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PUSPIPTEK ENERGY RESOURCES LABORATORY ASSESSMENT OF BIOMASS PROGRAM AND FACILITIES

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REPORT OF USAID/USDA BIOMASS ENERGY TEAM

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EXECUTIVE SUMMARY

1.0 Introduction

In March 1980 a U.S. Department of Energy team was requested by the U.S. Agency for International Development (USAID) to prepare a planning study for the PUSPIPTEK Energy Resource Laboratory. The report contained recommendations for various energy programs, including energy from biomass. Early attention to increasing energy available from biomass was recommended in the report because of the substantial amounts of such resources available in Indonesia. The possibility of USAID sending a biomass energy team to Indonesia was then presented by U.S. representatives, and was favorably received by representatives of Indonesia. A biomass team thus spent three weeks in Indonesia from November 3 to November 24, 1980.

The objectives of the biomass energy team were to formulate specific plans and projects to be carried out by the PUSPIPTEK Energy Resource Laboratory (PERL/LSDE), and subsequently develop the biomass energy laboratory layout and facility and equipment requirements. Included were technology and resource base assessments and identification of technical and economic problems in developing specific conversion technologies.

2.0 Biomass Production

Indonesia is blessed with abundant renewable resources. The question is whether these renewable resources can supply

significantly more energy, commercial as well as non-commercial, without adverse effects on the food and fiber supply. Currently, 122 million hectares are in forest and are classified as 47 million hectares production forest, 40 million hectares protection forest, 10 million hectares conservation forest, and 25 million hectares reserved forest. Unproductive land in Indonesia amounts to 42 million hectares.

Current use of woody biomass for energy has increased by 2.2 percent per year during the period 1969-1976, with consumption exceeding recorded production by some 36 million tons in 1976 on Java alone. Although serious problems arise with such a disparity between production and consumption, there is good potential to make a marked improvement in the fuelwood and biomass energy situation on Java and the outer islands without either harm to the environment or infringement upon production of valuable forest products. Fast growing fuelwood species, fuelwood plantations, and agricultural residue use can improve the situation on the island of Java, while mill residues can be used by the forestry industry on the outer islands to make those industries energy self-sufficient.

Recommended research and development projects in biomass production include field plot evaluations and comparison of promising fuelwood species, utilizing wood residues in the forest products industry on the outer islands, determining the suitability of using various agricultural wastes on Java, assessing energy

farming practices and potentials, and surveying available peat resources and applicable conversion technologies for peat. The role of PERL/LSDE in such efforts should be that of catalyst and coordinator rather than the principal investigating institution, in that existing and experienced organizations in agronomy and agriculture are well suited for such tasks.

3.0 Biomass Conversion Technologies and Technical Prerequisites for Development in Indonesia

3.1 Direct Combustion of Biomass

Firewood and agricultural waste have historically been used for domestic energy purposes in Indonesia. In the absence of sufficient quantities of biomass fuels, however, it has been necessary to resort to kerosene use. Solar (diesel) fuel is most commonly used in industry also because of a price advantage over biomass. The opportunities for expanding the current use of biomass then is good, particularly for household use and in the forest products industry, and should be encouraged by active support from the government. Examples of such support would include financial incentives, joint field demonstrations of combustion technologies with organizations such PLN (local state-run utility) and the forest products industry, and intensive planting of fast growing trees for rural household energy needs.

It is recommended that demonstration projects be established for small-scale wood-fired power plants to supply electrical

energy needs on the outer islands in an effort to replace solar and oil-fired plants. It is also suggested that the fuelwood supply be increased on Java by establishing fuelwood plantations, refining and improving charcoal production technology and developing highly efficient charcoal-fired stoves. Since direct combustion is a mature technology, technology development activities at PERL/LSDE would be minimal and consist of technical data dissemination, wood combustion pilot demonstration projects in the field, and commercialization of efficient charcoal stove designs.

3.2 Gasification

Gasification of biomass is another mature technology being refined and developed worldwide, as well as in Indonesia. At the present time, several small gasifier projects are underway in Indonesia, including one such USAID-sponsored assessing the potential of advanced-gasification technology for methanol production. Since gasification technologies are commercially available today, this technology can find immediate application in different energy-consuming sectors. In the forest products industry, gasification technologies can compete with direct combustion under certain circumstances. Gasification should also be considered for retrofitting of existing small PLN oil-fired electricity plants in Sumatra and Kalimantan. Small scale gasifiers can also supply energy for different agricultural operations, including irrigation pumps and rice mills.

PERL/LSDE should be equipped to conduct gasification research and development, including basic studies, bench and pilot scale

research. Descriptions of recommended projects and resources for gasification research and development are found in Sections 4.0 and 5.0.

3.3 Pyrolysis

Pyrolysis technology has been receiving much research and development effort in developed countries, and in Indonesia as well. Low temperature small-scale pyrolysis of agricultural wastes has been given high priority in Indonesia, particularly for use at rice mills in rural areas. Research done to date indicate that pyrolytic technologies may hold most promise at large scale (greater than 100 tonnes/day) applications, however, while other technologies are better suited for small scale biomass conversion systems.

It is recommended that PERL/LSDE initially conduct bench scale studies of fluidized-bed, low temperature pyrolysis of different feedstocks, during which time such data are collected as to develop design criteria for pilot scale systems. Pilot scale development of such technology should also be undertaken at PERL/LSDE, as well as basic studies of advanced pyrolytic conversion techniques in an effort to develop those technologies.

3.4 Alcohol Production

The technology of alcohol production from biomass is well developed and has been given high priority for development in Indonesia. An ambitious program of development of as much as twenty million kl/yr additional production capacity by the

year 2000 is planned, and plans have already been drawn up to begin pilot plant work in 1981. Conventional technologies developed elsewhere for production of ethanol from starch and sugar feedstocks are likely to be used, with sweet potatoes, cassava and Sago palm being the feedstocks considered.

Based upon such an ambitious program, it is recommended that considerable research and development effort be placed in fermentation technology, beginning with continuous bench scale research and continuing through pilot scale demonstration units as warranted. BPP Teknologi would take the lead role in initiating such efforts, and at PERL/LSDE would begin a coordinated development program of bench scale studies using feedstocks previously untried (such as Sago or cellulosic feedstocks) basic research on development of high temperature yeast strains, pilot plant demonstration of fermentation techniques and equipment for more conventional feedstock sources such as sweet potatoes, and waste treatment studies for process effluents from alcohol production facilities. Already, USAID monies have been allocated to the first of these four program phases, with additional technical and financial assistance being provided for pilot scale demonstration by West Germany.

3.5 Methane Fermentation

The production of fuel gas (biogas) from digestion of organic wastes to methane and carbon dioxide is widely practiced throughout the world, and has been utilized to some extent in Indonesia

as well. Research efforts are currently underway or have been completed to assess different design configurations, feedstocks, operational modes, and construction materials. Results have been mixed and suggest only limited success in promoting commercialization of the technology in the country. As such, only limited funding and research effort is recommended for development of this technology.

The recommended role of BPP Teknologi in promoting commercialization of this technology is that of coordinator of field projects and being the institution for continued research in the area of methane fermentation. Already several field projects have been initiated, including one project supported with funds from USAID. Refinement and optimization of these existing projects should be continued to more reliably assess performance of such technologies, while new projects should be limited to gas processing and equipment studies, and development of thermophilic anaerobic digestion technology.

4.0 Biomass Program at PERL/LSDE: Equipment Needs and Specifications

The study team worked closely with members of BPP Teknologi on the actual physical layout of the energy laboratory buildings. The original concept of the Indonesian planners is to construct a total of eight two or three story buildings to serve as laboratory facilities shown in their architectural sheet no. 03, with each building having a basic modular area of 500 m^2 per floor. Also, a series of seven similarly sized buildings are to be built adjacent to the proposed laboratories, as well as a

separate pilot plant building. Under such a proposed design, it is recommended that there be five basic bench scale laboratories in the Energy complex consisting of a workshop/mechanical laboratory, a central chemical (analytical) laboratory, a biological, physics, and electronics laboratory, with the remainder being reserved for non-biomass related laboratory studies. The seven other similarly sized units can serve to house related technical support, software, and administrative facilities, the pilot plant area serving to house five or six pilot scale demonstrations.

Equipment needs and specifications for recommended biomass energy projects undertaken at PERL/LSDE were reviewed by the study team in an effort to identify proposed project costs and requirements. Analytical equipment needs and costs total just over US$300,000 (US$301,660) under the recommended analytical laboratory plan (see Table 4-1). Estimated equipment costs for each of the recommended bench and pilot scale efforts are summarized below.

Estimated Expenditures for Proposed Biomass Laboratories

	Equipment Item	Estimated Dollar Cost
1.	Fuel log extruder unit	US$ 30,000
2	Pelletizer	30,000
3.	Downdraft gasifier connected to internal combustion engine	200,000
4.	Gasification/pyrolysis equipment, including vessels, boiler, feed equipment, and storage tanks	500,000
5.	Oxygen blown gasifier	750,000

Estimated Expenditures for Proposed Biomass Laboratories (Cont'd)

	Equipment Item	Estimated Dollar Cost
6.	Bench scale ethanol production from Sago	US$ 110,000[1]
7.	Bench scale waste treatment of residuals from ethanol production	5,000[2]
8.	Pilot scale alcohol unit	200,000
9.	Pilot scale anaerobic digester for methane production from water hyacinth	225,000[1]
10.	Bench scale thermophilic anaerobic digestion unit	25,000
11.	Rice straw gasifier for D.C. electricity	49,600[1]
	TOTAL	US$2,124,600

[1]Monies previously allocated by USAID.

[2]Analytical laboratory equipment specified in Table 4-1 with minor additions and modifications shall suffice for majority of equipment costs.

Also recommended (see Section 3.1.3.2) are two additional pilot demonstration plants, so called dendrothermal plants. These projects would not be located at PERL/LSDE, but should be carried out in close cooperation between BPP Teknologi personnel, PLN (State Electricity Corporation) and the Department of Forestry. The projects are as follows:

	Item	Cost
1.	500 KWe wood fired electric power plant for rural area	US$ 660,000
2.	1,500 KWe wood fired cogeneration plant for a sawmill or plywood mill	1,400,000
		US$2,060,000

Funding for such projects would have less priority than providing analytical equipment and equipment for pilot and bench scale

projects listed above. Total estimated costs then for the proposed program of biomass research and development work undertaken by PERL/LSDE comes to $US2,426,260 (including US$301,660 for lab equipment).

5.0 Personnel and Training

Personnel requirements for the biomass energy laboratory have been estimated for the various biomass energy projects recommended in Table 3-4 and suggested in Section 2.0. The total personnel requirements have been divided into five categories, including: 1) support staff for the central analytical laboratory; 2) senior scientists and engineers; 3) junior scientists and engineers; 4) workshop and mechanical laboratory personnel; and 5) administrative personnel. Between 9-13 support staff are recommended to staff the central analytical laboratory, 33 senior scientists/engineers to provide project management and technical expertise, 49-61 junior scientists/engineers to provide technical support, 7-9 workshop/mechanical laboratory technicians, and 4 administrators to administrate the biomass energy facilities and projects for a total of 102-120 personnel. Approximately 25 of these positions are required for staffing the entire energy laboratory complex, however, not just the biomass part of the complex. (For training requirements and proposed programs for these personnel, see Table 5-3.)

1.0 INTRODUCTION

1.1 Background

It is planned that PUSPIPTEK, the National Center for Research, Science and Technology, will have facilities for energy and energy resource development. The promulgation of advanced energy technology by PUSPIPTEK is intended to stimulate the development of an energy industry which would lead to regeneration of natural energy resources as well as conservation of oil and gas.

In March 1980, a U.S. Department of Energy team was requested by the U.S. Agency for International Development (USAID) to prepare a planning study for the PUSPIPTEK Energy Resources Laboratory (PERL/LSDE). The report, dated July 1980, contained recommendations for various energy programs, including energy from biomass. Early attention to increasing the energy potentially available from biomass was recommended because of the substantial amounts of such resources which can be produced with fertile soil and the favorable climate of Indonesia.

As a continuation of planning for the PUSPIPTEK Energy Resources Laboratory, the subject of more definitive planning of the biomass energy component of the laboratory was discussed in July 1980. The possibility of USAID sending a biomass energy team to Indonesia was presented by U.S. representatives, and was favorably received by representatives of Indonesia.

The biomass team thus spent three weeks in Indonesia from November 3 to November 24, 1980.

1.2 Objectives

The basic objectives of the biomass energy team were to formulate specific plans and projects to be carried out by the PUSPIPTEK Energy ResourcesLaboratory, and from such program planning develop the biomass energy laboratory layout and the facility and equipment requirements.

1.3 Scope of Work

With the above objectives as the predominant goals of the biomass team, the total scope of work included analyses of the potential for various biomass energy forms and conversion processes in order to develop the program and its related equipment and facility requirements. Therefore the scope of work included the following, much of which has already been carried out by Indonesian biomass energy specialists:

1. Analyze the results of existing energy demand and biomass resource studies in terms of which biomass conversion technologies appear to have the greatest potential for meeting specific needs in the household, industry, agricultural and transportation sectors.
2. Identify the principal technical and economic problems to developing and applying specific conversion technologies, such as gasification of biomass, direct combustion, alcohol from sugar and starch-bearing crops, and charcoal production.
3. Develop initial calculations on the optimum size of alcohol plants, cost of production, and alcohol yields.
4. Review existing studies of the economic feasibility of using the forest residues in Kalimantan to meet energy requirements in Java.
5. Review the experience of fuelwood plantations in Indonesia, such

as the one in Toyomerto Village in East Java.

6. Recommend books, reports, and professional papers and journals on biomass technologies that should be acquired for the library at the energy laboratory.

7. Help Indonesian planners and specialists to develop a specific three to five year program of specific biomass technologies that could be carried out or coordinated by the PUSPIPTEK Energy ResourcesLaboratory.

2.0 BIOMASS PRODUCTION IN INDONESIA

Indonesia is blessed with abundant renewable resources. These resources provide food and fiber for Indonesia's growing population and also for export. In addition, they provide large amounts of energy, mostly in non-commercial form. The question is whether these renewable resources can supply significantly more energy, commercial as well as non-commercial, without adverse effects on the food and fiber supply.

2.1 Present Situation

Of the 190 million hectares of land in Indonesia, about 24 million hectares or 13 percent can safely be used for agricultural purposes. An additional 26 percent or 51 million hectares can be used for agriculture provided appropriate conservation measures are taken. Some 60 percent or 115 million hectares should be in forest.

Currently, a total of 122 million hectares are in forest, of which only 2.9 million hectares are on Java and Madura comprising 2.18 percent of the total land area of these two islands.

The forests of Indonesia are classified as:

Production Forest	47 million hectares
Protection Forest	40 million hectares
Conservation Forest	10 million hectares
Reserved Forest	25 million hectares
TOTAL	122 million hectares

According to the Directorate of Reforestation and Rehabilitation, unproductive land in Indonesia in need of rehabilitation amounts to 42 million hectares, broken down as follows:

Denuded forests and second growth	23 million hectares
Denuded soils and alang alang	16 million hectares
Rainfed agricultural land	3 million hectares

Twenty million of the 42 million unproductive hectares are considered critical or seriously eroded:

Alang alang (Imperata cylindrica)	13 million hectares
Secondary growth (belukar)	4 million hectares
Rainfed cropland (tegalan)	3 million hectares

Wastelands on Java count 4 million hectares or more than 30 percent of the total land area.

(Source for the above statistics: "Forestry for Industrial and Rural Development in Indonesia".)

Areas of major crops from an energy point of view were reported for 1978 by the Biro Pusat Statistik:

TABLE 2-1. AREA AND PRODUCTION OF MAJOR CROPS 1978

Crop	Area	Production		
		Java & Madura	Outer Islands	Total
	(1000 ha)	(1000 tons)	(1000 tons)	(1000 tons)
Wetland Paddy	7,653	15,205	9,060	24,265
Dryland Paddy	1,240	437	1,177	16,614
Maize	3,028	2,819	1,037	3,856
Cassava	1,383	9,471	3,490	12,961
Sweet Potatoes	293	1,007	1,227	2,234
Peanuts	514	322	117	439
Soybeans	741	450	120	570

These crops produced residues in 1977 as follows:

TABLE 2-2. PRODUCTION OF CROP RESIDUES 1977

Crop	1000 Tons of Residue
Rice straw	934
Rice hulls	337
Maize	63
Sweet potatoes	246
Cassava	1,202
Soybeans	31
Peanut shells	34
Coconut shells	1,434
Fruits	363
Vegetables	152

(after Biro Pusat Statistik, 1979)

2.1.1 Current Use of Biomass for Energy

The Ministry of Agriculture reports that during 1969-1976, fuelwood consumption increased by 2.2 percent each year.

In 1976, fuelwood production and consumption were as follows:

TABLE 2-3. FUELWOOD PRODUCTION AND CONSUMPTION 1976

	Java	Outer Islands	Total
Production	1,251	21,304	22,555 (1000 tons)
Consumption	37,127	23,107	60,234 (1000 tons)
Difference	35,876	1,803	37,679

On Java, consumption exceeded recorded production by some 36 million tons in 1976. The discrepancy is made up of fuelwood production in home gardens (pekarangan), farm plot boundaries, community lands, and pilfering from public lands; in what proportions is not known.

Production of non-wood residues in 1976 was:

Java	35,447,625 tons
Outer Islands	30,563,173 tons
Total	66,010,798 tons

These residues are from food crop, cocoanut, oil palm and tea plantations.(after Hardjodarsono, 1978)

Currently, non-wood residues are not being fully exploited for energy. However, reliable data on their use are lacking.

2.2 Problems and Potentials on Java

On Java, a burgeoning population uses more and more land to grow food and in doing so leaves less and less land to grow fuelwood, a traditional cooking fuel for the rural and large parts of the urban population.

The rural population can no longer supply the needed fuelwood from its own property, and in pilfering from public lands contributes to deforestation and attendant erosion, serious problems in their own right.

The urban population has been switching to kerosene, a heavily subsidized fuel. If the urban dweller is to switch again from kerosene to firewood, a traditional cooking fuel even in cities, there must be an ample, dependable and cheap supply of firewood or charcoal. It was noted with some surprise that the urban population uses very little charcoal and that, in fact, there seems to be resistance to the use of charcoal.

A number of studies are currently being undertaken on consumption patterns of fuelwood, etc. These studies will provide information about

the amount of cooking fuel needed in the cities and in the country, now and in the future.

Much basic silvicultural and yield information on fuelwood species is needed. A few, rather fragmented studies on fast-growing fuelwood species are underway, but these will not begin to answer questions of what species to grow, where and what production will ensue.

There is a need for an accurate assessment of non-wood residues from agriculture, etc. There seems to be ample opportunity for using these residues to convert to energy. Lacking, however, are precise data on present utilization and excess availability for energy.

There is good potential, however, to make a marked improvement in the firewood situation on Java without harming either the environment or infringing upon production of valuable forest products.

A number of potentially fast-growing tree species have been identified that can improve the soil and yield fodder or other benefits as well. Once the silvicultural and yield information has been accumulated, an action program of tree planting can be undertaken with two thrusts:

1. Through a strong extension effort, pursuade the small farmer to plant fast-growing fuelwood species on part of his housegarden and around some of his fields. In this manner he may become more nearly, if not completely, self-sufficient in firewood.
2. Establish extensive fuelwood plantations on the so-called wastelands of which there are 4 million hectares in Java. Here is where the soil improving capacity of many of the leguminous tree species

will pay off handsomely. The yields on these impoverished soils will be lower than average but will increase as time goes by. At a yield of 10 tons biomass per hectare per year the 4 million hectares would yield more than the total present fuelwood consumption on Java.

In making an economic analysis of making the necessary investments in tree planting, the benefits of halting erosion, etc., should be taken into account. The question of distance from supply to consumer comes up. In this context, charcoal can assume great importance. A rule of thumb states that firewood can be transported economically up to 80 kilometers and charcoal up to 600 kilometers. Here is an opportunity to overcome the urban resistance to using charcoal, and supplying urban centers from large plantations where the harvested wood is converted to charcoal by local citizens in many small portable metal kilns. Thus, many jobs would be created in planting and tending trees, making charcoal, and transporting it to the city.

Agricultural residues, once their availability has been determined, can play an important role in rural energy supply. Pyrolytic conversion of rice hulls has been tested on Java and proved feasible; no doubt other residues could be used as well.

2.3 Problems and Potentials on the Outer Islands

Scarce populations, abundant renewable resources, forest exploitation, and clearing for transmigration projects characterize significant portions of the outer islands, especially Kalimantan and Sumatra.

A serious energy problem on these islands is the amount of petroleum fuel used by forest industry--sawmills, plywood mills, etc. Here is an opportunity to use the mill residues and to some extent logging residues to make forest industry energy self-sufficient.

The idea that woody residues could be shipped to Java to supply cooking fuel does not hold much promise at present, for two reasons. Forest industry will use all its mill waste to generate its own power and not much is known about the kinds, sizes, and amounts of logging residues available for export. The other reason is excessive transportation cost between islands; it alone exceeds the cost of competing fuel on Java. In the future, there may be an opportunity to utilize woody residue in excess of industries' needs and that generated by transmigration projects to produce a fuel such as charcoal or densified pellets or even methanol for export to Java. But first there must be detailed studies of raw material supply, production costs, transportation costs, and marketing of the product. For now, making forest industry self-sufficent in energy has priority.

The outer islands offer an opportunity to use biomass for energy either in the form of the crop itself such as sweet potatoes or cassave, or as crop residue such as straw, hulls, leaves, inflorescences, etc. Information is needed on conversion processes, crop yields, residue yields, the logistics of harvesting and transporting the biomass to the conversion plant, and storage of the biomass prior to economic analysis.

2.4 Biomass Production Projects

Consideration must be given to adequate biomass production if conversion to energy is to be successful. The following suggestions for biomass production projects are a follow-up of and provide a sharper focus on the recommended research programs mentioned in the Preliminary Planning Study for PERL/LSDE (p. 32-35).

1. Comprehensive and coordinated field plot evaluation and comparison of promising fuelwood species over a range of climatic conditions, soils, and elevations.

   There seems to be no doubt that fuelwood should play an important role in energy consumption by the rural and poor urban population on the island of Java. Thus far, some field trials have been undertaken by several forestry institutions and faculties. However, close coordination and a systematic approach to avoid unnecessary duplication is lacking. Species recommended for evaluation are:

   Acacia auriculiformis
   Acacia mangium
   Calliandra confusa (callothyrsus)
   Casuarina Equisitifolia
   Gliricidia maculata
   Leucaena leucocephala
   Sesbania grandiflora and others

   Not all species should be evaluated at each location. Study of published silvical requirements should reduce the number of species to be compared to a reasonable number.

The experimental design, as well as plant layout, should be standardized so that the data from all trials can be subjected to a comprehensive analysis, probably with the help of a computer. For the experimental design, advice should be sought from Dr. Ir. Setyono Sastrosumarto, Vice Dean of the Faculty of Forestry at Gajah Mada University. Dr. Sastrosumarto has a Ph.D. in Experimental Statistics and probably would welcome this consultation in addition to his administrative duties.

Measurement of plantations should also be standardized. In addition to the conventional forestry measurements as height (total and merchantable) and diameter at breast height, the above-ground biomass should be measured in terms of oven dry weight including bark, and branches down to 1 cm diameter. Regression equations can be developed to relate green weight to oven dry weight and the required sampling intensity must be established.

It will probably be best to use a standard spacing for the species trials in the beginning. Once a species has proven to be superior in a particular site, a spacing trial can be started if needed.

