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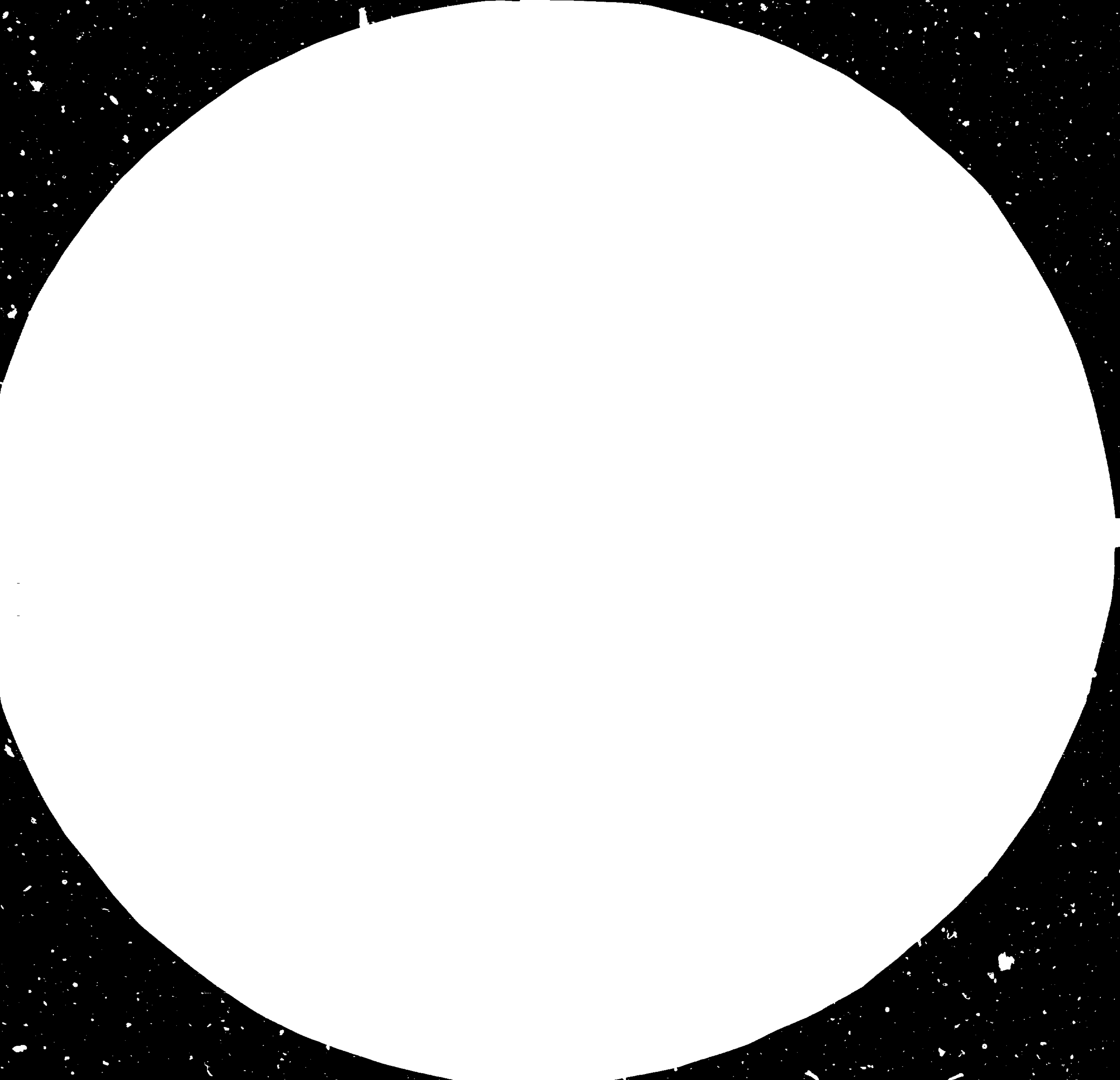

