PD-AAJ-008
ISN=165

38604 00/101

ALTERNATIVE ENERGY RESOURCE DEVELOPMENT PROJECT

Consultant Report

on

Research Program for Biomass Conversion

Submitted to

USAID

by

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02 October 1981

FINAL DRAFT

I. Summary

This report investigates the energy use levels in the non-commercial sector. The non-commercial energy supply is from the conversion of firewood, crop residue, and animal dung into energy. The projected needs are studied and present demands are considered. Processes are reviewed for converting these fuels; firewood, crops residue and animal dung to other energy forms including heat or other useable forms of chemical energy. These three products, make up the principle or more readily used forms of biomass resource in India and there description describes the biomass sector. The energy policies of India are reviewed especially as they relate to renewable biomass sources. From these policies a strategy is developed for providing increased biomass fuel stocks through reforestation, irrigation and planned harvesting techniques.

The forestry program is given top priority and a research development program for producer gas pump sets is suggested. The biomass fuel for the pumpsets can be either crop residue or fuelwood. Systems for the use of the crop residue or the fuelwood will be suggested where either the products will be charred first and then gasified or gasfied directly. The results will provide an evaluation of the two options. The pumpset will supply irrigation for the crops or wood plantations and in both cases biomass is used to increase the biomass product. Crop residue amounts presently appear as the only biomass material with a small surplus and the use of this surplus to increase the supply is attractive.

Another area for consideration is planning a harvesting system for a maturing fuelwood plantation. The study will provide a tool for maximizing the efficiency of utilization in driving the planned 1.5 MW power station.

The last research topic is providing limited support in the area of alcohol fuels with suggested funding of the pretreatment work at IIT Delhi. The steam explosion process is being considered, examining the adaptibility to India's biomass feeds. The pilot scale system will be modified as required to improve its performance.

The suggested projects in this paper should make optimal use of USAID's limited financial resources while having a high potential for truly increasing the fuel supply of India. It is also recommended that IIT Delhi become a Biomass Centre for conversion processes along with the Botanical Research Institute Lucknow, and Madurai Kamraj University, Madurai as Biomass Centres for production. The details follow in the report.

II. Introduction

Energy use and availability is of prime importance in providing the desired and planned development of the Indian people. There is a direct correlation between the standard of living and the per capita energy consumption with every modern economic activity requiring some form of energy. The energy demands in India are provided by the conversion of all common energy resources with a special feature of unusually low per capita consumption(1). The Nairobi paper defined the per capita consumption at 315 kg of coal equivalent per year. The population of India was taken at 680 million people. The energy use was divided into two principal categories:

- Commercial energy
- Non-commercial energy

III. Energy Division: Commercial

The commercial category covers principally energy provided by three resources coal, oil and electricity. Figure 1(2) provides a pictorial review of the growth in this category, directly relating the movement of India into modern industrialization.

Non Commercial (Biomass Sector)

The non-commercial energy use is defined from the conversion of:

- firewood
- agricultural waste
- animal dung
- into other energy forms in the household sector.

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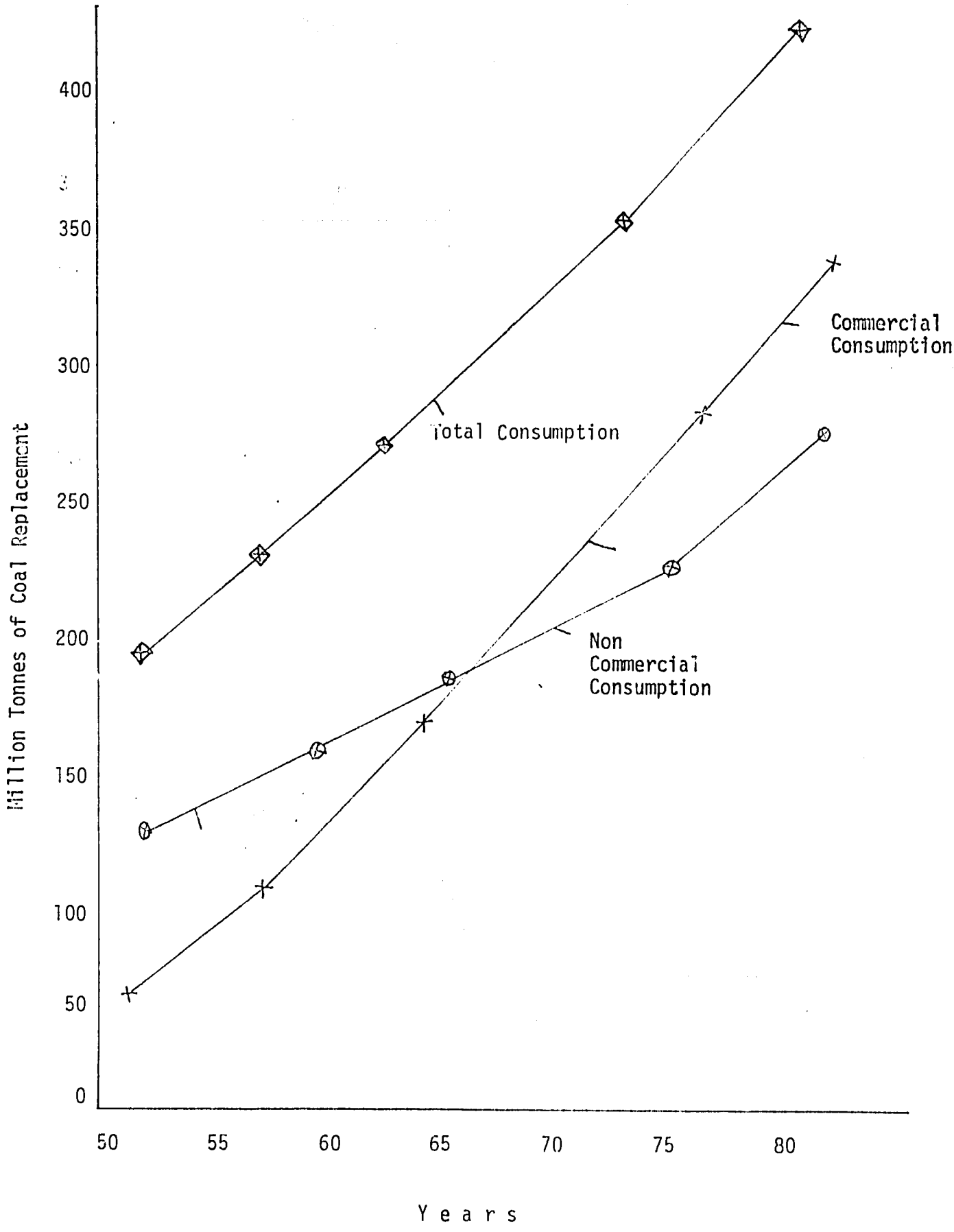
(1) "National Paper," United Nations Conference on Renewable Sources of Energy; Nairobi, August 1981

(2) "Report of the Working Group on Energy Policy," Government of India Planning Commission, New Delhi 1979.

Figure 1


Million Tonnes of Coal Replacement
400
350
300
250
200
150
100
50
0
50
55
60
65
70
75
80
Years
Total Consumption
Commercial Consumption
Non Commercial Consumption

The growth in the non-commercial category is shown in figure 1 with the increase directly predicted by the population increase. The third curve of figure 1 shows India's total energy use. The curve was found by simply adding the commercial and non-commercial values.

The total energy use is divided into five sectors with an approximate total distribution of:

50% household
11% agriculture
21% industry
18.5% transportation
0.5% other

The 50% total use in the shousehold sector is principally supplied by non commercial energy (biomass) with a 65% firewood, 15% agricultural waste and 20% animal dung assumed division. The non commercial energy percentage reported by the Cooking Group for Energy Policy for the household sector (2) is higher in the rural area (81%) as compared to the urban area (51%). There is also considerable biomass energy supplied in the commercial category with approximately one million tonnes of firewood used in organized industry, 20 million tonnes in unorganized industries and 30 million tonnes of bagasse used in the sugar industry. These quantities are not considered in the discussion of the non-commercial category but will have an effect on the total biomass demand.

Biomass supplies the longest use segment of the total energy demand and each of the three distinct fuels will be discussed separately regarding there contribution to the non commercial needs .

Firewood

Firewood is the most important non-commercial fuel in India. It is obtained from forest, privately owned plantations wood lots, roadsides, banks of rivers and canal, parks and other miscellaneous sources. The forest cover is 23% of the total land mass (approximately 0.75 million sq.km) of India. This forest resource is presently experiencing severe pressure to harvest the wood; for fuel, fiber and as a construction material with the economic factors favoring materials and fiber.

In 1975-76 the annual firewood consumption was estimated to be 203 million cubic meters (3) with an estimated 13 million cubic meters from India's forest. A quick glance at these numbers and a reminder of the principles of the conservation of mass reveals a huge 90+% deficit in firewood production with the remaining coming from farm forest and tree-lands outside the forest. These alternate sources have been severly depleted leaving pilferage to provide the total suggested.

The results of these demands are severe deforestation and forest damage. Further considering the continued population growth and the demand increasing directly as predicted by this growth, several agencies and scientist have projected the needs.Parikh(see appendix)suggest a need of 350 million cubic meters by 2000 while the National Commission of Agriculture(3)

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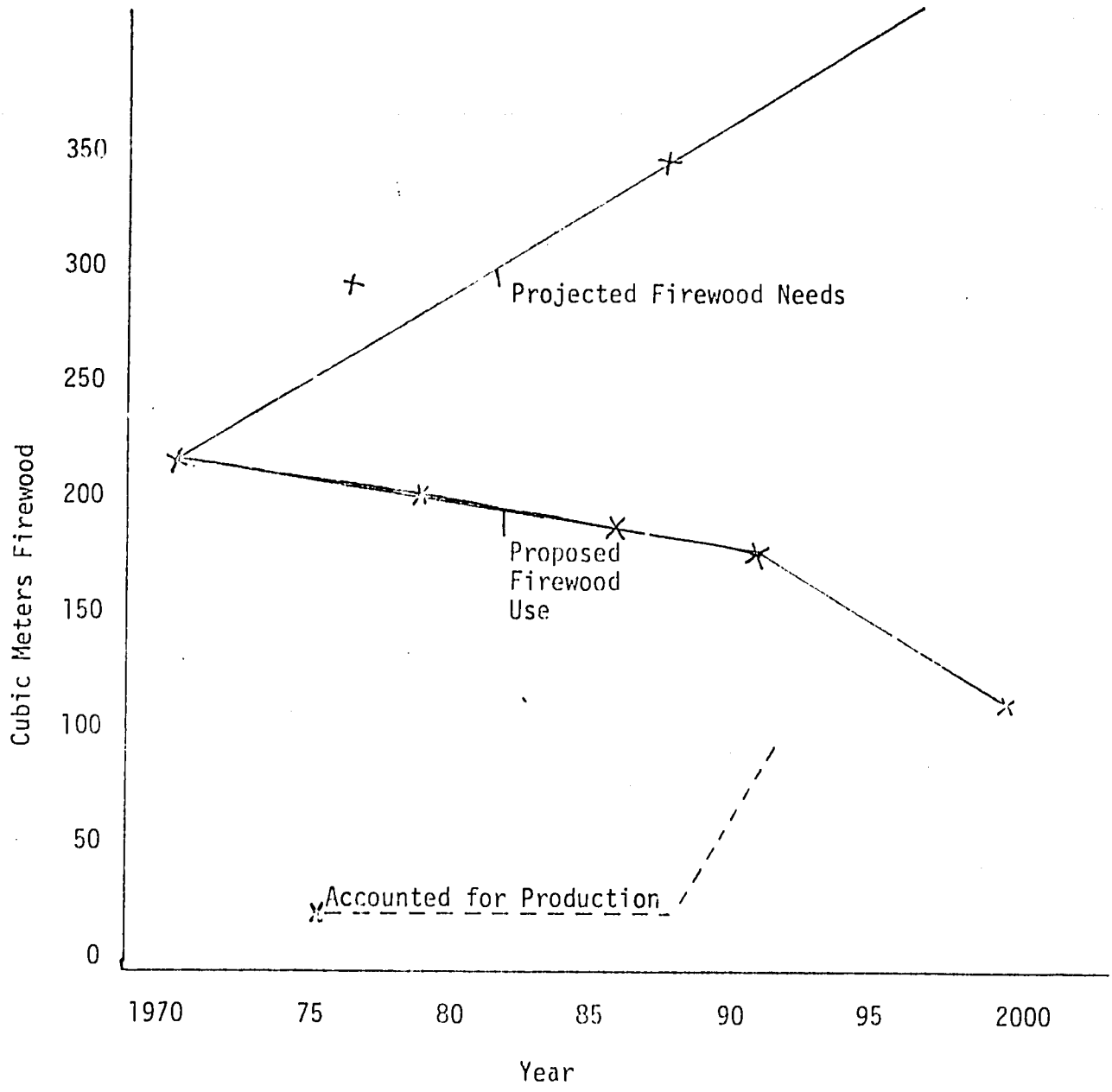
(3) "Production and Availability of Biomass: State of the Art Report" Department of Science and Technology G.O.I. New Delhi, 1980

(4) S.P. Dubey and R. Chakravarti "Forestry for Rural Energy Production in India", ESAP/FAO/UNEP Expert Group, Fuel and Charcoal, Bangkok, May 1981.

(5) Parikh K. "Energy" Mac Millian 1976.

Figure 2

Projected Firewood Needs



predicts 256 million needed by 1980 and 300 million by 1990. This hypothesis points to a deficit of 100 million cubic meters by 1990. These projections are shown in figure 2 along with the 13 million m^3 accounted for production in 1975. The energy policy group though suggest a different demand curve as shown in the proposed firewood use curve of figure 2. This curve actually shows a decrease in demand and use. The reduction is assumed to be provided by increased efficiency of conversion in cooking,use of electricity, and biogas, especially after 1987. The efficiency increases will be provided by improved stoves, rural electrification, and increased biogas utilization. These projections seem very optimistic and disagree with many others. Even so the government believes that the demands for fuel wood can be met if an adequate investment is made (2) in social forest programs and present stand improvements. However, Dubey (4) suggests that 25 million + ha of waste land be turned into forest or plantations immediately to provide the future demands. He further suggest that the real energy crisis in India is not the shortage of oil but the shortage of firewood. The rapidly decreasing availability of previously free firewood will have series social and economic effect on the welfare of the poor. In conclusion India has a serious wood fuel crisis and the problems are:

1) India population is increasing
2) India per capita energy use is increasing
3) Resources are decreasing
4) Wood is the principal and most demanded source of energy
5) Household energy conversion systems are inefficient
6) Reforestation to preceding slowly

The strategies for solving or reducing the problem have to consider the entire energy, economic and social system and any attempted shifts in energy use patterns will be difficult to program and realize.