The time required for useful results to emerge will be around 5 years, considering seed collection, nursery production, site preparation and planting, and 3-4 years growth. However, this kind of time schedule requires solid planning, tight coordination and dedication on the part of all participants in the effort.

From this effort will flow essential information that will allow

foresters to decide which species to plant and, what is equally important, predict future production in terms of energy content.

Parallel to the field plot trials should be a series of tests designed to obtain comparative growth and yield information of species planted in single rows. This type of information will be needed to help the small farmer supply his own fuel needs by planting in the "house garden" and along the edge of his fields. The range of sites will be much narrower here than in the field plot trials and the choice of species also will be narrower, leading to early results.

Some recently started field trials of Leucaena leucacephala were observed. One small plantation near the school of forestry in Yogyakarta showed excellent growth under very favorable circumstances. Other plantations on critically eroded soils did not grow nearly as well. This is to be expected but should not cause disappointment. The soils are relatively poor now but with nitrogen fixing legumes should improve with time, resulting in increased growth. Meanwhile, the soils are covered with useful vegetation, lessening erosion and producing fodder and firewood in modest quantities.

2. Utilization of Wood Residue

Logging and forest product manufacture create vast amounts of wood that form a potential source of energy. Estimates of logging residue amount to about 50 percent of the standing volume harvested. Sawmill residue runs to 35-50 percent of log volume processed. While total volume harvested varies considerably on the outer islands,

it is safe to say that logging and sawmill waste run into many millions of m^3. This potential source of energy should be studied in considerable detail to determine if and how it should be utilized.

a. Sawmill residue (slabs, edgings, and sawdust) and other processing residue should be studied for the 1,115 sawmills and an unknown number of units of wood using industry. Data should be collected on energy use (diesel oil, electricity) and feasibility of converting the residue to energy and thus make the enterprise energy self-sufficient. Energy self-sufficiency of the wood products industry should be a near-term goal in Indonesia. PERL/LSDE could develop data on conversion units (combustion, steam turbine, electricity or gasification) and promote their acquisition by the wood products industry. See Section 3.1.3.1 for details on recommended activities to be undertaken at PERL/LSDE.

b. Sawmill residue in excess of self-sufficiency needs and logging residue could be studied with respect to volume, sizes, concentrating the residue at roadside or mill site, chipping costs, and quality of chips. Chips could be used as a source of fiber for pulp, feedstock for acid hydrolysis, or fuel for direct combustion. The feasibility of producing charcoal in small portable kilns for export to Java or elsewhere should be studied.

3. Make surveys of agricultural waste on Java, determining how much will be available each year, in what concentrations, and in what condition (moisture content, need for cleaning, proximate and ultimate analysis, etc.) Make feasibility studies for possible pilot plant applications.

4. Study the feasibility of energy farming in the framework of transmigration projects, using sweet potatoes, cassava, Sago palm, and others.

5. Make a survey of peat deposits in Indonesia and study the use of peat for energy (see Appendix C).

2.5 Institutional Considerations

The role of the PERL/LSDE in biomass production should probably be governed by the fact that PERL/LSDE is primarily an engineering and chemical laboratory. In the field of biomass for energy it will strongly emphasize conversion and play only a modest role in biomass production. There would be no point in duplicating existing and experienced organizations in agronomy and forestry that are part of the Department of Agriculture and the Universities at Bogor and Yogyakarta and others.

PERL/LSDE's role in biomass production should be that of a catalyst and coordinator among the institutions mentioned above. There is much to be surveyed, tested and developed in agriculture and forestry crops and residues. At present the work is fragmentary, duplicative and often insignificant in scale owing to lack of funds.

PERL/LSDE could assume a leadership role by engaging an experienced research administrator in forestry or agriculture. A person with a national reputation and demonstrated ability could meld the work of various independent units into a coherent program by drafting an overall design and providing grants where they will achieve the greatest results.

3.0 BIOMASS CONVERSION TECHNOLOGIES AND TECHNICAL PREREQUISITES FOR DEVELOPMENT IN INDONESIA

3.1 Direct Combustion of Biomass

3.1.1 Technical Description and Present Use

Firewood and agricultural waste materials have historically been used as sources of energy for cooking purposes in Indonesia. As the population has increased, however, especially in Java, the demand for firewood has begun to exceed the natural biomass resource supply. Numerous studies have been made to determine the amounts of each form of energy used for household cooking and other activities, but there has continued to be a lack of firewood in heavily populated areas. In the absence of sufficient quantities of firewood materials, it has been necessary to resort to the use of increasing amounts of kerosene for both cooking and lighting purposes. Table 3-1 shows a recent compilation of household energy uses, from which it is seen that kerosene use is increasing by approximately 10% per year, while charcoal, which is a common fuel source in many countries, is not being developed in Indonesia.

In order to provide assistance to the people with low income levels who must resort to the use of kerosene, the Indonesian government has subsidized its cost. This has resulted in benefits to the poor people, but since 1969 the increase in kerosene use has become so great that substantial amounts must now be imported to meet the demand. It has been seen in the many surveys made that dependence on kerosene increases with proximity to cities and heavily populated areas, and that 80% of household consumption

TABLE 3-1.

QUANTITY OF ENERGY USED BY HOUSEHOLDS IN INDONESIA*

X 1000 TCE**

YEAR	ENERGY TYPE			
	OIL (KEROSENE)	LPG***	CHARCOAL	FIREWOOD & AGRICULTURAL WASTE
1974	3,171	22	34	17,349
1975	3,636	33	42	19,038
1976	3,948	38	44	21,221
1977	4,390	41	52	23,158
1978	4,786	30	38	25,310
1979	5,269	32	34	27,315

*BPPT/Bechtel program of energy modeling: report under preparation (1980)

**Tonnes Coal Equivalent

***Liquified Petroleum Gas

is for cooking, with 20% for lighting purposes. The amount of kerosene used for household purposes in the period 1969-1978 is shown in Table 3-2.

Direct combustion of biomass, particularly woody biomass, to produce steam and electric power, is also widely practiced in the forest products industry (i.e., plywood, lumber, and pulp and paper operation) around the world. It is a well-known technology, and considerable operating experience has been accumulated through successful operation of wood residue burning installations in different forest products industries. For example, burning of wood waste (bark, low quality chips) and processing residue (black liquor) to supply part of the in-plant energy needs, is an integral part of the present day pulp and paper mill operations.

As the price of conventional energy sources (particularly oil) is rising, the utilization of processing waste to supply part of in-plant energy needs is becoming more popular among the different forest products industries. Consequently, many saw mill and plywood mill operators around the world have either installed or are considering wood-waste boilers for producing steam and/or electricity. Also, a small municipal utility in Vermont, U.S.A., has retrofitted an old coal-fired generating station to burn wood chips.

Low-moisture (less than 50 percent wet basis) woody biomass is

TABLE 3-2.

CONSUMPTION OF KEROSENE BY HOUSEHOLDS*

1969 - 1978 (kiloliter)

Year	Sale of Kerosene	Consumption of Kerosene by the Households	Consumption of Kerosene for Cooking only
1969	2,700,067	2,160,053	1,728,042
1970	2,732,195	2,185,756	1,748,604
1971	2,817,548	2,254,038	1,803,230
1972	3,306,580	2,645,264	2,116,211
1973	3,681,977	2,945,581	2,356,464
1974	4,258,050	3,406,440	2,725,152
1975	4,882,663	3,906,130	3,124,904
1976	5,302,722	4,242,177	3,393,741
1977	5,895,330	4,716,264	3,773,011
1978	6,426,000	5,140,800	4,112,640

*Source: Directorate General of Oil and Natural Gas (1978)
Progress Report "Utilization of Firewood and Agricultural Waste in Indonesia", Satawati Hadi, et al, LPHH (April 1979)

an excellent feedstock for different industrial boilers. The capacity of these boilers can range from as low as 2500 kilograms of steam per hour to large single boilers producing more than 180,000 kilograms of steam per hour. Larger boilers (greater than 34,000 kg/hr) invariably use traveling grates, and the most common design is the "spreader-stoker" type. Fixed grates are generally used for smaller boilers. The details regarding the design concept of different wood-fired boilers are presented in several literature sources. Each wood-fired or biomass-fired boiler is designed based on the fuel characteristics and intended application. Within the design limitations, provisions can be made to burn different biomass fuels (wood waste, agricultural, etc.) either alone or in combination with conventional fuels like oil, gas, and coal. When electricity is the desired energy product, boilers capable of producing high-pressure superheated steam are preferably used in conjunction with steam turbine-generators; if both steam and electricity are required, then the system could be designed to operate in a cogeneration (simultaneous production of process steam and electricity) mode.

3.1.2 Potential Application of Direct Combustion in Indonesia

Direct combustion of biomass (firewood) provides the bulk of household energy needs in rural areas of Indonesia. On a limited scale, biomass is currently being used to provide energy in certain industries. For example, the palm oil mills utilize a large portion of the waste (fiber and fruit shell) to produce steam and electric power for the in-plant use. Also, most of

the existing plywood mills use their own wood waste to produce steam for drying the lumber and finished products. Almost all the small-scale brick and roof tile manufacturing operations use wood and other agricultural wastes to fire their kilns.

The opportunities for expanding the current use of biomass in the industrial sector, particularly the forest products industries, and introduction of biomass (wood) as a fuel for electricity generation in remote and isolated rural areas of Indonesia are briefly described in the following section. Also, the problems of fuel wood supply for household use on the island of Java and ways to mitigate this situation are briefly discussed.

3.1.2.1 Forest Products Industry. The forest products industry is rapidly growing in Indonesia. Particularly the plywood and pulp and paper operations are expanding at a faster rate. The potential of using saw and plywood mill waste for producing energy is promising. Almost all the existing saw mills and plywood mills use diesel generators for supplying plant power requirements. This is particularly true for the plants which are located on the islands of Sumatra and Kalimantan. The waste available from the saw and plywood mills can be used to generate the energy requirements of these mills. For example, an average size saw mill processes approximately 50,000 m^3 of logs per year. About 30 to 40 percent of this quantity is generally considered to be waste material. The average power requirement of this mill is 500 kW; the waste material, if

burned in wood-fired boilers, could produce energy in excess of the mill needs. Most of the plywood mills at the present time burn a part of their waste to produce steam for drying the lumber and the finished products. However, these mills are powered by diesel generators. The plywood mill can be an ideal site for locating a wood-fired cogeneration (simultaneous production of electricity and steam) plant. Thus, both the steam and the electricity needs of the mill could be met by utilizing the waste generated in the mill.

Even though the forest products industry in Indonesia offers promise for wood-based electric power generation, certain technical, economical, and institutional barriers would have to be overcome for any meaningful acceptance of this technology. For example, at the present time, the diesel fuel is still less expensive compared to the other alternative energy sources. In most regions, the electric power from the local utility (PLN) is not available for industrial customers; this is particularly true for the forest products operations on the islands of Sumatra and Kalimantan. In regions where the utility power is available for the industrial customers, its reliability is questionable. These factors are the major driving force, particularly in the case of the forest products industry, for the extended use of diesel fuel for captive energy generation within each industry.

The high front-end investment in wood-fired electric power plants

and the lack of local operating experience on the part of the Indonesian forest products industry will also slow down the acceptance of this technology. However, these barriers in part can be mitigated by an active support of the government for the commercialization of this technology. Financial incentives (i.e., loan guarantees and tax credits) and joint field demonstration projects between the forest products industry, PLN*, and PERL/LSDE, would help eliminate most of the major barriers and promote the direct biomass combustion technology.

3.1.2.2 Electricity Generation. The use of small wood-fired electric power plants should only be considered for the islands of Sumatra, Kalimantan, and other forest-rich islands. These islands not only have the resource, but also provide ideal sites for demonstrating the technical and economic feasibility of small-scale (0.5-10 MW_e) wood-fired power plants. The transportation of wood waste from Kalimantan and Sumatra to a central wood-fired electricity-generating station on the island of Java will be prohibitive in cost, particularly since the island of Java will have a large coal-fired central electric power generating station by the year 1983, and it will be almost impossible for any wood-based electric power plant to be cost competitive on this island.

At the present time, about half of the electricity eneration of the islands of Sumatra, Kalimantan, and Sulawesi is done

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*Local state-owned utility

by the PLN (state-owned utility). PLN currently has about 584 MW_e of oil-fired installed capacity on these three islands. These installations range from a small diesel engine/generator of 40 KW output capacity to about 30 MW_e oil-fired steam-electric power plant. But the majority of these plants are diesel engine/generators with an output capacity of about 1 MW_e or less.

Since most of the forest resources in Indonesia are present on these islands, and the existing logging operations are generating large quantities of waste, the use of this waste wood for producing electric power for local consumption appears to be a viable option. These wood-fired electric power plants, depending on location and size of the local market, may range from as low as 500 KW to 10 MW generating capacity. The primary market for these plants would be neighboring saw and plywood mills and the surrounding rural areas. For the successful implementation of these small wood-fired power plants, cooperation between PLN (local utility), the Department of Forestry, and the forest products industry is essential.

3.1.2.3 Household Energy Use. The natural growth of biomass in Indonesia could also be exploited to increase the use of firewood and agricultural waste materials as household energy supplies, thereby decreasing Indonesia's dependence on kerosene. Forestry activities now produce waste consisting of 30-40% of the trees, but unfortunately their locations are far removed from large population centers, and transportation costs thus

become prohibitive. Agricultural wastes are also plentiful, but again, transportation becomes a problem.

Standard practice which has been used for generations on a worldwide basis for concentrating the energy values in fuelwood and agricultural wastes so that they can be transported and used economically in populated areas is their conversion to charcoal. It is a curious fact that charcoal is used only very slightly in Indonesia for cooking purposes, and its use is not increasing in spite of the need to transport firewood for longer and longer distances. Rather than concentrate on charcoal, the emphasis has been placed in increased kerosene usage, which is now becoming a burden to the government, and could become a nearly intolerable burden to both the government and the low income population if allowed to accelerate into the future.

In view of these facts, programs of reforestation with fast growing trees, conversion to charcoal, and developing more highly efficient charcoal-fired stoves should be accelerated. On Java alone it is estimated that 20 million hectares of class 4 land which is not suitable for agricultural production could be used for fast growing trees. Nearly 4 million hectares are subject to severe erosion because of deforestation, and planting fast growing trees in these areas would serve the two purposes of mitigating erosion and providing fuelwood.

3.1.3 Role of PERL/LSDE in Developing the Direct Combustion Technology

Direct combustion of wood or biomass for industrial/utility

energy generation is an established technology; several wood or wood residue-fired boilers are operating in the U.S.A. Also, on a limited scale, wood-fired and palm oil processing waste-fired* boilers are presently operating in Indonesia. Since wood combustion is a mature technology, the technology development activities at PERL/LSDE in this area will be minimal. However, as a national energy laboratory, PERL/LSDE could be very instrumental in promoting direct combustion of wood/biomass for steam and/or electricity generation both in the industrial and utility sectors of Indonesia.

The promotion of direct combustion of biomass for steam and electric power production in Indonesia can be done by:

1. Technical data and information dissemination
2. Pilot demonstration projects

Both of these functions can be carried out by the technical staff of the planned PERL/LSDE. The description of these functions is given below.

3.1.3.1 Technical Data and Information Dissemination. PERL/LSDE should be equipped to generate technical data and information related to the direct combustion of biomass/wood for energy production. Major effort of this technical data generation should be focused on the characterization of different biomass fuels. This characterization would particularly include the

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*The fiber and the fruit shell.

determination of proximate, ultimate analyses, heating value, and the combustion characteristics of different biomass fuels common in Indonesia. Other properties like ash analysis, ash fusion temperatures, specific gravity, and bulk density should be determined for various biomass fuels. Experimental units should be set up to develop technical data on advance feed preparation (pelletization, extrusion, and drying) and combustion (fluidized-bed combustion) processes for different biomass feed-stocks. Technical and economic feasibility studies should be conducted to determine the cost competitiveness of different biomass-based electric power plants. These studies should also focus on the identification of possible demonstration sites for wood-based steam electric power plants.

The technical data and information generated by the PERL/LSDE can be published as a technical handbook on burning wood/biomass for energy. This handbook should also include information on the availability and type of hardware (equipment) needed for setting up a wood/biomass-fired power plant. This information can be obtained from similar handbooks published in the U.S.A. and also by contacting the local representative of different equipment vendors.

The resources needed to carry out this task at PERL/LSDE are given in Sections 4.0 and 5.0.

3.1.3.2 Pilot Demonstration Projects. As indicated earlier, the direct combustion of wood/biomass is a mature technology. Therefore, no pilot development work is needed at the PERL/LSDE. However, in order to enhance public confidence in the technology, pilot demonstration projects are required.

The implementation of these demonstration projects would partly depend on the results of the technical and economic feasibility studies and the local government policies for promoting the technology. Two pilot demonstration projects are recommended. These pilot demonstration projects should be located in the field.

One of these projects may be a small (0.5 MW_e) wood-fired electric power plant on the island of either Sumatra or Kalimantan. For an effective implementation of this project, the PERL/LSDE staff would have to work in close cooperation with PLN and the Department of Forestry; the PERL/LSDE staff may preferably monitor such a demonstration project with PLN assuming the operating responsibility.

Another wood-fired steam- and/or electricity-producing plant (1,500 kW) should be set up in an industrial setting. This could be a joint project between a saw or a plywood mill in Kalimantan or Sumatra, and, once again, PERL/LSDE would provide technical assistance and preferably assume the project monitoring role. These two projects, if successfully implemented, would help promote the extended use of wood and agricultural residue for

providing a small portion of industrial and utility energy needs of Indonesia. A brief description of these two projects is given in Table 3-3.

Efforts which can be carried out by BPP Teknologi personnel or supervised contractors to increase household supplies of fuelwood include:

1. Inventory and designation of the locations and extent of the land which could be used for firewood forests, particularly where the need for firewood is critical.
2. Studies of varieties of firewoods which possess high heat energy, are fast growing, and can grow well in marginally poor soils not suitable for food production.

Efforts at PERL/LSDE to increase the technology of charcoal production and improved stoves are shown in the schedule of phased implementation in Section 3.6, as follows:

1. Considerable development of charcoal production techniques should be undertaken. The old methods of producing charcoal in a pit, with the biomass covered with soil to limit oxygen supply in the process has been replaced by modern metal charcoal plants, which can be stationary or transportable. These can be made easily in Indonesia and used efficiently for both firewood and agricultural wastes. Improvement in design and development of standard designs for specific feedstocks should be carried out. Charcoal packaging and transportation should also be developed. These activities can be carried out by coordinating existing personnel and equipment located at the various research institutions, and forging an intensive field demonstration program.

TABLE 3-3.

DESCRIPTION OF TWO PILOT DEMONSTRATION WOOD-BASED STEAM ELECTRIC PLANTS

	PROJECT NO. 1	PROJECT NO. 2
Type	small rural wood-fired electric power plant	wood-fired cogeneration plant
Preferred location	near a rural community in Sumatra or Kalimantan	existing saw or plywood mill in Sumatra, Kalimantan, or other wood-rich islands
Capacity	500 kW (900 kg/hr of bone dry wood)	1,500 kW_e - 20,000 kg/hr of saturated steam at 2.5 kg/cm^2 (3,900 kg/hr of bone dry wood)
Operating Conditions		
boiler	330^oC (625^oF) 26 kg/cm^2 (350 psig)	330^oC (625^oF) 26 kg/cm^2 (350 psig)
turbine	exhaust = 8.8 cm Hg abs (3.5" abs) rpm = 5,000	exhaust = 2.5 kg/cm^2 (20 psig) rpm = 5,000
generator	rpm = 1,800 volts = 480	rpm = 1,800 volts = 480
total steam rate	8.1 kg/kWh (18 lbs/kWh)	12.2 kg/kWh (27 lbs/kWh)

Major equipment: wood chipper, fuel storage bin, boiler, turbine generator, and auxiliary equipment

Equipment price: F.O.B. New York	US$660,000	US$1,400,000

2. Stoves for direct combustion of biomass materials and charcoal commonly operate at 15 to 20% efficiency, but some designs are stated to have as high as 35% efficiency of heating energy obtained. Development of more efficient stoves is well underway and should be accelerated, with a widespread field demonstration program administered by personnel at PERL/LSDE.

3.2 Gasification

3.2.1. Technical Description

Gasification is the thermal decomposition of solid carbonaceous fuels (i.e., coal, wood, biomass, etc.) in the presence of limited (less than stoichiometric amount) supply of air to produce combustible fuel gases. When air is the only gasifying agent used in the process, the product gas mainly consists of carbon monoxide, carbon dioxide, nitrogen, with small amounts of hydrogen, methane, and other hydrocarbons. The quantity of hydrogen in the product gas can be increased by using steam along with air. The quality of the product gas can be improved by using pure oxygen instead of air as an oxidant.

Reactors used for gasification are usually characterized by the flow of solids and gases. The principal reactor configurations are:

1. Fixed or moving bed
2. Fluidized-bed
3. Entrained-bed

The details regarding different types of gasification reactors

are available in literature; also, suggested reading material on biomass gasification is given in Section 6.0. Of the three types of gasifier mentioned above, only air-blown fixed or moving bed gasifiers have been commercially available for converting wood/biomass into a fuel gas. The capacities of these gasifiers range from small to intermediate (5 kg/hr - 10 ton/hr); a variety of biomass feedstock can be used, however, low moisture (less than 30 percent wet basis*) woody biomass or agricultural waste are required for trouble-free operation.

The low calorific value (low-Btu) gas produced from different air-blown biomass/wood gasifiers was used in internal-combustion engines, both stationary and mobile, steam boilers and ceramic kilns, etc., for many years in different parts of the world. Because of the availability of cheap petroleum fuels, the popularity of these gas generators was lost, and by 1950, this technology was more or less abandoned. However, as the availability of petroleum-derived fuels is shrinking, the old air-blown biomass/wood gasification technology is now being revitalized.

Several experimental gasifiers are being operated at universities and energy research centers around the world to test the operation of the gasifiers and the application of the product gas. Advanced biomass gasification techniques (i.e., fluidized-bed, high pressure, and oxygen-blown) are being developed at several research

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*Weight of water divided by the total weight of wet biomass fuel.

centers in the U.S.A. These gasification technologies are particularly being developed for large-scale (greater than 500 ton/day bone dry biomass) synthesis gas (CO and H_2) production operations. In Indonesia research and development work is slowly expanding in the biomass gasification area. At the present time, an Imbert gas generator and retrofitted diesel engine (25 kW output) is operating at the solar village in Picon. This gasifier diesel generator set is currently being used to pump irrigation water.

A small bench-scale (about 3 kg/hr) gasifier is presently being tested for different biomass feedstock at ITB in Bandung. At the BPP Teknologi, plans are currently underway to construct a small charcoal gasifier to produce DC electricity. The capacity of this gasifier-engine generator will be about 5 kW. Also, a technical and economic feasibility study is being conducted to assess the potential of biomass-based methanol production technology in Indonesia.

3.2.2 Potential Application of Biomass Gasification in Indonesia

As indicated earlier, the low calorific (low-Btu) value gas produced from an air-blown biomass gasifier can be used to operate internal combustion engines to fire boilers, drying kilns, etc. Since the gasification technology for producing low-calorific value gas is commercially available, in the near term, this technology would find application in different Indonesian energy-consuming sectors. Application of this technology in different sectors is given below.

3.2.2.1 Forest Products Industry. As indicated earlier, the existing saw and plywood mill produces a sizable amount of waste wood. This waste wood can be converted to supply the in-plant energy needs of these mills. Direct combustion of this waste to produce steam and use of turbine-generator to supply electricity for the mill is presented earlier. The energy needs of the mill can also be met by using an atmospheric pressure air-blown gas generator. The suitability of these two alternative energy supply systems would largely depend on the relative economics, ease of operation and compatibility with the existing energy supply system. If a new mill is being constructed, the direct combustion system would probably have an economic advantage over a gasification system. However, in the case of existing mills, the gasification option offers better flexibility and compatibility with the existing energy generation system of the mill.