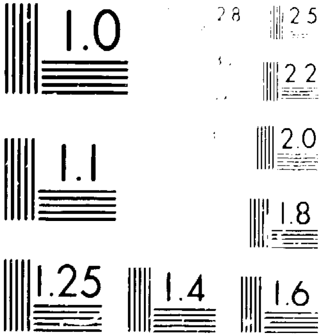
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Assistance in Producer Gas Technology

SI/DOM/81/803
DOMINICAN REPUBLIC

Technical Report*
Fuel Production from Renewable Sources

Prepared for the Government of the Dominican Republic by the
United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Robert O.Williams, expert in Producer Gas Technology

United Nations Industrial Development Organization
Vienna

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ABSTRACT

This report outlines the activities and findings of the author while assisting the Government of the Dominican Republic develop a gasifier testing programme.

The proposed application for the gasifiers is on small cattle ranches where sugar cane will be grown to provide a source of animal feed and the waste product--bagasse--used as gasifier fuel. Technical and institutional aspects of the project background are presented in the INTRODUCTION. A gasifier, acquired from Sweden for testing, is described in CHAPTER I. The author's activities during his mission are presented in CHAPTER II. Also included in this chapter are the author's comments on the existing equipment and proposed test programme. The potential for Biomass Energy in the Dominican Republic, including gasification, is presented in CHAPTER III. Suggestions for future cooperation with the Government of the Dominican Republic in developing its biomass resources are listed in CHAPTER IV.

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INTRODUCTION

The concept behind the project undertaken by the Consultant involves the coproduction of animal feed and biomass fuel from sugar cane. It requires that cattle farmers grow cane, extract sugar juice from the cane with a small roll crusher, sun dry the remaining fibrous residue (bagasse) and use it as fuel in a small gasifier plant. Low-Btu gas would be used as fuel in an internal combustion engine to provide shaft horsepower for on-farm use such as driving the cane crusher or generating electricity.

The project originated with the State Sugar Council (Consejo Estatal del azucar) which includes an animal husbandry division, (CEAGANA). The concept was proposed to CEAGANA by outside consultants including representatives of the Overseas Development Administration of Great Britain. Gasification equipment was acquired from Sweden for the purpose of evaluating its performance on bagasse.

Subsequently the project was transferred to the Comision Nacional de Politica Energetica for implementation, who are now preparing a test programme for the equipment.

Gasification equipment is in place on property owned by the Comision. A detailed description of the plant is given in Chapter 1.

A Swedish Engineer is currently working with the Comision completing installation of the equipment and developing a test programme. The Swedish aid agency is committed to a long term project of assistance to the Comision with its gasifier programme. The funding body is the Swedish Commission for Technical Cooperation (SCTC). Hardware and technical assistance are being supplied by Regut, a commercial consulting organization.

SUMMARY AND RECOMMENDATION

The "Comision Energetica" of the Dominican Republic is currently requesting funding from the Swedish Government for the support of its gasifier testing and development programme.

In the author's opinion the proposed programme should be simplified and emphasis placed upon more practical aspects of gasifier application.

Based on an analysis of the pattern of energy consumption in the Dominican Republic, the author considers the following aspects of biomass energy development, as they pertain to the Dominican situation, to be worthy of future technical cooperation:

Determination of the market for gasifiers.
Improvement in the design of rice husk furnaces used in rice drying.
Study the coproduction of electricity and charcoal from wood obtained from proposed energy plantations.
Investigate the practicality of biomass densification and drying to render it suitable for thermochemical conversion to useful energy.

I. DESCRIPTION OF GASIFIER PLANT

A. Gasifier reactor

The reactor is of the fixed bed, downdraft type. Reactor internals are standard for this configuration. Significant features include:

1. Vertically extended, cylindrical internal fuel reservoir, installed specifically for use with low density fuels such as bagasse.
2. Provision for collection and removal of condensate from an annular chamber surrounding the lower part of the internal fuel reservoir.
3. Pre heating of combustion air in an annular chamber surrounding the fuel combustion zone.
4. Gas exit near base of reactor (no attempt to preheat internal fuel reservoir).
5. Manually rotated eccentric grate.

