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The feasibility of harnessing renewable sources of energy in Indonesia

Report of a joint project on the feasibility of harnessing renewable sources of energy in Indonesia

February 1984

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PREFACE

One of the key words that prevailed in the seventies was "the energy crisis". Although this term could have several definitions, the most important consequence of the "so-called" energy crisis was the general realization that fossil fuel resources, especially oil and natural gas, are finite in nature, and that in spite of a temporary oil glut or even a drop in oil/real prices, countries should start applying energy conservation measures and exploring the possibilities of using other sources of energy, particularly indigenous and renewable ones. Sooner or later all countries in general, and developing countries in particular, will establish an optimum "energy mix" to meet their demands for development.

The pressing need to develop alternative energy sources and to work on energy conservation is of particular importance in the rural areas of developing countries. It is here where hundreds of millions of people live far from the mainstream of development and in conditions of abject poverty which cause degradation of the quality of life and hence of the social dimension of the human environment. It is here that people depend almost entirely on fuelwood as their source of energy, cut down millions of trees every year and use this wood rather inefficiently, causing serious soil erosion, desertification and pollution problems thus aggravating the environmental and ecological situation of the Globe. It is here where the lack of energy sources does not mean shutting down air-conditioning, driving slowly, etc., but it means less meals to cook and more distances to walk. It is here where an increase of efficiency in the wood burning stoves of only a few per cent could mean a decrease of 50 per cent or more in firewood consumption.

The Governing Council of the United Nations Environment Programme has fully recognized this problem and at its 3rd session in 1975, requested the Executive Director of UNEP to accord high priority to the establishment in some rural areas of developing countries of a few demonstration (experimental) centres which will harness, individually or in combination, locally available renewable sources of energy. At its 4th session, in 1976, the Governing Council requested the Executive Director to accelerate an active energy programme involving the rational utilization of renewable resources for energy generation which will have a positive impact on rural development, consistent with environmentally-sound practices, and at its 7th session, in 1979, the Executive Director was urged to promote more activities related to the development of renewable sources of energy, energy conservation measures and the development of efficient technologies for the production and use of energy.

The present report describes the results of a project jointly undertaken by UNEP and the Ministry of Mines and Energy, Indonesia, to harness renewable sources of energy in Indonesia. It included three main activities. Surveys on energy consumption and supply in the rural areas, testing the efficiencies of available fuelwood stoves with the target of identifying and developing, in the future, more efficient and environmentally-sound stoves and, finally, demonstrating the feasibility of biogas production and use in Indonesia with the target of promoting development and use of new and renewable sources of energy in these areas.

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Nairobi, February 1984

INTRODUCTION

A question of major concern in both developed and developing countries is that of energy, involving as it does problems at the national, regional and international levels.

The problem of energy in Indonesia, in North Sulawesi and in Aceh in particular, is an urgent one in view of the important strategic, political and socio-economic roles played by energy in development in these areas. The national income derives mainly from petroleum exports. Indonesia's energy consumption is also dependent on oil. Nevertheless, alternative energy resources do exist but domestic consumption must be regulated to be more productive and more useful to the people.

Indonesia is a tropical country situated on the equator and comprising of thousands of widely scattered islands. A large proportion of the population live in the rural areas and are small-scale peasant farmers with little formal education and relatively low incomes. Rural development is therefore of high priority in Indonesia's overall national development.

Indonesia's population of almost 150 million would clearly absorb the local available energy. Even though technology has barely touched the rural areas, the enormous rural population will still absorb a very large amount of energy. Since the greater part of this energy is in the form of firewood, it is necessary to know the size of their daily firewood consumption.

This large energy demand can be met only in those areas which have abundant natural resources. Nevertheless, if not carefully controlled, the utilization of firewood will clearly endanger the conservation of the forests and natural environment. In several parts of Indonesia, in fact, this has already happened and uncontrolled damage to the forests has caused serious damage to the environment.

Whereas the annual increases both in the population and in their requirements will cause a corresponding increase in the demand for energy, the actual capacity of natural and energy resources is limited. Moreover, the rapid development of technology also presents huge energy demands. Aside from the grave issues of the world energy crisis, therefore, in order to meet some part of these energy demands, it is necessary to investigate the possibilities of utilizing waste, such as agricultural and industrial waste and animal dung, as alternative sources of energy.

Waste contains carbohydrates in which are stored large amounts of energy. By an anaerobic microbiological process, the substances contained in the waste can be fermented to give off gases, one of which is methane (CH_4), which can be burnt as a fuel for heating and lighting.

The objectives of the present study may be summarized in the following:

1. To study rural energy requirements and energy supply in the province of North Sulawesi and Aceh. In this respect two surveys were conducted in Minahasa in North Sulawesi and in Aceh. Sample populations were selected based on geographical location, potential of the region and location and size of sample populations (sub-districts, villages). Generally, the surveys covered the following items:

a) family income

b) domestic consumption of solid fuel

c) domestic consumption of kerosene

d) domestic energy consumption

e) energy consumed by appliances

f) time taken for collecting solid fuel

g) land ownership and production value

h) classification of households according to use of fuels.

Two types of data were collected; Primary data which was collected from:

- direct measurements of the amounts of fuels used by the inhabitants, including firewood, biomass, agricultural waste, kerosene and electricity;
- questionnaires and interviews, and

Secondary data which was collected from:

- villages, sub-districts, districts and provincial offices;
- other sources related to this study, and
- direct observation in the field.

2. To develop technologies for increasing the efficient use of fuelwood. In this respect, traditional fuelwood stoves were compared with modified versions.

3. To demonstrate the feasibility of biogas production and use in Indonesian rural areas through the construction of family-size biogas plants using locally available organic wastes. In this respect, two types of biogas plants were constructed: one made of ferro-cement and the other with a steel gas holder. Th.ee units of each type were constructed.

CHAPTER I

REGIONAL INFORMATION ON SULAWESI

A. GEOGRAPHICAL CONDITIONS

1. Location and size of area

The province of North Sulawesi is situated on the northern peninsular of the island of Sulawesi between latitude $0^{o}30'$ - $4^{o}30'$ north and longitude 121^{o} - 127^{o} east (Fig.1). The peninsular stretches in an east-west direction, the northernmost point being the 77 islands of the Sangihe and Talaud groups. The province is bounded to the north by the Sulawesi Sea, the Republic of the Philippines and the Pacific Ocean; to the east by the Moluccas Sea; to the south by Tomini Bay, and to the west by the province of Central Sulawesi. The province covers a total land area of about 25,800 km^2, as shown in Table 1.

Table 1.1: Land area of North Sulawesi Province

Type of land	Area in km^2	% of total area
Forest	14,760	57.23
Plantation	2,650	10.28
Fields	1,560	6.05
Rice paddies	430	1.67
Back yards/house gardens	220	0.84
Lakes and rivers	300	1.16
Other	5,780	22.77
Total	25,800	100.00

Source: Indonesian Regional Planning and Development Board, 1981.

The district Minahasa in which the survey was undertaken has an area of about 4,500 km^2 and consists of 27 sub-districts which include 405 villages.

2. Topography and soil conditions

(a) Topography:

This area comprises both plains and mountains. The mountains tend to form a chain with peaks rising to over 1,000 metres above sea level. There are several lakes and rivers which have potential for the development of tourism, irrigation and energy supply. In Minahasa there are Lakes Tondano (5,000 ha), and Linou and on the borders of Minahasa and Bolaang Mongondow there is Lake Mooat (900 ha). The rivers in Minahasa are: the Poigar (54.2km); Ranoyapo (151,9km); Tondano (39.9km) and Talawaan (34.8km). The river Tondano in Minahas has a waterfall

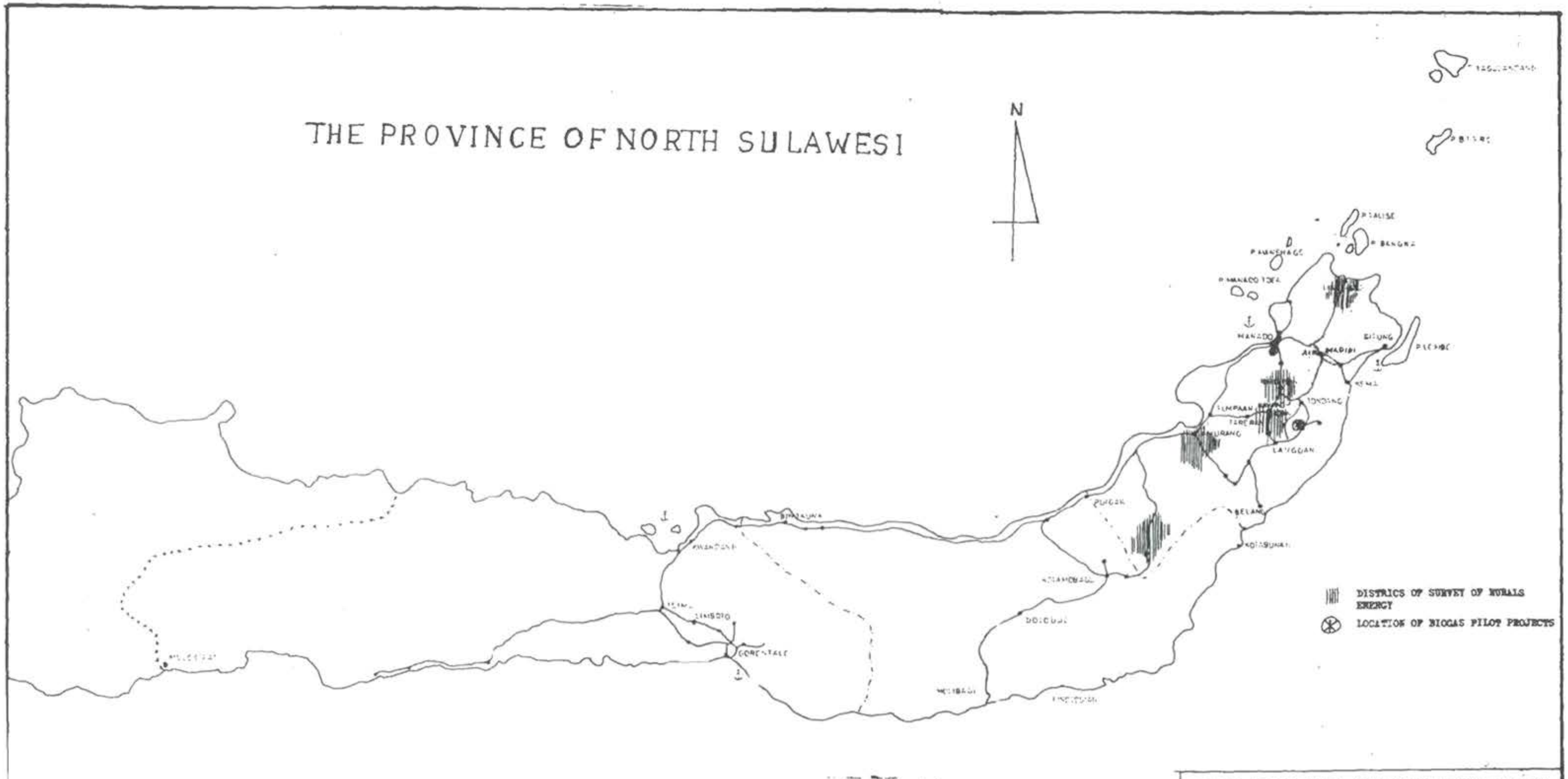
THE PROVINCE OF NORTH SULAWESI
N
MANADO
BITUNG
TONDANO
LANGOAN
BELANG
KOTABUNAN
DISTRICS OF SURVEY OF RURALS ENERGY
LOCATION OF BIOGAS PILOT PROJECTS
PUSAT PERENCANAAN DAN PENGEMBANGAN UNSRAT

Fig. 1.1

which is used for generating hydro-electric power, while the river water itself is used for irrigation and drinking. The rivers in Bolaang Mongondow and Gorontalo are used mostly for irrigation.

b) Soil:

Most of the soils can be used for several crops, such as coffee, rice, maize, vegetables, root crops, fruits, sugar-cane, coconut groves and various types of animal fodder.

c) Land use:

Land use could be classified into three broad categories:

(i) Land suitable for a variety of uses, i.e. for annual seasonal crops, grazing, forest crops/plantations, nature reservices, etc.;

(ii) Land suitable for only limited use, e.g. only forest or cattle grazing;

(iii) Land which must remain permanently covered by forest.

2. Climate

The rainfall decreases from relatively high rainfall in the northern parts of North Sulawesi to low rainfall in southern parts. North Sulawesi is affected by the monsoon winds. The air temperature falls as height above sea-level increases.

B. POPULATION

The population of North Sulawesi was 1,310,054 in 1961, 1,717,671 in 1971 and 2,107,807 in 1980. The total population of Minahasa in 1980 was 672,912 with a population density of 149/km^2. During the period 1961-1971 the average population growth in North Sulawesi was 2.75 per cent per annum. During 1971-1980 this fell to 2.23 per cent per annum due to the effect of the Family Planning Programme. The population is unevenly distributed, approximately 24 per cent being concentrated mainly in the urban areas, the remaining 76 per cent spread throughout the rural areas. The majority of people earn their income from farming (65.49%), the remainder from a variety of sectors: industry and mining 4.73 per cent, transportation 2.19 per cent, trade 5.05 per cent, building 1.72 per cent, services 12.83 per cent, finance 0.24 per cent, electricity and drinking water supply 0.25 per cent, and other sectors 7.50 per cent.

The religions in this province are Christianity, Islam, Buddhism and Hinduism. North Sulawesi receives migrants sent through the Government's population transmigration scheme. They are settled mainly in the Gorontalo and Bolaang Mongondow districts.

Education is adequate in North Sulawesi. Formal education is provided from kindergarten level through to university. The participation of private and religious groups in development has made the people greatly aware of the value of education. This has gone hand in hand with government efforts to improve education opportunities for school-age children.

The general level of public health is relatively good and continues to improve as a result of the various health programmes undertaken by government, private and religious agencies.

C. ECONOMY

The major source of income is farming, which covers food crops, coconut, clove, nutmeg and coffee plantations, animal husbandry, fish and the processing of forest products. A large part of the industrial sector is devoted to the processing of agricultural produce (particularly coconuts) and to food industries. The average rate of economic growth is 13.05 per cent per annum (for the period 1974-1977). The contribution of each sector to the economy is as follows: farming 43.59 per cent, mining 0.39 per cent, industry 6.34 per cent, construction 1.96 per cent, electricity and drinking water 0.13 per cent, transport and communications 7.98 per cent, trade 23.69 per cent, banks and other financial institutions 0.92 per cent, house rental 2.04 per cent, government and security 8.98 per cent, services 4.02 per cent.

