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Report of a mission to the United States and the Philippines

(24 April - 16 May 1980)

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I. SUMMARY AND RECOMMENDATIONS

Based on previous knowledge available to UNIDO on the production of alcohol from cellulosic materials and the information gathered during the visits and discussions with the various institutions in the U.S.A. and the Philippines, the members of the Mission have reached the following conclusions:

1. One of the most important aspects of the energy problem is the shortage of liquid fuels, which is creating serious problems to a large number of developing countries.

2. One of the most promising means to overcome the shortage of liquid fuels is the production of ethanol of motor fuel quality by the action of micro-organisms on carbohydrates (sugars, starches and cellulosic materials).

   This option has the following main advantages:

   a) It is based on renewable resources.

   b) It has no adverse effect on the environment.

3. The alcohol is produced from carbohydrates utilizing three different processes depending on the raw materials employed:

   a) Fermentation of already existing sugars produced by certain agricultural products (sugar cane, sugar beet, fruits, etc.);

   b) Hydrolysis of starches from different crops (corn, potatoes, cassava, etc.) followed by fermentation of the sugars produced;

   c) Hydrolysis of cellulosic materials and fermentation of the sugars produced.

4. The hydrolysis of starches or cellulosic materials can be carried out using chemical or enzymatic techniques.

5. The chemical hydrolysis has the following pertinent characteristics:

   a) The reaction conditions are strong and corrosion aggressiveness is high; as a result, special and expensive materials of construction have to be used in some parts of the plant.

   b) Due to the strong chemical conditions used in the reaction, the sugars which are formed are partly decomposed, leading to lower yields.

   c) Due to the non specifity of the acid attack, some by-products which are detrimental in the subsequent fermentation step are formed.

   d) Rather short retention times (6-7 hrs), as compared with the enzymatic process (24 hrs), which leads to smaller hydrolysis reactor sizes.

6. The enzymatic hydrolysis has the following pertinent characteristics:

   a) The reaction conditions are mild, and consequently, the corrosion aggressiveness is low; regular materials of construction can be used.

   b) The sugar yields are higher.

   c) Due to the enzymes specificity, no detrimental by-products for the fermentation step are formed.

7. New types of fungi and bacteria are being developed, using bio-engineering techniques, which would allow for shorter retention times of the enzymatic step or direct degradation of cellulose to ethanol. This technology might be ready for industrial application within the next five years.

8. At present, from the technical point of view, the enzymatic path seems to be a better alternative when compared with the chemical path. Moreover, there is great room for improvement in this enzymatic process.

9. Two promising technologies for the enzymatic hydrolysis have been developed, up to different levels by the U.S. Army Research and Development Command (Natick) and by Gulf Oil Chemicals Company.

10. The Gulf process embodies some unique features, such as the use of whole enzyme culture, the simultaneous saccharification fermentation and the distillation of the unfiltered alcchol broth, which gives it some clear advantages over the Natick's technology.

11. The Gulf process has been developed and tested up to the pre-pilot plant level; further developmental work and pilot testing needs to be conducted to improve on the process economics and to get techno-economic data before an industrial plant could be designed. For this purpose a 50 t/day feed pilot plant has been designed by the Gulf team.

12. The Natick team has concentrated mostly on investigations related to enzyme production and saccharification; they have done almost no work on the fermentation or on the distillation parts of the process. They have built and tested their process in a 50 kg/day feed plant.

13. In general, it can be said that the Gulf team has approximately 24 months lead over the Natick's team; aside from that, the Gulf process has a definite advantage, namely the simultaneous saccharification/fermentation.

14. The Gulf team has obtained some patents in connexion with their process. The Natick team has no patent rights on their process. This, associated with the fact that Natick is a U.S. Government agency,might make it easier to negotiate with

Natick regarding better conditions for the transfer of technology to developing countries.

15. Enlisting the services of some key persons from the Natick team and integrating them with others experienced in fermentation of sugars and in chemical plant design, an independent technology to produce alcohol from cellulosic materials could be developed. However, the same result could be achieved much quicker using the present Gulf knowledge provided the appropriate arrangements are made for the use by developing countries of Gulf's proprietary knowledge.

16. During the visit to the U.S.A. the Mission could not gain access to some basic information to fully evaluate both technologies; this is particularly true of the Gulf's case, for which an elasticity study on various parameters has already been undertaken by Katzen Associates and which could not be released for detailed studies by the Mission at this stage.

17. The discussion with representatives of the U.S. AID indicated that they consider the technology of producing alcohol from cellulose of paramount importance to developing countries. They would be willing to co-operate with UNIDO in financing a project to construct a pilot plant in the Philippines, provided the proposed sequential approach would be adapted, namely, to conduct a techno-economic study for the project, including a survey on the availability of raw materials and the potential of fuel alcohol in some developing countries.

18. The technologies to produce ethanol from cellulosic materials, although in an advanced stage of development, are not yet fully developed. This gives a good opportunity to the developing countries to get on the 'technological wagon' at the right time and to develop an independent capacity in this sector.

A well designed project might serve to develop not only technological capability to produce ethanol from cellulosic materials, but to train people and form the infrastructure to handle the new and very important techniques and technologies of bio-engineering.

19. The project would be implemented in two phases. Phase I is a techno-economic study of the pilot plant and a survey of raw materials in selected developing countries with an estimated cost of US$150.000. Phase II would be the actual construction and operation for two years of the pilot plant whose estimated cost would be US$17,7 million.

The proposed contributions of the various parties are as follows:

Phase I

UNDP (IPF)	US$	100.000
United States Agency for International Development (U.S. AID)	US$	50.000

Phase II

UNDP (IPF and Interim Fund for Science and Technology for Development)	US$	3,975.000
United States Agency for International Development (U.S. AID)	US$	5,675.000
Philippines Government (in equivalent local currency)	US$	8,050.000

20. The establishment of a pilot plant for the production of alcohol from cellulosic raw materials would represent a major step on the route outlined by the Industrial Development Board for UNIDO to intensify its efforts in the energy field, including the efficient production of new and renewable sources of energy from biomass.

In the light of the above, the Mission recommends

a) that UNIDO should conduct a techno-economic study for the establishment of the pilot plant in selected developing countries. This would include a detailed evaluation of Gulf Oil Company and Natick Research and Development Command technologies and a survey on the availability of cellulosic raw materials to produce ethanol. The draft terms of reference for the studies are included in Annex II.

b) that based on the result of these studies, to proceed with the implementation of Phase II of the project. This would require the preparation of a detailed project document. This document should define the financial contribution of U.S. AID, UNDP and the Government of the Philippines, and the schedule of implementation.

c) to initiate the necessary steps for the establishment of appropriate legal and administrative systems to enable developing countries to share the technological know-how developed through this project.

II. VISITS AND DISCUSSIONS UNDERTAKEN BY THE MISSION IN THE UNITED STATES AND THE PHILIPPINES

1. Introduction - Why Crop Residues for Energy?

The rapid depletion of fossil energy supplies, the continued increase in per capita world energy consumption, and the rapid growth in world population emphasize the need to develop alternative energy sources.

Energy resources are utilized as solid, liquid or gaseous fuels and as electricity. Only coal and biomass* offer an application in all four of these uses. Crude oil and gas are used as liquid or gaseous fuels, and for electricity generation. Hydro-power and nuclear, geothermal, solar, wind and ocean energy have one common characteristic and limitation; they are primarily useful only in the form of electricity. This tie-in to electricity is a very significant constraint on these six energy sources because the present technology and life-style of our society are dependent upon the availability of mobile fuels such as oil and gas.

Biomass is an ideal source of energy because (a) it is renewable (b) it can be converted to any of the four types of power (c) its utilization does not have an adverse effect on the environment (unlike coal, it is very low in sulphur and ash) (d) it does not create any waste problems (as the use of coal or nuclear power does) because the unused portions of biomass can be returned to the soil or in certain instances used as animal feed.

Plant biomass (forestry, agricultural products) have traditionally been used as energy sources. A great problem of growing crops for energy conversion is competition with food and fibre crops for available land and water. However, crop residues such as rice straw, sugar cane bagasse, corn stover, banana stalks, coconut shells and husks can be utilized for biomass energy

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* Biomass is defined here as recently-living plant material capable of being converted to liquid, solid or gaseous fuels, chemicals, or other products.

conversion. The bulk of the cell wall in such crops is made up of cellulose, where it is found in close association with lignin and other materials (such as hemicelluloses and pectins). Cellulose is by far the most abundant, renewable and readily available of all solid organic material, comprising almost one third of the weight of all trees, grasses and straws. The annual net yield of cellulose worldwide (from photosynthesis) is estimated at 10^{11} tons.

Energy can be obtained from biomass by direct combustion, by gasification (anaerobic digestion or thermochemical gasification), or through the production of ethanol (normal alcohol). The latter technology is the subject matter of this report.

2. Waste Cellulose Conversion to Alcohol

Cellulose is a polymer of glucose units linked to each other. The degradation of the cellulose polymer to its monomer, glucose can be accomplished either chemically (acid hydrolysis) or biologically (enzymatic hydrolysis). The glucose produced can be subsequently fermented to alcohol by yeast.

There are various advantages in the use of enzymes, instead of acid, to hydrolyze cellulose [1]. The use of acid requires expensive, corrosion-proof equipment. Moreover, the crystalline structure of cellulose makes it very resistant to acid, so the temperature and acid concentration needed to accomplish hydrolysis cause decompostion of the resulting sugars. Consequently, the process must be balanced so that the velocity of the hydrolysis reaction is sufficiently high to compensate for the decomposition of the desired products. Glucose yields of approximately 50% of the cellulose used have been obtained by acid hydrolysis.