The reactor is batch fed, manually through a lid on top of the internal fuel reservoir which is spring-loaded to provide an explosion vent.

The grate requires periodic rotation during gasifier operation. Char accummulates in a chamber below the grate from where it must be removed. Char removal must be performed on a cold reactor--probably each day before start-up.

B. Gas cleaning/cooling plant

Hot gas exiting the reactor is delivered to a fibre glass filter where particulate carryover is removed. The filter is in the form of a single fibre glass "sock" supported on wire mesh. The sock is housed in a container with appropriate baffles to direct the gas flow inside to outside. Soot build-up on the inside of the filter must be removed with a soft brush. Access ports on the container are provided for cleaning and soot removal. The container is insulated to keep it hot thus avoiding condensation of tars/aqueous fractions on the sock resulting in blockage.

Leaving the filter, hot gas is passed to a double-pass, finned-tube radiator, (two tubes per pass, four in total), for cooling. No external forced draft of air across the tubes was provided. A suitable trap is installed to collect condensate from inside the tubes.

C. Engine

A two-cylinder, air-cooled, Diesel engine is mounted on a common skid with the gasifier plant. The engine, a Petter PH2, 12.5 bhp, 1,500 rev/min type, has been converted to dual fuel (low-Btu gas and Diesel) operation.

Downstream from the radiator/cooler the gas enters a mixing chamber into which air is admitted through a filter. The gas/air mixture is then delivered to each cylinder through the existing air intake valves. Hand-operated, butterfly valves control the supply of air to the mixer and the supply of mixture to the engine.

Diesel injector pumps of lower capacity than normal are installed on the engine. A means of manually locking the pump rack into a position, which allows only a minimum flow of Diesel fuel to the cylinders, is installed.

D. Instrumentation

Dial (bi-metal strip) thermometers are installed to indicate the following temperatures:

1. Reactor gas exit
2. Filter exit gas
3. Cooler/radiator exit gas

Tappings into the pipework at selected locations in the system are connected by clear plastic tubing to a series of U-tube manometers. Following pressures are indicated:

1. Reactor exit gas static
2. Filter differential
3. Cooler/radiator differential

E. Start-up

After the addition of suitable solid fuel, the gasifier is ignited by special "matches" inserted through an ignition port. Start-up combustion air is provided by a hand-cranked fan. During start-up gas is flared through a pipe installed directly on the gasifier reactor.

Meanwhile the engine is started on Diesel by hand-cranking without compression (exhaust valves locked open) a heavy flywheel to gain momentum. When gas is available for engine use, the hand fan is stopped, the flare sealed and the gasifier reverts to suction mode--fluid flow through the system is induced by manifold vacuum from the engine. Engine air supply (mixture) and throttle valves are set manually. The pump rack is backed off to reduce Diesel flow to a presumed 10 to 20% of total energy input to the engine.

II. INPUT BY THE CONSULTANT

A. Provision of suitable load

The engine was supplied from Sweden without a suitable load. Following discussions with the Swedish engineer, the Comission was advised to procure either:

1. A mechanical load, prony brake, or dynamometer, or
2. a 10 kWe synchronous generator with suitable electrical load such as an array of radiant heat lamps.

The Swedish engineer is proposing to determine optimum operating conditions for the system with different gasifier fuels and with differing loads on the engine. In the author's opinion the mechanical brake would be both simpler and cheaper, however, such equipment will need to be supplied from Sweden. Furthermore, the author proposed that the Comision embark upon a simpler test programme (see Subsection C) to determine overall system efficiency and general operating parameters. Such a programme is within the capabilities of the Comision staff and could be undertaken without outside assistance. Fine tuning of the engine could follow with assistance from Swedish personnel.

B. Comments on existing equipment

The author had the following comments about the equipment as supplied from Sweden and discussed them with the Comision technical staff.

