BIBLIOGRAPHIC DATA SHEET

PN-AAJ-489

BIOMASS FOR ENERGY IN ECUADOR: AN ASSESSMENT

PERSONAL AUTHORS - BEINHART, G.

CORPORATE AUTHORS - USDA/FS
USDA/SEA

1981, 99P.
(PREPARED BY USDA/FS-SEA BIOMASS ENERGY TEAM)

ARC NUMBER - EC333.79.B422
CONTRACT NUMBER - DS/EY
PROJECT NUMBERS -
SUBJECT CLASS - AP000000G520

DESCRIPTORS -

ECUADOR	BIOMASS
ENERGY	ALTERNATIVE ENERGY
BIOGAS	WASTE CONVERSION
FUELWOOD	ENERGY CONSUMPTION
ENERGY NEEDS	ASSESSMENTS
RENEWABLE RESOURCES	AGRICULTURAL WASTES

EC
333.79
B422

PN-AAJ-489

REPORT OF
USDA/FS-SEA BIOMASS ENERGY TEAM
FOR
OFFICE OF ENERGY
DEVELOPMENT SUPPORT BUREAU
USAID

BIOMASS - FOR - ENERGY IN ECUADOR: AN ASSESSMENT

G. BEINHART
J. F. HENRY

JANUARY 1981

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY i

I. INTRODUCTION. 1

II. BIOMASS RESOURCES IN ECUADOR 4

A. Fuelwood Production and Utilization. 4
1. Background 4
2. Fuelwood Utilization and its Problems. 4
3. Potential Resources. 6
4. INE Fuelwood Program 7

B. Crop Residues and Other Waste Materials. 8
1. Crop Production Overview 8
2. Crop Residues. 8
a. Solid Fuel from Bagasse 15
b. Solid Fuel from Hulls 16
c. Others. 20
- Solid Fuel from Cotton Trash. 20
- Solid Fuel from Sawdust 20
3. Animal Wastes 20
a. Availability. 20
b. Biogas Production 22
c. Market for Biogas 24
4. Municipal Wastes. 25
a. Solid Wastes Availability 25
b. Refused Derived Fuel (RDF) from Solid Wastes. . . . 26
c. Steam and Electricity Production from Solid Wastes. 29
d. Biogas Production from Liquid Wastes. 30

C. INE Biogas Demonstration Program. 32

D. Energy Crops. 34

III. CONCLUSIONS AND RECOMMENDATIONS. 36

A. General Conclusions 36
1. Time Frame. 36
2. The Performance of INE in Biomass-for-Energy Activities 36
3. The Role of United States Institutions. 37

B. Recommendations for Specific Actions. 38

APPENDICES 42

I. Ecuador's Energy Consumption 43

PAGE

II. Contacts in Ecuador 48

III. Field Trips 53

IV. Infrastructure and Context. 61

V. Potential for Residues Production in the Agrobusiness Industries. . 75

VI. Sugar Mill Operations 77

VII. Production of Substitute Solid Fuels from Residues. 79

VIII. Steam and Electricity Production from Solid Wastes. 86

IX. Units and Conversion Factors. 89

REFERENCES 90

LIST OF TABLES

NUMBER	TITLE	PAGE
1.	Crops and Crop Residues	12
2.	Major Agroindustries of Interest for Energy Production	13
3.	Characteristics of a Substitute Solid Fuel Plant Using Bagasse Residues from a Sugar Mill in the Province of Imbabura	17
4.	Animal Production and Potential Wastes	21
5.	Potential Municipal Solid Wastes Resources	27
6.	Potential Municipal Solid Wastes from Provincial Capitals	28
A.1	Energy Consumption by End-Use Sector in Ecuador	45
A.2	Number of Agroindustries by Type and Provinces	72
A.3	Major Agroindustries of Interest for Energy Production	75
A.4	Production of Fuel Logs from Bagasse	80
A.5	Production of Fuel Pellets from Municipal Solid Wastes	82
A.6	Production of Fuel Logs from Cotton Trash	85
A.7	Steam and Electricity Production from Solid Wastes	87

LIST OF FIGURES

NUMBER	TITLE	PAGE
1	Production Areas of the Main Crops	9
2.	Locations of the Main Agroindustries	14
3.	Cost of Substitute Fuel From Bagasse	18
4.	Cost of Biogas	23
5.	Cost of Electricity Generated From Solid Waste	31
A.1	Energy Balance for Ecuador	44

EXECUTIVE SUMMARY

The authors of this report, representing the USDA-FS/SEA Bioresources Team, visited Ecuador from 17 November to 4 December 1980 to assess the nation's biomass resources and to recommend ways to better utilize these resources for energy production. Our objectives were further refined by officials of Instituto Nacional de Energia and the USAID Mission in Quito: review INE's fuelwood program; evaluate crop residues as energy sources; review the INE biogas demonstration program; and assess the feasibility of "energy crops" for Ecuador.

Fuelwood remains the dominant fuel for low-income families in Ecuador. The nation's continuing growth in population has created needs for more cropland and for greater amounts of fuelwood; as a result, forests have been cleared and local firewood is increasingly scarce in many populous regions. INE plans to alleviate shortages by encouraging both greater production and more efficient use of fuelwood.

Some crop residues (sugar cane bagasse, sawdust, rice hulls, pulp of coffee and cacao, cotton stalks) may be compressed to form solid fuel substitutes for wood. Some of these materials are readily available at mills, simplifying raw material collection. We report cost analyses of hypothetical cases which suggest that solid fuels from crop residues may be economically feasible and warrant further study.

Municipal wastes might be valuable energy sources for Ecuador. Solid wastes can be processed into a Refuse-Derived Fuel (RDF) that could substitute directly for wood or coal in solid-fueled industrial boilers or could be

converted into a low-Btu gas and used in modified oil-fueled boilers. We estimate that electricity generated from RDF should be competitive in price with that from a commercial electrical grid if waste-conversion plants to make RDF can be financed at low interest rates. The true feasibility of such an operation will depend upon the quantity and nature of wastes available, costs of collecting them, and costs of preparing RDF.

Manure from farm animals can be used to produce biogas (a mixture of methane and carbon dioxide) as a fuel for rural homes and small industries. Estimating the overall potential for this is difficult because quantities of manure actually available are uncertain, and likely markets for the biogas are not clearly defined. These and other uncertainties may be clarified during the course of INE's biogas demonstration program that is now beginning. Seven small (3 to 15m^3 capacity) generators are being installed in rural locations from the Sierra to the Pacific coast to demonstrate biogas generation and use. Basically, we believe this is a well-conceived program that can be of great benefit to Ecuador's rural poor. Implementation must be improved, however, if the program is to succeed. We believe a comprehensive "systems approach" must be followed for each unit; our recommendatons for this are listed below.

Section III of this report gives our conclusions and recommendations for action. In capsule form, the recommendations are as follows:

<u>For the INE Fuelwood Program</u>:

1. Identify major sources and distribution patterns (both commercial and non-commercial) of fuelwood; set priorities for actions to increase supplies.

2. Identify geographical areas where fuelwood shortages are most acute, and develop regional plans to meet the needs.

3. Form an interagency task force to ensure that "fuelwood production components" are included in all GOE forestry projects.

4. Develop, and promote the use of, more efficient wood cookstoves.

5. Determine the technical and economic feasibility of wood-substitute solid fuels from crop residues; sponsor production and marketing trials for any which appear feasible.

Municipal solid waste can be used as fuel, reducing some demands for wood.

6. INE should determine the feasibility of producing RDF (at least in major cities having regular trash collection) and using it as an industrial fuel.

INE's demonstration biogas program should emphasize a "systems approach".

7. Each demonstration unit should have a comprehensive plan accounting for (a) feedstock; (b) operation of digestor; (c) biogas utilization; (d) residue utilization; (e) complete cost data; and (f) operator and consumer reactions. Types of data to be collected, and frequencies of collection, should be specified, and should be the same for all sites.

8. INE should require each operator to adhere to the comprehensive plan for his unit, and monitor to ensure compliance.

9. Summary data from all sites should be maintained on a continuing basis -- with frequent analyses -- in INE headquarters.

10. Applied research on the technology and economics of biogas production, distribution, and utilization should be strengthened.

11. Two or three skilled engineers should be appointed by INE as "trouble shooters" to provide technical backstopping for the demonstration units.

12. After the program has operated for approximately one year, results should be used to analyze the probable feasibility of biogas fuel in Ecuador.

USAID support, though necessarily limited to selected INE activities, appears to be very effective and should be continued along present lines. We suggest only one new initiative:

13. An international newsletter (possibly prepared by the USDA Bioresources Team for distribution by USAID Office of Energy to AID Missions world wide) could inform USAID/Quito and INE personnel about important projects, publications, meetings, etc., directed to the production, processing, and utilization of biomass-for-energy. Timely dissemination of such information would help national energy agencies such as INE.

"Energy crops" (woody or herbaceous plants cultivated primarily as sources of energy) could be produced at many locations within Ecuador without competing with food crop production. Economically, however, we do not believe that energy farming is feasible under present conditions. Therefore, we recommend that no action be taken at this time.

BIOMASS-FOR-ENERGY IN ECUADOR: AN ASSESSMENT

I. INTRODUCTION

In October, 1980, the USAID Mission in Ecuador and the Government of Ecuador (GOE) requested an assessment of Ecuadorean biomass-for-energy resources and programs. The Office of Energy (DS/EY) of USAID Washington forwarded the request to the USDA-FS/SEA Bioresources Team which provides such services under terms of a USAID/USDA PASA. The authors of this report were selected to conduct the assessment and visited Ecuador from 17 November 1980 to 6 December 1980.

The general objectives of the visit as defined by the traffic cable were:

"The purpose of the visit is to assess biomass resources of the country, to recommend actions which may increase their utilization as renewable supplements to -- or substitutes for -- non-renewable fuels. To make this assessment the team, working closely with appropriate officials of GOE and AID/E, will: 1. Survey existing biomass resources in ecologically and geographically different regions of the country; 2. Consider possible new approaches to biomass production including, for example, introduction of new plant species and/or changes in management of existing ones; 3. Compile systematic data on existing technologies for converting biomass to useful fuels, and identify additional technologies needed to increase the conversion and utilization of bioresources for energy; 4. Review the existing institutional infrastructure (e.g. government, academic, and private-sector industry/forestry/agriculture) which may determine capabilities for technological changes; 5. Identify non-technological factors (e.g., socio-economic, geographic, economic, etc.) which must be considered before

technologically-feasible programs are approved or rejected; 6. Respond to specific requests of GOE and AID/E as they are put forth; 7. Submit a comprehensive report to GOE and AID/E summarizing the present status of bioresources, estimating future potentials, and identifying options to be faced by GOE and AID/E officials."

The scope of our work was made more specific by Dr. Carlos Quevedo, Executive Director of Instituto Nacional de Energia (INE) and Mr. Gary Vaughan, AID Capital Development Officer. As the GOE agency responsible for energy affairs, INE sponsors several biomass-for-energy programs, some of which receive AID funding. While all of INE's biomass activities would be reviewed, we were asked to pay particular attention to:

1. Fuelwood Programs. INE is promoting both increased production of fuelwood and its more efficient use as a domestic fuel; we were to evaluate these efforts.

2. Crop Residues. Some residues are already used as fuels but many are discarded as waste. We were asked to review present uses and assess potential new uses of residues from:

   a. Sugarcane (bagasse)

   b. Grain crops (wheat straw, corn stovers, rice hulls, etc.)

   c. Tree crops (pulp from coffee and cacao "beans", etc.)

   d. Others (banana plants, weeds, etc.)

3. Biogas Demonstration Projects. Seven biogas generators are either in operation or soon will be ready; INE plans to use these to demonstrate the value of biogas fuel for farms and other small-scale users. We were asked to visit as many of the generators as possible and to evaluate the INE biogas program.

4. Energy Plantations. We were asked to assess the feasibility of growing crops for conversion to fuels in locations not suited to the production of higher-priority food crops or livestock.

Our findings for each of the four program areas are presented below in Section II of this report, while Section III includes general conclusions and specific recommendations for the consideration of INE and USAID officials.

In carrying out this work, we read many documents to obtain background information, had meetings with many persons involved with aspects of biomass, travelled extensively through the Sierra and Coastal regions, and visited industrial users of biomass. These activities are summarized in the Appendices listed in the Table of Contents and attached to this report.

II. BIOMASS RESOURCES OF ECUADOR

This section presents our findings of the biomass resources of Ecuador, their present utilization and future potentials. These findings are organized according to the specific request of INE and USAID officials.

A. Fuelwood Production and Utilization.

1. Background.

In 1956 the National Forest Service estimated that about 70 percent of Ecuador was covered by forests. Present estimates are that about 56 percent of the land is covered by natural forests. Although some artificial (managed) forests have been planted, natural forests are being reduced at a fast pace. This situation is brought about by a number of factors such as the failure by the wood products industry to comply with reforestation laws and by squatters settling in deforested areas without regard to the possible ecological consequences. As a result, erosion and desertification have become very serious problems especially in the Sierra where steep slopes and high rainfall are common (8, 9).

According to FAO data (10), 3.8 million cubic meters of wood were harvested in 1978. About half of this amount (1.9 million m^3) was used for fuelwood and charcoal production; the rest was (sawlogs, veneer logs, sawnwood, etc).

2. Fuelwood Utilization and Its Problems.

An annual harvest of 1.9×10^6 m^3 of fuelwood (FAO data) amounts to an energy value of 422 MTEP*. In contrast, a recent INE survey (1) estimates that Ecuador's rural population uses 783 MTEP annually. We cannot

explain the large discrepancy between estimates but the FAO data probably do not include fuelwood cut from small lots, cutting of brush and hedgerows, etc. Actually, there is little organized information on quantity of fuelwood used and where it comes from; many families gather all of their wood without payment but other families must purchase part or all of their fuelwood needs. Better information on the commercial aspects of fuelwood could significantly improve programs to meet future needs.

Continuing demand for fuelwood contributes the over-exploitation of Ecuadorean forests; trees, shrubs and bushes are all cut, and even roots are dug up for fuel. Serious damage to forest ecosystems caused by fuelwood collection is a common problem in many developing countries (12). To lessen the pressures on existing forests, and to reverse present trends, one or more of the following steps will be necessary: use other fuels in place of wood; increase supplies of fuelwood (woodlots and/or multipurpose, properly-managed forest plantations); increase the efficiency of using wood as a fuel.

Ecuador's newly-exploited petroleum resources have profoundly modified national energy-use habits. Bottled gas, kerosene, and even gasoline are frequently replacing wood as a fuel in both home and industries. On the other hand, rapid growth of population and pervasive rural proverty tend to maintain a steady demand for fuelwood. Despite increased use of fossil fuels (Appendix I), it is probable that wood will continue to be a major energy source in Ecuador for the forseeable future.

* MTEP: Thousand Ton Equivalent of Petroleum = 10^{10}kcal=3.97 x 10^{10} Btu (see Appendix IX).

The principal use of fuelwood in Ecuador appears to be for preparing family meals. Wood-burning cook stoves are generally inefficient, particularly in rural homes where the "stove" may be 3 stones supporting a vessel over an open fire. Any improvement in the efficiency of cook stoves, therefore, should tend to reduce per capital use of fuelwood.

According to recent INE estimates (16), the average energy needed for cooking is 977 kcal/person/day while about 2 kg of fuelwood/person/day are used-- a 16% efficiency, well within the range reported by various authors (12). By doubling the efficiency to 32% (a reasonable goal), a family of four would save about S/912 ($33) per year; assuming that the investment in the improved stove must be repaid in a year, this annual saving equals the maximum acceptable price. A lower initial cost, of course, would reduce the time needed to pay back the investments.

INE plans to test metal stoves of improved design; if test results are promising, INE will promote their widespread use by users of fuelwood. The outer surfaces of metal stoves, however, radiate energy and serve as space heaters. If this housewarming effect is not desired, an efficient stove made of bricks or cement would be better than one of metal.

3. Potential Resources.

If future fuelwood needs are to be met without further destruction of existing forests, a large-scale, systematic program to establish and maintain tree plantations is urgently needed. Plantations may range from small community woodlots to large, multipurpose forests yielding a variety of

products--but they must provide fuelwood needed by area residents. A number of reforestation projects are now underway in Ecuador, on both public and private lands. It is our understanding, however, that these projects generally emphasize lumber production and do not emphasize fuelwood needs. INE may be able to collaborate with sponsors of such reforestation projects (both public- and private-sector) to include fuelwood production as an important objective. Also, INE could work with MAG to determine the best species and management systems, production costs, etc. for producing fuelwood in different regions of the country.