1. Food crops

Food crops include rice, secondary crops, vegetables and fruit. The paddy fields generally produce two crops a year yielding an average of 4 - 4.5 tonnes of dry milled rice per hectare. Dry fields yield an average of 1.6 tonnes of dry milled rice per hectare. Total rice production in 1980 reached 387,073 tonnes. Secondary crops include maize, cassava, sweet potatoes, groundnuts and small green pea (Phaseolus radiatus), which are cultivated in fields, back yards, and under coconut trees, and which may be grown as monoculture, diculture or polyculture, may be interplanted with other crops or planted in rotation. In 1980, the production of secondary crops constituted: maize 160,760 tonnes, cassava 99,400 tonnes, sweet potatoes 49,840 tonnes, groundnuts 10,960 tonnes, soy beans 11,780 tonnes and small green pea (Phaseolus radiatus)1,117 tonnes. Vegetables are grown on highland plains. In 1980, vegetable produce reached 53,976 tonnes, part of which was sold outside the area. Fruit-growing is still only incidental.

2. Plantations

North Sulawesi's main source of income is from plantations. About 60 per cent of the province's total agricultural land area is planted with coconuts, and about 70 per cent of the population grow coconuts. Next in popularity come cloves and nutmeg. The average production rate of coconut palms is 55 nuts per tree, the total production in 1980 being 228,339.75 tonnes. Clove production reached 15,000 tonnes in 1977 and 12,042 tonnes in 1980. Nutmeg is grown on its own, particularly on Siau Island, and constitutes the third most important commodity after coconuts and cloves. Efforts are being made to increase its cultivation and in 1980 nutmeg covered a total of 23,701 hectares and yielded 9,422.5 tonnes.

3. Animal husbandry

The major types of livestock are cattle, pigs, goats, chickens and ducks, most farmers normally keeping a variety of animals. The aims of animal husbandry are to provide meat for local consumption, to increase family income and, in the case of cattle, to plough the land and pull carts. The amount of livestock is, however, still insufficient to meet the needs of the population in view of the current move to improve their diet, particularly as regards animal protein.

4. Fish

The waters of North Sulawesi are a great potential source of food, in particular tuna, which can be managed economically for consumption and export. The total area of waters is 314,981 sq.km producing a yield of 0.84 tonne/sq.km./year, which is estimated to total around 264,000 tonne/year. However, this potential has not yet been tapped to the maximum. The total fish production in 1980 was 59,901.21 tonnes, which comprised 50,312.5 tonnes of sea fish, 2,249.61 tonnes from fresh-water fish farming, and 5,069.10 tonnes from public waters.

5. Forestry

Approximately 1,475,622 hectares (57.22 per cent of the whole province) is estimated to be covered by forest. This can be divided into protective forest 341,789 ha, productive forest 550,350 ha, reserve forest 577,222 ha, and nature reserves 6,331 ha. A variety of woods grow there, for example: ironwood, meranti, frangipanni wood (cempaka). Other products include rattan and and resin. The 1980 figure for timber production was 119,172 m^3, of which 44,923m^3 was exported. As part of the nature conservation programme, reafforestation is being undertaken, particularly in critical areas of Gorontalo and Minahasa.

6. Industry and mining

The first industries to be developed were those which exploited the region's resources, in particular the manufacture of coconut oil. Other industries which have since grown up include car component manufacture, cold storage for fish, copper plating at Bitung, zinc, dry docks/shipyards, oxygen, saw-mills, etc. Small and medium size industries processing agricultural produce, producing foodstuffs and handicraft are found throughout the province. The main handicrafts are drawn-thread-work in Gorontalo, ebony carving in Sangihe-Talaud, and porcelain in Minahasa. Mining activities are as yet confined to inventarization, surveys and exploration. The results of several surveys have indicated the presence of sizeable deposits of valuable minerals, including: copper, gold, nickel, titanium, iron, manganese, raw materials for cement production and sulphur. Sulphur has already been exploited. Kaolin has also been exploited in Toraget-Langaowan in the Minahasa district, yielding 36,000 tonnes per annum. In addition, there are potential geothermal energy sites in Lahendong village (Minahasa) and Kotamobagu which could be developed.

7. Trade

The major trade commodities are agricultural and industrial products such as copra, clovers, nutmeg and coconut oil. Other commodities include goods for consumpton, building materials and services.

Distribution, whether for export-import, inter-island or local markets, is centred in Bitung and Manado. Cargo/ freight companies are found mostly in Bitung, banks and insurance companies in Manado. Export commodities include coconut oil, copra, copra cake, nutmeg, rubber, rattan, timber, dried grated nutmeg, kaolin, rice bran, clove leaf oil, coffee beans and nutmeg oil. The major export commodity is coconut oil (33.24 per cent), which is followed by copra (21.13 per cent), copra cake (14.05 per cent), timber (12.57 per cent), nutmeg (6.41 per cent). Inter-island trade figures for 1980 put cloves at 7.340.249 tonnes, copra at 23,494.589 tonnes and coffee at 664 tonnes.

CHAPTER II

HOUSEHOLD SURVEY IN MINAHASA "SULAWESI"

A. RURAL HOUSEHOLD INCOMES

The district of Minahasa was chosen to undertake the household survey. General information on Minahasa is given in Chapter I. Some formats for undertaking the survey are shown in Annex I.

The results of this survey show that the rural family income in Minahasa is derived mainly from farming and amounts to Rp 1,180,000 (US$1220)* per annum on average (the range being Rp 144,000 - Rp 7,935,000) with an average income per capita of Rp 272,000 per annum (range: Rp 30,000 to Rp 2,102,000). When classified into low, middle and high family-income groups the results showed the average annual incomes per household and per capita in each group to be as listed in Table 2.1 below. The proportion of rural families in Minahasa having an annual per capita income greater than US$200 (± Rp 127,000) was 62 per cent, the remaining 38 per cent receiving less than US$200).

Table 2.1: Average annual family incomes in Minahasa District, classified according to income group (in Rupiah)

Income group	Number of households surveyed	Average family income (Rp/HH/year)**	Average per capita income(Rp/cap/year)
Low	6	178,000 ± 20,000	49,000 ± 22,000
Middle	25	376,000 ± 80,000	96,000 ± 44,000
High	69	1,570,000 ± 1,407,000	355,000 ± 360,000

** HH = household

B. FUEL CONSUMPTON PER HOUSEHOLD

The average consumption of kerosene per household for cooking was 1.3 litres/day, and for lighting 0.71 litres/day. Average kerosene consumption per capita was 0.265 litres/day (cooking) and 0.168 litres/day (lighting). The average consumption of solid fuel was 7.105 kg/day/household and 1.611 kg/day/capita. For cooking, the fuel used most was wood followed by agricultural waste including coconut shells, husks, etc. Fuel consumption figures for each family income group are given in Table 2.2

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* Since 1982 1US$ = 970 Rupiah

Table 2.2: Average daily domestic solid fuel consumption in Minahasa District, according to family income group (in kilograms)

Income group	Average solid fuel consumption per household (kg/day)	Average solid fuel consumption per capita(kg/day)
Low	5.75	1.36
Middle	6.54	1.78
High	6.29	1.32

The consumption of liquid fuel, both for cooking and lighting, tended to increase with family income, as shown in Table 2.3:

Table 2.3: Average daily domestic consumption of kerosene in Minahasa District, according to family income group (in litres)

Income Group	Average kerosene consumption			
	per household (l/day)		per capita (l/day)	
	for cooking	for lighting	cooking	lighting
Low	0.06	0.393	0.02	0.115
Middle	0.29	0.36	0.073	0.09
High	0.65	0.43	0.13	0.09

Nevertheless, it can be seen from Table 2.4 that solid fuel is still the most commonly used fuel for cooking for most families in Minahasa District (80 per cent):

Table 2.4: Number of households[1] using different types of fuel in Minahasa District, according to family income group

Income Group	Solid fuel		Liquid fuel		Electricity
	wood	agricultural waste	for cooking	for lighting	
Low	2 (33.3%)	3 (50%)	1 (16.7%)	5 (83.3%)	1 (16.7%)
Middle	15 (60%)	8 (32%)	9 (36%)	15 (60%)	8 (32%)
High	45 (65.2%)	15 (21.7%)	31 (44.9%)	38 (55.1%)	43 (62.3%)

It should be noted that several households usually use more than one energy source at the same time; solid fuel, liquid fuel and electricity. Out of 89 per cent of households using solid fuels for cooking, 65.2 per cent used firewood, 21.7 per cent used biomass, particularly coconut shells and husks, and 1.4 per cent used agricultural waste. Only 41 per cent used kerosene for the same purpose. For lighting, the picture was different. The number of households using kerosene for lighting (58%) was almost equal with the number using electricity (52%). Furthermore, it can be seen that the role of solid fuel was almost the same for each income group. However, the type of solid fuel used varied: the higher the income group the more wood was used for cooking, the lower the income group the more biomass. For lighting, kerosene was used most by the low income group and least by the high income group, whereas electricity was used most by the high income group and least by the low.

C. ANNUAL DOMESTIC FUEL/ENERGY CONSUMPTION

The consumption of solid fuel for cooking by all income groups (see Table 2.5) averaged 1,990 kg per household. The consumption of kerosene appears to be a little less for cooking than for lighting, averaging 124 l/household for cooking and 130 l/household for lighting. There is a tendency for kerosene consumption for cooking to increase as the family income increases. Solid fuel consumption first increases with income and then decreases again for the high income group. Table 2.5 shows the average amounts of solid fuel, kerosene for cooking and kerosene for lighting consumed by each income group in one year.

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1) for number of households surveyed in each group, please refer to Table 2.1.

Table 2.5: Average annual fuel consumption per household in Minahasa District, according to family income group, using data based on actual measurements and adjusted for seasonal variations

Income Group	Solid fuel for cooking						Kerosene					
	Firewood		Agricultural Residues		Total		For cooking		For lighting		Total	
	kg	GJ	kg	GJ	kg	GJ	litres	GJ	litres	GJ	litres	GJ
Low	1363	24.9	554.5	8	1917.5	32.9	68.5	2.55	128	4.77	196.5	7.32
Middle	1392	25.3	682	9.9	2074	35.2	89.16	3.32	103	3.85	192	7.17
High	1634	28.43	344	5.3	1978	33.73	215	8	158	5.89	373	13.80
Over-all Av.	1463	26.2	527	7.7	1990	33.9	124	4.6	130	4.8	254	9.4

The annual energy consumption follows the same pattern as the annual fuel consumption. As family incomes increase so energy consumpton from solid fuel first increases and then decreases (see Figs 2.1 and 2.2). Energy consumption from agricultural residues is greatest for the middle income group, and that from firewood is greatest for the high income group. The greatest use of kerosene, as might be expected, is among the high income group. The consumption efficiency of fuels for all income groups was found to be the same; 0.05 for cooking by solid fuel, 0.4 for cooking by kerosene, 0.18 for lighting by kerosene and 0.6 for lighting by electricity. This implies that the income level does not affect consumption efficiency.

D. FUEL CONSUMPTION BY APPLIANCES AND TIME SPENT COLLECTING SOLID FUEL

The amount of fuel consumed by household appliances tended to increase with income, as shown in Table 2.6:

Table 2.6: Average amount of fuel consumed by household appliances in Minahasa District

Income Group	Solid fuel			Kerosene			Electricity			
	Amount used kg/day	MJ/day	No. of appliances	Amount used l/day	MJ/day	No. of appliances	Amount used kWh	MJ	Capacity Watt	No. of appliances
Low	6.94	119	1	0.6	22.4	1.1	0.5	1.8	18.3	0.3
Middle	7.52	127.6	1.12	0.6	22.4	1.1	1.12	4	57.6	1.4
High	8.1	138	1.26	1.1	41	1.4	2.29	8.26	183	3

On average, the amount of solid fuel collected per minute was 1.47kg/min (low income group), 1.18 kg/min (middle income group), and 1.15kg/min (high income group), as shown in Table 2.7. It should be noted that the time spent by men in collecting fuel increases with income groups as the amount increases, but the amount collected per minute decreases as the income increases.

Table 2.7: Average amount of time spent in collecting fuel per household in Minahasa District

Income Group	Time spent collecting fuel (minutes per week)			Amount collected	
	men	women	children	kg	kg/min
Low	17.5	3.3	2.5	34.3	1.47
Middle	42.2	4	1.2	55.8	1.18
High	53.4	1.2	2.5	65.6	1.15