1. Potential problems with the gasifier reactor, in particular bridging of low density fuels in the internal fuel reservoir, blocking of the grate passages with char, and grate jamming with tramp material.
2. Blocking the fibre glass filter with condensible matter at start-up, when the filter material and container are cold.

3. The timing of the engine required adjustment for correct performance in dual fuel mode. As supplied, the injection was timed for 100% Diesel operation, so overheating occurred during dual fuel operation. With the author's assistance, timing was advanced 4°. Comision staff were instructed how to make further changes if necessary.
4. The author expressed his reservations about the use of a Diesel engine rather than a gasoline engine--preferably supplied already connected to a generator. While Diesel engines are more rugged and tend to be lower speed than gasoline engines of equivalent capacity, they are expensive in the 10 kW sizes (about $US 10,000), more expensive to maintain, and the continued use of pilot Diesel fuel (minimum 10% of total energy input) can contribute substantially to operating costs.

C. Proposed test programme

The following test programme, designed to determine efficiency and operating parameters for the gasifier was proposed:

1. Determine the consumption of solid fuel by the gasifier with different electrical loads (e.g., 1,3,5 and 7.5 kWe) for wood fuel and bagasse.
2. Measure heat of combustion and moisture content of the two fuels as delivered to the gasifier.
3. Calculate overall energy conversion efficiency of the system defined as: $\frac{\text{kWe output measured at the bus}}{\text{MJ/hour as fuel input to gasifier}}$
4. Measure the consumption of Diesel during dual fuel operation of the engine.
5. Acquire information about the following practical considerations:

-- Frequency with which gasifier must be refueled.

-- Extent to which the fuel bridges and needs to be manually broken.

-- Frequency with which char must be removed.

-- Ability to respond to sudden changes in electrical load.

-- Frequency with which gas cooling and cleaning equipment requires attention.

D. Equipment list

The following items of equipment are required to implement the test programme proposed in Section C.

1. Device for weighing the solid fuel consumed by the gasifier (platform scale or heavy duty spring balance).
2. Means of measuring consumption of Diesel fuel (either a flowmeter in the line or a liquid level indicator on the tank).
3. 60 Hz, 3-phase synchronous generator.
4. Suitable shaft coupling.
5. Balanced load for the generator comprised of radiant heating lamps with appropriate switches.
6. Fused disconnect.
7. Extension to the existing frame to support the generator.

E. Fuel preparation

A test unit sugar cane crusher, installed on the premises of CEAGANA, was used to extract juice from about 50 kg of cane. Subsequently, the bagasse was dried in the sun and cut up by hand into pieces suitable for use in the gasifier.

On his return to the USA, the consultant forwarded technical information on state-of-the-art biomass densification to Comision staff.

III. POTENTIAL FOR BIOMASS ENERGY IN THE DOMINICAN REPUBLIC

A. Fuels

The following agricultural residues are generated:

1. Rice hulls and straw
2. Sugar cane bagasse
3. Coffee husks and pulp
4. Maize (corn) cobs
5. Coconut husks and fibres
6. Manioc
7. Cocao
8. Beans/bananas/plantanes, other fruit
9. Cotton stalks and gin trash

Bagasse is used extensively in sugar factory boilers. At some locations there is a surplus of bagasse, at others a deficit. There is room for improvement in the efficiency of much of the installed boiler plant. This would release considerable quantities of bagasse fuel for other uses.

Rice hulls and coffee husks are generated in large quantities, a portion of which is currently used as fuel in furnaces to generate heat for drying. About 200 such husk-fired dryers are installed.

Of the remaining types of residues, bean waste, manioc waste, and coconut husks can be considered potential biomass fuels since they are generated at central locations where there is a need for energy.

Firewood and charcoal are used extensively in the residential sector, mostly for cooking, however, deforestation is a problem. Wood fuel should only be given consideration in conjunction with energy tree plantations.