Agricultural Waste

The agricultural waste level in producing the non commercial energy quantities was assumed to be 15% of the total value. The actual quantities available depends on the crop levels and the end uses of the actual residue. Table 1(2) shows the production amounts

Desrciption	Area(thousand Acres)	Production (thousand/ tonnes)	Agricultural Waste (thousand/tonnes)
Rice	39475	48470	77984
Wheat	20454	28846	50480
Maize	6031	7256	8707
Cotton	7350	1012	3036
Jute	584	755	1510
Barley	2802	3192	4788
Other minor groups	67422	36157	28926
Sugar cane	2762	140604	28121
Total			203552

Table 1 Residue Production India 1975

The total residue was approximately 200 million tonnes with forty tonnes of the residue used in the commercial sector. The remaining residue is burnt on fields, used for fodder,as roofing material, for composting, and other needs. It appears that this residue at least in some limited quantities could be available as a fuel. A paper by Gupta etal(6) provided an energy balance on a Punjab village. The major crops were wheat, maize, paddy, cotton, groundnut and fodder. The waste generated were animal excrita, crops residues and left over fodder. The quantities of surplus paddy straw and wheat straw were 14.7×10^3 and 14.4×10^3 quintals respectively. The total energy of the surplus residue and dung would provide 11×10^9 Kcals of energy. The input energy to the village was only 7.8×10^9 Kcals. Figure 3 taken from the paper shows these comparsions. The main conclusions for this report is the avaialbility of approximately 1000+ tonnes of coal equivalent crop residue/village at least in this area.

Figures 4 and 5 (2) show the residue use as projections as provided by the Energy Policy working group. This area is encouraging and with the contemplated increases in agricultural efficiency even greater surplus quantities will exist.

Animal Dung

The use of animal dung as non-commercial energy source is highly developed in India. Just to provide a few numbers the cattle population in India (1972) was 237 million. Average dung obtained per animal per day is 10 kg (7) with an average collection rate of 66%. The Energy Policy Group(2) suggested that 20% of the non commercial energy is supplied by dung. The dung can be dried and burnt or used in Biogas Plants(7). Again the suggested use rates (2) and past performance are shown in figure 6. The decrease in use after 80 is questionable, especially in regards to the projected exp nsion of the Biogas systems. In this regard the next section of the report will discuss the general conversion processes for biomass (non-commercial energy sources).

IV. Biomass Conversion (Biomass-material originating from growing matter)

The principal biomass conversion processes are:

- Combustion
- Gasification
- Digestion
- Liquid fuels processes

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(6) M.C. Gupta, B.S. Pathak, S.L. Jindal and A.P. Bhatnagar, "Energy Balance and Utilization of Agricultural Waste and Farm" Journal Agricultural Engg. Vol XVIII No.I

(7) "Biogas Technology and Utilization: Status Report", Department of Science and Technology, GOI, New Delhi 1981.

Figure 3

Energy Requirements and Energy Potential of Agricultural Wastes Available (Punjab Village)

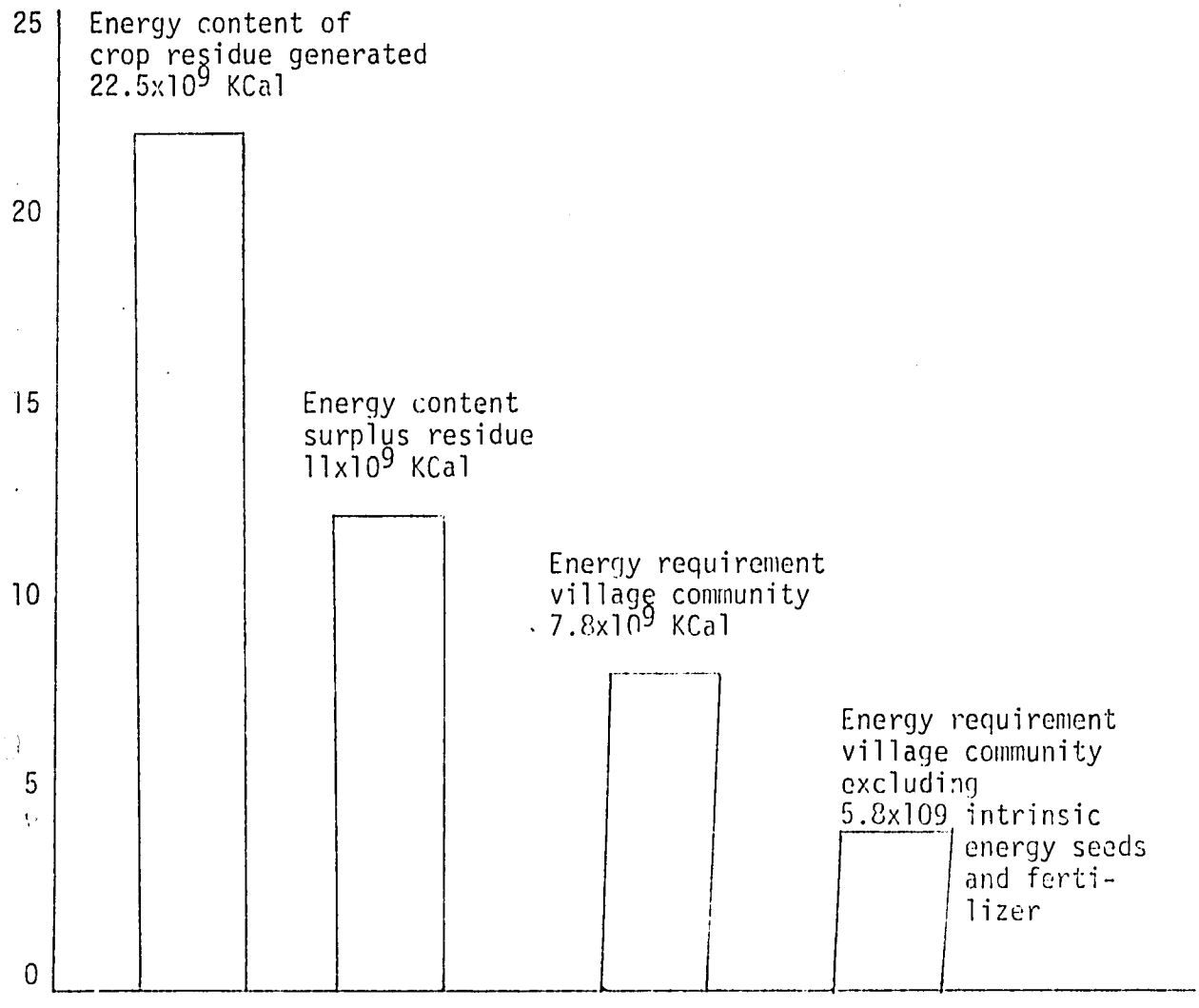
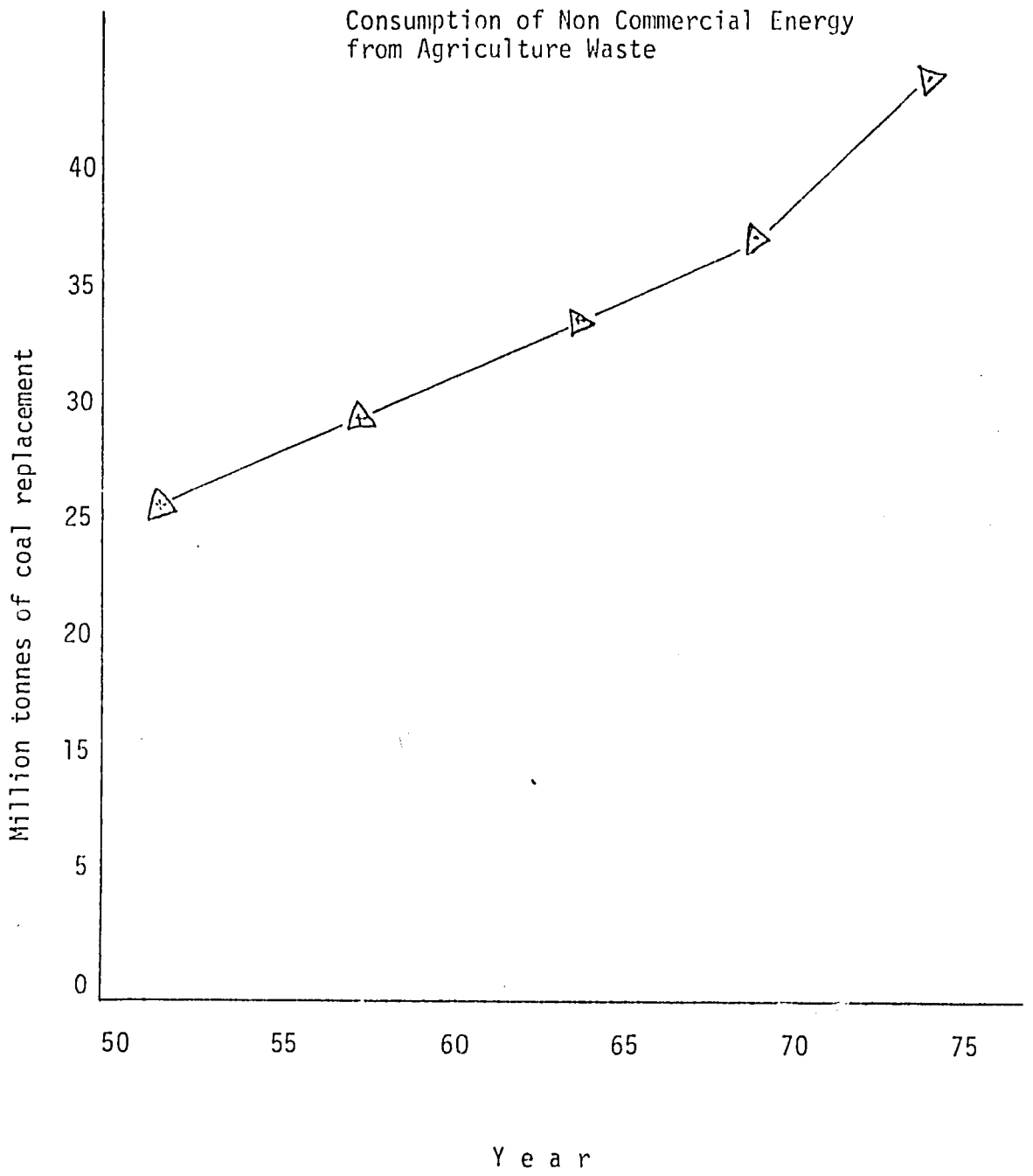


Figure 4


Consumption of Non Commercial Energy
from Agriculture Waste
Million tonnes of coal replacement
0
5
15
20
25
30
35
40
50
55
60
65
70
75
Year