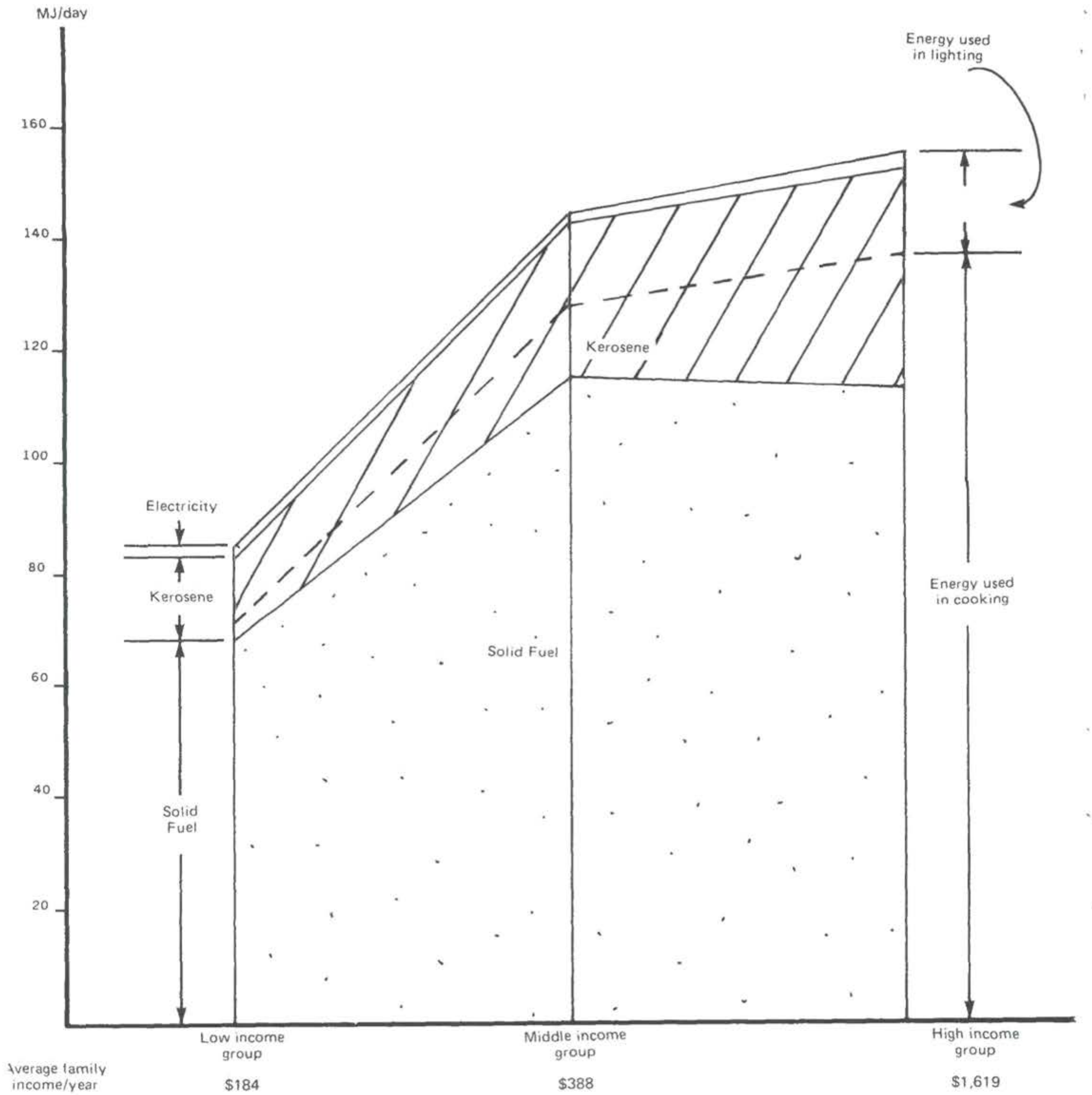


Fig. 2.1 Daily Average Energy Consumption per household in Minahasa

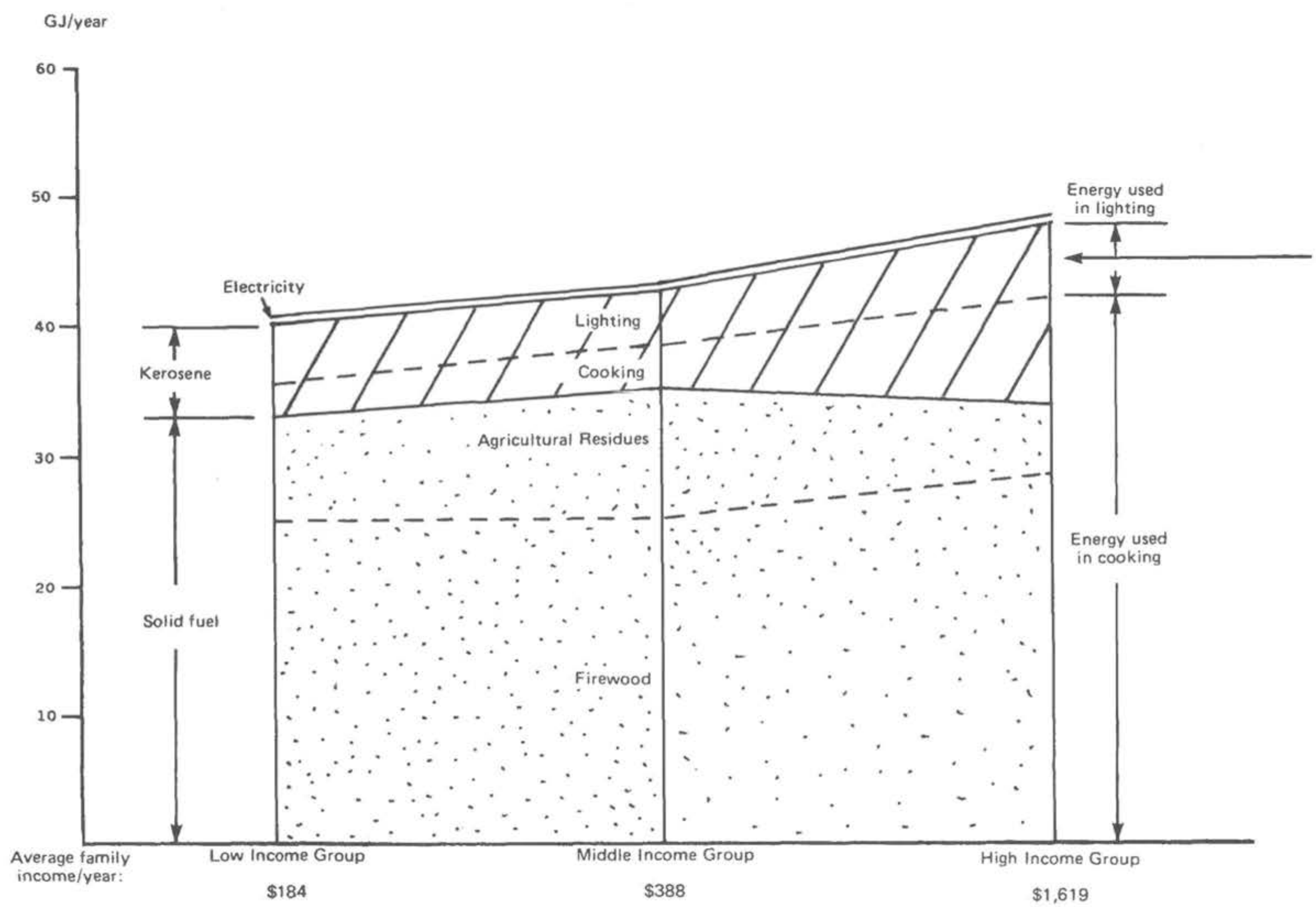


Fig. 2.2 Annual Average Domestic Energy Consumption (adjusted for seasonal variation) per household in Minahasa

E. LAND OWNERSHIP AND PRODUCTION VALUE

In general, the amount of land owned by a household depends on its income, which is, in turn, affected by the production value of land owned, as shown in Table 2.8:

Table 2.8: Average area of land owned and annual production value per household

Income group	Area of land owned(in ha)	Production value (in Rp)
Low	1.250 ± 0.418	132,466.667 ± 42,173.29
Middle	1.774 ± 1.229	183,154.000 ± 143,875.28
High	2.682 ± 2.140	995,415.388 ± 140,031.97

From Table 2.8 it can be seen that the amount of land owned by low income families ranged from 0.832 ha to 1.668 ha, with a production value ranging from Rp 90,293.377 to Rp 174,639.951. Middle income families owned 0.545 - 3.003 ha with production value Rp 39,278.72 - Rp 327,029.28, and high income families owned 0.542 - 4.822 ha with production value Rp 855,383.418 - Rp 1,135,447.358. It can be seen that, in general, the amount of land owned and the production value are very closely related in all three income groups.

F. CLASSIFICATION OF HOUSEHOLDS ACCORDING TO FUEL USE

Households can be classified according to their use of fuel, as shown in Table 2.9 below. It can be seen from the table that the percentage use of kerosene and solid fuel was similar for all three income groups, although there was a tendency for that of solid fuel to increase slightly with income. The percentage use of electricity clearly rose with income.

Table 2.9: Classification of households according to fuel use in Minahasa District

Income group	No. of house-holds	Type of household					
		Electricity consumers		Kerosene consumers		Solid fuel consumers	
		No.	% of h/holds	No.	% of h/holds	No.	% of h/holds
Low	6	1	16.67	5	83.33	5	83.33
Middle	25	8	32.00	20	80.00	22	88.00
High	69	34	49.27	61	93.84	62	95.38

It should be noted that several households use the three energy sources (solid fuel, kerosene and electricity) side-by-side.

CHAPTER III

SURVEY OF ACEH

A. GENERAL INFORMATION

The Province of Aceh consists of ten level II districts, i.e. 8 rural districts (kabupaten) and 2 municipalities (kotamadya) as shown in Fig.3.1. Of these level II districts, only two are situated totally inland, the others all being on the coast with some part of each extending inland.

The areas of population density are concentrated mostly along the north and east coasts where transportation facilities in inland areas has given rise to many problems there, one of these being the high prices of goods which have to be brought in from outside, among them kerosene.

Aceh covers a total land area of 5,539,000 ha, about 75 per cent of which is forest. The value of this forest as a source of natural wealth cannot be estimated. In addition to the many other vital functions which the forest performs, it also acts as a source of firewood for Aceh's rural population. This consumption of firewood is certainly large, but just how large was not known. Like Minahasa, Aceh also possesses a great deal of biological waste which could be utilized as a source of biogas energy.

This survey was therefore also carried out to determine how much and what kind of energy is used daily by Aceh's rural population. It can be seen, therefore, that conditions in Aceh, both geo-physical and socio-economic, are not homogenous. This fact was taken into consideration in the selection of districts to be surveyed.

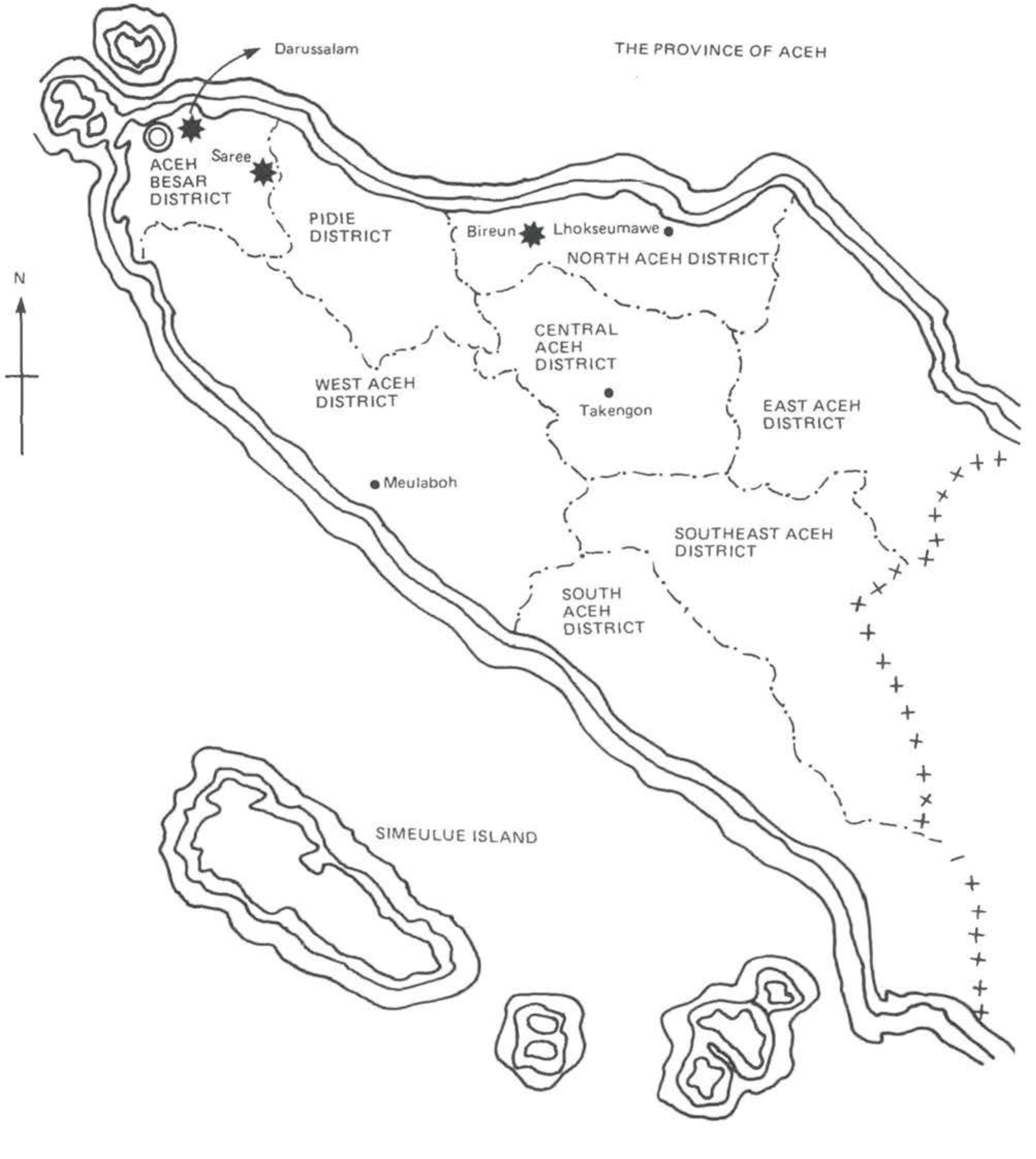
B. SURVEY METHODOLOGY

In this survey, four of Aceh's level II districts were taken as a sample. Selection was based on the availability of firewood and on the degree of synchronization with the regional development plans drawn up by the Aceh Regional Development Planning Board (BAPPEDA). The four level II districts selected were chosen to represent as closely as possible the whole province of Aceh. They were:

- North Aceh Kabupaten, which represents the North and East coasts,
- West Aceh Kabupaten, which represents the West coast and South,
- Aceh Besar Kabupaten, which represents the further end of the coast, and
- Central Aceh Kabupaten, which represents the inland areas (Fig.3.1).

Since this is a survey of rural areas, no municipalities were included in the sample.

A sample of 100 families was taken constituting 25 families from each district. The sample was taken in the following manner: three sub-districts were chosen at random from each district, then a number of villages chosen at random from each sub-district, and a number of families chosen at random from each village to give a total of 25 families per district. Three villages were selected from North Aceh, five from West Aceh, eight from Aceh Besar, and six from Central Aceh.



✸ Locations of Biogas Pilot Projects :

Darussalam	(Aceh Besar District)
Saree	
Bireun	(North Aceh District)

◎ Provincial capital

• Town

FIG. 3.1 MAP OF ACEH

Data on each family was obtained by means of a questionnaire administered by the survey team, who visited each family. The questionnaire was supplied by the Directorate General of Energy, of the Department of Mines and Energy.

Each family was visited three times at intervals of 24 hours. In addition to interviewing the family, the survey team also measured the amounts of firewood and kerosene consumed as fuels in these rural households.

C. RESULTS OF THE GENERAL SURVEYS (ECONOMIC AND SOCIAL)

The information obtained during visits to the 100 sample families can be inventorized as follows:

1. Family characteristics

Several characteristics were noted, including family size, number of children, and frequency of meals. The average family size was observed to be 6.6 persons, with a range of one to eleven. The majority (68%) of families consisted of 5-8 persons. The most common (22%) was seven persons.