For example, the gasification option provides the opportunity of retrofitting the existing diesel-generators. This retrofit will be simple if a mixture (90 percent gas and 10 percent diesel fuel) of gas and diesel fuel is burned. However, for using 100 percent biomass-based low calorific value gas, the existing engines would have to be retrofitted extensively. This retrofit, depending upon the type of engine, may turn out to be more expensive than purchasing a new dual-fuel diesel engine. In the former retrofit case where a mixture of diesel fuel and the low calorific value gas is to be burned, the existing diesel engine capacity will be derated to a certain extent. However,

since most of the existing diesel engines are oversized, this derating would not seriously impact the normal mill operation.

Another potential market for the wood based low calorific value gas is to provide fuel for the tractors and logging machines used in the existing logging operations in Kalimantan and Sumatra. Several mobile gasifiers were developed for vehicles between World Wars I and II. The producer gas produced was used to power trucks as early as 1921. The retrofit of existing wood-harvesting machines to run on wood-based gas is not simple. The impacts of such retrofit on the productivity of these harvesting and logging machines should be carefully evaluated. Nevertheless, the size of the existing logging operations and future growth in this industry offer a large potential for the introduction of mobile gas generators in the logging industry.

The relative economics of combustion and gasification alternative energy supply options should be evaluated. However, the simple design, quick start-up, and minimum attendance requirement of small gas generator plants (less than 500 kW) cannot be denied.

3.2.2.2 Electricity Generation. The gasification option could also be considered for retrofitting the existing small (less than 10 MW_e) PLN oil-fired electricity-generating plants in Sumatra and Kalimantan. As indicated earlier, the lack of wood resources and the planned large (about 400 MW_e) coal-fired central stations on the island of Java, will make the small

wood-based electricity production plants uneconomical on this island. Therefore, the wood-based electricity generation option should be restricted only to the other islands, particularly Sumatra and Kalimantan. Once again, a comparative economic analysis should be conducted to determine the cost competitiveness of direct wood-based electricity generation and wood-based low calorific value (low-Btu) retrofit system.

3.2.2.3 Agriculture. The low calorific gas generators are suitable for supplying energy for different agriculture and/or related operations. For example, the agricultural waste (crop residue) can be used to produce a low calorific value gas which, in turn, could power a retrofitted diesel generator to drive either an irrigation pump or a rice mill. In Indonesia, rice husks and rice straw are the most commonly available agricultural residue (see Biomass Production). The higher ash content (silica) of rice husks does create some operational difficulties for the gas generators, but these difficulties can be overcome by certain design modifications. In some cases, densification of rice husks prior to gasification may be required.

3.2.2.4 Application of Advanced Gasification Technologies. Advanced gasification technologies, i.e., high pressure gasification, fluid-bed gasification, oxygen-blown gasification and catalytic gasification, are being developed in the U.S.A. for the production of synthesis gas (CO/H_2) on a large scale. This synthesis gas, in turn, could be used in the production of

different chemicals and fuels. Methanol is one of the chemical/fuels which could be produced via this biomass gasification (oxygen-blown) and subsequent catalytic synthesis route. Since methanol is one of the liquid fuels which is being given high priority as a gasoline additive in the short run and gasoline substitute in the long run, the need for developing advanced biomass gasification technologies cannot be overemphasized.

In Indonesia, there seems to be a great amount of interest in developing an alcohol fuel (both ethanol and methanol) industry. In line with this interest, serious efforts should be made for developing advanced biomass gasification technologies, particularly for gasifying wood and wood residue.

3.2.3 Role of PERL/LSDE in Developing Gasification Technologies

PERL/LSDE should be equipped to conduct advanced batch and bench-scale (continuous) gasification tests on different biomass feedstocks. These bench-scale tests would particularly involve testing of different gasification catalysts, operating conditions (high pressure and temperatures), kinetic determination, testing different designs of grate, fire box and ash-slagging characteristics. The bench-scale testing would also involve special catalyst evaluations and determination of reaction mechanisms for the gasification of different biomass species. The batch experiments would develop basic data for designing continuous bench-scale equipment, and the data produced in the continuous bench-scale advancedgasification experiments could be used for

designing the pilot facilities. The bench scale equipment can also be designed, using data produced in similar advancedgasification experiments elsewhere.

Initially, the pilot gasification tests at PERL/LSDE should concentrate on operating low calorific value gas generators for different biomass feedstocks. Two pilot gasifiers, one updraft design and one downdraft design, should be constructed. The gases produced from these gasifiers, using various biomass feedstock, should be tested in internal combustion engines and small oil-fired boilers respectively.

After the successful operation of these two pilot gasifiers, and accumulation of enough design data from bench scale (continuous) experiments on advancedgasification processes, a third pilot gasifier should be designed to test high pressure (greater than 100 psig), oxygen-blown gasification of biomass to generate synthesis gas.

The resources required to carry out the above-mentioned biomass gasification research and development activities at PERL/LSDE are presented in Sections 4.0 and 5.0.

3.3 Pyrolysis

3.3.1 Technical Description

Pyrolysis is the thermal decomposition of solid carbonaceous fuels in the absence of air, which produces combustible gases, oils (tars), and solid char residue. When air is not present in the system, the heat input for pyrolysis is provided by

burning a conventional fuel or part of the product gases. Most of the pyrolysis processes, however, use a small quantity of air, and the partial combustion of a portion of product char supplies the pyrolysis heat. The major differences between gasification and pyrolysis are the operating temperatures and quantity of air* used in the process. The gasification process uses more air than the pyrolysis process and, consequently, higher temperatures are reached during gasification.

In general, the operating temperatures and the presence of water vapor in the low-temperature pyrolysis system controls the relative quantities of gas, oil and char products. Higher temperatures favor the production of gas and decrease the oil yields. The presence of water vapor in the system also promotes steam gasification and cracking reactions, which increase the gas production at the expense of both reduced oil and char yields.

Several experimental and pilot pyrolysis units have been built and tested in the U.S.A. These units were designed to test a variety of biomass feedstocks; the most common being municipal solid waste, wood chips and agricultural waste. In Indonesia, research and development work on low temperature pyrolysis has primarily focused on developing small (1 tonne/day) rice husk pyrolysis systems for the local rice mills. Two one-tonne-per-day

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*When partial oxidation is used to supply the process heat.

pyrolysis systems have been installed near Bandung; one of these units is installed at an existing rice mill. The main purpose of this ongoing research and development activity is to test the operation of a small rice husk pyrolysis unit and find appropriate utilization for the pyrolysis products. The initial data obtained from the operation of the pyrolysis unit have resulted in several process modifications. These modifications are expected to improve the system performance. So far, the oil yields have been lower than the original expectations. Also, it was found that the pyrolysis oil was not a suitable substitute for domestic kerosene use.

3.3.2 Potential Application of Pyrolysis in Indonesia

As indicated earlier, the pyrolysis of biomass results in a number of products which, depending upon the operational temperature, may include a non-condensable gas, condensable hydrocarbons of a range of viscosities, and a char. The product oil (condensable hydrocarbons) is a highly oxygenated (greater than 20 percent) viscous liquid, with corrosive properties. The oil is not similar to any conventional petroleum-based liquid fuels. However, with proper equipment modifications, it can be burned in industrial heavy fuel oil (residual fuel oil) burning installations.

The pyrolysis of rice husks gives powdered char, which contains more than 40 percent ash (silica). Also, the product gases, except for direct burning, cannot be directly (without extensive cleaning) used in internal combustion engines. In this sense,

pyrolysis does not convert biomass directly to usable energy products, but it produces three different products that can be further processed or refined for intended application. As a result, a small-scale (1 tonne/day) pyrolysis plant may not be able to process and market the energy products (particularly oil and char) effectively. Moreover, since the quantity and the quality of different pyrolysis * products are extremely dependent upon the operating conditions, a close control of these operating conditions is essential for obtaining a proper yield of consistent quality energy products.

Because of this inherent requirement of a pyrolysis process, it would be very difficult to obtain a consistent quality energy product from a simple inexpensive small pyrolysis unit. If all the required controls are used to improve the performance of a small pyrolysis plant, it would no longer be an inexpensive system. Therefore, it seems that the ability of the pyrolysis process to extract a range of more valuable hydrocarbons from biomass may only be exploited at a large-scale (at least 100 tonnes/day of bone dry biomass) operation. Small-scale biomass conversion systems should be primarily restricted to combustion and air-blown gasification technologies.

A quick look at the biomass resource availability in Indonesia would indicate that only wood and wood residue could sustain the operation of large-scale pyrolysis plants. Once again, because of

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*The term pyrolysis refers to low temperature pyrolysis process.

the wood fuel transportation cost limitations, these plants would have to be located near the wood resources; this would require the plants to be located on the islands of Sumatra and/or Kalimantan. The economic feasibility of large wood-based pyrolysis plants would very much depend on the marketability of pyrolytic oil and char. Based on the results of studies conducted in the U.S.A., it could be safely assumed that the pyrolytic oil, after necessary equipment modifications, could be used in industrial residual fuel oil-fired installations. The product char could be used for household (particularly rural) energy needs. Another emerging application for the product char is its use in existing residual oil-fired industrial and utility boilers as a char/oil mixture. The feasibility of this application, however, depends on the successful adoption of coal/oil mixture combustion technology for the char/oil mixture combustion. It should be recognized that char, depending on its volatile content, has different combustion properties than most of the coals.

The gaseous product of a pyrolysis process has low to intermediate energy content; thus, it cannot be economically transported over long distances. The best use of this product would be at the plant site. For example, it could be used to supply the pyrolysis heat and in-plant power to run the equipment.

3.3.3 Role of PERL/LSDE in Developing Pyrolysis Technology

In the light of the above discussion, it is recommended that

initially PERL/LSDE should conduct bench-scale experiments on fluidized-bed pyrolysis of different wood/biomass feedstocks. During these bench-scale experiments, the optimum operating parameters (temperature, residence time, feed size, etc.) should be determined. Also, the yield of different energy products for various operating conditions should be determined. Other important parameters, like fluidizing medium, fluidization velocity, and bed height should be determined. After the successful bench-scale testing, the data developed should be used to design and construct a pilot pyrolysis unit for further technology development work at PERL/LSDE. At the present time, it is expected that one of the pilot up-draft low-calorific gasification units, which is recommended for the initial pilot work at PERL/LSDE, could later be retrofitted to operate in a pyrolysis mode. If this retrofit is feasible, then the need for constructing a separate pilot facility for the pyrolysis unit would be eliminated.

During the pilot pyrolysis testing period, design data should be collected for future large-scale (greater than 100 tonne/day) demonstration plants. Also, sufficient quantities of pyrolysis products (gas, pyrolytic oil, and char) should be collected for an extensive product characterization and utilization tests. These tests would include, but not be limited to, the burning of pyrolytic oil and char in combination with residual fuel oil at conditions simulating industrial oil burning installations. These combustion tests would produce vital performance data for

pyrolytic energy products.

Along with the development of a low-temperature pyrolysis technology, advanced pyrolysis technologies should be explored and developed at PERL/LSDE. Flash pyrolysis is one of the advanced technologies which is actively being developed at several research and development centers in the U.S.A. Similar programs could be set up at PERL/LSDE for developing this technology.

The resources required to carry out the proposed research and development work in biomass pyrolysis at PERL are presented in Sections 4.0 and 5.0.

3.4 Alcohol Production

3.4.1 Technical Description

Biomass ethanol is a major renewable energy source which offers immediate prospects of providing a premium liquid fuel based on available domestic biomass resources to partially replace petroleum product demand in Indonesia. Ethanol use as a substitute for the lighter petroleum products such as gasoline and naptha would complement efforts to promote wood, hydroelectric, coal and solar energy as substitutes to heavier petroleum products (fuel oils) to replace a substantial portion of petroleum demand in the country.

The technology of alcohol fermentation is well known throughout the world, although recent process and design alterations have resulted in several refinements in the technology. The basic principles of the fermentation process consist of feedstock preparation, which consists of formation of a solution of fermentable sugars (if not already present in the feedstock), followed by fermentation of the sugars to ethanol by specially selected strains of yeast, after which ethanol is separated from a fermented mixture, usually by distillation. Feedstocks normally used in ethanol fermentation include sugar as starch-bearing crops, such as sugar cane and cassava, and some cellulosic biomass such as woody biomass. The major byproducts from fermentation include ethanol (either hydrous or anhydrous, depending on the type of separation techniques employed), wet

stillage, which consists of yeast biomass and left-over solids not fermented, and carbon dioxide gas evolved by yeast during the fermentation process. The technology has been developed to produce ethanol in this manner in plants ranging in capacity from a few liters per day up to several million liters per year.

Not surprisingly then, many countries have begun to implement national policies to develop an alcohol fuels program to provide for a major portion of their petroleum based fuel demands. Brazil, of course, is the world leader in developing an alcohol based fuel economy, and has developed an aggressive national alcohol program throughout the country. But even with the large successes enjoyed by Brazil in their program, implementation of the program has not progressed as quickly as expected due to a variety of reasons, including limited availability of subsidized financing, marginal economics, high investment requirements, high production costs, agricultural and industrial management problems, difficulties in storage and maintenance, etc. Other programs, such as in the United States, have yet to develop to a stage where fuel alcohol production capacity is significant enough to have impacted petroleum use. These national programs, however, will only be successful in countries with sufficient land mass relative to demand, adequate solar energy, water resources to grow food and feed at surplus levels, and can convert easily to an alcohol-based fuel economy.

3.4.2 Potential Application of Alcohol Fermentation in Indonesia

Indonesia, possessing some of these characteristics, has embarked upon an ambitious program aimed at the ultimate development of new alcohol production capacity of nearly 20,000,000 Kl/yr of power alcohol by the year 2000. By contrast, current production of ethanol from biomass in Indonesia totals only approximately 30,000 Kl/yr from 9 plants, the majority being exported for beverage purposes, while production capacity in Brazil is expected to be only between 4-6 million Kl/yr in 1985.

The new program, conceived to consist of as many as 4,000 5,000 Kl/yr ethanol plants, is a key component in the new transmigration program developed by the government to redistribute the country's population more evenly among the thousands of island land masses comprising the nation. These 5,000 Kl/yr alcohol plants, using locally grown surplus agricultural crops such as sweet potatoes and cassava, and Sago palm harvested from nearby tropical marsh forestlands, will serve as the local fuel base for individual transmigration areas (4,000 families) or for export purposes. Already, the first of these plants is scheduled for construction in 1981 in a transmigration area located in South Sumatra with technical assistance from West Germany. In the vicinity of this plant feedstock consisting of sweet potatoes will be grown by individual farmers on their individual 2 ha farms, with ¼ ha being allocated on each farm for production of the feedstock. With proper crop management,

it is anticipated by Indonesian planners that the centralized ethanol plant will be able to continuously process feedstock and produce power alcohol for distribution to distant markets or use within the area, providing both employment and a fuel base for continued expansion.

In the wake of such an ambitious and rapid development program, it is imperative that a major research and development program be undertaken by Indonesia in order to standardize and develop on a reasonable scale an industry utilizing technology adapted to conditions peculiar to the various regions of the country. This is especially important since several other research efforts have concluded that in some situations it may be more technically feasible or cost-effective from an energy standpoint to utilize other biomass technologies such as direct combustion, gasification, char production or methane fermentation rather than using ethanol production technology to supply energy needs in remote areas.

Based upon discussions then with Indonesian planners, site visits and preliminary analyses by the study team, the following general recommendations are offered regarding the direction and scope of research and development work to be carried out in order to support implementation of an ethanol fermentation industry on the appropriate scale:

1. Develop appropriately sized standard alcohol production units taking into consideration technical, economic and social constraints peculiar to each region of the country,

including such factors as fuel consumption for production of the ethanol (i.e., energy balances), utilization and/or disposal of waste products, cost of harvesting and transport of feedstocks to production facilities, and diversion of alcohol for beverage purposes.

2. Perform an economic assessment of the impact of large scale diversion of biomass for production of fuels rather than production for foodstuffs, particularly at the village level during periods of drought, famine, etc.
3. Develop the appropriate infrastructure to manage production, distribution and utilization of the fuels in a manner which maximizes substitution for conventional fuels.
4. Implementation of a training program for development of a skilled work force at a level commensurate with the needs of the fermentation industry to satisfactorily operate and maintain installed equipment.

3.4.3 Role of PERL/LSDE in Developing Alcohol Production Technology

While the above mentioned recommendations are general in nature, the study team has also identified specific projects which BPP Teknologi should initiate at the energy laboratory at PERL/LSDE or in conjunction with the various institutions involved in related work, with BPP Teknologi being the overall coordinator for all research efforts. BPP Teknologi should also coordinate its efforts and the efforts of those institutions currently working with BPP Teknologi on research projects with other

governmental planning institutions, such that the overall thrust of hardware development managed by BPP Teknologi is consistent with the goals and policies of the rest of the government. Specific recommendations include the following:

1. Although fermentation technology is well known, it has only been in recent years that much engineering effort has been put into refinement of existing technology and development of new hardware to improve the energy efficiency of alcohol production. As a result, several advances in equipment and process technology are available and BPP Teknologi should endeavor to adapt these new technologies into a standardized fermentation plant at PERL/LSDE. Due consideration should be given to development of techniques to process cellulosic or woody biomass to alcohol, as this technology is beginning to emerge as a technically viable alternative to sugar or starch-based alcohol plants. This calls for establishment of both bench and pilot scale testing of alternative plant designs at the lab with the intent of developing a series of process trains to maximize the net energy return from either wood, sugar, or starch-based biomass.

   A suggested program sequence for process development includes:

   a) Preliminary bench scale studies of process components, such as feedstock receiving, storage and processing equipment, pre-treatment equipment including cookers (with particular emphasis on cellulosic feedstock

pre-treatment techniques), fermentors, beer stills and rectifying columns, process chemicals storage and use, stillage processing equipment and product storage. Raw material needs, process efficiency and materials of construction are important parameters to evaluate at this stage. Equipment and facilities for bench scale evaluation work is described in Section 4.2.2.

b) Process trains should then be developed for a given type of feedstock such that evaluation of a continuous process train is possible. Feedstocks which apparently are under consideration at this time include Sago, cassava and sweet potatoes, all starch-based crops; but consideration should also be given towards identification and development of key process train components for cellulosic based crops as well, as this technology may prove fruitful with further research.

c) Optimization of the process trains should be developed next at a bench scale, with the emphasis being on maximum heat recovery, waste utilization and energy efficiency. A prime consideration here should be the development of appropriate heat exchangers, waste recovery techniques (such as yeast recovery and recycle), anaerobic digestion techniques for stillage solids for production of fuel gas (biogas) for re-use in the process, use of fusel oils produced for energy purposes, and low-energy methods for utilization of the CO_2 produced in the fermentation

step. Also important here is to determine an overall energy balance for the entire optimum system, and determine outputs of all products and wastes. This stage is especially important to development of ethanol from cellulosic feedstocks, as this technology is only beginning to emerge at this time. However, this stage cannot be completed until after preliminary bench batch tests are complete.

d) Once an optimal bench scale continuous fermentation system has been identified, the pilot scale facility should be constructed to scale up the results of the bench scale unit to demonstration size, perhaps on the order of one-tenth the size of the projected commercial scale facilities. Recommended pilot plant size would be on the order of 500 Kl/yr, if it is assumed that commercial scale facilities will be on the order of 5,000 Kl/yr. At this time, the pilot plant would serve as a training plant at which a work force of skilled operators could be trained in methods of operation and maintenance of such a facility. It is also anticipated that such a plant could serve as the demonstration model for advanced techniques and equipment in fermentation technology which likely will be developed over the next several years for ethanol production from cellulosic feedstocks. As a start, the equipment and layout of the pilot plant would conform as closely as possible to the

5,000 Kl/yr plant currently under design, or to the design developed in bench studies, with modifications made if further bench scale studies demonstrate a technically and economically feasible method for pre-treatment of cellulosic feedstocks.

2. Secondly, consideration should be given to developing low-cost and low energy consuming wastewater treatment technologies for all waste products produced from alcohol production facilities, including those facilities currently in operation. Special consideration should be given to recovery and re-use of the stillage for refeed if investigation shows the stillage to be of sufficient quality. A three-phased approach is needed here:

   a) Identification and characterization of wastewater streams from bench and/or pilot scale facilities. This procedure would be identical to any other standard wastewater characterization study and could be carried out at PERL/LSDE or any other analytical laboratories.

   b) Development of wastewater treatment approaches. It is anticipated that conventional and innovative biological wastewater treatment schemes for relatively concentrated organic waste streams will be sufficient. Selection of the appropriate method should be verified by continuous bench and pilot plant studies done at PERL/LSDE, with perhaps a portion of the wastewater treatment facilities for the entire laboratory being devoted for such work.

c) Recovery and re-use techniques should be evaluated, if warranted, to establish the feasibility of waste recovery and utilization. Techniques to recover stillage solids such as centrifugation, drum drying, solar drying, vacuum filtration, and filter presses should be evaluated for efficiency, energy consumption, and economic viability. Such testing should be performed at PERL/LSDE as part of a continuing research effort using the treatment facilities for the entire complex. Feeding trials of the stillage, either wet or dry, might be performed in conjunction with personnel at PPPT (P3T) in Ciawi.

3. A third major area of work should be: 1) development of efficient yeast cultures which operate at high fermentation temperatures, and 2) studies of nutrient limitations of yeast utilizing starch and sugar based substrates. In each case the nature and scope of this work is basic, and thus would best be done at the various research institutions such as universities specializing in basic biological research. The scope of the first effort would be to develop yeast strains capable of fermenting sugars from Sago, cassava, sweet potatoes, or sugar based crops at temperatures around 37 - 39°C or above using conventional fermentation technology. The scope of the second work would be to identify any nutrient limitations to the process for a given type of feedstock, and develop methods to enhance the fermentation process.

4. Testing and development of reliable equipment common to the rural villages to utilize ethanol for a variety of purposes.

Although there exists voluminous information in the literature on performance of engines and other equipment running on alcohol, developmental work should be undertaken at PERL/LSDE to evaluate equipment performance on those items common to the villager who will use alcohol as a fuel. More importantly, however, should be the refinement of new equipment to use the fuel should the situation warrant such development. This testing should be done in a laboratory space shared with the other projects in biomass conversion technologies, as such alternative fuel testing for equipment will be common to several of these projects. A tentative location for such work would be in the workshop/mechanical laboratory.

5. A continuing training/seminar program should be maintained at the lab to ensure staff members are kept informed of the current direction and results of work being done worldwide on ethanol production. Such a program might include post-graduate education at technical institutions abroad (e.g., University of Wisconsin, Madison) for staff scientists, travel and participation in international meetings, and series of regularly scheduled seminars conducted by technical consultants from industry, visiting scientists, or in-house staff members.

3.5 Methane Fermentation

3.5.1 Technical Description

The use of biomass for production of a methane-rich fuel gas (biogas) via anaerobic fermentation has been utilized in several parts of the world for many years. In countries such as India, the Peoples Republic of China, the Republic of Korea, Taiwan and Thailand, government development programs have led to the construction of many small-scale anaerobic digestion units. These programs have met with mixed success however, due to factors such as relatively high capital costs for digesters, difficulties in developing simple operating techniques for rural areas, social constraints on the use of wastes for energy purposes and in cooperation between individuals in operating community systems, and net energy yields which are only slightly greater in value than the costs involved. Nonetheless, some of these developmental efforts by various countries have resulted in significant improvements in sanitation and reduction in conventional fuel use (e.g., firewood, kerosene) in particular areas.