Waste cellulose invariably contains other impurities which will react with the acid, thereby producing other unwanted by-products which may inhibit the yeast function in the fermentation reaction. The enzyme on the other hand is specific for cellulose and does not react with impurities or other materials which may be present in the waste. Among the advantages of enzymatic hydrolysis is that the process takes place at moderate conditions so that the glucose yield is high and is directly related to the weight of the cellulose used.

Problems associated with efficient biological conversion of cellulose to ethanol are being investigated in various institutions. The researchers hope eventually (perhaps within the next five years) to construct, through genetic engineering techniques, micro-organisms that are ethanol resistant and that can produce, at a faster rate, a higher concentration of ethanol directly from cellulose.

3. UNIDO Fermentation Alcohol Programme

A UNIDO Task Force on Energy Problems was established in 1978 to develop a UNIDO programme in the field of energy. The Industrial Development Board, in its twelfth session (May 1978) suggested that UNIDO focus its efforts on two priority areas: technical assistance programmes to meet the developing countries' specific energy needs, particularly in the development of commercially feasible non-conventional energy sources, and advice to developing countries on national energy policies [2].

In March 1979, UNIDO organized a workshop on "Fermentation Alcohol for Use as Fuel and Chemical Feedstock in Developing Countries" which provided UNIDO with the impetus for a programme of assistance to developing countries in this area. Almost simultaneously, the "First Consultation Meeting on the Petrochemical Industry" organized by UNIDO in Mexico City (March 1979) called on UNIDO to study alterrative sources of feedstock for petrochemical production such as coal and fermentation alcohol.

In its fourteenth session (May 1980), the Industrial Development Board agreed that in order to accelerate the industrialization of developing countries, UNIDO's programme of work for 1981 and 1982-1983 should give priority to activities in certain areas, among which is "energy-related industrial technology" [3]. In addition, "the Board stressed that a high priority should be accorded to the operational and promotional activities of UNIDO in the development, selection, acquisition, adaptation, transfer and use of industrial technology so as to facilitate the generation of increased and more appropriate flows of technologies to the developing countries and to strengthen their technological capabilities".

4. UNDP Energy Fund

The UNDP Administrator proposed at the 27th Governing Council of UNDP the establishment of an Energy Fund. In addition to a petroleum surveys component, "the second component of the Fund would finance pre-investment assessments of non-petroleum energy resources which require large investments for their development. Conventional, new and renewable sources of energy to be assessed would potentially include carbon, nuclear, hydro-electric, etc. Other new and renewable sources of energy, such as biomass, solar, etc. would also be investigated through surveys, demonstrations and small pilot plants".

In selecting projects in the area of new and renewable sources of energy, the Fund would pay particular attention to:

a) Projects that have been identified in a country's energy plan; and

b) Projects whose results could have application in other countries having similar resource endowments.

The proposal explained that the Fund was intended to supplement other financial resources which might be available to developing countries, both bilateral and multilateral (e.g. IPF, Interim Fund of Science and Technology).

In his address to the Governing Council on 4 June 1980, the Executive Director of UNIDO stated that a priority area identified by the Third Conference of UNIDO related to the industry/energy interface and that UNIDO intended to intensify its efforts in three major directions, one of which was "the efficient production of new and renewable sources of energy, including biomass-derived fuels".

The Executive Director further stated that "should the Governing Council decide to establish the Energy Fund, UNIDO would welcome the opportunity to assist in projects designed to investigate new and renewable sources of energy through demonstration and small pilot plants".

5. The Philippines Energy Problem and the Alcogas Programme

The Philippines is at present overwhelmingly dependent on imported crude oil for its energy requirements, constituting 93-95% of national energy consumption, excluding firewood. In 1979 the Philippines had a trade imbalance of US$1,64 billion, 97 per cent of which is directly attributable to oil imports. (The oil bill amounted to US$1,596 billion in 1979). This trade deficit will continue to increase with the growth in energy consumption in the country, and as a result of the rising cost of imported oil. Faced with this situation, the Government, through the Ministry of Energy, is undertaking major programmes to develop both conventional and non-conventional indigenous energy resources.

One of these programmes is the Alcogas Programme. The immediate objective of the programme is the production of anhydrous alcohol (99,5%) for blending with gasoline up to 20% alcohol. Basic raw materials would be sugar cane (and molasses), cassava, sweet potato, sorghum, corn, etc. The alcohol produced would be blended with gasoline at bulk plants of oil companies. The Alcogas programme hopes to attain the 20% blend target in 1986 when the gasoline requirements are projected to be 2.973 million litres and the corresponding alcohol requirements would be 595 million litres. In 1988 alcohol requirements are expected to rise to 634 million litres.

A long-term objective of the Alcogas programme is to produce enough alcohol for 100% alcohol engines and to produce ethylene for the chemical industries by dehydration of alcohol. To achieve the objectives of the Alcogas programme in the medium and long-term, and to save available land for food and fibre crops, the Government would like to investigate the technical and economic feasibility of producing alcohol from crop residues, annually renewable and abundant in the Philippines (please refer to Annex IV which gives an estimate of the annual production of these residues).

The President of the Philippines, in February 1980, has created an "Alcohol Commission" with the Minister of Energy as

its Chairman, under the Office of the President (please see Annex I for Executive Order No. 580 creating an Alcohol Commission). The Commission is responsible for accelerating the implementation of the Alcogas programme. One of the main functions of the Commission is to "promote and co-ordinate the conduct of research and development activities on alcohol production, its utilization as motor fuel; as well as various feedstock possibilities". It is in this context that the Executive Director of the Alcohol Commission, Mr. H. Zayco, who is at the same time a Governor of the Board of Investments, has requested UNIDO's assistance in the establishment of a pilot plant for the production of alcohol from cellulosic material. It is worth noting in this connexion that the ESCAP ministers of industry in their October 1979 meeting have called upon UNIDO to play a role in supporting the energy resources development programmes of their countries.

6. Object of the Mission

In response to the request of the Government of the Philippines, and in line with UNIDO's involvement in following up developments in the energy field, and the potential of utilizing the technology of producing alcohol from cellulosic wastes in other developing countries, it was deemed necessary to undertake an exploratory mission to the United States and to the Philippines.

The object of the mission was:

(i) to investigate the current state of development of the technology of producing alcohol from cellulosic raw materials through the enzymatic process;

(ii) to explore the extent and mode of co-operation of the technology owners with UNIDO in the establishment of a pilot plant in the Philippines;

(iii) to establish the production capacity and approximate investment costs of the proposed pilot plant;

(iv) to discuss with competent authorities in the U.S. AID the extent of their co-operation with UNIDO in the implementation of the project, in view of their interest expressed in the project;

(v) to discuss with the concerned Government authorities, and with the UNDP Resident Representative in the Philippines, Government inputs to the project, possible UNDP inputs and the approach to be followed in project implementation.

The Mission was composed of

M. El Halfawy	Senior Inter-regional Adviser, Industrial Operations Division
L. Soto-Krebs*	Special Technical Adviser, Technology Group
W. Kamel	Industrial Development Officer, Development and Transfer of Technology Section

The Mission visited the U.S.A. between 21 April and 6 May and the Philippines from 11-16 May 1980.

Before visiting the U.S.A., the following information was available to members of the Mission either from published literature or through private communications:

a) The higher cost of ethanol as a liquid fuel from corn and sugar cane juice (e.g. as compared with synthetic crude from coal liquefaction) is attributable primarily to the cost of the raw material which represents about two thirds of the production cost. The use of low-cost crop residues (or municipal solid waste, later abbreviated to M.S.W.) should, in principle, substantially lower the production cost. Unfortunately, due to the relative inaccessibility of the cellulose in these substrates to enzymatic hydrolysis, the reduced raw material cost is overshadowed by the cost of pre-treatment of the substrate and its saccharification (hydrolysis to glucose sugar) [4]. Generally a vigorous physical and/or chemical pre-treatment is required to significantly increase the susceptibility of the substrate to enzymatic hydrolysis. Examples of physical

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* L. Soto-Krebs was not associated with the Mission during visits to Katzen Associates and to the Philippines.

pre-treatment are pot milling, ball milling and compression milling. As an example of chemical pre-treatment bagasse has been treated with dilute caustic soda. It is obvious that the pre-treatment step of cellulosic waste material is an important variable which will affect not only the degree of saccharification, but also the economics of alcohol production.

b) The U.S. Army Natick Laboratory in Massachusetts has been a centre of research on enzymes and the enzymatic hydrolysis of cellulose for about thirty years. Scientists at Natick have developed a hydrolysis process based on the use of enzymes (referred to as the cellulose complex) produced by mutant strains of the fungus Trichoderma reesei. The process produces glucose syrup (up to 15%) from cellulosic substrates [5].

c) Gulf Oil Chemicals Company, Shawnee Mission, Kansas, U.S.A. began in 1971 a biochemical research programme with the object of searching for alternate feedstocks for their petrochemical business. Subsequent research led to the construction of a cellulose to ethanol pilot plant at Pittsburg, Kansas, with a capacity of one ton per day cellulosic waste feedstock [7][10]. The pilot plant has been in operation since January 1976.

