STAFF SUMMARY REPORT:

SYMPOSIUM ON BIOMASS SUBSTITUTES FOR LIQUID FUELS

Campinas, Brazil
February 9-12, 1982

Sponsored by:
Interciencia Association
Sociedade Brasileira para O Progresso da Ciência
Secretaria de Tecnologia Industrial - Ministério da Indústria e Comercio
Conselho Nacional de Desenvolvimento Cientifico e Tecnológico
Empresa Brasileira de Pesquisa Agropecuária

and the

Board on Science and Technology for International Development
Office of International Affairs
National Research Council
Washington, D.C.

National Academy of Sciences
Washington, D.C. 1982

This report is a summary of BOSTID participation in the Symposium on Biomass Substitutes for Liquid Fuels, held in Campinas, Brazil, February 9-12, 1982. The activity was jointly sponsored by the Interciencia Association, the Brazilian Society for Scientific Progress, the Brazilian Ministry of Industry and Commerce, the National Research Council of Brazil, the Brazilian Corporation for Agricultural Research, and the Board on Science and Technology for International Development, U.S. National Research Council.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This staff summary report was prepared by the Board on Science and Technology for International Development, Office of International Affairs, National Research Council, for the Bureau for Science and Technology, U.S. Agency for International Development, Washington, D.C., under Grant No. DAN-5538-G-SS-1023-00.

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## PREFACE

In the spring of 1981, the Interciencia Association invited the National Academy of Sciences (NAS) through the Board on Science and Technology for International Development (BOSTID) to cosponsor a symposium entitled, "Biomass Substitutes for Liquid Fuels." The symposium was planned for February 9-12, 1982 in Campinas, Brazil. The Interciencia Association, a federation of eight associations for the advancement of sciences in the Americas with its secretariat in Washington, D.C., has an active symposium program and has organized over 14 meetings since 1976. As BOSTID had been involved in alternative energy development studies and bilateral activities with many Latin American countries, an agreement was reached to cosponsor and help organize the symposium.

Using funds provided by its grant from the U.S. Agency for International Development, the NAS agreed to provide staff time as well as travel and subsistence expenses for 20 participants, half from the United States and half from Latin America outside of Brazil. Participants from Brazil and Canada would be funded by their respective countries. It was understood that the U.S. participants would be selected by BOSTID and appointed to an ad hoc panel of the NAS. Other participants would be selected by the Interciencia Association through its network of national associations. The Brazilian host organization, the Sociedade Brasileira para O Progresso da Ciência (SBPC), was charged with providing a meeting place, local travel, and the symposium secretariat.

## SUMMARY

Nobel laureate Melvin Calvin described the Campinas Symposium as one of the most encouraging and forward-looking meetings on the potential of liquid fuels from biomass he had ever attended. Starting with experience gained from Brazil's national alcohol fuels program, which uses traditional resources and technology, the symposium's participants charted future directions for biofuels programs based on nonfood crops and emerging technologies. Some of the R & D efforts needed to make such programs feasible in view of limited environmental and human resources were identified by the group.

While it was recognized that most developing nations face increasing food and energy deficits, many at the conference agreed that well-designed national biomass energy programs could also improve agriculture and indigenous food supplies. (An independent statement of this view by Arthur J. Scott is included in Appendix C.) Since the cost of liquid fuels from biomass depends primarily upon the cost of raw materials, successful projects will require support not only for the development of efficient conversion technologies, but more importantly, for substantial efforts to increase local capabilities in the agricultural sector. The need for substantial, long-term funding of agricultural research and training was emphasized.

In the short run, the application of fairly simple, existing technology to agriculture and forestry in the tropics should double average yields per hectare while reducing the cost of production per unit of product by 20-50 percent. Such efforts are applicable to both small- and medium-sized farms and can provide much needed rural employment opportunities. The increased yields obtained can be applied

initially to fuel production, and in the future diverted to supply food markets, since developments in biomass energy systems are expected to allow the substitution of nonfood resources for energy production. In particular, wood from forested land unsuitable for agriculture was thought to have enormous potential in the tropics. This was detailed in an editorial in Science, which is found in Appendix D.

In his remarks at the final plenary, BOSTID Panel Chairman Philip Abelson emphasized the importance of taking a long-term, integrated systems approach to biofuels development. In particular, he noted the universal belief that strong measures to protect important land and water resources should be required of any new bioenergy project.

Research areas identified by symposium participants as needing increased attention in order to exploit the potential of biofuels included:

- Improving the understanding and utilization of tropical soils and soil microorganisms.

