710. In other

TABLE 19

CAPACITIES AND COST OF BIOGAS PLANTS IN INDIA

Size of Biogas Plant (Cubic Metre)	Revised Estimated Cost as on April 1978 (Rs)
2	2,800
3	3,620
4	4,035
6	5,010
8	6,000
10	7,320
15	10,200
20	13,800
25	15,360
35	22,080
45	24,890
60	31,200
85	46,560
140	67,500

Source: Gobar Gas- Why and How, 1979, Published by the Khadi and Village Industries Commission, Bombay, INDIA, p. 9.

words it would cost Rs. 125.57 per person in the village (study area) of 794 persons. Cost of these biogas plants would be 20% lower when a subsidy of 20% from the total cost is considered.

PLAN B: Under this plan it has been assumed that a 6 m^3/day biogas plant size is shared by three families of 8 persons per family. Since each family of 8 persons would require 1.95m^3 of biogas for cooking and lighting per day, 6m^3/day biogas plant size would provide gas for 3 families or 24 persons. As there are 794 persons and 98 family households in the village (study area), 33 biogas plants of this size would be Rs. 165,330. Since 1 biogas plant of 6m^3 size costs Rs. 5,010, and it would be shared by 3 family households having 8 persons per family household, it would cost Rs. 208.75 per person. This cost figure is higher than under Plan A where per person cost for a biogas plant is only Rs. 125.57. A subsidy of 20% of the total cost provided by the Federal Government has not been considered in this case also.

PLAN C: Under this plan it is assumed that 98 family households in the study area would have their own family unit of biogas plant. Each family household of 8 persons per family would require a biogas plant of 2m^3 size to obtain their daily gas consumption demand of 1.95 m^3 for cooking and lighting. Since the 2m^3 biogas plant size costs Rs. 2,800, the total cost of 98 biogas plants for 98 family households in the village would be Rs. 274,400 or Rs. 345.59 per person. When a subsidy of 25% of the total cost provided by the Federal Government is considered, the cost would be accordingly lower, but this cost figure would be still higher than costs under Plan A and Plan B.

It seems obvious from Table 19, that the cost of biogas plant decreases with the increase in the size of the plant. Plans A, B and C further show that the per capita cost also decreases with the size of biogas plant. A detailed economic appraisal of the investment in a biogas plant unit would require quantification and valuation of primary benefits, of secondary benefits as well as of the direct and indirect costs associated with the installation of the biogas plant. Data on detail costs of each size of biogas plant shown in Table 21 are scant except for the $6m^3$ per day plant. Therefore a detail benefit/cost analysis of biogas plants discussed under Plan A and Plan C has not been discussed. However, based on data provided by the Khadi and Village Industries Commission for a $6m^3$ per day capacity plant, benefits and costs may be summarized for the Plan B as follows:

(A) Primary Benefits:

1. Biogas as a source of fuel for cooking and lighting
2. Digested manure (slurry) as fertilizer

(B) Secondary Benefits:

1. Convenience of cooking with a clean fuel

2. Reduction in uncertainty of energy supply

3. Renewable resource of energy

4. Self sufficiency in terms of reduction of imports of kerosene

5. Employment to the local people

6. Reduction in health costs (smokeless and odorless stoves and improvement in sanitary system)

(C) Direct Costs:

1. Capital Cost

   Cost of gas holder
   Cost of pipeline and appliances
   Cost of civil construction

2. Operating Costs

   Cost of dung (used as major input in biogas plant)
   Cost of painting of gas holder
   Cost of maintenance of gas plant

(d) Indirect Cost:

1. Depriving poor section in the society of dung

Capital costs:

Cost of Gas holders:	Rs. 66,000.00
Cost of pipeline and appliances:	Rs. 24,750.00
Cost of civil construction:	Rs. 74,580.00
Total Capital cost of 33 biogas plants	Rs.165,330.00

Annual Operating Costs:

	Previous use of Cattle-dung	
	Farmland Fertilizer	Fuel (dung cakes)
Interest @ 12% on capital -to be repaid in five installments (compounded)	Rs. 11,903.76	Rs. 11,903.76
Gas holders (10 years life) Depreciation 10%	Rs. 6,600.00	Rs. 6,600.00
Pipelines & appliances (30 years life) Depreciation 3.3%	Rs. 816.75	Rs. 816.75
Civil work (40 years life) Depreciation 2.5%	Rs. 1,864.50	Rs. 1,864.50
Painting of Gas holders	Rs. 1,650.00	Rs. 1,650.00
Cost of dung as Farmyard Manure - (14.8 x 33 = 488.4 tonnes) @ Rs. 40/ tonne	Rs. 19,536.00	-----
Cost of dung as Fuel (in terms of Kerosene equivalent	-----	Rs. 28,234.00
Total annual operating cost of 33 biogas plants of $6m^3$/day size:	Rs. 44,021.01	Rs. 52,719.80