4. INE Fuelwood Programs.

In its role as planning and coordinating agency for Ecuadorean energy affairs, INE must deal with the production, distribution, and utilization of fuelwood.

To date, INE apparently has no programs to increase the production of fuelwood. The Ecuadorean Forest Service, an agency of MAG, has various projects in reforestation, forest management, etc. The U.S. Peace Corps is assigning a dozen or more Volunteers to work with MAG foresters and extension agents in community forestry projects. We believe that INE should work with these agencies so that forestry projects will include fuelwood production components.

INE and the MAG extension service recently surveyed (11) fuel use by rural residents in several provinces; results show where, and to what extent, kerosene and other fossil fuels are affecting traditional uses of fuelwood.

The planning and execution of this survey appear to have been excellent--as far as they went. We believe that a followup survey should be carried out to obtain information about the sources and methods of distributing fuelwood throughout the country. Where does it come from? How is it distributed? Of the total amount used, what proportion is bought and sold, etc.

To increase the efficiency of fuelwood utilization, INE also plans to test wood stoves of improved design. We believe that this is a much needed undertaking. We understand that this program will include essential socioeconomic data gathering aspects such as social acceptance of the new system, availability of materials and infrastructure for the manufacture of the equipment, economics from the end-user point of view, etc.

B. Crop Residues and Other Waste Materials.

1. Crop Production Overview.

Figure 1 shows the areas of production of the main crops by regions and provinces. Most of the cereals, livestock, and some irrigated sugarcane, corn and beans are produced in the Sierra region. Export crops such as bananas, coffee and cacao, rice, cotton, and cattle are produced mostly in the Coastal region.

2. Crop Residues.

Crop residues, i.e., the plant parts not used for food, fiber or feed, may be valuable sources of energy if their use does not create ecological or environmental problems. Crop residues can be converted to energy or fuels through a variety of processes: direct combustion, gasification, pyrolysis, fermentation, etc. The selection of the most

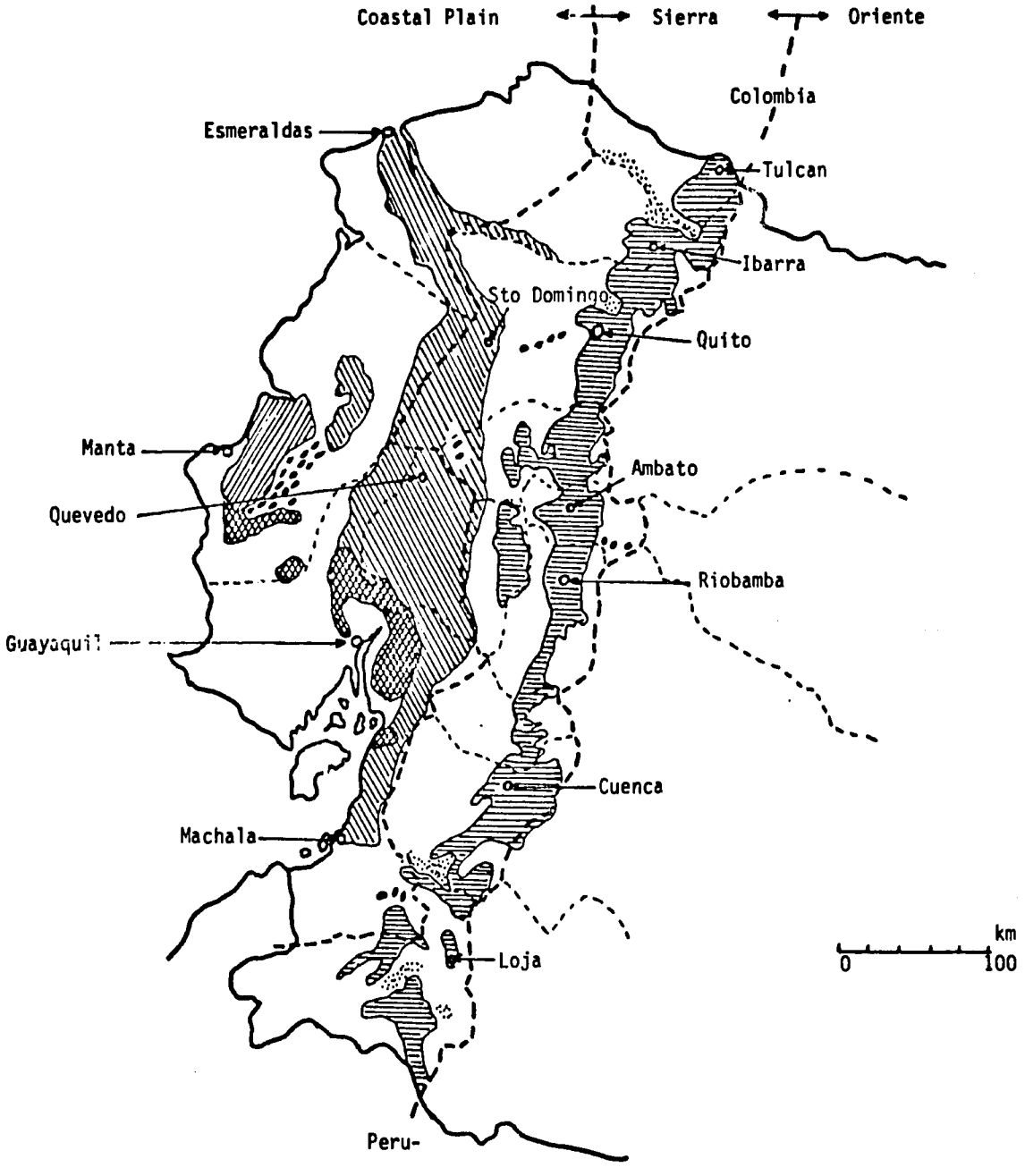
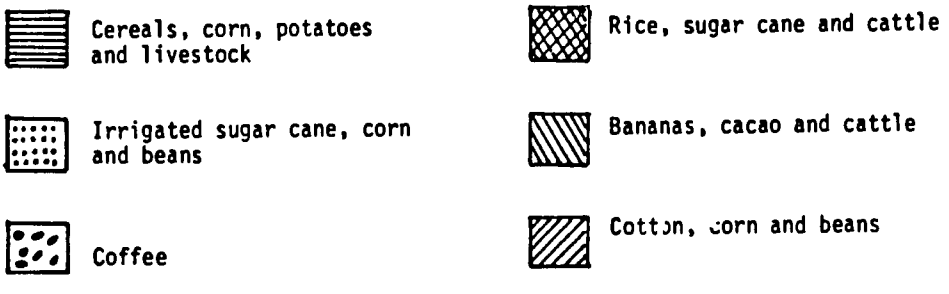


Figure 1- Agricultural Production in Ecuador



Source: Reference 3

appropriate conversion technology will depend upon both the nature of the crop and the end result desired. Generally speaking, the dry residues are best suited for direct combustion, gasification, or pyrolysis; moist residues are most easily converted through wet fermentation or digestion. High-lignin crops (woody species for example) are difficult to ferment without extensive processing but are easy to burn directly.

In view of INE's expressed concern about fuelwood supplies and utilization, our analysis of the energy potential of crop residues has mostly considered residues as solid fuels to substitute for fuelwood. Substitute solid fuels can be obtained by compressing crop residues to form pellets (stoker fuel), briquets, or logs. Examples of the process are described in Appendix VII for various residues.

Table 1 shows the production of the major crops of Ecuador, the types of residues, and their probable availability. Some of the major residues--bagasse, rice, coffee and cocoa hulls--are expected to be available mostly at the processing plants; i.e., agroindustrial plants.

Agroindustries are industries processing products from the agricultural or forest sectors. In view of the potential for recovery of crop residues at processing sites, the regional distribution of agroindustries was analyzed using a MAG inventory (7) to identify the most promising industries and their locations (Appendix V).

Six categories of agroindustries have potential for energy production from wastes: meat products; milk products; vegetable processing; mills processing wheat, rice, coffee and cocoa; sugar mills; and wood products plants. Table 2 characterizes these industries and Figure 2 indicates the location of the main industries by provinces.

TABLE 1 CROPS AND CROP RESIDUES

Crops	Major Area Of Production	Production (1,000 MT)	Potential Residues	Residues Availability
Wheat, Barley, Rye, Oats	Sierra	47	Straw Hulls	Used partly for feed (see Appendix III) on farms. Available at mills, no data.
Rice	Coastal Plain	303	Hulls	Available at mills. Some used on cotton fields, some burned (see Appendix III).
Maize	Sierra	217	Stalks	Partly left in field, practice should be maintained for erosion control(See Appendix III). Partly available at farms.
Potatoes	Sierra	545	Plants in field	Probably turned in ground.
Roots and Tubers	--	764	--	No data available
Pulses, total[1]	Sierra	73	Plants in field. Pods	Probably turned in ground.
Vegetables, total	Sierra, Coastal Plain	307	From consumers From processing	In city/town garbage At processing plants
Fruits, total[2]	Sierra, Coastal Plain	4103	From consumers From processing	In city/town garbage At processing plants
Sugar cane	Sierra, Coastal Plain	7000	Bagasse	Available at some sugar mills (See Appendix VI)
Coffee (green)	Sierra, Coastal Plain	102	Hulls	Available at mills (See Appendix III).
Cocoa	Coastal Plain	78	Hulls	Presumably available at mills
Cotton Fiber	Coastal Plain	10	Plants in field Processing residues	Presently burned in field (see Appendix III). Available at mills, no data available.
Bananas	Coastal Plain	2391	Plants in field Packing, export Residues/rejects	Probably not available (see Appendix III). Amounts not available

Source: Reference 4.

[1] Includes dry beans, dry broad beans, dry peas and lentils
[2] Excludes bananas and plantains

TABLE 2 - MAJOR AGROINDUSTRIES OF INTEREST FOR ENERGY PRODUCTION

Industries	Residues	Number of Enterprizes in Country	Comments
Meat Products	Biodegradable material	22	Amounts of residues not known. Industries of fairly uniform size
Milk Products	Biodegradable material	37	Amounts of residues not known. Industries of variable sizes.
Vegetable Processing	Biodegradable material	21	Amounts of residues now known. Industries of variable sizes.
Mill Products:			
Wheat	Hulls	36	Smaller potential of mill industries. Industries of variable sizes.
Rice	Hulls	39	Significant potential. Industries of widely variable sizes. Some residues used by farmers on cotton fields (see Appendix III)
Coffee/Cocao	Hulls or pulp	11	Largest potential of mill industries. Size of industries widely variable.
Sugar Mills	Bagasse	6	A large fraction of the bagasse is used for fuel in the plants. At least one plant identified which has surplus residues (see Appendix III). Size of industries widely variable.
Wood Products.	Sawdust	112	Only unused residue observed was sawdust. Potentially significant potential. Industries of variable sizes.

Source: Appendix V.

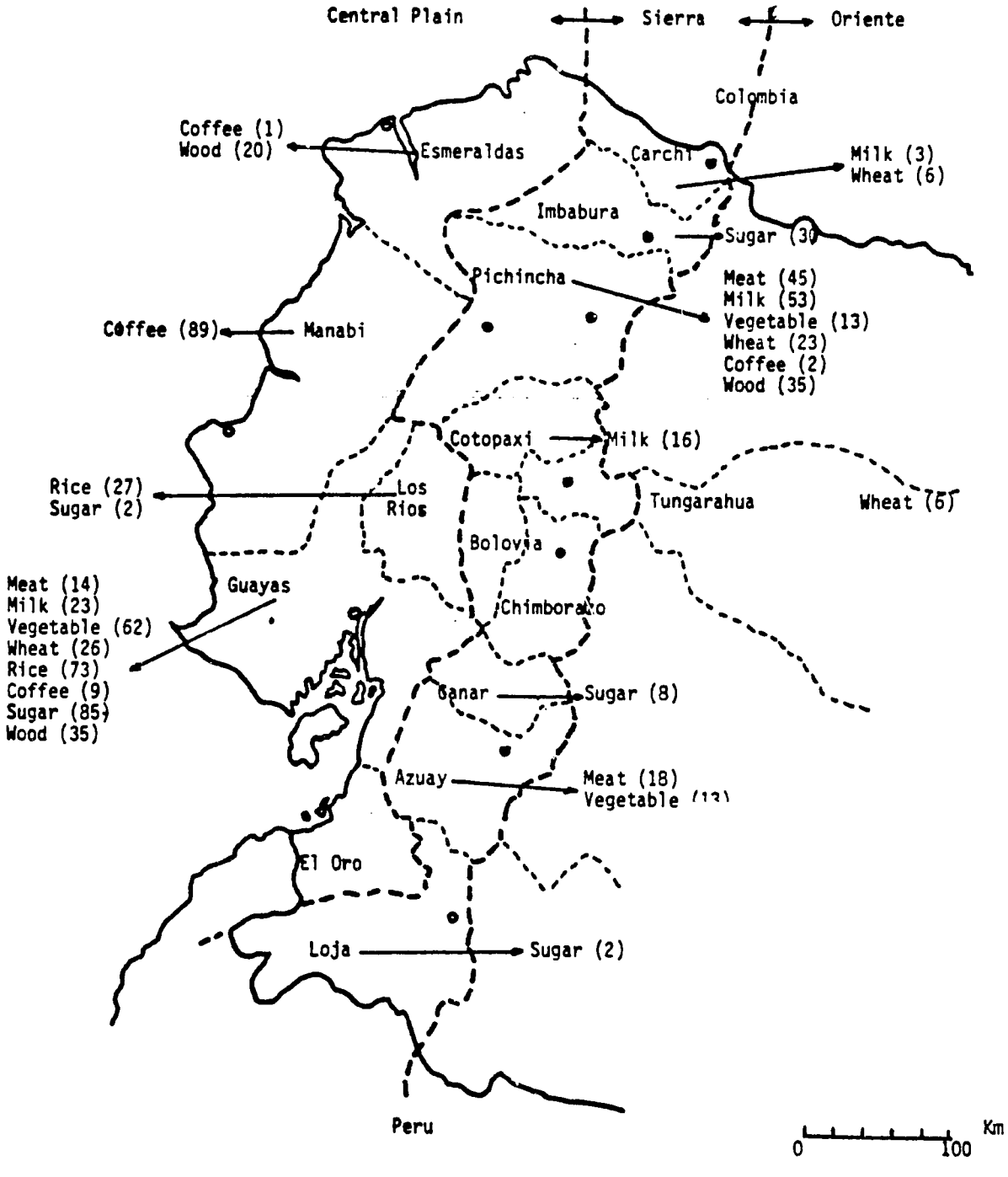


Figure 2—Location of the Main Agroindustries with Residues for Energy Production By Provinces

( ) Estimate of the production capacity in province in percent of national capacity

Most meat and milk industries are in the Sierra region. Vegetable processing is concentrated in the Coastal Plain in the province of Guayas. Wheat and other cereals are milled in the Sierra, while rice is milled in the Coastal Plain. Coffee milling is concentrated in the Province of Manabi. The larger sugar mills are in the Coastal Plain, province of Guayas, with a few smaller plants dispersed in the Sierra. Wood processing occurs both in the Coastal and Sierra regions. Residues from other crops such as fruits and vegetables, will be concentrated at food processing plants or where refuse is collected (city or town garbage or farm/family garbage).

Some dry residues (eg. cotton stalks, corn stovers, wheat straw, etc.), presently plowed under or burned in the field (see Appendix III), could be collected on farms for use as solid fuels in place of fuelwood. Others (eg. cotton gin trash, rice hulls, coffee and cacao pulp, bagasse, and municipal solid wastes), are already collected at processing mills or other central sites. To be practical fuels, such materials must burn well and be competitive in cost per unit energy with other sources of energy. Cost of collection must be low, and distribution to the end user must be convenient and cheap. Distribution costs in rural areas where end-users are widely dispersed may make the fuel too expensive.

a. Solid Fuel from Bagasse. A sugar mill that we visited in Imbabura Province (Appendix VI) was used to calculate the potential costs of bagasse as a substitute solid fuel (Appendix VII). The analysis assumes the purchase of a hydraulic press (readily available) to compress the fibrous material into briquets or artificial logs. The selling price of the substitute fuel allows for capital, operating, and labor costs and provides a

30 percent profit margin. Transportation costs must be added to this price if the profit margin is to be maintained. Table 3 summarizes the main characteristics of the operation. Figure 3 shows the cost of the delivered fuel logs as a function of the distance of distribution. It is apparent that on a weight basis artificial logs would be competitive with fuelwood within about 80 km (about 50 miles) of the plant. Because of its lower moisture content, the artificial log will provide more energy per unit weight than fuelwood and, on this basis, artificial logs could be competitive with fuelwood up to about 600 km if transportated by rail.