- Developing new plant varieties suited to unused lands utilizing traditional crop breeding techniques coupled with modern methods of tissue culture and genetic engineering.

- Finding ways to produce liquid fuels from wood economically by (1) improving technologies for the conversion of cellulose and hemicellulose to ethanol; and (2) finding important uses for by-products, especially lignin.

- Determining the potential of oil-producing plants and trees by careful agronomic studies and research in oil processing technologies.

Finally, participants observed that planners must recognize that successful biofuels programs require carefully coordinated, long-term investments in R & D by multidisciplinary teams of scientists and engineers seeking integrated solutions to the complex development problems of rural economies which differ in important ways from country to country. Were the potential benefits of such efforts any less than adequate food and energy for all, the challenge might not be worth the effort.

## WORKING GROUP REPORTS

Detailed reports of each of the three working groups will be published by the Interciencia Association for distribution to participants, sponsoring organizations, and interested parties. The brief workshop summaries that follow were prepared by the attending staff member, and have been reviewed by the chairman of the NAS panel and the chairperson and rapporteur representing the panel at each workshop.

### WORKSHOP 1: PRODUCTION OF RAW MATERIALS

Objective: To review current technology and identify research needs

Chairpersons: Maro Ran-ir Sondahl (Brazil)
J. Laurence Kulp (USA)

Rapporteurs: Hugo Salazar (Colombia)
Paul Bente (USA)

BOSTID Staff: David Mog

Participants:

ABELSON, Philip
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CALVIN, Melvin
FURLANI, Pedro
GORGATTI Neto, Ágide
MONACO, Lourival
ORLANDO Filho, José
PEREIRA, Antonio Roberto
ROBERTSON, Ernie
VINIEGRA Gonzalez, Gustavo

Discussions focused on crop types and techniques for improving production yields and energy efficiency. Consideration was given to technological inputs at all stages of production including land preparation, fertilization and planting, irrigation requirements, weed and insect pest control, growth regulation, and harvest and transport. Brief issues papers outlined problems and prospects associated with each discussion topic:

| Day | Paper Topic | Presenter |
|---|---|---|
| Tuesday | 1. Traditional sugar crops | José Orlando Filho (Brazil) |
| | 2. Oil-bearing plants, new crops, and genetic engineering | Melvin Calvin (USA) |
| | 3. Traditional starch crops | Alvaro Bueno (Brazil) |
| Wednesday | 4. Wood and forest by-products | Ernie Robertson (Canada) |
| | 5. Tissue culture and vegetative propagation | Maro Ran-ir Sondahl (Brazil) |

A brief description of the flow of work is provided here to help the reader understand the process followed by all three workshops.

After discussion of the final topic on Wednesday, Hugo Salazar shared information about recent experience in Colombia with liquid fuels from biomass. He noted that less than 25 percent of the arable land in Colombia is currently under cultivation and that there are good opportunities for rapidly increasing biomass production.

Before the end of Wednesday's session, the group began to prepare a workshop report. Two elements of analysis were agreed upon: (1) productivity, i.e., current and potential yields per hectare per year, and (2) economics of production. With each crop or species, efforts were made to project the biomass yield that could result from intensive breeding practices and improved crop management. Current costs of production were estimated, and costs with improved yields were projected. While carrying out this analysis, the group was encouraged to identify major R & D needs.

The Thursday morning workshop session was devoted largely to discussions with chairmen representing workshops 2 and 3. This activity provided useful cross-disciplinary exchanges in advance of report preparation.

Three matters of common concern emerged. First was the long down time (3-5 months) of many Brazilian cane alcohol plants, associated with the traditional cane production cycle. The merits of cane breeding to allow for year-round harvest versus crop rotation or intercropping schemes were discussed. The group favored moving away from complete dependence on cane and bringing the better agricultural land (now dedicated to cane) into production of crops that could be used either for food or energy feedstocks (e.g., sweet sorghum or cassava).

A second concern was possible environmental problems created by large stillage volumes produced by the alcohol plants. However, workshop participants felt reasonably confident that the stillage could be managed successfully, noting that this was being demonstrated in the larger Brazilian plants where stillage is routinely returned to the soil to reduce irrigation and fertilization needs.