7. Visit to the U.S. Army Natick Research and Development Command, Massachusetts

The Mission was received by Mr. Leo A. Spano, Director of the Pollution Abatement Division, Food Sciences Laboratory. Mr. Spano briefed the Mission on Natick's process and activities in the field of cellulose hydrolysis and alcohol production.

The first step in the process is the production of the enzyme complex (cellulase). This is done by growing the fungus Trichoderma reesei in a culture medium containing part of the cellulosic feedstock and various nutrient salts. Following its growth the fungus culture is filtered and the clear filtrate which is the enzyme solution is used in the saccharification reaction. The feedstock

is pre-treated by milling and in the form of 20% slurry introduced to the reactor, together with the enzyme solution to produce glucose. The crude, glucose syrup is filtered for use in a fermentation step by yeast followed by distillation to produce alcohol.

Research in Natick has succeeded in increasing the enzyme activity sixteen-fold and the rate of enzyme production twelve-fold. The hydrolysis time was reduced from 48 to 24 hours and the milling time from 24 hours to about 5 minutes.

In Natick, they have investigated many types of pre-treatment. The most promising and economic in their opinion is compression (two-roll) milling.

Many cellulosic materials have been evaluated and hydrolysed on a bench scale. These included soft and hard woods, municipal solid waste, newsprint, paper mill waste, sugar cane bagasse, papyrus, banana stalks and oil palm fruit stalks.

The success of the laboratory experiments initiated the construction of a highly instrumented pilot plant which is used to study the effect of various factors on the fungal growth and enzyme biosynthesis, as well as on the saccharification of cellulose by the cellulase complex. The Mission visited the pilot plant as well as the research laboratories. The pilot plant has a capacity of 50 kg per day of cellulosic waste feed-stock. It has been operating since 1974.

The pilot plant consists of such equipment as

a) Fermentors for enzyme production
b) Substrate handling and preparation equipment
c) Enzyme reactors
d) Holding tanks and auxiliary vessels
e) Instrumentation modules
f) Enzyme recovery and storage.

The equipment is built up under the principle of modularity. New modules can be added to the system without the necessity to re-arrange its building elements. The instrumentation makes it possible to be coupled with a computer programme for process control on the basis of the rheological and biological conditions of the process.

However, the pilot plant did not have any equipment for glucose fermentation to alcohol neither for alcohol distillation. These steps were only carried out in the bench scale experiments. Mr. Spano informed the Mission that in the laboratory they have also carried out simultaneous and uncoupled batch and continuous saccharification and fermentation experiments. These studies indicated an increased yield of alcohol when the hydrolysis and fermentation to ethanol steps were combined. But simultaneous saccharification/fermentation was not tried in the pilot plant.

Mr. Spano mentioned that he had been trying to construct a one ton/day pilot plant based on municipal solid waste to produce fuel grade ethanol. The object would be to develop process refinements and collect the necessary design data for a 50 t/day pilot plant as a step to a commercial scale one. However, the necessary funds for constructing such a one ton/day plant were not allocated. Instead, the Mission was told that the Solar Energy Research Institute has recently contracted Gulf for use of their one ton/day plant to optimize Natick process variables using different feedstocks and different pre-treatment techniques.

Mr. Spano also informed the Mission of a visit to the University of Arkansas (Biomass Research Centre) which he would take in the near future at the request of the Department of Energy. The object was to discuss ways and means of co-ordinating the activities of the two institutions in enzyme research and cellulose to alcohol technology so as to avoid any duplication of effort.

According to Spano's calculations the enzyme cost needed to produce one gallon of alcohol is about 45 Cents. (This is to be compared with 21 Cents estimated by Katzen for the Gulf process).

In October 1979, the Natick group [5] published an assessment of ethanol production from urban waste. Their cost analysis was based on a plant with a capacity of 25 million gallons of 95% fuel grade alcohol. The plant would consume 495.000 tons/y of cellulosic waste containing 375.000 kg of enzyme hydrolyzable material, 45% of which would be converted to fermentable sugars which in turn would be converted to

ethanol (40% yield). The total fixed investment of such a plant was estimated to be about US$52 million.

On this basis the factory cost of one gallon of fuel grade ethanol (95%) was calculated to be US$1,22, but if credits are taken for cellular biomass to be used as animal feed, and for residual cellulose from hydrolysis (used as fuel), the factory cost would be US$0,94/gallon.

8. Visit to Katzen Associates, Cincinnati, Ohio - Gulf Research and Development

Katzen Associates have been the consulting engineers for Gulf Oil Chemicals Co. during the development of the Gulf technology. Discussions were held at the Katzen office in Cincinnati with Dr. Raphael Katzen, President of Katzen Associates International, Inc. and Mr. Richard Silver, Staff Engineer of Gulf Research and Development Co.

Mr. Silver informed the Mission that (i) the technology of the process is owned jointly by Gulf and Nippon mining, (ii) Katzen Associates are their agents outside U.S.A., (iii) ownership of the technology within U.S.A. had been transferred to the University of Arkansas; Katzen Associates are also their agents for licensing, (iv) for a proposed pilot plant in the Philippines they were not going to charge any fees for patent rights and the know-how; however, Gulf's ability to provide other inputs would be limited, (v) services for the design, construction, start-up and assistance in operation of the pilot plant would have to be provided by Katzen Associates and the University of Arkansas with whom UNIDO has to negotiate for the delivery of such services.

However, Mr. Silver indicated that Gulf would require to be compensated for the transfer of their know-how and proprietary rights for future commercial operation of plants based on the Gulf process. The Mission's reply to Mr. Silver was as follows: Should this project materialize, UNIDO and the Government of the Philippines would be investing large sums of money in constructing and operating the pilot plant. The Gulf process has not been commercially proven, and additional development work was required

to introduce refinements and improvements in the process itself and in the utilization of the by-products. The Philippines pilot plant would contribute considerably to this development effort. Gulf would be informed of, and given full access to, improvements in technology achieved; also arrangements could be made for Gulf personnel or prospective licensees from developed countries to have access to the pilot plant. In return, Gulf would be required to make available to UNIDO the know-how and Gulf proprietary rights free of charge for the use of UNIDO in developing countries only.

Mr. Silver said that it was not in his competence to give a decision on this matter and that he would have to take it up with Gulf management for consideration.

Dr. Katzen informed the Mission that the Gulf pilot plant of 1 ton/day capacity started operation in January 1976 but recently active research and development work has been transferred to the Biomass Research Centre, University of Arkansas, directed by Professor G. Emert. At present, Prof. Emert is organizing a consortium to construct a 50 t/day cellulosic waste conversion facility, the operation of which will enable scaling up to a commercial plant of 1.000 to 2.000 t/day cellulosic waste feedstock.

Katzen had already completed for Gulf the design and equipment specifications for a 50 t/day pilot plant. It has been designed for continuous operation and many improvements on the present pilot plant, particularly in pre-treatment and alcohol distillation have been incorporated in the design. The design will be used by the Arkansas Consortium.

Katzen believes that Gulf technology for cellulose conversion to alcohol is at a more advanced stage of development compared to other technologies and can be commercialized in 4-5 years time. The main advantages of the Gulf process today, according to Dr. Katzen, are:

a) The enzymatic process uses unpurified (whole culture) preparation of Trichoderma Reesi. There is no need for filteration as in the Natick process. Only 48 hrs

are needed to prepare the enzyme, whereas in Natick they need at least 4 days. The enzyme required for the production of one gallon of alcohol would cost US Cents 21 to produce. (In Natick this cost is minimum 45 Cents.)

b) The saccharification of cellulose to glucose and fermentation of glucose to ethanol take place simultaneously and in the same vessel. This results in 25-40% increase in product (alcohol) yield over a conventional two-step saccharification to glucose followed by fermentation to ethanol process. The increased yield is attributed to the removal of glucose, an inhibitor of the cellulase system, by the yeast.

c) Another advantage of this process is that the yeast growth rapidly produces an anaerobic environment, which eliminates the necessity of strict aseptic conditions [6].

d) The process in the new 50 t/day design is continuous in all stages.

e) The Gulf process uses in the alcohol recovery section a low energy consumption distillation system developed by Katzen for maximum heat recovery and heat re-use [9].

The meeting discussed the possible capacity of the Philippines pilot plant and it was agreed that a facility of 50 t/day cellulosic waste feedstock capacity would be appropriate. The operation of a plant of this size - and not a much smaller one - for about two years and the results obtained therefrom would lead to definition of scale-up criteria to large commercial plants (1.000 - 2.000 t/day feedstock). A pilot plant of this size would also be constructed using standard commercially available equipment and no special designs or orders would be required.

Gulf and Katzen agreed to provide at no cost the designs and equipment specifications for the 50 t/day pilot plant already prepared for Gulf by Katzen. Naturally, some modifi-

cations, additions or deletions would be needed to adapt these to the conditions of the Philippines and to the site chosen.

The meeting also agreed that it would be advisable to implement this project in two phases. The first phase would be a techno-economic assessment of the proposed pilot plant and the potential of commercialization in the Philippines (please see Annex II for draft terms of reference of Phase I). The second phase would be the actual construction and operation of the pilot plant. Three months would be needed to conduct the techno-economic study; the pilot plant could start up 33 months later.

The first phase is estimated to cost US$150.000.