B. Technologies and applications

1. Gasification

On-farm use at small cattle ranches using bagasse fuel from cane grown for animal feed. Applications would be power generation and farm machinery. Remote electricity generation. Retrofit of existing oil-fired boilers in industry and agro-industry.

2. Direct combustion

Improved design of rice husk/coffee husk furnaces used at existing dryer facilities. Small biomass-fired steam boilers in the agroindustrial sector for generation of process steam (possible cogeneration applications).

3. Charcoal

Co-production of charcoal and electricity (1 to 10 MWe) using rotary kilns technology and waste heat boiler/steam turbine in conjunction with development of energy plantations.

C. Current Pattern of energy consumption

1. Fuels

In 1980 the Dominican Republic consumed a total of 4,150,000 TOE, 33% of which was wood (including that coverted to charcoal), 50% was derived from imported oil and petroleum products. The balance was made up of other biomass fuels, primarily bagasse used in sugar factory boilers.

2. Electricity

In 1980, 870,000 TOE of petroleum product fuels were converted to electricity at an efficiency of about 20%. A distribution grid connects major cities across the country. A total of about 300 MW of base load capacity are installed at four oil-fired steam power plants. A further 160 MW (gas turbines and reciprocating Diesels) are available to meet peak requirements; 165 MW of hydroelectric capacity are installed.

3. Energy consumption

Final energy consumption, by sector, and costs (converted into the common unit of US$/million Btu where appropriate) are presented in Table 1. The major energy consuming sector with potential for expanding its use of biomass fuel is in industrial boilers.

D. Replacement of conventional fuels with biomass

1. Transport sector

At US$ 13.6/MM Btu for gasoline it is possible that an economic case could be made for the use of biomass-fueled, vehicle-mounted gasifiers. There are considerable practical difficulties associated with the use of this technology, however, and it will probably be used only in cases where liquid fuels are not available.

2. Industrial sector

Almost half of the fuel consumed by this sector is bunker C, available at US$ 3.3/MM Btu. Development of biomass energy in this sector will have the greatest impact (compared to other sectors), on reducing imported oil. Industrial boilers and furnaces can be converted to biomass by retrofitting with gasifiers or replacement with solid fuel systems. Bagasse fuel could be made available by improving the efficiency with which it is currently utilized in sugar industry boilers. Rice hulls, coffee husks and coconut husks are also available for use in boilers and furnaces.

Wood fuel is currently available at US$ 0.55/MM Btu. Use of this wood is being discouraged since it results in

TABLE 1

PATTERN OF ENERGY CONSUMPTION IN THE DOMINICAN REPUBLIC

SECTOR	FUEL	TOE x 10^3	COST (RD$/unit)	COST (US $/million Btu)[4]
Transport	Gasoline	438	2.57/gal (US)	US$ 13.6/MM Btu
	Diesel	186	1.15/gal	US$ 5.7/MM Btu
	Fuel Oil	11	0.72/gal	US$ 3.3/MM Btu
Industrial[1]	Wood fuel	32	7.5 /tonne[5]	US$ 0.55/MM Btu
	Other biomass[2]	589	--	
	Liquid gas	15	22.85/100 lb	
	Diesel/gas oil	23	1.15/gal	US$ 5.7/MM Btu
	Bunker C	400	0.72/gal	US$ 3.3/MM Btu
	Electricity	57	0.11/kWh	
Residential Commercial and Public	Wood fuel	509	7.5/tonne	US$ 0.55/MM Btu
	Charcoal	467	7.5/35 kg	US$ 5.10/MM Btu
	Liquid gas	100	22.85/100 lb	US$
	Kerosene	70	0.96/gal	US$ 4.10/MM Btu
	Electricity	90	0.11/kWh	US$
Agriculture[3]	Diesel	12	1.15/gal	US$ 5.7/MM Btu

[1] Includes agro industry.

[2] Primarily bagasse used in the sugar industry.

[3] Probably use small quantities of other fuels.