The number of children ranged from 0 to 9, with an average of 4.8 per family. The most common (20%) was three. Eighty-eight per cent of families had 0-6 children. The average age of the family members was 26.6 years.

In rural areas, energy is needed for cooking and lighting. In general, food is cooked only for the family. This was deduced from the survey, which showed that out of the 100 families observed, 631.95 family members ate at home in one week. Ninety-five per cent of the families stated that they ate 21 meals a week. The remaining 5 per cent ate at home 10-20 times a week.

The number of non-family members who ate with the families observed during one week was very small. Out of 100 families, only 12 per cent entertained guests to a meal. In other words, the average number of non-family members who ate with a family was only one every six weeks. The survey also showed that it was rare for families to eat out. Only 2 per cent of the families observed stated that they ate out, and that only once a week.

2. Family income

The average total income was Rp 886,153 (US$913) per household a year. Table 3.1 shows the annual average income per household. The majority (53%) of households observed had two sources of income, 30 per cent had only one, and the remaining 17 per cent three. Sources of income included daily wages (cash and non-cash).

Table 3.1: Average income

Income Group	Number of house-holds	Average annual income	
		RP	US$
Low	5	less than 150,000	less than 155
Middle	8	150,000... 250,000	155... 258
High	87	more than 250,000	more than 258
Overall average family income 886,153 Rp (US$913)			

3. Agricultural land-use and yield

Of the 100 households visited, 49 per cent farmed areas of less than 1 hectare, 24 per cent 1-2 hectares, and the remaining 13 per cent more than 2 hectares. The average for each household was 1.09 ha with a range of 0.08 to 4.0 ha. The crops grown included rice, secondary crops such as legumes, cassava and vegetables, and annual crops such as coconuts, coffee, oranges and cloves.

Of these 100 families, only 86 per cent farmed the land; 48 per cent cultivated only one type of crop, either rice or a secondary crop or an annual crop, 25 per cent cultivated two types of crop, and 7 per cent cultivated three. Table 3.2 shows the crops, the average land area devoted to each, the average annual value of the crop, and the average value of crops sold.

Table 3.2: Crops: average land area cultivated per household, value of yield, value of crops sold, and percentage of sample households cultivating each crop.

Crop	Average land area culti-vated per household	Average value of yield (RP/ year/house-hold	Average value of crop sold Rp/year/ household	Percentage of sample family cultivating each crop
Rice	0.860	266,607	150,400	51
Secondary Crops	0.675	133,278	90,300	37
Other crops	1.077	310,671	305,670	31

The average value of crops harvested annually by the 86 per cent of the sample who farmed the land was Rp 365,700 (US$377). Of these 36.25 per cent obtained less than Rp 150,000 (US$155) a year, 28.75 per cent obtained Rp 150,000 to Rp 250,000 (US$155...258) and the remaining 35 per cent obtained more than Rp 250,000 (US$258) per year. Table 3.3 shows the frequency of households for each level of income in relation to the land area farmed.

Table 3.3: Frequency of households obtaining each level of income, and land area farmed.

Income group	Land area farmed		
	0 - 0.99 ha	1 - 2 ha	over 2 ha
Low	41	8	0
Middle	7	14	2
High	1	2	11

From Table 3.3, we can conclude that the large majority of families cultivate less than one hectare of land with an income of less than Rp 150,000 (US$155) per annum. The number of farming families obtaining over Rp 250,000 (US$258) per annum increases with the area of land cultivated. Although the opposite is also true, i.e. income tends to fall as the area cultivated decreases, the data do show that it is still possible for a farmer to obtain an income of over Rp 250,000 per annum from only one hectare of land.

4. Animal husbandry

All the households visited kept a variety of livestock, the overall total numbering 144 buffalo, 233 cattle, 165 goats and 1709 ducks and chickens. The range of livestock kept by any one family was 1 - 2 buffalo, 1 - 4 cattle, 1 - 3 goats, and 1 - 30 ducks and/or chickens.

5. House size

The floor area of houses occupied by the households ranged from 20 to over 80 m^2, as detailed in Table 3.4. The data shows that most (71%) of the households observed occupied houses with a floor area of over $40m^2$.

Table 3.4: Area of houses per household

Floor area of house (m^2)	Percentage of households(%)
20	7
21 - 40	22
41 - 60	21
61 - 80	32
over 80	18

6. Transportation

Sixty-one per cent of the households visited made use of the transportation facilities available: 1 per cent used a car, 39 per cent minibus, 1 per cent bus, and 20 per cent motor-cycle. It would seem that small vehicles are popular in these rural areas. The distance travelled in one week by those 59 per cent of households who made most use of transport is given below:

Table 3.5: Distance travelled by 59 per cent of the households

Distance travelled (km/week)	Percentage of households (%)
5	24
4.1 - 5	4
3.1 - 4	2
2.1 - 3	11
1.1 - 2	4
0.1 - 1	14

D. RESULTS OF HOUSEHOLD ENERGY SURVEYS

1. Types of fuel employed

The families visited during the survey both collected and bought fuel. The energy consumed from fuel collected by each family came from an average of two types, and ranged from one to eight types of fuel. Types of fuel collected included wood, twigs, coconut leaves, coconut sheaths and coconut shells. In general (38%), families tended to use just one type of fuel, only 2 per cent using as many as eight.

The types of fuel purchased for energy requirements averaged two per family, with a range of one to four. Fifty-five per cent of families purchased one type of fuel, 4 per cent purchased four types. The great majority, therefore, bought only one type of fuel, i.e. kerosene, which they used for cooking and lighting. The types of fuel purchased were kerosene, petrol, methylated spirits and wood charcoal.

2. Solid fuel consumption

The data obtained during the survey show that 93 per cent of the sample households used firewood for cooking. During the two-day visits firewood consumption per family was also measured. If these data are projected for one year, we get the figures shown in Table 3.6 (no account was made for seasonal variation).

Table 3.6: Projected annual consumption per household of solid fuel (kg/year/household)

District	Firewood	Coconut materials	Charcoal	Average price of kerosene in Rupiah/l
North Aceh	667	1871	32	83.3
Central Aceh	2648	-	-	90.9
West Aceh	1363	98	78	93.9
Aceh Besar	2885	1711	23	79.3
Average	1891	920	33	33

Table 3.6 shows the consumption of wood and coconut materials together to be much higher in Aceh Besar than in the three other districts. The wood consumption in Central Aceh is also large but, as coconut palms do not grow there, there is no consumption of coconut materials for fuel. This should be linked with the availability and price of other fuel too. The price is seen to be more expensive in Central and West Aceh than in North Aceh and Aceh Besar.

The survey indicated that the solid fuel most used in rural areas is wood (wood, twigs and bamboo) 66.48 per cent, followed by coconut materials (leaves, husks, shells and leaf sheaths) 32.5 per cent, and lastly wood charcoal 1.17 per cent. No-one seemed to be utilizing waste (such as chaff or wood shavings). Each family tended to use more than one type of fuel for cooking, the types used varying from family to family. Solid fuels always used in rural areas are as follows:

a) Trees: trees were rarely cut down for firewood, with the exception of those which were no longer productive, such as old coconut, rubber and coffee trees;

b) Twigs: twigs from various trees, such as mango, organge, jackfruit, pine, coffee, rubber, bamboo, "bayur" and "dadap", were utilized for firewood;

c) Coconut: coconut leaves, husks, shells and leaf sheaths.

3. Liquid fuel consumption

Kerosene was used in a variety of lamps (including pressure lanterns, and oil lamps with or without mantle) for lighting. For cooking, 16 per cent of the sample families used kerosene as well as wood, while 7 per cent used only kerosene.

On average, families used 2.10 litres of kerosene in two days, or 1.05 litre/family/day. Table 3.7 shows the projection of these figures per household per year for each district.

Out of the 100 households, only 31 per cent used petrol for motor cycles. Petrol consumption was found to be 0.53 litre/household/day.

Table 3.7: Projected Annual Liquid fuel consumption per household (litres/year/household)

District	Kerosene	Petrol
North Aceh	304	133
Central Aceh	328	-
West Aceh	315	385
Aceh Besar	581	258
Average	382	194

It can be seen from Table 3.7 that the kerosene consumption in Aceh Besar is almost double that in the other districts.

Only 16 per cent of the sample families used electricity for lighting. No use of electricity for home industries was observed. On average, families used 0.80/kWh per family over two days, i.e. 0.40/kWh/family/day.

The survey showed the liquid fuel most commonly used in rural areas to be kerosene 66.34 per cent, followed by petrol 33.66 per cent. Kerosene was used for lighting and cooking, petrol for motorcycles. Methylated spirits were also used by some of the families surveyed but in relatively very small quantities.

4. Fuel utilization

The main use of fuel was observed to be for cooking, cooking fuels falling into two major categories: oil and gas, and wood. Oil, gas and electricity are used more in the towns. The fuel most commonly used in rural areas is wood. In Central Aceh District, wood is also widely used for heating as the air temperature there is quite cold, especially at night. The highest consumption of energy per household was found to be in Aceh Besar followed by Central Aceh for the reason given above. (Please see Table 3.8 showing annual projected energy consumption in Aceh per household/year.)

5. Time needed for collecting fuel

As described above, the primary fuels collected by Aceh's rural population were firewood, twigs and coconut materials (leaves, husks, shells, trunk and sheaths). This survey shows the main fuel collected to be wood (80.5%), followed by coconut materials (18.5%), other fuels such as bamboo and rice straw constituting only 1 per cent. The types of wood and twigs utilized vary from place to place. Coconut palms do not grow in Central Aceh District and therefore are not used for fuel there. Besides, 7 per cent of the whole sample did not use wood at all, but instead used kerosene for cooking.

For the 100 sample families, the total amount of firewood collected for cooking was 14,273 kg per week. This means 20.4 kg wood was collected per family per day. The figure of 14,273 kg can be broken down into: wood and twigs 11,206 kg, coconut leaves 625 kg, coconut shells and husks 826 kg, and coconut sheaths and trunks 1,616 kg.

Eighty-nine per cent of the families collected fuel twice a week, 8 per cent three times a week, and only 3 per cent once a week.

In general, most of the fuel collecting was done by women. Women took up 62.9 per cent of the total time taken for collecting wood and twigs, 84.9 per cent of the total time for coconut materials (see Table 3.9).

Table 3.8 Annual projected energy consumption in Aceh given per household per year

District	Solid Fuel						Kerosene		Petrol		Total
	Firewood		Agricultural[1] residues		Charcoal						
	kg	GJ	kg	GJ	kg	GJ	Litres	GJ	Litres	GJ	GJ
North Aceh	667	11.9	1871	27.8	32	0.93	304	11.3	133	4.8	56
Central Aceh	2648	47.3	-	-	-	-	328	12.2	-	-	59.5
West Aceh	1363	24.4	98	1.46	78	2.26	315	11.7	385	13.9	54
Aceh Besar	2885	51.6	1711	25.4	23	0.67	581	21.6	258	9.3	99.3
Overall Average	1891	33.8	920	13.7	33	0.96	382	14.2	194	7	67

1) Consists mainly of coconut material and residues

The following heat values were assumed:

1kg firewood	=	17.873 MJ
1 litre of kerosene	=	37.263 MJ = 8.9 Mcal
1kg Charcoal	=	29 MJ
1 litre Gasoline	=	36 MJ
1kg of Agricultural residue	=	14.84 MJ

The average time needed to collect one kilogram of firewood was 2 minutes 17 seconds, a rate of 27.6 kg per hour.

Table 3.9: Time taken by men, women and children for collecting fuel.

Fuel	Time taken					
	Men		Women		Children	
	minutes	%	minutes	%	minutes	%
Wood	3316	26	7849	60.9	1305	10.5
Coconut materials	1651	8.9	15729	84.9	1150	6.2

6. Appliances and fuel utilization

In general, cooking in rural areas is done over a wood-burning stove. Lighting is usually by kerosene lamps, some families using pressure lanterns. Table 3.10 shows the types and numbers of fuel-using appliances utilized by the sample.

Table 3.10: Types and numbers of appliances, and amounts of fuel usedper household

Place	Av.no.of cooking stoves	Amount of firewood consumed (kg/week	Av.no.of pressure lanterns (h/hold)	Av.amt. of kero-sene consumed (litre/ week	Av.no.of kerosene lamps	Av.amount of petrol consumed litre/ week
Aceh Province	2.16	50.37	1.16	7.25	2.62	4.73
North Aceh District	2.40	51.54	1.19	6.36	2.48	5.41
West Aceh District	2.46	41.81	1.00	9.06	4.50	6.90
Aceh Besar District	1.70	42.06	1.26	7.82	1.55	3.67
Central Aceh District	2.09	66.07	1.18	5.76	2.43	2.94

CHAPTER IV

TESTING OF FUELWOOD STOVES

A. INTRODUCTION

Following the survey on energy consumption which has shown that fuelwood represented the primary source of energy in the rural areas of the two districts surveyed, the two following activities were undertaken:

First: to test the efficiency of a number of available fuelwood stoves in use in these areas as a first step for the development and promotion of more efficient and environmentally-sound stoves.

Second: to construct biogas demonstration plants in those areas where the raw material is available and the local conditions are relevant.

In this chapter the efficiency test of the stoves is described and the results are given, whereas the biogas demonstration plants will be dealt with in the next chapter.

B. TYPES OF STOVE

Several types of cooking stoves were made available in the rural areas of Indonesia including the "Lorena", "Clay Modification" and "Concrete Modification". The types of stove tested in this study included:

1. Cooking stoves from Cikarawang village which were made of a mixture of clay, ash and black palm fibre. They have two outlets*for cooking and an opening for stoking firewood, but they have no chimney.

2. Traditional cooking stoves from Neglasari village (one of the locations of the study) are made from a mixture of clay (60 per cent), kitchen ash 40 per cent and the fibre from 10 to 15 coconuts per stove. They have two cooking outlets and an opening for stoking firewood but, like the first one, have no chimney (see Fig.4.1). These two stoves are quite similar and have the same dimensions (Fig.4.2).

3. The first modification of this stove has been designed using concrete made from sand and grey cement in the proportions 4 : 1 by volume. The first design has two cooking outlets with a straight/direct connecting channel; it has an opening for stoking firewood, which can be closed with a zinc door, and is equipped with a ceramic chimney. This stove will be referred to here by the code name M_I (see Fig.4.3).

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* the cooking outlet is a round hole in which the saucepan or kettle is placed.