The third concern was the demand for costly nitrogen fertilizer that would be created by intensive crop production for energy. Problems of providing reliable supplies at reasonable costs were foreseen. The conversion team noted that wood alcohol plants can easily be adapted to produce ammonia for fertilizer. Thus, for modern, large-scale cane alcohol operations, the excess woody biomass from cane processing could be sufficient to supply an ammonia plant that would serve the nitrogen fertilizer needs of a fairly large agricultural region. It was agreed that this concept should be explored.

Following the interactive sessions, the group began writing its report. In the afternoon, some of the symposium's participants toured the Campinas Institute of Agronomy, while the remainder visited a large cane alcohol project in Piracicaba.

At the final plenary, workshop chairman Sondahl summarized the general conclusions of the production workshop:

- Plant Resources. All plant species under serious consideration as energy crops will require research and breeding efforts directed at maximizing the value of the crop as an energy resource.

- Soils. More attention must be paid to soil management in order to sustain fertility and conserve soil, the basic resource. This will be especially important for attempts to exploit marginal drylands and the generally infertile and fragile tropical wetlands.

- Energy Efficiency. Breeding objectives and cultivation and harvesting practices must stress energy conservation, since the economics of bioenergy schemes is strongly influenced by the cost of energy inputs, including fertilizer, at the

production end. Research on biological nitrogen fixation will be especially important.

- Manpower/Training. Successful implementation of bioenergy projects (except those based on waste or surplus production) will require significant resources devoted to training and support of professionals in the agricultural sciences, as well as the improvement of extension services to farmers.

- Funding. The need for continuous, long-term funding must be recognized since the successful application of modern plant breeding programs, from the laboratory to the field, is a long-term process that requires the sustained efforts of highly trained, interdisciplinary teams.

The workshop's findings regarding potential crop yields, production costs, and research needs were organized by plant type.

Sugarcane

Cane yields have probably approached their low technology yield limit but could double to 150 tons/hectare/year with high technology approaches. Cost of production could decrease 25 percent to $8/ton of cane.

Major research needs are:

- Breeding to extend the crop season and improve disease resistance

- Breeding coupled with nutrition studies and soil and water management for utilization of marginal lands

- Exploring the potential of intercropping and crop rotation systems.

Cassava

Cassava yields could double with low technology and increase by five or six times to 50 or 60 tons/hectare/year with high technology efforts. Cost estimates were in the range of $25/ton. Cassava has distinct advantages for production by small farmers in marginal areas. Cane is superior for large-scale operations.

Research needs are:

- Breeding for improved yields and drought- and pest-resistance

- Examining the potential of leaf material as fodder
- Intercropping and crop rotation experiments
- Improved mechanical harvesting technology (nearly 50 percent of the root is lost with traditional hand harvesting).

Oil-Bearing Plants and Trees

Copaiba. Only preliminary information exists for oil yields from trees. An estimate of 4 tons/hectare/year was made for copaiba assuming 20 liters of oil every 6 months for a plot of 100 trees/hectare. The first copaiba plantation was established 2 years ago in the Amazon region. Costs of production have not been projected.

Palm. The oil palm has been better studied, and yields can probably be doubled from the present 5 tons/hectare/year. Current production costs of $300/ton might be reduced by one third.

Euphorbia. The extraction of oil from euphorbia is estimated to cost about the same as that for palm oil, with yields on the order of 4 tons/hectare/year. However, euphorbia yields an additional 10 tons of sugar and 36 tons of bagasse which, if used effectively, would offset oil production costs. In addition, euphorbia can be produced on marginal lands subject to drought.

Alternative Markets. The edible palm and peanut oil market presently commands about $600/ton, and prices for specialty oils such as castor are as high as $1,000/ton. These prices are three to five times the current price of diesel oil; therefore, their use as diesel fuel substitutes is not practical on any large scale in the near term.

The research needs of oil-bearing plants and trees are:

- Careful studies on oil yields under a variety of field conditions
- Research to define nutritional and water requirements
- Agroeconomic studies of production and harvesting costs
- Breeding and pest and soil management for improved productivity in promising species. Deserving further study are: oil palm; peanut and castor bean; trees, including the copaiba; and herbaceous species, including euphorbia.

Trees and Woody Plants

It was estimated that improved practices could increase annual forest yields by three to five times the present average (about 20 tons/hectare/year in the tropics) with a reduction in cost per ton of raw material for energy on the order of 50 percent to between $10 and $20/dry ton.

- Major research priorities are:

  - Developing tissue and meristem culture for rapid propagation of promising species and for increased variability
  - Determination of minimum soil and fertilizer requirements on marginal lands
  - Exploring the potential of short-term rotation species including bamboo and leucaena
  - Exploring the potential of leaf material for fodder or high value chemicals
  - Developing efficient harvesting and transport systems.