It is not surprising, therefore, for Indonesia to investigate the feasibility of a wide-scale implementation of anaerobic fermentation technology as it relates to the particular situation in the country. Research efforts are currently underway to assess available biomass resources for use as feedstocks for

anaerobic digestion units, particularly quantities and availability of water hyacinth (eichornia crassipes). This macrophyte, growing in nutrient-rich, warm, fresh water frequently obstructs drainage of farm lands, encroaches upon aquaculture ponds and completely encloses fresh water pools behind hydroelectric dam facilities. Estimates of water hyacinth growth and extent in Indonesia are incomplete, but preliminary estimates indicate approximately 6 million hectares of fresh water surface area in the country are covered by water hyacinth. Being rich in nutrients such as nitrogen and phosphorus, and being approximately 90% water, 10% solids (of which 80% are volatile), the water hyacinth has been reported to be a good substrate for anaerobic fermentation processes.

Other biomass materials available for use as potential feedstocks for production of biogas include, but are not limited to, animal and human wastes, and agricultural residues such as rice straw, bagasse, peanut wastes, etc. Quantitative data concerning availability of these resources is shown in Tables 2-1 and 3-4.

Within the framework of various technical and economic constraints, investigations have been undertaken by various groups and institutions within the country to evaluate the feasibility of using these residues for production of biogas via methane fermentation. At the Bandung Technological Institute (ITB), several simple small-scale experimental digesters have been

TABLE 3-4.

POTENTIAL BIOMASS FEEDSTOCKS FOR CONVERSION TO BIOGAS VIA METHANE FERMENTATION PROCESSES (after Taylor, 1979)

Type	Population[1]	Total Production	Amount Available for Methane Fermentation
Animal Waste	($X10^3$)	(Kg/yr X 10^{10})	(Kg/yr X 10^{10})
Cattle, Buffalo	9,510	1.02	0.72
Horses, Mules, Donkey	708	0.038	0.027
Pigs	4,378	0.13	0.11
Sheep, Goats	10,633	0.16	0.048
Poultry	131,142	0.068	0.021

[1] Production data for 1975.

constructed and installed in the field at Cicurug and Lembang using animal wastes as the feedstocks. The Indonesian Petroleum Institute (LEMIGAS) is sponsoring two methane fermentation projects at Gajah Mada University, one a pilot scale fermentation tank of the Chinese design located at the research farm of the Department of Animal Husbandry and the other a bench scale study of digestion of animal wastes. LEMIGAS is also supporting anaerobic fermentation research at Cepu.

Other current anaerobic fermentation projects include the bag anaerobic digesters installed at P3T in Ciawi, operating in the mesophilic mode utilizing animal wastes; the Chinese style fixed-dome digester constructed at the Solar Village of Picon; the pilot scale digester developed by Biotrap near Bogor; and the water hyacinth digester operated in the mesophilic mode at Cilangkap. Also planned for construction and operation in the immediate future is a thermophilic anaerobic digestion system to be installed at Serpong, utilizing cattle dung as feedstock.

The nature and scope of these various on-going or completed projects are wide-ranging, including evaluation of both small (family size) and larger size (industrial/commercial scale) digestion units. Variables evaluated include: use of different feedstocks such as water hyacinth or animal wastes feedstocks; different design configurations (e.g., Chinese fixed-cover and Indian floating cover) and level of complexity; various materials of construction such as steel, ferrocement, cement

and rubber-based products (e.g., butyl digestion bags at Ciawi), and both mesophilic and thermophilic digester design. It is unfortunate, however, that the data collected to date from these projects is not sufficient enough in detail or quality to be used towards development of a set of standardized criteria and details for technically and economically feasible digester construction and operation applicable on a wide scale in Indonesia. Moreover, the fact that several of these digestion units once operating are no longer functioning or have not as yet been able to be demonstrated as capable of functioning as intended is a further barrier to implementation of anaerobic fermentation technology throughout the country. Several key technical questions must therefore be resolved prior to development of standardized digester design criteria and effective utilization of the technology within the country.

3.5.2 Potential Applications in Indonesia

Not only is it necessary to refine and continue the basic studies being carried out by the various institutions conducting the above-mentioned research, but it is also necessary to realize the limited role which anaerobic fermentation technologies can play in reducing conventional energy usage in the residential/rural, transportation, and commercial/industrial sectors of the country. Several technical, economic and social constraints, such as ability to easily obtain, harvest, and prepare adequate quantities and quality of feedstocks for digesters, to operate and maintain digesters for continuous

long-term satisfactory operation, and the ability of individual farmers to bear the cost of a biogas plant will all act to limit its application in the rural sector; other constraints, such as the unfavorable economics of using biogas as a motor fuel substitute for the transportation sector and ability to develop proper feedstock handling and by-product processing in the commercial/industrial sector will limit development and implementation of the technology in those sectors as well. Thus, only appropriate and limited amounts of resources should be made available to development of an industry for implementation of anaerobic fermentation technology in Indonesia.

In view of the brief analysis herein, the study team has developed three general recommendations for continued research leading to implementation of anaerobic fermentation technology in Indonesia on the widest possible scale. These recommendations, however, are based upon the conclusion that this fermentation technology has only limited application in Indonesia, perhaps only by trained farmers in rural areas with easy access to ample water hyacinth supplies, or at selected animal feedlots or other commercial/industrial facilities with readily available feedstocks or wastes of sufficient size and character to warrant the capital investment.

GENERAL RECOMMENDATIONS

1. Confine research and development efforts to two major paths: 1) continued investigation of small scale digestion technologies applicable to the Indonesian rural or village situation; and 2) investigation of applicable digestion technology for small to medium size industrial operations such as feedlots, possessing readily available feedstock or waste materials and markets for the by-products (digested effluent and biogas).

2. For the first major path, consideration should be given to development of digester designs which are simple to operate, easy to maintain, use local materials, require a minimum of conventional energy input for a given output, and are easily assimilated into the normal living habits of the rural villager or farmer.

3. For the second major path, consideration should be given to development of digester designs which are likewise the easiest to operate and maintain, maximize net energy production, provide by-products for which ready markets exist, and can easily be assimilated into normal work operations and routines.

3.5.3 Role of PERL/LSDE in Developing Methane Fermentation Technology

To implement these general recommendations, specific projects are recommended below, incorporating existing or presently planned work efforts of BPP Teknologi at PERL/LSDE or other institutions located elsewhere, those projects being coordinated by BPP Teknologi.

EXISTING PROJECTS

1. Water Hyacinth Indian Digester Design

   a) A primary consideration in this project is the determination of the potential energy value of water hyacinth and the land required to grow sufficient feedstock for supplying a digester. Part of the current project should be oriented towards determination of growth rates of hyacinths in Indonesia, factors affecting production of the hyacinth and its potential energy value in the form of biogas. Once a yield of hyacinth is determined (expressed as kg/m^2-day), gas production data from existing digesters can be used to determine net energy production from hyacinth per unit land area and thus land area required to fuel the needs of the users of the gas. The existing digesters at Cilangkap may serve as the unit to determine gas yield from hyacinths, and the proposed 1 ha experimental pond to be located at PERL/LSDE may be used to evaluate growth rates and yields of hyacinths under varying natural conditions.

b) Emphasis should be directed towards development of harvesting and processing systems which allow the hyacinth to be ground to the proper size, mixed with proper amounts of dilution water and fed by gravity flow to digestion units. It is suggested that hardware be developed to process the hyacinth and the front-end of the digestion system be hydraulically designed to incorporate these principles. The hardware for harvesting and processing could be developed in the mechanical laboratory at PERL/LSDE, while the hydraulic design of the loading system be completed and built as part of the next field pilot plant digester built for this project.

c) One of the most important portions of this project is the development of design parameters for a standardized digester design using hyacinth as the basic feedstock. To date, data have not been developed which describe optimal detention time for a given temperature, digester volume, degree of particle size reduction, provision for gas storage, solids loading rate, influent feed solids concentration, degree of mixing required, influent and effluent configurations, optimal loading schedules and use of other substrates to enhance gas production. Each of these parameters must be evaluated prior to development of a standard digester design for wide distribution. It is suggested, then, that preliminary bench scale experimentation be continued either at Padjadjaran University

or PERL/LSDE to determine some of these parameters, after which they may be incorporated into the next design of a pilot scale plant in the field.

d) Another important consideration is the long-term performance under varying temperature and loading conditions. Studies should evaluate digester performance over a period of at least 1½ - 2 years and evaluate maintenance requirements for the unit. This should be done in the field using either the existing digesters at Cilangkap or the next units constructed in the field.

e) A complete evaluation should be undertaken to determine appropriate uses of and ultimate disposal options for the digested effluent from digesters using hyacinths as the feedstock. Available data indicate that substrates such as hyacinth (e.g., marine kelp) may produce a digested sludge with a relatively high protein content and nutrient value as to be used for refeed to animals or fertilizer for different crops, including fish in aquaculture ponds. Evaluations could be carried out in conjunction with the energy farming projects to determine the suitability of the effluent for use as fertilizer for fast-growing trees or for aquaculture (fish farming or nutrient addition to hyacinth ponds). Uses of the effluent for animal feed could be undertaken as a joint project with P3T, and fertilization trials

conducted on test plots located either at PERL/LSDE or any of the other institutions having experimental plots.

f) Development of a standardized gas utilization system should be undertaken in order to develop a safe, reliable method to capture, store and utilize the biogas for rural home use. This is extremely important in that biogas would be used around homes and structures made, in many cases, of non-flame resistant materials, and could precipitate an accident if the gas were not properly handled. It is also important to develop appropriate gas-burning cooking and lighting devices, adapted from current technology used in the rural areas. These items should be carried out at PERL/LSDE initially, then field demonstrated after their reliability has been determined in the lab.

g) A final consideration is the overall material and energy balance for digesters utilizing water hyacinth. It is critical that a mass and energy balance be developed for the digester to conclusively demonstrate the viability of using water hyacinth as a feedstock for anaerobic digesters. Consideration should be given to all energy inputs to the system including the energy required to obtain, harvest, process and load the feedstock and to maintain the unit in satisfactory operation; also,

consideration should be given to the efficiency of conversion of the gas to energy using the technology which will be available to the rural people. These data should be developed using existing pilot scale equipment and gas using appliances in the field.

2. Chinese Digester Design at Picon

Continued research work at the Solar Village on operation and optimization of the Chinese style anaerobic digester should focus on the following areas:

a) Development of a gravity feed system to charge the digester. This should include a dung collection system, a straw and grit removal system and a larger slurry holding tank to mix the dung with water to make the slurry. It is important to note that the present method of collecting raw dung mixed with bedding material, and loading the digester by hand will lead to inefficient operation and performance of the digester. An efficient dung collection and preparation system should first be analyzed and developed by BPPT Teknologi, then the hardware installed at Picon in order to evaluate performance characteristics. The importance of this "front-end" component of the system cannot be overemphasized.

b) Establishment of design parameters for the digester suitable for the peculiar situation found in the rural areas of the country. That is, develop optimum retention

time, solids loading rate, influent solids concentration, gas yields, loading schedule, maintenance schedule, etc., for the kind of waste available. These parameters may be evaluated in either bench scale or pilot scale models, but should in any case be verified using the pilot plant digester at Picon.

c) Evaluate long-term performance of the digester through continued and thorough monitoring of the digester at Picon for a period of at least 1½ - 2 years, monitoring gas production, digester materials durability, influent and effluent quality, and maintenance required. The monitoring program should be as thorough as possible so that an accurate assessment of the viability and desireability of such a design is made and the feasibility of using dung materials in rural areas of Indonesia is ascertained.

3. Animal Dung Digester at P3T, Ciawi

It is recommended that personnel of BPP Teknologi attempt to develop a working relationship with the personnel at P3T for the purpose of establishing a mutual working agreement to operate and optimize the newly constructed anaerobic digester at Ciawi. As the plant at Ciawi contains modern equipment and utilizes advanced techniques in feedstock handling, gas processing and by-product (biogas and digested sludge) utilization, it would be advantageous to work together with the remaining Australian personnel prior to

their departure in operating and maintaining the plant. Through actual operating and maintenance of such a unit, valuable experience could be gained by BPP Teknologi personnel in the design aspects and operation of commercial/ industrial scale mesophilic digestion units.

Benefits from such working experience would be: 1) familiarization with advanced gas processing and by-product utilization equipment; 2) knowledge of digester operation and maintenance requirements; and 3) development of trained personnel capable of assisting in the design and development of future similarly sized and operated units, if warranted.

NEW PROJECTS

1. Thermophilic Anaerobic Digester

As preliminary data from other thermophilic anaerobic digesters throughout the world indicate at least partial success with their programs, it would be advantageous for BPP Teknologi to undertake a thorough analysis of the feasibility of thermophilic anaerobic digestion technology. Both bench and pilot scale units would be appropriate, and it is recommended that these projects be carried out at PERL/LSDE in a sequential fashion. The research and development program should include, but not limit itself to, the following:

a) Bench scale studies to develop design parameters for optimal operation of thermophilic units. Included should be evaluations of retention time, solids loading rate,

influent solids concentration, addition of nutrients or other feedstocks to enhance gas production and pre-processing of the raw feedstock to remove sand grit, etc. Also to be performed are routine tests of influent and effluent quality.

b) Bench scale evaluation of reusable effluent yields. Included should be evaluation of potential nutritive value of the digested effluent for ruminant animals and possible recovery methods of the valuable portions of the effluent. Recovery methods to be evaluated might consist of centrifugation, solar drying, direct reuse by mixing with other substrates, etc. Preliminary feeding trials of the products from bench scale units could be conducted in co-operation with personnel from P3T at Ciawi.

c) Pilot scale studies should be undertaken at PERL/LSDE and oriented towards engineering and development of the design features for full scale facilities. Design criteria developed in bench scale studies should be used for the pilot scale test design on which engineering modifications may be made to optimize the design concepts for a thermophilic digester. Studies should include, but not be limited to, the following: 1) development of optimal pre-processing and loading techniques of the feedstock, with emphasis given to hydraulic or gravity

feeding of the influent to the digester; 2) developing optimal methods for heating the influent and maintaining digester temperatures in the thermophilic range, including such techniques as influent/effluent heat exchangers, solar heating, various insulation schemes, internal hot-water heating arrangements, steam injection, etc.; 3) design studies of inlet and outlet configurations to maximize mixing by non-mechanical or electrical means; 4) mixing studies to determine actual mixing requirements; 5) equipment evaluation of hardware utilized to remove sand, grit and other undesirable material from the influent, evaluating techniques such as cyclone separators, corrugated sand traps, etc.; 6) process control studies to development equipment and techniques to effectively operate and maintain the digester in continuous satisfactory operation, such as temperature and pressure controllers, mixer controllers, etc.; 7) material and energy balance studies to assess net energy production and process effluent characteristics, with emphasis being on development of an operational schedule which yields a maximum of net energy and/or reusable effluent; 8) evaluation of materials of construction needed to construct thermophilic systems; and 9) engineering economic analysis of the system to develop system costs and benefits. Construction costs using various materials of construction should be evaluated, with the intent being to develop the lowest overall system cost.

2. Gas Utilization Studies

An effort should be undertaken to evaluate the entire array of possible methods for using biogas produced from either bench or pilot scale facilities built, operated or managed by personnel of BPP Teknologi. Such efforts should include use of the gas for direct cooking and lighting, and for electricity generation via modified internal combustion or diesel engine-generator sets. The laboratory efforts should consist of a series of experiments evaluating the performance of equipment modified to run on biogas rather than conventional fuels, and developing new ways or appliances to utilize the gas which can be readily assimilated into the rural and industrial/commercial sectors of the country.

3.6 Schedule of Phased Implementation

Based on the evaluation and recommendations set forth above for future biomass energy projects to be carried out under the direction of BPP Teknologi, the study team has developed a generalized concept for phased implementation over the next 3-5 years of the recommended biomass work at the energy laboratory. In the first phase, it is envisioned that three major kinds of activities will be undertaken, consisting of: a) construction of pilot plants for projects involving mature technologies which are now being demonstrated or have been demonstrated either here in Indonesia or elsewhere previously; b) bench scale development of less well-developed or demonstrated technologies which are promising and have a probable chance for successful implementation in Indonesia; and c) basic studies with perhaps advanced training abroad on the feasibility and viability of advanced conversion technologies such as ethanol production from cellulosic feedstocks or methanol production using advanced gasification equipment.

Phase I would last approximately 1-1½ years, depending upon the type of projects and nature of activity.

Phase II would also consist of three major types of activities, and would be a continuation of projects which had progressed satisfactorily through Phase I. Other projects conceived during the preceding period would also be initiated during this period. In Phase II, there would be: a) continued operation of pilot plants built during Phase I to develop a more effective working knowledge of the technology by a wider

group of personnel, perhaps those ultimately charged with the responsibility of implementing the technology on the widest feasible scale; b) construction of additional pilot plant works, should earlier bench scale studies prove promising; and c) development of bench scale studies for the advanced conversion technologies if circumstances should warrant such investment. This phase would also last approximately 1½-2 years, depending upon level of personnel working on the projects, equipment and financial arrangements, etc.

The last phase, Phase III, would complete development of some technologies to the commercial stage, while at the same time provide for an active R & D program to nurture along less well-developed technologies and investigate future directions for development. In this stage, BPP Teknologi would serve three functions, including: a) assuming the role as coordinator for technology transfer of those technologies proven to be technically, economically, and socially feasible at PERL/LSDE or other fellow institutions, and providing a manpower training center from which the skilled workforce to implement the technology is developed; b) maintaining active demonstration pilot plants for projects just reaching the pilot scale stage in order to encourage eventual development of these technologies, if warranted; and c) continue investigating new channels of research in an effort to continually upgrade and promote the use of biomass energy technologies. This phase would be a continuing effort.

Within this general framework, the recommended projects and activities at PERL/LSDE described in the earlier sections of this report have been categorized and are shown below in Table 3-5.

TAB
RECOMMENDED IMPLEMENTATION S

ACTIVITY PHASE / TECHNOLOGY AREA	PHASE I			
	PILOT/DEMO	BENCH SCALE	BASIC RESEARCH	PILOT/DE
1. DIRECT COMBUSTION	- Wood-Fired Electric Plant (Utility) - Wood-Fired Electric Plant (Industry)	- Pelletization and extrusion of feedstock - Fluid-bed combustion	- -	More field proj (Commercializat
2. GASIFICATION Air-blown (Atmosphere pressure) Advance gasification (oxygen, fluid-bed, etc.	a. Down-draft gasifier b. Up-draft gasifier	- Fluid-bed gasifier, oxygen-blown (atm. pressure) - Thermal balance test	- Catalyst evaluation - High pressure autoclave test, basic gasification mechanism	- Fluid-bed air gasification -
3. PYROLYSIS Charcoal production Low-temperature pyrolysis Flash-pyrolysis (advance)	a. Improved kiln field demonstration -	- - Fluid-bed pyrolysis	- - - Batch flash pyrolysis test	- More field pr - Fluid-bed pyr
4. ALCOHOL Conventional technology Advance technology	-	- Batch and continuous fermentation technology evaluation	- Yeast evaluation - Basic research in hydrolysis	- Pilot testing batch and con fermentation
5. BIO-GAS Mesophilic Thermophilic	a. Pilot testing water hyacinths -	- - Batch and continuous fermentation technology evaluation using animal dung	-	- Continued tes field product - Pilot testing

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ABLE 3-5
N SCHEDULE FOR BIOMASS ENERGY PROJECTS AT PERL/LSDE

PHASE II			PHASE III		
T/DEMO	BENCH SCALE	BASIC RESEARCH	PILOT/DEMO	BENCH SCALE	BASIC RESEARCH
projects lization	-	-	- Field projects (commercialization	-	-
d air-blown tion -	- Thermal balance test - High pressure oxygen-blown gasification	- Catalyst evaluation test	- High pressure oxygen blown gasification	- High pressure oxygen-blown gasification	
ld projects d pyrolysis	- - Products characterization (char, oil, gas) - Flash pyrolysis testing	- - More studies on flash pyrolysis	- Continued commercialization - Continued testing of fluid-bed pyrolysis - Product testing and application	- - Continued flash pyrolysis testing - Product evaluation	- -
sting of d continuous tion processes -	- Alternative fermentation technology testing - Pre-treatment technology testing	- Continued yeast evaluation - Continued pre-treatment technology testing	- Continued fermentation testing and field projects - Pilot pre-treatment technology	- Advance separation technologies - Continued pre-treatment technology	- Yeast evaluation
testing/ ducts ting	- Continued anaerobic digestion evaluation	-	- Continued commercialization	-	-

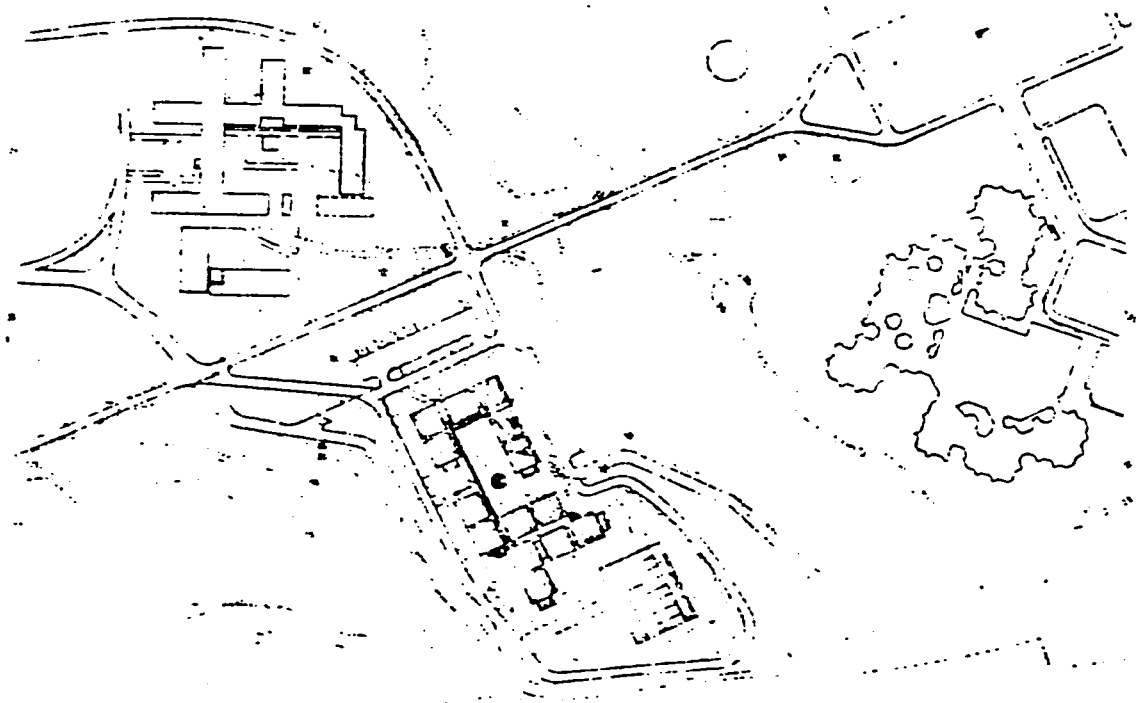
4.0 BIOMASS PROGRAM AT PERL/LSDE: EQUIPMENT NEEDS AND SPACE REQUIREMENTS

4.1 General Laboratory Plan

The July 1980 Preliminary Planning Report for the PERL/LSDE Energy Laboratory and consultation of senior scientists of BPP Teknologi has resulted in an architectural concept of the laboratories as shown in the attached Sheets S01-03. It can be seen that the facility has four designated areas of office, laboratories, pilot plant, and an open area or pond for research and experimentation. Included in the laboratories and pilot plant area also are workshops.