The investment breakdown of the second phase, based on data provided by Katzen, assuming that the pilot plant would be constructed adjacent to an existing sugar mill in the Philippines, is as follows:

Fixed Investment 50 t/d Pilot Plant

	US$	
Land	free	
Equipment F.O.B	3,550.000	
Freight and insurance	700.000	
Engineering and training of local staff	1,000.000	
Construction overhead	800.000	
Sub-total	6,050.000	
Contingency	600.000	
Total foreign currency component		6,650.000
Field materials	1,700.000	
Direct labour	1,700.000	
Building and structures	1,000.000	
Sub-total	4,400.000	
Contingency	400.000	
Total local currency component		4,800.000
Total fixed investment		11,450.000

The breakdown of the equipment cost is as follows:

	US$
Raw materials handling	98.000
Raw materials preparational (pre-treatment)	956.000
Enzyme preparation	807.000
Simultaneous saccharification and fermentation	616.000
Alcohol recovery	222.000
Solid separation and evaporation	691.000
Facilities and utilities	160.000
Total equipment	3,550.000

The pilot plant will be operated for a minimum period of two years to establish the engineering baseline for the design and construction of full scale plants which are likely to follow, not only in the Philippines, but in other developing countries. Several agricultural residues will be tried since residues are seasonal but the plant must run around the year. The cellular biomass (stillage) from the alcohol recovery plant is evaporated to produce 60% solids content syrup animal feed by-product. Extensive animal feed tests will have to be conducted on this by-product. Also the engineering and economic problems of collection, transportation, storage and pre-treatment of the agricultural residues have to be investigated.

During the operations of the pilot plant, modifications and equipment additions might have to be introduced. A lump sum of US$1,25 million has to be allocated for these modifications. The annual operating costs of the pilot plant are estimated as follows:

Estimated Annual Operating Expenses

	US$
Raw materials	140.000
Chemicals and nutrients	200.000
Power	400.000
Steam	250.000
Labour (7 supervisory, 9 lab. and office, 36 operators)	500.000
Maintenance	60.000
Tests and evaluations	700.000
International consultants	250.000
Annual operating costs (excluding depreciation)	2,500.000

Operating expenses for two years are US$5,000.000 of which US$2,000.000 will be foreign currency.

In summary the total cost of the second phase is estimated to be US$17,700.000 detailed as follows:

Total cost of the second phase (Construction and two-year operation of 50 t/day pilot plant)

	US$		
	Foreign Currency	Local Currency	Total
Fixed Investment	6,640.000	4,800.000	11,450.000
Modifications and Additions	1,000.000	250.000	1,250.000
Operating Expenses (2 years)	2,000.000	3,000.000	5,000.000
Total	9,640.000	8,050.000	17,700.000

The proposed contribution of the various parties towards the implementation of the project during a five years period can be summarized as follows:

Phase I	US$
U.S. AID	50.000
UNDP	100.000
Government of the Philippines - only contribution in kind (staff, office and transportation facilities)	

Phase II	US$
a) U.S. AID	
Equipment	3,550.000
Freight and Insurance	700.000
Modifications and Equipment Additions)	1,000.000
Contingency	425.000
Sub-Total	5,675.000
b) UNDP (IPF and possibly Interim Fund for Science and Technology for Development)	
Engineering and Training	1,000.000
Construction Overhead	800.000
Tests and Evaluations	1,000.000
International Consultants	500.000
Chemical and Nutrients	400.000
Contingency and Miscellaneous	275.000
Sub-Total	3,975.000
c) Government	
Civil Engineering and Building	4,400.000
Modifications and Additions	250.000
Local Operating Expenses (Staff, Labour, Raw Materials, Utilities)	3,000.000
Contingency	400.000
Sub-Total	8,050.000

Detailed description of the Gulf process, its techno-economic feasibility, the various agricultural residues tested and the yields obtained therefrom have been given by Emert and Katzen in various publications [7][8][9]. For example, Rivers and Emert [8] estimate for U.S. conditions the total fixed investment for a plant to produce 25 million U.S. gallons per year of 95% alcohol to be US$74,62 million and for a 50 million U.S. gallons per year capacity to be US$118,93 million. The production cost of alcohol from the former would be US$1.235 and from the latter US$1.084 per U.S. gallon based on a municipal solid waste of US$15.75 per ton, and no credit given either to the by-product animal feed or to the solids (to be used as fuel) separated after the saccharification/ fermentation. If this credit is taken into consideration, the alcohol production cost would drop to US$0.897 and US$0.744 per gallon.

9. Discussions with Officials of U.S. AID, Washington D.C.

Present: Dr. Norman Brown, Special Adviser on Energy to the Assistant Administrator, Bureau for Asia

Robert Nachtrieb, Philippines Desk Officer, Bureau for Asia

Alan Jacobs, Director, Office of Energy, Development Support Bureau

Melvin Schuweiler, Co-ordinator, UNIDO Affairs

Members of the Mission met with the above mentioned officials of U.S. AID at their headquarters in Washington D.C. The objective of the meeting was to present the concept of the project proposal and to explore possible collaboration between UNIDO and U.S. AID in implementing the project. A brief presentation was made on the project proposal and the findings of the Mission as a result of the talks held with both Gulf Research and Development Co., Katzen Associates, and U.S. Army Natick Research and Development Command. In response, representatives of U.S. AID reiterated their interest to provide adequate support to UNIDO for the project proposal under review and stated that renewable energy programmes have been accorded high priority within programmes pursued by the Agency.

U.S. AID agreed with the suggestion that the project should be executed in two phases; the first phase to comprise a techno-economic study for the construction of a 50 t/day pilot plant in the Philippines, the second phase to include design, procurement and construction of the pilot plant for conversion of cellulosic waste to ethanol, and the operation of this plant for two years. The implementation of Phase II would be subject to favourable indication obtained through the techno-economic study (Phase I). In addition, it was recommended by U.S. AID that the study to be carried out under Phase I should also investigate the potential of utilizing such technology in other developing countries to provide part of their liquid fuel requirements as well as the availability of cellulosic waste materials in those countries for the use in future commercial plants. This global part of the study would constitute the basis for possible utilization of the technology in various developing countries.

As to the contribution of U.S. AID, members of the Mission were informed that for the first phase U.S. AID would be willing to finance the full costs, using funds available at the Office of Energy of U.S. AID. However, since it was desirable to start Phase I as soon as possible, it was considered extremely difficult to channel such contribution to UNIDO under trust fund arrangements, as this would entail a long bureaucratic and administrative procedure within U.S. AID. Regarding the contribution of the Agency to Phase II it was stated by the officials present at the meeting that no final commitment could be made at this stage and before Phase I is concluded. However, in case favourable results are obtained, U.S. AID would be willing to consider the financing of the equipment component of the project which will be about US$6 million (please refer to preliminary costing data for Phase II, Section 8). This contribution could partly be furnished from the funds allocated to the U.S. AID Central Funding Programme, partly from funds available under their Energy Programme and partly from funds allocated under their Country Programme in the Philippines. At the request of the Mission U.S. AID will consider the possibility of providing such contributions to UNIDO under trust fund arrangements.

Preliminary terms of reference for the techno-economic study were worked out by the Mission in collaboration with responsible officials of the Agency and a total of US$150.000 was considered a reasonable cost estimate for such a study. In the terms of reference U.S. AID emphasized their view that the Agency attached a great importance to the project's impact on rural areas.

It was further decided during the meeting that Mr. Nachtrieb would be available in Manila during the visit of the Mission, scheduled to take place between 11-16 May 1980, and that further meetings should be arranged with the local U.S. AID office in Manila for finalizing the terms of reference of Phase I, taking into account the outcome of discussions held with the responsible authorities of the Philippines Government on the further development of the project.

The Agency nominated both Mr. Jacobs and Mr. Schuweiler to be the main point of contact for UNIDO on future matters concerning the project.

10. Meeting at the University of Arkansas and Visit to Gulf Pilot Plant

Present: Dr. George H. Emert, Professor, University of Arkansas (team leader)
Paul J. Blotkamp, Research Associate (U.A.)
Dana K. Becker, Research Associate (U.A.)

Mr. Paul Blotkamp made a presentation in which he described the work going on in their laboratories. The members of the Mission asked for clarification and information on some issues. The following notable features can be stated:

a) Gulf Oil Chemicals Company started the project on enzymatic hydrolysis of cellulosic materials in 1972. Dr. Emert and Mr. Becker were members of the Gulf team.

b) Gulf decided to suspend further development of the ethanol project because of higher priority attached to other energy-related projects.

c) Gulf came to an agreement with the University of Arkansas through which they transferred, free of charge, approx. US$1,5 million in equipment and, what is more important, its previous know-how in the area. At the same time they gave the University a grant for US$800.000 to continue work in the area.

d) At the time of the transfer Gulf had invested approx. US$8 million in the project.

e) At the University of Arkansas they have worked up to the bench scale in the pre-treatment of various cellulosic materials, the production of the enzyme, simultaneous saccharification/fermentation and distillation parts of the process. As feedstock for their work they have used various woods, several crop residues, pulp mill waste and M.S.W. [8].

f) In connexion with the pre-treatment they have concluded that the best method to accomplish the process is by agitated bead milling the raw materials; they claim that this is the only good economically feasible pre-treatment.

They claim that Natick tests with roll mills are only of academic value, due to the high energy input and high roll wear.

In any case, Mr. Blotkamp mentioned that, in his opinion, the pre-treatment step could be dispensed with and substituted by an increase in residence time from 24 hours to 90 hours in the simultaneous saccharification/fermentation process which would add only 9c to the cost of the final ethanol.

On the other hand, a study made by Raphael Katzen Associates for Gulf states that 'the economic viability of the Gulf process and other enzyme processes depends in large measures on finding a low cost process for enhancing cellulosic reactivity'.