WORKSHOP 2: CONVERSION TECHNOLOGIES

Objective: To review problems and identify promising research areas

Chairpersons: José Roberto Moreira (Brazil)
Edward Lipinsky (USA)

Rapporteurs: Julio Araújo (Brazil)
Henry Bungay (USA)

BOSTID Staff: Griffin Shay

Participants:

| | |
|---|---|
| BEAULNES, Aurèle | SERRA, Gil Eduardo |
| COOKE, Norman | STUPIELLO, José Paul |
| FEICHTNER, João Carlos | SUMMERS, Barbara |
| PEREZ Alva, Simón | TANGO, João Shojiro |
| SANTIAGO, Miguel de | TAVARES, Flavio |

Discussion focused on the conversion (using chemical, thermal, or biological means) of specific types of raw materials, including those listed below. Consideration was given to technological inputs at all

stages, including storage and pretreatment of the raw materials; specific primary chemical or thermal processing steps (fermentation, hydrogenation, pyrolysis, etc.); separation and purification of products; recovery, processing, and disposal of by-products ($CO_2$, stillage, etc.); and "net energy efficiency." Brief issues papers outlined problems and prospects associated with each discussion topic.

| Day | Paper Topic | Presenter |
|---|---|---|
| Tuesday | 1. Conversion of starch and sugar | Miguel de Santiago (Argentina) |
| | 2. Conversion of cellulosics | Barbara Summers (Canada) |
| Wednesday | 3. Conversion of crop residues and solid wastes | Edward Lipinsky (USA) |
| | 4. Vegetable oils as fuels | João Shojiro Tango (Brazil) |

Some of the issues discussed and conclusions reached:

Starch and Sugar

The primary source of fuel alcohol in Brazil--sugar cane--cannot be harvested year-round, resulting in distillery shutdowns of three to six months with a corresponding reduction in employment and production. The development and introduction of sugar cane varieties that mature or retain acceptable levels of sugar in months that are not now productive would be a promising area for research. Where harvesting in the rainy season is difficult because of soggy soils, low soil compaction equipment might be developed through modification of logging machines designed for boggy areas.

The use of excess bagasse as a substrate for ethanol production was also discussed. In general, the various biological methods for lignocellulose conversion to fermentable sugar were thought to merit a higher research priority.

Other alternatives considered for extending the period of operations included: storage of juice or juice concentrates for use in the off-season; production and drying of sugar cane pith (using the Tilby process, for example) for alcohol production in the off-season; and using rotation or intercropping to produce feedstocks that might be processed after the cane harvest, such as cassava or sweet sorghum.

## Cellulosics

Research on lignocellulose hydrolysis has shifted from consideration of cellulose alone to refining biomass into an array of valuable products. Priority should be given to processes that separate cellulose, hemicellulose, and lignin into useful forms. Once separated to a fairly pure state, cellulose converts well to sugars using acid or enzyme methods. Commercialization of either process, however, will require reducing enzyme costs, or solving corrosion and recovery problems associated with acid use. Liquid fuels from biomass can also be obtained by thermochemical processes. The conversion of lignocellulose to synthesis gas enables the production of methanol for use as a fuel or chemical feedstock. Ammonia can also be produced from synthesis gas as an alternative to petroleum-derived fertilizer.

Biomass has been directly converted to a fuel oil on the pilot scale by high pressure reaction with hydrogen or carbon monoxide; however, these direct liquefaction processes are far from commercial application. The products obtained resemble heavy fuel oil, but are often unstable and corrosive, and blend poorly with petroleum-based fuels. Both pretreatment of the feed and post-treatment of the product have been examined, but add significantly to the cost.

Among all the opportunities in cellulose conversion, the working group felt that production of ammonia from lignocellulose (especially bagasse) merited strong research attention.

## Vegetable Oils

As gasoline is replaced with ethanol, the need to provide diesel fuel from biomass increases. Freight transportation and mass transit depend heavily on diesel power. Vegetable oils and terpenoids from plants and trees have been tested as diesel substitutes. Soy, palm, sunflower, coconut, and babassu oils have also been tested, as well as terpenes from various euphorbias, and oil-bearing trees.

The major factors impeding broader use of vegetable oils are price and performance. Although the margin is narrowing, food and industrial markets for vegetable oils command a higher price than would diesel substitution. In addition, the viscosities, melting points, and instabilities of various vegetable oils all work against direct substitution for diesel oil.