Annual Benefit	Previous use of dung as	
	Farmyard Manure	Fuel
Production of Fertilizer (slurry) from 33 biogas plants of $6m^3$/day size (22.32 x 33 - 736.56 tonnes) @ Rs. 50/tonne	Rs. 36,828.00	Rs. 36,828.00
Production of Biogas from 33 biogas plant of $6m^3$/day size per year ($6m^3$ x 33 x 365 days = $72270m^3$ per year) at the rate comparable to kerosene of equivalent thermal heat ($72270m^3$ x 0.620 litre kerosene = 44807.40 litre kerosene) @ $s. 1.20/ litre of kerosene	Rs. 53,768.88	Rs. 53,768.88
Total Benefit	Rs. 90,596.88	Rs. 90,596.88

	Cost	Benefit	Net Benefit
When dung formerly used as fertilizer	Rs.44,021.01	Rs.90,596.88	Rs.46,575.87
When dung formerly used as fuel (dung cakes)	Rs.52,719.81	Rs.90,596.88	Rs.37,877.07

Note: The above estimate is based on 1978 prices.

The loan repayment of Rs. 165,330 will have to be paid (Rs.33,066) annually for five years. For the first five years, therefore the net income for the two fertilizer and fuel are (Rs. 46,575.87 - Rs. 33,066) Rs. 13,509.87 and (Rs. 37,877.07 - Rs. 33,066) Rs. 4,811.07 respectively. After the repayment of interest installments however, the figures for income would increase to (Rs. 46,575.87 + Rs. 11,903.76) 58,479.63 and (Rs. 37,877.07 + Rs. 11,903.76) Rs. 49,780.83 for fertilizer and fuel respectively.

As subsidy of 20% total cost which is provided by the Federal Government, has not been considered in these calculations, the incidence of interest and repayment would be accordingly lower.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

In the proceeding chapters of this practicum, a general overview of the anaerobic digestion for the potential generation of biogas and its utilization, from locally available organic materials in particular from animal manure and human night-soil in a typical Indian village has been discussed and assessed. The discussion in this practicum led to the following conclusions:

1. The energy demand in terms of biogas needed for cooking and lighting in the typical village area as estimated in this study came out to be $194m^3$ per day or $70810m^3$ per year.
2. Considering this particular village of 794 persons living in 98 houses, and 220 animals (cattle and water buffalo), it was found that available animal manure and night-soil as input materials for biogas plant(s) would produce a quantity of $124m^3$ of biogas per day or $45250m^3$ of biogas per year for cooking and lighting purposes. This supply of biogas energy would not fulfill the total demand--which is $194m^3$ of biogas per day or $70810m^3$ per year for cooking and lighting by the villagers, as a result present available supply would be only enough to fulfill 64% of the total demand for biogas.

3. The social impact associated with the installation of biogas plants indicates that the installation of biogas plants by high socio-economic group would result in an increasing tendency to have stable-bound cattle in order to augment the collection of dung. This would deprive the poorer sections in rural society of a cheap source of fuel for their energy needs and a source of income. As one of the main sources of income to many poor villagers in Indian Society is through the collection of dung and preparation of cow-dung cakes for sale as fuel to high economic groups in the village.

   On the positive side, there are several advantages associated with the installation of biogas plants. It is expected that the use of biogas plant would not only contribute to the production of biogas as energy and by product slurry as an organic fertilizer but also play a major role in improving health and sanitation in the villages.

4. Both technical and economic considerations indicated that adoption of biogas plants for biogas production is feasible and beneficial. However, cost data for the large, medium and small-scale plans for biogas plant operation indicate that the larger the scale of each system, the

less will be the cost for the installation of the biogas plant. Technology to apply the anaerobic system in India exists and has been known for years. Equipment and components for anaerobic digestion systems are available on the market and some government agencies such as the Khadi and Village Industries Commission and the Indian Agricultural Research Institute provide technical help to the customers in installing and operating biogas plants.

Finally, as a concluding remark especially in the context of the specific natures of problems existing in India, it may be stated that unless the rate of growth of the population of India can be very effectively checked in the immediate future almost all of her problems will continue to assume more and more threatening proportions, the energy problem being one of the problems very vitally linked up with the others.