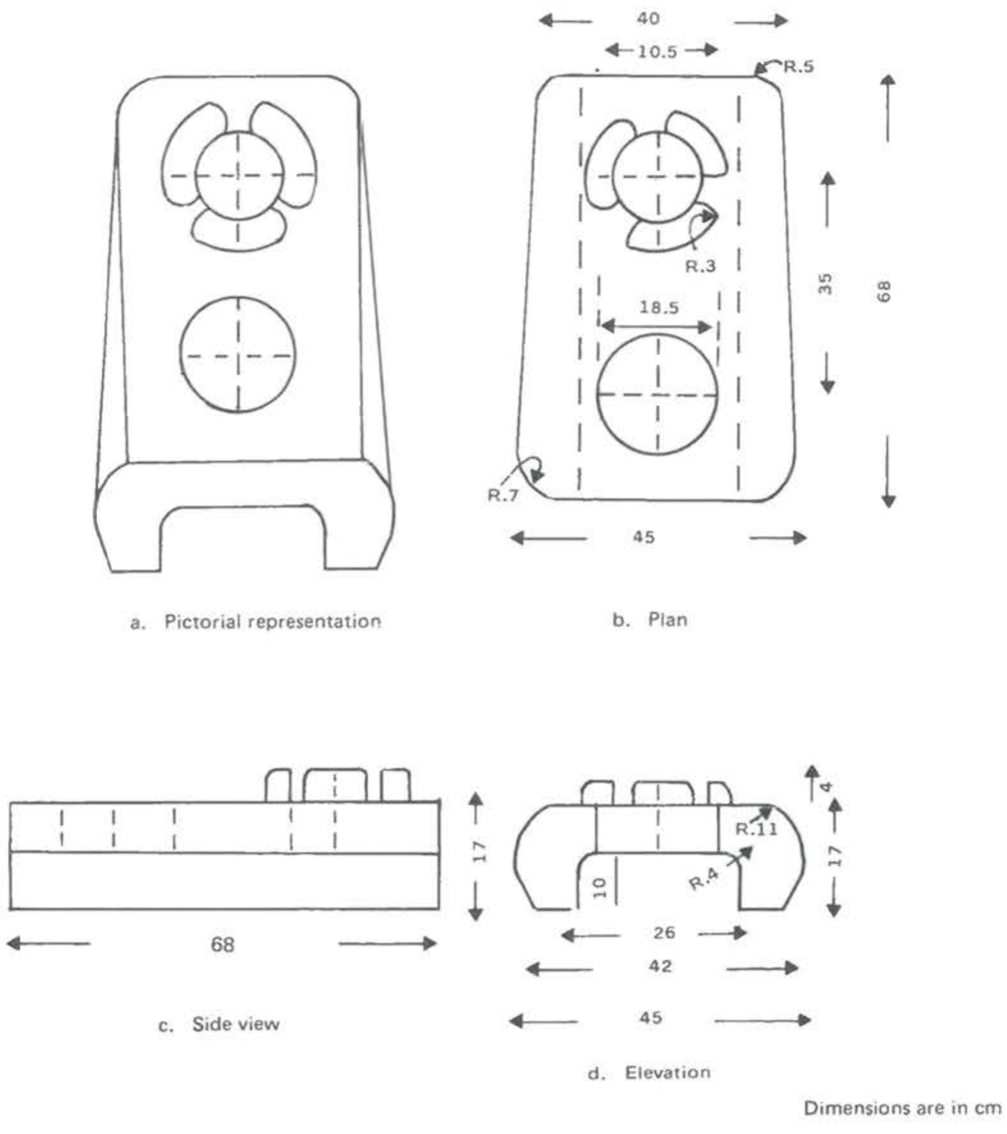

Fig. 4.1 Traditional Stove from Neglasari Village

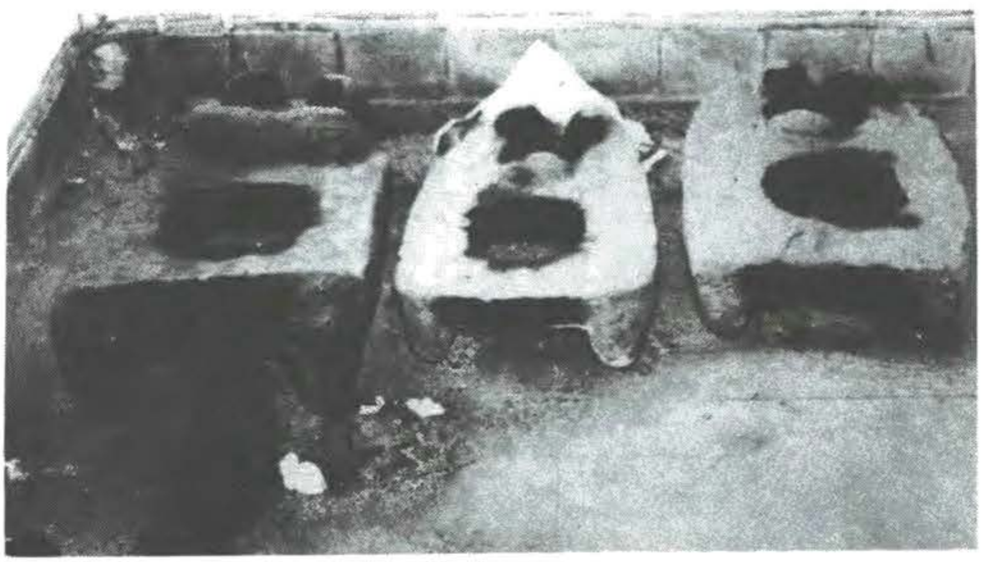

Fig.4.2 Traditional Stove

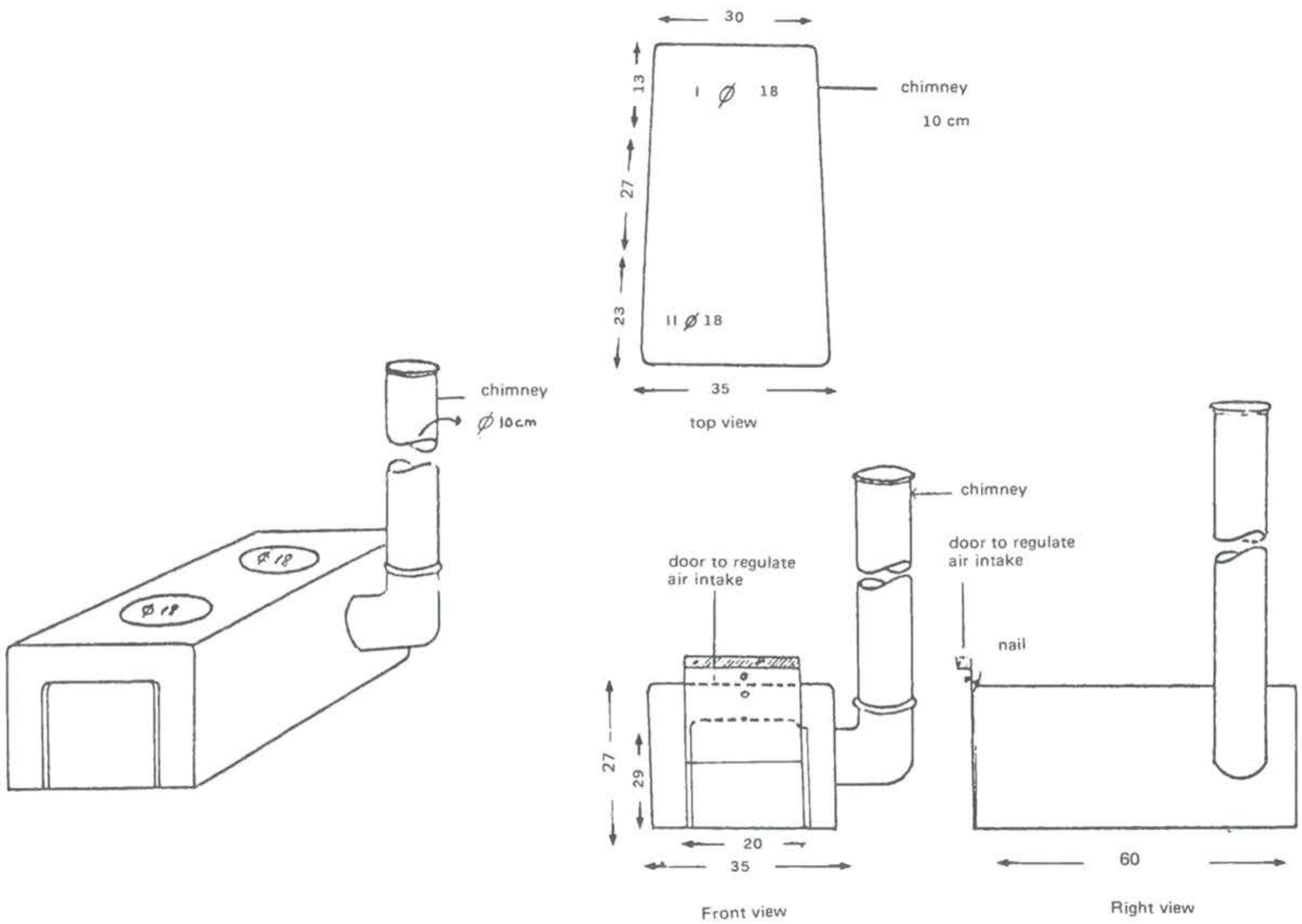

Fig. 4.3 Modification M_I

4. The second modification is larger with two cooking outlets connected by a slanting channel, a stoking hole with a zinc door, and a ceramic chimney. This stove will be referred to here by the code name Modification M_{II} (Fig.4.4).

5. A third modification, referred to as Modification T, is made from a mixture of clay and sand in the ratio 3:2. This stove has two cooking outlets of diameter 21 cm and 18 cm connected by a slanting channel. The fuel opening measures 10 x 15 cm and has a zinc door, and the chimney diameter is 9 cm. (Fig.4.5). The exterior measurements of the stove are 46 cm x 45 cm x 27 cm.

6. The Lorena stove (Fig.4.5) is made from a mixture of clay and sand in the ratio 3:2 by volume. It has three cooking outlets, a fuel opening with a zinc door, and a covered chimney. Two of the cooking outlets have a diameter of 23 cm and the third has a diameter of 18 cm. The stoking hole measures 13 cm x 18 cm, and the chimney diameter is 11 cm. The Lorena stove's external dimensions are 81 cm x 63 cm x 26 cm.

C. METHOD OF TESTING

The types of stove tested included the traditional stoves, the modified ones and the Lorena clay stove. The initial testing of three types of traditional stove (from Cikarwang and Neglasari villages), using rubber tree wood, indicated differences in their efficiency. The traditional stove which showed the highest heating efficiency and was deemed the best was the one from Neglasari (Fig.4.1). This was selected as the traditional stove to be used in the subsequent tests.

The cooking vessels employed in the tests were two aluminium kettles, one each of the following sizes:

Size I : ∅ 24 cm, depth 14 cm, weight 353.7 gram.

Size II : ∅ 20 cm, depth 11 cm, weight 237.3 gram.

The fuels used in the tests were agricultural waste (i.e. corn cobs), sawdust charcoal brickets, chaff brickets and rubber tree wood for comparison.

The medium to be heated in the tests was water: 3 litres in kettle I, and 2 litres in kettle II.

The temperature of the water before, during and at the end of the process was measured using a mercury 100°C thermometer. The air temperature in the chimney was measured with a mercury 420°C thermometer, which was also used to measure the air temperature in cooking outlet II of the traditional stove. The heat of the fire itself (the heat source) was measured with CA thermocouples. The water, air and fire temperatures were measured every five minutes. In addition, throughout the process, the temperatures were also measured of the surrounding air, the air at the stoking opening, and the wall of the stove.