It is estimated that excess bagasse from this mill could satisfy solid fuel needs of about 20,000 people yearly. The economic potential of using these residues, therefore, appears attractive and should be investigated.

b. Solid Fuel From Hulls. Coffee and cacao pulp probably can be formed into logs in much the same fashion as bagasse. A binder may be needed to hold the materials together. Significant amounts of residues appear to be available but no quantitiative data could be obtained.

Rice hulls present some specific problems due to their high content of silica. They burn poorly and abrade the equipment used in their processing, but have been used sucessfully in industrial boilers to generate steam (21). Equipment has been tested to form rice into logs but it is not clear if this technology has a real future. Rice hulls can be burned in specially-designed home stoves, but such stoves would be an extra expense for the user. Pyrolysis of rice hulls yields charcoal and various chemicals such as acetic

TABLE 3 - CHARACTERISTICS OF A SUBSTITUTE SOLID FUEL PLANT USING BAGASSE RESIDUES FROM A SUGAR MILL IN THE PROVINCE OF IMBABURA[1]

Bagasse Residues: 90 MT/day (50% moisture)

Log production: 58.4 MT/day (23% moisture)

11,680 MT/year

Capital Investment: S/16,440,000 ($600,000)[2]

Capital Cost: 18% of capital per year[3]

Operating Costs: 4% of capital per year

Lifetime: 25 years

Labor force: 140 man/month per year[4]

Profit: 30% of total yearly costs

Cost at plant gate: Soo.50 per kg

Population served: 16,000 people[5]

20,000 people[6]

[1] See description in Appendix VI

[2] Reference 19

[3] Reference 20

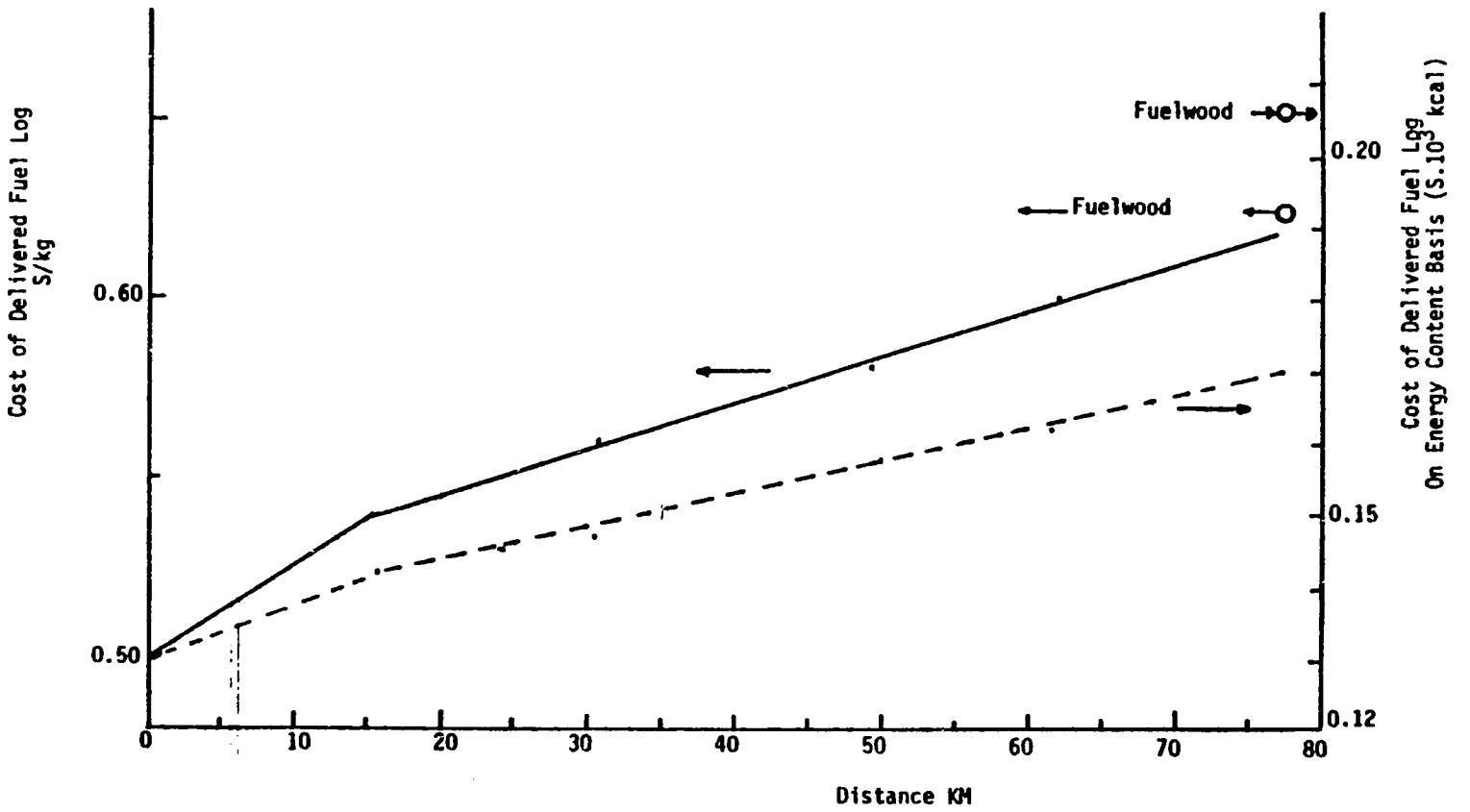
[4] Estimated

[5] Based on 2 kg wood fuel per capita per day (Reference 11)

[6] Based on higher calorific value of the substitute fuel.

Figure 3 - Cost of Delivered Fuel Logs Made From Bagasse

Data from Appendix V.
Transport by truck



acid, methanol and acetone; the charcoal, however, is finely divided and difficult to recover. In short, any attempt to convert rice hulls to useful fuels or chemicals may confront technical and economic problems; these problems should be recognized.

c. Others.

Solid Fuel from Cotton Residues. If cotton stalks (presently burned in the field) can be removed without ecological damage, they might also be converted to a substitute solid fuel. We present (Appendix VII) calculations for a hypothetical plant to be operated a few months of the year by a farm family. This plant would be operated by two persons, and would require a grinder and a hydraulic press both of which could be run from a truck engine by pulleys. If capital cost are no greater than S/13,000 and if the fuel logs are sold on the basis of their fuel value rather than on a weight basis, an average income of about S/3,500 per month could be realized for a three months working period. Based on published data of cotton production and standard residue factors (22), the solid fuel from cotton trash could provide the cooking fuel needs for about 20,000 people per year.

- Solid Fuel From Sawdust. The hydraulic press used for bagasse could also be used for sawdust and the analysis suggests that fuel logs derived from sawdust could also be economically attractive as a substitute fuel. Although we saw numerous sawdust piles, some of which were burning, we found no estimates of the quantity of sawdust actually available.

3. Animal Wastes.

a. Availability.

The major areas of cattle and livestock production are shown in Figure 1. Table 4 shows the inventory of the major classes of animals, and the potential for residue (manure) collection. Manure can only be collected economically from confined animals. From direct observation (Appendix III)

TABLE 4 - ANIMAL PRODUCTION AND POTENTIAL WASTES

Animals	Main Area of Production	Production (1,000 Heads)	Potential Residues	Residues Availability
Milking Cows	Sierra	600	Manure	Can be collected while animals are confined either in small farms (3-4 cows) or larger herds (20-80 cows), (see Appendix III)
Horses, Mules, Asses	Sierra, Coastal Plain	579	Manure	Can be collected while animals are confined.
Cattle	Coastal Plain	2,532	Manure	Can be collected while animals are confined.
Pigs, sheep, goats	Sierra and Coastal Plain	5,950	Manure	Can be collected while animals are confined.
Chicken, etc.[1]	Sierra and Coastal Plain	23,121	Manure	Can be collected while animals are confined.
Animals slaughtered[2]	Sierra and Coastal Plain	2,459	Manure	Can be collected while animals are confined at slaughter house.

Source: Reference 4.

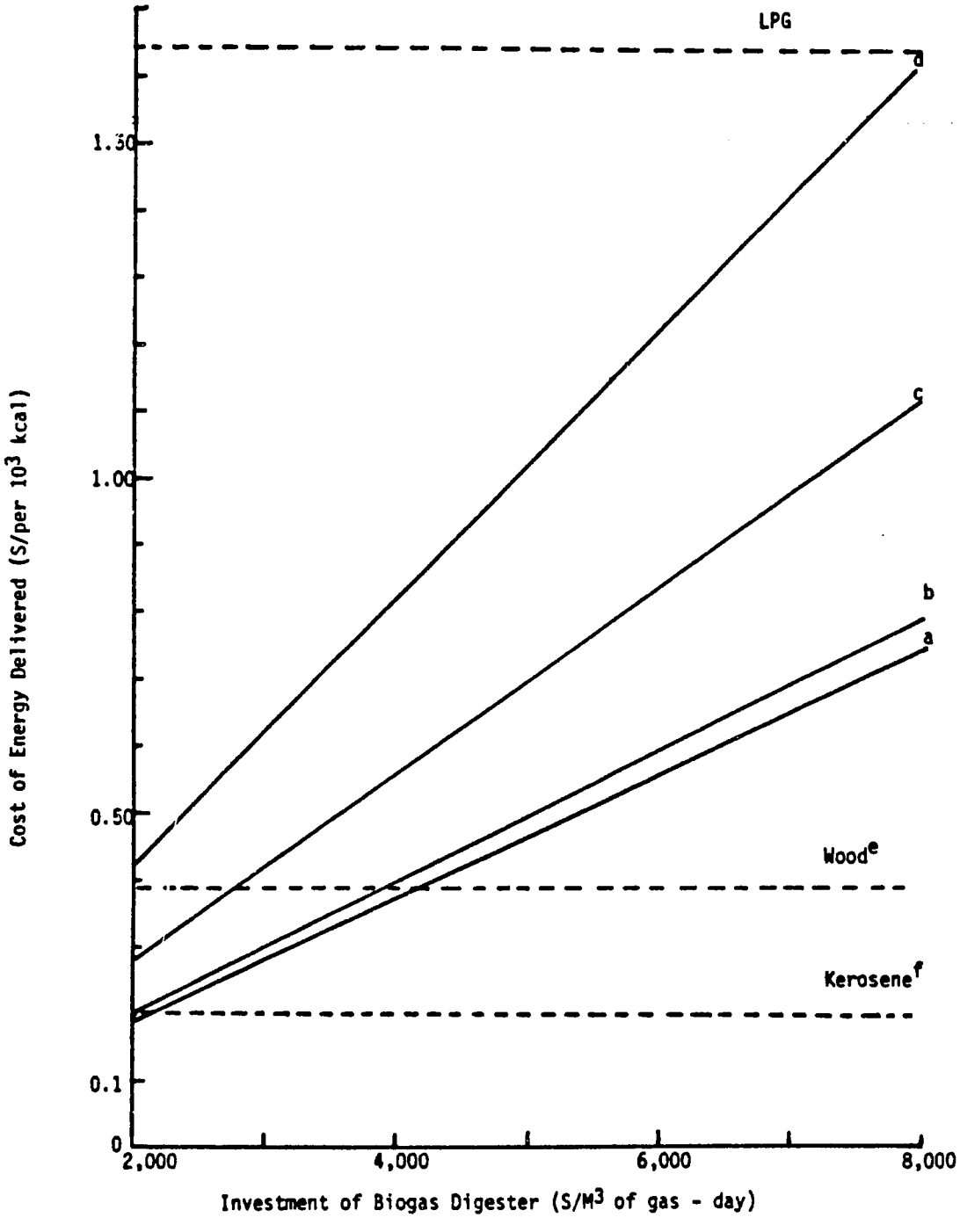
1 Includes ducks and turkeys.
2 Includes beef, veal, mutton, lamb, goat and pigs.

and discussions with Peace Corps Volunteers (Appendix II), it is apparent that Ecuadorean cattle spend most of the day in open pastures, and are confined only for milking, or overnight for safekeeping. If the animals are confined for half of each day, the amount of collectible manure should, therefore, be approximately one half of the daily amounts quoted in standard reference books (5, 6).

b. Biogas Production.

The production of biogas from animal manure is a well known technology. Digesters can be very simple but even so may cost more than poor rural families can afford. This is illustrated in Figure 4 which shows that capital cost of the digesters is a critical element in determining the competitive position of biogas versus other fuels. If biogas is to be an important fuel, for poor families, its cost must be very low.

Figure 4 - Comparison of Cost of Delivered Energy From Various Fuels



a. Fixed equal repayments over 15 years, no interest

b. 7% on cost of digester

All other fuels: 40% conversion

c. 10% on cost of digester

d. 15% on cost of digester

e. Wood at 15% conversion

f. Wood at 32% conversion

Biogas contains varying amounts of H_2S and NH_3 which corrode equipment and create health hazards. The impurities can be eliminated by traps in the distribution lines but this adds to the costs and complexities of a biogas system. The possible need for such refinements should be accounted for in planning any biogas installation.

Theoretically, any organic material can be anaerobically digested to produce biogas. Practically, however, conversion efficiencies vary widely between difficult feedstocks, methods of preparing of the material, and operating conditions. Animal manures, milk, meat and cellulosic plant materials are easily digested. High-lignin plant materials are less readily digested. Data are needed to establish the potential value for biogas production of residues available in Ecuador.

Biogas generators require large amounts of water to dilute the solid residues being digested. In arid areas of the country, such as Manabi Province, inadequae water supplies may make biogas generators impractical. Designs for water-recycling generators should be developed.

c. The Market for Biogas.

The obvious market for biogas is the rural sector where biogas could substitute for scarce fuelwood. For a farm with livestock, biogas could be produced from collected manure. Assuming 977 kcal per day per person are needed for home cooking, a family of four will need 3,908 kcal per day for cooking. Assuming a combustion efficiency of 40% for biogas in cook stoves, the family would require 9,770 kcal (2 cubic meters) of biogas per day. For a manure output of 11 kg cow per day as is reported for India (5)

and a production of $0.062m^3$ of biogas per kg of manure, the family will require the total daily manure output of 3 cows. If only half of this manure is actually collected, the family would require 6 cows to provide the needed biogas. Although speculative, these estimates suggest that, on many small farms, the collected manure will not generate enough biogas to satisfy all fuel needs. Multi-family or community systems, with appropriate distribution methods, may be a practical approach.

4. Municipal Wastes.

Municipal wastes can be converted to energy. Solid wastes are directly burned to produce steam in many plants now operating in Western Europe, Japan, and the United States. Suitable boilers are sold in sizes ranging from small units, with daily capacities of a few tons of wastes, to large custom-designed plants burning more than 1,000 tons per day of solid wastes (24, 25). Steam from the boiler can be used to heat buildings, or for ind;strial process heat, or to generate electricity. Sewage and other liquid wastes can be anaerobically digested to biogas. From our travels within Ecuador, and from conversations with INE officials, we believe that municipal wastes are not now being utilized. Because of high initial costs, it may not be feasible to extract energy from municipal wastes at this time; in the longer term, however, INE should seriously consider this option. The following discussion is offered to indicate some possibilities.

a. Availability of Solid Wastes.

We used official census data (18) and several assumptions about per capita waste disposal to calculate amounts of solid wastes which might be available in the cities and towns of Ecuador. We assumed an average "waste

production" of 0.75 kg per person per day (one-half the 1975 U.S. rate (17)), with the waste having a heat content of 2,560 kcal/kg (4,620 Btu/lb); we further assumed 100% collection of available wastes in all cities and major towns of Ecuador (Table 5) or, for a more limited hypotheticl case, only the capital cities of the Sierra and Coastal Provinces (Table 6). The true national "output" of solid wastes presumably would be intermediate between the estimates of Tables 5 and 6.

The amounts of solid waste we estimated have heat contents equivalent of from 142,000 tons (Table 6) to 192,000 tons (Table 5) of petroleum -- roughtly comparable to Ecuador's total production of electrical energy in 1978 (Appendix I). An energy resource of this magnitude merits consideration; INE may wish to develop methods to recover the energy that is now being thrown away.

b. Refuse-Derived Fuel (RDF) From Solid Wastes.

Municipal trash includes a wide variety of discarded materials. If this raw waste is sorted, and non-combustibles (metal, glass, rocks, etc.) removed, the remainder is organic, combustible matter; shredding and drying this matter yields a dispersed, fluffy Refuse-Derived Fuel (RDF) that can be burned directly or mixed with other fuels such as coal or oil.