The laboratory area consists of eight buildings, each with a basic modular area of approximately 500 m^2 per floor. The buildings will be generally two stories high, with some future buildings possibly three stories high as the program expands. It is envisioned that the pilot plant area will be similar to a pre-fabricated steel building one story high, with a height of 10 meters, and with a part of the area not covered by a roof. Under such a design, it is recommended that there be five basic laboratories in the Energy Complex, consisting of a workshop/mechanical laboratory, chemical (analytical) laboratory, biological laboratory, physics laboratory, and electronics laboratory. Of the eight laboratory buildings, the remainder would be for other non-biomass related bench scale studies, workshops, and storage.

It is important to state that there are two factors which should



BLOCK PLAN 1

PROYEK PUSAT PENELITIAN ILMU PENGETAHUAN & TEKNOLOGI

ARCHITEK

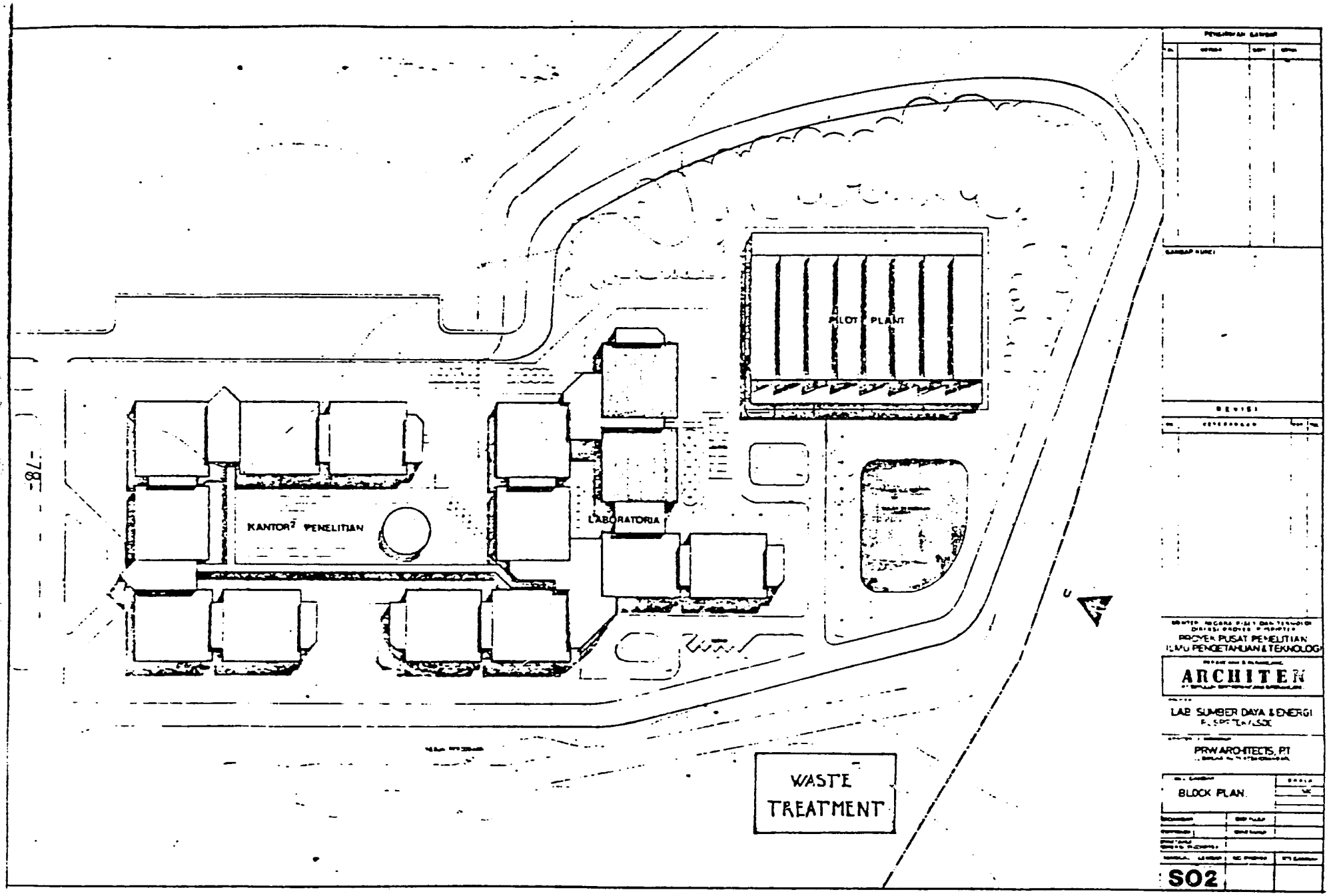
LAB SUMBER DAYA & ENERGI

PRW ARCHITECTS PT

BLOCK PLAN

S01

Best Available Document


PILOT PLANT
KANTOR² PENELITIAN
LABORATORIA
WASTE TREATMENT
PROYEK PUSAT PENELITIAN ILMU PENGETAHUAN & TEKNOLOGI
ARCHITEN
LAB. SUMBER DAYA & ENERGI
PRW ARCHITECTS, PT
BLOCK PLAN
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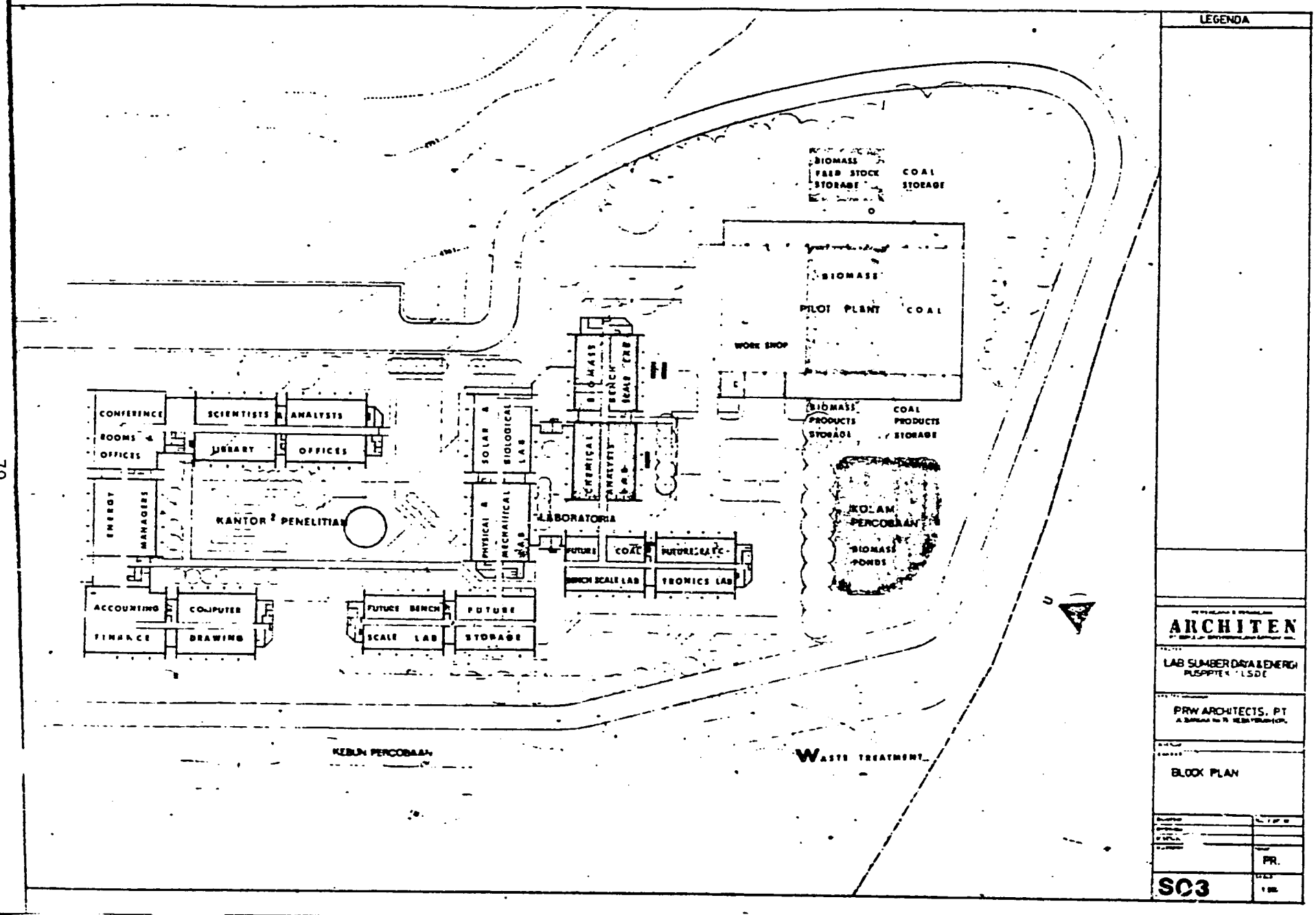
LEGENDA
BIOMASS FEED STOCK STORAGE
COAL STORAGE
BIOMASS
PILOT PLANT
COAL
WORK SHOP
BIOMASS PRODUCTS STORAGE
COAL PRODUCTS STORAGE
KOLAM PERCOBAAN
BIOMASS PONDS
CONFERENCE ROOMS & OFFICES
SCIENTISTS
ANALYSTS
LIBRARY
OFFICES
ENERGY MANAGERS
KANTOR PENELITIAN
SOLAR & BIOLOGICAL LAB
PHYSICAL & MECHANICAL LAB
BIOMASS BENCH SCALE LAB
CHEMICAL ANALYSIS LAB
LABORATORIA
FUTURE
COAL
FUTURE ETC.
BENCH SCALE LAB
TRONICS LAB
ACCOUNTING
COMPUTER
FINANCE
DRAWING
FUTURE BENCH SCALE LAB
FUTURE STORAGE
KEBUN PERCOBAAN
WASTE TREATMENT
ARCHITEN
LAB SUMBER DAYA & ENERGI
PUSPIPTEK LSDE
PRW ARCHITECTS, PT
BLOCK PLAN
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SO3

guide the biomass energy laboratory planning and design process. First, it is important that laboratories for biomass be flexible so that laboratories for other non-conventional energy forms can be added to the system later. These include such programs as solar, coal conversion, and mini-hydro, to name a few. The second consideration is that the construction funds available will probably not allow building all eight energy laboratory buildings, offices, and pilot plant area at once. Therefore, a program of phased construction is recommended.

The suggested general layout of the laboratory and pilot plant area are shown in the accompanying Sheet 03. The layout suggests functional areas to the entire complex, the first for administrative and software facilities, including office space for senior scientists, managers, accounting and finance, plus space for conference rooms, drafting, computer and library facilities; the second consists of the five laboratories mentioned above to conduct bench scale and analytical work; and the third consists of the pilot plant area to conduct pilot scale development work on a variety of energy projects. The concept behind such an arrangement is to consolidate personnel and facilities associated with software, development and administration into one sub-complex, and to do likewise for other personnel and facilities associated with hardware at similar stages of development, either at bench or pilot scale. An important consideration here is to minimize unnecessary duplication of equipment or facilities while providing for sufficient flexibility in operation

and flow of people, equipment, data and materials.

The layout of the five basic laboratories (excluding pilot plant area) is designed around a central chemical (referred to herein as analytical) laboratory, in which it is envisioned that virtually all analytical work will be done to avoid unnecessary duplication of equipment. Surrounding the analytical laboratory then are a series of "bench scale" buildings in which bench scale experimentation of biomass, coal, solar, mini-hydro or other energy projects may be undertaken, while the majority of the analytical work associated with such projects is done at the analytical laboratory centrally located within the complex. Workshop and storage space is also included, as such space is needed for equipment construction and maintenance, and long-term storage.

The pilot plant area is designed to facilitate an efficient flow of large volumes of biomass and other feedstocks through the complex. Raw materials may be stockpiled on the eastern side of the building, after which by-products and/or wastes may be stored or disposed of on the western side of the building. Work shop space is allocated in order to provide easy access for maintenance vehicles and other transport to the rest of the complex.

With a recommended program of phased construction, it is envisioned that in the first year 2000 m^2 of laboratory space might be constructed. Priority should be given to development of the analytical and biomass bench laboratories first, as the analytical laboratory

is central to the entire energy complex and the biomass energy projects are the projects most likely to be commercialized first. Although it would be possible to construct four buildings initially to a height of one floor, it would seem more efficient in terms of future activities to construct two buildings of two stories high as complete buildings at the outset. The two suggested buildings are shown as I and II on the attached Drawing S03.

The first building, the biomass bench scale laboratory, would house all bench scale biomass projects recommended in Table 3-5 . Both stories of the building would be devoted to biomass projects, although the second floor might be devoted to other research and development work until the time that additional facilities could be built. The second building, the analytical laboratory, would house the analytical equipment and also take up the entire floor space of that particular module. Again, until all analytical equipment and capabilities were obtained, that module could provide space for other projects or laboratory facilities.

In summary, it is suggested that two of the eight buildings (modules) planned for the energy program be constructed as complete, two story buildings initially, housing the analytical and biomass bench laboratories, with additional modules constructed as the program develops.

The pilot plant area should be built as soon as additional funding is made available and could be completed in phases as needed. The area should contain sufficient space for non-biomass related

pilot work (as detailed in the first PERL/LSDE report) as well as biomass related pilot plant work described herein. The area should also maintain its own workshop for the construction, maintenance, and repair of pilot plant equipment. A suggested layout of the area is shown in Sheet S03. Covered storage areas will also be required to stockpile biomass materials prior to use, and areas will be required for storage of energy products and residues after pilot plant processing. An overhead crane of at least 10 tonne capacity should be provided at the pilot plant for moving heavy equipment.

Wastewater treatment facilities should also be constructed, and one possible location for the plant is shown on Sheets S02-03. The plant should be capable of being operated for the purpose of carrying out research investigations, as water pollution control from conversion facilities will be an important component of research work done at PERL/LSDE. Biomass and coal materials, for example, have the characteristic of causing potentially severe pollution problems if residues from conversion processes are not properly handled. As a result, research on effective treatment techniques should be carried out as a continuing activity at the Energy Resources Center.

An open space area, as noted on Sheets S01-03, should be provided for an experimental water hyacinth pond, waste treatment pond, solar energy studies, storage, and future use.

It is suggested that priorities for the Energy Resource Center be initially the construction of the initial energy laboratories and workshop, pilot plant area, and experimental pond. Some office space can be provided initially in the laboratories, and it would be anticipated that until the office building complex is constructed, additional needed office space can be made available in other buildings at PUSPIPTEK.

4.1.1 Summary of Design Considerations for Biomass Part of Energy Resources Laboratory

I. Nature of Work to be Undertaken at the Laboratory

The development programs in biomass will consist of:

A. Thermochemical Conversion Technologies

1. Pyrolysis/char production
2. Gasification
3. Methanol production
4. Direct combustion
   a. domestic use
   b. commercial/industrial use

B. Bio-chemical Conversion Technologies

1. Methane Fermentation - Bio-gas
2. Alcohol Production from Sugar, Starch or Cellulosic Feedstock

C. Processing/Handling/Transport of Biomass Materials

II. General Layout of Facilities

A. Components of Biomass Energy Labs

There will be three components consisting of:

1. Analytical laboratory also serving the needs of other non-biomass projects
2. Bench scale/batch system laboratory
3. Pilot scale/demonstration facilities laboratory also serving the needs of other non-biomass projects

B. General Design Consideration for Components of Biomass Energy Laboratories

The following considerations should be taken into account in design of the laboratories:

1. Utilities

   a. proper power source
   b. water & waste disposal (solid & liquid)
   c. H.V.A.C.
   d. transportation of materials
   e. compressed air and gas sources
   f. communications and data transmission

2. Site Layout

   a. separation and/or integration of facilities with others which have similar functions (see Sec. 4.1)
   b. security
   c. building access for delivery/export
   d. position in relation to sun

C. Analytical Lab Design Considerations

1. The utilities needed include:

   a. electricity
   b. natural gas
   c. water & waste disposal
   d. storage of wastes
   e. compressed air
   f. H.V.A.C.
      1) cold room
      2) other constant temperature rooms
      3) ventilation
      4) air conditioning
   g. communications/data transmission to computer facilities
   h. service and maintenance facilities

2. Typical layout shown in Fig. 4-1. This is only one module plan, which may be nearly duplicated for all bench-scale laboratories. The architect may submit various alternative plans, but they should include:

   a. transportation

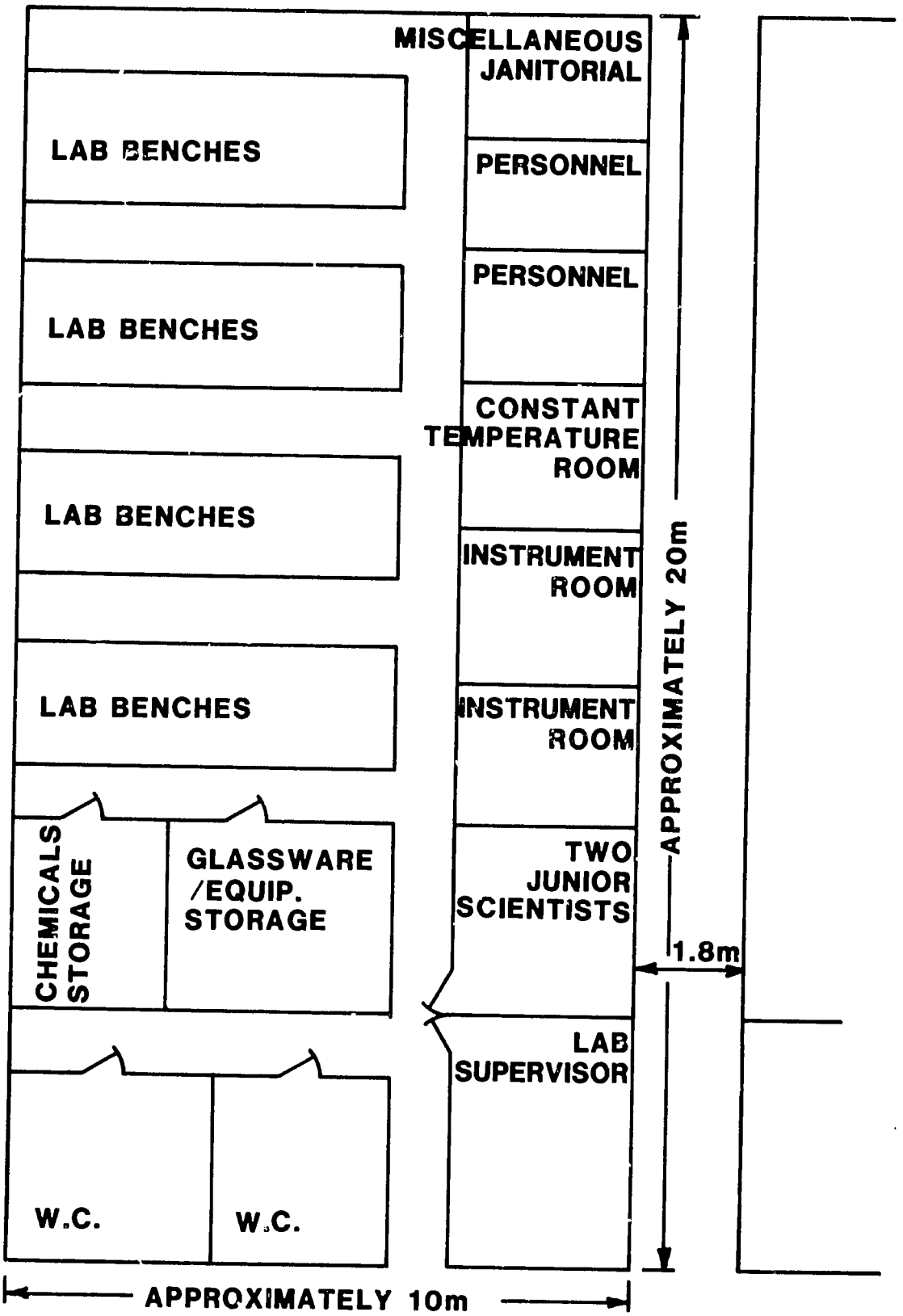

Figure 4-1 TYPICAL LABORATORY MODULE
(NOT TO SCALE)

1) stairs of adequate width
2) adequate corridor space
3) good flow of incoming deliveries of materials; for example, loading and unloading
4) minimum distance between analytical lab and other labs
5) transport of materials to/from analytical lab and others - need enclosed, large corridors

b. office space

1) analytical personnel

a. space for some scientists, separate from analytical bench

b. space for some technicians separate from analytical bench

2) clean-up operation

a. showers

b. lockers

3) data reduction and analysis

c. materials storage/equipment supply room

1) space for supervisor
2) storage of glassware
3) storage of chemicals
4) storage of analytical apparatus
5) storage of supplies

d. space for equipment repair, maintenance and fabrication

1) shop for component assembly
2) service equipment provisions
3) adequate floor space to work
4) clean areas for delicate equipment

e. waste storage/processing/disposal

1) enclosed areas
2) well-ventilated areas
3) waste processing equipment

a. size reduction

b. combustion

c. solidification

4) emergency equipment

a. fire prevention

b. explosion prevention

c. protection against corrosion by chemicals

f. restrooms

g. space for janitorial supplies & equipment

h. equipment layout

1) lab benches should be separated from office space for each laboratory. Each laboratory module should have a supervisor's office and the office of several senior and junior scientists, so that qualified personnel are constantly available to supervise technicians.

2) lab space should be allocated on basis of type of analyses carried out, and not necessarily by project.

3) there should be a central supply area, repair & fabrication shop, and sample storage rooms.

4) there should be a separated waste processing/disposal area.

5) need to have corridors at least 1.8 m wide.

6) need either distilled water distribution system or central distillation column & distribution network for distilled water.

7) need emergency showers located very close to lab benches.

8) hood space should be provided at appropriate benches.

9) there should be segregated space for equipment requiring strict environmental control, such as gas chromatograph, analytical balances, etc.

10) a central area should be provided where samples can be brought for processing through the analytical lab.

D. Bench Scale Laboratory Design Consideration

These include:

1. Layout in relation to applicable analytical facilities

a. should be on same floor whenever possible

b. if not located in same building, should have ready access to analytical lab by enclosed service ways.

2. Office space

   a. office space for scientists/technicians

   b. office space located near bench scale equipment

   c. need reliable communication between analytical lab and pilot scale testing lab

3. Fabrication, maintenance and repair shop needed

   a. may be in conjunction with analytical lab work area

   b. shops need to be large enough to construct bench scale components

4. Restroom/shower/locker facilities

   a. in conjunction with facilities for analytical lab

5. Utilities

   a. same as analytical lab

6. Equipment layout

   a. similar to analytical lab, but requires more open space and provisions for raw materials processing

   b. need area to receive and store raw materials

   c. provisions for monitoring apparatus important

7. Products and/or waste processing, storage, and disposal

   Criteria similar to those for analytical lab

E. Demonstration Scale Laboratory (Pilot Plant Area)

The types of equipment in this area depend on the project underway at any one time: The pilot plants envisioned initially are:

1. Pyrolysis (1)

2. Gasifier(s) (2)

3. Thermophilic digester (1)

4. Ethanol plant (1)
   2 front-end trains sugar base, starch base

5. Methanol (adjacent to gasifier) (1)

4.2 Equipment and Specifications

4.2.1 Analytical Laboratories

Procurement of equipment for the central analytical laboratory can be expected to begin as soon as possible before the buildings are complete, as long lead times are most typically required for lab equipment purchases. Procurement should be conducted on an incremental basis, beginning with supplies and apparatus needed regardless of type of project pursued, followed by selection of equipment needed to conduct the recommended research of Phase I (see Table 3-5). Table 4-1 has been developed to illustrate the nature, type and cost of all equipment requirements for the entire planning period considered. Transportation and delivery charges to Indonesia are not included.