[4] US$ 1.00 = $RD 1.6

[5] 50% moisture. Heat of combustion of 19 million Btu/tonne (dry). Price at which wood is currently available.

deforestation. Wood fuel from the proposed energy plantations will cost in the order of US$ 1.00 to US$ 1.50 per million Btu. The current price of Bunker C is US$ 3.3 per million Btu.

Further study is required to determine the costs of additional operating labor and equipment required for solid fuel using systems. Currently, the total cost of operating a biomass-fueled plant is probably comparable to that of operating a conventional Bunker C plant, but as the price of Bunker C increases the biomass option will become substantially more attractive.

3. Agricultural sector

Diesel is the only significant fuel used in this sector--primarily for agricultural tractors. The opportunity to replace petroleum with biomass fuel is very limited. Nevertheless, there is scope for the introduction of small scale gasification plant as a means of developing mechanization, improving the standard of living of the agricultural community and in the long term, increasing agricultural productivity. The current gasifier program at the Comision Energetica was developed with these objectives in mind.

A major institutional investment will be required since it is unlikely that individual farmers will be able to afford the equipment without financial assistance (inexpensive loans, etc.).

4. Residential, commercial and public sector

About 80% of the energy consumed by this sector is firewood and charcoal, used mostly for domestic cooking. The problem arising from wood energy consumption in this sector is one of deforestation from indiscriminate tree felling. It should be addressed by a program of energy plantations, improved charcoal production and use of more efficient wood stoves.

5. Electricity

It is unlikely that biomass technology will play any significant part in generating electricity for the existing distribution grid. The scale of existing plant is too large. Logistical problems of fuel supply would be substantial. Within areas currently served by the distribution grid, electricity generated by means of biomass-fueled gasifiers, will not be less expensive than the current price of purchased power of RD$ 0.11/kWh, unless the units are sized above 50 kW. In sizes less than 50 kW insufficient power will be generated to cover the cost of operating labor and capital even assuming that fuel for the gasifier is free.

Further power plants co-producing electricity (1 to 10 MW) and charcoal, used in conjunction with energy plantations, might provide electrical energy as the demand in rural areas increases. An alternative to this approach is the use of small gasifier-engine-generators (10 to 50 kW) at each rural demand center.

IV. THE COMISION ENERGETICA AND FUTURE AREAS FOR COOPERATION

The Comision Energetica has been in existence for about four years, the biomass energy section about two years. Areas currently under investigation include methane fermentation, gasification, combustion, charcoal production and energy plantations.

In addition to the gasifier development project, the Comision is to receive assistance from a US University with its energy plantation program.

The following are suggestions for future cooperation in the form of a technical assistance programme with the Comision Energetica.

A scope of work for each project has been selected which is complimentary to work which will be undertaken as part of other technical assistance programmes.

A. Gasification--market survey

Determine the size of the current and future potential market for small scale gasifiers delivering shaft horse power and electricity. Particular emphasis to be placed upon:

1. Small cattle farms. The gasifier will be part of an integrated scheme to provide animal feed from sugar cane. The fuel will be bagasse.
2. Sugar cane field workers' villages. Provision of electricity. Fuel will be bagasse.
3. Rural electrification. Villages remote from existing electricity distribution and without mini-hydro potential. Fuel supply from new energy "wood lots."
4. Small agro-industry. Coconuts, coffee, rice, etc. using agricultural residues generated at each site.
5. Other.

B. Biomass furnaces--demonstration project

Develop and demonstrate an improved design of rice husk/ coffee husk furnace for coffee/rice drying.

C. Energy plantations--feasibility study

Determine the feasibility of the combined production of charcoal and electricity (1 to 10 MWe) in rural areas using wood fuel from the proposed energy plantations.

D. Preparation of biomass fuels

Characterize existing biomass fuels and determine the extent to which they require preparation (densification/drying) to make them suitable for thermochemical conversion. This could be a two phase project, the second phase involving acquisition of hardware such as cubing or pelletizing equipment.