TABLE 5 POTENTIAL MUNICIPAL SOLID WASTES RESOURCES

Region/Provinces	Urban Population (10^3 Inhabitants	Wastes (10^3 MT/Year)	Heating Value (10^9 kcal/year)
SIERRA:			
Carchi	38.1	10.4	26.6
Imbalura	69.6	19.1	48.8
Pichincha	658.7	180.3	461.6
Catopaxi	32.4	8.9	22.7
Tungurahua	93.6	25.6	65.6
Chimbarazo	88.2	24.1	61.8
Bolivar	19.1	5.2	13.4
Canar	19.9	5.4	13.9
Azuay	117.5	32.2	82.3
Loja	125.7	34.4	88.1
Total Sierra	1,262.8	345.6	884.8
COASTAL PLAIN:			
Esmeraldas	72.1	19.7	50.5
Manabi	218.0	59.7	152.8
Guayas	956.6	261.9	670.4
Los Rios	97.4	26.7	68.3
Eloro	126.4	34.6	88.6
Total Coastal Plain	1,470.5	402.6	1,030.6
TOTAL	2,733.3	748.2	1,915.4

Source: Reference 18

[1] MT/year = metric ton/year

TABLE 6 POTENTIAL MUNICIPAL SOLID WASTES FOR PROVINCIAL CAPITALS

Provinces	Capitals	Estimated Population 1 (thousands)	Wastes (10^3 MT/year	Heating Valu (10^3 kcal/yea
SIERRA:				
Carchi	Tulcan	19.7	5.4	13.8
Imbabura	Ibarra	31.2	8.5	21.9
Pichincha	Quito	613.0	167.8	429.6
Cotopaxi	Latacunga	18.1	5.0	12.7
Tungurahua	Ambato	75.1	20.6	52.6
Chimbarazo	Riobamba	50.4	13.8	35.3
Bolivar	Guaranda	12.3	3.4	8.6
Canar	Azogues	10.0	2.7	7.0
Azuay	Cuenca	95.5	26.1	66.9
Lojo	Loja	44.0	12.0	30.8
Total Sierra	--	969.3	265.3	679.2
COASTAL PLAINS:				
Esmeraldas	Esmeraldas	62.0	17.0	43.4
Manabi	Portoviejo	47.3	12.9	33.1
Guayas	Quayaquil	857.1	234.6	600.7
Los Rios	Babahoyo	44.0	12.0	30.8
El Oro	Machala	40.9	11.2	28.7
Total Coastal Plain	--	1,051.3	287.7	736.7
TOTAL	--	2,020.6	553.0	1,415.9

Source: adapted from reference 18

[1] 1974 estimates
[2] MT/year = Metric tons per year

Municipal wastes often include materials which are toxic or at least potentially hazardous to humans and animals; unless done carefully, burning these wastes may spread dangerous combustion products over wide areas. RDF, therefore, should be burned only in plants having effective pollution control devices.

Shredded RDF can be compressed into pellets comparable, in fuel value and suitability for use in automatic stokers, to dry wood chips or coal; boilers using those solid fuels would require only minor modifications to accept RDF pellets instead. We calculate (Appendix VII) that RDF pellets should cost approximately S/0.30/kg, less than half the S/0.63/kg cost of fuelwood; with this differential, RDF could easily be preferred as a substitute for wood fuel for industrial boilers.

Oil-fueled boiler systems would require more extensive modifications to accept RDF as fuel; the RDF must be gasified, and the oil burners must be replaced with burners suitable for the lower-quality gas. We have estimated (Appendix VII) the cost of the gaseous fuel by adding the gasifier costs (capital, maintenance, and operating expenses) to the basic cost of the solid RDF. On this basis, we calculate a cost of S/0.15 per 10^3 kcal for RDF-derived gas, 50% increase over the cost (S/0.10 per 10^3kcal) of solid RDF but competitive with the cost of fuel oil deleiverd at the plant at a price of S/1.34 per liter ($0.19/gal).

c. Steam and Electricity Production From Solid Waste Fuels.

RDF-heated boilers can produce steam to drive electric generators and/or provide heat for many purposes. From data published on existing systems, we have estimated the costs of generating electricity from

RDF (Appendix VIII). According to our calculations (Table 5), a city with a population of at least 40,000 should be able to generate electricity from RDF at costs equal to or less than prices charged by an outside supplier -- if the waste processing plant can be financed at low interest rates. At present prices for petroleum in Ecuador, an RDF-based electrical generating plant cannot compete with a diesel-fueled plant but any upward movement of oil prices (seemingly inevitable) will tend to make RDF more competitive; in the medium- to long-term future, electrical generation from solid wastes may be highly attractive in Ecuador.

d. Biogas Production From Municipal Liquid Wastes.

Municipal sewage, animal manure, and other cellulosic materials can be anaerobically digested to form biogas (basically a mixture of methane and carbon dioxide), a useful fuel. Presently, the fuel value of biogas is not enough to pay for the costs of installing a sewage treatment plant. If, however, such a plant must be installed for public health or other reasons, it may be economically feasible to add a biogas generating plant to the system.

We used U.S. Environmental Protection Agency (EPA) data (23) to estimate the cost of biogas from an anaerobic waste treatment plant treating 3.8 million litres per day (in the U.S. this would represent a city of ca. 40,000 population). Depending on the amount used to heat the waste digesters, costs would range from S/1.58 to S/1.98 per 10^3 kcal, much higher than Liquified Petroleum Gas (Figure 4). If, however, the primary purpose of a treatment plant is to render municipal wastes safe, any fuel value of biogas can be credited against the costs of waste treatment, and would thus have positive

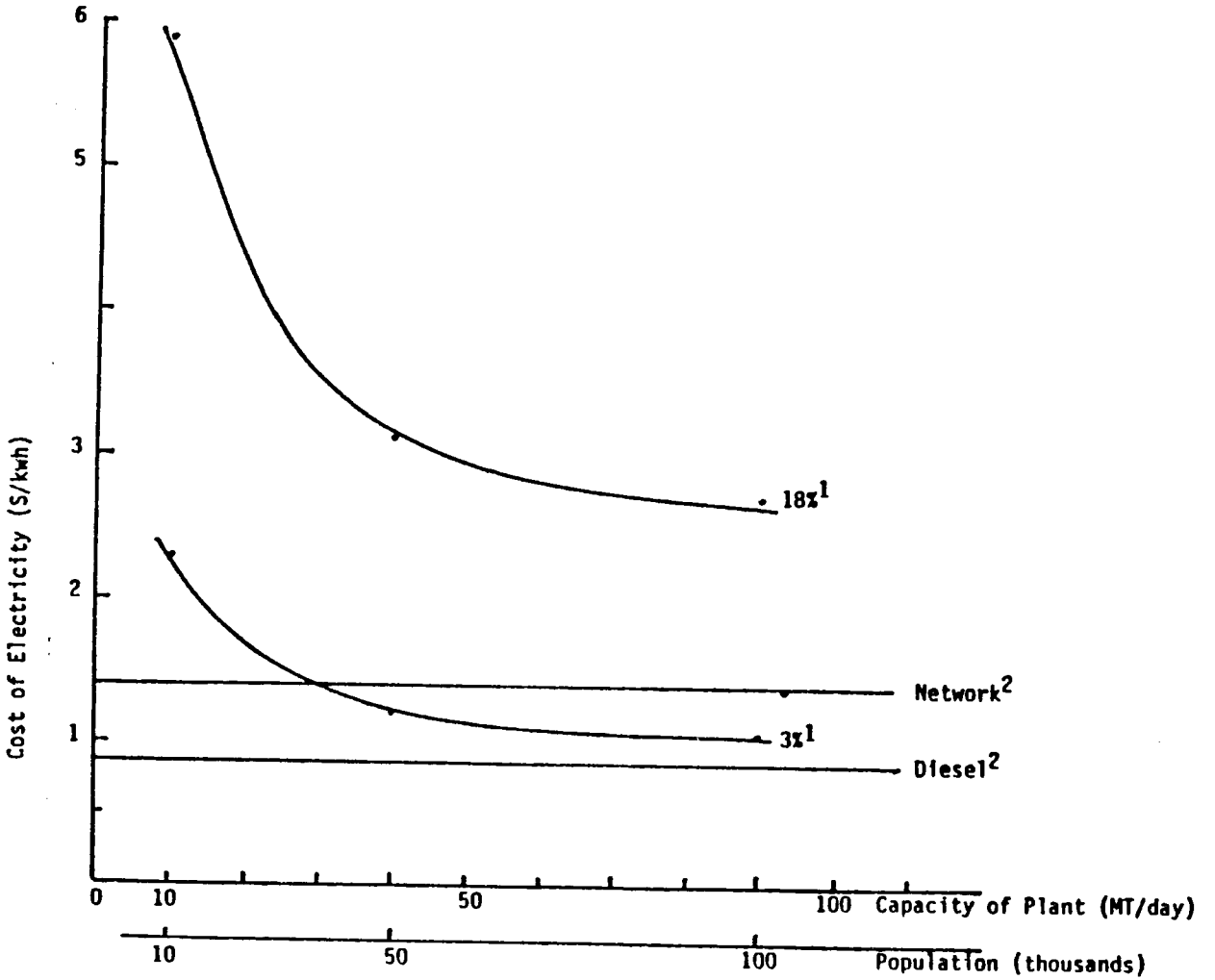


Figure 5 - Cost of Electricity Generated From Solid Wastes

[1]Capital recovery factors
[2]Prices for electricity quoted by representatives of the sugar mill Ingenio San Carlos (Guayaquil).

Economic value. On the basis of our survey, only Quito and Guayaquil, among Ecuadorean cities, now have central sewage systems and these do not treat wastes to render them bacteriogically safe; it is likely, therefore, that biogas production from sewage wastes is probably a long-term option for Ecuadorean cities.

C. INE Biogas Demonstration Program.

We reviewed this program with Ing. Eduardo Yanez and Sr. Eduardo Moran. INE is establishing seven small biogas generators at locations throughout the country. These demonstration units could have an impressive impact on rural communities which now lack sufficient fuel. Unfortunately, our visits to several sites leave us with the impression that the plans are not yet being implemented completely. We are particularly concerned about three aspects of the program: gathering of data, using the gas, and market analysis.

Few systematic data (on biogas production, operating conditions, using effluents as fetilizers, etc.) are being collected. Digesters now operating, and those to begin in the near future, should provide the data needed to expand the program at a future date. Research support should be strengthened.

Using locally-available materials, a simple cookstove has been designed by INE, and is being tested with the biogas generators; an ordinary stove used at one site was badly corroded, indicating a need to purify the gas before use. Additional research is needed to study the production of biogas from alternative feedstocks (weeds, crop residues, etc.), since most small farmers probably do not have enough livestock manure to support a single-family

digester. By-products of the digestors should be put to effective use; both the solid and liquid effluents are valuable fertilizers for non-food crops. Before they are used for food crops, however, INE should establish that they are completely free of pathogenic organisms, and that heavy metal contents are not high. Effluents of each generator should be monitored on a continuing basis -- at least until each has an experienced, well-trained operator.

We are very favorably impressed by parts of this biogas demonstration program, and by the enthusiasm and dedication of INE staff working on the program. What concerns us is that the various parts do not seem to add up to an integrated approach.

We believe that INE should insist upon a "systems approach" for this demonstration program. Raw materials go in a digester and produce biogas which is distributed to homes or processing plants where it is used as fuel. Residues are utilized in a worthwhile way. If biogas is to have value in Ecuador, this entire sequence will have to work in a reliable, economic way. The crucial question is: can the System operate reliably to produce acceptable fuel in rural Ecuador? This is no doubt that organic matter is anaerobically digested by certain organisms, yielding methane and carbon dioxide. There is doubt, however, whether this process can be harnessed to improve the lives of farm families: and it is this doubt that the INE program should address. Our recommendations for strengthening the program are given in Section III.

D. Energy Crops

The concept of "energy farming" (i.e., growing crops specifically for their energy value), often proposed (13), is now being tested on a very large scale in Brazil where fuel alcohol is produced from sugar cane, and eucalyptus trees are p.anted to provide inudstrial charcoal. Wood fuel is harvested from short-rotation forests in several countries (14), and some U.S. paper companies produce pulpwood from similar short-cycle plantations(15).

We were asked by Dr. Quevedo to consider the potential for energy farming in Ecuador, with one important restraint: the GOE will not support energy farming that competes with food crops for land, water, or other primary resources. Food production has highest priority and will continue to have it in the forseeable future. Our task, then, was to consider the feasibility of growing energy crops in places where food crops cannot be cultivated.

Ecuador possesses a tremendous variety of topographies, soils, and climates; there are many zones within the country unsuitable for food crops but which would support production of large quantities of biomass. In some (eg. rainforests), huge biomass reserves already exist; in others (eg. steep, deforested slopes in the Sierra), energy farming could protect soils from erosion, replenish water supplies, and otherwise improve adjoining croplands. If asked simply, "Could energy farming be practiced in Ecuador without reducing food production?", our answer would be equally simple: "Yes."

If asked, on the other hand, "Is energy farming feasible in Ecuador?", we would answer "No." At least, not now or in the immediate future." The difference between the two questions and answers is mostly economic. Crude

biomass has a low market value as a solid fuel; total costs (production, harvesting, processing, transporting) may equal or exceed its market value unless it is used very near the point of production. Liquid or gaseous fuels derived from biomass have higher values than solid biomass but the costs of production are also higher and yields are not high. Government subsidies could make it economically attractive to entrepeneurs to convert biomass to liquid or gaseous fuels but Ecuador's petroleum supplies eliminate the need for such an approach at this time.

Finally, technological breakthroughs could alter the economics of energy farming. Much research throughout the world seeks improved chemical or biochemical conversion lignocellulosic material to liquid fuel; engineers are improving the equipment used in processing biomass, and new devices are being invented. Steady technological advances should steadily reduce costs of biomass-derived fuels; any major "breakthrough" would drastically reduce costs and improve biomass economics. If the economics of biomass fuels do become attractive, energy farming in Ecuador could become very big business.

III. CONCLUSIONS AND RECOMMENDATIONS

A. General Conclusions

1. Time Frame.

Because Ecuador currently produces more than enough petroleum to meet domestic needs there is no immediate pressure to produce new fuels from renewable resources. Despite this favorable situation, the GOE recognizes that alternative fuels will be needed in the medium- to long-term future, and has made INE responsible for developing alternative fuels before domestic petroleum supplies decline to a crisis level. We are impressed by the way INE is carrying out its mission.

2. The performance of INE in biomass-for-energy activities.

a. Planning. INE is doing an excellent job of defining needs, setting priorities, and planning activities to develop practical biomass fuels for Ecuador. We directed particular attention to INE's fuelwood and biogas programs; both programs have clearly stated objectives, and operating plans are well concieved and logically arranged. While outside experts advise on particular technical matters, and undoubtedly contribute significantly to planning, INE's own professional staff deserves the credit for combining diverse inputs to form comprehensive plans for applying technology to national goals.

b. Program execution. INE is a policy-making and planning agency; with a staff of only about a dozen professionals responsibile for both petroleum and renewable energy sources, INE cannot execute the plans which it

draws up. Other organizations are contracted to execute the plans. This is probably a desirable arrangement, although it appears that improvements are needed. We believe that program execution is not as good as program planning.

c. Technical capacity of INE staff. The professional staff members with whom we worked were excellent. Each was well trained, articulate, and able to explain his work as well as the relation of that work to the overall goals of INE and of the national government, and was obviously highly motivated in his work. These persons were all young and relatively recent graduates of universities. We recommend that these individuals receive continual educational opportunities to maintain their professional skills at their present high levels.

3. The Role of United States Institutions.

a. USAID. At present, USAID funds are contributing significantly to INE's progress by supporting certain action programs, by providing training for selected INE staff, and by bringing U.S. experts to Ecuador to perform specific TDY assignments for INE. Despite the relatively small total of these USAID funds, they are being utilized efficiently and are achieving very positive results for INE. We are impressed by the harmonious and productive relationships between USAID and INE officials; maintenance of these relationships will ensure that USAID support for INE will continue to be a sound investment.

b. Peace Corps. Unlike USAID, the Peace Corps (PC) assigns persons to work in INE programs. PC Volunteers are already working in the INE biogas program. Also, a new community forestry program being initiated by PC and MAG seemingly offers an opportunity for strengthening INE's fuelwood

program. As discussed with PC and INE officials, we believe that adding an "energy component" to this program would have many benefits. Once again, we were favorably impressed by the way in which PC and INE officials work together, and by the effective work of the Volunteers assigned to INE Progra

B. Recommendations for Specific Actions.

For the INE fuelwood program we recommend:

1. Systematic information should be obtained on present sources o fuelwood. Questions to be answered include (but are not limited to): What proportion of wood users have their own supplies, and thus do not purchase fuelwood?; What are the commercial characteristics of the "fuelwood industry (costs at point of supply, in rural villages, in cities; distribution and marketing patterns; regional differences, total magnitude)?; What are the major sources of fuelwood (undergrowth and hedgerows; small woodlots; natural forests; managed plantations)? and so forth. Information on charcoal production, distribution, and costs should also be obtained. This project would supplement INE's already-completed survey of the patterns of use of woo and competitive domestic fuels.