The cost figures shown in Table 4-1 are in terms of 1980 U.S. dollars. While being based upon most currently listed prices for such equipment, they serve only as estimates and are therefore subject to change. Analytical laboratory equipment costs total $US301,660.

4.2.2 Bench Scale Laboratories

Bench scale laboratories, as indicated in the earlier section, should be located adjacent to the analytical laboratory. Depending on the type of project, part of the bench scale work could be conducted in the analytical laboratory. For example, routine fuel analysis (both ultimate and proximate analysis) can be conducted in the analytical laboratory. Also, fuel

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
FOR PHYSICAL PARAMETERS									
PH METER, PROBES AND STANDS - $520/UNIT	5	$ 2,600	X	X			X	X	
CONDUCTIVITY METER & PROBES - BRIDGE & DIP CELL - $600/UNIT	5	3,000	X				X	X	
DISSOLVED OXYGEN METER W/PROBE (YSI OR EQUIVALENT) - $800/UNIT	4	3,200	X	X	X		X	X	
ANALYTICAL BALANCE (METTLER OR EQUIVALENT) - $2,500/UNIT	4	10,000	X	X	X		X	X	
TOP LOADING BALANCE (METTLER MECH. OR EQUIVALENT) - $2,000/UNIT	6	12,000					X	X	
VACUUM OVEN (HEATING TO 280°C) - FISCHER ISOTEMP OR EQUIVALENT - $850/UNIT	3	2,550	X	X	X		X	X	
LABORATORY OVEN (AIRDRAFT HEATING TO 200°C) - FISCHER BRAND OR EQUIVALENT - $200/UNIT	5	1,000	X	X	X		X	X	
MUFFLE FURNACE - (THERMOLYNE OR EQUIVALENT) $600/UNIT	4	2,400	X	X	X		X	X	
DESSICATOR CABINET - $175/UNIT	4	700					X	X	
VACUUM PUMPS (FISCHER DD OR EQUIVALENT - $700/UNIT	6	4,200	X	X	X		X	X	
MELTING POINT, DENSITY AND VISCOSITY (APPARATUS (STANDARD ASTM)									
-M.P. APPARATUS - $400/UNIT	2	800							
-VISCOMETER (PRECISION SCIENTIFIC OR EQUIVALENT) $2,000/UNIT	2	4,000							
-HYDROMETER - $10/UNIT	4	40		X	X		X	X	

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
CENTRIFUGE - FISCHER TABLETOP OR EQUIVALENT W/ACCESSORIES - $700/UNIT	3	2,100					X	X	
VAPOR PRESSURE OSMOMETER - OSMETTE MODEL A OR EQUIVALENT - $3,200/UNIT	1	3,200	X	X	X				
BOMB CALORIMETER (PARR MODEL 1241 OR EQUIVALENT) - $3,500/UNIT	2	7,000	X	X	X	X	X	X	
FREEZER FOR SAMPLE STORAGE - $2,000/UNIT	4	8,000	X	X	X	X	X	X	
SIEVE TRAYS - $25/UNIT	20	1,000	X	X	X			X	
VACUUM FILTERING APPARATUS - $250/UNIT	4	1,000	X		X		X	X	
THERMAL ANALYSIS SYSTEM (DUPONT MODEL 990) * W/CENTRAL PROGRAMMER AND RECORDER AND DIFFERENTIAL SCANNING CALORIMETER - $40,000/UNIT	1	40,000		X	X	X			
TEMPERATURE PROBE, CONTROLS, STRIP CHART RECORDERS									
THERMOMETERS - $5/UNIT	20	100	X	X	X		X	X	
RECORDERS - $160/UNIT	3	480	X	X	X		X	X	
CONTROLLERS & PROBE - $550/UNIT	3	1,650	X	X	X		X	X	
MOBILE DESSICATOR - $65/UNIT (FISCHER BRAND OR EQUIVALENT)	10	650							
SUB-TOTAL		$111,670							

*BEST USED IN BENCH AND/OR PILOT AREAS

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
FOR CHEMICAL PARAMETERS									
RESEARCH GAS CHROMATOGRAPH W/FLAME IONIZATION DETECTOR AND THERMAL CONDUCTIVITY DETECTORS, TEMPERATURE PROGRAMMABLE, DUAL COLUMN & CONTINUOUS INTEGRATOR (HEWLETT-PACKARD OR EQUIVALENT) - $21,500/UNIT *	2	43,000	X	X	X	X	X	X	
ORSAT GAS ANALYZER - $570/UNIT	2	1,140	X					X	
FISCHER GAS PARTIONER (MODEL 1200 OR EQUIVALENT) - $3,500/UNIT	1	3,500		X	X			X	
ATOMIC ABSORPTION SPECTROPHOTOMETER									
FLAMELESS (JARRELL-ASH FLA-100 GRAPHITE TUBE ATOMIZER OR EQUIVALENT) - $6,000/UNIT	1	6,000					X	X	
FLAME (FISCHER/JARRELL-ASH DIAL - ATOM III OR EQUIVALENT) - $6,500/UNIT	1	6,500		X	X	X	X		
NOTE: DOES NOT INCLUDE ELEMENT LAMPS @ $200/LAMP									
SPECTROPHOTOMETER, SPECTRONIC 70 OR EQUIVALENT - $1,600/UNIT	2	3,200			X		X	X	
AUTOCLAVE (MARKE FORGE STM-E OR EQUIVALENT) - $2,500/UNIT	2	5,000		X	X		X	X	
PRESSURIZED GAS CYLINDERS FOR N_2, He, O_2, N_2O, ACETLYENE - $10/UNIT (NOTE: NEEDS FREQUENT REPLACEMENT)	10	100					X	X	

*ONE UNIT SHOULD BE MADE AVAILABLE IN BENCH OR PILOT PLANT AREAS

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
KJELDAHL NITROGEN DIGESTION APPARATUS COMBINATION DIGESTION/DISTILLATION UNITS	1	5,300					X	X	
AUTO-ANALYZER (TECHNICON II OR EQUIVALENT) NITRATE & NITRITE CARTRIDGE INCLUDED	1	14,100	X				X	X	
BENCH TOP FUME HOOD - $3,500/UNIT	4	14,000		X	X	X	X	X	
LAMINAR FLOW IN FUME HOOD - $2,400/UNIT	1	2,400		X	X		X	X	
SOXHLET EXTRACTORS W/HEATING MANTLES - $250/UNIT	8	2,000		X	X	X	X		
ROTARY VACUUM EVAPORATORS - $1,050/UNIT (INCLD. WATER BATH)	8	8,400		X	X	X	X		
INSTANT THIN LAYER CHROMOTOGRAPHY KIT (GELMAN OR EQUIVALENT) - $150/UNIT	2	300			X	X	X		
STANDARD DISTILLATION APPARATUS (PYREX OR EQUIVALENT)	8	1,600		X	X	X	X		
HIGH PRESSURE LIQUID CHROMATOGRAPH WITH VARIABLE U.V. AND VISIBLE SPECTROPHOTOMETER.	1	30,000			X	X	X		
LIQUID BATH HEATER AND SHAKING MECHANISM FOR SAMPLE HEATING TO 300°C - $500/UNIT	3	1,500			X	X	X	X	
STANDARD REFLUX APPARATUS W/BENCH TOP HEATERS & RELATED APPARATUS - INCLUDES HEATER, CONDENSORS, ADAPTERS AND MANIFOLD $550/UNIT (6 SAMPLES)	4	2,200	X	X	X	X	X	X	
CARBON ANALYZER	1	3,500		X	X	X	X	X	
SUB-TOTAL		153,330							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
MISCELLANEOUS			REQUIRED FOR ANALYTICAL LAB REGARDLESS OF PROJECT						
RUBBER STOPPERS - $12/Kg	50Kg	$ 600							
TONGS - $20/UNIT (AVG. OF SELECTED SAMPLES)	20	400							
FORCEPS - $20/Pkg. 10	10	200							
CLAMPS - AVG. $5/UNIT (ASSORTED SIZES & APPLICATIONS)	200	1,000							
TUBING									
GLASS									
TYGON - ASSORTED SIZES $2/M	500M	1,000							
RUBBER - ASSORTED SIZES $1.50/M	500M	750							
LAB CARTS - $150/UNIT	15	2,250							
BRUSHES - ASSORTED SIZES) - AVG. $5/Pkg. of 12	4	20							
FUNNELS									
(PLASTIC) - (ASSORTED SIZES) - AVG. $25/Pkg OF 24	2	50							
FILTERING - (ASSORTED SIZES) - AVG. $25/Pkg OF 12	2	50							
SEPARATORY FUNNEL - (ASSORTED SIZES) AVG. $40/Pkg OF 2	4	160							
DISHWASHER MOBILE $2,000/UNIT	2	4,000							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
CONDENSORS - $80/Pkg. OF 4	2	160	REQUIRED FOR ANALYTICAL LAB REGARDLESS OF PROJECT						
pH INDICATOR PAPERS - $3/Pkg.	16	30							
SAMPLE CONTAINERS									
POLYPROPYLENE, VARYING SIZE FROM 50 ml TO 1 l SCREW-LOCK TOP - AVG. $35/CASE OF 72	4	140							
20 l POLYPROPYLENE CARBOY (NALGENE OR EQUIVALENT) $60/CASE OF 4	6	1,440							
STOP WATCH - $40/UNIT	2	80							
STANDARD MULTI-PIECE TOOL KIT	1	400							
STANDARD FILTER PAPER (WHATMAN 0.45 MICRON OR EQUIVALENT) - $20/Pkg. OF 100	5	100							
MAGNETIC STIRRERS - $200/UNIT	20	4,000							
BENCH TOP HEATERS (HOT PLATES) - $140/UNIT	4	640							
RING STANDS W/SUPPORT COLUMNS - $50/UNIT	12	600							
BUNSEN BURNERS - $20/UNIT	12	240							
WATER DISTILLATION APPARATUS (CORNING MEGA-PURE OR EQUIVALENT - $1,500/UNIT	2	3,000							
AIR COMPRESSOR, 3/4 Hp - $600/UNIT	1	600							
CONSTANT TEMP. CIRCULATING BATH - $900/UNIT	2	1,800							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT CUMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
SUPPORT COLUMNS - $160/UNIT	4	640	REQUIRED FOR ANALYTICAL LAB REGARDLESS OF PROJECT						
BURET SUPPORTS - $50/UNIT	12	600							
SUB-TOTAL		24,950							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
GLASSWARE			REQUIRED FOR ANALYTICAL LAB REGARDLESS OF PROJECT						
BEAKERS									
50 ml $42/Pkg OF 48	2	84							
100 ml $46/Pkg. OF 48	2	92							
250 ml $42/Pkg. OF 48	2	84							
1000 ml $60/Pkg. OF 24	2	120							
2000 ml $40/Pkg. OF 8	2	80							
REAGENT BOTTLES									
125 ml $220/Pkg. OF 48	1	220							
500 ml $140/Pkg. OF 24	2	280							
1000 ml $110/Pkg. OF 6	10	1100							
POLYTHLYENE WASH BOTTLES									
250 ml $50/Pkg. OF 36	2	100							
500 ml $40/Pkg. OF 24	2	80							
DISPENSING BOTTLE									
250 ml $70/Pkg. OF 36	1	70							
POLYPROPYLENE SPIGOT BOTTLE									
10 l $175/Pkg. OF 6	2	350							
20 l $150/Pkg. OF 4	3	450							
BURETS									
10 ml $80/Pkg. OF 2	5	400							
25 ml $85/Pkg. OF 2	5	425							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
BURETS (CONTINUED)			REQUIRED FOR ANALYTICAL LAB REGARDLESS OF PROJECT						
50 ml $85/Pkg. OF 2	5	425							
100 ml $100/Pkg. OF 2	5	500							
GRADUATED CENTRIFUGE TUBES									
15 ml $40/Pkg. OF 12	2	80							
50 ml $60/Pkg. OF 12	2	120							
100 ml $145/Pkg. OF 12	2	290							
HIGH TEMP. CRUCIBLES									
FILTERING - $90/Pkg. OF 8	4	360							
GOOCH AVG. $45/Pkg. OF 24 (VARIOUS SIZES)	2	90							
CRUCIBLE COVERS - $90/Pkg. OF 72	1	90							
BACTERIOLOGICAL PIPETS									
1 ml $20/Pkg. OF 12	3	60							
11 ml $25/Pkg. OF 12	3	75							
VOLUMETRIC PIPETS									
1 ml $43/Pkg. OF 18	2	86							
2 ml $43/Pkg. OF 18	2	86							
5 ml $47/Pkg. OF 18	2	94							
10 ml $52/Pkg. OF 18	2	104							
20 ml $62/Pkg. OF 18	2	124							
25 ml $65/Pkg. OF 18	2	130							
50 ml $55/Pkg. OF 12	2	110							
100 ml $78/Pkg OF 12	2	156							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICATION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
PIPET SUCTION BULBS - $15/UNIT	15	225							
VARIABLE VOLUME DISPENSER (REPIPET)									
1 ml - $100/UNIT	2	200							
5 ml - $100/UNIT	2	200							
10 ml - $100/UNIT	2	200							
20 ml - $115/UNIT	2	230							
50 ml - $130/UNIT	2	260							
AUTOMATIC DISPENSER (OXFORD OR EQUIVALENT) - $120/UNIT	8	960							
TEST TUBES									
VARIABLE SIZE - AVG. COST $80/Pkg. OF 720	1	80							
NESSLER TUBES									
50 ml, VOLUMETRIC, W/CAP $65/Pkg. OF 6	4	260							
SAMPLE CONTAINERS									
GLASS, VARYING SIZES FROM 50 ml TO 2 l, WITH SCREW-LOCK PLASTIC TOPS - AVG. COST = $24/Pkg. OF 24	5	120							
FLASKS									
SIDE-ARM, VARYING SIZES - AVG. COST = $80/Pkg OF 18	2	160							
STANDARD, VARYING SIZES - AVG. COST = $20/Pkg. OF 12	6	120							
BOILING, VARYING SIZES - AVG. COST - $25/Pkg. OF 6	8	200							

TABLE 4-1. ANALYTICAL LABORATORY EQUIPMENT & SPECIFICATIONS

(CONTINUED)

FACILITIES & EQUIPMENT	QTY	TOTAL COST (US DOLLARS)	DIRECT COMBUSTION	GASIFICA-TION	PYROLYSIS	METHANOL	ETHANOL	BIOGAS	OTHER
FLASKS (CONTINUED)									
DISTILLING, VARYING SIZES - AVG COST - $60/Pkg. OF 6	3	180							
COD, VARYING SIZES - AVG. COST = $40/Pkg. OF 6	15	600							
VOLUMETRIC, VARYING SIZES - AVG. COST - $75/Pkg. OF 6	10	750							
SUB-TOTAL		11,660							
GRAND TOTAL		$301,660							

gas composition and associated gross heating value of the by-product gases from several of the bench scale projects can be determined in the analytical laboratory. In addition, the laboratory can be equipped to carry out ash analysis and its fusion temperature determination. The equipment needed to conduct the above mentioned analysis is listed in the analytical laboratory section (4.2.1).

The nature of the bench scale research and development work to be conducted at PERL/LSDE in biomass combustion, gasification, pyrolysis, alcohol and methane fermentation areas is already described in Section 3.0. Some specific bench scale projects for these technology areas are given in the following section.

4.2.2.1 Direct Combustion. Since direct combustion of biomass is an old and matured technology, the recommended bench scale research and development work in this area will be limited to some advance feedstock preparation and combustion techniques. The implementation schedule of recommended bench scale research work in the direct combustion area is presented in Table 3-5.

It is recommended that during Phase I, PERL/LSDE should carry out two bench scale densification projects. The main objective of these projects would be to quantify the relationship between processing parameters (i.e., moisture content, and particle size) and product characteristics (i.e., density, heating cohesiveness, etc.). Also during Phase I, bench

scale experiments on fluidized-bed combustion of different biomass feedstocks are recommended. A brief description of these projects is given in Table 4-2.

4.2.2.2 Gasification/Pyrolysis. The implementation schedule for the recommended bench scale development work in the gasification/pyrolysis area to be conducted at PERL/LSDE is presented in Table 3-5. It is recommended that during Phase I, PERL/LSDE should conduct continuous feed bench scale experiments on advance gasification and pyrolysis schemes. These experiments would include, but not be limited to fluidized-bed and catalytic gasification of different biomass feedstocks. Along with the continuous bench scale experiments, special batch fed experiments should be conducted for catalyst evaluation and other advance (flash) pyrolysis studies.

Most of the equipment required to conduct bench scale experiments in the gasification/pyrolysis area are already presented under the analytical laboratory section (4.2.1). Depending on the type of an experiment, some components will have to be fabricated using local materials (i.e., metallic tubing, quartz pipe, and drums, etc.). These components generally include: a) plug flow tubular reactors; and b) small fluidized-bed reactors.

Some special equipment will also be required to support bench scale research and development work in gasification and pyrolysis areas. For example, in order to determine

TABLE 4-2.

DESCRIPTION OF RECOMMENDED BENCH SCALE PROJECTS IN DIRECT COMBUSTION AREA

	PROJECT NO. 1	PROJECT NO. 2	PROJECT NO. 3
Type	Small fuel log production unit	Small pelletization unit	Small fluidized bed combustion unit
Capacity	2 Tonne/day (of 3 inch-diameter 12-inch long fuel logs	3 Tonne/day (pellets of ½-inch diameter, 1 inch long)	30 kg/hr (bone dry biomass)
Feedstock	wood-waste, sawdust, and agricultural waste		
Floorspace	4M x 15M minimum headroom = 3M	2M x 4M minimum headroom = 4M	
Major Equipment	Extruder, Hammermill, feed hopper	Pellet mill, Hammermill, dryer, feed-storage bin and 23 kw motor	
Budget Equipment Price	US$25,000-30,000	US$30,000	

gasification/pyrolysis rates of different biomass feedstocks under various operating conditions (temperature, pressure, feed gases, etc.) a thermal balance reactor system is required. This system with some modifications can also be used (During Phase II) for determining gasification rates at higher pressures. A Dupont Thermal Analysis System (Model 990) with a central programmer and recorder would provide continuous capability of measuring weight loss of biomass feedstocks under different gasification/pyrolysis conditions. The price (F.O.B. New York) of this equipment is approximately $30,000 (U.S. Dollars).

A differential scanning calorimeter can also be later added to the Dupont Thermal Analysis System. This scanning calorimeter would be useful in determining the heat of gasification and pyrolysis reactions. A Dupont differential scanning colorimeter system would cost (F.O.B. New York) approximately US$10,000.

During Phases II and III the bench scale research and development work at PERL/LSDE should concentrate on the development and testing of high pressure (greater than 8.0 kg/cm^2) oxygen-blown gasifiers. Either the bench scale or analytical laboratory should also be equipped to carry out extensive product characterization tests for the pyrolysis products (char, oil, gas) collected from the pilot plant operations. The testing of the flash pyrolysis process should continue at bench scale to collect design data for future scale-up, and also to quantify the effect of operating conditions (i.e., temperature, rate of

heat increase, and residence time) on the product quality.

4.2.2.3 Alcohol Production. Although the fermentation process is a mature technology, several process modifications and advances have refined the technology substantially. As a result, it is necessary that such modifications be evaluated in light of the conditions which will most typically be encountered in Indonesia, particularly in transmigration areas. Therefore, the recommended implementation schedule for research and development work (Table 3-5) at PERL/LSDE also includes a program of bench and pilot scale studies for alcohol production.

It is recommended that during Phase I, PERL/LSDE should carry out two sets of studies, one basic and one bench scale. As discussed earlier, basic studies in yeast evaluation and cellulosic feedstock (i.e., woody biomass) hydrolysis are recommended, although such work would likely be most effectively carried out by researchers at existing institutions such as IPB at Bogor. The main objectives of bench scale work at PERL/LSDE in alcohol should be to develop the appropriate process trains, equipment types, and process design parameters for each of the various feedstocks likely to be utilized in the field. A brief description of this project is given in Table 4-3.

It should be noted that already monies have been made available by USAID for one bench scale project, that being bench scale

TABLE 4-3.

DESCRIPTION OF RECOMMENDED BENCH SCALE PROJECTS IN ALCOHOL/METHANE FERMENTATION

	PROJECT NO. 1	PROJECT NO. 2	PROJECT NO. 3
Type	Ethanol production from Sago	Waste treatment of ethanol production residuals	Thermophilic anaerobic digestion of animal dung
Capacity	11.4-18.9 l/hr. (3-5 gal/hr) ethanol (95.4%)	57-94.5 l/m(15-25 gal/hr)	0.2M/digester (4 digesters minimum)
Feedstock	Sago palm	Wastewater & stillage (solids)	Animal dung
Floorspace	8M x 15M minimum headroom = 4.5M	5M x 10M minimum headroom = 3M	6M x 10M minimum headroom = 3.5M
Major Equipment	Grinder/chipper, cooker, fermenter, distillation columns, storage	Solids separation units, biological treatment systems, solids dewatering (equipment varies depending upon treatment method selected)	Mixing tank, digesters, heat exchangers, mixers
Budget Equipment Price	US$110,000[1]	US$5,000	US$25,000

[1] Funds currently allocated through USAID Program, "Alternative Energy Sources for Rural Development"

production of ethanol from Sago. Similar work can proceed on cellulosic feedstocks during Phases II or III, following completion of the suggested basic studies, using much of the same equipment and materials from the first set of bench scale studies with some modifications. In addition, further developmental work on a bench scale should be undertaken during Phases II and III to evaluate promising alternative processing techniques presently being refined elsewhere such as extruder/cookers, vacuum distillation towers, continuous fermenting vessels, etc. It is important that such work be done in the laboratory on a bench rather than pilot scale first since controlled conditions are required for meaningful results and can best be obtained in the laboratory.

Another important consideration during these bench scale projects is to evaluate wastewater and solid waste treatment of waste products from these units, with special consideration of recovery and reuse of stillage (i.e., solids). A three-phased project approach to this problem is described in Section 3.4.3 and summarized in Table 4-3.

4.2.2.4 Methane Fermentation. Since considerable research and development has been undertaken already in methane fermentation technology, bench scale work at PERL/LSDE should be limited in scope to development during Phase I of a thermophilic anaerobic digester. The main objectives of this unit will be to evaluate process technology under

controlled conditions, develop national design parameters for the planned or other future pilot scale units and conduct evaluations of effluent reuse feasibility. A brief summary of such a project is given in Table 4-3, and is described in greater detail in Section 3.5.3.

4.2.3 Pilot Plant Area

The pilot plant area at PERL/LSDE would be used for testing different biomass conversion technologies on a scale approximately 1/100th to 1/10th the size of full-scale operations. Initially these pilot projects would involve mature technologies which are now being demonstrated or have been demonstrated either in Indonesia or elsewhere previously. During the later phases of research and development work at PERL/LSDE, additional pilot plants would be constructed to test advance biomass conversion processes, should earlier bench scale studies prove promising.

The recommended pilot testing activities for different technology areas are described in the next sections.

4.2.3.1 Direct Combustion. As indicated earlier, the direct combustion technology does not require any process development efforts at pilot scale; therefore, the pilot plant area at PERL/LSDE would not have any project in direct combustion. However, two pilot field demonstration projects are recommended to enhance the public confidence in this technology. The description of these projects is given in Section 3.1.3.