It is recommended that:

- since at present only 64% of the demand for biogas for cooking and lighting could be satisfied from the available supply in the study area, the program of installing biogas plants should only be implemented when the remaining 36% of the demand of biogas energy is fulfilled.
- a closed thermal system should be developed for combustion stoves being used at present in villages to reduce heat

losses and thus increase thermal efficiency,

- research should be continued on the anaerobic digestion of cereal crop residues, as cereal crop residues contain significant amounts of energy which may represent a potential energy input for future energy utilization,
- design of latrines from the point of view of aesthetics, hygienic and non-manual introduction of human night-soil into biogas plants should be developed,
- since gas holders of biogas plants are required to be painted every year as otherwise rusting occurs, some corrosion resistant paint or material should be found to reduce annual operating cost of biogas plants, and
- comparative economics of biogas energy distributions by pipeline and in cylinders should be analysed.

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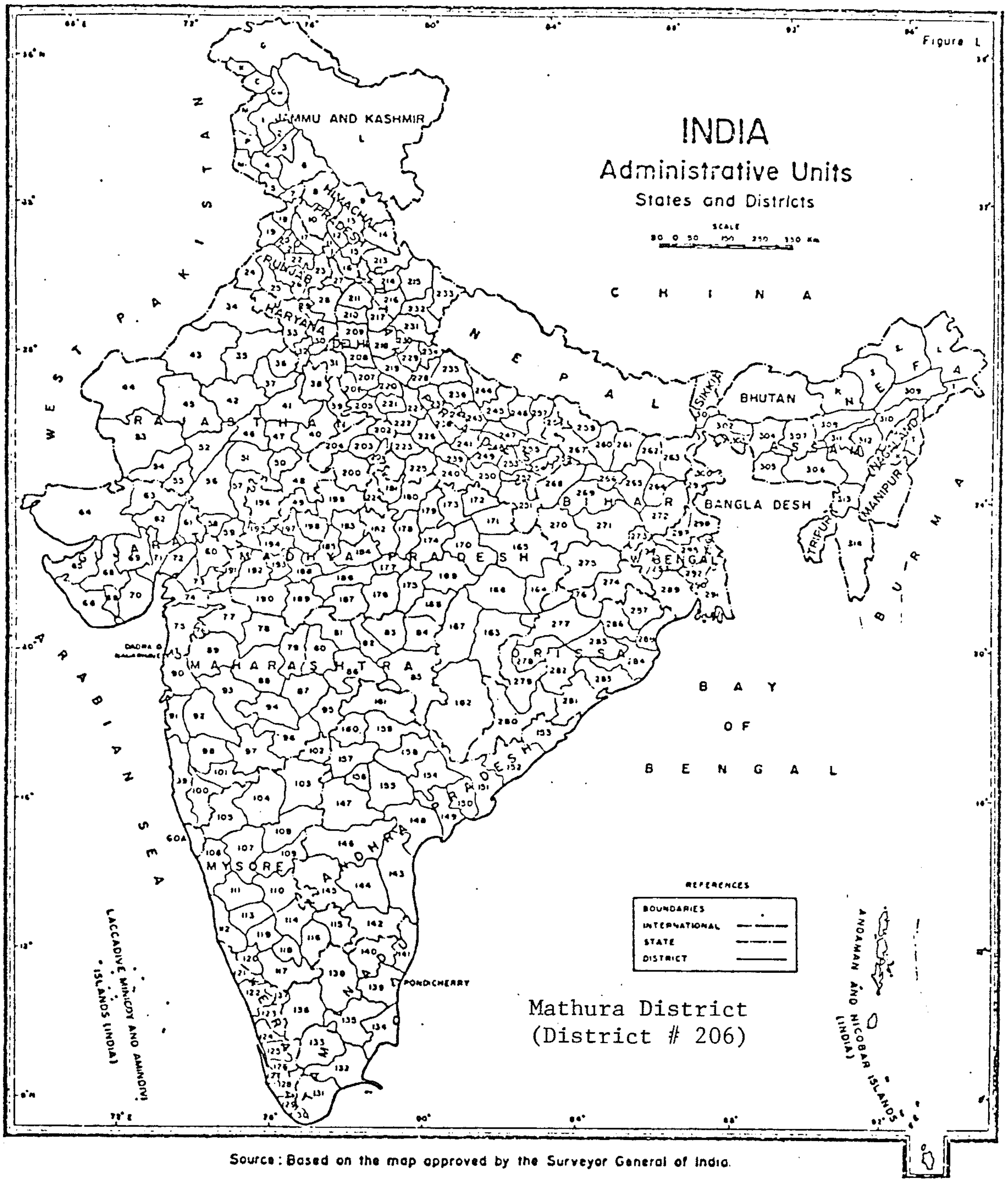
APPENDICES



Source: Based on the map approved by the Surveyor General of India.