Terpenes from new plants and trees are believed to be far from commercial use, and strong misgivings were expressed about sustainable yields and economic recovery and processing costs.

The additional challenge in this area is to avoid the food versus fuel problem by developing crops for land unsuitable for food production.

WORKSHOP 3: ECONOMIC, SOCIAL, AND ENVIRONMENTAL ISSUES

| | |
|---|---|
| Objective: | To examine barriers to commercialization of biofuel technologies and to identify needs for information and research |
| Chairpersons: | Luis Masson Meiss (Peru)<br>David Pimentel (USA) |
| Rapporteurs: | Jose Goldemberg (Brazil)<br>Wallace Tyner (USA) |
| Interciencia Staff: | James Rowe |

Participants:

| | |
|---|---|
| GENTINA, Juan Carlos | ORLANDO Filho, José |
| JOHNSON, Bruce | SALA, Oscar |
| NAVARRO, Alfredo | WRIGHT, James |

Discussion focused on five areas: food versus fuel, fuel versus chemicals and feedstock, large systems versus small plants, net energy efficiency, and public energy policy. Five brief issues papers helped guide the discussions:

| Day | Paper Topic | Presenter |
|---|---|---|
| Tuesday | 1. Economic aspects | Alfredo Navarro Serrano (Colombia)<br>Wallace Tyner (USA) |
| Wednesday | 2. Environmental concerns | José Orlando Filho (Brazil)<br>Luis Masson Meiss (Peru) |
| | 3. Social impacts and public policy | James Wright (Brazil) |

By the end of the first session, 15 separate issues or subtopics had been identified, and were consolidated into four general categories:

- Land use and economics
- Equity issues
- Environment
- Technology

The following is a summary of the conclusions reached on each general category.

## Land Use and Economics

The issue of food versus fuel--a land use question--was considered of major importance. It was agreed that "biomass liquid fuel production clearly has the potential to displace food production...." As with other workshop issues, it was evident that the specific effects of biomass energy programs differ by country and crop. The least adverse effects of biofuels production would occur in countries that are net exporters of food and have land available for agricultural expansion. The risk of increased food prices and the resulting effects on the poor are greater with the use of grains than with most other crops.

Currently, biomass liquid fuels are more expensive than petroleum-based fuels in most countries. However, some countries may choose to develop biomass fuels despite the higher cost for a number of reasons. For example, foreign exchange difficulties are often caused by importing oil; there are social benefits to be gained by domestic energy production; and the opportunity cost of resources such as land and labor may be lower than their market cost. The situation in Colombia, as outlined by Dr. Navarro, is especially interesting inasmuch as the main objective is not the production of cane-derived fuel, but rather, development of rural areas.

## Equity Issues

Employment opportunities that could be created by biomass energy production systems were viewed as having considerable potential in such labor-intensive crops as sugar and cassava. Problems include the seasonal nature of crops and rather high occupational injury levels.

## Environment

Environmental risks in large-scale biomass farming received attention second only to the food versus fuel issue. Soil erosion and depletion of soil or organic matter (particularly from planting slopes and marginal lands) were viewed as serious. Water pollution (especially from liquid stillage) is another concern, but a manageable problem. On the positive side, where ethanol is widely used as a motor fuel, improvements in air quality of urban areas are expected.

## Technology

The major technological issues discussed were "small versus large," and alternative end uses of biomass energy by-products and raw materials. The social and economic aspects of Brazil's experiment with the 500 liters/day "micro distillery" were analyzed, as well as the potential for small-scale production of vegetable oils for fuel. The group stressed the need for countries to create appropriate research components to explore alternative end-uses of biomass and the commercialization of important by-products. Such research efforts would be of prime importance, especially in the successful commercialization of ethanol from cellulosic materials.

## PERSPECTIVES

BOSTID panel members, commenting on the symposium, felt that the time was well spent and noted that important information was exchanged and significant new contacts were made. Several participants indicated that the direction and emphasis of their research or professional efforts had changed somewhat as a result of the meeting. Most could also provide anecdotal information suggesting that the conference will have significant impacts on the biofuels or agricultural and forestry resources programs of several countries. It should be noted that Argentina, Brazil, Canada, Colombia, and Peru were represented by participants from key planning and policy making positions. A letter with comments on the value of the meeting from an executive in the Colombian Oil Company is included in Appendix D.