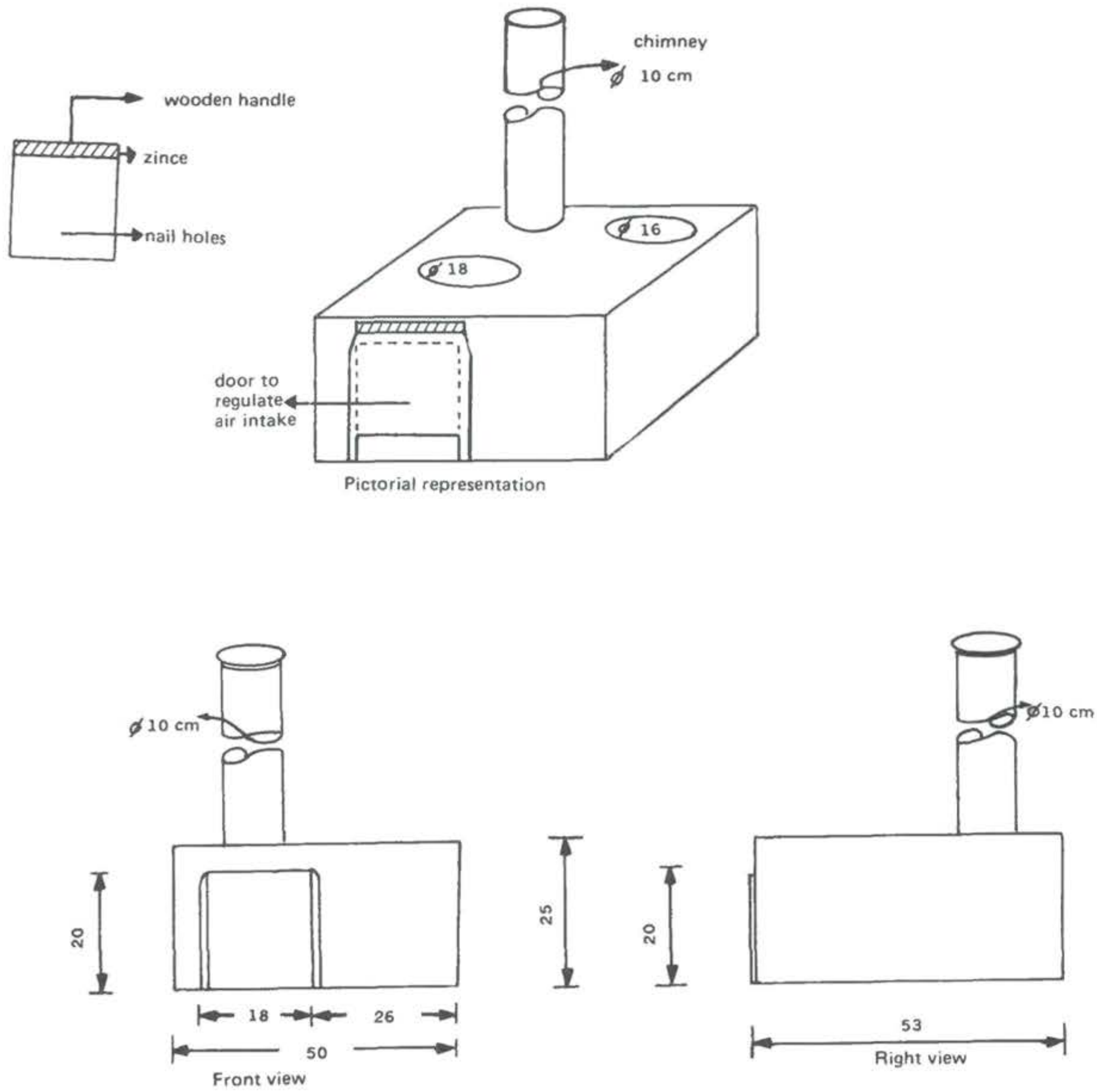

Fig. 4.4 Modification M_{II}

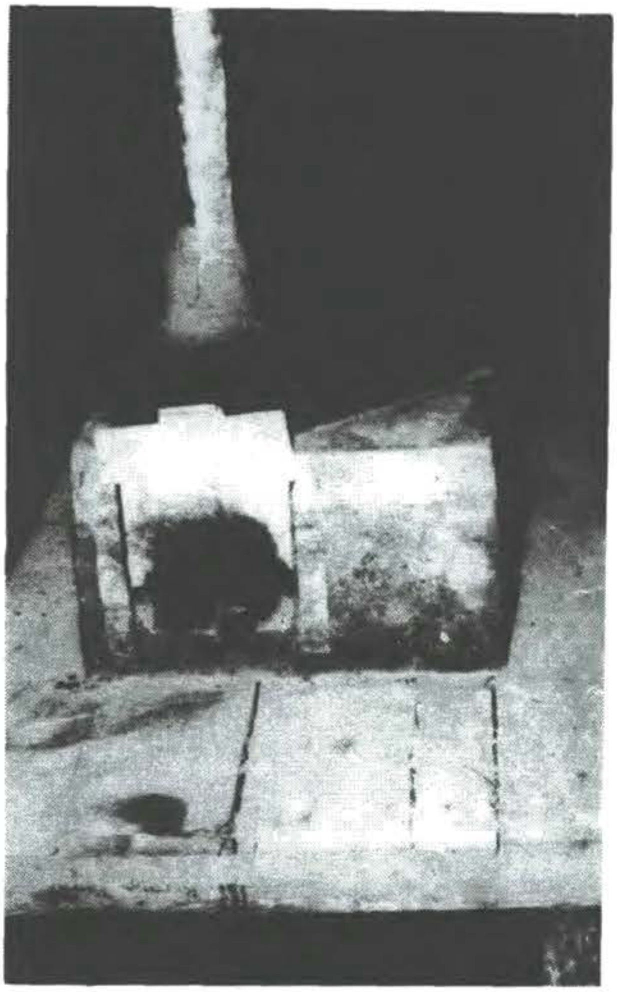

Fig.4.5 Stove, Modification T

The initial and remaining amounts of fuel were weighed using a triple beam balance of maximum capacity 2610 gram.

The water was heated until a constant fire temperature was obtained. This was assumed to be the combustion temperature. The process was considered to be completed when all the remaining fuel had been removed from the stove, but the heating time was counted up to the moment the fire was completely extinguished.

The efficiency of the stoves can be calculated by comparing the amount of heat absorbed by the water for its rise in temperature and evaporation (Q_o) and the heat value of the fuel used throughout the process (Q_1), using the following formula:

$$\text{Efficiency} = \frac{Q_o}{Q_1} \times 100\ \%$$

D. TEST RESULT

The average figures resulting from the tests on various stoves burning a variety of woods and solid fuels are given in Table 4.1.

1. Results using firewood

The stoves were tested burning firewood as a basis for comparison with other fuels. The data in Table 4.1 show a wide variation in the heating efficiency of the stoves. The highest efficiency, 14.25 per cent, was obtained from the traditional stove, and when an iron tripod was fitted to the cooking outlet it rose to 15.75 per cent. The lowest efficiency, 7.75 per cent, was obtained from Modification M_I.

The low efficiency of the Modification and Lorena stoves compared to the traditional one was due to the smallness of their hearths which necessitated the removal of ashes and, consequently, heat each time more fuel was added, the low combustion rate caused by the low density of fuel and the rapid rate of heat flow to the walls of the concrete stove. An increase in heating efficiency was noted, however, when an iron tripod was fitted to the cooking outlet. This was due to the fact that the red hot iron conducted extra heat directly from the fire to the saucepan.

2. Results using corn cobs

The data in Table 4.1 show that although the heat rate per minute was lower for corn cobs than for wood, nevertheless the combustion temperatures for these two fuels did not differ greatly. Similarly, the heating efficiency obtained from corn cobs was almost the same (varying about 1 - 2 %) as that obtained from wood, using the same stove.

Table 4.1: Results of tests on different stoves using several kinds of fuel[1]

Type of stove	Type of fuel		Calorific value of fuel (kJ/kg)	Combustion temperature (°C)	Fuel combustion rate (kg/hour)	Heat output (kJ/minute)	Heat capacity of(2) stove (kW)	Heating efficiency %
	Type	Moisture Content						
Traditional	Rubber wood	15%	16032	595	1.746	66.006	1.091	14.25
Traditional	Corn cobs	12.1%	16338	500.2	0.849	35.425	0.605	15.35
Traditional	Chaff brickets	12.1%	14654	565.7	0.816	19.742	0.343	10.83
Traditional	Sawdust charcoal brickets	5.1%	16705	-	0.498	9.714	0.162	7.0
Traditional + iron tripod (3)	Rubber wood	15%	16032	719	1.872	74.935	1.341	15.75
Modification M_I	Rubber wood	12.94%	16374	595	1.003	21.805	0.435	7.75
Modification M_{II}	Rubber wood	12.94%	16374	608	1.113	24.678	0.449	7.84
Modification T	Rubber wood	12.94%	16032	585.6	0.722	25.778	0.515	13.12
Modification T	Corn cobs	12.99%	16189	509.3	0.557	15.661	0.342	10.57
Lorena	Rubber wood	12.94%	16032	622.5	1.310	39.950	0.751	10.46
Lorena	Corn cobs	12.94%	16189	710.5	0.934	32.040	0.544	12.0

(1) The figures given are the averages for two replications of tests in the laboratory

(2) Calculated from the highest values obtained in the tests for combustion rate and efficiency

(3) The iron tripod was fitted to cooking outlet I.

The lower heat rate obtained from corn cobs, which means a decrease in the stove's heat capacity, was due to the lower fuel combustion rate which, in turn, was caused by the lower density (weight/volume) of corn cobs as compared to wood.

The disadvantage of using corn cobs as a fuel is that their combustion rate is so fast that the stove would need replenishing very frequently. This means that while the stove is in use, time would have to be set aside especially for stoking which could be impractical in rural areas since other jobs are usually carried out at the same time as cooking. As regards cleanliness, corn cobs tend to produce more soot than firewood does but it produces less ash.

The results of the tests on a variety of stoves using corn cobs as fuel, indicate different fuel combustion rates and heat efficiency levels for each type of stove. The highest efficiency level (15.35%) was obtained using the traditional stove, and the lowest (10.57%) using Modification T. One of the reasons for the low efficiency of Modification T was the smallness of its hearth, which necessitated the removal of ash each time more fuel was added. This caused more heat loss and, therefore, less efficiency.

3. Results using chaff brickets and sawdust charcoal brickets

These two fuels were tested only on the traditional stove. The levels of efficiency obtained for the traditional stove using chaff brickets and sawdust charcoal brickets were, respectively, 10.38 per cent and 7 per cent. The heat rate was 19.742kJ/minute for chaff brickets and 9.714kJ/minute for sawdust charcoal brickets, while the combustion temperature was 565.8^{o}C for chaff brickets and 414.2^{o}C for sawdust charcoal brickets.

There are, however, several disadvantages to using these brickets which make them unlikely to be popular among the rural population.

The disadvantages of chaff brickets are that they do not ignite or burn easily, their combustion rate is low, they sometimes need to be fanned, and they therefore require perseverance on the part of the user. Their advantages over wood and corn cobs, however, are that they produce less soot, much less smoke during ignition and combustion, (although they do produce a considerable amount of smoke when being extinguished) and they leave a residue of ash lumps rather than scattered ash. A simpler technology is needed to produce the brickets for popularizing their use.

The test results and observations also indicate that sawdust charcoal brickets would not be a viable fuel for daily use in traditional stoves. Not only is their heating efficiency low (only 7%), but they are also difficult to burn and need constant fanning.

4. Conclusions

The design of an efficient, environmentally-sound, cheap and socially-acceptable wood stove is not an easy task.

a) The tests described above on several types of stoves, burning various types of fuel, indicate that the traditional stove from Neglasari has a good heating efficiency, i.e. 14.25 per cent for rubber wood, 15.13 per cent for corn cobs, 10.83 per cent for chaff brickets, and 7 per cent for sawdust charcoal brickets. The level of efficiency can be raised still further to 15.75 per cent using rubber wood, if an iron tripod is fitted to the cooking outlet.

b) The Lorena and Modification stoves are environmentally more sound and better than the traditional stove as regards the amounts of smoke, ash and soot produced. They are also better made. The concrete stove is cheaper and easier to use than the traditional Lorena and clay Modified stoves, but its design needs to be improved so that a higher level of efficiency can be obtained.

Based on the above tests and information, an environmentally-sound, efficient stove was recommended. The so-called "pogbi" stove (Bellerive Foundation, 1981) has a higher efficiency in view of the larger surface of kettle exposed to the fire, the design of the chimney and the improved design of the stove body and kettle. The stove is, however, more expensive than the ones tested above. A subsidy will be needed, particularly for large-scale production of the kettles.

CHAPTER V

BIOGAS PILOT PLANTS

Biogas offers a variety of advantages which make it an attractive energy alternative for the rural areas of Indonesia:

1. Biogas units have been developed almost entirely by developing countries, particularly for rural areas.

2. The systems can be fabricated locally using local material and manpower.

3. Biogas can be used directly for cooking or illumination. These two uses represent the main energy requirement of rural inhabitants. It can also be used to run internal combustion engines for the production of electrical or mechanical power.

4. In addition to energy production, the biogas digesters produce a slurry which can be used effectively as a fertilizer.

5. The raw materials needed for the systems are increasingly abundant as a result of steps being taken to increase the supply and consumption of animal protein.

6. Improved sanitation can result when animal and human wastes are processed through the system in which the greatest part of the parasites and pathogens are eliminated or neutralized.

7. Storage of biogas is an integral component of the plant, thus biogas is easily stored under normal temperature and pressure.

8. System operation is labour intensive. In most cases unskilled labour could be trained for construction, operation and maintenance purposes.

Potential disadvantages are, however, associated with biogas digesters:

1. Liquid slurry can contaminate ground water if improperly handled.

2. The anaerobic process is sensitive to pH and to temperature variation..

3. Animal wastes must be collected, mixed with fresh water and fed daily into the digester. Thus water should also be easily available.

4. Care has to be taken, particularly during the periodic maintenance periods, to minimize explosion risks.

5. Initial costs may be high before the utilization of cheap local material is mastered or large-scale manufacturing in the case of ferro-cement or steel gasholders.

A. SITE SELECTION

The siting of the biogas digester was based on several considerations, including:

1. availability of animal dung and water as the raw material for producing biogas;

2. the enthusiasm of the inhabitants, their desire to own a digester tank, and their ability to maintain and operate it to produce biogas;

3. the probability that biogas will be needed and actually utilized for daily cooking and lighting;

4. the inhabitants' willingness to act as pioneers in the use of biogas and to pass on their knowledge to others in the surrounding area and

5. easy and quick accessibility to the site for monitoring by project staff from Syiah Kuala University, in view of the fact that this is the first biogas project to be undertaken in Aceh.

The survey indicated that in the rural areas people tend to use mostly wood and coconut materials as cooking fuel. The livestock population is also large, an average of 1.5 animals per person (in North Aceh) and in several villages there are several persons who possess large numbers of livestock.

The following three places were therefore chosen as sites for installing family-sized ($5m^3$ capacity) digester tanks:

- Syiah Kuala University Experimental Farm, in the Darussalam sub-district of Aceh Besar;

- SPP-SNAKMA (Agricultural Development School and Animal Husbandry High School), in the Saree sub-district of Aceh Besar;

- The backyard of a leading cattle farmer (Ibrahim Ali-Basyah) at Kampung Blang Ketumba, Kilmetre 4.8 on the Bireun-Takengon road, in the Jeumpa sub-district of North Aceh

These sites are shown on the map (Fig.3.1).

In order to function well, a 5 m^3 digester must be supplied with at least 100 kg dung/cattle waste a day, for which a minimum of 8 penned cattle or buffalo is needed.

B. SELECTION OF TYPE AND SIZE OF BIOGAS PLANT

Biogas digesters developed in China and India range in capacity from $2m^3$ to $150m^3$/biogas/day. This corresponds to a digester volume of 5 to $375m^3$ of the Indian type and 6.7 to $500m^3$ of the Chinese type.

The advantages of the Chinese (fixed-dome) type are:

1. No steel sheets are required;
2. Generally it runs on a batch-continuous process, hence plant waste may be included;
3. It has a relatively low construction cost. (In China this is about US$3.5 to 5/$m^3$ of digester volume). Thus the construction cost of a digester which produces $2m^3$ of biogas/day will be US$25...35 in China (1980 price level);
4. Less earth surface is being used as the digester and gas holder are both built below ground surface.

The disadvantages of this type are:

1. The necessity of removing the sludge twice or more often a year;
2. The unfamiliarity with the type outside China and the lack of construction and plastering experience.

On the other hand, the advantages of the Indian (floating gas holder) type are:

1. The gas holder can be lifted up to facilitate removal of any build-up of scum and rotated to give limited stirring;
2. The floating gas holder provides a constant gas pressure to the appliances;
3. It is simpler to build, operate and maintain.

The disadvantages of this type are:

1. Steel gas holders are most commonly used but they are expensive (about 40% of the total cost of the plant);
2. Ferro-cement gas holders are not yet popular but they have considerable potential, particularly if constructed on a large scale;
3. In India the cost of this type is about US$20 to 30/$m^3$ of digester volume. Thus the construction costs of a digester which produces $2m^3$ of biogas/day will be US$100...150 in India (1980 price level). (ESCAP, 1980).

4. The exterior of the sides of the steel gas holder rusts badly. This, together with the flexible pipe connecting the gas holder to the main gas pipe, are major maintenance items.