FIGURE 1 (A)

Key to Figure 1 (A)

Id. No.	*State/District*
	Jammu-Kashmir
1	Baramulla
2	Srinagar
3	Anantnāg
4	Udhampur
5	Jammu
6	Doda
7	Kathua
	Himachal Pradesh
8	Chamba
9	Lahaul-Spiti
10	Kangra
11	Bilaspur
12	Mandi
13	Kulu
14	Kinnaur
15	Mahasu
16	Sirmur
	Punjab
17	Hoshiarpur
18	Gurdaspur
19	Amritsar
20	Kapurthala
21	Jullundur
22	Ludhiana
23	Patiala
24	Ferozepur
25	Bhatinda
26	Sangrur
	Haryana
27	Ambala
28	Karnal
29	Jind
30	Rohtak
31	Gurgaon
32	Mohindergarh
33	Hissar
	Rajasthan
34	Ganganagar
35	Churu
36	Jhunjhunu
37	Sikar
38	Alwar
39	Bhartpur
40	Sawai Madhopur
41	Jaipur
42	Nagaur
43	Bikaner
44	Jaisalmer
45	Jodhpur
46	Ajmer
47	Tonk
48	Kotah
49	Jhalawar
50	Bundi
51	Bhilwara
52	Pali
53	Barmer
54	Jalore
55	Sirhoi
56	Udaipur
57	Chittorgarh
58	Dungarpur
59	Banswara
	Gujarat
60	Panch Mahals
61	Sabar Kantha
62	Mehsana
63	Banas Kantha
64	Kutch
65	Jamnagar
66	Junagadh
67	Amreli
68	Rajkot
69	Surendranagar
70	Bhavnagar
71	Ahmedabad
72	Kaira
73	Baroda
74	Broach
75	Surat
76	Dangs
	Maharashtra
77	Dhulia
78	Jalgaon
79	Buldhana
80	Akola
81	Amravati
82	Wardha
83	Nagpur
84	Bhandara
85	Chanda

Id. No.	*State/District*
86	Yeotmal
87	Parbhani
88	Aurangabad
89	Nasik
90	Thana
91	Kolaba
92	Poona
93	Ahmednagar
94	Bhir
95	Nanded
96	Osmanabad
97	Sholapur
98	Satara
99	Ratnagiri
100	Kolhapur
101	Sangli
	Mysore (Karnataka)
102	Bidar
103	Gulbarga
104	Bijapur
105	Belgaum
106	North Kanara
107	Dharwar
108	Raichur
109	Bellary
110	Chitradurga
111	Shimoga
112	South Kanara
113	Chikmagalur
114	Tumkur
115	Kolar
116	Bangalore
117	Mysore
118	Mandya
119	Hassan
120	Coorg
	Kerala
121	Cannanore
122	Kozhikode
123	Palghat
124	Trichur
125	Ernakulam
126	Kottayam
127	Alleppey
128	Quilon
129	Trivandrum
	Tamil Nadu
130	Kanyakumari
131	Tirunelveli
132	Ramanathapuram
133	Madurai
134	Thanjavur
135	Tiruchirapalli
136	Coimbatore
137	Nilgiris
138	Salem
139	South Arcot
140	North Arcot
141	Chingleput
	Andhra Pradesh
142	Chittoor
143	Nellore
144	Cuddapah
145	Anantapur
146	Kurnool
147	Mahbubnagar
148	Guntur
149	Krishna
150	West Godavari
151	East Godavari
152	Visakhapatnam
153	Srikakulam
154	Khammam
155	Nalgonda
156	Hyderabad
157	Medak
158	Warangal
159	Karimnagar
160	Nizamabad
161	Adilabad
	Madhya Pradesh
162	Bastar
163	Raipur
164	Raigarh
165	Surguja
166	Bilaspur
167	Durg
168	Balaghat
169	Mandla
170	Shadol
171	Sidhi
172	Rewa
173	Satna
174	Jabalpur
175	Seoni
176	Chhindwara
177	Narsimhapur
178	Damoh
179	Panna
180	Chhatarpur
181	Tikamgarh
182	Sagar
183	Vidisha
184	Raisen
185	Sehore
186	Hoshangabad
187	Betul
188	Dewas
189	East Nimar
190	West Nimar
191	Jhabua
192	Dhar
193	Indore
194	Ujjain
195	Ratlam
196	Mandsaur
197	Shajapur
198	Rajgarh
199	Guna