There seemed to be unanimous agreement that the symposium's basic concept and structure were sound, and that the participants represented a useful mix of experience and professional points of view. While most felt that a high degree of consensus had been reached about future possibilities and research needs and priorities, several panelists expressed concern that overriding political and economic concerns would channel scarce resources into technically outdated or unsound projects. Evidence that this has been occurring was presented at the symposium.

# APPENDIX A

## Participants

NAS Panel

Philip H. Abelson (Chairman), Editor
Science
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Washington, D.C.

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São Caetano do Sul

Pedro R. Furlani, Professor
Instituto Agronomico de Campinas
Campinas

*Appointed to panel and participated in planning meeting, but unable to attend meeting in Brazil.

José Goldemberg, Professor
Instituto de Fisica
Universidade de São Paulo
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Ágide Gorgatti Netto
Empresa Brasileira de Pesquisa Agropecuária
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James Coulter Wright, Professor
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Universidade de São Paulo
São Paulo

Latin American Participants

Norman E. Borlaug, Director
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El Batan, Texcoco, Mexico

Juan Carlos Gentina, Director
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Luis Masson Meiss, Head
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National Research Council
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Marco Antonio Dinato Bruno, Executive Director
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São Paulo

Bilingual Secretaries

Liliana Krasbuch

Nicete Mordo

Anita Salama

APPENDIX B

Conference Agenda

Tuesday, February 9

Morning Plenary: Lourival Monaco (Brazil), presiding

Welcome and Introductory Remarks:

Crodowaldo Pavan, President, Brazilian Society for Scientific Progress

Oswaldo Palma, Secretary of Industries, Commerce, Science and Technology, State of São Paulo

Mauricio Matos Peixoto, President, Academy of Sciences, São Paulo

Presentations:

| | | |
|---|---|---|
| 1. | Biomass Fuels Projects and Environmental Conservations | David Pimentel (USA) |
| 2. | Biomass from Forests | J. Laurence Kulp (USA) |
| 3. | Canadian Efforts in Wood Liquefaction | Norman Cooke (Canada) |

Discussion Period

Afternoon Luncheon

Concurrent Meetings of Workshops 1, 2, and 3

Evening Informal Reception and Dinner

Plenary: (continuation of morning program)
George Bata (Canada), presiding

| | | |
|---|---|---|
| 4. | Biomass Development in an Oil Exporting Country: Food, Feed, or Fuel? | Gustavo Viniegra Gonzales (Mexico) |
| 5. | Brazilian Strategies for Increasing Resources | Ágide Gorgatti Neto (Brazil) |

Wednesday, February 10

Morning Plenary: Philip Abelson (USA), presiding

| | | |
|---|---|---|
| 1. | Alcohol from Cellulose in Peru | Simón Perez Alva (Peru) |
| 2. | Biofuels Development in Chile: Case Study | Juan Carlos Gentina (Chile) |
| 3. | Sustaining Agricultural Productivity for Food and Fuel | Norman Borlaug (USA) |
| 4. | Impact of Proalcool | Bruce Johnson (Brazil) |
| 5. | Status of Cellulose Hydrolysis Commercialization in the USA | Henry Bungay (USA) |
| 6. | Prospects for Enhanced Conversion Processes for Carbohydrates in Brazil | Julio Araújo (Brazil) |

Discussion Period

Afternoon Luncheon

Concurrent Meetings of Workshops 1, 2, and 3

Evening Dinner

Public Lecture: Crodowaldo Pavan (Brazil), presiding
"Hydrocarbons from Plants and Trees," Melvin Calvin (USA)

Discussion Period

Thursday, February 11

Morning — Interactive Workshop Sessions

Concurrent meeting of Workshops 1, 2, and 3 with brief progress reports by chairmen of each of the other groups followed by discussion. Chairmen rotated as follows:

| | Workshop 1: Production | Workshop 2: Conversion | Workshop 3: Economic, Social, and Environmental |
|---|---|---|---|
| Session I | Lipinsky<br>Moreira | Pimentel<br>Masson Meiss | Sondahl<br>Kulp |
| Session II | Pimentel<br>Masson Meiss | Sondahl<br>Kulp | Lipinsky<br>Moreira |
| Session III | Sondahl<br>Kulp | Lipinsky<br>Moreira | Pimentel<br>Masson Meiss |

Afternoon — Luncheon

Field trip to facilities near the city of Piracicaba for observation and briefings on cane production and alcohol and sugar production and distribution.

Evening — Open

Friday, February 12

Morning — Drafting session for chairpersons and rapporteurs of Workshops 1, 2, and 3 and an informal discussion session for the remaining participants with Prof. Lourival Monaco (Brazil), presiding.