Taking this into account, and particularly the unavailability of the experience needed in plastering and constructing the Chinese digester, it was decided to construct the Indian digester.

According to the survey undertaken, the average family size was found to be between 6 and 7 persons. Cooking 3 meals for 6 persons would need about $1.5m^3$/day of biogas. Assuming that the family will need to use a mantle lamp equivalent to 40 watts for 5 to 6 hours every day, this would need about $0.5m^3$/day. The estimated total requirements of the family will thus be about $2m^3$/day. The capacity of the Indian digester producing this amount daily is about $5m^3$. This was the size of the digester chosen. The daily amount of dung needed is about 60 kg of cattle dung or 40 kg of pig manure. The water to dung ratio is about 1 : 1 by weight, i.e. 60 litres in the case of cattle dung or 40 litres of water in the case of pig manure will be needed daily. The daily amount of 60 kg of cattle dung could be produced by 4 cows or 3 buffaloes and the daily amount of 40 kg of pig manure could be produced by about 15 pigs. These figures were within the range given in the survey.

C. CONSTRUCTION AND OPERATION OF BIOGAS PLANTS

The three digesters constructed in Sulawesi were provided with steel gas holders and brick digesters. Those in Aceh were built of ferro-cement. The time taken in the different constructional activities is given in Table 5.1.

Table 5.1: Constructional activities of biogas plant

Type of work	Time needed in days for digester with steel gas holder	Time needed in days for digester with ferro-cement gas holder
1. Preparatory work	2	2
2. Construction of frame (gas holder & digester)	7	7
3. Digging	4	5
4. Plastering	7	11
5. Filling in with dung and water	3	5

The constructional period of the ferro-cement is relatively long. However, this could be decreased by training more workers so that both the gas holder and the digester could be simultaneously constructed. Also, the digester body could be constructed from lime concrete, concrete, pre-cast concrete or bricks, which are easier to handle and do not require any special experience as in the case of ferro-cement. The gas holder, however, could still be constructed from ferro-cement, particularly when a few are to be made at the same time using the same mould.

The digester floor is, however, usually made of concrete or masonary. The latter is simpler and cheaper to use. Concrete should be used when it is cheaper locally or when the condition of the ground is very bad.

Figure 5.1 shows a sectional elevation of the steel gas holder digester constructed in Sulawesi, whereas Fig.5.2 shows the same biogas plant in operation. The ferro-cement digester/gas holder are shown in Fig.5.3 in detail. Figures 5.4...5.12 are pictures showing the constructional and operational steps of the ferro-cement biogas plant.

1. Total cost (including interest)

For 5 per cent interest and ten years' repayment period the annuity factor is 7.72*.

Thus the annual payment = $\frac{1725}{7.72}$ = US$222.

The total cost of the loan, including interest

= 222 x 10 = US$2220

2. Annual cost

Assuming that the life of the gas plant is 20 years the average cost per year of the loan spread over 20 years = US$111.

The repairs and maintenance cost of the ferro-cement plant are minimal. Operating costs are also considered part of the daily routine work of the family. Accordingly, the time required to operate the biogas plant is not usually considered.

3. Benefits from energy production

The amount of biogas produced/day is roughly equivalent to 2 litres of kerosene at 250 Rp. This is equivalent to about US$95/year.

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* This could be calculated from the formula:

$$a = \text{annuity factor} = \frac{1-(1+i)^{-n}}{i}$$

where i = rate of interest in per cent and n = payment period in years.

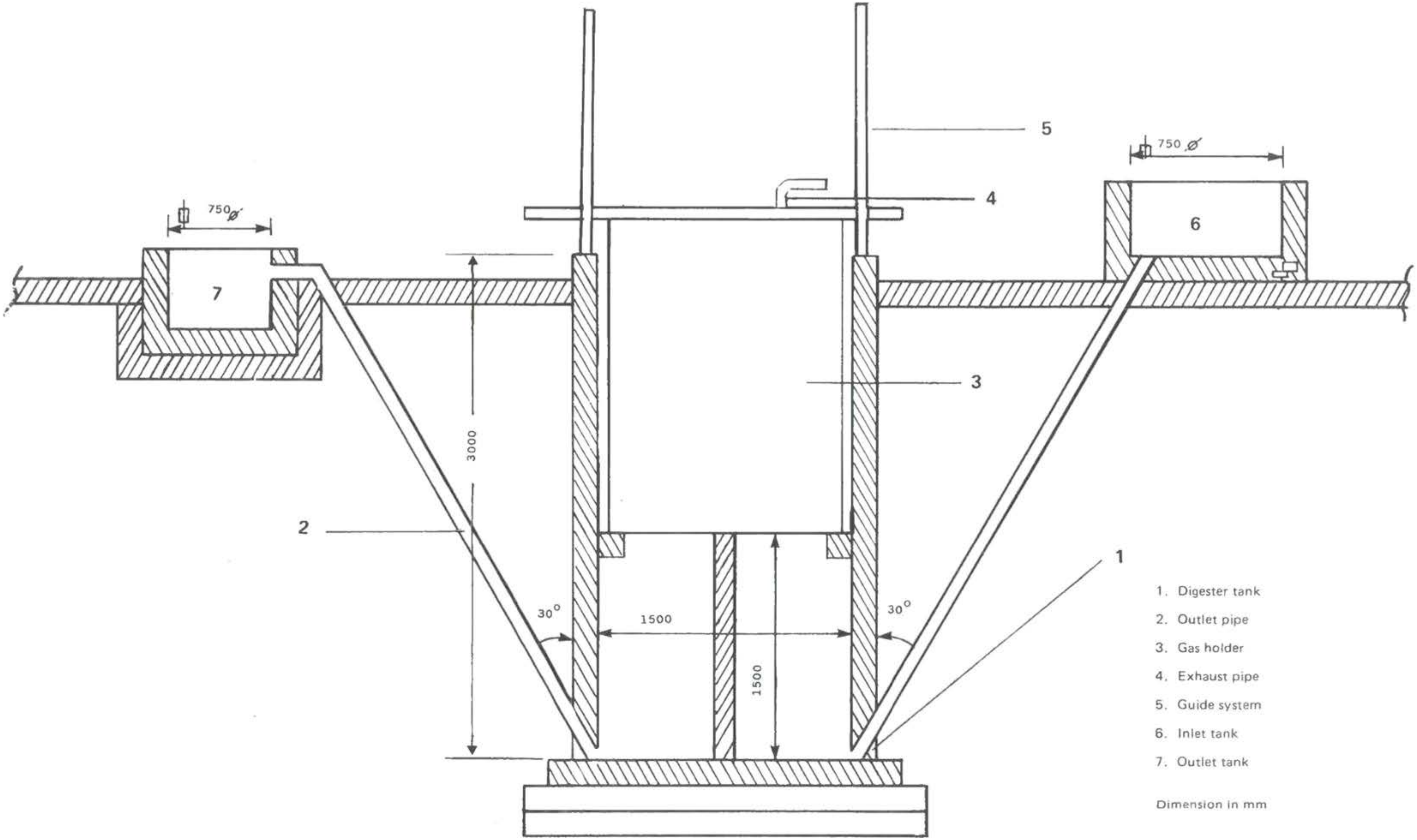

Fig. 5.1 Digester with steel gas holder (Sulawesi)

Fig.5.2

Photograph of steel gas holder digester in operation (Sulawesi)

Fig.5.2 Steel Gas Holder Digester in Operation (Sulawesi)

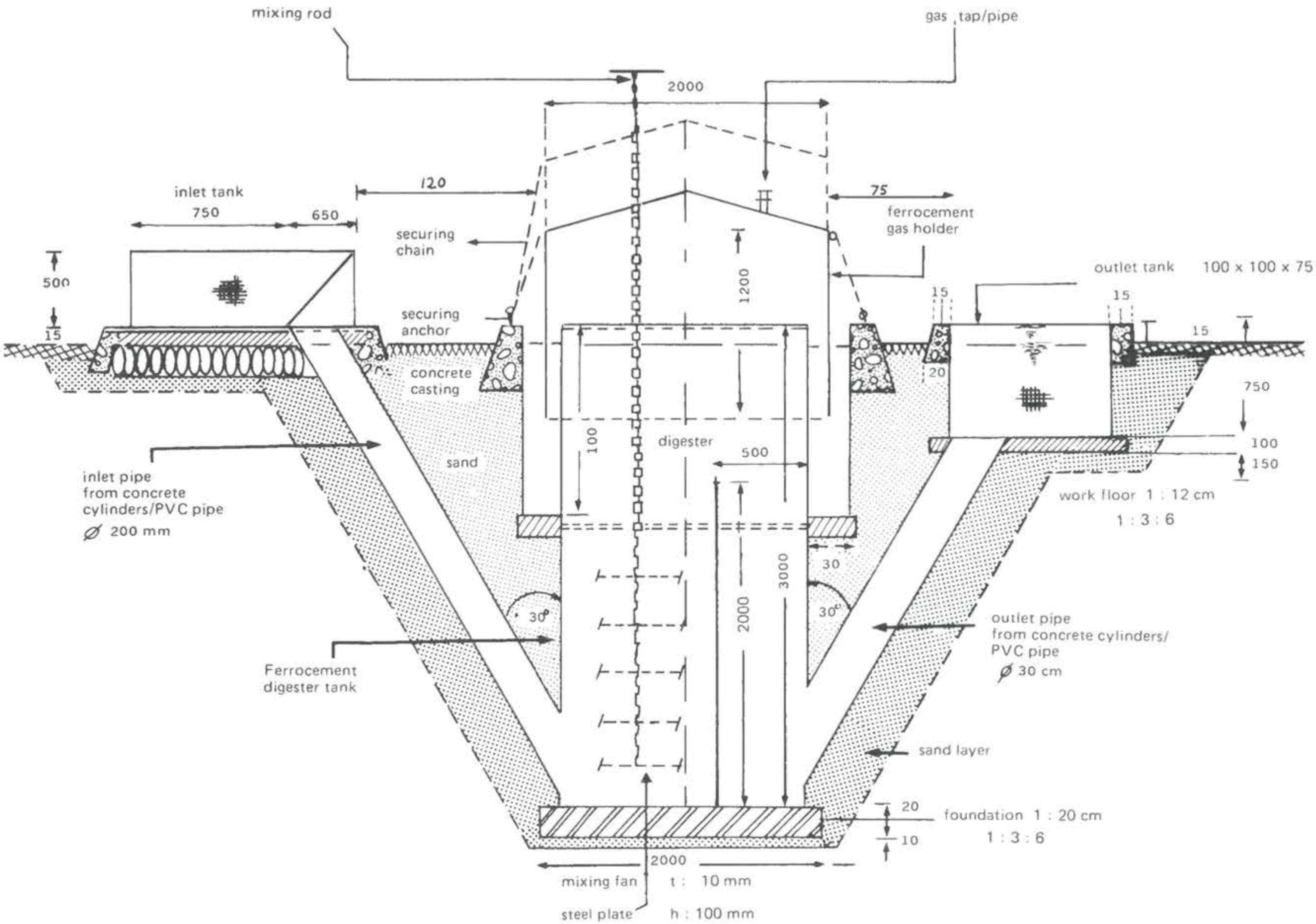

Fig. 5.3 Ferro-cement digester (Aceh)

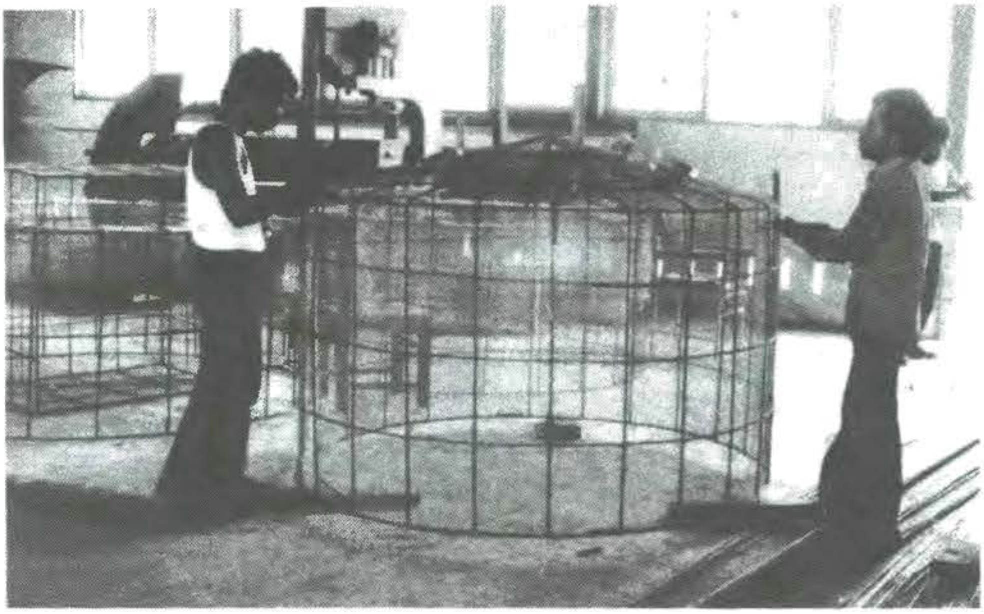

Fig.5.4 Construction of frame and fitting of wire mesh of ferro cement gas holder (Aceh)

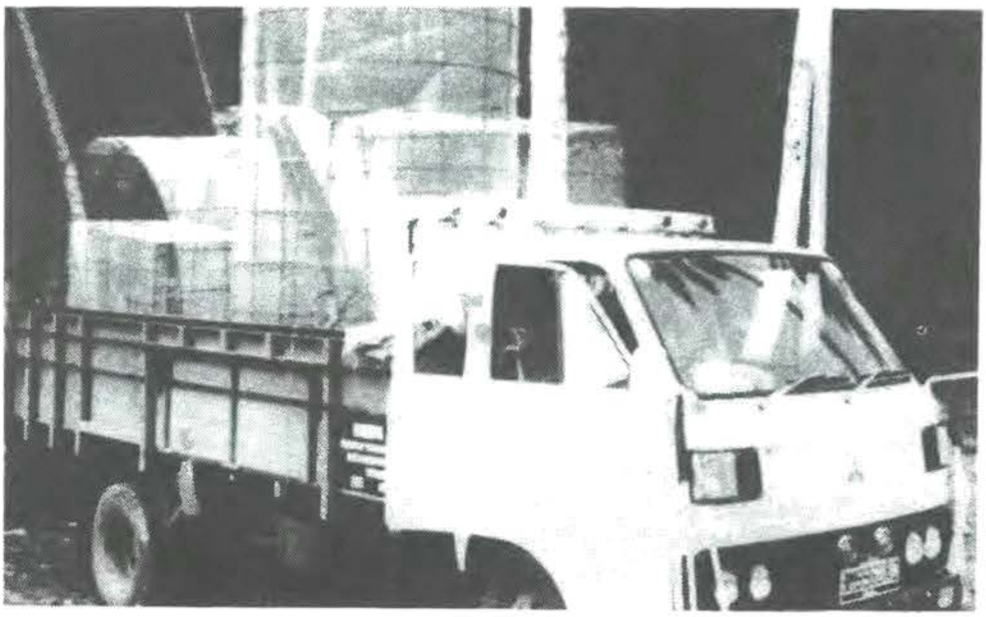

Fig.5.5 Transportation of frames to project sites (Aceh)