2. Geographical areas where additional fuelwood is most needed should be identified, priorities established, and plans drawn to meet the needs. INE should determine the amount of wood needed to meet the energy needs of each area, and work with MAG (which could identify suitable production sites, resources needed, etc.) to develop operating plans to meet the needs.

3. INE may wish to form an inter-agency task force to ensure that fuelwood production is a major objective of all GOE forestry projects. Besides the MAG Forest Service, a variety of community, provincial, and regional development authorities are carrying out programs in which trees are planted and/or managed for various purposes. Coordination by INE could produce relatively large increases in fuelwood supplies with very little additional work and no increase in bureaucracy.

4. INE should continue to develop, and promote the widespread use of, more efficient wood stoves. This program must have sociological inputs (are stoves only for cooking, or are they also used to warm the home?; etc.) as well as engineering (designed for combustion efficiency, construction using available materials, etc.) and economic ones (costs of producing and distributing the improved stove vs costs of alternatives, etc.).

5. Possible substitutes for fuelwood should be investigated. Physical tests should be made of briquettes, artificial logs, et., made by compressing crop residues (bagasse, sawdust, plant stalks, etc.); economic analyses (amounts available, collection and processing costs, distribution and marketing, etc.) should be made for those substitutes which appear to be most promising.

6. Municipal wastes may provide significant quantities of usable energy. Solid wastes, processed into a Refuse-Derived Fuel (RDF), can substitute for wood or coal in industrial boilers; we recommend that INE study the feasibility of using RDF in major cities with systematic trash collection

services. City sewage can be digested anaerobically to form biogas; INE may wish to examine the feasibility of such systems, at least for Quito and Guyaquil.

The INE biogas demonstration program will operable seven small-scale biogas generators at different sites throughout Ecuador. After visiting several of these sites, we believe that the program can be strengthened by implementing a systems management a]]rpacje for each generator. Specifically, we recommend:

7. Each demonstration site should have an operating plan accounting for (a) feedstock (source, nature, daily amount, etc.); (b) digestor performance (quantity and quality of gas, maintenanceof digestor, etc.); (c) utilization of biogas (who uses how much, and how is it distributed and/or stored, etc.); (d) disposition of solid and liquid residues (assessment of safety; value as fertilizer, etc.); (e) data on costs (capital plus labor minus values of gas and residues, etc.); and (f) operator and consumer reactions (positive and negative responses of those who operate the system and use its products). The plan should specify the type of data to be collected and the frequency of collection.

8. In contracting for operation of each demonstration unit, INE should insist that the comprehensive plan be followed--and should monitor operators to ensure conformance.

9. Operational data from all seven units should be maintained on a continual basis in INE's Quito offices, with frequently-updated analyses of items (a) through (f) listed above in recommendation 6.

10. Present research activities should be strengthened and broadened to study the technology and economics of biogas production (in different climates, from different feedstocks, etc.), distribution (to a single user or to many, etc.), and utilization (for home cooking, or for industrial process, etc.).

11. A "trouble-shooting team" of two or three highly-skilled engineers should be appointed by INE to provide technical support for the (generally inexperienced) operators of the biogas demonstration units. One or more team members should be on the scene within 24 hours of a call for help, thus minimizing lost time when "something goes wrong".

12. Economic analyses should be made to determine the probable future of biogas. A year's experience with the seven demonstration units should permit INE to define potential markets and to predict how well biogas can compete with wood, LPG, kerosene, etc. in meeting market demands.

USAID is one of several non-Ecuadorean agencies providing financial and technical support to INE. The selective nature of USAID support seems to be appropriate, especially since it ensures efficient use of limited funds. We offer only one recommendation for additional action:

13. An international newsletter of biomass-for-energy would be a useful service to INE and to national energy agencies in other countries. By reporting on biomass-related meetings, publications, active projects, etc., such a newsletter would notify readers of current developments in a complex and diffuse subject matter field. The USDA Bioresources Team might be the appropriate group to prepare the newsletter, which could then be circulated by the Office of Energy of USAID/Washington to AID Missions worldwide.

APPENDICES

I. Ecuador's Energy Consumption

II. Contacts in Ecuador

III. Field Trips

IV. Infrastructure and Context

V. Potential for Residue Production in the Agrobusiness Industries

VI. Sugar Mill Operations

VII. Production of Substitute Solid Fuels from Residues

'III. Steam and Electricity Production from Solid Wastes

IX. Units and Conversion Factors

APPENDIX I: ECUADOR'S ENERGY CONSUMPTION

The data discussed in this section were obtained from the Energy Balance analysis performed by the Instituto Nacional de Energia, (1).

A. Overview of Ecuador's Energy Balance.

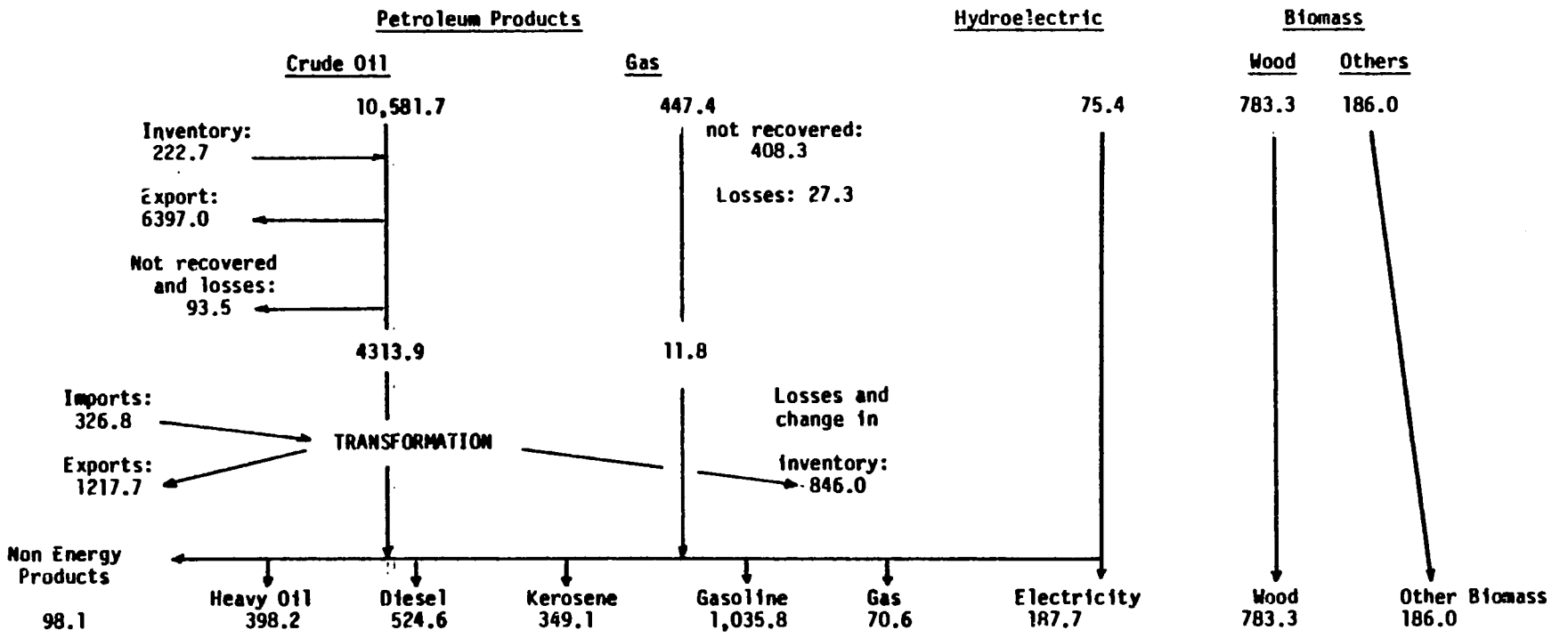
Figure A.1 summarizes the energy balance for Ecuador for the year 1978. A few facts are worth noticing:

- petroleum derivatives (including LPG) account for about 61 percent of the energy input to the end-use sector,
- despite the fact that it exports about 60 percent of its crude production, Ecuador imports significant amounts of finished products because of its lack of refining capacity. These imports are priced at world prices,
- electricity accounts for about 5 percent of the energy input to end-users. Despite the large hydroelectric potential in Ecuador, about 60 percent of the electricity is generated in oil-fired thermal stations,
- about 28 percent of the energy input to the end-user sector is in the form of biomass. About 80 percent of this input is in the form of fuelwood and the remainder corresponds to bagasse used in sugar mills.

B. Energy Consumption by End-Use Sector.

Table A.1 summarizes the energy consumptions by fuel and end-use sectors.

FIGURE A.1 ENERGY BALANCE FOR ECUADOR (1978)[1]



[1] Units: Thousand Ton Equivalent of Petroleum (See Appendix IX for conversion to other Units).

Source: adapted from Reference 1.

TABLE A.1 - ENERGY CONSUMPTION BY END-USE SECTOR IN ECUADOR (1978)[1]

Energy Sources	Sectors					Total
	Residential, Commercial, Public	Agriculture, Fishing	Industry	Transport	Others	
Biomass:						
- Wood	783.3 (100)	--	--	--	--	783.3 (100)
- Others	--	--	186.0 (100)	--	--	186.0 (100)
Electricity:	130.4 (69.5)	--	54.0 (28.8)	--	3.3 (1.7)	187.7 (100)
Petroleum Products:						
Liquid gas	68.9 (97.6)	--	1.7 (2.4)	--	--	70.6 (100)
Kerosene, jet fuel	200.5 (57.4)	--	37.4 (10.7)	111.2(31.9)	--	349.1 (100)
Diesel	--	158.3 (30.2)	79.9 (15.2)	272.5(51.9)	13.9(2.7)	524.6 (100)
Heavy Oil	--	--	223.2 (56.1)	175.0(43.9)	--	398.2 (100)
Gasoline	81.1 (7.8)	--	--	954.7(92.2)	--	1,035.8 (100)
Total:	1,264.2	158.3	582.2	1,513.4	17.2	3,535.3
Percent of Total Consumption	35.8	4.5	16.5	42.8	0.4	100

[1] Thousand Tons Equivalent of Petroleum

The largest consuming sector is the transportation sector (about 43 percent) for which gasoline is the major energy input.

The second highest energy consuming sector is the residential, commercial, and public sector. About 62 percent of the energy input to this sector is in the form of fuelwood used for cooking in the rural areas (2). Kerosene and liquid gas used presumably mostly for cooking are the next major input to the sector. A certain replacement of fuelwood by kerosene and gas has been recorded in rural areas in recent years.

The third largest energy consuming sector is the industrial sector in which biomass (bagasse used for fuel by sugar mills) accounts for about 32 percent of the energy input to the sector.

C. Trends in Energy Consumption.

During the 1972-1978 period the energy consumption of the transportation sector (excluding airplanes) has increased at a rate of about 13 percent. This situation is encouaged by a government policy which keeps the price of gasoline artificially low, well below world prices, although some gasoline is imported to Ecuador at world prices.

During the 1969-1978 period, the contribution of fuelwood to the residential sector has decreased from about 80 percent of the total input to the sector to about 62 percent. In parallel, the consumption of petroleum products and electricity has increased significantly during the same period. This switch

to modern fuel such as kerosene has also been noted by INE in their survey of cooking fuel use in the rural residential sector. The switch to petroleum products is encouraged by the artifically low price of these fuels in the country. It must, however, be noted that scarcity of petroleum cooking fuels has been reported in some regions and was observed by the team in Tulcan. It is therefore expected that fuelwood will still play an important role in rural areas for many years to come.

The energy consumption of the industrial sector increased at a rate of about 8 percent per year during the 1972-78 period. The largest increase is recorded for petroleum products consumption.

D. Energy Programs.

The energy consumption of petroleum products has increased dramatically during the 1972-78 period particularly in the transport sector. It is feared that increased consumption could reach the level of Ecuador's exports by 1985 thereby eleminating a precious source of income to the country.

One of the methods considered to reduce consumption is to bring the price of petroleum fuels in Ecuador to the level of world prices for the same fuels. This is a politically very unattractive option which is not expected to be implemented fully in the near future.

Other options pursued by INE to reduce the expansion of petroleum consumption and maintain a position of petroleum exporting nation include conservation in the industrial and transportation sector and the use of renewable resources, i.e., hydroelectric, solar and biomass.

APPENDIX II: CONTACTS IN ECUADOR

This appendix lists the contacts established in Ecuador during the November 17-December 6, 1980, visit of the biomass team and summarizes briefly the discussions held during the meetings with the people/groups listed.

1. USAID Mission - Quito.

Several meetings were held with members of the Mission listed below. The team was briefed and the Mission's programs were reviewed with:

- Gary Vaughan, Acting Capital Development Officer
- Dr. Vincent Gusumano, Rural Development Officer
- Dr. Fausto Moldonato, Soil Scientist, RDO
- Leopoldo Garza.

2. Instituto Nacional de Energia (INE) - Quito.

The team used INE's offices as headquarters. Briefing and discussions were held with:

Dr. Carlos E. Quevedo, Director

Dr. Eduardo Moran (Program planning and fuelwood)

Jaime Andrade (Fuelwood).

Dr. Jan Jasiewicz (U.N. representative from Poland - conservation)

Pierre Vernet (Technical assistance from France - energy balance)

Eduardo Janez (Biogas)

3. Ministerio de Agricultura y Ganaderia - Quito.

a. Raul Morales - Chief of Department of Agroindustry. Review of banana, coffee, cocoa, rice, sugar and cotton industries. Little or no energy

data are available. Fish and meat industries apparently have little or no residues. No milk industry, mostly imports of powder milk. (This statement was contradicted by agroindustries' data and observations by the team). The use of cereal residues (straw) for energy could create soil nutrient and erosion problems as some straw is presently recycled to the soil. General overview of agroindustry, but the team's observations during trip suggest that more specific and region/site specific evaluations should be made. Statistical data on production of crops and process data on agroindustries appear to exist but were not made available to the team.

b. Victor Alomoto - Direction of Forestry, Department of Supervicion y Studios. Statistical data on forests established by AIMA (Association Industriales Madererios) exist but were not available. Some data on pine growth in the Sierra (reforestation projects) were shown but not released. Typical data for pinus radiata:

- 2.5m x 2.5m plantings
- 1,600 trees/ha
- productivity varies from 2 to about 40 cubic meters per hectare-year according to soil, rain and altitude.

4. Peace Corps - Quito.

Meetings with:

- Dave Jocelyn, Director.
- Thomas Guerrero.
- Napo Ceballos (biogas).
- Peace Corps volunteers assigned to several locations.

a. Review of the Peace Corps Biogas Program (Napo Ceballos). The Peace Corps initiated some biogas projects about 5 years ago. The purpose was to prove the potential for biogas production under conditions existing in Ecuador. Among these projects a cooperative digester ($20m^3$) was installed in Iluman. Members of the coop bring manure, or their cows for milking, at the coop. Problems have occured in convincing people of the need for discipline and regularity in operating the digester and in using the gas. At present, gas is supplied to people in tire inner tubes. The cost of the project (paid by AID) was about $4,000.

Since about one year, the biogas activities have been expanded in conjunction and in support of the INE biogas program. Seven volunteers are presently setting up demonstration digesters in various areas of the country: 1 in Oriente, 2 in Manabi (close to Porto Viecho), 1 in Joja, 1 in Imbabura, 1 in Santa Helena and 1 in Guayaquil at the Polytechnic Institute.

All digesters operate on cow manure and range in capacity from 3 to $15m^3$.

Human excrements are not used because of the risk of spreading amoebic diseases. At present cow manure is sometimes used dry for fertilier, but is not very efficient in that form. The sludge from the digesters therefore could be much more valuable as fertilizer.

The market for these digesters includes "family" systems (3 - $6m^3$) for subsistance farmers owning a few animals and some land and cooperatives ($15m^3$ and up) where the gas can be used for processing the milk or returned to the members of the coop.