In connexion with the production of the enzyme complex, it can be mentioned:

a) They are using the same strain of fungi of the Natick's team for the production of the enzymes for the hydrolysis process.

b) The retention time for the process is 48 hours.

c) At the end of the process they do not separate the micellium from the liquid; instead they feed the whole culture to the saccharification/fermentation tank. This is one of the most important factors in decreasing the costs of the enzyme production. They claim that the cellulase enzyme complex produced by their method is much more active than the ones produced by all the other methods.

In connexion with the saccharification/fermentation process, it can be mentioned:

a) Here is where the Gulf process differs mostly from other processes and would be considered as the most important feature of the whole process. In the Gulf process the simultaneous saccharification/fermentation process (SSF) is used. The decreased rate of reaction in the saccharification process arising from the sugars present is overcome by using the sugars as soon as they are formed; the sugars are fermented to ethanol. This is accomplished by keeping the alcohol concentration low (under 5 per cent).

b) The SSF process has been operated using different feedstocks (giving different alcohol yields). But in general they think they have no problems in processing them. When they had problems it was with woods having high lignin content.

c) For the fermentation process a strain of Candida Brasica developed by Bio Research Ltd. is used which gives a better performance compared with other yeasts in the simultaneous process.

d) The residence time in the SSF process is 24 hours. They use about 15% slurry (8% cellulose content) to get 3,6% by volume alcohol.

e) In the SSF process Gulf started using one reactor to carry out the whole reaction, then they tried two

reactors with improved results. At present they are adding a third reactor. This is being done by trial and error, instead of using the kinetic information which they already have.

On the distillation part the following can be mentioned:

a) The whole broth is distilled after separating the yeast mass.

b) For the distillation of the whole broth Gulf developed together with Katzen Associates a special column design (baffle type) which proved to be successful. This column produces 25% by volume of alcohol solution which is concentrated up to anhydrous alcohol using known techniques.

c) Application has been made for patents on the design of the column. The new system would reduce the cost of the whole process.

When the Mission inquired about the influence of various parameters on the final cost of alcohol, the University of Arkansas team mentioned that they could not disclose more information. They mentioned that a thorough feasibility study on a 50 t/day pilot plant had been completed by Raphael Katzen Associates. This study included most of the information the Mission wanted to have. Katzen Associates would have to be contacted in this respect.

Laboratory facilities at the University of Arkansas

The University of Arkansas is fully and very well equipped to conduct all the basic biochemical and chemical developmental work on the processes for ethanol production. The same is true for chemical and biochemical testing.

Pilot plant facility

With the experience gained at the laboratory scale, Gulf Oil Chemicals Co. designed, built and operated a 1 ton/day feed material pilot plant at their Shawnee Mission, Kansas, U.S.A. The Mission visited that pilot facility on 6 May 1980 accompanied by Mr. Dana K. Becker.

In connexion with the pilot plant, the following can be mentioned:

a) The pilot plant is still owned by the Gulf Chemical Co., though the personnel from the University of Arkansas runs it when a specific test is designed and the appropriate contractual arrangements completed.

b) The pilot plant has no facilities for pre-treatment of the raw materials; consequently the plant has to be fed with the raw materials as they come.

c) The plant has the sterilization or pasteurization equipment as needed.

d) The tower for distillation of the broth to produce the 25% alcohol solution was designed and built under the supervision of Raphael Katzen Associates. It is well instrumented and looks very appropriate for pilot testing.

e) All the conditions, except those for pre-treatment, have been tried at the pilot plant and the experimental work, as far as the Arkansas Gulf project is concerned has been considered complete.

f) At the pilot plant they have tried municipal solid waste, pulp mill waste and saw mill waste. Woods and agricultural residues were tried on bench scale only.

g) At the bench scale they have achieved an 81% overall conversion. In the pilot plant, due to the lack of pre-treatment, they have achieved 50-55% conversion to alcohol.

Other trials with the pilot plant

The Gulf pilot plant has been rented by the Solar Energy Research Institute (Boulder, Colorado), under contract with the Department of Energy of U.S.A. to make a series of pilot testing of other raw materials and using a new strain and knowledge developed by the Natick's team and knowledge developed by Purdue University, the University of California, Berkeley, Massachusetts

Institute of Technology, University of Connecticut, Rutgers University, Dartmouth University and University of Pennsylvania.

Team at the University of Arkansas

The team at the University seems to be qualified to do all the basic work and testing in connexion with the basic bio-chemical and chemical knowledge; they lack the capacity to make the bridge between that knowledge and chemical engineering and design.

Semi-industrial plant

Based on the pilot plant data, Raphael Katzen Associates have developed a larger pilot plant to treat 50 t/day of feed material and for which financing is being looked for. That facility has provisions for pre-treatment of raw materials, semi-continuous SSF and a very good material and energy balance.

11. Discussions with the Executive Director and Members of the Philippine National Alcohol Commission, Ministry of Energy

In response to a previous request by the Government of the Philippines to UNIDO concerning the project proposal for establishing a pilot plant for the production of alcohol from cellulosic raw materials in the Philippines, members of the Mission met with Governor Zayco, Executive Director, and other officials of the Philippine National Alcohol Commission.

Governor Zayco and his colleagues were briefed on the objectives of the Mission and its findings in the United States. It was further explained by the members of the Mission that, as a result of its consultations and findings on the state-of-the-art of available technologies, it is proposed to execute the project in two phases as explained earlier in Section 8.

The first phase was estimated to amount to US$150.000. The major part could be provided from the UNDP IPF, pending discussions with Mr. Devarajan, UNDP Resident Representative in Manila; the rest would be reimbursed under contributions by the U.S. AID Energy Office.

Concerning the costs of the second phase, the Mission indicated that a total of US$12 million will be required for constructing the pilot plant of which the Government's contribution will amount to about US$4 million; this will cover the costs of labour, personnel and civil engineering work. The pilot plant is expected to start up three years after completion of the techno-economic study under Phase I.

In reply, Governor Zayco informed the Mission that the Government of the Philippines has accorded a high priority to energy-related technologies and has established an extensive programme on the development of renewable energy resources to be implemented by the Centre for Non-Conventional Energy Development under the auspices of the Ministry of Energy. Furthermore, the Government, in its Energy Programme 1979-1988, has stipulated that its production target for non-conventional energy, including fuel alcohol, is to reach the equivalent of 2,395.000 barrels of crude oil per year in 1988, in comparison to the present total of 5.700 barrels per year.

Governor Zayco reaffirmed the interest of his Government and especially of the Alcohol Commission in exploring the possibility of the production of alcohol from cellulosic waste material as suggested in the project proposal under review. He believed that the Ministry of Energy will make the necessary budget allocation to cover the local component of the costs of the project. He approved the approach proposed by the Mission: namely to implement the project in two phases. He suggested that in the first phase the techno-economic study should elaborate more on the possiblity of utilizing alternative feedstocks in addition to sugar cane bagasse, such as rice straw, rice hulls and ipil-ipils which are available in sufficient quantities in the Philippines. The only problem which might arise in this connexion is to identify appropriate methods for the collection and transportation of such waste cellulosic raw materials required for the operation of commercial plants in future.

It was suggested during the meeting that the most appropriate counterpart organization would be either the Centre

for Non-Conventional Energy Development or the newly established National Institute of Biotechnology and Applied Microbiology (BIO-TECH) at the Philippines University (please see Annex III: Draft Programme of the National Institute of Biotechnology and Applied Microbiology). A third alternative could be the establishment of a project team, consisting of representatives of both institutions. Governor Zayco advised members of the Mission to meet with the management of both institutions to discuss prospects of their participation in the implementation of the project proposal.

It was agreed, at the end of the meeting, that an official request for initiating the work on Phase I would be submitted by the Alcohol Commission through the Ministry of Energy to the UNDP office in Manila for their consideration. In their request, the Government would make known their intention to contribute the full amount of the local cost component of Phase II, pending favourable results achieved under Phase I.

As to the question of possible sites for construction of a pilot plant and in view of the fact that the National Institute of Biotechnology and Applied Microbiology and the Centre for Non-Conventional Energy Development are located near Manila, Governor Zayco was of the opinion that the pilot plant should not be sited far from the counterpart institution. This will enable more efficient working conditions during the implementation stage of the project. For this purpose it was considered appropriate that members of the Mission should meet with the management of the Canlubang Sugar Estate to obtain an overall picture of the potential for utilizing existing sugar industries for the location of a pilot plant.

Members of the Mission were asked to formulate, before leaving Manila, draft terms of reference to reflect the extent of the work to be carried out within the frame of the techno-economic study (Phase I). In complying with this request the Mission prepared the draft terms of reference (please see Annex II), a copy of which was handed over to Governor Zayco's office as well as to UNDP in Manila.

12. Meeting with Mr. Devarajan, UNDP Resident Representative

After providing brief background information on the project proposal and on the discussions held with the Alcohol Commission and U.S. AID on the subject, the Mission explained the proposed methodology for implementing the project in two phases. Mr. Devarajan was asked about the possibility of UNDP providing the US$100.000, necessary for financing the first phase; the remaining US$50.000 would be provided by U.S. AID. In response, Mr. Devarajan explained that he could make available the required funds, if an official Government request is received. He said further that, in addition to any forthcoming contributions in Phase II of the project, to be contributed by UNDP in the next programming cycle, the project would also seem to qualify for co-financing under the Science and Technology Fund. He advised that UNIDO should explore this possibility with the responsible officers of the Fund and the extent of the contribution which could be expected.