4.2.3.2 Gasification/Pyrolysis. The pilot plant area at PERL/LSDE would test gasification and pyrolysis technologies at relatively large scale (5.0 to 10.0 tonne/day bone dry biomass) of operation, such that the design and operating data collected could be successfully used for subsequent scale-up to commercial scale demonstration projects. The implementation schedule of recommended pilot projects in the gasification/pyrolysis area is presented in Table 3-5.

It is recommended that during Phase I, PERL/LSDE should run two pilot projects to test the air-blown gasification of different biomass feedstocks; one of these projects would use a downdraft gasifier, which would be directly hooked to an internal combustion engine (i.e., a retrofitted diesel engine, dual-fuel engine, or a gas engine). This project would produce important operating data and design parameters for biomass-based gas generators.

The second air-blown biomass gasification project would involve an updraft gasifier, which would be close coupled to a small oil and/or gas-fired boiler. This gasification plant would test the suitability of different biomass feedstocks for generating a low calorific value fuel gas. Particularly it would test the effect of feedstock quality (i.e., moisture content, consistency) and other operating conditions on the quality of product fuel gas. It will also determine the combustion characteristics of this fuel

gas and other data related to its use in industrial fuel burning equipment.

After the completion of updraft gasification tests, it is recommended that the data produced during the Phase I bench scale fluidized-bed gasification tests should be used to modify the updraft gasifier to run in a fluid-bed mode. The fluidized-bed gasification tests for different biomass feedstocks are to be carried out during the Phase II of recommended research and development activities at PERL/LSDE (see Table 3-5). These tests would provide important performance data for the fluidized-bed gasification system.

At the present time it is expected that the above-mentioned fluidized-bed gasification test facility could later be retrofitted to operate in a pyrolysis mode. If this retrofit is feasible, then the need for constructing a separate pilot facility to test the pyrolysis process would be eliminated. These pyrolysis tests would produce design data for future large scale (greater than 100 tonne/day) demonstration plants. Also sufficient quantities of pyrolysis products (i.e., oil, char and gas) would be available for conducting extensive product characterization and utilization tests.

Advanced, high pressure (greater than 8.0 kg/sq/cm) oxygen-blown biomass gasification (pilot testing) process development work is recommended for Phase III. The Phase II bench scale experiments would provide the necessary design data

for the high pressure oxygen-blown gasification pilot facility. The operation of this pilot facility would produce design and operating data for future commercial scale demonstration projects.

A description of recommended pilot projects in the gasification/pyrolysis area is given in Table 4-4.

4.2.3.3 Alcohol Production. The pilot plant area at PERL/LSDE would test alcohol production technologies developed through bench scale evaluations as mentioned above. The capacity of the unit should be on the order of one-tenth the planned capacity for full-scale production facilities (presently planned for 5,000 kl/yr), or approximately 500 kl/yr (57 l/hr). The design and operating data collected in the bench scale evaluations during Phase I would thus serve as the basis for scale-up to pilot facilities during Phase II. Continuing bench scale work on alternative feedstocks and processing techniques through Phases II and III yielding promising results could then be incorporated into the pilot facilities as warranted. Data obtained from this work would be used for subsequent scale-up to commercial scale demonstration projects.

An added feature of having such a facility at PERL/LSDE would be that BPP Teknologi could provide on-the-job training for operators of the first phase of commercial scale facilities, and provide a center for continuing training

TABLE 4-4.

DESCRIPTION OF RECOMMENDED PILOT PROJECTS IN GASIFICATION/PYROLYSIS

	PROJECT NO. 1	PROJECT NO. 2	PROJECT NO. 3
Type	Downdraft gasifier, hooked to an internal combustion engine	a) updraft gasifier with a close-coupled boiler b) fluid-bed gasification/ pyrolysis tests c) pyrolysis product utilization tests	High pressure oxygen-blown gasifier
Capacity	115 kg/hr of bone dry biomass (input), 165 Kwe (output)	200 to 450 kg/hr of bone dry biomass	150 to 450 kg/hr of bone dry biomass
Feedstock	Low moisture (less than 25.0 percent) wood chips, agricultural waste and other biomass feedstocks	Wood chips, logging waste, saw and plywood mill waste, and agricultural waste	Wood chips
Floorspace	12M(L) x 6M(W) with minimum headroom of 8M	15M(L) x 12M(W) minimum headroom of 8M	9M(L) x 9M(W) headroom = 18M
Major Equipment	Gasifier, internal combustion engine, fuel bin, fuel gas scrubber, etc.	Gasification/pyrolysis vessel, small oil/gas-fired boiler, cyclone, feed bins, producer-storage tanks, etc.	Gasifier, lockhopper, packed-bed, gas clean-up, etc.
Budget Equipment Price (F.O.B. New York)	$200,000 (U.S. dollars)	$500,000 (U.S. dollars)	$750,000 (U.S. dollars)

and education of a skilled work force. As process refinements and technological advances are made, the pilot facility could be retrofitted and serve as a valuable training tool for the large work force that will be needed to achieve the level of production set by the government. Table 4-5 describes the recommended pilot scale project. Further pilot scale work should also be undertaken on wastewater and solid wastes treatment of residuals from bench or pilot alcohol production facilities once bench scale work has been initiated. Such work may consist of expanded treatment system facilities in the bench laboratory, or more preferably would consist of working with the waste treatment facilities for the entire energy laboratory complex.

4.2.3.4 Methane Fermentation. As described earlier (Section 3.5), pilot scale demonstration facilities are presently operating or have been operated already, including projects such as the Indian-style digesters at Cilangkap. the Chinese style digester at Picon, and the bag digesters at Ciawi. As such, recommendations have been given (Section 3.5.3) towards continued developmental work at these sites to generate the needed data to fully exploit such technologies. There will be a need, however, for space for a thermophilic anaerobic digestion unit already well into the design stage. This unit, being designed and built with assistance from West Germany, will serve as the unit which will be capable of evaluating the economic feasibility of such an approach,

TABLE 4-5.

DESCRIPTION OF RECOMMENDED PILOT SCALE ALCOHOL PRODUCTION PLANT

	PROJECT
Type	Alcohol production unit (various feedstocks)
Capacity	500 kl/yr (130,000 gal/yr)
Feedstock	Sago, sweet potatoes, cassava, cellulosic biomass
Floorspace	10M x 20M minimum headroom = 6.5M
Major Equipment	Grinder/chipper, cooker/extruder, fermentation tanks, distillation columns, storage (equipment varies according to feedstock utilized)
Budget Equipment Price	US$200,000

as well as demonstrating the technical feasibility of the proposed design approach. It should be mentioned that this facility will not nor should not serve as the unit by which key design and operating parameters are evaluated, since only under strict laboratory conditions can such evaluations be made with certainty.

5.0 PERSONNEL AND TRAINING

5.1 Personnel Required and Job Descriptions

Personnel requirements for the Biomass Energy Laboratory at PERL/LSDE have been estimated for the various biomass energy research and development projects recommended in Table 3-5 (Implementation Schedule for Biomass Energy Projects at PERL/LSDE) and suggested in Sec. 2.0 (Biomass Production in Indonesia). The total personnel requirements for the biomass laboratory have been divided into five categories, consistent with the general laboratory plan and layout described in Sec. 4.1 and Figures S01 through S03:

1) Analytical support personnel to staff the central analytical laboratory; 2) senior scientists and engineers to act as project managers and principal investigators on the projects undertaken by the biomass laboratory; 3) junior scientists and engineers to serve as project engineers and research scientists; 4) workshop and mechanical laboratory personnel to staff workshop and mechanical laboratory space, and provide technical support for the various projects; and 5) administrative personnel to provide administrative services for the biomass bench laboratory and related facilities.

Table 5-1 gives a breakdown of personnel requirements by Implementation Phase; job descriptions for each job category listed in Table 5-1 are detailed below.

Between 9-13 analytical support personnel are recommended to staff the central analytical laboratory, including 1 senior chemist acting

TABLE 5-1.

PERSONNEL REQUIREMENTS
FOR BIOMASS ENERGY LABORATORY AT PERL/LSDE

Category and Position	Phase I	Phase II	Phase III	Totals
I. Analytical Support Personnel (Analytical Laboratories)				
A. Lab Supervisor	1	0	0	1
B. Senior Chemist	1-2	1-2	1	3-5
C. Technicians	2	2-3	1-2	5-7
				9-13
II. Senior Scientist/Engineer				
A. Senior Engineer/ Project Manager	8	3	11	22
B. Senior Scientist/ Project Manager	10	-	-	10
C. Statistician	1	-	-	1
				33
III. Junior Scientists/ Engineer				
A. Project Engineer	9-11	8-10	8-10	25-31
B. Research Scientist	7	2	-	9
C. Technician	5-7	5-7	5-7	15-21
				49-61
IV. Workshop/Mechanical Laboratory Personnel				
A. Supervisor	1	1	0	2
B. Technician	2-3	1-2	1-2	5-7
				7-9
V. Administration				
A. Program Director (Biomass Produc.)	1	-	-	1
B. Bldg. & Equipment Maintenance	1	-	-	1
C. Supplies & Equipment Procurement	1	-	-	1
D. Data Management & Communications	1	-	-	1
				4

as laboratory supervisor, 3 to 5 additional senior chemists to operate and maintain analytical equipment, and 5 to 7 technicians to provide technical support in the lab. A total of 32 senior scientists/engineers are also recommended to provide project management and technical expertise on specific biomass projects in their related work areas. 49-61 junior scientists/engineers and technicians are suggested to provide the technical support staff for the biomass projects, while a support crew of between 7-9 personnel is recommended to maintain the workshop and mechanical laboratory spaces. An additional 4 personnel are suggested to serve as administrators of the biomass energy projects, including a biomass program director and supervisors for building and equipment maintenance, supplies and equipment procurement, and data management and communications.

The total recommended staff of between 102-120 individuals includes as many as 25 personnel which would work not only on biomass projects but also on the other energy projects undertaken at the laboratory including coal, solar, hydro, etc. Those positions would consist of the analytical support, workshop/mechanical laboratory and administration personnel outlined in Table 5-1.

Job Descriptions

The following brief job descriptions are intended to serve as a guide in selection of trained personnel to staff and direct the biomass energy projects undertaken by BPP Teknologi either at PERL/LSDE or in conjunction with other institutions in the field, as described

above. The list of descriptions includes some for personnel which would also be assisting on other energy projects undertaken at the laboratory, such as staff for the central analytical facilities and workshop crew, but does not include descriptions for those additional personnel needed to administer and maintain the entire energy laboratory, of which the biomass program constitutes a portion.

TABLE 5-2

GENERAL JOB DESCRIPTION FOR RECOMMENDED PERSONNEL TO STAFF BIOMASS ENERGY PROJECTS AT PERL/LSDE

Category and Position	Job Description
I. Analytical Support Personnel	
A. Lab Supervisor	Supervise all operations related to central analytical laboratory, including material and supplies procurement, equipment maintenance, handling and scheduling of analytical work, laboratory maintenance, data management and records keeping, etc.
B. Senior Chemist	Responsible for specialized analytical equipment and procedures, including equipment operation and maintenance, methods development for analysis of samples and management of specialized analytical projects.
C. Technician	Assist in preparation and handling of samples; perform routine analytical tests; assist senior analytical personnel in performance of specialized testing procedures.
II. Senior Scientists/Engineers	
A. Senior Engineer/Project Manager	Act as project manager, to coordinate and supervise lower personnel assigned to assist on project. Prepare project schedule, budget, and program; possess

A. Senior Engineer/Project Manager (cont'd)	well rounded knowledge of their technical specialty, including literature, guidelines, techniques, methods, etc., prepare technical specifications; procurement and selection of equipment; review and approval all drawings for equipment and instrumentation; supervise installation and operation of bench and pilot scale projects.
B. Senior Scientist/Project Manager	Act as Project Manager to coordinate and supervise lower personnel assigned to assist on projects; prepare project schedule, budget, and program; possess well rounded knowledge of their technical specialty, including literature, techniques, methods of analysis, etc.,; responsible for conduct of basic research work and results, development of experimental investigations, techniques and methods.
C. Statistician	Assist other personnel in development and analysis of statistically valid experimental investigations; review and prepare reports, articles, etc.
III. Junior Scientist/Engineer	
A. Project Engineer	Perform all duties related to design, construction and operation of research projects, including preparation of plans and drawings, design of apparatus and methods of investigation, installation and operation of experimental equipment, supervision of technical support personnel; responsible for conduct of experimental programs and technical report.
B. Research Scientist	Perform all duties related to design and conduct of basic research investigations, including design of apparatus and methods of investigation, installation and operation of experimental apparatus, preparation of technical report of results.
C. Technician	Assist project engineers and research scientists in conduct of basic, bench and pilot scale studies, including construction and operation of experimental equipment, monitoring & maintenance of equipment and facilities.

IV. Workshop/Mechanical Laboratory Personnel

A. Supervisor	Act as coordinator of workshop and maintenance personnel completing scheduling and planning of workshop activities, materials and supplies procurement, equipment maintenance and shop activities. Also responsible for assignment of technical support staff to maintain laboratory equipment and facilities located outside of workshop areas.
B. Technician	Assist in maintenance of existing laboratory and field experimental equipment and facilities, operation of workshop and mechanical laboratory equipment, and in design and construction of basic, bench and pilot scale experimental apparatus located within the various modules of the energy laboratory complex.

V. Administration

A. Program Director	Responsible for organization and administration of all biomass energy projects; duties include coordination and guidance of senior personnel/project managers, scheduling, budgeting and planning of biomass energy projects, management and supervision of project work to insure satisfactory completion with respect to research and development efforts.
B. Building and Equipment Maintenance	Responsible for organization and management of equipment and facilities at PERL/LSDE, including buildings, analytical equipment, support facilities, grounds, etc.
C. Supplies and Equipment Procurement	Responsible for procurement of all supplies, equipment, etc., necessary for day-to-day operations and particular experimental investigations.
D. Data Management and Communications	Responsible for organization and supervision of communications and data collection, transport and processing, (including computer facilities) at PERL/LSDE.

5.2 Training Plan

The attainment in a relatively brief period of time of the necessary numbers of trained personnel for biomass energy projects as suggested above requires an immediate government commitment to training and education, the importance of which cannot be overemphasized. As noted in the previous planning work done by the earlier American team, training and education may take several forms: 1) on-the-job training assignments abroad, where senior staff are invited to participate in on-going research programs in the U.S. national laboratories or elsewhere; 2) post-graduate scholarships in-country, awarded to qualified applicants for graduate studies at suitable Indonesian educational insitutions; 3) post-graduate scholarships abroad for qualified applicants for either MS or PhD degrees; 4) in-house consultants from developed countries assigned to the laboratory on a short-term basis to provide additional staff training in-country and assistance on development projects; and 5) periodic seminars and lectures by both visiting or in-house scientists and engineers to keep staff briefed on current advances in pertinent fields.

For the personnel recommended above in Table 5-1 to staff the jobs described in Table 5-2, a set of training programs has been developed incorporating some of these training alternatives wherever appropriate. The intent of these suggested programs is to provide individuals with sufficient background to either direct or participate in the recommended biomass energy projects, including biomass production, thermochemical conversion (direct combustion, pyrolysis, charcoal production, gasification,

methanol production) or biochemical conversion (ethanol production, and methane fermentation) technologies. Table 5-3 presents these training requirements for personnel.

TABLE 5-3. STAFF TRAINING REQUIREMENTS

Position	Function	Academic Training	Field Training
Senior Engineer	Thermochemical Conversion Technologies	-	1 to 3 months Possible Sites University Experimental Stations U.S. Forestry Labs Research Institutes (e.g., Institute of Gas Technology)
Senior Scientist	Thermochemical Conversion Technologies	-	1 to 3 months Possible Sites Institute of Gas Technology Battelle Columbus Labs University Experimental Stations (e.g., Texas Tech., Ga. Institute of Technology, MIT)
Project Engineer	Thermochemical Conversion Technologies	1 yr. graduate training abroad Possible Schools Mech. Engr. Department, Oregon State University Mech. Engr. Department Auburn University Mech. Engr. Department Georgia Institute of Tech. Chem. Engr. Department University of Virginia Forest Products Lab Univ. of Cal., Berkeley	3 to 6 months

TABLE 5-3. STAFF TRAINING REQUIREMENTS (CONT'D)

Position	Function	Academic Training	Field Training
Research Scientist	Thermochemical Conversion Technologies	1 yr. training with forestry or chemistry departments at many U.S. universities*(emphasis on wood and fuels characterization)	3 to 6 months Possible Sites Research institutes such as Institute of Gas Technology, Battelle Columbus Labs, Forest Products Lab, U.S.F.S.
Senior Engineer	Biochemical Conversion Technologies	-	1 to 3 months Possible Sites USDA Research Center Clay Center, Nebraska Institute of Gas Technology APACE Research Centre, Australia
Senior Scientist	Biochemical Conversion Technologies	-	1 to 3 months Possible Sites Institute of Gas Technology USDA Research Center, Clay Center, Nebraska U.S. Army Natick Research and Development Command
Project Engineer	Biochemical Conversion Technologies	1 yr. graduate training abroad Possible Schools Environmental Engr. Dept., Stanford University School of Civil Engineering, University of Illinois Ag. Engineering Dept., Cornell University	3 to 6 months Possible Sites Institute of Gas Technology USDA Research Center, Clay Center, Nebraska Ga. Institute of Technology Engr. Exp. Station

* Attendance at the same university where appropriate project engineer is in attendance may be desirable

TABLE 5-3. STAFF TRAINING REQUIREMENTS (CONT'D)

Position	Function	Academic Training	Field Training
Research Scientist	Biochemical Conversion Technologies	1 yr. graduate training abroad Possible Schools Env. Engineering Dept., Stanford University Ag. Engineering Dept., Cornell University Chemical Engr. Dept., Kansas State University	University of Arkansas Biomass Research Center Institute of Gas Technology U.S. Army R & D Command
Administrator	Program Director Biomass Production	-	3 to 6 months Travel and discussion with other administrators on how to built coherent research programs out of several independent efforts
Research Scientist	Biomass Production (Silviculture)	2 yrs. graduate training: silviculture, forest genetics Possible Schools N.C. State University University of Washington University of Wisconsin, Madison	U.S.F.S. Forest Products Lab, Madison, Wisconsin Forest Products Lab, University of Cal., Berkeley
Research Scientist	Biomass Production (Wood Technology)	2 yrs. graduate training forest products technology Possible Schools N.C. State University University of Washington S.U.N.Y.	-

TABLE 5-3. STAFF TRAINING REQUIREMENTS (CONT'D)

Position	Function	Academic Training	Field Training
Research Scientist	Biomass Production (Agronomy)	2 yrs. graduate training agronomy at Southern institution where rice and other tropical crops, under study Possible Schools	-
Project Engineer	Biomass Production (Agricultural Economics)	2 yrs. graduate training in agricultural economics Possible Schools	-
Senior Chemist	Analytical (Chemical) Laboratory	6 months to 1 yr. training with university or government laboratories in U.S. (emphasis on analyses of wood and fuels characterization, standard wet chemical analyses used in sanitary engr., or instruction on advanced analytical techniques and equipment	None Required
Staistician	Experimental Statistics & Design	2 yrs. graduate training in experimental statistics Possible Schools N.C. State University Iowa State University	-

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4. Kadir, Abdul. 1979. The Problem of Firewood as a Source of Energy in Indonesia. Paper presented at the World Energy Conference in Dresden. 17p.

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6. Rachmatsjah, A. 1979. Rural Energy Conservation, in particular firewood. Paper presented at the Workshop on Energy Conservation. 7p.

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8. Kadir, Abdul and A. Arismunandar. 1980. Energy problems of the developing countries with special reference to the firewood dilemma in Indonesia. Department of Energy and Mines. 20 p.

9. Yudibrote, H. 1978. A Case Study on the Environmental Impacts of Wanagama 1. Proc. 8th World Forestry Congress. 11 p.

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1. Steam/Its generation and use, Chapters 5 through 8, Babcock and Wilcox, New York, USA.

2. Corder, S.E., "Wood and Bark of Fuel," Research Bulletin 14, Oregon State University, School of Forestry, August 1973.

3. "Burlington, Vermont Refuse-Wood Power Plant." A Conceptual Study. Henningson, Durham and Richardson, Inc., December 1977, Washington, D.C., USA.

DIRECT COMBUSTION (Continued)

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9. IR. Sudja, PLN (Indonesian State Owned Electric Utility), November 1980.

GASIFICATION/PYROLYSIS

1. Rambush, N.E., Modern Gas Producers, Van Nostrad Company, New York, 1923.

2. Thermal Conversion of Solid Wastes and Biomass. Jones, J.L. and S.B. Radding, Editors. ACS Symposium Series 130. American Chemical Society, Washington, D.C. 1979.

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4. Overend, R., "Gasification - An Overview" Paper presented at the Retrofit '79, a workshop on air gasification, February 2, 1979, Seattle, Washington.

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7. Demeter, J., Pittsburgh Energy Technology Center, Private Communication, December 1980.

ALCOHOL (ETHANOL) PRODUCTION

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2. Alcohol Fuels Workshop Presented For Farmers Home Administration, USDA and Economic Development Administration, US Dept. of Commerce, Batter Research and Engineering Company, January, 1980.

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4. Methodology Manual For Small-Scale Ethanol Production For Gasohol, Development Planning and Research Associates, Inc., Manhattan, Kansas, April 1980.

5. Small-Scale Ethanol Production For Gasohol, Development Planning and Research Associates, Inc., April 1980.

6. Manual De Construcao E Operracao De Uma Microusina De Alcool Etilico, Volume II, Manual de Operacao e Manutencao, Instituto De Pesquisas Technologicas Do Estado De Sao Paulo S/A - IPT, Sao Paulo, 1980.

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METHANE FERMENTATION

1. Biogas and Waste Recycling, The Philippine Experience Maramba, Felix D. Regal Printing Co., 1978.

2. Practical Building of Methane Power Plants For Rural Energy Independence, L.J. Fry, Standard Printing, 1974.

METHANE FERMENTATION (Continued)

3. Methane Generation From Human, Animal and Agricultural Wastes, National Academy of Sciences, Washington, D.C., 1977

4. Bio-Gas: Achievements and Challenges, M.A. Sathianathan, Association of Voluntary Agencies For Rural Development, 1975.

5. Biogas and Alcohol Fuels Production: Proceedings of A Seminar on Biomass Energy for City, Farm, and Industry. JG Press, Inc., 1980.

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7. State of the Art Review: Methane Fermentation of Biomass, US Department of Agriculture - Forest Service and Agency for International Development, Washington, D.C., 1980.

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9. Clean Fuels From Biomass, Sewage, Urban Refuse, and Agricultural Wastes, Symposium I Papers, Institute of Gas Technology, January 1976.

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12. Report on the Design and Operation of a Full-Scale Anaerobic Dairy Manure Digester, Ecotope Group, Prepared for the U.S. Department of Energy, Division of Solar Technology, September 1979.