Id. No.	*State/District*
200	Shivpuri
201	Datia
202	Bhind
203	Gwalior
204	Morena
	Uttar Pradesh
205	Agra
206	Mathura
207	Aligarh
208	Bulandshahr
209	Meerut
210	Muzaffarnagar
211	Saharanpur
212	Dehradun
213	Uttarkashi
214	Tehri-Garhwal
215	Chamoli
216	Garhwal
217	Bijnor
218	Moradabad
219	Budaun
220	Etah
221	Mainpuri
222	Etawah
223	Jalaun
224	Jhansi
225	Hamirpur
226	Kanpur
227	Farrukhabad
228	Shahjahanpur
229	Bareilly
230	Rampur
231	Naini Tal
232	Almora
233	Pithoragarh
234	Pilibhit
235	Kheri
236	Sitapur
237	Hardoi
238	Unnao
239	Fatehpur
240	Banda
241	Rai Bareli
242	Lucknow
243	Bara Banki
244	Bahraich
245	Gonda
246	Basti
247	Faizabad
248	Sultanpur
249	Partapgarh
250	Allahabad
251	Mirzapur
252	Varanasi
253	Jaunpur
254	Ghazipur
255	Azamgarh
256	Ballia
257	Gorakhpur
258	Deoria
	Bihar
259	Champaran
260	Muzaffarpur
261	Darbhanga
262	Saharsa
263	Purnea
264	Bhagalpur
265	Monghyr
266	Patna
267	Saran
268	Shahabad
269	Gaya
270	Palamau
271	Hazaribagh
272	Santal Parganas
273	Dhanbad
274	Singhbhum
275	Ranchi
	Orissa
276	Sundargarh
277	Sambalpur
278	Bolangir
279	Kalahandi
280	Koraput
281	Ganjam
282	Baudh Khondmals (Phulbani)
283	Puri
284	Cuttack
285	Dhenkanal
286	Keonjhar
287	Mayurbhanj
288	Balasore
	West Bengal
289	Midnapur
290	Howrah
291	Twenty Four Parganas
292	Hoogly
293	Bankura
294	Purulia
295	Burdwan
296	Nadia
297	Birbhum
298	Murshidabad
299	Malda
300	West Dinajpur
301	Darjeeling
302	Jalpaiguri
303	Cooch Behar
	Assam
304	Golpara
305	Garo Hills
306	Khasi and Jaintia Hills
307	Kamrup
308	Darrang
309	Lakhimpur
310	Sibsagar
311	Nowgong
312	Mikir and North Cachar Hills

Id. No.	*State/District*	*Id. No.*	*State/District*	*Id. No.*	*State/District*
313	Cachar	Gw	Gilgit Wazarat	Si	Siang Frontier Division
314	Mizo Hills	L	Ladakh	L	Luhit Frontier Division
		M	Muzaffarbad	T	Tirap Frontier Division
		P	Punch		
		Mi	Mirpur		

Units for which Data is not Available

Jammu and Kashmir		North-Eastern Frontier Agencies (N.E.F.A.)		Nagaland	
G	Gilgit	K	Kameng Frontier Division	T	Tuensang
K	Kbayali Pradesh	S	Subansiri Frontier Division	K	Kohima
C	Chilas			M	Mokokchung

GOBAR GAS SCHEME
KHADI & VILLAGE INDUSTRIES COMMISSION
'Gramodaya Irla Road, Vile Parle (West),
BOMBAY 400 056.

QUESTIONNAIRE

1) Name and full address of the party intending to construct the gas plant.

Name ____________________

Place __________ P. O. __________

Block __________ Taluka __________

District __________ State __________

2) Number of Cattle available :

i) Buffaloes Big __________ Small __________

ii) Cows, Big __________ Small __________

3) State, whether you wish to connect your latrine to the gas plant

Number of persons who will be using the latrine .. .. .. __________

4) Use of Gas :

i) Give number of persons for whom cooking is to be done .. .. __________

ii) Number of lamps required .. .. __________

iii) Hours of using Lamps .. . __________

5) Give an idea of the subsoil .. .. __________

i) Classification of soil structure as soft, hard rocky, sandy clays with details of depth of each __________

ii) Depth of water table. __________

6) i) State whether you are interested in taking loan from the Nationalised Banks, if so, please give the Name & full address of the nearest branch __________

____

ii) If loan is not required, the subsidy/grant can be paid after completion of gas plant.