13. Meeting with the Centre for Non-Conventional Energy Development and the National Institute of Biotechnology and Applied Microbiology (BIO-TECH)

In line with the wishes of Governor Zayco, Executive Director of the Philippine National Alcohol Commission, the Mission met successively with the management of the above mentioned two institutions. In exploring the possibility of which institute would act as a counterpart agency for implementing the project, it was understood during the meeting with Dr. Ernesto N. Terrado, Administrator of the Centre for Non-Conventional Energy Development, that this Centre had been entrusted with the implementation of a major portion of the foreign aid programmes in the energy field both at bi- and multilateral levels. For this reason it seemed to him that NEDA might be more willing to approve the project, if BIO-TECH was the counterpart agency, as the project falls definately within the terms of reference and competence of BIO-TECH.

BIO-TECH was recently established and had been receiving the full support of President Marcos in conducting R and D work, including

the establishment of pilot plants in the field of biotechnological industry, particularly those applying to the energy sector. Furthermore, the institute had been recently provided with a substantial financial support by the Marcos' Foundation to enable it to conduct its work programme (please see Annex V).

In the meeting with Dr. William G. Padolina, Deputy Director of BIO-TECH, he confirmed their interest in implementing the project. Dr. Padolina mentioned that he would prepare the draft request to be submitted to UNDP through official channels.

Members of the Mission felt that both institutes have sufficient professional competence and manpower to be considered as suitable counterpart agencies for the project. A final decision on this matter will be communicated to UNIDO within the frame of the Government's official request.

14. Meeting with Mr. Arturo D. Gorrez, Factory Manager, Canlubang Sugar Estate

The meeting with Mr. Gorrez was of an informative and exploratory nature to investigate the possibility of establishing a pilot plant in conjunction with an existing sugar mill. This mill has a rated capacity of 6.200 t/day of cane. At present it operates 163 days instead of 247 days a year. This is due to the fact that farmers do not produce sugar cane in sufficient quantities to supply the existing sugar mills, which, in turn, is attributed to the low incomes of farmers on sugar plantations. It was learned from Mr. Gorrez that all the bagasse produced at present in his factory is fully utilized as fuel for the sugar mill and for the pulp plant (no supplement of fuel oil is required), which is part of the estate. The estate already owns a farm which is sufficient for supplying 30 per cent of their sugar cane requirements, 70 per cent is bought directly from the farmers. He thought that as the international price of sugar rises and the farmers grow sugar cane, there would be excess bagasse available for processing by the proposed pilot plant.

The estate also includes a distillery plant with a capacity of 180.000 l/day, if given enough incentives. As to the

possibility of establishing the proposed pilot plant on the estate, Mr. Gorrez welcomed such a proposal and promised that, in the event that it is realized, his enterprise would make adequate contributions to support the operation of the pilot plant, particularly as regards trained manpower, utilities and supply of raw materials. Mr. Gorrez informed the Mission that the estate has adequate research facilities which could be beneficial to the operation of the proposed pilot plant. A possible site within the mill was shown to the Mission. The advantage of this particular mill is that it is only 24 km from the University and BIO-TECH and 52 km from Manila. It is also located in a rice producing area, so that sufficient rice straw would also be available as feedstock.

15. Meeting with U.S. AID Local Office in Manila

Members of the Mission met with Mr. Schwarzwalder, Director of U.S. AID office in Manila and others of his colleagues. Also present at the meeting was Mr. Nachtrieb, Philippines Desk Officer at U.S. AID in Washington D.C. Mr. Schwarzwalder was briefly informed by the Mission on the results of the discussions held with officials of the Government of the Philippines on the project proposal as well as on the outcome of the previous meetings held at U.S. AID headquarters. The members of the Mission further informed the meeting that the UNDP Res. Rep. has expressed his willingness to share in the financing of the first phase of the project, namely the techno-economic study, with a contribution of US$100.000, which would mean U.S. AID's share would be US$50.000. Mr. Nachtrieb thought that the proposed financing arrangements would be acceptable to U.S. AID. The Mission was asked about the appropriate date for starting the implementation of the first phase. It was agreed that such a date would have to be decided on after UNIDO has received the official request of the Government of the Philippines. Regarding the second phase, Mr. Nachtrieb reiterated the position of U.S. AID made earlier during the meeting held in Washington D.C. (please see Section 9). Mr. Schwarzwalder commented that, in his opinion, the project has interregional implications, and that therefore it might be

appropriate that U.S. AID headquarters should draw on other budgetary funds, rather than charging all of the US$6 million (the contribution of U.S. AID) to the Philippines Country Programme, which is at present in the range of US$40-50 million/ year. In reply, Mr. Nachtrieb informed the meeting that this matter could be solved internally, and that the possibility of utilizing U.S. AID Central Funds for financing a major part of their contribution will be considered. During the meeting it was suggested that UNIDO might wish to subcontract the Philippines part of the first phase (UNDP finances) to a consulting firm with relevant experience in the field of production of alcohol from cellulosic raw materials. This would avoid problems which might arise, if individual experts were contracted, who might not have enough practical experience in this particular field to be able to carry out the study efficiently. The contribution of U.S. AID to the first phase would be mainly through providing the services of two experts to undertake the study of available crop residues and the potential of fuel alcohol in selected developing countries. This is in addition to travel funds and other miscellaneous expenses. Finally, it was agreed that in order to co-ordinate the inputs of both agencies, UNIDO will keep U.S. AID in Washington D.C., as well as their local office in Manila, apprised of the further development of this particular project proposal.

16. Other Matters

Members of the Mission met with officials of the National Grain Authority and the International Rice Institute on an informal basis with the objective of obtaining relevant data on the utilization of rice wastes in the Philippines, such as rice straw and hulls bearing in mind the potential of such wastes as a feedstock to the proposed pilot plant. Although both institutes explained that they were mainly dealing with rice itself and not with rice wastes, the members of the Mission were able to obtain the following information:

(i) The total cultivated area for rice plantations in the Philippines is about 2,1 million ha.

(ii) The quantity of rice straw is estimated to be about 30 t/ha.

(iii) The present rice hulls are used partly as an additive for animal feed. However, the major part is directly burned in the fields.

(iv) The Laguna region, which is directly adjacent to Metro Manila, is considered to be a centre of rice production in the Philippines.

(Annex IV provides data on agro-forestry wastes in the Philippines.)

At the end of the Mission two separate meetings for briefing purposes were held: the first in the National Economic Development Agency (NEDA, co-ordinating agency) with Mr. Vicente Salazar, Chief Economic Development Specialist (officer responsible for U.S. AID programme) and Mr. E. Sangoyo (responsible for all UNDP assisted projects), and the second with Mr. Alain Morvan, UNDP Deputy Resident Representative, who were informed of all discussions held with the Government and U.S. AID on the subject. NEDA officials expressed their support for the project proposal.

ANNEX I

Office of the President of the Philippines
Malacañang

EXECUTIVE ORDER NO. 580

CREATING AN ALCOHOL COMMISSION

WHEREAS, the rising cost of motor fuel has affected and continuously affects the economy of the country;

WHEREAS, in order to cushion the adverse effect of high motor fuel cost on the economy, it is imperative that alternative sources of motor fuel be immediately developed;

WHEREAS, it is therefore necessary to provide for an effective agency that would formulate and carry out a national program for the production of alternative sources of motor fuel; and

WHEREAS, under Presidential Decree No. 1416, the President is empowered to undertake such organizational and related improvements as may be appropriate in the light of changing circumstances and new developments.

NOW, THEREFORE, I, FERDINAND E. MARCOS, President of the Philippines, by virtue of the powers vested in me by the Constitution, and pursuant to the authority vested in me by Presidential Decree No. 1416, do hereby order:

SECTION 1. Creation of an Alcohol Commission. - There is hereby created an Alcohol Commission, hereinafter referred to as the Commission, under the Office of the President which shall be responsible for effecting the production, in the soonest possible time, of alcohol in adequate quantities for blending with gasoline for use as motor fuel.

SECTION 2. Powers and Functions of the Commission. - The Commission shall have the following functions:

1. Formulate and define the policies, plans and programs and the necessary guidelines for carrying out and implementing a national program for the production and distribution of alcohol for blending with gasoline as motor fuel;

2. Promote the production and distillation of alcohol from alternative sources such as sugar, cassava and sorghum and the effective utilization of their by-products;

3. Promote and coordinate the conduct of research and development activities on alcohol production, its utilization as motor fuel; as well as various feedstock possibilities;

4. Determine and indicate the areas of responsibility of the various agencies involved in the program, including those not represented in the Commission;

5. Determine, in consultation with the implementing agencies concerned, their respective work programs and time schedules for carrying them out, and resolve actual or potential areas of conflict, overlapping of jurisdiction or functions, including, but not limited to, the question of pricing;

6. Monitor and evaluate all on-going projects undertaken by the various agencies concerned to ensure their proper implementation in accordance with pre-determined schedules;

7. Where necessary and in the interest of accelerating the implementation of the alcogas program, engage directly in any aspect of the alcogas program, including land development agricultural production, distillation, and other related activities; and

8. Perform such other functions as may be provided by law.

SECTION 3. Organization of the Commission. - The Commission shall be governed by a board of commissioners composed of the Minister of Energy, who shall be ex-oficio Chairman of the Commission, the Chairman of the Philippine Sugar Commission, who shall be ex-oficio Vice Chairman of the Commission, the Minister of Finance, the Minister of Agriculture, the Minister of Industry, the Minister of Natural Resources and another Commissioner to be appointed by the President from the private sector.