Fig.5.6 Plastering of digester frame

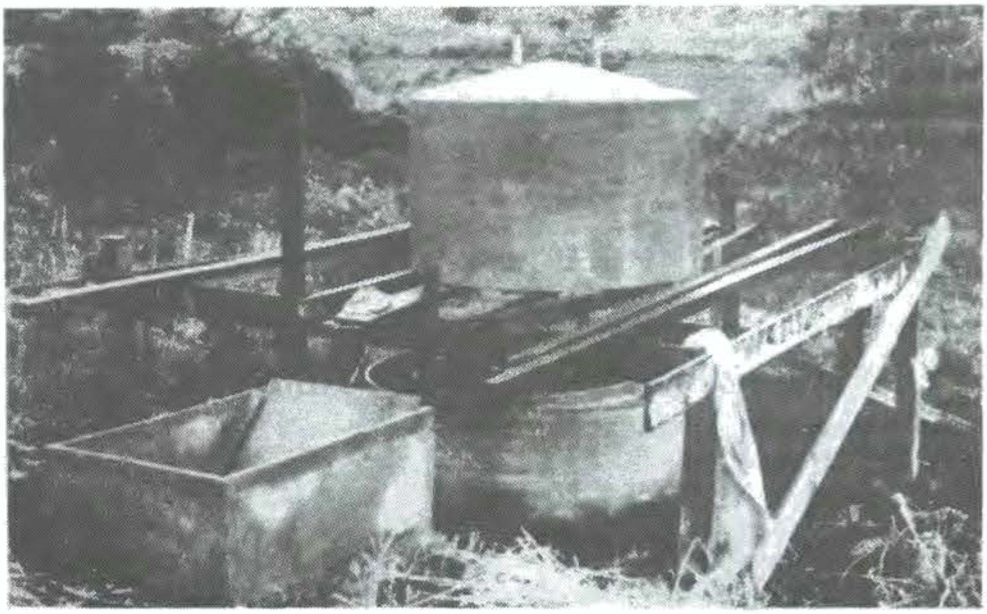

Fig.5.7 After plastering, gas holder ready to be lowered

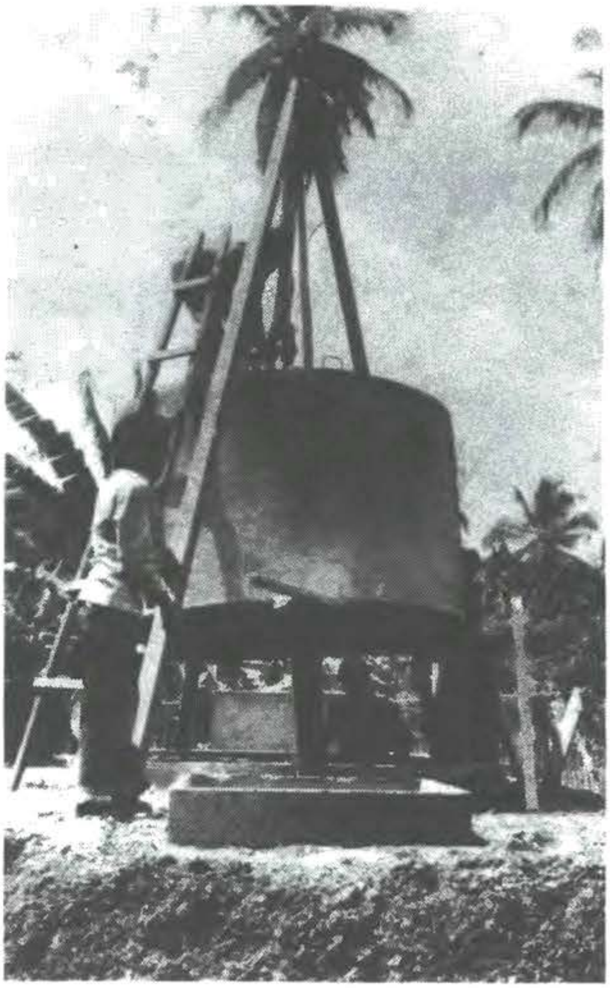

Fig.5.8 Preparing to lower the gas tank lid

Fig.5.9 Gas holder in place

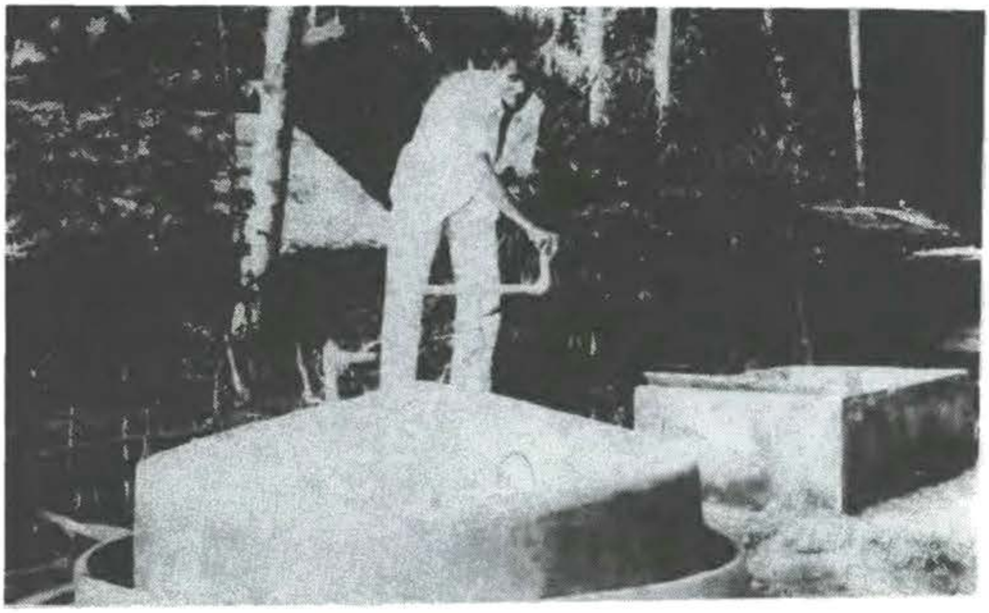

Fig.5.10 Attaching stirring handle

Fig.5.11 Loading and stirring first load of dung

Fig.5.12 Biogas plant in operation

4. Benefits from improvement in value of fertilizer

The annual amount of dung needed is about 30t. The fresh dung has initially 0.12 per cent Nitrogen. Thus the total amount of Nitrogen in 30t = 36kg. Using the current method of making farmyard manure, about 50 per cent of this Nigrogen is lost. In the biogas process about 90 per cent of the Nitrogen remains in the slurry.

If urea costs US$0.5/kg and is 46 per cent Nitrogen, then lkg of Nitrogen costs about US$1.1.

Thus the benefit of improved Nitrogen value of manure =

$$36 \times 1.1 \times .4 = \$16$$

5. Costs and benefits

The annual cost, according to the above assumption was US$111. This, in the above particular example, is equal to the benefits of producing energy from biogas US$95, plus the improvement in the fertilizer value US$16 = US$111. Two points should be emphasized in this respect:

First, the kerosene prices used above are the local ones which are usually heavily subsidized in most of the developing countries including Indonesia. This distorts the facts and the actual savings both on the individual and country-scale and necessitates the provision of at least similar subsidies to biogas technology.

Second, other benefits are not included in the above comparison and it is usually difficult to evaluate most of them exactly. These benefits are going to be discussed in what follows.

D. ENVIRONMENTAL ASPECTS

1. Health and hygenic aspects of biogas

In comparison to firewood and dung cakes, biogas is a much cleaner source. The products of biogas combustion are carbon dioxide and water vapour (CO_2 and H_2O), which are not considered pollutants. The hydrogen sulphide produced is usually less than 1 per cent and because of its unpleasant smell it warns people if there is a leak. It also forms an acid when mixed with water, and this is mildly corrosive. Generally, as a gas released in this small quantity, it has minor environmental health impacts. Accordingly, as biogas replaces firewood and cow-dung or decreases their use, this has indirect positive health aspects. Firewood, dung cakes and agricultural wastes, when directly burned, produce considerable amounts of particulates (3.2...1.3% by weight), Organics (2.4...1.0% by weight) and sulphur dioxide (2.0...1% by weight) and other pollutants such as nitrogen oxides, carbon monoxide and hydrogen sulphide. The commonly reported (Vohra, 1981) health effects of exposure to smoke containing these pollutants and gases during domestic cooking are asthma, chronic bronchitis, emphysema, chronic cor pulmonale and cataract of the eyes. Cor pulmonale is caused by chronic obstructive pulmonary disorders and accounts for rising morbidity trends in a number of countries in the South-East Asia region. Estimates based on surveys conducted in Northern India and Nepal show that nearly 1...1.3 per cent of the rural population surveyed suffered from cor pulmonale (WHO, 1979). The incidence of chronic bronchitis and emphysema was much higher.

On the other hand, the use of biogas would improve the hygenic surroundings thus eliminating or decreasing the number of mosquitos, flies and insects that breed on wet manure heaps. The parasites and pathogens in the dung are almost eliminated in the course of the fermentation process. Accordingly, the spread of parasitic diseases will decrease considerably.

2. Conservation of forests

Expanded utilization of biogas and other renewable energy sources will gradually decrease the use of fuelwood which will accordingly decrease the aggravated problem of deforestation and its consequences, such as soil erosion, flash floods, desertification, etc. Deforestation of tropical forests has been estimated to occur at a rate of about 11 million ha/year (UNEP, 1982). Most of this deforestation occurs, and will continue to occur, in the developing countries.

3. Social aspects

a) The health effects and the effect on health bills of the farmers.

This has been discussed in some detail under the environmental aspects. The social impacts of the improvement in the farmers' health should not be overlooked. Simply, it will increase their production, decrease their expenditure on health bills and improve their standard of living.

b) The advantage of having cleaner villages.

This matter should also be explained to villagers in order that they will see biogas as a viable possibility, get involved and become interested in its promotion. In the particular case of the biogas plants in Aceh, the cleanliness value resulting from the use of biogas instead of fuelwood was estimated to be Rp18,000 (US$19)/year.

c) Creating employment and improving facilities in the village.

New employment is created in biogas construction and related industries. In addition the provision of lighting and/or electricity will improve the facilities in the village and encourage bright young people to stay in the community.

CHAPTER VI

CONCLUSIONS

The present project includes undertaking surveys on energy requirements in two districts in Indonesia: Minahasa (Sulawesi) and Aceh). The survey gives additional information on topography and soil conditions, climate, population, economy and social activities. The survey undertaken in Sulawesi has shown that over 80 per cent of the domestic energy consumption comes from fuelwood for the low and middle-income groups. For the high-income group over 70 per cent of the domestic energy consumption comes from fuelwood. More than 86 per cent of this energy is used for cooking and the rest for lighting.

The survey in Aceh showed that about 80 per cent of energy consumption is covered by fuelwood and that the villagers collect about 27kg of firewood an hour. Most of Aceh's farmers own about 3 or 4 cattle for ploughing. This was enough to run a $5m^3$ digester. However, some difficulties exist in the collection of dung because most of the animals graze the whole day.

A few types of firewood stoves were tested. The design of an efficient, environmentally-sound, socially-acceptable and cheap wood stove is not an easy task. Traditional stoves have efficiencies of around 15 per cent but are hazardous from the health and environmental point of view, particularly if used indoors. The provision of a smoke pipe for these stoves will improve their environmental characteristics but will decrease their efficiency. Similarly, if cement is used as construction material instead of traditional clay, this could increase heat dissipation through the walls, hence decreasing the stove's efficiency.

A new type which exposes more of the surface area of the kettle to the fire and decreases air draught through the chimney was found to combine efficiency with a decrease in the environmental impacts of fuelwood stoves. Efforts to popularize these stoves are needed in order to decrease costs.

Three biogas plants with steel gas holders were built in Sulawesi and three made of ferro-cement were built in Aceh. The ferro-cement digesters were found to be slightly more expensive than the steel gas holder ones mainly because of the construction costs which required skilled labourers and technicians. In undertaking a cost/benefit analysis the biogas plant was economically justified, assuming an interest rate of 5 per cent and a loan repayment period of ten years. The benefits taken into consideration were the costs of kerosene saved and the improvement in the fertilizing value of the slurry. The other environmental, health and social benefits were listed, discussed and in some cases evaluated but they were not included in the cost/benefit analysis. Local (subsidized) kerosene prices were used. This restricted the cost/benefit analysis to the consumer level and precluded the benefits at the country-level (savings on foreign currency by cutting down on local consumption of kerosene).

Finally, it should be mentioned that in order to cut down on fuelwood utilization and alleviate the consequences of deforestation, the introduction and promotion of efficient, environmentally-sound and socially-acceptable fuelwood stoves is an important step in the right direction. Recommended types have to be tested in different regions. The selected type should be the subject of intensive, promotional programmes by different institutions.

The promotion of biogas technology and arrangements for educational programmes and information dissemination on the benefits and the ways of constructing biogas plants is another complementary step towards the promotion of efficient utilization of new and renewable sources of energy by substituting fuelwood with biogas.

In addition to these two steps, fuelwood plantation programmes should continue side by side with the above efforts for decreasing fuelwood consumption through efficient utilization and substitution. Although this activity was not included in the present project, several fuelwood plantation projects are currently being carried out in Indonesia. These include demonstration projects in several parts of Java, e.g. Albizzia falcatoria and Leucasua leucocephalax for planting in home gardens, marginal lands and on dry farming land, Gliricidiamaculta and Caliandra callothyrus for planting in fences around farmyards and Sesbania granddifolia for planting on the dykes of irrigated fields.

Another effective approach to increase fuelwood production is through forest management. The productivity of a well-managed forest could be ten times more than that of a badly managed forest.

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