13

Figure 5

Projected Demand Non Commercial
Supplied by Agricultural Waste

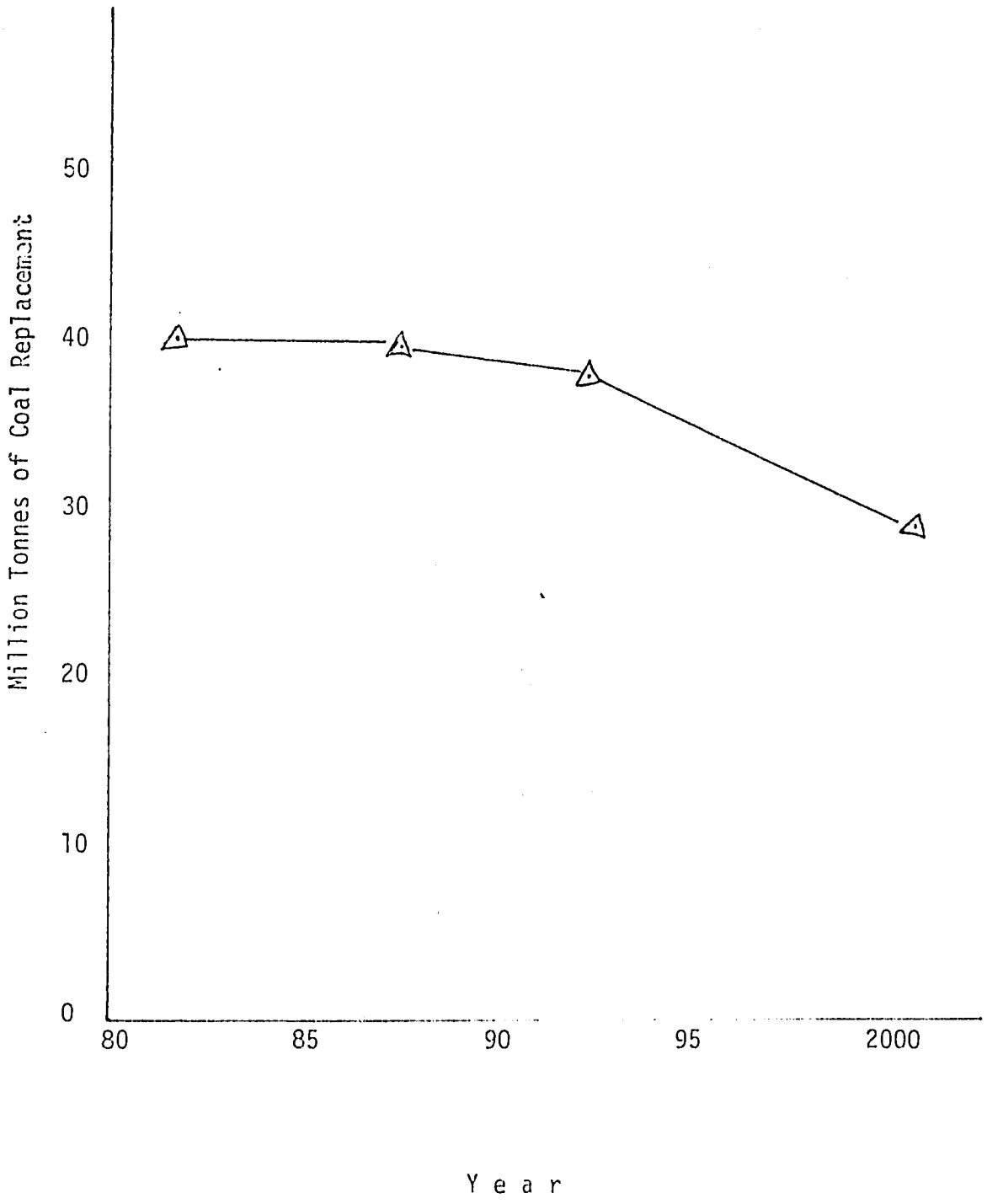
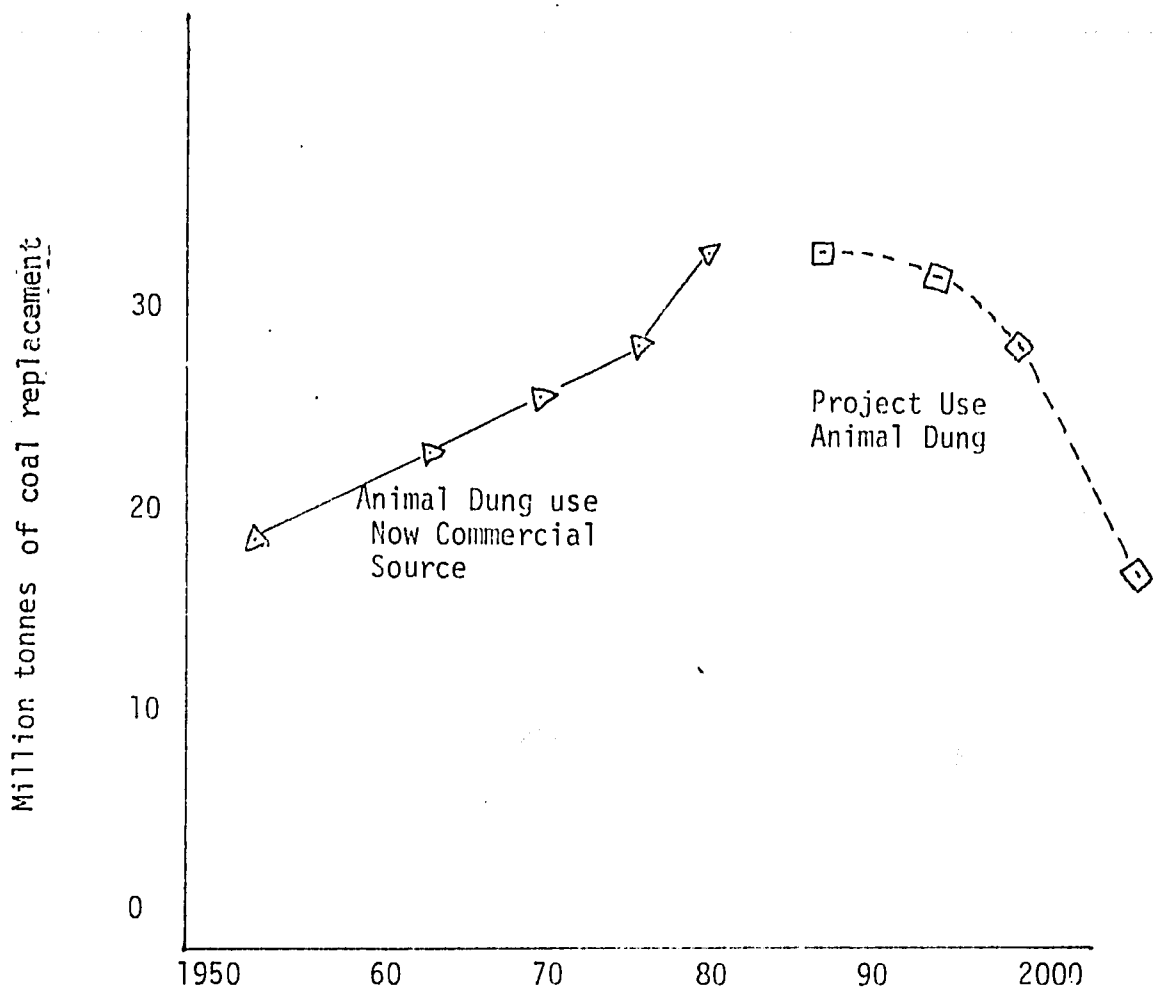


Figure 6

Past and Projected Use
Animal Dung as an Energy Source



Combustion

Combustion is the oxidation of the two primary combustable elements in biomass fuel. The equations are:

$$C + O_2 = CO_2 + \text{heat}$$

$$2H_2 + O_2 = 2H_2O + \text{heat}$$

Energy production using the combustion process is a controlled burning attempting to maximize the heat release from the carbon and hydrogen elements of the fuel.

The oxygen for combustion is normally supplied using air. This burning process occurs in three stages:

1) drying
2) distillation
3) carbon conversion

The drying process simply removes the water from the biomass particle with the energy for drying furnished by burning other fuel. The process occurs at a relative constant temperature approximately 212° while permitting the water to evaporate. The distillation stage occurs as the biomass particles temperature begins rising above 212. The increased temperature breaks the wood molecule releasing the combustible gases (volatiles) that burn in contact with the combustion air. The volatile fraction of the biomass can be very high and can supply an appreciable amount of the released energy. Once the volatiles have been released or driven off the remaining fuel is char or charcoal. The charcoal is mostly carbon mixed with the non combustible ash of the fuel. The carbon is consumed as oxygen comes in contact with the exposed charcoal particles completing the combustion process and leaving the ash fraction as the remaining residue.

The combustion process involved in the use of the village cooking stoves could be greatly improved. A simple efficiency (8) change from 10 to 20% would make a large difference in the firewood needs. All the biomass forms of interest (firewood, crop residue and dung) are used for heat production through the combustion process in the non-commercial and commercial areas. India has or is using wood and Bagasse in large industrial processes. They are familiar with steam raising in boilers and electrical production from the steam generated. They have also worked to improve their cooking systems used in the villages.

Gasification

Gasification is an old technique which had received special attention in Europe during World War II. Since that time the availability of oil and gas has reduced the interest but since 1974 and the oil embargo interest has greatly increased. Biomass gasification process can be summarized by the following steps:

a) Some of the latent chemical energy in biomass is released by combustion to produce sensible heat.

b) Most of the sensible heat is reconverted to latent energy by evaporating water, by breaking down and volatizing complex wood molecules, and by reducing CO_2 and H_2O to produce CO and H_2.

c) Reaction products flow from the gasifier as a heated gas and tar with char collecting as solid particles. The division of the gas, tar, and char depends on the gasification temparature. The energy value of the gas will be 100 to 500 Btu/SCF depending upon the gasification process.

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(8) " ood consuming cook stoves: a Design Guide" ; Vita/ITDG Publication, Mt Rainier Maryland.

The four basis process for producing gas are:

- Air gasification
- Oxygen gasification
- Steam gasification
- Pyrolysis

Air gasification simply follows the previously listed steps normally producing 100 to 150 Btu/SCF gas.

Oxygen Gasification uses pure oxygen instead of air for the combustion in the first step of the gasification process. The gas produced is medium Btu in the 250-350 Btu/SCF range. This gas is normally good for use as a methanol feed stock or as a fuel gas. The principal Btu increase is derived from eliminating the nitrogen dilution in the air gasification. Temperature contorl will be a problem, and steam is often used for controlling the high temperature.

Steam gasification omits the first step of the gasification process and the heat must be supplied by highly superheating the steam or by external means. The gas produced can be a high quality medium Btu gas. Steam gasification processes are in the research stages except for the old water gas system for producing town gas.

Pyrolysis is defined as the destructive distillation of biomass with most pyrolysis processes being a special case of gasification. The systems are usually units operated as air blown gasifiers except the char production is optimized and the gas normally just exhausted to the atmosphere. Although some of the newer designs actually pyrolysis the product, omitting no air, providing an excellent char and gas. The char production levels can be as high as 30% of the dry fuel (9) and the gas contain up to 400 Btu/SCF. The processes which do not use air or oxygen will require a large external heat input. These pyrolysis and gasification techniques are again available in India. Large gasification systems existed and charcoal is an available product for heating and cooking.

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(9) J. Knight "Pyr is of Pine Sawdust," from Thermal uses and Proprieties of carbohydrat Lignins, Academic Press 1976.

There are site specific locations where both medium sized pyrolysers and gasifiers should be considered. This subject will be further discussed in later sections with specific emphasis to the village scene and its specific biomass resources.

Digester

India is a world leader in the implementation of this technology as demonstrated by its development record. The biogas systems are anaerobic digester producing combustible gas from the feed materials. The most common feed material is animal dung but algae, crop residues, forest litter garbage, grass, human waste, paper waste sea weed, spent sugar, refinery waste, straw, and water hyacinth have been used. Gas yields varying as a function of the material have been suggested. Normal yields(10) from cow dung are 30 litres/kg with a 30 - 40 day residuce time. The gas produced is approximately 50-60% methane and 30 to 40% CO_2 and 5% H_2. The gas produced can be used to drive engines, burn in stoves, provide lighting, or used in other energy processes. The outgoing slurry still has its principal ingredients and has become enriched in nutrient contents. India has installed 80,000 plants (11) and are encouraging construction of 3,000,000 plants during the Sixth Plan. They have several different designs with continued improvements in operations and efficiency provided by increased understanding of the mechanisms. The Indian level of expertise appears to lead the world in this area. India's technical expertise(10) has been requested and supplied in Tanjania, Botswana, Srilanka, Iraq, Nepal, Iran and Samalia.

Liquid Fuels Processes

The two liquid fuels considered are methanol and ethanol. The processes for providing the liquids are fermentation for the ethanol and thermochemical processes for the methanol.

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(10) "Gobar gas: Retrospect and prospects," Khadi and Village Ind. Comm., Bombay, 1979.

(11) "Bihar to build 720 biogas plants," Economic Times, July, 1981.

Ethanol

Two basic types of technology (12) exist for producing ethanol. If a feedstock which is high in sugars is used - such as sugarcane or sweet sorghum - the sugars can be fermented using a yeast enzyme to produce carbon dioxide and ethanol and subsequently distilled to concentrate the alchohol. Producing alcohol from sugarcane is very similar to production of sugar: the cane is crushed to extract the sugar juice; remaining plant materials, known as bagasse, are often burned to supply heat for the fermentation and distillation processes; and other leftover liquid wastes, called "stillage", must be disposed of.

If starchy or cellulosic materials, such as good grains and wood, are used for ethanol production, they must first be turned into sugar, and subsequently into alcohol. The process for grains is that used in the production of whiskey and other alcohols from corn, wheat, and other grains. Since the carbohydrates end up as alcohol, leftovers from grain mashes used to produce alcohol are high in protein and have been used as a valuable feed supplement for livestock and in U.S. markets might serve to recover as much as half the original feedstock costs.

Wood or stover as a feedback is of great interest due to its availability Plants using acid hydrolysis to convert wood into alcohol have been used in the United States, the Soviet Union, and Switzerland, and are now being designed in Brazil. There is also a large body of related experience with the chemistry of the process, since the decomposition of wood by acids or

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(12) E. Cuelski and Ramsay, "Prospects for fuel alcohols from Biomass in Developing Countries," presented United Nations Conference on long term Energy Resources; Montreal, Canada, December, 1979.

Alkalis is routinely carried out as part of the operation of making wood pulp, and sugars and alcohols are a common by-product. Enzymes might also be used to extract sugar from wood; this method is still at the pilot stage.

Methanol

Methanol is produced through the thermochemical conversion of the carbon, hydrogen, and oxygen of biomass materials into new compounds that are more convenient for many energy end uses. It involves breaking the chemical bounds of the organic molecules through putting them under stress by applying heat or high pressures. Numerous techniques can be used which vary the heat, pressure, and timing of the process, and thus diverse fuel forms can be produced.

The synthesis gas derived from pyrolysis can be turned into liquid methanol, by means of a long-established, completely commercial technology which involves first "shifting" the hydrogen to carbon ratio to a higher values characteristic of methanol and then combining them by using a catalyst to"reassemble" the molecules.*

In this process the carbon dioxide produced is then partially removed by a hot carbonate system and a crude methanol product created through a methanol synthesis and catalysts. For industrial use, this 75 to 90 percent crude methanol product is then further processed, but such processing may

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* In fact, commercial methanol is made by "reforming" natural gas into synthetic gas. A possible alternate to the production of pyrolytic gas, cleaned biogas from anaerobic fermentation, could also be used as a hydrocarbon source to replace natural gas feed; this possibility has been little examined.

not be necessary for its use as fuel. India has existing methanol plants using naptha as the feedstock.

V. Indian Energy Policy

The suggested policy for energy use for the Six Year Plan (13) was:

1) Identification of the consumption pattern of energy in industry, transport, agriculture and household use.
2) Improving the efficiency of production distribution and utilization of energy from all sources.
3) Development of energy generation through efficient and new forms of utilization of coal.
4) Development of breeder reactors and utilizing thorium resources for development of atomic energy.
5) Development of alternative sources of energy, especially renewable resources (solar thermal, solar photovoltaic, wind, biogas).
6) Use of agricultural residues, new sources of biomass and waste material for meeting energy needs,

The suggested policy for agriculture and food (13) was:

1) Creating higher genetic potentials of yields in pulses and oilseeds as major strategy for eradication of protein-calories malnutrition.
2) Upgrading of country's horticulture resources of fruits and vegetables and development of improved post-harvest storage and processing technique to minimize losses. Utilization of agro-wastes and biomass for production of energy and various industrial products.
3) Evolving alternative models of a crop and animal production so that the present highly energy-intensive techniques are replaced with those

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(13) "Report on the Working Group on Science and Technology for the Sixth Plan" Planning Commission, New Delhi, December 1980

which aim at combining high levels of production with a high degree of efficiency in the form of a better energy input-output ratio, through greater dependence on biofertilizers and renewable resources of energy including solar energy.

4) Selective mechanization of agriculture both for increased production and to remove drudgery of farm men and women.

5) Experimentation with semi-cooked foods for better retention of nutritional quality and for freeing women from tedious house-keeping chores so that their energy could be directed to more productive tasks of nation building.

6) Development of low-cost food mixed for a balanced diet, particularly for the vulnerable group of underprivileged sections of the society, especially children and lactating mothers.

The new Five Year Plan(14) especially recognizes the needs to develop new and renewable sources of energy. It states the idea that new energy technologies are particularly suited for the introduction of small-scale decentralized energy systems into India's rural agricultural economy. With the possibilities of the production of energy for domestic use as well as for rural industry and agriculture through adoptions of renewable technologies.

They hope to enter this development by

1) implementing large scale programs in energy, forestry, biogas (social forestry, energy plantations etc.)

2) carry out field testing and demonstration on a country-wide basis of

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(14) Sixth Five Year Plan 1980-85, Part II Planning Commission, Government of India 1981.

near term technologies (gasification pyrolysis and combustion),

3) intensify research and development of other long term technologies (ethanol fermentation).