The Commission shall have an Executive Director to be appointed by the President. The Executive Director who shall be the Chief Executive Officer of the Commission shall be under the administrative supervision and control of the Chairman.

SECTION 4. Implementing Agencies. - The implementation of the alcogas program shall be the responsibility of the various agencies concerned as directed and coordinated by the Commission. Initially, this shall be as follows:

a. The Philippine Sugar Commission shall promote the establishment of alcohol distilleries, whether public or privately owned, and ensure the adequate supply of sugar cane for the production of alcohol.

b. The Ministry of Energy, through the Philippine National Oil Company, shall be the exclusive buyer, unless otherwise decided upon subsequently by the Commission, of alcohol produced for use as motor fuel and shall be responsible for the distribution of alcogas.

c. The Ministry of Agriculture shall study the technical aspects and problems of alcohol production from agricultural crops such as cassava, corn and sorghum, including an economic cost analysis thereof, and promote the production of alcohol from these crops as may be found to be technically and economically feasible.

d. The Ministry of Industry shall promote the manufacture of car and truck engines that can most efficiently accommodate the use of alcogas as motor fuel, and through the Board of Investments, process and approve applications for establishing projects related to the implementation of the alcogas program.

e. The Ministry of Finance shall study and make recommendations on the extent of reduction or elimination of sales taxes on alcohol, to enable alcogas to compete effectively with gasoline prices at the pump stations.

f. The Ministry of Natural Resources shall identify new land areas of the public domain that can be made available for the production of agricultural crops such as sugar cane, corn, cassava and sorghum to be used as feedstock for the production of alcohol.

The other implementing agencies shall support the alcogas program according to their respective areas of concern and as may be determined by the Commission.

SECTION 5. Appropriations. - There is hereby appropriated such amount as may be necessary to defray the operational expenses of the Commission for 1980. Thereafter, the appropriation of the Commission shall be included in the General Appropriations Act.

SECTION 6. Repealing Clause.- Letter of Instructions No. 838 creating the Inter-Agency Committee to Accelerate the Implementation of the National Alcogas Program and such other laws, rules and regulations inconsistent herewith are hereby repealed or modified accordingly.

SECTION 7. Effectivity. - This Executive Order shall take effect immediately.

Done in the City of Manila, this 16th day of February , in the year of Our Lord, Nineteen Hundred and Eighty.

FERDINAND E. MARCOS
President of the Philippines

BY THE PRESIDENT:

JUAN C. TUVERA
Presidential Assistant

DRAFT

TECHNO-ECONOMIC STUDY ON THE ESTABLISHMENT OF PILOT PLANT FOR THE PRODUCTION OF ETHANOL FROM CELLULOSIC WASTE MATERIALS

- The Government of the Philippines has embarked on a national programme for the production of alternatives of motor fuels, mainly Ethanol. The requirements of alcohol in 1988 , to replace 20% of gasoline, is estimated to be 634 million liters. All the excess molasses presently exported, if processed, can substitute only 6% of gasoline requirements. On the other hand, the Republic of the Philippines has a variety abundant cellulosic agriculture and forestry waste such as rice straw, rice hulls, bagasse and wood residues. Recent biochemical research has been successful in converting these cellulosic wastes into ethanol using enzymes for the hydrolysis of the cellulose to glucose followed by fermentation of the latter to ethanol.

The Government of the Philippines intends to construct a pilot plant for the conversion of various agricultural residues to ethanol. The capacity of this pilot plant will be 50 tons of feedstock per day. The information and data gained from the operation of this pilot plant will eventually lead to the construction of one or more commercial scale plants in the country. It should be noted that alcohol is needed not only as a motor fuel but also as a chemical feedstock in future.

As a result of the discussions held with UNIDO mission which visited Manila between 11-16 May 1980, it was agreed that this project would be implemented in two phases:

Phase I - Techno-economic study for construction of 50 t/day pilot plant;

Phase II - Design, Procurement and Construction of 50 t/day cellulosic waste conversion plant, and the operation of this plant for two years (should the results of Phase I be favourable).

It is expected that the techno-economic study under Phase I above, will address itself to the following:

1 - A technical and economic assessment of the technologies available for converting cellulosic materials into motor fuel ethanol and recommendation of that technology most appropriate to Philippine conditions and feedstocks.

2 - A survey of the various feedstocks available in the Philippines, their quantities, geographical distribution, and their estimated cost delivered to a commercial size plant.

3 - In consultation with the competent Philippine authorities, recommendation of a suitable location for the pilot plant and a preliminary layout.

4 - An itemized estimate of the investment cost and the operating cost of the pilot plant for two years, taking into consideration (i) equipment that could be manufactured locally, (ii) the possibility of introducing modifications and additions to the pilot plant, as required, during the two years of operation.

5 - Pilot plant requirements of personnel, utilities and chemicals.

6 - Training needs in the Philippines and abroad for the operation of the pilot plant.

7 - Institutional support for the operation of the pilot plant, i.e., testing, quality control and research laboratories either in a neighbouring factory or in a nearby institution.

8 - A detailed schedule for the construction of the pilot plant.

9 - Suggestions of possible locations for one or more commercial size plants based on the raw material survey under (2) above.

10 - (a) An estimate of the investment and annual operating costs of commercial plants of different capacities indicating the effect of economy of scale on the production cost of motor fuel ethanol (e.g 100 tons/day feedstock).

(b) A flow sheet indicating energy and materials balances in commercial plants.

11 - An examination of the possibility of producing the enzyme in a central facility and, for rural development, carrying out the saccorification and fermentation in several relatively smaller satellite plants.

DRAFT PROGRAMME

OF THE

NATIONAL INSTITUTES OF BIOTECHNOLOGY AND APPLIED MICROBIOLOGY (BIOTECH)

University of the Philippines at Los Baños
April 1, 1980

Recent scientific breakthroughs in microbiology, genetics, engineering and chemistry have shown the increased ability of man to modify and exploit the factors of inheritance in plants, animals, and microorganisms in order to increase their ability to provide for man's needs. It has been demonstrated that microbially-mediated production of chemical compounds involved technologies that are cleaner, more material and energy efficient, and dependent on cheap raw materials like sugars, starches and celluloses which are derived from products of primary agriculture and forestry. More importantly, these new industrial microbiological processes provide for renewable and non-conventional sources of energy.

In view of these innovations in technology, President Marcos , upon the recommendation of Minister Geronimo Z. Velasco and Chancellor Emil Q. Javier, approved the establishment of the NATIONAL INSTITUTES OF BIOTECHNOLOGY AND APPLIED MICROBIOLOGY on November 9, 1979. The INSTITUTE was formally established at UPLB on December 20, 1979 by the Board of Regents of the University of the Philippine System. The Letter of Instructions releasing the funds for the operations of the institute was signed by President Marcos on March 31, 1980. It is envisioned that the INSTITUTE will mobilize and train national competence in the applications of microbiology, genetics, engineering, chemistry & related disciplines

on the problems of fuel alcohol production, chemical syntheses based on alcohol and its derivatives, biofuels from crops and agricultural by-products, single-cell protein production, antibiotics and hormone production and many other applications.

With the generous support of the Marcos Foundation, the Ministry of Energy and the Philippine National Oil Company, the INSTITUTE hopes to gather the best available Filipino scientists in biotechnology and applied microbiology to provide direction and support of individual and interdisciplinary research, assist in manpower training, and provide extension services especially in fuel alcohol production, nitrogen fixation and enhancement of soil nutrient uptake, food fermentation and other areas critical to national development.

The INSTITUTE supports the basic commitment of UPLB to rural development, in general, and to the small farmer in particular. While the INSTITUTE addresses itself to technology-generation for the establishment and improvement of large-scale industries, equal attention shall be devoted to the pursuit of appropriate technology for our rural communities.

FUNCTIONS AND ACTIVITIES

The INSTITUTE is envisioned to become the national center for research in microbiology, genetics, chemistry and engineering with the end of harnessing the new technological developments and scientific breakthroughs in these fields in the generation of energy from renewable sources, in the further improvement of crop, livestock, fishery and forest production and utilization, in the synthesis of various valuable nutrients, drugs and chemicals, in the protection of the environment and other useful applications.

The INSTITUTE is likewise intended to develop and provide the country with the necessary expertise and technological knowhow for the development of the corresponding trades and industries that will come about as a result of technological development in the above fields of study.

To accomplish the above functions, the INSTITUTE shall, in addition to the others that the INSTITUTE may later deem appropriate, undertake the following major activities:

Major Activities:

a. Conduct mission-oriented research, technology development, extension and planning required to develop small-scale and large scale industries based on biotechnology and applied microbiology;

b. Develop and implement manpower training programs designed to upgrade the manpower pool needed to meet the national requirements in biotechnological industries and applied microbiology;

c. Establish linkages between research and industrial operations and formulate and adopt techniques to facilitate the commercial application of laboratory-tested biotechnological processes;

d. Extend scientific advice to government and private entities and collect fees therefor, and

e. Establish a national repository of microbial genetic resources for use by the INSTITUTE, the UNIVERSITY and other national entities for research and development and higher education purposes.