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APPENDIX A

LIST OF PEOPLE CONTACTED

LIST OF PEOPLE CONTACTED

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Ir. Hidayat	BPPT Cilangkap
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Prof. Ida Bagus Agra	U. Gajah Mada
Prof. Sri Warnajati	U. Gajah Mada
Prof. Sukoharto	U. Gajah Mada
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R. D. Hardy	Consultant
Dr. Ir. Z. Coto	Forestry Faculty, I.P.B.
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Ir. H. Soewandi	Min. of Agriculture
Mr. A. Hammand	Min. of Agriculture
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Dr. S. Sasmojo	Vice-Dir., DTC, ITB
Dr. Saswanadi	ITB, Bandung
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Mr. Hartoyo Wardi	Chem. Proc. Div., LPHH
Dr. Hartoyo	Chief of Division Chemical Processing, LPHH
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APPENDIX B

LIST OF EQUIPMENT VENDORS

Wood Chipper

Morbark Industries Box 1000 Winn, Michigan 48896	Attn: Gerry Morey Telex 227443 Phone (517) 866-2381
Bush Hog Div. (Allied Products Corp.) P. O. Box 1039 Selma, Alabama 36701	
Fulghum Ind., Inc. S. Main Street Wadley, Georgia 30477	Phone (912) 252-5223
Nicholson Mfg. Co. 3760 E. Marginal Way South Seattle, Washington 98134	Telex 032-204 Phone (206) 682-2752
Passavant Corp. P. O. Box 2503 Birmingham, Alabama	
Vermeer Mfg. Co. 3804 New Sharon Rd. Pella, Iowa 50219	Phone (515) 628-3141
Lindig Mfg. Corp. 1881 W. Country Rd. C St. Paul, Minnesota 55113	Phone (612) 633-3072
Universal Saw and Tool Co. Tylertown, Mississippi 39667	Phone (601) 876-3442
HMC Corporation 23 Maple Street Contoocook, NW 03229	Phone (603) 746-4691
Superior Machine Co., Inc. 492 Cashua Road P. O. Box 3258 Florence, South Carolina 29502	Phone (803) 662-1042
Murray Machinery, Inc. 104 Murray Blvd. Wausau, Wisconsin 54401	Attn: D. Demopoulos Phone (715) 845-3151

Silo and Feeder

Sprout Waldron Div. (Koppers Inc.) 802 Logan Street Muncy, Pennsylvania 17756	Telex 841411 Phone (717) 546-8211
National Bulk Equipment, Inc. 12729 Riley Street Holland, Michigan 49423	Phone (616) 399-2220
Godfrey Conveyn Co. P. O. Box 1088 Elkhart, Indiana 46514	Phone (219) 293-9535
Roger Dunbar, Inc. P. O. Box 149-T New Paris, Indiana 46553	Phone (219) 831-2960
Marietta Techtonics, Inc. Box 323 T Marietta, Ohio 45750	Phone (614) 373-9445

Steam Generator

Indeck Power Plant Equipment Design/Construction 1075 Noel Avenue Wheeling, Illinois 60090	Attn: John Forsyth Phone (312) 541-8300
ABCO Industries, Inc. 2675 East Highway 80 Abilene, Texas 79604	Attn: Don Briston Phone (915) 677-2011
York Shipley E.N. Poyet Associates, Inc. P. O. Box 349 York, Pennsylvania 17405	Attn: Larry Kreischer Phone (305) 666-1938
American FYR-FEEDER Eng. P. O. Box 285 1265 Rand Road Des Plaines, Illinois 60016	Attn: Victor A. Ganger Phone (312) 298-0044
Wellons, Inc. P. O. Box 381 Sherwood, Oregon 97140	Attn: Martin Nye Phone (503) 625-6131
Ray Burner Co. 1303 San Jose Avenue San Francisco, California 94112	Phone (415) 333-5800

Steam Generator (Concluded)

Industrial Boiler P. O. Box 936 Thomasville, Georgia 31792	Phone (912) 226-3024
Zurn Industries, Inc. Energy Division One Zurn Place Erie, Pennsylvania 16512	Phone (814) 452-2111
Deltak Corp. P. O. Box 9496 T Minneapolis, Minnesota 55440	Telex 290812 Phone (612) 544-3371
Lasker Boiler & Eng. Corp. 3203 S. Walcott Avenue Chicago, Illinois 60608	Phone (313) 523-3700

Turbine Generator Set

Terry Corporation Ralph Healey & Associates, Inc. P. O. Box 93643 Atlanta, Georgia 30318	Phone (404) 351-1861
Elliot Overseas Company 1570 Madruga Avenue Coral Gables, Florida 33146	Telex 518703 Phone (305) 661-6081
Worthington Turbodyne Corp. 5915 Ponce de Leon Blvd. Suite 11 Coral Gables, Florida 33146	Attn: Nector Mayorga Telex 519590 Phone (305) 661-1087 Rich Whinery (716) 593-1234 (NY)
Trane Murray Div. (Trane Co.) 1106 Washington Street P. O. Box 967 Burlington, Iowa 52601	Phone (319) 753-5431
Skinner Engineering Co. P. O. Box 1149 Erie, Pennsylvania 16512	Phone (814) 454-7103
The O'Brien Machine Co. Green St. and Powerhouse Place Downington, Pennsylvania 19335	Telex 835319 Phone (215) 269-6600
All Power Supply Co. 130 E. Washington Street P. O. Box 1189 Norristown, Pennsylvania 19404	Phone (215) 279-2880

Turbine Generator Set (Concluded)

Energistics, Inc.
1917 Lynn Boulevard
Birmingham, Alabama

Therms Electron Corp.
101 First Avenue
Waltham, Massachusetts 02154 — Phone (617) 890-8700

Coppus Engineering Corp.
341 Park Avenue
Worcester, Massachusetts

Condensers

G.E.A. Power Cooling System
P. O. Box 81608
John T. Hopkins Drive
San Diego, California 92138 — Phone (714) 455-4270

Graham Mfg. Co., Dept. G
170 Great Neck Road
Great Neck, New York 11021 — Phone (516) 482-5200

Ecodyne Corp.
MRM Div. Dept. TR
608 First Street SW
Massillon, Ohio 44646 — Phone (216) 832-5091

Boiler Feed Water Preparation Unit

Southeastern Control Corp. — Attn: Dave N. Bauer
P. O. Box 1420
8333 S.E. Pine Circle
Hobe Sound, Florida 33455 — Phone (305) 546-3884

Riley Beaird
P. O. Box 31115
Shreveport, Louisiana 71130 — Phone (414) 962-0100

Gasifiers

Biomass Corporation — Attn: Theodore H. Crane
951 Live Oak Boulevard
Yuba City, California 95991 — Phone (916) 674-7230

Foster Wheeler Energy Corp. — Attn: Roger J. Broeker
110 South Orange Avenue
Livingston, New Jersey 07039 — Phone (201) 533-2667

Gasifiers (Concluded)

Halcyon Associates, Inc. Maple Street East Andover, New Hampshire 03231	Attn: William G. Finnie Phone (603) 735-5356
Imbert Steinweg, Nr. 11 Arnsberg 2, Germany	Attn: Walter Zerbin Telex 84222 insd Phone (01931)35 ug
DUVANT One Old Country Road Carle Place, New York 11514	Attn: George F. Bonnico Phone (212) 895-3224

Pyrolysis System

Energy Resources Co., Inc. 185 Alewife Parkway Cambridge, Massachusetts 02138	Attn: Mr. Robert Nordstrom Phone (617) 661-3111
ENERCO, Inc. 126 Old Oxford Valley Road Langhorne, Pennslyvania 19047	Attn: M. J. Thomson Phone (215) 493-6565

Densification System

Sprout-Waldron Koppers Co., Inc. Muncy, Pennslyvania 17756	Attn: Timothy Williams Phone (717) 546-8211
Bio-Solar R & D Corporation Eugene, Oregon 97401	Phone (503) 686-0785

Package Alcohol Plants

Energy Restoration, Inc. 1201 J Street Century House, Suite 403 Lincoln, Nebraska 68508	Phone (402) 475-9237
ACR Process Corporation 808 S. Lincoln #14 Urbana, Illinois 11801	Phone (217) 351-5070
Davy McKee Corporation 10 S. Riverside Plaza Chicago, Illinois 60606	Attn: Cal Todd Phone (312) 454-3810
Alcohol Equipment Corporation c/o Washington Gasohol Commission 51 NW Alder Street Ephrata, Washington 98823	Phone (509) 754-3463

Package Alcohol Plants (Concluded)

Alcohol Plant Supply Co. P. O. Box 248 Sherwood, Oregon 97140	Attn: Carl Santesson Phone (503) 244-3230
Easy Engineering 3353 Larimer Street Denver, Colorado 80205	Attn: Don Kates Phone (303) 893-8936
Energy Independence Corp. P. O. Box 389 Howard Lake, Minnesota 55349	Attn: Jeff Ellefson Phone (612) 543-3277
Vulcan Cincinnati, Inc. 2900 Vernon Place Cincinnati, Ohio 45219	Attn: Simon P. Klosky III Phone (513) 281-2800
Seven Energy Corporation 3760 Vance Wheat Ridge, Colorado 80033	Phone (303) 425-4239
Day and Zimmerman, Inc. 1818 Market Street Philadelphia, Pennslyvania 19103	Attn: William Jones Phone (215) 299-8193
Bechtel Corp. 50 Beale Street 15th Floor, Room B15 San Francisco, California 94119	Attn: Jackson Yu Phone (415) 768-2971
International Engineering Co. Morrison-Knudson Construction Co. Box 7808 Boise, Idaho 83729	Attn: Bart O'Keefe Phone (208) 386-5670
Great Northern Equipment Co. 3550 Northern Avenue Springfield, Illinois 62707	Phone (217) 787-9870
Ethanol International, Inc. 1704 3rd Street Brookings, South Dakota 57007	Attn: Dr. Robert Middaugh Phone (605) 692-5760

Component Manufacturers

Double "A" Products Division of Ad-Art, Inc. P. O. Box 1107 Albert Lea, Minnesota 56007	Small scale distillation equipment Phone (507) 373-1458

Component Manufacturers (Continued)

Archy Zeithamer Rural Route 2, Box 63 Alexandria, Minnesota 56308	Small scale ethanol equipment Phone (612) 763-7392
Jim Pufahl Rural Route 2, Box 99 Milbank, South Dakota 57252	Distillation column Phone (605) 432-4169
Conrad Industries Box 130 Bonapart, Iowa 52620	Small scale stills Phone (319) 592-3131
Middle State Manufacturing, Inc. P. O. Box 788 Columbus, Nebraska 68601	Fritz residue burner, alcohol engine, grain drying Attn: Bill Fritz Phone (402) 564-1411
Kargard Industries Marinette, Wisconsin 54143	Stainless steel tanks Phone (715) 735-9311
Cole-Parmer Instruments Co. 7425 N. Oak Park Ave. Chicago, Illinois 60648	Components Phone (312) 647-7600
Protectoseal Co. 225 West Foster Ave. Bensonville, Illinois 60106	Components Phone (312) 595-0800
M & W Gear Co. Gibson City, Illinois 60936	Diesel engine conversion Phone (217) 784-4261
Stone & Webster One Penn Plaza 250 West 34th Street New York, New York 10001	Pre-built alcohol stills Attn: Miles Conners Phone (212) 760-2000
Jacobson Machine Works, Inc. 2445 Nevada Ave. N. Minneapolis, Minnesota 55427	Hammer mills, grinders, and processing equipment Phone (612) 544-8781
D. N. Gray Biotechnology and Toxicology Toledo, Ohio 43666	Components Phone (419) 247-9206
W. A. Bell P. O. Box 105 Florence, South Carolina 29503	Compoments

Component Manufacturers (Concluded)

Abbeon Industrial 123-52 A Gray Avenue Santa Barbara, California 93101	Phone (805) 966-0810
Fort Wayne Dairy Equipment Co. Box 269 Fort Wayne, Indiana 46801	Components Phone (219) 424-5517
Ernst Gage Co. 250 S. Livingston Ave. Livingston, New Jersey 07039	Components Phone (201) 992-1400
Flexi Liners 5940 Reeds Rd. Mission, Kansas 66202	Fermentation tank liners Phone (913) 265-1234
Tomco Equipment Co. 1862 S. Duth Hidden Hills Parkway Stone Mountain, Georgia 30088	Attn: Morton Bradlyn Phone (404) 466-2235

Enzymes, Antibiotics and Yeast

G. B. Fermentation Industry, Inc. One North Broadway Des Plaines, Illinois 60061	Phone (312) 827-9700
Grove Engineering 1714 Gervais Avenue North St. Paul, Minnesota 55109	Enzymes to convert cellulose to alcohol Phone (612) 777-8545
Miles Laboratories Marschale Division 1127 Myrtle Elkhart, Indiana 46514	
Nova Laboratories 59 Danbury Road Wilton, Connecticut 06897	Phone (203) 762-2401
Bicon (U S.) Inc. 261 Midland Avenue Lexington, Kentucky 40507	Phone (606) 254- 0517
Enzyme Development Corp. 210 Plaza New York, New York 10001	Attn: Randy Ross Phone (212) 736-1580

Enzymes, Antibiotics and Yeast (Concluded)

Fermco Biochemicals, Inc. 2638 Delton Lane Elk Grove Village, Illinois 60007	Enzymes Phone (312) 595-3131
Rohm and Haas Independence Mall West Philadelphia, Pennsylvania 19105	Enzymes Phone (215) 592-2517
Schwartz Service International, Ltd. 230 Washington Street Mt. Vernon, New York 10551	Attn: Mr. Aberdein Phone (914) 664-1100
National Laboratories Development Center Pollution Abatement Division, U.S. Army Natick, Massachusetts 10760	Attn: Leo A. Spano Phone (617) 653-2914

Anaerobic Digesters

Farm Gas Ltd. Industrial Estate Love Lane, Bishop's Castle Salop, SY9 5AQ England	Digesters Phone (Bishop's Castle) 05883 348
Lockstone Developments Easebourne Lane Midhurst Sussex GU29 9AZ England	Bag digesters Attn: J. C. V. Mitchell Phone (073 081 3169)
Macro Energetics S/A Rua de Aurora 295 S/1410 Recife - PE - BRAZIL	Digesters, gas holders Attn: Oswald Rediz de Campos Phone (081) 2223284
Union Industrial Research Laboratories Hsinchu, Taiwan	Digesters
Bio-Fuels Engineering 5606 14th Avenue N.W. P. O. Box 70324 Seattle, Washington 98107	Digesters Attn: Charles Warsinske Phone (206) 789-3340
Energy Harvest, Inc. 1735 I Street N.W., Suite 602 Washington, D.C. 20006	Digesters Attn: Bernard Nagelvoort Phone (202) 659-3030
Anaerobic Energy Systems, Inc. P. O. Box 1477 170 North Florida Ave. Bartow, Florida 33830	Digesters Attn: Elizabeth Coppinger Phone (813) 533-4161

Anaerobic Digesters (Concluded)

Perennial Energy Box 15 Dora, Missouri 65637	Digesters Attn: Ted Landers
Bio-Gas of Colorado 5611 Kendall Court Arvada, Colorado 80002	Digesters Attn: Susan Schellenbach Phone (303) 422-4354
Globe Linings, Inc. 1901 E. Wardlow Road P. O. Box 7396 Long Beach, California 90807	Digesters Attn: William B. Karp Phone (213) 426-2587

Digestion Equipment Components

Staff Industries, Inc. 240 Chene Street Detroit, Michigan 48207	Linings and covers Phone (313) 259-1820
Ferguson Industries P. O. Box 20519 Dallas, Texas 75228	Tanks Attn: Jesse Burns Phone (214) 556-0010
Cabot Corporation 1020 West Park Ave. Kokomo, Indiana 46901	Tanks, vessels, plates Phone (317) 457-8411
Bengal Scientific and Technical Works, Ltd. 2013 Asiomi Dutt Road Calcutta - 29 India	Biogas appliances
Gas Crafters Gordkandas Bungalow Gandhji Road Bombay 400054 India	Biogas appliances
Gelber Pumps 5806 N. Lincoln Ave. Chicago, Illinois 60659	Pumps Phone (312) 769-2535
PACO Pacific Pumping Co. Division of Baltimore Aircoil Co., Inc. P. O. Box 12924 845 92nd Avenue Oakland, California 94604	

Digestion Equipment Components (Concluded)

Vaughn Co., Inc. 364 Monte-Elina Road Montesano, Washington 98563	Chopper pumps Attn: Gerald F. Scheelke Phone (206) 249-4042
Acrison, Inc. 20 Empire Blvd. Moonachie, New Jersey 07074	Continuous blenders, feeders, hoppers Phone (201) 440-8300
The Burhans-Sharpe Co. 2255 Harbor Avenue S.W. P. O. Box 3906 Seattle, Washington 98124	Mixers Phone (206) 932-1030
Day Mixing 4932 Beech Street Cincinnati, Ohio 45212	Mixers, blenders Attn: Robert Miller Phone (513) 841-3621
Vibra Screw Incorporated 755 Union Boulevard Totowa, New Jersey 07511	Blenders, feeders Phone (201) 256-7410
Dean Products, Inc. 985 Dean Street Brooklyn, New York 11238	Heat exchangers Attn: William Whitacre Phone (212) 789-4444
Smith Environmental Corporation 1718 Highland Ave. Durate, California 91010	Heat recovery systems Phone (213) 357-1186
Central Plants, Inc. P. O. Box 3233 6140 Bristol Parkway Culver City, California 90230	Digester gas processing Phone (213) 645-2967
Air Resources, Inc. 600 N. First Bank Drive Palatine, Illinois 60067	Gas processing systems Attn: M. C. Larkin Phone (312) 359-7810
Empire Generator Corp. W190 N11260 Carnegie Drive Germantown, Wisconsin 53022	Generators Attn: Joseph Willmuth Phone (414) 255-2700

PEAT

INTRODUCTION

Peat is the partially decomposed remains of plants frequently referred to as geological young coal. It varies in structure from the only slightly decomposed and fibrous moss peats to the black, sticky, highly decomposed peats usually found in the deepest strata of a bog. The most extensive peat deposits in the world usually occur where glaciation has produced topographic depressions and/or gently sloping lake plains, and where abundant and well-distributed rainfall, high humidity and cool temperatures tend to retard the decomposition of plant material produced in water rich areas.

Peat is a highly versatile resource. It can be combusted in process steam boilers, electric generating plants, and in combined district heating/power operations. It can be milled and compressed into briquettes to be used as a domestic heating and cooking fuel, and it can be processed to produce activated carbon, peat coke, tars, phenolic by-products, and wax. It can be used, when properly treated, as a medium for absorbing oil spills and as a filtration material. Natural and reclaimed peat bogs can be drained, prepared, and used "in situ" for the production of vegetables, grasses, grass seed, and many varieties of trees. After harvesting and drying, peat can also be used as a potting soil and soil conditioner, and when fortified with fertilizer it can be spread on fields as manure. The actual and potential uses for peat are extensive, and research is continually lengthening the list.

In addition to predicted energy shortages, which could be partially overcome by using peat as an energy supply, present and predicted shortages of food, fertilizer, and fiber crops point to the enormous potential peat holds for these other uses as well.

RESEARCH

All of the peat-producing countries in Europe have active peat research efforts. Most of this research is carried out by research organizations having divisions specializing in peat studies. The research facilities include the following:

Technical Research Center of Finland (Finland)

Soviet Peat Institute (U.S.S.R.)

Macauley Institute for Soil Research (Scotland)

Bord na Mona and Lullymore Agricultural Research Institute (Ireland)

These peat research centers have among them active programs relating to peat in the following areas:

- Coke
- Activated Carbon
- Wastewater Treatment
- Adsorption
- Chemicals
  - Furfural
  - Fumic Acids
  - Phenols
  - Alcohol
  - Tars
- Gasification
- Liquefaction
- Wet Carbonization
- Pyrolysis
- Fluidized Bed Thermal Processing
- Purification of Solvents Through Filtration

HARVESTING ·

Peat was harvested for centuries in Germany, the Netherlands, Scotland and Ireland where it was hand-cut with spades called "slanes". A strong person working for about two weeks could cut enough brick-like peat sods to laste an entire winter as fuel for cooking and heating. The cut sods were left to dry in the wind and sun, and were then brought in from the bog and stacked in ricks for further drying and storage. The mechanization of peat production received its first impetus in Germany toward the end of the nineteenth century. With the rapid expansion of industry, fuel became scarce and costly, and the possibility of harvesting peat by some mechanical method was actively pursued by engineers. The first peat cutting machines were actually kneading and shaping machines into which peat had to be fed and from which it had to be taken by hand. These experiments with kneading and macerating showed that peat which was mixed in this manner produced a much firmer and denser sod, when air dried, than did slane-cut peat.

Although improvements in excavating, macerating and drying techniques altered some of the early sod cutting procedures, these primitive machines, which were steam operated and which pulled themselves forward on rails by means of a winch, were the forerunners of the modern "Bagger" excavators currently used in the U.S.S.R., Ireland, and Finland.

In the 1930's, the advent of milled peat production further changed the nature of peat harvesting techniques. The milled peat process, which was developed by Soviet technicians, was more like harvesting than excavating

and was essentially a "surficial" process which removed only a thin layer of peat from the field being worked. These two techniques, modified by some recent developments, are now universally used in peat production.

ENERGY

Peat has been an important fuel in many countries for centuries. The Romans mentioned its use at the time of their conquest of northern and western Europe. They observed that the people of these regions dug "soil" from the marshlands with their hands, dried it, and then burned it to cook their food and keep themselves warm. It was first used on a large scale in Germany, Denmark, and the Netherlands, but due to the exhaustion of the peat reserves and especially to the competition provided by other fuels, these countries no longer use peat as a fuel.

The first country to use peat on an industrial scale was the Soviet Union when shortly after the revolution, the Soviets introduced a program to develop their fuel peat industry. The Irish were the next to recognize the importance of fuel peat and started a rapid expansion of their fuel peat use about thirty years ago. The recent energy crisis has forced several other countries to take a fresh look at their neglected peat reserves. In 1971, Finland initiated fuel peat development planning to increase tenfold their total annual production. Sweden, which ceased fuel peat production in the 1960's, is now planning three district heating/electricity generating power plants. Greece has plans for utilizing a deep peat bog for electricity generation, and Canada has shown interest in fuel peat as a potential domestic fuel.

Although the present world use of fuel peat corresponds to only about 0.4 percent of that of fossil fuels, and has therefore a small overall impact on the world energy supply situation, it is of considerable local significance in those countries where it is used. For instance, peat accounts for 30 percent of Ireland's energy supply, for about 17 percent of the energy supply to the Leningrad district in the U.S.S.R., and about two percent of the total energy supply in the Soviet Union as a whole, and four percent in Finland.

An appreciation of the total energy content in the world's peat reserves can be obtained by making a comparison with oil. Assuming a total world supply of the order of 300 billion tons, and an oven-dried calorific value of about half that of oil (about 9,500 BTU per pound) the hydrogen equivalent may be calculated at around 155 billion tons of oil. This is about 55 percent greater than the total known oil reserves today.

Peat has become an economically attractive fuel in Finland, Ireland, and the Soviet Union. In all three countries peat was very competitive with fossil fuels in 1975:

TABLE C-1.
COMPARISON OF PEAT ENERGY COSTS AND CONVENTIONAL FUELS COST
(Dollars per million BTU)

Fuel	Soviet Union	Finland	Ireland
Coal	1.00*	1.79	--
Oil	.92	2.34	5.34**
Natural Gas	.89	2.60	--
Peat	.57	1.15	3.07**

* Estimated

** 1974 figures

RECLAMATION

Reclamation of peatlands is a common practice in all European countries where peat has been extracted for fuel and horticultural purposes. Many of the peatlands in Scotland, Germany, Finland, the Soviet Union and Ireland have been dramatically transformed into productive land for crop and tree production, or reclaimed to recreational uses, fish production, and wildlife habitat areas. In all European peat producing countries there are now laws pertaining to the depth of peat which must be left in place by harvesting operations and laws pertaining to the use of harvested peatlands.

In Scotland, which probably has some of the oldest reclaimed peatlands in Europe, there are many areas where all of the peat has been removed, and these areas now constitute some of the most productive agricultural lands in the country.

First Colony Farms of Creswell, North Carolina, purchased land at about $100/acre and removed several acres of peat and grew indigenous crops to the area: soy, sorghum, and corn. They have stated that yields have been as much as 50 percent greater than the state average and that land values may have improved by as much as $1,300/acre.