Date   Signature of the party

TABLE No. I

No. of Gas Plants, value of products from 1962-63 to 1977-78

Year	No. of gas plants	Value of Production Rs. in lakhs* Gas	Manure	Total Rs. lakhs
1962-63	315	1.29	0.86	2.15
1963-64	203	2.13	1.42	3.55
1964-65	230	3.09	2.06	5.15
1965-66	204	3.93	2.62	6.55
1966-67	313	5.35	3.48	8.83
1967-68	436	6.95	4.67	11.62
1968-69	664	9.48	6.65	16.13
1969-70	720	13.17	8.48	21.65
1970-71	811	15.97	10.71	26.68
1971-72	1041	21.25	20.78	42.03
1972-73	1065	26.61	25.26	51.87
1973-74	856	100.11	70.43	170.54
1974-75	6650	197.21	138.70	335.91
1975-76	13476	369.95	301.14	671.09
1976-77	18595	624.89	508.66	1133.55
1977-78	14340	821.50	668.70	1490.20
Total	59919			

TABLE No. II

Funds disbursed from 1962-63 to 77-78

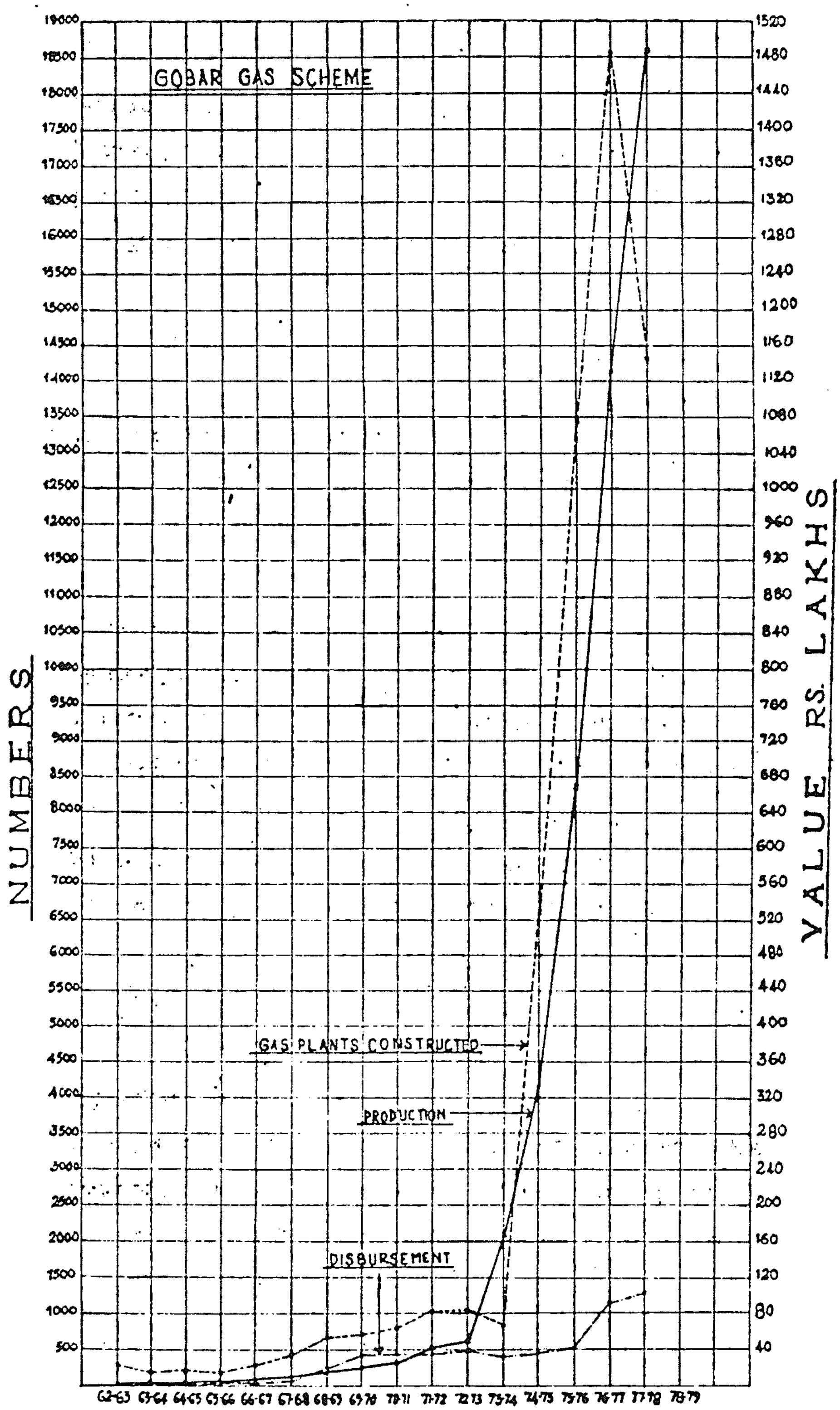
Year	Disbursements Grant	Loan	Rs. in lakhs* Total Rs. lakhs
1962-63	0.87	1.27	2.14
1963-64	1.21	1.79	3.00
1964-65	0.75	1.10	1.85
1965-66	2.03	2.96	4.99
1966-67	1.58	3.38	4.96
1967-68	3.94	5.64	9.58
1968-69	5.41	15.45	20.86
1969-70	6.13	29.93	36.06
1970-71	9.76	29.92	39.68
1971-72	7.27	32.32	39.59
1972-73	9.17	31.20	40.37
1973-74	11.82	24.09	35.91
1974-75	36.07	3.18	39.25
1975-76	44.62	1.03	45.65
1976-77	92.49	3.32	95.81
1977-78	103.11	1.25	104.36
Total	291.61	187.80	478.41