The digester project is conducted by the Peace Corp under management of INE. The digesters should be in operation by the end of 1980 or early 1981. The project should provide construction cost data, performance data and social data (response from the end-users).

b. Review of Fuelwood Supplies. The source of fuelwood is not quite clear. Some fuelwood is collected directly by the users. This has resulted in overcutting of trees and of brush in areas prone to erosion. Some fuelwood is purchased either in the form of wood or of charcoal. The origin of the raw material is not clearly identified and neither is the infrastructure for bringing the fuelwood to the market. A survey similar to that sponsored by INE on the patterns of usage of fuelwood could help clarify the situation. In collaboration with MAG, the Peace Corps will launch about 12 wood management projects aiming at improving the quality and productivity of village and small owner woodlots. This project could be expanded to include an "energy component" i.e., activities devoted to the improvement of the loca fuelwood supplies. The Peace Corps would be interested in participating in such projects and mechanisms to initiate the energy components were discussed. A possible approach would first establish an agreement of cooperation between MAG, the Peace Corps and INE. Bids for fuelwood projects would then be asked from Peace Corps volunteers or other groups. A selection of projects would then be made and the projects retained funded.

5. Escuela Superior Politecnica del Litoral (ESPOL, Guayaquil).

- Professor Alfredo Barriga.
- Other members of the engineering staff.
- (Discussions are reported in Appendix III, site visits)

6. Private Industry.

- Engineers of the Tabulela Ingenio, Chota Valley.

- Sr. Jorge Granja Torres, Deputy Chief of Administration, Ingenio San Carlos, near Guyaquil.

- (Discussions are reported in Appendix VI - Sugar Mills)

APPENDIX III: FIELD TRIPS.

1. Visit to Hacienda Correa, Guamani (South of Quito)

a. Biogas Digester. This Gobar type digester is the first of a series of demonstration units planned by INE. The system is build of bricks with a cement lining and has a floating metal cover recovering the gas. The digester tank is about 3m (9.4 ft) in diameter and 4.8m (15.7 ft) deep, for a volume of about 34 cubic meters (about 1,090 cubic feet). The system includes an inlet mixing tank and an effluent tank (both tanks are in concrete). The effluent is released to a field. At present, the system is fed two wheelbarrows full of cow manure every two days and generates about 4 cubic meters (141 cubic feet) of gas per day. The gas is about 54 percent methane. The metal cover weights about 250 kg (550 lbs). This creates a pressure of about 8 centimeters (3 inches) of water, which is enough to carry the biogas to its point of use. The digester operates in the mesophylic temperature range; no insulation or auxiliary heating are used. Projections are that, when fully operational, the digester will produce about 6 cubic meters (312 cubic feet) of biogas per day for a daily feed of 350 kg (770 lbs) of a mixture of manure and vegetable residues at 15 percent solids.

The system is installed on a dairy farm and samples of gas are collected daily by INE. The methane content of the biogas is measured by Escuela Politecnica Nacional in Quito. No other data are recorded at present and the biogas is either vented or used for demonstrations. The owner of the farm appears very satisfied and interested by the experiment. The cost of the system is estimated to be S/40,000 ($1,460).

b. Wood-Fired Brick Kiln. The kiln is fired from underneath with wood logs (eucalyptus) and produces brick of very uneven quality: burned at the bottom of the kiln and not homogeneously dried at the top. The use of a small low Btu gasifier could provide a means of distributing heat more evenly through the kiln but would require some investment for the equipment and gas distribution within the kiln; this equipment may be too expensive for small family operations of this type. Many other family size operations were observed in the area.

2. Trip from Quito to Tulcan (Northern Sierra; provinces of Pichincha, Imbabura and Carchi).

Dr. Fausto Moldonado from the USAID Mission accompanied the team on this visit. The following summarizes the observations of the team:

a. Northern Pichincha and parts of Imbabura.

- Significant dairy industry obtaining milk from large herds (20-60 heads) or from individual farmers (2-4 heads). The animals graze during the day and are confined at night. The large herds are milked at the farm while the small farmers often milk the animals in the field.

- Farmland ownership is divided between minifundistas (1 hectare or so), small subsistance farmers (a few hectares and a few heads of cattle) and larger (mostly grazing) holdings with large herds.

- Fuelwood is gathered from public lands, along roads, etc., and from woodlots or rows of trees along field boundaries mostly planted with eucalyptus. The woodlots often appear poorly managed.

- Some dry land areas (rolling hills) unused at present are subject to erosion and could probably be reclaimed through planting of species usable for fuelwood. The growth potential is probably low but the benefits in terms of land stabilization could be significant. Such reclamation projects however would probably be very expensive to implement.

- Crops are cultivated on very steep slopes which have been cleared of all their cover vegetation. Many cases of extensive erosion were noticed.

b. Visit to the Office of the Department of Forestry in Ibarra (Province of Imbabura). The main function of the office is reforestation of the highlands (80% pine, 20% eucalyptus) mostly for timber production. The mission of the office also includes control against over exploitation of the forests for fuelwood production. The office is not concerned with the actual production of fuelwood. At present, the species most used for fuelwood are eucalyptus and accacia.

The recommendations of the office for eucalyptus plantings are:

- 3x3 meters (about 10x10 ft) minimum spacing,
- harvest at 6 to 8 years for the production of poles,
- harvest at 10 to 15 years for lumber production.

Fuelwood can be produced through regrowth (coppice) from the stumps after harvest.

c. Visit to a Sugar Mill in the Chota Valley. The Chota Valley has a tropical climate and produces large amounts of sugar cane. A visit to a local sugar mill is reported separately in Appendix VI.

d. Provinces of Imbabura and Carchi.

- In the area of Tulcan and El Angel many erosion problems are apparent. Layers of topsoil of about 1 m (about 3 feet) thick have been completely washed away.

- Leguminous species such as accacia grow on the dry slopes.

- On the western side of the valley (old road from Tulcan to Ibarra) there is apparently little use of the land except for grazing. The potential for growth (wood) is probably limited except perhaps for pine. The existence of a delicate top soil layer could however mitigate against extensive use of this land without a strict (and expensive) soil conservation program.

3. Trip from Quito to Guyaquil through the provinces of Pichincha, Cotopaxi, Tungarahua, Chimborazo, Canar and Guayas.

- Many sawmills including one in the suburbs of Quito were noticed. While all solid residues (slab, end-cuts, etc.) are stacked for future use as fuel (fuelwood, charcoal), large quantities of sawdust are burned.

- Significant amounts of fuelwood appeared to be available (mostly eucalyptus) in the Riobamba area.

- In the higher parts of the inter Andean Valley (southern part, Alusi region), wide and dry plateau areas appear little used. Their potential for fuelwood production should be investigated.

- In the lower part of the valley, between Quito and Riobamba many cattle operations (small: 3-4 cows, large: 20-60 cows) were noticed as was the case in the northern part of the valley (see trip report No. 2).

- The last part of the trip was in the Guayas Province which is reported in more detail in later trip reports. Crops included tropical fruits, sugar cane, rice, coffee, etc.

- In many small farms, straw is extensively used to feed animals.

4. Visit to the Provinces of Guayas, Manabi and El Oro.

a. Visit to Escualo Superior Politecnica del Litoral (ESPOL) in Guayaquil - Biogas activities (Discussion with Ken Demers, Peace Corps Volunteer). As part of the general INE biogas program, the Peace Corps conducts some basic experiments on digestion of cow manure, soya residues, rice and coffee hulls and corn husks. These experiments are very basic, with little control and, so far, have not been very successful.

An above ground digester of about 110 liters (30 gal tank) with a gas storage tank has been operated but little systematic data appear available. (Probable cost of this unit S/2,000 = $73).

A new Gobar type system is under construction.

- Other activities (Discussion with Professor Alfredo Barriga). ESPOL also pursues activities in solar energy and biomass conversion. One of their problems appears to be obtaining recent, current information (including costs) on these conversion technologies. Some of the reports brought by the team were most welcomed by ESPOL. There is probably a function of technology transfer to be performed with ESPOL.

b. Visit to the Sugar Mill Ingenio San Carlos (about 40 miles east of Guayaquil). This is the largest mill in Ecuador (about 30 percent of the country's sugar production) and one among the largest in the world (capacity: 8,500 to 10,000 metric tons cane per day). A more detailed description is given in Appendix VI dealing with sugar mills.

c. Visit to the Provinces of Guayas (West of Guayaquil) and Manabi. The region visited included several production areas: the plain west of Guayaquil with rice, cotton, cattle and chicken production, a transition, hilly, tropical zone with coffee and tropical fruit production and a semidesertic region close to the coast around Jipijapa.

- Sawmills: burn the sawdust and have electric power.

- Large rice mills: burn large amounts of rice hulls and the mills observed had electricity available.

- Small rice mill (village size): produces rice grain or flour. The hulls are taken away by local farmers to burn on cotton fields. The operation visited used a 10-15 HP diesel engine as power source.

- Cotton fields: trash (stalks, etc) is burned in piles or windrows before planting. It is not believed that burning has any other purpose than discarding the residues because if it was done for weed control or recycling of the minerals, burning would presumably be done over the whole surface of the field (this should be confirmed however).

In some cases, rice hulls are spread over the cotton field and burned. This could be a simplified method of disposal which does not require the piling of the trash before burning.

- Cotton mill: some residues were evident but no quantitative data was available. The plant observed had electricity.

- Poultry farms: several poultry farms (estimated several thousand animals each) were observed. No data available concerning the amount or method of disposal of the residues.

- Coffee mill in Jipijapa: The fresh coffee beans are purchased from individual farmers or dealers. The beans are air/sun dried on an open air concrete area. After drying the beans are dehulled. The green coffee beans are shipped. A small fraction of the hulls (the finer parts) is used in brick manufactures (mixed with the clay) and the larger part is burned. The air dried hulls could be used as fuel or perhaps digested for biogas production. The plant visited had public electric power. No data on annual capacity could be obtained. The plant also treats castor beans.

d. Visits to the Provinces of Guayas (southeast of Guayaquil) and El Oro. This is a rich agricultural region.

- Rice plantations and sugar plantations are common in the area directly across the bay from Guayaquil.

- Cocoa production: many small farms with their individual concrete pad for drying the cocoa nut were observed. It is not clear where the dehulling operation is performed.

- Banana plantations: large plantations for the production of fruits for export exist in the area. The trees are cut to harvest the fruits. The cut trees are left in the plantation presumably for recycling of the nutrients although this was not confirmed. No data was obtained concerning the quantity of fruit residues or rejects prior to shipping.

- Cattle production: large grazing areas and at least one large size feedlot were also observed in the coastal area.

- Large areas of apparently unmanaged brush/wood/pasture were observed which could be used for biomass fuel production.

- In the zone around Guayaquil, water hyacynth grows extensively in low and wet areas and in water channels.

- Much of the area surveyed in this trip has access to electricity.

APPENDIX IV - INFRASTRUCTURE AND CONTEXT

A. The Institutional Context of Ecuadorian Energy Programs.

1. Ecuadorian Institutions.

The present Government of Ecuador, elected in 1979, has comprehensive plans for improving socio-economic conditions through rational utilization of natural resources. Responsibility for achieving national goals rests with a variety of ministeries, each with numerous agencies, and most programs require extensive collaboration among several bureaucratic units.

a. Ministry of Natural Resources and Energy. Responsibility for energy matters is shared equally by this ministry and a higher council of energy; under their oversight, the Instituto Nacional de Energia (INE) actually directs GOE energy programs. INE is responsible for some aspects of petroleum resources as well as programs to develop alternate energy sources including hydro, solar, wind and biomass.

b. Ministry of Agriculture (MAG). Many of the INE's biomass programs require direct collaboration with one or more MAG agencies: Instituto Nacional de Investigacion Agropecuaria (INIAP); Forestry Service; and Extension Service. We did not have time to contact each of these MAG agencies but we believe that INE is establishing effective working relationships to carry out its mission.

c. Universities. INE works collaboratively with several universities of Ecuador. We reviewed some of this work at the Escuela Superior Politecnica del Litoral of Guyaquil (see Appendix III); similar collaboration exists between INE and the National Polytechnic University located in Quito but we did not have time to visit this campus.

d. Regional Development Authorities, and Other Ecuadorian Agencies. The GOE, committed to a vigorous program of social and economic development, has constituted a number of Regional Development Authorities whose goals are generally similar: each authority administers a coordinated program designed to improve the economic well-being of a particular geographical region.

In addition to these Authorities, the GOE expects in the immediate future to inaugurate 17 new Integrated Rural Development (IRD) projects. Each IRD will address the needs of a single rural region. INE plans to work with several of the RDAs and IRDs and may thereby be able to incorporate biomass-for-energy components into rural development programs of very high national priority.

2. United States Government (USG) Agencies.

a. USAID. From the Loan Office, we obtained needed documents and information, including explanations of relationships between USAID and INE. The Rural Development Office provided valuable information about Ecuadorean agriculture as related to biomass production. From the Science and Technology Office, we learned of potential linkages with INE on energy-related matters.

b. U. S. Peace Corps. Leaders of the organization reviewed for us the several ways in which Peace Corps volunteers are involved in biomass-for-energy activities in INE. Seven volunteers are already linked to INE's biogass program, while some 14 new volunteers may soon work with MAG on forestry projects which can include fuelwood components (See Appendices II and III).

3. International and Third-Country Institutions.

USAID is only one of several external organizations supporting INE programs: Inter-American organizations; the United Nations; and the governments of several other nations are also important sources of technical assistance.

a. Regional Organizations. The Organization of American States (OAS) is involved in a regional development project in the Esmeraldas river basin in the northwest of Ecuador; while it is not clear if INE is involved, there are implications for renewable energy sources in the project. The Instituto Centro Americano de Investigaciones Technicas Industriales (ICAITI), with headquarters in Guatemala City, sponsors work on generation and utilization of biogas from biomass; the Organization Latino Americana de Energia (OLADE), with headquarters in Quito, has installed three biogas generators in Ecuador.

b. Others. INE is receiving assistance from experts representing a variety of sponsors: the United Nations, World Bank, European Economic Community, and the governments of several nations (see Apendix II).

B. Biomass-for-Energy In Ecuador: Primary Considerations.

Sources of information on matters pertaining to Ecuadorean biomass production and utilization include maps, statistical summaries, and published reports from AID, INE, and other GOE agencies. For our purposes, "primary" information described (qualitatively and/or quantitatively) biomass materials acutally available, as well as the ways in which they are used as energy.

1. Sources of Production.

a. Forest Products.

i. Present Usage. In Ecuador, as in many other countries, fuelwood for kitchen stoves is the most important use of biomass for energy. Recently, however, rapid population growth, intensive cultivation of food crops, and failure to replace harvested trees have led to the deforestation of extensive areas; as a result, fuelwood is now scarce and expensive for many families, rural as well as urban. Kerosene and bottled gas are being used by many of these families. Industrial use of fuelwood is limited mostly to small local operations (eg. brick-making plants, lumber kilns, etc.). To date, Ecuadorean industries do not seem to suffer from a lack of fuelwood.

ii. Production. Trees grow well in most parts of Ecuador; indeed, vast areas of the country are covered by forests.The annual production of woody biomass by Ecuadorean forests far exceeds the amount needed for fuel purposes. Unfortunately, the excess production occurs in remote locations. Although wood is scarce in densely-populated regions, it is probably uneconomic to transport fuelwood over long distances, except if the fuelwood is processed into a material of higher energy content than fuelwood such as charcoal or processed logs or briquets. Presently, the upland population centers do not have adequate fuelwood resources, and the situation is steadily growing worse. The need for extensive reforestation in populated regions is recognized by INE, concerned with increasing fuel production, by many other GOE agencies, and by USAID and other international organizations supporting Ecuadorean efforts to conserve natural resources and reduce losses due to soil erosion, water losses, and similar dangers to the natural environment.

b. Cultivated Crops. The possibility of growing crops as sources of energy has received much attention in recent years. In at least two countries, national policies are being implemented to produce energy from biomass. Brazil is obtaining ethanol from sugarcane on a massive scale and South Africa has ambitious plans to produce sunflower oil as a replacement for diesel fuel. In these examples of "energy farming", the crops grown for fuel compete directly with crops grown for more traditional purposes--for food, fiber or feed. We were told by INE officials that Ecuador will not support energy farming enterprises because domestic food production presently is inadequate to meet the basic needs of the population.

A second approach to obtaining energy from cultivated crops is to convert residues (parts not presently used as food or otherwise) into solid, liquid, or gaseous fuels. INE officials asked us to consider the residues available from major Ecuadorean crops and to evaluate the potential value of these residues as energy sources.

c. Animal products. The feces of domesticated livestock contain significant amounts of carbonaceous matter which has passed undigested through the animals. Animal manures, therefore, can provide biomass-for-energy: dried manure can be used as a solid fuel and burned directly; a more sophisticated approach is to inoculate liquefied manure with anaerobic bacteria which digest the cellulose and produce "biogas", basically a mixture of methane and carbon dioxide. INE has given high priority to a program to demonstrate biogas generation from cattle manure and its use as a domestic and industrial fuel. Seven Peace Corps volunteers are assigned to the INE biogas

program, and universities in Quito and Guyaquil are also collaborating to the programs. INE officials requested that we evaluate this program in some detail.