The report(13) from the working group on energy policy Had suggested:

1. increased forestation,
2. methods of using crop residue as an energy source,
3. biogas improvements and cost reductions,
4. investigation of pyrolysis,
5. producer gas units for rural application,
6. fermentation process for liquid fuels,

In discussions with senior officials of the newly created Commission on Additional Sources of Energy, it was stated(15)that the GOI's goals were to develop all areas of biomass utilization with high priority to social forestry and near term conversion concepts and equipment. The near term processes of course include the continued distribution of biogas systems in the village but other strategies and developments are being identified. The Economic Times (16) provided an article stating the governments plans to replace entirely the diesel oil requirement for pumping by the year 2000. They plan to replace this energy requirement by using renewable sources including biomass and hydro power. The results are evident. The Indian Government is dedicated to establishing an aggressive program for biomass production and conversion.

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(15) Discussions held with, C.A.S.E. officials.

(16) "Diesel Substitution Plan on the Anvil" - Economic Times, July 14, 1981.

The question is with limited resources how can one optimize the effect and what areas in the biomass program should be emphasized for USAID support.

V Strategy

A suggested strategy is outlined in descending priority. It is hoped that this strategy will support India's efforts in renewable energy and provide wise use of USAID funds. The strategy topics in order are:

a) reforestation (social forestry,energy plantations)

b) producer gas pump sets

c) plantation harvest planning

d) other interesting conversion processes

Reforestation

The data produced relating the firewood needs of India and the effects these needs have had on the forest provides an immediate decision. A strong and decisive reforestation program must be entered immediately. The biomass centers need to be established and their work directed to near term reforestation goals as quickly as possible. Dr. Seckler of Ford Foundation suggested a second Green Revolution (17). He provided an economic analysis suggesting the cost for production of the needed plantations. He infact suggested advanced payments for planting village forest, paid directly to the landowner. He also suggested using small gasifiers to supply diesel engines for pumping water to irrigate the plantations increasing the production. The conclusion to be drawn is the forestry program has to be launched immediately, hopefully, from with haste and maximum efficiency for the benefit of all.

benefit of all.

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(17)D. Seckler and D. Joshi "Energy from Trees: Thousand Green Revolution."

Producer Gas Pumpsets

Producer gas pumpsets are another area of special interest in forming a strategy for the conversion processes. The pumpset idea will provides as small biomass gasifier producing the gas for fiering the pump's internal combustion engine. This strategy will require laboratory development and field demonstration providing the direction for the commercial application in rural areas as suggested by the government policy.

The first consideration is the available fuel. In reviewing the non-commercial sources the agricultural residue data provided at least the possibility of 1000 + tons of equivalent residue in some villages. Considering this residue and its use in a downdraft gasifier (19) several questions arise including; gasifier design, fuel characteristics, operating performance, maintenance, and reliability. The downdraft system is normally chosen for running engine systems because,

1) Reduced tar levels in the produced gas
2) Increase gasification rates per cross sectional area of the gasifier.

At the same time this type of gasifier (19) will require a careful fuel selection (preparation) and controlled moisture content. The fuel selection(19) is interpreted to mean the fuel must contain reasonably constant sized fuel

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(18) A.K.N. Reddy, "A strategy for Resolving India's Oil Crisis," Current Science 50, 1981.

(19) A. Kaupp and J.R. Goss, "State of the Rt. for Small Scale (to 50 KW) Gas Producer - Engine Systems" Final Report USDA Forest Service Contract No. 53-319R-0-141.

particles. With the thought of using rice hulls, rice straw and wheat straw, this requirement will be difficult to satisfy. Dr. Rogers (20) of the Ford Foundation has suggested a small down draft gasifier using charcoal instead of the raw biomass. The 1,000+ ton/village residue surplus could be charred and prepared as fuel for the gasifier. The gasification than becomes simply

$$C + 1/2O_2 \longrightarrow CO$$

$$C + 2H_2O \longrightarrow CO_2 + 2H_2$$

where of course both the CO and H_2 are combustible. This gasification of the charred residue greatly reduces the need for gas clean-up since the volatiles were removed in the charcoal process. The hot gas from the gasifier will simply pass through a small cyclone, filter combination and into the engine. The disadvantage of this approach is the considerable loss of energy in the charring process (pyrolysis) figure 7 but this approach is near term and can use the residue. The engine can be either a diesel or gasoline engine typically in the 3 to 5 horsepower range. The engine gasifier systems using a prepared char is at the development stage with information on engine reliability, gasifier operation, and gas quality needed.

The charcoal system suggested is a beehive kiln type design using trays permitting the residue use. The produced charcoal would then be prepared by extruding a blended charcoal, clay mixture through a hand operated sausage grinder.

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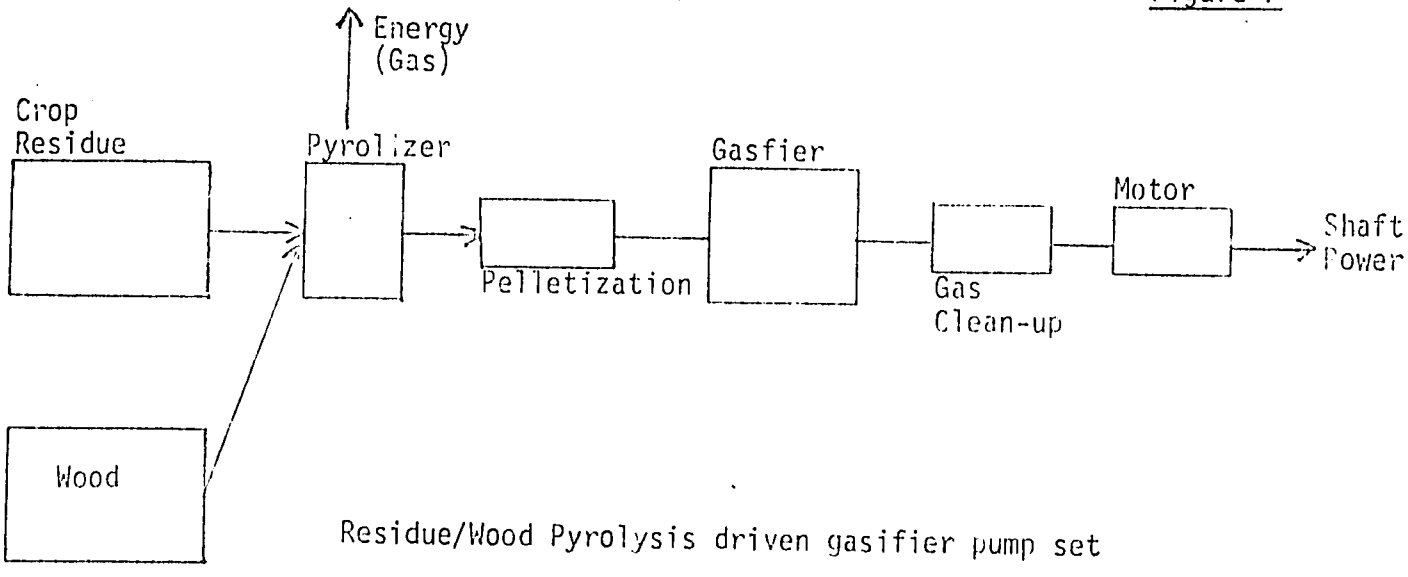
(20) P. Rogers "The Economic of a small Producer Gas-Engine System", New Delhi; August 1981.

Figure 7



Residue/Wood Pyrolysis driven gasifier pump set

Prof. Grover (21) suggest a cost of production of 0.35 rupees per kilogram considering capital, residue and operating costs. The value of the charcoal in Delhi is 1.3 rupee/kilogram. Prof. Grover needs to consider several other pyrolysis and extrusion possibilities including Tatom's designs (22) and other innovative concepts. Prof. Grover will also use wood in the charring process to compare wood to the residue in the pumping systems. The most important part of this work is the actual field demonstration and development. The success of the demonstration of this strategy in the field will define the merit. The important features of using residue to pump irrigation water is:

1) biomass material is surplus
2) use increases productivity
3) productivity increases surplus (through irrigation)
4) provides new village industry in charcoal production
5) provides additional jobs
6) increased economic income from selling charcoal
7) improved cooking efficiency using charcoal.

The concept was described schematically in figure 7 with the principal disadvantage being the loss of energy from the pyrolysis process. Dr. Grover suggest a pyrolysis process only to the point of driving off the necessary harmful tars, but whether a village could control the system to this degree is questioned.

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(21) P. Grover "Production of smokeless Brifuelted fuel from Agricultural Forest Waste", Chemical Engineering, I.I.T. Delhi.

(22) J. Tatem et al Pyrolysis of Rice Husks in Indonesia, USAID Project No. 497-0268.

Dr. Seckler (17) suggest the direct gasification of the biomass product as demonstrated schematically in figure 8.

Jyoti Solar Energy Institute has prepared a proposal to investigate this option. They suggest a three year program involving a one year design and laboratory development with 2 year field demonstration. The unit size will be in the 3-5hp range. The feedstocks will be primarily wood with crop residue as an alternative if it is a feasible input material. The fuel preparation step will be given considerable attention and the decision to pelletize or beneficate will be evaluated in the experimental and design phase. The system as shown in figure 8 includes wood or residue feeding the gasifier either through the pelletizer or by passing directly into the producer unit. The gas passes through the filtering system into the engine. The gas will contain increased tar levels and filter performance and engine operational characteristics are key points of evaluation.

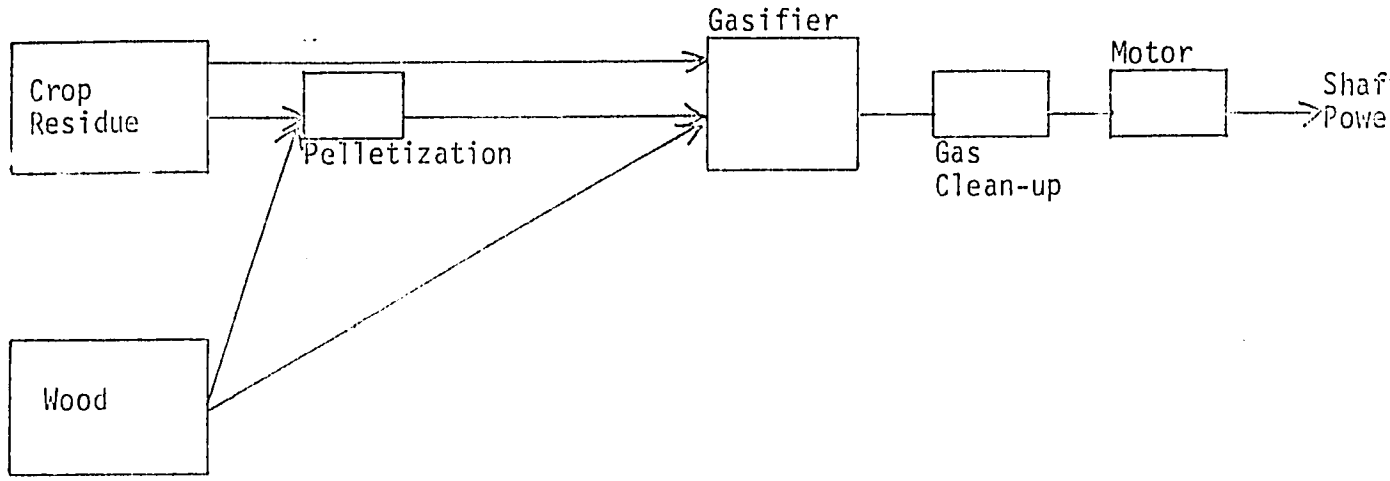
Once the two projects are completed it is essential that relative performance can be evaluated and compared. The initial programs should contain data collection and design quality controls preventing the completion of the projects without representative and complete results expressed in high quality data and equipment. A strategy for providing this quality assurance is

a. data collection system and design review at the initial stage (conducted by Biomass Energy System Branch, U.S. Department of Energy).

b. independent evaluation of two systems figure 7 and figure 8 at project completion (conducted by Biomass Energy System Branch, U.S. Department of Energy).

The scope of work for the technical monitor (DOE) is given in Appendix I.

Figure 8


Crop
Residue
Pelletization
Gasifier
Gas
Clean-up
Motor
Shaft
Power
Wood

The evaluation will be made using the results of the projects and will provide a comparison of the two approaches providing the decision-makers a proven strategy for the lift irrigation using producer gas generators. Additional assistance in lift irrigation using producer gas generators. Add-engine design changes will also be provided. Dr. Mathur of IIT, Delhi has suggested a development project in this area. He will evaluate on a short-term basis.

a. engine selection; diesel or petrol
b. cooling; air or water
c. engine life
d. maintenance

He will on a long term basis provide an engine design specifically for the producer gas, evaluate materials of construction and suggest the emissions from the engine.

Dr. Mathur will consider these evaluations for both the char driven system and the biomass driven unit. His work will need to be evaluated by DOE on its initial visit and his data will be important in the final review process. The scheduled time period is 3 years for the development projects with 6 months for the final assessment and recommendations. His proposal is included in App.B. Hindustan Brown Boveri Co. of India and Sweden has expressed interest in the commercialization of this pumpset technology. An AID supported market feasibility study would provide an interesting early data point especially when one realizes that there are 4.4 million diesel pump sets in India today. The consideration of this market study after the first year of research and development should be programmed and considered at that time.

Energy Plantation Harvesting Plan

The Gujarat Forest Department has undertaken an experimental plantations at Gandhinagar under dry conditions experimenting with 8 different tree species on 1.5x1.5 meter spacings. The plantings to date are

Albizzia lebbeck (Siri's), 79-80-12 ha
Eucalyptus hybird (Nilgiri), 80-81-10 ha
Dalbugia sissoo (Sissoo), 81-82-10 ha

The harvested trees are to be used in running a 1.5 MW power station. The station will be designed and built by the Gujarat Energy Board (GEB). It is proposed that the Gujarat Energy Development Agency (GEDA) investigate in conjunction with GEB and the Gujarat Agricultuve University methods and plans for harvesting and transporting the wood fuel. The questions to be answered are:

1) methods of removing trees
2) methods for preparing fuel from the harvested tree
3) transportation systems
4) assurance of fuel acceptability at the GEB station
5) economics of proposed system
6) field testing of proposed fuel treatment systems
7) environmental factors
8) a final designed harvesting system for the Gujarat plantation.

The results of this work will provide the country experience in harvest planning of these new fuelwood plantations. In planning the harvest new types of chipping designs and wood handling can be examined and tested but India's labor availability must be considered and used in providing a system benefitting all.