Afternoon — Luncheon

Final Plenary: Lourival Monaco (Brazil), presiding

| | | |
|---|---|---|
| 1. | Summary of the Brazilian Alcohol Program | José Israel Vargas (Brazil) |
| 2. | Frontiers of Biomass Technology Worldwide | Paul Bente (USA) |

3. Workshop Reports:

   Workshop 1 - Maro Ran-ir Sondahl (Brazil)
   Workshop 2 - Edward Lipinsky (USA)
   Workshop 3 - Wallace Tyner (USA)

4. Summary of the Campinas Symposium — Philip Abelson (USA)

5. Closing remarks:

   Auréle Beaulnes (Canada)
   Alfredo Navarro Serrano (Colombia)
   Lourival Monaco (Brazil)

Adjournment

THE JOURNAL OF COMMERCE, Monday, March 29, 1982

# nology Key to World Food Problems

THUR J. SCOTT
Director
ate Planning Services
e Memorial Institute

l observer, the problems
ie world's people seem
ol or even solved. After
: early 1970s, hasn't the
ood grown steadily in
opulation increases? We
he papers that the Poles
g food, but isn't that a
politics causing farmers
eir backs on a failed
ystem?

that, except for continen-
nost of the world has seen
ss in slowly improving its
tion and delivery. Reasons
accelerated application of
ical technology. The pro-
formance of countries now
from these advancements
y to return to old levels.
yielding cereal grain varie-
sion of land under irriga-
tance of pesticides, and the
l introduction of commer-
izers are becoming com-

roduction boosts have been
e gradual enlightenment of
nts. Social and economic
e harvesting payoffs where
ove the income and quality
ural people. These attitudes
art of leaders are being
out more often within a
which accepts that agricul-
and should be the central
of agrarian societies, rather
remphasis on urban indus-
n.

negative side, overall prog-
not reveal the many disap-
and intractible problems at
level of consumption, where
ace and distribution distor-
tinue to cause severe priva-
t would be incorrect to claim
rable developments are uni-
ut they appear to be occur-
l prospects are good for their
tion.

nism over positive trends
ly sprouts during periods
e world's grainaries are full,

are now; but the more serious
erm risks remain with us. The
population continues to ex-
that it is likely to double in
ars, and crop-killing weather
s must be expected.

aps the most pervasive and
problems of a more immedi-
l controllable kind, and where
logy offers important future
, concerns the availability and

use of energy in low income countries.

During the decade of the 1970s, the highly industrialized countries such as the United States and those of western Europe continued to make impressive gains through research and technology in refining the efficiency of their agricultural systems, particularly in plant genetics, pest and disease control, and energy conservation.

Energy cost dislocations are especially important in shaping future priorities for technology. In the food surplus countries energy price increases have been dealt with through widespread adjustments in agricultural production and distribution practices along with requisite price, supply, and demand rebalances. It has been a difficult transition, but one which is more or less under control and in which technology has been instrumental.

Energy consequences for the non-oil producing, low-income nations have been quite another story. The present Central American dilemma surrounding El Salvador, for example, is in large part a saga of declining living standards being suffered to meet exorbitant oil import bills which are being paid for out of stagnant agricultural export earnings. This problem reaches into all corners of the region, especially the agricultural sector.

Nevertheless, it is within this sector where science and technology offer solid hope for a solution. The time required is probably 10-20 years for making a thorough turnaround, but the groundwork is now in place for a broadly structured attack on a major part of the energy problems of these and similar agrarian countries which lie within the boundaries of the tropics and semi-tropical latitudes.

The key is to develop industries and commerce in the production, processing, and value-added manufacture of energy fuels and chemicals from domestically produced, renewable resources. This is no less than the challenge of establishing self-sustaining fuels and chemicals industries involving production of high-yielding field or forest crops and their collection and conversion to stored fuels or chemicals using fermentation or thermochemical techniques.

A basic requirement for economically successful bioprocessing schemes is to have agriculturally

*The key is to develop industries and commerce in the production, processing, and value-added manufacture of energy fuels and chemicals from domestically produced, renewable resources.*

superior plant feed stocks in terms of photosynthetic efficiency, stress tolerance, pest resistance, and carbon-fixing productivity. However, identification and development of high performance food or biomass plants is an agricultural practice which is barely under way in semi-tropical zones.