In the conduct of the aforementioned activities the INSTITUTE may undertake, among others, the following which will enable it to discharge its functions efficiently and effectively, subject to approval by the Board of Regents, and, whenever appropriate, upon the recommendation of the INSTITUTE'S advisory council (COUNCIL):

Enabling Activities

a. Construct buildings, laboratories, offices and other facilities and purchase equipment locally or from abroad;

b. Receive donations, grants, scholarships and such similar benefits and scheme;

c. Negotiate loans and contributions for capital expenditures, staff development, and operations from organizations or individuals, local or foreign, public or private;

d. Recruit, employ and/or engage highly competent expertise, not otherwise available in the INSTITUTE or the UNIVERSITY, from local and/or expatriate sources;

f. Enter into agreements or relationships with similar institutions or organizations, both national and foreign, in the furtherance of its functions;

g. Do such acts and perform such other functions as are germane to the foregoing.

RESEARCH PROGRAMS

The research program of the INSTITUTE for the next five years (1980-1985) shall focus on eight main areas of concern herein ranked according to priority:

I. BIOFUELS FROM AGRICULTURAL CROPS AND RESIDUES
(Initially this program will support the National Alcogas Program)

A. Survey of existing distilleries, analysis of problems and possible plant improvement.

B. Technical evaluation of distillery plant proposals.

C. Research and Development on:

1. Batch and continuous fermentation processes based on raw materials like sugar cane, cassava and sweet potato.

2. Improvement of microorganisms for alcohol production.

3. Enzyme production and applications in saccharification.

4. Distillery waste management and utilization.

D. Technical manpower training for distillery plant management and maintenance.

II. ESTABLISHMENT AND IMPROVEMENT OF RURAL-BASED FOOD FERMENTATION PROCESSES

A. Research and Development on:

1. Processing of traditional fermented foods-process evaluation and improvement.

2. Upgrading nutritive quality through fermentation.

3. Improvement of microorganisms used in food fermentation.

B. Quality evaluation and standardization of ferme nted products

III. ENHANCEMENT OF NITROGEN FIXATION AND SOIL NUTRIENT AVAILABILITY TO CROPS AND REFORESTATION SPECIES

A. Research involving survey, isolation, testing characterization and identification of microorganisms (N-fixing and mycorrhiza)

B. Ecological studies and evaluation of effectiveness of microorganisms under laboratory, greenhouse and field conditions.

C. Genetic modification to improve potential of microorganisms.

D. Large-scale inoculant production.

IV. MICROBIAL GENETICS (INCLUDING MICROBIAL GENE BANK)

A. Collection, storage evaluation, genetic improvement, packaging, exchange and distribution of microorganisms for alcohol production, food fermentation industries, N-fixation and mycorrhiza, etc.

B. For the Microbial Gene Bank - NIBAM will maintain basic collections but researchers can keep active collections.

V. PLANT BIOMASS CONVERSION

- Research and Development on microbially-mediated conversion of cellulosic agricultural by-products into useful chemicals.

VI. ANTIBIOTICS, VACCINES AND MICROBIAL INSECTICIDES PRODUCTION

- Research and Development on microbial production of antibiotics and vaccines.

- Microorganisms in the biological control of insects.

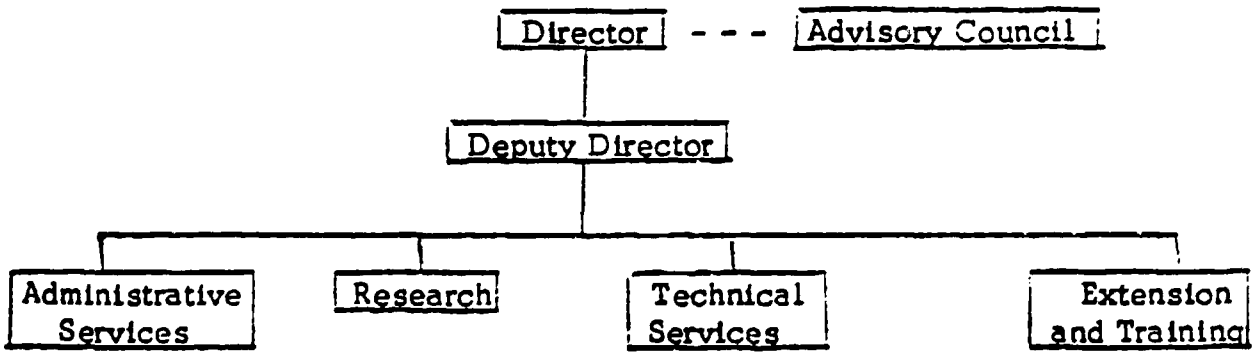
VII. MICROBIAL BIOMASS PRODUCTION

- Research and development on SCP, mushroom production using indigenous substrates and strains.

VIII. HYDROCARBON-LIKE OILS FROM PLANTS

-Research and Development on the use of plants with large yields of hydrocarbon like oils.

ORGANIZATION



Clerical	Task Force Groups	Glassblowing	Photography
Maintenance	Gene Bank	Machine Shop	Public Relations
Purchasing	Basic Micro Lab	Electronics	Training Program
Property	Biochem Lab	Pilot Plant Facility	Library and Documentation Services
		Central Analytical Lab	
		Library and Documentation Services	

AGRO-FORESTRY WASTES
Annual Production

	Quantity (Millions MT)	Oil Equivalent (Millions of Barrels)
Rice Hull	1.5	1.89
Rice Straw	9.7	14.54
Corn Cob	0.6	0.87
Corn Stalks	2.7	4.05
Bagasse	7.5	12.10
Wood Wastes	1.3	2.00
Logging Wastes	2.0	4.00
Coconut Shell	1.9	8.72
Coconut Petiole	4.6	7.10
Peanut Shell and Coffee Hull	0.0	0.40
Grass, reeds, leaves	0.0	0.50
		67.87

Data were derived from following sources:

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NATIONAL INSTITUTE OF BIOTECHNOLOGY
AND APPLIED MICROBIOLOGY

OUTLINE OF THE RESEARCH PROGRAMME FOR 1980

PROGRAM: BIOFUELS FROM AGRICULTURAL CROPS AND RESIDUES
(Support for the National Alcogas Program)

Project I: Processing and Fermentation of Cassava and Sweet Potato for Alcohol Production

Project II: Production of Alcohol from Sugarcane Juice and Molasses using Rapid and Continuous Flow Fermentation

Project III: Collection, Selection and Genetic Improvement of Microorganisms for Alcohol Production

Project IV: Management and Utilization of Distillery Wastes

Project V: Biogas Production from Agro-Industrial Residues

Project VI: Extension - Technology Transfer in Philippine Alcohol Distilleries

PROGRAM: ENHANCEMENT OF NITROGEN FIXATION AND SOIL NUTRIENT AVAILABILITY FOR IMPROVED CROP AND FOREST PRODUCTION

Sub-Program I. N-Fixation by the Legume - Rhizobium Symbiosis in Food Crops

Project I: Selection of Rhizobium strains from grain Legumes

Project II: Ecological Studies of Rhizobia Introduced as Seed Inoculant

Project III: Evaluation of Legume Inoculants

Sub-Program II. Nitrogen Fixation by the Rhizobium Legume Symbiosis in Agro-Forest Crops

Project V: Development of Rhizobium Technology for agro-forestation.

Project II: Utilization of rhizobia in the reforestation and regeneration of degraded agro-forest ecosystems.

Project III: The Rhizobium-Legume Symbiosis in Reforestation Species (Narra and Albizzia)

Project IV: Nitrogen-Fixation in Pasture and Forage Legumes

Sub-Program III: Nitrogen-Fixation in Non-Leguminous Plants

Project I: Algae as Nitrogen Fixers in Upland Ecosystems

Project II: Plant-Microbial Association in Cereals and Grasses

Project III: Harnessing the Nodulated, Non-Leguminous Tree Species for Forest Regeneration

Sub-Program IV: Mycorrhiza

Project I: Isolation, characterization and identification of mycorrhizal fungi in agricultural and forestry crops.

Project II: Screening the effectiveness of mycorrhizal fungi

Project III: Yield improvement of leguminous plants by Rhizobium-mycorrhizal inoculants

Project IV: Incorporation of Nitrogen-Fixation genes of Rhizobium into mycorrhizal fungi

Project V. Mass Inocula Production

FOOD FERMENTATION

PROGRAM TITLE: ESTABLISHMENT AND IMPROVEMENT OF RURAL-BASED FOOD FERMENTATION PROCESSES

Project I: Survey and collection of fermented foods and isolation of microorganisms

Project II: Purification, identification and selection of microorganisms

Project III: Evaluation of Traditional Food Fermentation Processes and Products

Project IV: Establishment of a Process to Upgrade the Nutritional Quality of Legumes Through Fermentation

Project V: Upgrading the Nutritive Quality of Cereals through Fermentation

Project VI: Genetics and Improvement of Selected Microorganisms

Project VII: Biochemistry and Physiology of Microbial Fermentation Process

Project VIII: Technology Transfer

MINOR PROJECTS:

1. Plant Biomass Conversion
2. Single-Cell Protein Production
3. Antibiotics
4. Vaccines
5. Microbial Leaching of Ores.

SPECIALIZED LABORATORIES

MICROBIAL GENETICS LABORATORY (Includes Gene Bank)

BIOCHEMISTRY LABORATORY

ANALYTICAL SERVICES LABORATORY

SUPPORT SERVICES

GLASSBLOWING SHOP

PILOT PLANT FACILITIES

MACHINE AND CARPENTRY SHOP

ELECTRONICS SHOP

LIBRARY AND DOCUMENTATION SERVICES

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