Other Interesting Conversion Processes

The Indian Institute of technology Delhi has a long history of research work in the area of blo technology of renewable resources. They are working in several areas of bio conversion of lignocellulosic materials into chemicals including ethanol and other substances. The area of prime interest at the present time is steam explosion of biomass as a pretreatment process. The pretreatment pilot scale plant will be used to evaluate this approach for varying biomass feed stocks found in India. The pretreatment results will be compare to other approaches and the improvements and knowledge will be integrated into new systems. The proposal is included in appendix D.

Several other interesting centers were visited and research projects reviewed (appendix F). The National Chemical Laboratory (NCL) in Pune is very active in tissue culture research and have requested support of this effort. It appears that coordination of NCL work with the biomass centers could provide a project with the needed funding. NCL is also involved in lignin research hoping to modify its surface characteristics and use the modified lignin as a polymer filler. The description is included in appendix E. The requested funding level is beyond the scope of this grant and other arrangements for funding should be investigated.

The Biocenter in Ahmedabad was also visited. The Biocentre is the lead institution for hydro carbon euphoria production and guayole investigation. They are very active and have a large need for equipment, travel funds and supplies. The work is exciting and very interesting but it is long term. Other sources funds need to be investigated including other USAID sources. As a final point in the strategy the consideration of a biomass centre for conversion processes could provide a focus and a special emphasis to the importance of this work to India and the world. India's Institute of Technology at Delhi has demonstrated a broad interest and involvement in the conversion areas includi: sification, pyrolysis, alternate fuel engines biogas and

formentation. This work is preceding in several departments including chemical engineering, mechanical engineering and bio-engineering. The ability to form strong working groups crossing department lines will provide outstanding team for leadership in this important area. It will be recommended that IIT Delhi be considered for this role.

VII. Conclusions

1. India has a severe firewood crisis resulting in large scale over harvesting and denuding of her timber resource.
2. Reforestation is absolutely essential and the program needs the total support of all India in providing the highest priority to this task. This priority has not been realized to date.
3. Crop residues appear to provide a small surplus to be used as fuel. Increased productivity in the residue area can be multiplied much quicker than in the forest sector.
4. The charcoal production systems will make crop residue more easily used as a fuel providing a valuable commercial product for the villages while reducing some demands on firewood.
5. The commercial producer gas pumpsets will increase residue production and energy plantation yields. They will decrease India's demands for imported light distillates (diesel).
6. Bio gas systems can make an inroad into India's village scene supplying some of the needed energy for cooking and lighting.
7. The plantation planners need to design efficient low cost harvesting systems designed with the end use properly defined and considered.
8. India has structured a well worded energy plan with considerable attention given the renewable (biomass) sector.
9. The strategy in this paper will aid in providing knowledge, equipment, and know how to the energy plan.

VIII. Recommendations

1. Funding of the village level charred biomass for irrigation proposal at a level of $191,000
2. Funding of the Jyoti Solar Institute biomass gasification demonstration at a level of $130,530
3. Funding of the proposal entitled Proceducer Gas Powered Small Horse Power Utility Engines for $127,930
4. Funding of the pretreatment by steam explosion of biomass at a level of $220,000.
5. A proposal for plantation harvest planning be solicited from Gujarat Energy Development Agency and funded at a later date.
6- Recommend that an effort be made to cordinate and fund on a limited basis the tissue culture work at the National Chemical Laboratory at Pune.
7. Recommend that DST considered naming IIT Delhi as a Biomas Center for conversion processes.
8. Recommend that the Biocenter consider soliciting funds from the new AID agency account entitled;Scientific and Technological Cooperation. The solicited funds would provide the Biocenter resources to perform their lead role in providing hydrocarbon euphoria research and guayule development.
9. Recommend that DOE's Biomas Energy Systems Branch be requested to provide technical monitoring on the funded conversion and planning projects.

IX. Budget	U S A I D ($)	Host Country (Rs.)
1) Village level gasification Charred Biomass for Irrigation	191,000	11,58,900
2) Jyoti Solar Institute	130,530	6,22,500
3) Producer Gas Powered Small Horse Power Utility Engines	127,930	9,17,500
4) Pre-treatment Steam Explosion	162,000	
5) Gujarat Energy Development Plantation Harvest Planning	40,000	
6) DOE Technical Monitoring	120,000	
	771,460	

Village Level Gasification Charred Biomass for Irrigation

		USAID		DST
Hardware		1,16,000		
Monitoring Equipment		2,64,500		
Calibration Gas		40,000		
Consumable Material				1,87,500
Demonstration Equipment		1,40,000		
Staff				4,64,400
Foreign Travel		3,00,000		
National Travel Consultants etc.				5,07,000
Foreign Consultants				
2 trips/yr. 50 days/yr. perdiem		4,65,700		
	53.3%	13,26,200	46.7%	11,58,900
Inflation	20%	2,65,200		
Contingency	10%	1,32,600		
Total		17,24,000		

(= 191,000 dollars)

Jyoti Solar Institute

		USAID		DST
Equipment		1,19,000		
Hardware		1,29,000		
Foreign Travel		1,50,000		
Foreign Consultants		4,65,700		
Staff				2,70,000
Consumables				1,87,500
Consultants (National)				1,65,000
Valibration gases		40,000		
	59% -	9,03,700	41%	6,22,500
20% Inflation		1,80,700		
10% contingency		90,400		
		11,74,800		

(= 130,530 dollars)

Producer Gas Powered Small Horse Power Utility Engines

	USAID		DST
Equipment	80,000		
Instrumention	240,000		
Consultations	100,000		
Foreign travel	100,000		
Foreign concultants	465,700		
	885,700		
Operational Expense		50,000x3	2,50,000
Staff			4,82,400
Consumables			1,20,000
Consultants (National)		5,5000x3	1,65,000
			9,17,400
20% Inflation	177,100		
10% Contingency	88,600		
	1,151,400		9,17,400
	($127,930)		

Steam Delignification of Lignocellulosic Residues Engineering Research Centre
I.I.T Delhi (3years)

	USAID(Rs.)	DST(Rs.)
Hardware	900,000	200,000
Travel	135,000	20,000
Supplies	135,000	80,000
Personnel		135,000
Other Expenses	45,000	30,000
		465,000
Rupees 12,15,000 (72%)		465,000 (28%)
Inflation (10%) 1,21,500		
Contingency (10%) 1,21,500		
14,58,000		
($162,000)		

Steam Delignification of Lignocellulosic Residues Engineering Research Centre
I.I.T Delhi (3years)

	USAID(Rs.)	DST(Rs.)
Hardware	900,000	200,000
Travel	135,000	20,000
Supplies	135,000	80,000
Personnel		135,000
Other Expenses	45,000	30,000
		465,000
Rupees 12,15,000 (72%)		465,000 (28%)
Inflation (10%) 1,21,500		
Contingency (10%) 1,21,500		
14,58,000		
($162,000)		

INDIAN INSTITUTE OF TECHNOLOGY: DELHI
CHEMICAL ENGINEERING DEPTT.

VILLAGE LEVEL GASIFICATION OF CHARRED BIOMASS FOR IRRIGATION

1. INTRODUCTION

Of all the potential alternative fuels available in India the one that is most neglected is the biomass. It has been estimated that in India each year over 200 million tons of agricultural residues are produced compared to 130 million tons of wood.

There is a world-wide interest in the development of gasifiers for substitution of biomass for fossil fuels in small internal combustion engines. Empirical work has recently been carried out on small system in Holland (Twente), Philippines (Cruz), Japan (Takada), Thailand (Beta Systems, Tatom), Tazania (Twente), U.S. (Goss, Saff, Tatom, Rogers), Canada (Mellinger), Indonesia (Tatom) and Ghana (Tatom). In addition to work on the small systems there is plenty of development on larger systems in Europe and the U.S. The bulk of the research and development, however, has focussed upon larger (15kw and above) wood fueled mobile units. It is our belief that there is a need for development of smaller (less than 5 kw) biomass fueled stationery units. One end use of particular importance in almost all third world countries is that of life irrigation.

The research outlined in this proposal is aimed at lift irrigation for smaller farmers (less than 2.5hectares) in areas with relatively low lifts (of the order of

contd...

10 20 meters). In India alone it has been estimated (Rogers) that there may be 25 million farms in this category.

A recent review of the "state of the art" for small scale gas producer-engine systems (Kaupp and Goss) is fairly pessimistic about the short term (next 5 years) applicability of these systems in developing Countries. Their arguments for this calculation are: (1) that there are no currently available "off the shelf" small scale gasifier engine systems, (2) that the reliability of the available custom made systems is not acceptable for use under low maintenance conditions, (3) that the older systems that were used extensively for transportation uses, during World War II and earlier, were only tested on high quality fuels such as coal, peat, charcoal and good quality wood. Other biomass fuels were not used except on rare occasions such as for rice mills in Italy and Vietnam, (4) that extensive research is needed on the fuel preparation for biomass fuel use, and (5) that the gas cleaning and the gasifier operation under heterogenous biomass fuel use needs further exploration.

Having reviewed the literature we can be sympathetic to Kaupp and Goss's conclusion, nevertheless, we believe that the applicability of the systems can be greatly speeded up by some basic assumptions as to the particular configuration of the systems to be used.

First and foremost, the literature and the folklore of gas producer-engine systems teaches one important [illegible] – the [illegible] of charcoal as a fuel greatly reduces [illegible]

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the system. Essentially, the cost of gas cleaning can be reduced to almost nothing, and the quality of the gas, from an energy point of view, is also much more consistent that with wood or biomass fuels. A decision to use charcoal should greatly accelerate the availability of the gasifier-engine system.

It may seem strange to recommend that the initial research focus upon a charcoal fueled system given that one of the problems in many third world countries is a severe shortage of wood fuels and hence charcoal. Moreover, in the traditional production of charcoal 50 to 60 % of the energy of the initial wood is lost. This is the reason why most of the gasifier research has been on wood rather than charcoal fired system. When biomass other than wood is to be used as fuel, however, a substantial amount of pre-processing is necessary. One can view the charcoal production as one of these pre-processes.

2. RESEARCH PROGRAMME

The research proposed herein deals with the development of proto-type system to integrate both the fuel preparation from biomass and the gasifier engine system. The research will develop operating system at IIT Delhi and we will then transfer this system to two demonstration units in villages in the surrounding areas. The field testing and monitoring of these systems will be carried out in collaboration with the U.P. Irrigation Research Institute at Roorkee and possibly the Irrigation Department of Haryana

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and the Haryana Agricultural University, Hissar. The research to be carried out at IIT Delhi falls in three areas.

The first area is that of char production from biomass using appropriate technology. A variety of feedstocks will investigated as fuels for char production using a small behive kiln developed by Grover (IITD) and also in very small low run ~~charred~~ units designed by the [illegible] pieces. The research on these units will concentrate on the yield and quality of the product and also on the gasification characteristics of the fuels with particular reference to evolution of tar during gasification. The research will also focus on the relative economics of these units.

The second area of research is the fuel preparation after the charring process. There exist many different ways for briquetting char. The research will concentrate on low cost method to produce char briquets suitable which can be produced without electric power and suitable for small gasifiers. Emphasis will be based on the strength and combustion characteristics and the cost of production of the char. Simultaneously, fundamental studies to find out the appropriate briquet size will also be carried out using thermo-grevematric analysis unit and differential thermo-gravematric apparatus available in the Institute.

The third area of research and development is that of the gasification process itself. The research will explore various configuration for the gasifier. Series of experimental gasifiers will be constructed including down-draft and fluidised bed unit [illegible] by Tecana Atlant[illegible]

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material used for construction of gasifier and screening and cooling system and the long-time performance of the gasifier.

In this research proposal we intend to use standard small petrol and diesel engine for irrigation purposes. Of course in order to use these engines with the gasifiers some modifications will have to be made in them. However, no major modification need be considered. The engine development will will be carried out by a separate research programme at IIT Delhi.

3. RESEARCH PERIOD AND PERIODICAL REVIEW

This research will be carried out over a period of three years at IIT Delhi. The installation of the two field projects will complete at the end of second year and carried out until the end of the research work.

In order to bring together research which is currently under way in India and the United States it is proposed to associate with this research project a group of personnel who are actively engaged in research and development on small gasifier engine system.

It is proposed that a research review committee will be established out of the panel proposed below.

Prof. J.R. Goss	Dept. of Agricultural Engineering University of California.
Prof. O.P. Jain	Director, I.I.T. Delhi.
Prof. C.S. Jha	Educational Adviser Ministry of Education, Govt. of India.
Dr. V.J. Flanigan	University of Missouri.
Dr. Peter Rogers	University of Harvard.
Dr. B.S. Pathak	Punjab Agricultural University.

contd...

Mr. B.S. Jain	Joyti Electricals, Baroda
Mr. M.M. Mehta	Escorts India
Prof. H.B. Mathur	I.I.T. Delhi
Mr. J.W. Tatom	Totam Consultant Ltd.
Mr. Maheshwar Dayal	Dept. of Science & Technology, Govt. of India.
Prof. R. Kumar	Indian Institute of Science Bangal

4. PROPOSED COLLABORATION

An important feature in Appropriate Technology system is to ensure that the economic and social dimensions of the technology are adequately considered before the technology is introduced. In order to ensure that this consideration is made it is proposed to directly employ an Economist as a staff person in addition to technical staff on the project and also to associate Prof. Ramesh Bhatia of the Institute for Economic Growth with the project.

In addition to technical staff at I.I.T. Delhi, Chemic Engineering Department with Prof. P.D. Grover as Coordinato other personnel who have expressed interest in direct parti cipation in this project are Prof. Peter Rogers of Harvard University (who is also interested in the Socio-economic dimensions of the technology), Dr. V.J. Flanigan of the University of Missouri who is interested in charcoal production and small scale fluidised bed gasifier. Dr. Flan has also expressed interest for direct participation in thi project.

In this proposal we have included an item for internat trave r IIT professional staff though we have not includ

international travel and per diem for the U.S. participants. We consider the international communication part of research to be critical element for the success of this project.

In conclusion the R&D can be directed towards following areas:-

1. How best to make fuel from various agricultural residues and other biomass fuels?
2. What are the properties of the fuel produced, size, ash content, energy content, and moisture content for each of the fuels?
3. What type of pre-processing is needed before fuel production, what type of processing is needed to make the fuel usable in the gasifier?
4. The configuration of the gasifier, should it be downdraft, cross-draft, updraft? fluidized bed etc.?
5. The materials to be used?
6. The need for moisture injection?
7. The size of the unit and the size of the storage hopper?
8. The amount of insulation in the unit.
9. The gas quality-chemical and thermodynamic.
10. The configuration of the system; cleaning first and then cooling?
11. The use of wet cleaning system; are there reliable easily maintained systems for this?
12. The materials to be used?

Prof. Peter Rogers
Harvard University

P.O. Grover

CHEMICAL ENGINEERING DEPARTMENT

BUDGETORY PROPOSAL FOR RESEARCH PROGRAMME FOR RESEARCH WORK AT I.I.T. DELHI.