Since 1974-75 Banks have provided loan to individual gas plants which is not given under the column of loan in the table and KVIC has given loan only to institutional plants, which is shown in the table. Subsidy provided by the Ministry of Agriculture since 1974-75 is also included in the column of grant.

*1 LAKH= 100,000

Source: Gobar Gas on the March 1979, Published by the Khadi& Village Industries Commission, Bombay,India,p.11

NUMBER OF BIOGAS PLANTS, VALUE OF PRODUCTS AND DISBURSED FUNDS



1 Lakh= 100,000

Source: Gobar Gas on the March,1979, Published by the Khadi & Village Industries Commission, Bombay,India,p.10

Indians cook with gobar gas

By SHARON ROSENHAUSE
The Los Angeles Times

KHERI KALAN, India — Chatter Lal Narwat was intrigued when he heard on the radio that cow dung could be converted into fuel.

"Father wouldn't believe it," Narwat said. "He said I wanted to waste his money."

But Narwat's mother settled the issue. She had been cooking with firewood, which irritated her eyes and blackened her kitchen, and she was ready to try something new. Narwat's father came up with the $400 needed for the equipment to recycle dung into what is called gobar gas. *Gobar*is Hindi for cow dung.

The Narwats were the first family to install a gobar gas plant in this prosperous village of 3,000 people about 35 miles south of New Delhi.

"When we started, people were laughing," Narwat said. "They thought I was crazy. Now, they're putting in their own plants."

Five other families have installed the plants. One-fourth of the cost of each was put up by the Haryana state government which, along with India's national government, has encouraged the production of gobar gas.

India has more than 200 million head of cattle and, according to Dr. V. Massey, the scientist in charge of gobar gas at the Indian Agricultural Research Institute in New Delhi, the animals produce more than 400 million tons of waste every year. When converted to fuel, he said, the waste can supply more than half of India's annual energy needs.

BULLETIN
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page 3

Biogas tests stir farmers' interest

by Ed Unrau

The file of letters Prof. Herb Lapp has in his agricultural engineering office from farmers who are serious about installing anaerobic digesters to harvest biogas from agricultural and organic wastes is only one indication that there is a grass root interest in this alternative energy source.

During a recent interview, Prof. Lapp showed one letter from an Ontario hog farmer whose specific questions gave clear evidence that he had already assembled a lot of basic information on his own. Another letter sought Prof. Lapp's advice on a proposed digester for a large farm in the Philippines.

Other indications of farmer interest came during a recent tour of the United States that took Prof. Lapp to biogas generating installations in more than a half dozen states from Washington to Florida. Not only did he find several farms with extensive installations, but he also found that one of the best biogas generators was designed and built by two tradesmen whose part-time farm activity involved caring for a flock of 16,000 chickens.

Prof. Lapp emphasizes that he "would never tell anyone that there are great energy savings to be realized through the use of biogas". But he does argue that biogas can be an important component in a program to conserve petroleum and natural gas supplies.

Biogas typically contains 60 to 70 per cent of methane in its volume with the balance being carbon dioxide and traces of other gases. This mix results in a fuel source that has less energy value than natural gas, making it necessary to burn more biogas for the same energy needs.

Anaerobic digestion is a controlled process in which bacteria break down organic matter in the absence of oxygen. One of the byproducts is biogas. It is possible to produce five cubic feet of biogas per day from the manure of one hog or 50 cubic feet from the manure of a dairy cow under optimum conditions. Thus, moderate to large livestock farmers have the raw materials to generate significant amounts of biogas for their own use.

For the past decade, Prof. Lapp has researched and written about the recovery of biogas from agricultural wastes. His work has included the operation of a small pilot plant at the university farm at Glenlea and several tours of installations in the U.S., Europe and Canada to look at what others are doing. As a result, Prof. Lapp's work has become so well known that any review of the literature will contain several references to his papers.