2. Converting Biomass to Useful Energy.

To date, the only significant utilization of biomass for energy in Ecuador is the direct burning of solid fuels.

Liquid and gaseous fuels are more desirable than solid fuels for many uses but chemical technology is needed to produce them from solid biomass. INE is supporting work on some conversion processes and also seeks more efficient utilization of all types of fuels.

a. Direct combustion of solid fuels.

i. Domestic use. As mentioned, burning firewood in home stoves is the most important domestic use of biomass energy. INE is working to develop more efficient stoves, and to demonstrate the advantages of such improved stoves.

ii. Industrial uses. Sugarcane bagasse is burned to provide process heat and to generate electricity for sugarmills. Wood wastes and fuelwood are burned to provide heat for industrial applications such as lumber kilns and brick factories.

C. Ecuadorean Biomass-For-Energy: Secondary Considerations

Each of the following factors will influence, at least indirectly, any program to produce and/or use biomass for energy in Ecuador.

1. Physical geography of Ecuador.

The massive Andes mountains divide Ecuador into three regions: (a) the Oriente (eastern) region, heavily forested but inaccessible, was not visited by the team and is not considered in this report; (b) the Sierra, including the heavily-populated upper slopes and high valleys of the Andes; and (c) the Pacific Coastal region west of the Sierra. Both the Sierra and Coastal regions contain numerous district subregions differing in altitude, topography, soils, and other physical characteristics.

2. Climatic factors.

Although bisected by the equator, Ecuador has a very wide range of climates, some of which are anything but "tropical." Temperatures display little seasonal variation but instead vary with altitude. At the low altitude of the Coastal and Oriente regions, temperatures are high throughout the year; at high altitudes in mountain valleys of the Sierra, days are cool and nights are cold throughout the year; intermediate altitudes have intermediate temperatures. Patterns of rainfall are complex, reflecting effects of altitude, geographic location, prevailing winds, etc. The differences in climates and physical geography combine to give Ecuador an extreme range of ecological zones. Some of these zones are highly favorable for production of biomass while others are unfavorable. In considering the feasibility of any proposed biomass-for-energy project the production capability of the specific locality must be carefully defined in terms of these factors.

3. Socio-Economic factors.

The conditions under which people live and work, the resources available to them, their aspirations for the future, and similar factors help

determine present energy usage and future needs. In Ecuador, some of these factors are particularly important in assessing feasibility of certain biomass-for-energy undertakings.

a. Population pressures. Ecuador's population is increasing rapidly--3% or more annually. Agriculturally productive regions are already densely populated. GOE statistics show that nearly 50% of rural land-owning families subsist on 1 hectare or less; approximately 65% of farms are 5 hectares or less. These minifundios are especially common in the Sierra region.

b. Land Tenure. In addition to farm families limited by the small size of their land holdings, there are many other rural families with no land of their own but who work as tenants on large farms.

c. Poverty. Official statistics confirm what is easily seen: rural poverty is a serious problem in Ecuador. Large families on small, eroded, farms, and with inadequate material or financial resources available to them, have little chance to improve their lot.

d. Government Policies and Plans. To combat proverty, improve the standard of living, and increase opportunities for rural families, the Government of Ecuador is attempting to bring the rural sector into the mainstream of the nation's economy. Some of the GOE initiatives affect potential utilization of biomass for energy.

4. Infra-Structure factors.

The geographic, climatic, and socio-economic conditions all contribute to infra-structrure problems that affect the production and use of biomass for energy.

a. The predominace of extremely small farms (minifundios) makes difficult the collection of large amounts of any biomass products; the amount of material produced on each farm will be relatively small.

b. Transportation difficulties add to the problems of minifundios. Moving relatively high-value fruits, vegetables, and grains from farm to market is difficult and expensive for many farmers. To transport unprocessed crop residues or other low-value biomass to an energy-conversion facility or to a market for this fuel is probably economically impractical at this time.

c. The isolation of most farms, and many farming communities, adds to the transportation problems. Although Ecuador has greatly expanded its highways in recent years, many communities remain isolated from markets. In one sense, this isolation is a good reason for developing community biomass-for-energy systems; where kerosene and bottled gas are not readily available, a system of producing and utilizing biomass as a community source of energy becomes more attractive.

5. Economics of Biomass-for-Energy.

Assuming that choices are available, the decision of whether biomass-for-energy is feasible depends upon relative costs (monetary, convenience, and effectiveness) of potential alternatives. Some biomass-derived fuels are economic in Ecuador today.

A number of biomass materials apparently are now available in Ecuador at extremely low cost; if these materials can be effectively used as fuels they can be cost-effective energy sources.

6. Government of Ecuador Policies Affecting Biomass-for-Energy.

As mentioned (C. 3 d) above, the GOE is strongly committed to raise the standard of living and economic strength of the rural sector of Ecuador. The following are GOE initiatives in which biomass-for-energy may play a part:

a. Seventeen Integrated Rural Development (IRD) projects have been approved by the GOE to strengthen the rural sector. Each IRD focuses upon a relatively small well-defined region, and will attempt to improve economic conditions through comprehensive development of transportation, infra-structure, etc.

b. Multiple-Agency Involvement in IRDs. Each IRD project require the participation of several GOE agencies. For those projects which we have examined, INE should participate to develop alternative energy sources for the regions involved.

c. Support by non-GOE institutions may be necessary if IRDs are to succeed. USAID/Quito apparently will help finance at least 3 of the IRD projects. Other international agencies may also be involved in certain of these projects.

d. Complexities increase in direct proportion to the number of agencies involved in any project. It is likely, therefore, that the IRD projects may suffer from the multiplicity of agencies involved. Rural development problems are extremely complex and require coordinated efforts of several agencies. Similarly, incorporation of biomass resources into a comprehensive energy plan will require that INE collaborate closely with several other GOE agencies.

APPENDIX V - POTENTIAL FOR RESIDUE PRODUCTION IN THE AGROBUSINESS INDUSTRIES.

Agrobusiness industries are industries which process agricultural or forest products. An inventory of these industries was established by the Ministerio de Agricultura y Granaderia (MAG) with the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) of France (Reference 7). The inventory is careful to distinguish between industries and artisanal operations.

Table A-2 shows a listing of the number of agroindustries of various types by provinces. This table is derived from Reference 7. The total number of enterprises listed is about 550.

Only those industries which produce residues easily convertible to energy are of interest in this analysis. A first selection was therefore done on that basis, which reduced the list to six major categories: wood products, mill products, milk products, meat products, vegetable processing, and sugar production.

Other important factors in determining the potential for energy production is the amount of residues produced and the size of the industries involved. The amounts of residues produced were estimated on the basis of residue factors as discussed in reference 6 and of production estimates as quoted in reference 4. The total amount of residues estimated is an indication of the potential contribution of the industry to the overall energy supply of the country. It must however be noted that a substantial fraction of the residues could be generated in operations too small to be listed in the inventory of reference 7. The estimates of residue availability are therefore upper limits and only indicative of the potential of the industry as a source of energy.

TABLE A.2 Cont'd

PROVINCES	3140 Tobacco	3211 Textiles	3212 Textile Products	3215	3220 Clothing	3231 Leather	3232 Pelts	3311 Wood Prod.	3312 Wood	3319 Wood Prod.	3411 Pulp & Paper	3511 Organic Chemicals	3550	Total
Carchi	--	--	--	--	--	--	--	3	--	--	--	--	--	14
Imbabura	--	1	--	--	--	--	--	3	--	--	--	--	--	15
Pichincha	3	17	--	3	--	3	--	43	--	--	1	1	--	161
Cotopaxi	1	--	--	--	--	--	--	--	--	--	--	--	--	16
Tungurahua	--	4	--	--	--	13	--	2	--	5	--	--	--	58
Chimborazo	--	1	--	--	--	1	--	2	--	--	--	--	--	13
Canar	--	--	--	--	--	--	--	--	--	--	--	--	--	3
Azuay	--	--	--	--	9	2	--	--	--	--	--	--	1	30
Loja	--	--	--	--	--	--	--	4	--	--	--	--	--	10
Esmeraldas	--	--	--	--	--	--	--	28	--	--	--	--	--	34
Manabi	--	1	1	--	--	--	--	1	--	--	--	--	--	10
Los Rios	--	--	--	--	--	--	--	4	--	--	--	--	--	25
Guayas	1	7	5	1	--	6	1	26	1	--	2	--	--	166
TOTAL	5	31	6	4	9	25	1	116	1	5	3	1	1	555

Notes to Table A-IV-1:

Source Reference 7

a Industrial Classification Number (Analogous to the SIC number used in the U.S.)

TABLE A.2 - NUMBER OF AGROINDUSTRIES BY TYPE AND PROVINCES

PROVINCES	3110[a]	3111 Meat Prod.	3112 Milk Produ.	3113 Veget. fruit Process.	3115 Veget & Oils	3116 Milk Prod.	3117 Baking Prod.	3118 Sugar Prod.	3119 Cocoa Prod.	3121 Food Prod.	3122 Animal Feed	3131 Spirits	3132 Wine	3133 Beer
Carchi	--	1	4	--	--	2	1	--	1	1	1	--	--	--
Imbabura	--	--	2	1	--	--	3	2	--	--	2	1	--	--
Pichincha	1	7	11	5	2	13	32	--	2	5	1	2	7	2
Cotopaxi	--	1	9	1	--	1	2	--	--	--	--	1	--	--
Tungurahua	--	2	2	2	--	6	6	--	2	2	1	6	5	--
Chimborazo	--	2	1	--	--	3	1	--	--	--	--	2	--	--
Canar	--	--	--	--	--	--	--	1	--	--	--	--	2	--
Azuay	--	3	1	4	--	1	5	--	--	--	1	3	--	--
Loja	--	2	1	--	--	1	--	1	--	--	--	1	--	--
Esmeraldas	--	1	--	--	--	5	--	--	--	--	--	--	--	--
Manabi	--	--	--	--	1	3	1	--	2	--	--	--	--	--
Los Rios	--	--	--	--	--	18	1	1	--	--	--	--	1	--
Guayas	--	3	6	8	3	30	26	4	10	5	7	6	6	1
TOTAL	1	22	37	21	6	83	78	9	17	13	13	24	19	3

The size of the industries is important as it relates to the collection and utilization of the residues. Large scale operations generating large amounts of residues create problems of distribution of the residues to the consumer. On the other end, small, dispersed industries can be better integrated in the energy consumption pattern of a dispersed population.

Table A.3 shows the distribution of the industries of interest by provinces and indicates the average size of these industries. It is apparent that the rice and coffee mills could supply significant amounts of residues for fuel and that their sizes vary widely. It was observed during site visits that sawdust is not always used in contrast to other wood residues. This could also be a source of fuel. Sugar mills often use all or a large fraction of their residue (bagasse). At least one case of non total use of bagasse was noted (Appendix VI).

TABLE A.3 - MAJOR AGROINDUSTRIES OF INTEREST FOR ENERGY PRODUCTION

Industries	Provinces	Potential Residues (MTEP)	Mean Size of Enterprize	Number of Enterprises	Comments
Meat Products (3111)	Pichincha	--	43	7	Types of
	Azuay	--	40	3	not
	Guayas	--	31	3	clearly
	Others	--	17	9	identified
	Total	N.A.	31	22	
Milk Products (3113)	Carchi		7	4	Amounts of
	Pichincha		45	11	residues
	Cotopaxi		16	9	not
	Guyas		35	6	identified
	Others		7	7	
	Total	N.A.	24	21	
Vegetable Processing (3113)	Pichincha		12	5	Amounts of
	Azuay		16	5	residues
	Guayas		37	8	not
	Others		15	4	identified
	Total	N.A.	24	21	
Mill Products (3116)					
Wheat	Carchi		24	2	
	Pichincha		33	6	
	Timgurahua		13	4	
	Guayas		74	3	
	Others		16	21	
	Total	3.1[b]	29	36	
Rice	Los Rios		8	16	Some hulls
	Guayas		16	22	discarded
	Others		2	1	at present
	Total	49.0[b]	13	39	(See
					Appendix III)
Coffee	Pichincha		3	5	Some hulls
	Esmeraldas		3	1	discarded
	Manabi		293	3	at present
	Guayas		45	2	(See
					Appendix III)

TABLE A.3 - MAJOR AGROINDUSTRIES OF INTEREST FOR ENERGY PRODUCTION (Cont'd)

Industries	Provinces	Potential Residues (MTEP)	Mean Size of Enterprize	Number of Enterprises	Comments
Sugar Mills (3118)	Imbabura		202	1	Much residue (bagasse) used for fuel or feedstock. (See Appendix III)
	Canar		561	1	
	Loja		121	1	
	Los Rios		170	1	
	Guayas		3038	2	
	Total	186[d]	1188	6[f]	
Wood Products	Pichincha		28	41	Only unused residue observed was sawdust
	Esmeraldas		25	27	
	Guayas		46	25	
	Others		17	19	
	Total	72.7[e]	30	112	

Source: adapted from Reference 7.

[a] Mean number of employees.
[b] Total amount of hulls estimated from production and residue factor (Reference 6)
[c] Includes cocoa
[d] From Reference 1
[e] Based on fine residues from production of sawnwood and plywood (Reference 6).
[f] Number of industries for which labor force data available.

APPENDIX VI - SUGAR MILL OPERATIONS

During its stay, the team had the opportunity to visit two sugar mills. The data collected are summarized below.

1. Sugar Mill Ingenio San Carlos.

Contacts: Jorge Torres

Ing. Manuel Aguilar, Chief Energy Department

This is the largest mill in the country (capacity from 8,000 to 10,000 MT of cane per day). The operating season extends over 180 to 190 days per year.

About 60 to 70 percent of the bagasse is used for fuel in 7 boilers having a total average capacity of about 217,000 kg (480,000 pounds) of steam per hour. This provides about 60 percent of the energy needs of the plant (steam and electricity). The supplementary energy is provided by boilers fired with Bunker C fuel. The remainder of the bagasse (about 40 percent) is sold to a subsidiary which manufactures heavy bags (cement, sugar, etc.) from this raw material. This plant therefore offers no potential for residue utilization. Complete materials and energy flow diagrams were obtained for the plant.

2. Sugar Mill in the Chota Valley. This small mill treats about 800 MT of cane per day for 200 days per year. Of the 280 MT of bagasse generated daily, about 100 MT are used to produce all the steam and electricity needs

of the plant. About half of the surplus bagasse (90 MT/day) is sold for animal feed, while the other half is discarded in a river where it creates a serious pollution problem for the plant itself. The surplus bagasse presently rejected could be converted to substitute solid fuel. The engineer responsible for the operation of the plant expressed much interest in this alternative use of the residues. The plant produces about 67.5 MT of sugar per day for in-country use and for export.

3. Other Sugar Mills. A large mill located in the province of Guayas was visited by an INE team. Their report indicates that this mill uses all the bagasse generated for energy production and also requires auxiliary fuel oil.

On the basis of the energy consumptions recorded for European and Cuban mills, sugar mills should be energy self-sufficient and have a surplus of bagasse as is the case in one of the mills visited. As indicated above this is not the case for some mills and therefore further data should be collected in order to estimate the real potential of bagasse as a source of substitute solid fuel.

APPENDIX VII - PRODUCTION OF SUBSTITUTE SOLID FUELS FROM RESIDUES.

The feasibility of converting some of the residues identified as potential resources to substitute solid fuel to replace or extend the fuelwood supply is discussed below.

1. Solid Fuel from Bagasse.

The process used for this discussion was developed by the British Columbia Research Council in Vancouver, Canada. The process uses a non-tapered screw and short die which accepts cold, wet feed and continuously extrudes hot logs. Natural binding agents in wood are sufficient for bonding the wood particles. The system accepts feeds of high moisture content and produces logs of about 23 percent moisture. Air drying of the logs reduces moisture to about 10 percent. The system produces logs about 30 cm in length, about 8 cm in diameter and weighting about 1.25 kg. Production capacity is 1 MT of logs per day (19).

For the purpose of this discussion equipment of larger capacity was assumed. Such equipment have been demonstrated by various manufacturers (19). An analysis of the cost of manufacturing logs from the 90 MT of surplus bagasse identified in a sugar mill in the Chota Valley (See Appendix VI) is presented in Table A.4. Although there is some uncertainty concerning the exact cost of the equipment, the analysis indicates that fuel logs delivered up to about 80 km can be competitive with fuelwood on a weight basis.