A. Cost of Hardwares	(Amount in Rupees)
1. Appropriate charring unit (1 No.)	20,000
2. Various units for briquetting and palletising	30,000
3. Gasifiers:	
a) Models for down draft type gasifiers (4 Nos.) of various designs and capacity.	30,000
b) Fluidised beds (2 Nos.)	25,000
4. Engine/pump sets:	
a) Diesel pump set (3 H.P.)	7,000
b) Petro l engine (2 - 3 H.P.)	4,000
Total	1,16,000

All the above equipment will be fabricated or procured indigenously.

B. Monitoring (Instruments) equipment

1. For charring unit and briquetted fuel.	
a) Flow meters, temperature indicators etc.	20,000
b) Bomb calorimeter with digital output (imported).	15,000
c) TGA and DTA units (available in the department)	Nil
d) Automatic carbon-hydrogen analyser (imported).	25,000
e) Digital output micro-balance for above analysis (imported).	30,000
f) Shattering test equipment for solid fuel.	2,000
2. [illegible]	

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contd...

2. For Gasifiers

a) Multi-channel gas analyser for CO, CO_2, H_2 and hydrocarbon (preferably Carle type)(imported)	60,000
b) Gas filter media for high temperature (imported).	10,000
c) Pressure Transducers (10 Nos) (imported).	25,000
d) Multi-channel Process scanning and data recording unit for fluidised bed (imported).	50,000
e) Special thermocouples(imported).	10,000
f) Polaroid camera (2 Nos.)	6,000
g) Films for above (20 Nos.)	1,500
Total	2,54,500

C. Cost of consumable material

Cost of Agricultural Residue (15 tons @ Rs. 500 per ton.	7,500
Reagents and chemicals.	20,000
Instrument repairs etc.	25,000
Insulation and other materials.	10,000
	62,500

D. For demonstration units in two villages (one unit each)

a) Charring units 2 Nos.	60,000
b) Briquetting units 2 Nos.	20,000
c) Gasifier 2 Nos.	10,000
d) Engines 2 Nos.	10,000

contd...

e) Operation expenses including labour, travel, stay expenses, security etc. 40,000

Total 1,40,000

These expenses do not include the infrastructure provided by UP Irrigation or HAU or any other field agency.

E. Personnel and staff for the project (yearly basis)

	Annual expenditure
a) Senior Scientific Officer-I Qualifications: Ph.D. in Chem.Engg. (One post @ Rs.2000/- p.m.)	24,000
b) Senior Scientific Officer-II Qualifications: M.Tech. in Chem.Engg. (two posts @ Rs.1500/- p.m.per person)	36,000
c) Chemist for analysis Qualification: M.Sc. in Analytical Chemistry (One post @ Rs.1000/- p.m.)	12,000
d) Senior Research Assistants Qualification: Bachelor in Chem.Engg. (2 posts; one each for charring, briquetting, gasification and engine running @ Rs.1000/- p.m. per person)	36,000
e) Lab. Attendants & Fitters/Documentation Assistants. (6 posts @ Rs.400/- per person)	20,800
f) Research Associate Energy Resource Economist @ Rs.1500 pm.	18,000
Total:	1,54,800

F. a) Consultancy charges to be paid to Consultants invited to advise on this project at the rate of Rs.500/- per day, 50 mandays per year. 25,000

b) Travel expenses to invited Consultants and investigators. 30,000

c) Foreign travels 2 trips per year @ Rs. 50,000 per trip. 1,00,000

Total: 1,55,000

d) Labour charges to Instt. staff.	10,000
e) National travel expenses.	20,000
f) Pay roll expenses. (Approximately 10% of direct wages).	16,000
g) Office expenses like stationery, report writing, zerox, purchase of books, publications etc.	30,000
h) Contingency.	30,000
Total:	2,69,000

Total yearly expenses (E + F) = 4,23,800

For three years = 4,23,800 x 3 = 12,71,400

Total Expenses:

A. Cost of Hardware	1,16,000
B. Monitoring equipment	2,54,500
C. Cost of consumable materials	62,500
D. Village Demonstration unit	1,40,000
E+F (for 3 years).	12,71,400
Grand Total:	18,44,400

INDIAN INSTITUTE OF TECHNOLOGY : DELHI

MECHANICAL ENGINEERING DEPARTMENT

Producer Gas Powered Small Horse Power Utility Engines

1. INTRODUCTION

Small horsepower combustion engines are being widely employ for driving irrigation pumpsets, portable generating sets, pestici spray sets etc.etc. Their numbers are rapidly growing and it is hard to see a replacement for them in foreseenable future. These engines operate on petroleum based fuels such as gasoline and dies oil, which are getting more and more scarce. Therefore the need to find alternate fuels for these engines is increasingly being realised the world over.

Biosolar fuels such as Alcohals and Biogas, Biomass fuel such as Producer gas are the possible alternate renewable fuels which have attributes of perennial renewal. The suitability of th fuels for part or complete replacement of petroleum based fuels, i combustion engines, has been under investigation in the department mechanical engineering for last 10-12 years.

In the institute project entitled Project 'U'. 'Utilization of Alternate Fuels for National Energy Needs', Coordinated by Prof. H.B. Mathur, extensive work has already been completed on efficient Utilization of Alcohols and Biogas as fuels in Combustio Engines of various types and ratings. Demonstration units of Biog Alcohol operated engine driven Pumpsets, Generating sets have been developed. Alcohols have also been tried in vehicular engines wit

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very encouraging results. Apart from this experimental work computerised design details of 'Alcohol Engines' and 'Biogas Engines' have been prepared for future use.

Over the years, during these investigations, necessary infrastructure of laboratory facilities and technical expertise has been developed for R and D work on engines and fuels. These facilities at IIT Delhi are considered to be amongst the best available in the country.

Apart from the work on Alcohols and Biogas some R and D work has also been carried out by us regarding production and utilization of Producer gas in small size utility engines. While large size producer gas plants are commercially available little or no work had so far been done in the country on the design and development of small capacity plants for operating combustion engines of 1 to 5 horse power range.

Development of small size Producer gas plants requires considerable R and D effort to over come the problems associated with the variations of fuel composition and characteristics, charging of fuel and its efficient combustion, cleaning and cooling of the gas produced, etc.etc.

Efficient utilization of Producer gas in existing petrol or diesel engines also poses certain problems because of the difference in the heat of combustion, stoichometry, combustion characteristics and composition of producer gas and the petroleum based liquid fuels for which these engines are designed.

These and such other problems need to be solved by a concerted R and D effort before the small size producer gas powered engines can [illegible] commercial [illegible]. It is proposed to [illegible]

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these R and D problems under this programme

2. SCOPE OF THE RESEARCH PROGRAMME

The proposed research programme aims at the efficient utilization of Producer gas in existing small size utility engines and development of 'Producer gas engines' specially designed to burn producer gas as a complete fuel.

It is proposed to achieve ~~xxxx~~ these aims and objectives through a set of short term and long term R and D projects designed to achieve certain immediate and certain long term goals.

The existing small utility combustion engines will be modified to operate as bifuel engines with minimal possible amount of conventional fuel supplied for initiating and sustaining combustion of Producer gas the main fuel. The design modifications in the intake, firing, and cooling systems of the engines, necessary for maximum amount of Producer gas substitution would have to be experimentally determined, and standardised.

The performance characteristics of these modified existing engines would be evaluated through a series of performance, governing, and fuel consumption tests under different conditions of operation. The engine operating parameters would be optimised for best results and the performance characteristics so obtained would be compared with those of the unmodified engine operating on the conventional petroleum fuels. This project would enable efficient utilization of producer gas in existing combustion engines with no major design modifications and would give and idea

about the relative performance of such engines.

The material compatibility of the engine components would have to be examined by subjecting the modified engines to a series of endurence tests and examining the components thereafter few wear, corrosion, errosion, gum - formation etc. Comparison of results with those obtained from similar tests on engines operating on the conventional fuels would give an idea about the material compatibility with Producer-gas fuel. This project would enable selection of suitable materials for greater reliability and durability of the Producer gas powered engine.

With the growing awareness of environmental pollution from engine exhaust, it would be necessary to investigate the emission characteristics of Producer-gas powered engines. This study would involve exhaust gas analysis under various engine operating conditions to identify the various exhaust pollutants and their concentrations. It would be worthwhile to compare these results with those obtained from similar tests carried out on the conventionally fuelled engines so as to get a relative idea about the pollution potential of Producer gas powered engines. This project would also give a direction in which exhaust emission control measures, if any, would be required.

Some basic combustion studies, on Producer-gas would be required to collect the requisite information regarding inflamability limits flame velocity, ignition delay, stiochometry, adiabitic ~~flame~~ flame temperatures etc. This basic combustion data would be useful in the design and development of the Producer-gas engine

which would be specially designed with the required fueling, firing, and cooling arrangements to achieve efficient utilization of Producer gas as a total fuel. This project would have a long term implication in enabling the Producer gas fired engine pumps or generating sets become commercially viable units in time to come.

In the above outlined research programme the R and D effort would be concentrated on the engine aspect of the gasifier (Producer gas unit) engine set. The development work on the gasifier would be carried out by another group at I.I.T. Delhi. However, to reduce the interdependence of these two groups we would have to make our own Producer gas units. This part of the work would also require a certain amount of developmental effort. As mentioned earlier small size gasifier designes would have to be evolved and fabricated so as to have the necessary source of gas available for uninterrupted R and D work on the engine.

In short the R and D would be directed towards finding answer to the following.

1. How best an existing S.I./CI engine can utilise producer gas.
2. What modifications need be carried out to make existing combustion engines operate on producer gas.
3. What should be the best method of inducting, regulating the gas in the engine.
4. What should be the optimum ignition arrangement, timing for best results.
5. How the power out, fuel consumption and smoothness of operation be effected by use of producer gas in existing engines.

6. What should be the minimum quantity of conventional fuels used for befuel operation of these engines.

7. How does the producer gas fuel effect the exhaust emissions from the engine. What are the major pollutants and their concentrations.

8. How is the engine component material compatibility with this fuel.

9. What is the extent of wear, errosion corrosion if any and what changes in materials are required.

10. What should be the design parameters of a Producer gas engine for total operation of this fuel.

11. How the fuel combustion characteristics, stoichometry, and composition differing as they do with the conventional fuels, have to be accounted for in the redesign of fueling, firing and combustion system for best results.

Research Duration Collaboration and Review

This research will be carried out over a period of three years at I.I.T. Delhi. In addition to the technical staff at I.I.T. Delhi, Mechanical Engineering Department, with Prof. H.B. Mathur as Coordinator, other personnel who have expressed interest in direct participation in this project are Prof. Peter Meyers of Harvard University, Dr. V.J. Flanigan of the University of Missouri. The progress of the work will be periodically reviewed by a review committee comprising of a group of persons who are involved and are interested in the R and D in this area. The following personnel may be considered for the formation of the review committee.

Foreign Experts

1.	Dr. Peter Rogers	University of Harvard
2.	Dr. V.J. Flanigan	University of Missouri
3.	Dr. P.S. Myers	University of Wisconsin.
4.	Prof. J.R. Goss	Dept. of Agricultural Engineering University of California.

Indian Experts

1.	Prof. O.P. Jain	Director, I.I.T. Delhi
2.	Dr. P.J. Manohar Rao	Chief Additional Director, Ministry of Agirucltura
3.	Prof. C.S. Jha	Educational Adviser, Govt. of India.
4.	Prof. C.P. Gupta	University of Roorkee
5.	Prof. R.K. Bakshi	University of Kurkshetra
6.	Prof. P.D. Grover	I.I.T. Delhi

Budget Proposal

A. Expenditure on Hardware

	Amount in Rupees
1. Small Horse power SI and CI Engines of various types and ratings, 4 Nos.	0,000
2. Pumps, dynamometers and instruments such as fuel gauges, air flow meters etc. etc. for test rigs of above engines	16,000
3. Suction gas producers of various ~~various~~ sizes and designs along with gas cleaning and cooling equipment	30,000
4. Engine spares and miscellaneous materials such as sheet metal, angle iron, pipes and fittings, fire clay bricks etc.etc. needed for making engine modifications/ test rigs etc.	14,000
Total:	80,000

60

B. Expenditure on Instrumentation

		Amount in (Rs
1.	Flow Meters (Fuel/Gas/Air)	30,000
2.	Exhaust Gas Analyzers/SO_2/CO_2 Analyzers/ Recorders (Imported)	50,000
3.	Gas Calorimeters	25,000
4.	Gas chromatograph with temp programming, calibration gas cylinders, strip chart recorders etc.etc. (Imported)	60,000
5.	Temperature Indicators/Thermocouples/ Pressure Sensors-transducers and Amplifiers (Imported)	10,000
6.	Digitap/Process monitoring and recording Units (Imported)	50,000
7.	Miscellaneous items/Instruments/ Gauges/ etc.etc.	10,000
	Total:	2,40,000

C) Cost of Consumables

1. Fuels (such as Petrol Diesel), lub oils for Engines	40,000
2. Coke/Coal/Residual fuel for gas producers	20,000
3. Reagents and Chemicals	20,000
4. Instruments repairs and replacements	25,000
5. Miscellaneous Consumables/Materials/Items used in experimentation/field trials	15,000
Total:	1,20,000

D) Operation Expenses

Expenditure on labour, travel, installation of and operation of demonstration units, stationery, secretarial Assistance, documentation facility etc.etc.	50,000

E) Personnel and Staff for the Project (Yearly basis)

Scientific Staff	Annual Expen
1. Senior Scientific Officer-I (One post about Rs. 2000/- p.m.)	24000.00
2. Senior Scientific Officer-II (Two posts about Rs. 1500 pm per person)	36,000.00
3. Senior Research Assistant (Three Posts about Rs. 1000 p.m. per person)	36,000.00
Supporting Staff	
1. Senior Technical Assistant/Junior Technical Assistant with Specialization in Engines/ Instrumentation (Three Posts about Rs. 1000/- p.m. per person)	36,000.00
2. Senior Laboratory Assistant/Junior Laboratory Assistant/Senior Mechanic with experience in operation and maintenance of Engines, Instruments, fabrication and manufacturing processes, (Three posts about Rs. 800/- p.m. per person)	28,800.00
Total:	1,60,800.00

F.(a)	Consultancy Charges to be paid to consultants invited to advise on this project at the rate of Rs. 500/- per day (50 Mandays per year)	25,000.00
(b)	Travel expenses to Invited consultants and investigators	30,000.00
(c)	Foreign travels (2 trips per year about Rs. 50,000 per trip	1,00,000.00
	Total:	Rs. 1,55,000.00

Development of Bio-Mass Gasifiers and Internal Combustion Engines: (3-5hp)

An alternative for utilization of bio-mass is its gasification to produce a combustible gas which could be used for running an internal combustion engine, which in could be coupled to an electric power generation system or to a pump, or could be used for providing power to any mechanical device.