This past spring Prof. Lapp was phoned, in his words "out of the blue", by an officer of the Solar Energy Research Institute of Golden, Colorado, and asked to visit biogas generators throughout the U.S. The objective of the tour was to provide case-study information useful to farmers and other prospective builders of anaerobic digesters. About two years ago Prof. Lapp published a long paper on biogas generators following a similar but more limited tour through the U.S. midwest.

Is it feasible to generate biogas from organic wastes and to use it as

Prof. H. Lapp

energy? Prof. Lapp answers the question by saying that it certainly is feasible from a technical standpoint, but he is much more cautious about the economic aspects. The economics of biogas are clouded by such things as the fact that anaerobic digesters work better in warm climates, that there are no proven systems easily available for installation, and that the recovery of biogas should be viewed as only one benefit.

For example, Prof. Lapp visited an anaerobic digester on a Pennsylvanian dairy farm with more than 1,000 cows. Although the owners use the biogas to power a diesel-driven electric generator which they claim saves more than $30,000 a year in electrical costs, Prof. Lapp thinks that this saving should not be taken in isolation from others arising out of the system. Water is recycled in the flush-collection process for manure and the two by-products of the digestion are used. After passing a solid/liquid separator, the liquid fraction is used as fertilizer through the irrigation system and the solid portion is dried for use as bedding in the pens. This system would cost more than $150,000 to build at present.

Prof. Lapp speculates that a cost-benefit analysis which looks at all possible benefits from a digestion system could improve the attractiveness of such installations. He is not at all sure that the recovery of biogas energy is by itself an economically strong reason for building such systems.

Nevertheless the energy potential is there; for example, a hog farmer who averages 1,000 hogs has enough manure to produce enough biogas per day to heat 1½ houses. While this does not eliminate the farmer's need for traditional fuels, it does represent a reduction in the amounts he will need, says Prof. Lapp. In Manitoba a hog farm of this size is not especially large and there are many that are even larger.

What Prof. Lapp would like to do is build a field-scale demonstration project in Manitoba, one that is designed and built from the ground up. This would allow the best technology and equipment to be optimally used and it would eliminate most, if not all, the compromises which creep in when an anaerobic digestion system is added to an existing cattle, hog, or poultry barn.

Prof. Lapp says that the demonstration project is necessary not only to demonstrate its feasibility but also to provide farmers and other potential builders with good information. As well, not all scientific problems associated with biogas production can be solved by gifted amateurs such as the two tradesmen (a plumber and an electrician) who built the superb installation in Wisconsin.

A Manitoba field project would accomplish two other things. Firstly, it would establish the parameters of a digestion system in a cold climate where some of the biogas would have to be used to maintain the system at an operational temperature. Secondly, it would show how such systems could be used on moderate and small livestock farms.

In any case, a continuation in the rise of costs for traditional energy sources, combined with the level of interest already existing, will ensure that "biogas from biomass" will continue to be explored for its potential as an alternative source of energy.

SOURCES OF INFORMATION ON BIOGAS PLANTS

Information on biogas plants may be obtained from the following sources:

1. Director Gobar Gas Scheme
   Khadi & Village Industries Commission
   Gramodaya
   Irla Road,Vile Parle(W)
   Bombay 400 056, India

2. Head of the Division of Soil Science and Agricultured Chemistry
   Indian Agricultural Research Institute
   New Delhi 110012, India
   or
   Farm Information Unit
   Directorate of Extention
   Ministry of Agriculture and Irrigation
   New Delhi, India

3. Gobar Gas Research Station
   Ajitmal,Etawah
   Uttar Pradesh, India

4. Director National Environmental Engineering Pesearch Institute
   Nehru Marg
   Nagpur-20, India

5. World Health Organization
   1211 Geneva 27
   Switzerland

6. Economic and Social Commission for Asia and the Pacific (ESCAP)
   Division of Industry, Housing and Technology
   United Nations Building
   Bangkok 2, Thailand

7. Bangladesh Academy for Rural DEvelopment
   Comilla
   Bangladesh

8. Appropriate Technology Development Organization
   Planning Commission
   Government of Pakistan
   Islamabad, Pakistan

9. The Biomass Energy Institute Inc.,
   304-870 Cambridge Street
   Winnipeg, Manitoba, Canada

10. H.M.Lapp, Professor
    Department of Agricultural Engineering,
    The University of Manitoba
    Winnipeg, Manitoba, Canada

11. A.B. Sparling, Professor
    Department of Civil Engineering
    The University of Manitoba
    Winnipeg, Manitoba, Canada