TABLE A.4 - PRODUCTION OF FUEL LOGS FROM BAGASSE

Surplus Bagasse: 90 MT/day (50% moisture)
Fuel logs: 58.4 MT/day (23% moisture)
Annual production: 11,680 MT (23% moisture)

Equipment Investment: S/13,974,000 ($510,000)
Installation: S/2,466,000 ($90,000)
Total Capital Investment: S/16,440,000 ($600,000)

Capital cost at 18%/year:	S/2,959,200
Maintenance and Repair at 4%/year:	657,600
Labor[1]:	840,000
Total:	S/4,456,800
Profit at 30%	1,337,040
Total	S/5,793,840

Cost per kg at plant gate: S/0.496 S/0.50

Transportation[4]:	0km	16km	32km	48km
S/kg	0	0.04	0.06	0.08
Total delivered cost: S/kg:	0.50	0.54	0.56	0.58
Total delivered cost: S/10^3kcal[2]:	0.13	0.142	0.147	0.157

Comparison: Fuelwood at S/12.50 per 20 kg: S/0.63/kg
S/0.21/10^3 kcal

Sources: references 19 and 20 (costs converted to 1980 dollars).

[1] 7 months operation x 4 shifts x 5 men/shifts = 140 man-months at S/6,000/ man-months.

[2] Fuel value of logs at 23% moisture: 0.282 x 10^7kcal/MT (6,900 Btu/lb)

[3] Fuel value of fuelwood: 0.3 x 10^7kcal (reference 1)

[4] Transportation by truck.

On an energy content basis, fuel logs appear much cheaper than fuelwood, if the concept of energy content can be conveyed to the end user. If rail transportation is available, fuel logs would be competitive with fuelwood on an energy content basis up to a delivery distance of about 600 km.

2. Solid Fuel From Municipal Solid Wastes.

Several companies have developed equipment to convert solid wastes into substitute fuel. The process involves removal of glass, metals, and other non-combustibles, shredding of the wastes, drying and/or adjustment of the moisture content and pelletization. The fuel is in the form of small cylinders about 0.6 cm in diameter and 2 cm long. The moisture content is between 20 and 24% (for one of the processes at least) and the heating value about 0.383×10^7 kcal/MT. Samples of pellets received from a manufacturer were rather brittle and their handling could create some problems.

Table A.5 shows an analysis of the cost of production of pellet fuel with equipment having a capacity of 120 MT/day of processed fuel. The equipment is operated 250 days/year (8 hours/day) which corresponds to a yearly production capacity of about 30,000 MT/year. Communication with a manufacturer suggest that about one third of the fuel produced will be required to generate process heat and mechanical power. The output for sale is therefore 19,800 MT/year.

TABLE A.5 - PRODUCTION OF FUEL PELLETS FROM MUNICIPAL SOLID WASTES

Wastes: about 130 MT/day (30% moisture)
Fuel Pellets: 120 MT/day (23% moisture)
Annual Production: 30,000 MT
Annual Production for Sale: 19,800 MT

Pelletizing Equipment:	S/3,864,000	($360,000)
Boiler:	5,480,000	($200,000)
Installation:	3,836,000	($140,000)
Total:	S/19,180,000	($700,000)

Capital costs at 18%/year	S/3,452,400
Maintenance and Repair at 4%/year:	767,200
Labor:	
2 workers[1]	144,000
1 foreman[2]	102,000
1 clerk[3]	84,000
Total:	S/4,555,600
Profit at 30%	1,366,680
Total	S/5,929,280

Cost per kg at plant gate: S/0.299 S/0.30 = S/0.107/10^3kcal[4]

Source: adapted from reference 19

[1] S/6000/month, 12 months
[2] S/9000/month, 12 months
[3] S/7000/month, 12 months
[4] Assuming 0.282 x 10^7 kcal/MT for refuse derived fuel.

This size equipment could process the wastes from a city of about 120,000 people. The data in the Table shows that substitute fuel could be produced at a cost very competitive with that of fuelwood (S/0.30/kg versus S/0.63/kg). Transportation costs are similar to those quoted in Table A.4 and therefore the substitute fuel could be transported quite far from its point of manufacture (an urban center) to the end-users and still be competitive with fuelwood. The production cost derived in Table A.5 is comparable to that quoted by U.S. manufacturers, i.e. $8-10 per short ton of substitute fuel if the wastes are assumed to be free as is assumed in Table A.5.

Refuse Derived Fuel (RDF) used in solid fuel boilers is therefore competitive with fuelwood for industrial applications.

Many industries however use petroleum derived fuel. Retrofitting an oil-fired boiler to operate on RDF would require the gasification of the RDF prior to use in the boiler. The cost of the fuel in its usable form (i.e., as low-Btu gas) will be augmented over that of the RDF by the capital, operating and maintenance costs of the gasifier. The cost added to the cost of RDF as a result of the gasification process was estimated assuming a capital cost of S/123,300 ($4,500) per ton per day of capacity of the gasifier (19), 18% capital recovery per year, 4% maintenance and repair per year, 90% on-line factor and 85% conversion from RDF to low-Btu gas. With these assumptions, the low Btu gas fired in the retrofitted boiler would cost S/0.153/10^3kcal or about S/0.053 more than the cost of the original RDF without transportation. Under these conditions, gasified RDF will be competitive with fuel oil delivered at the plant at a price of S/1.34 per liter ($0.19 per gallon).

3. Solid Fuels From Cotton Trash

Cotton trash presently burned in the fields could be a raw material to manufacture fuel logs. The resource is dispersed in the fields and does not lend itself to a large scale, centralized operation. It is envisioned that a two person team using a grinder (similar to that used to prepare animal feed) and a hydraulic press could manufacture logs. Both pieces of equipment could be driven by pulleys from a small truck engine for instance.

No cost data is available for this type of equipment which could in fact probably be fabricated locally.

An estimate of the potential profit of such an operation is presented in Table A.6 for two assumed capital costs of the equipment. The fuel logs are assumed to have a higher resale value than fuelwood because of their higher heating value. Under these assumptions between 200 and 369 hours of work per year would be needed to recover yearly capital and maintenance costs. After that, a profit of about S/5,300 could be realized per month. For a total three month period this would correspond to an average monthly income of about S/3,500 for the low cost equipment and S/1760 for the higher cost equipment. If fuel logs were sold at the price of fuelwood, (i.e., on a weight basis) the break even periods would be 370 hours and 739 hours which would make the business proposition less attractive under the assumptions used in the Table.

TABLE A.6 - PRODUCTION OF FUEL LOGS FROM COTTON TRASH

Assumptions:

Cost of Equipment:	S/13,700 ($500)	S/27,400 ($1,000)
Productivity:	One 1 kg log/ 2 minutes or 30 kg fuel logs/hour	
Fuel log moisture:	15%	
Heating value:	4.2 10^3kcal/kg (7500 Btu/lb)	
Log selling price:	S/0.88/kg[1]	

Operating costs:

Depreciation (5 years, straight)	S/2,740/year	S/5,480/year
Maintainance & Repair (4%)	S/548/year	S/1096/year
Gasoline, oil	S/10/hour	S/10/hour

Break-even period[2]	200 hours	400 hours

Potential average profit per month after recovery of yearly costs	S/3,500/month	S/1,760/month

[1] Based on higher heating value of fuel log over fuelwood.
Fuelwood at S/0.63/kg

[2] Working period needed to recover the yearly capital and maintenance costs.

APPENDIX VIII - STEAM AND ELECTRICITY PRODUCTION FROM SOLID WASTES

Steam and/or electricity can be recovered from mass burning of municipal solids wastes. The cost of producing electricity in a unit cogenerating steam and electricity was estimated using data published for a plant currently in operation in Paris, France, (25). The electricity produced may account for 5 to 15 percent of the total energy output (steam and electricity) of the unit.

Table A-7 summarizes the analysis performed for cities of 10,000 to 100,000 people. Two levels of financing were considered: an 18% capital recovery factor and a 3% capital recovery factor. The higher level corresponds to financing programs used by forest products industries in the U.S. (20) while the lower level corresponds to a financing method involving low interest international agency for example. The energy recovered is in the form of steam and electricity in variable proportions. The cost of electricity is estimated assuming that electricity and steam are sold at the same price on the basis of their energy content.

The data show that the energy produced by small systems is more expensive than for larger systems because of the diseconomy of scale affecting the small units. It is also apparent that provided low interest capital is made available, electricity produced from solid wastes in systems of about 30 MT/day and over can be competitive with network electricity priced at S/1.40/KWH (current price paid by the Sugar Mill Ingenio San Carlos in the province of Guayas). At present, electricity produced by Diesel generators is still cheaper in that region. Small increases in diesel fuel price however would make waste-derived electricity competitive. Urban wastes therefore

TABLE A-7 - STEAM AND ELECTRICITY PRODUCTION FROM SOLID WASTES

Population (thousands)		10	50	100
Solid Wastes (MT/day)		7.5	37.5	75
Capacity of Plant (MT/day)		10	40	90
Investment (10^6 S/)		54.5	144	254
Capital Cost @ 18%/year	(10^6 S/year)	9.81	25.92	45.72
@ 3%/year	(10^6 S/year)	1.64	4.32	7.62
Maintenance & Repair @ 4%/year	(10^6 S/year)	2.18	5.76	10.16
Labor @ 2.5%/year	(10^6 S/year)	1.36	3.60	6.35
Total: (Capital @ 18%)	(10^6 S/year)	13.35	35.28	62.23
(Capital @ 3%)	(10^6 S/Year)	5.18	13.60	24.13
Total Energy Produced (Steam & Electricity - 10^9kcal/year)		1.96	9.78	19.55
Cost of Energy: S/10^3kcal (18% Capital)		6.811	3.607	3.188
(3% Capital)		2.643	1.391	1.234
Cost of Electricity: S/KWH (18% Capital)		5.868	3.103	2.376
(3% Capital)		2.277	1.203	1.061

Compairson: Electricity from GRID: S/1.40/kwh (Quoted at Sugar Mill Ingenio San Carlos - Appendix VI)
Electricity from Diesel Genrator: S/0.85/kwh (same source)

Source: Adapted from references 20, 24, 25.

could be an attractive alternative to provide electricity in many areas of the country where it is not available or to expand the capacity of generation where electricity is already available. The competitive position of waste derived electricity with respect to hydroelectricity has not been evaluated. This should be done on a case-by-case basis.

Mass burning of wastes displaces about 1 barrel of fuel oil per metric ton of wastes burned. Therefore, recovering the energy from the wastes of a city of 50,000 people could save about 13,700 barrels of oil per year. At a price of S/1,096 ($40) per barrel, the value of the oil saved over just less than 10 years would repay for the capital investment of the waste recovery system.

APPENDIX IX

UNITS AND CONVERSION FACTORS[1]

1000 TEP = MTEP = Thousand Ton Equivalent of Petroleum
= 10^{10} kcal
= 3.968×10^{10} Btu
= 19.18 BEP/d

BEP/d = Barrel Equivalent of Petroleum per Day.

Wood = 0.300 TEP/T = 0.3 10^7 kcal/T = 5,400 Btu/lb

Bagasse = 0.200 TEP/T = 3,600 Btu/lb

Natural gas = 0.0360 TEP/MCF = 1.43 MMBtu/MCF

Crude = 0.143 TEP/BL = 135,000 Btu/gallon

LPG = 0.0966 TEP/BL = 91,300 Btu/gallon
= 1.14 TEP/T = 20,560 Btu/lb

Gasoline = 0.1221 TEP/BL = 115,400 Btu/gallon

Kerosene = 0.1329 TEP/BL = 125,600 Btu/gallon

Jet Fuel = 0.1324 TEP/BL = 125,100 Btu/gallon

Diesel = 0.1387 TEP/BL = 131,000 Btu/gallon

Heavy oil = 0.1387 TEP/BL = 131,000 Btu/gallon

Others = 0.1343 TEP/BL = 126,900 Btu/gallon

Electricity = 0.086 TEP/MWh = 3,413 Btu/kwh

[1] Values used in INE's Energy Balance Report (Reference 1) and adopted for the present report.

REFERENCES

1. Pierre Vernet, Herman Lopez and Eduardo Moran, "Balances Energeticos - IV Parte: Balances Consolidados, 1969-1978", Estudio INE No. 7, Quito, August 1980.

2. Instituto Nacional di Energia - Report on the Use of fuelwood in the rural sector in Ecuador - In preparation. Results discussed prior to publication with E. Moran.

3. International Bank for Reconstruction and Development, " Current Economic Position and Prospects of Ecuador", Report No. 507-EC, August 1974.

4. Food and Agriculture Organization of the United nations (FAO), "FAO Production Yearbook, volume 33, 1979", FAO Statistics Series No. 28, Rome, 1980.

5. National Academy of Sciences, "Methane Generation from Human, Animal and Agricultural Wastes", Washington, D.C. 1977.

6. R. K. Ernest, R. H. Hamilton, N. S. Borgeson, F. A. Schooley and R. L. Dickenson, "Mission Analysis for the Federal Fuels from Biomass Program - Volume III: Feedstock Availability" Final Report, SRI International, SAN-0115-T1, Menlo Park, CA., January 1979.

7. Republica del Ecuador, Ministerio de Agricultura y Ganaderia and Republique Francaise, Office of Recherche Scientifique et Technique Outre Mer, "Inventario de Empresas Agroindustriales", Quito, Ecuador, November 1977.

8. Fausto Maldonado, "Forest and Soil Conservation in Ecuador" Report for the U.S. Agency for International Development - Ecuador, Quito, Ecuador, April 1980.

9. Instituto Nacional de Energia, "Manejo de Recursos Forestales", Quito, Ecuador, November 1980.

10. Food and Agriculture Organization of the United Nations (FAO), "Forest Resources Yearbook 1979", FAO Statistics, 1980.

11. Instituto Nacional de Energia, "Fuelwood Utilization in Ecuador, Report in Preparation , December 1980.

12. John S. Spears, Forestry Adviser, World Bank," Wood as an Energy Source - The Situation in the Developing World", Presentation at the 103d Annual Meeting of the American Forestry Association, October 1978.

13. J. A. Alich, Jr., and R. E. Inman, "Effective Utilization of Solar Energy to Produce Clean Fuels," Stanford Research Institute, NSF/RANN/SE/GI/38723, Menlo Park, California, 1974.

14. J. F. Henry, "The Silvicultural Energy Farm in Perspective" in Progress in Biomass Conversion, Volume 1, Ed. K. V. Sarkanen and D. A. Tillman, Academic Press, N.Y., 1979.

15. B. F. Malac and R. D. Heeren, "Hardwood Plantation Management" Southern Journal of Applied Forestry, Volume 3, No. 1, 3-6, February 1979.

16. Instituto Nacional de Energia, "Trabajos Preliminares Sobre Possibilities of Implementing Large Scale Alcohol Production In Ecuador and Consumo de Lena y Bagazo" Internal Report, 1980.

17. Laurence Berkeley Laboratory, "Energy Conservation: Policy Issues and End-Use Scenarios of Savings Potential Part 2: Tradeoffs of Municipal Solid Waste Processing Alternatives", LBL 7896, University of California, Berkeley, September 1978.

18. Ministerio de Agricultura y Ganaderia, "Diagnostico Socio-Economic del Medio Rural Ecuatoriano: Formacion de las Estructuras Agrarias en el Ecuador", Documento A: Metadologia, Quito, March 1979.

19. J. J. Fritz, J. J. Gordon, J. F. Henry and V. Thanh Nguyen, "Status Revoew of Wood Biomass Gasification, Pyrolysis and Densification Technologies", the MITRE Corporation, MTR-8031, McLean, Va., January 1979.

20. D. A. Tillman, "The Economic Values of Wood Residues as Fuel", in Progress in Biomass Conversion, Volume 1, Ed. K. V. Sarkanen and D. A. Tillman, Academic Press, N.Y., 1979.

21. Food and Agriculture Organization of the United Nations, "Rice Husks" Conversion to Energy" FAO Agricultural Services Bulletin 31, Rome 1978.

22. R. K. Ernest et al, "Mission Analysis for the Federal Fuels From Biomass Program - Volume III: Feedstock Availability" SRI International, Menlo Park, CA, SAN-0115-T1, January 1979.

23. U.S. Environmental Protection Agency, "A Guide to the Selection of Cost-Effective Waste Water Treatment Systems" Technical Report EPA-43019-75-002, Washington, D.C., July 1975.

24. J. A. Abert and H. Alter, "A survey of United States and European Practices for Recovering Energy from Municipal Waste", in Progress in Biomass Conversion, Volume 1, Ed. K. V. Sarkanen and D. A. Tillman, Academic PRess, N.Y., 1979.

25. Argonne National Laboratory, "Proceedings of the International Conference on European Waste-to-Energy Technology", ANL/CNSV-TM-14, Argonne, Ill., September 1980.