Bio-mass gasifiers are appropriate in all senses of the word; technology required for fabrication, operation and maintenance is simple; they are relatively less expensive; they use locally available resources; they are efficient in small sizes; they do not emit noxious pollutants; they can utilize a variety of resources and so on.

The system efficiencies of biomass gasifier systems compare well with other means of utilizing bio-mass (Table 1.). On the basis of these efficiencies and estimated calorific valud of feed material at 3500 kcal/kg, approximately 1.3 kg of input will be necessary per kwh of power produced.

It is sometimes argued that any scheme for utilizing local resources is bound not to succeed, as these resources are not waste in literal sense, they being put to some use in a system. For example, rice straw though generally considered as waste is used for thatching of roofs. Use of rice straw in bio-mass gasifiers would therefore make it unavailable for thatching, for which no immediate substitute is locally available. It has however been shown that the extra agricultural waste production as a result increased yield due to irrigation, and other modern practices

made possible by availability of power would alone be sufficient to meet the requirements of gasifiers. In addition, if gasifier program is coupled with aforestation, the requirements of biomass gasifiers could be met from additional firewood that would be available.

Development and demonstration of viability of gasifiers compatible with the properties of available resources and with the requirements of an area under consideration, thus becomes very desirable. Jyoti Solar Energy Institute with their experience and commitment propose to make a beginning in this direction by launching a development and demonstration project for biomass gasifiers and internal combustion engine systems for use in Indian villages. It is believed that such a system could go a long way in overcoming the constraint of availability of energy in development of these villages.

In the following, complete details of the proposed project including technological and financial requirements are given.

Proposed Program

1. Program Objective

As mentioned in the preceding paragraphs, bio-mass gasification and motive power generation used for group set application thereof is the best suitable for India's village scene. For such regions, it is desirable to develop a small engine to deliver power sufficient for the local pumpset requirements. It is believed that a 5 biomass gasifier would be adequate to meet various needs of these hilly regions. The objective of the prgramme therefore would be

(i) to develop and demonstrate a 5 biomass gasifier-cum-internal combustion engine.

2. Program Stages

With the above objective in mind, the program is proposed to be divided into undermentioned stages. These stages may or may not bear a separate temporal identity in which case the division would just underscore the tasks to be carried out:

1. Design and development of a 5 gasifier
2. Modifications on a 5 engine to run on the gas produced by the 5 gasifier.
3. Trials and laboratory demonstration of the 5 gasifier and internal combustion engine system
4. Field demonstration of the 5 hp system
5. Design and development of the 5 rice husk gasifier
6. Development of 100% gas run engine

3. Program Management:

The principal investigator for the program will be Dr. R.M. Dave, Director of Jyoti Solar Energy Institute. He will be assisted by Dr. B.C. Jain as Technical Adviser.

It is proposed to hold quarterly consultative meeting between Jyoti Solar Energy Institute and the USAID for review of progress.

Jyoti Solar Energy Institute would also submit a quarterly report. The USAID on the work carried out and the progress made.

A comprehensive report giving the details of work carried out and experience gathered will be submitted to the USAID at the end of the program.

4. Facilities Available at Jyoti Solar Energy Institute:

The Jyoti Solar Energy Institute is attached to Birla Vishvakarma Mahavidyalaya (Engineering College) which corducts Under Graduate as well as Graduate programs in Engineering. Since its establishment in 1979, Jyoti Solar Energy Institute has undertaken number of research programmes, a list of which alongwith funding agencies and funds received are gien in Annexure 2.

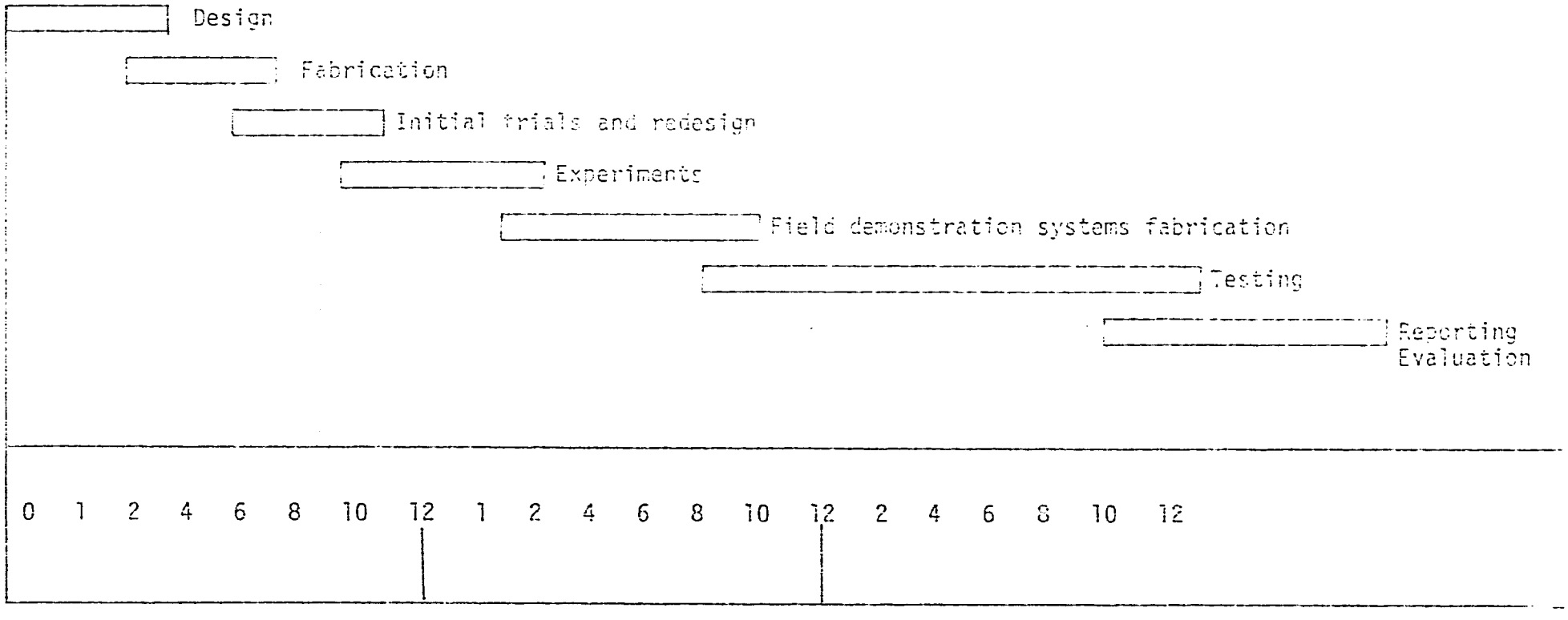
The College is equipped with scientific equipments necessary for measurement of physical and flow quantities. Its workshop is equipped with various tools and machines for fabrication of different jobs that would have to be carried out as a part of the proposed research exercise. In addition to above, the Collage possesses an updraft type charcoal gas producer coupled with a gas engine. Currently, attempts are being made to commission this gas producer-cum-engine unit.

BUDGET

Jyoti Solar Institute Biomass Gasification - Engine System Demonstration

	Year 1	Year 2	Year 3
Personnel			
2 Technical	48,000	48,000	48,000
1 Technical	7,200	7,200	7,200
2 Helper	4,800	4,800	4,800
Senior Scientific Officers (3-1/4 time)	18,000	18,000	18,000
Chemist	12,000	12,000	12,000
	90,000	90,000	90,000
Equipment			
Chromatograph (Carle H ,CO,CO_2,O_2,N_2,CH_4,C_2H_4, C_3+) U.S.	54,000	-	-
Filter Media	10,000	-	-
Pressure Tranducers	25,000	-	-
Thermocouples	10,000	-	-
Flow meters temperature Incl.	20,000	-	-
	1,19,000	-	-
Hardware			
Units for Biquetting or Pelletizing	30,000	-	-
Gasifiers	77,000	-	-
Engines	22,000	-	-
	1,29,000	-	-
Consumables			
Instrument Repair	25,000	25,000	25,000
Insulation	10,000	10,000	10,000
Chemicals	20,000	20,000	20,000
Residue	7,500	7,500	7,500
	62,500	62,500	62,500
Consultants			
Invited Advisers 50 days/year	25,000	25,000	25,000
Travel Consultants	30,000	30,000	30,000
Foreign Travel 1 trip/year	50,000	50,000	50,000
	1,05,000	1,05,000	1,05,000
Office Exp.			
Labor Charges	10,000	10,000	10,000
National Travel	20,000	20,000	20,000
Payroll Exp.	9,000	9,000	9,000
Office Exp.	20,000	20,000	20,000
	59,000	59,000	59,000

Biomass Gasification - Engine System Demonstration
(Jyoti Solar, Institute)
3-5hp



Steam delignification of lignocellulosic residues

Rapidly worsening petroleum situation, both for economic and strategic reasons, have compelled the world to seek alternate energy from renewable resources. Ethanol being one of the major building blocks for organic chemicals, is a promising alternative. As a consequence there is considerable interest towards biomass refining to obtain ethanol.

The Government of India has given a high priority to the development of renewable energy resources especially to provide alternative energy on a decentralized basis and to substitute the use of the fossil fuel. BERC has contributed significantly in the areas of enzyme production, hydrolysis and novel reactors for ethanol production.

One of the bottlenecks in the total bioconversion of lignocellulose to ethanol is pretreatment. Steam explosion technique for the delignification of lignocellulosic residues seems to be the least energy intensive. Moreover the pretreated substrate is highly susceptible to enzymatic hydrolysis. Which are continuous treatment by steam under certain conditions have been basically the development work done by [illegible] in Canada. A close cooperative [illegible] between these groups for the development of efficient pretreatment of agricultural residue such as bagasse, rice straw, [illegible] straw etc. could be very effective in bringing about [illegible] in this area.

Our research projects would be oriented towards this end beginning 1987. After [illegible] completion of the total indigenous process would be ready for pilot plant trials and subsequent large scale production [illegible] based on lignocellulosics.

Best Available Document

Period : Three years

Proposed Budget Estimates

Personnel	Rs.1,05,000
Equipment	Rs.2,00,000
	$ 1,00,000
Travel	Rs. 20,000
	$ 15,000
Supplies	Rs. 80,000
	$ 15,000
Other expenses	Rs. 30,000
	$ 5,000
Total	Rs.4,[illegible],000
	$ 1,35,000

Best Available Document

Biological Delignification

Biological delignification has been attempted by a few laboratories around the world and this has the special advantage of low energy requirements and would not create problems of pollution. The BERC has developed several fungal and other microorganisms which are active in using the lignin and providing celluloses for further processing. As a second priority we would like to pursue this as a programme if you should consider the steam pretreatment of lignocellulosics as a first priority. We believe this needs to be done because it may be possible to develop these processes in combination with advanced enzyme technology and the immobilization techniques and thereby reduce the reactor size and initial investments. The approximate cost of this project would be about Rs.3,50,000 of which Rs.1,50,000 and $ 25,000 over a period of three years. The total budget is divided on headings similar to what we have projected for the establishment of the steam delignification process.

Best Available Document

Appendix E

Materials Engineering of Lignin/Cellulose Waste [Polymer Science and Engg Project]

Objectives :

Develop coupling agents/surface modification of Lignin and Cellulosic fillers for use in polymers.

Develop technology for turning waste wood (chips, saw dust, bagasse, cereal stocks) into highly engineered wood sheets that match the size and strength of plywood at a cheaper price.

Potential End-uses/applications :

Fillers and extenders for polymers

High quality building materials to be used for making pre-fab home components (walls, floors) furniture etc.

Rationale:

A variety of cellulosic waste materials with high lignin content (20-25 percent) are available in India. The amount of bagasse produced in India in 1977 was 8.5 million tonnes on a dry basis. Bagasse contains 45 percent cellulose, 20 percent lignin, 28 percent pentosans and rest sugar and minerals. Waste lignin from paper mills is currently being dumped causing environmental hazards due to its corrosive characteristics. Cereal stocks from farms, sugarcane trash etc. are available in large quantities which

are currently burnt. There is need to develop value-added products from these waste materials for better indigenous resource utilization and to reduce environmental pollution.

Scope:

The project involves exploring chemical modification routes followed by product development by using composite technology. Lignin structure has hydroxyl and phenolic groups, and also a few points of unsaturation. These offer sites for chemical modification via reactions with alcohols, acids and vinyl monomers. A few examples of the approaches are given below:

a) Wood waste is a naturally occuring, weak fibre inforced composite. If the bonds between the strong, cellulosic fibres and the lignin matrix can be strengthened by impregnation with suitable cross-linking agents followed by in-situ polymerization, stronger composites could be obtained. Aliphatic and aromatic bicarboxylic acids, carboxyl ended polyester fibre waste, vinyl monomers and castor oil would be tried as crosslinking agents.

b) Lignin surface will be modified by suitable coupling agents with ester or amide groups at the free end for using the modified lignin in polyesters, nylons poloyolefins.

c) Reactions of lignin with asphalt will be explored .

d) Material systems will be developed by mixing the wood waste with 5 percent resin (urea formaldehyde, phenolic, isocyanate glue) and wax followed by curing of the thermosets.

Once the preferred chemical modification routes are established, the kinetics of preparing the materials will be investigated for developing economically viable conversion processes. This would involve studies in rheology, foaming, effect of filler dispersion on composite properties etc.

Budget

Equipment	$400,000	-	400,000
Foreign Travel	$ 2,000		
Perdiem (3 months)	$ 7,650		
T o t a l	$ 9,650 x 3	-	28,950
Foreign Consultants			
Travel	$ 2,000		
Perdiem (30 day x 85)	$ 2,550		
Rate ($192x30)	$ 5,760		
	$ 10,310 x 3	-	30,930
			459,880

INSTITUTIONS IN THE U.S. FOR COLLABORATION ON THE LIGNIN-CELLULOSE PROJECT

1. Forest Products Laboratory, Madison, Wisconsin
2. Washington State University (Prof. John Talbott)
3. Southeastern Forest Experiment Station, Athens, Georgin.
4. Purdue University, Lafayette, Indiana
5. Empire state paper research institute - (Prof. Leopald, Prof. Dence)
   and College of Forestry - (Prof. Schuerch, Prof. Smid)
6. State University of New York

   Syracuse, New York 13210.

Appendix F

Itinerary

Delhi	Ford Foundation	Dr. Peter Rogers
Delhi	I.I.T. Delhi	Dr. P.D. Grover
Ahmedabad	Biocenter	Mr. Suresh Patel
Vallab Vidyanagar (Gujarat	Jyoti Solar Institute	Dr. R.M.Dave
Baroda	Jyoti Energy Div.	Dr. B. Mazumdar
Delhi	Ford Foundation	Dr. D. Seckler
Delhi	I.I.T. Delhi	Dr. H.B. Mathur
Bombay	Khadi & Village Industries Commission	Mr. V.N. Sharma
Pune	National Chemical Laboratory	Dr. C. Ramon Dr. R. Mashelkar
Delhi	I.I.T Delhi	Dr. K.S. Gopal Krishnon

Figure 1 shows a plot of population versus time for India. The data was plotted from the 1981 census report*, paper 1 of 1981. The population level 1981 was recorded 683,810 people. Extrapolating the data to 2000 using first point (1951) to last point (1981) provides a 2000 populations of 880 x 10^6 people using the two last points (1971-81) provides a 2000 population of approximately 9.45 million people both of the two extrapolation methods are conservative becuase of the compounding effect provided by the growing numbers. Also shown in figure 1 is the non-commercial energy levels with a first point to last point extrapolation.

Figure 2 plots the firewood use, crop residue use and animal dung use versus time. The data (2) represents the demand for these 3 fuels forming the non commercial sector. Parikh suggested a firewood need by 2000 of 350 x 10^6 m^3. Plotting this point on figure 2 provides the extrapolations as graphically demonstrated.

Converting the 350 x 10^6 m^3 to population using the average 0.38 mtcr per person (2) reveals a 2000 population of

$$\frac{350 \times 10^6}{.38} = 921 \times 10^6 \text{ population}$$

Slightly below the extrapolation of figure 1. The suggestion of 350 x 10^6 m^3 by 2000 certainly is not a unreasonable assumption and in fact is conservative. the only reason the demand won't be at this level is that the firewood will not be available; unless prompt and effective evaluated action is begun.

The lack of firewood will shift the use to crop residue and dung as they remain available.

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* Census of India 1981:
P. Padmanabha "Provisional Population Totals"
Paper 1, 1981 Registrar Demand & Census

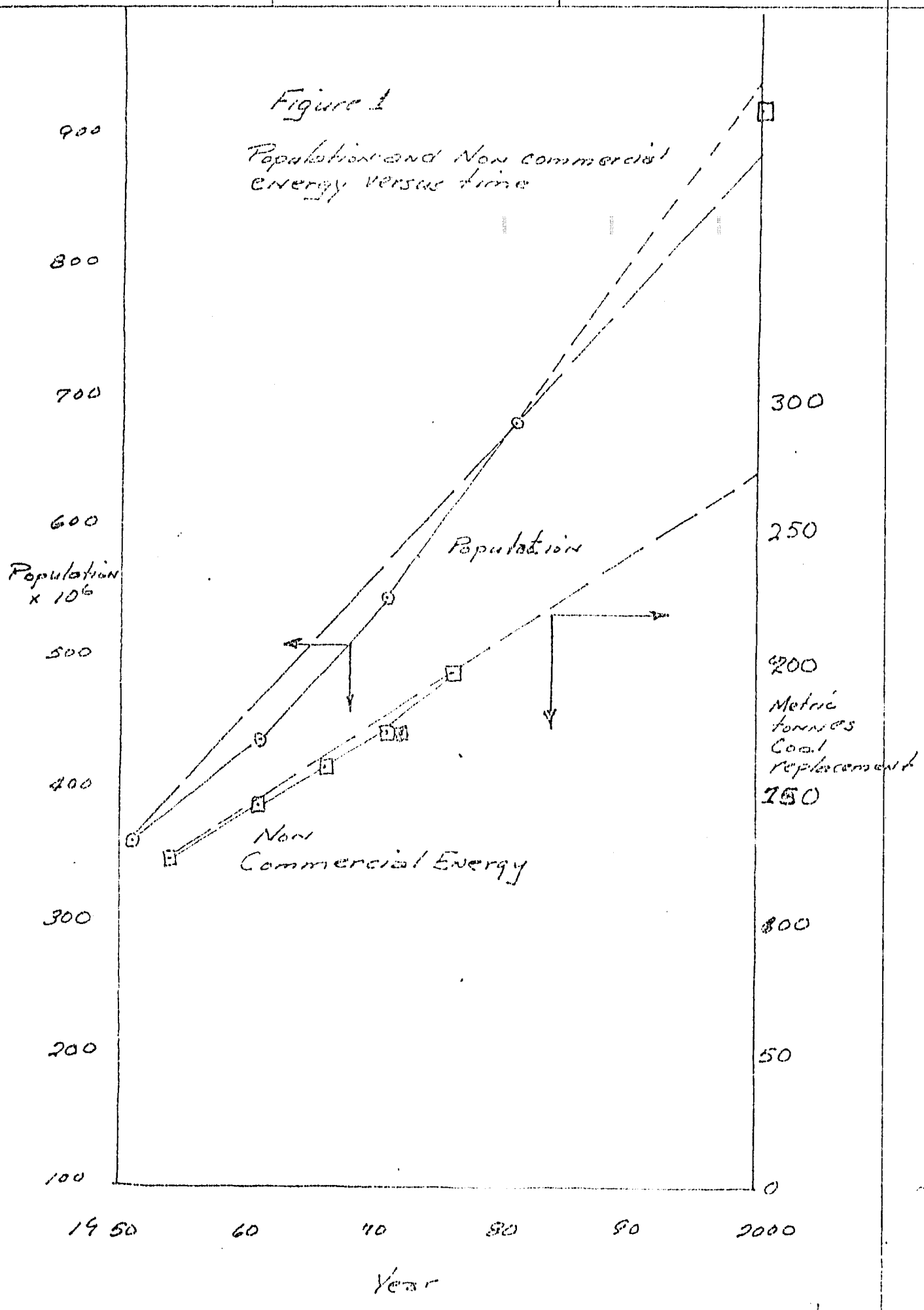
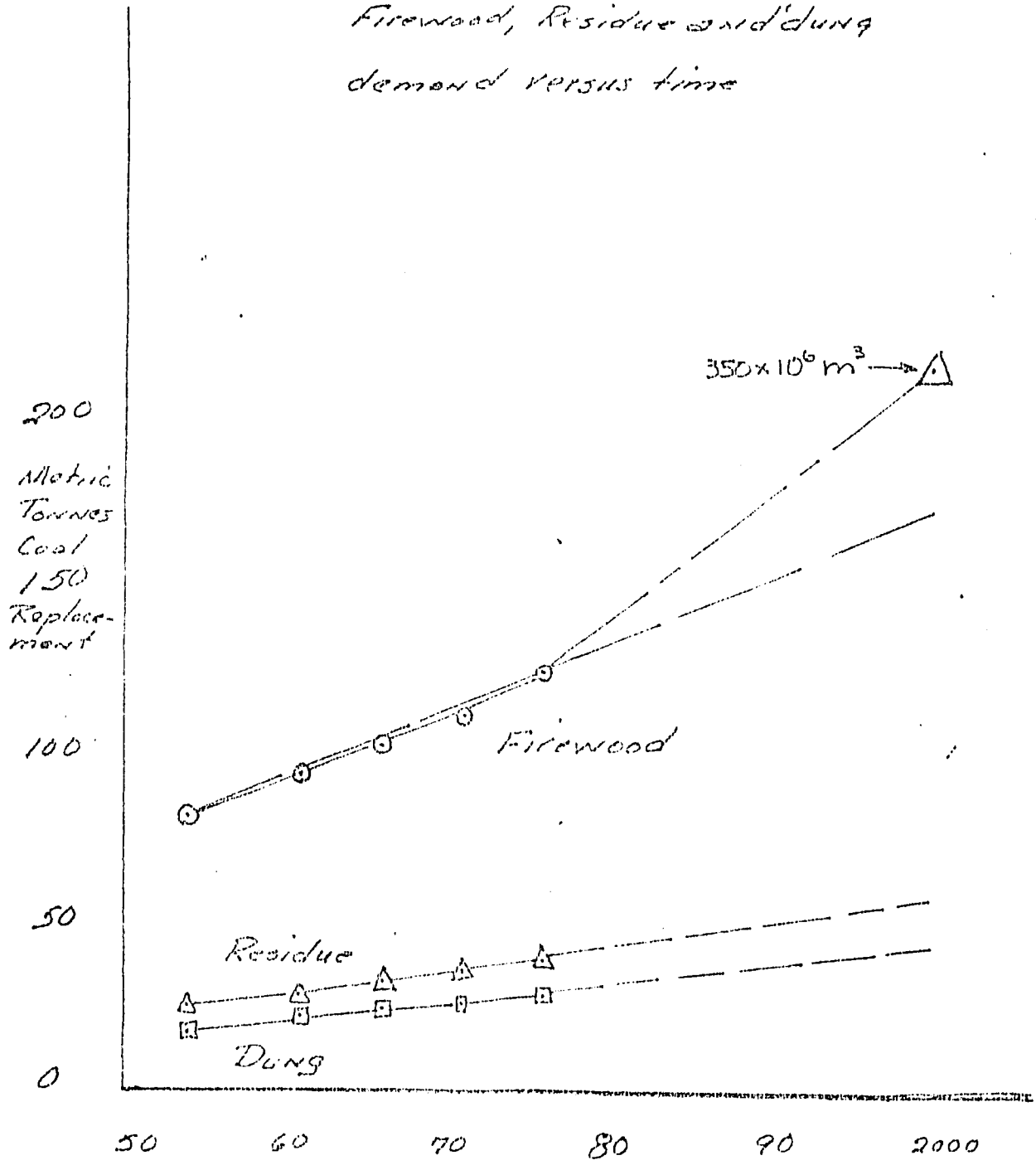

Population and Non commercial energy versus time
900
800
700
600
500
400
300
200
100
Population x 10^6
300
250
200
150
100
50
0
Metric tonnes Coal replacement
Population
Non Commercial Energy
1950
60
70
80
90
2000
Year

Figure 2

Firewood, Residue and dung demand versus time



Energy Impact (Agricultural waste - charcoal)

The use of agricultural residue as a fuel for charcoal could make a significant impact on the total energy demands. Table 1 provided agricultural waste levels at 200,000,000 tonnes for 1975-76 of course these quantities have alternates uses. But just considering converting 25% of the residue to charcoal would provide:

200,000,000 tonnes x 1/4 = 50,000,000 tonnes

Assume 40% moisture
Dry Product
50,000,000 x .6 = 30,000,000 tons

Million tonnes of coal replacement

30,000,000 x .95 = 28.5 mtcr

Assume 55% energy conversion to charcoal

28.5 mtcr x .55 = 15.7 mtcr

Total non commercial energy

1975-76 194.6 mtcr

$\frac{15.7}{194.6} \times 100 = \underline{\underline{8.1\%}}$

50% conversion

$\frac{31.4}{194.6} \times 100 = \underline{\underline{16.1\%}}$

The energy impact would be 8.1% of the total non-commercial use in 1976 using only 25% of the available residue, using 50% the impact would be 16,2% of the non-commercial quantity.

The original pumpset idea suggested is really beyond this consideration becau the use of the fuel in a pumpset to irrigate unirrigated land will increase the yield. Dr. Rogers of the Ford Foundation (Delhi) predicts a 53% yield increase required to provide 1500 hours of irrigation. This increases

seems to be in the realm of possibility. The charcoal used would be produced by the yield increase providing increased profits from the crop still leaving the remaining residue to be used or sold either as residue or charcoal.

If 25,000,000 hectares (suggested by Dubey) were irrigated assuming 12,500 m^3 of water/ha

12,500 m^3 /ha x 25 x 10^6 ha = 312.5 x 10^{12} m^3/year (assuming 16 meter lift) (diesel cost of 1833.6/25,000 m^3 of water)

$$\frac{1833.6 \text{ rupees}}{25{,}000 \text{ m}^3} \times 312{,}10^{12} \text{m}^3/\text{year} = 22.9 \times 10^{12} \text{rupees}$$

$$\frac{22.9 \times 10^{12} \text{ rupees}}{3.2 \text{ rupees/liter}} = \underline{\underline{7.15 \times 10^{12}}} \text{ liters of diesel}$$

Using producer gas to irrigate this planted 25x10^6 hectares would save 7150 billion liters of diesel while eliminating the fuelwood crisis in India.

Scope of Work (Project technical monitors)

The Department of Energy, Biomass Energy Systems Branch will be the technical monitors for the USAID alternative Energy Resources Development (386-0474) as related to Conversions Processes for Biomass fuels. They will be responsible for

1) Securing Project Plans

a) stated objectives
b) projects schedules
c) planned rates of expenditure
d) a prepared and approved scope of work for each project

2) Evaluating the equipment

a) designs
b) data gathering systems
c) safety plans

3) Quality assurance and quality control

a) providing and initial visit for data quality assurance
b) providing on site visits annually

4) Securing project status

a) contract management status reports (monthly)
b) project technical status reports (monthly)
c) a draft technical report and a final technical report from each project.

5) Recommending project modifications

a) modifications per necessary design changes
b) modifications per schedule over-runs
c) modifications/technical results suggesting a project termination or change of direction
d) termination due to lack of progress

6) Evaluation

a) evaluation of completed projects results
b) comparison of pump-set operation via direct biomass gasification/ charred biomass gasification
c) recommendation for project direction and management decisions.

7) Reporting to USAID India Mission

a) monthly status report to USAID mission India providing project status
b) monthly management report describing scheduling and budgeting percents

c) draft final report and final technical report summarizing the research effort and its conclusions and recommendation.

Priorities

The project priorites were established by

1) Near term technologies

2) Balance between conversion technologies

3) Assessment of the effect on the village level

4) Probability of success

5) Project cost

6) Basic or applied research

The priorities were assessed by determing the projects response to the 6 items. The gasification projects are near term proven technologies which require demonstration and limited development. The charring pyrolysis project requires adaptation to India's crop residues and innovative designs steps for providing a prepared gasifier fuel material.

The probability of success of these projects supported by the engine work has a high potential for making a real impact upon India's energy needs and her agricultural production.

The harvesting study is near term work with a low price for conducting the work. It will provide guidelines for later work and really acts as the pilot project in India for this type of effort.

The fermentation work was chosen by asking IIT for their recommendation in regards to the work they assessed to have the highest priority. This work is also nearterm proven technology which needs India demonstration and assessment.

The fermentation work at Pune has received U.N. sponsorship and the legnin project was simply to expensive for the limited budget. The tissue culture work was suggested to have the highest priority at NCL but this funding needs to be coordinated through the biomass production efforts not through the conversion considerations.