These regions will need a great deal of hand-on help and resources from temperate zone countries. However, the opportunities are good, because food surplus nations are moving rapidly to research and develop new bioprocessing technologies within the context of their own domestic opportunities.

It is from these new technologies that the energy deficient countries can benefit. Areas of opportunity which will be the targets for worldwide R&D investments in agriculture and which especially bear on the energy and food deficits of developing countries will include:

— Altering the genetic traits of plants at the cellular level: The improvement of plant behavior through cell culture techniques and genetic engineering methods, coupled with traditional plant selection and improvement research, offer a major longer-term opportunity to help introduce more productive food crops and biomass feedstocks to otherwise marginal growing areas. In the meantime, the aggressive application of well-established plant breeding technology can furnish high payoff to the bioprocessing opportunities of needy countries.

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— Genetic engineering of microorganisms: Superior processing flow sheets for biomass conversion and end-product characteristics will depend upon tailoring all variables to achieve optimum yields of the most valuable chemicals and fuels. Much is already known about the performance of fermentation systems employing traditional microorganisms. However, genetically engineered microorganisms and accompanying advanced fermentation systems are likely to revolutionize bioprocessing in speed, reliability, and efficiency.

— Using cellulose to replace simple sugars and starches: Advances in enzyme technology and our understanding of cellulose chemistry should make possible the production of simple sugars from wood and agriculture residues. The sugars could be added to the human diet or to animal feed.

Alternatively, fuel grade or chemical ethanol could be produced from them. Single cell protein is another potential end use for sugars derived from cellulose. Mastery of this technology will increase the supply of food, feed, chemicals, and fuels by making use of woody resources that are currently under-used.

— Nitrogen: Availability of fixed nitrogen for energy-deficient countries poses a special long-term concern since all agricultural or biomass production is influenced by the availability of this nutrient whose price and supply is tied to petroleum. While the new bio-engineering technologies offer only long-range hope of furnishing nitrogen-fixing qualities to non-legume plants, it is a research challenge with large potential.

In the shorter term, it is quite possible that direct combustion conversion processes of biomass to yield medium Btu gas can be brought to the point that nitrogen-based fertilizers are affordable from domestically produced feedstocks.

— Other paths, such as use of fermentation to yield hydrogen for ammonia production, may also provide solutions. These or other variations for obtaining efficient systems for nitrogen-fixation in fuel deficit countries appear likely to occur in the next 10 to 15 years if the technology progresses as now indicated.

This compressed picture of the world's opportunities for technology in agriculture is limited to but one element of the developing world's needs, namely energy; but it should demonstrate that today's opportunities for keeping on top of the world's population-food problem will heavily involve R&D, particularly biotechnology; indeed, the shift of emphasis to a cellular level focus in biological research is among the most important developments to happen to the

## APPENDIX D

### Press Coverage

As a consequence of widespread public interest in Brazil in the national alcohol program, there was regular local newspaper, radio, and television coverage of the meeting. In addition, Norman Borlaug, Edward Lipinsky, David Mog, and David Pimentel participated in a tape-recorded discussion of liquid fuels from biomass with Gary Lee Treadway, a reporter from the Voice of America, for rebroadcast worldwide. An article that appeared in Science follows.

2 March 1982, Volume 215, Number 4538 SCIENCE

# Energy and Chemicals from Trees

An analysis of presentations at a conference on "Biomass Substitutes for Liquid Fuels," held on 9 to 12 February at Campinas, Brazil,* shows that a combination of factors will guarantee the increasing importance of the culture of trees and the applications of forest products. Some factors—such as the need to develop renewable alternatives to oil and the growing requirements for food and energy—are well known. Less widely appreciated is the need to decrease soil erosion by growing vegetation that will hold the soil in place. Agricultural practices have led to loss of about one-fourth of the topsoil in the world as a whole and about one-third in the United States. Much of the erosion has occurred on hilly terrains, which should be protected with perennial vegetation such as grasses, shrubs, or trees.

One impediment to forestation has been economics. Individual farmers have been able to obtain a considerably larger return from an annual crop than from trees, and typical yields of wood from natural forests have been small. However, in the Pacific Northwest, hilly land devoted to timber produces a return far above what it would yield in annual crops. Moreover, we are in the early phases of improvement in biomass yield from trees. For example, before 1960 the natural annual growth of loblolly pine in South Carolina was 3 dry tons per hectare. Through selection of superior stock and better forest management, the annual growth has been increased to 11 tons per hectare; yields of 18 tons are in prospect and 30 tons is an ultimate possibility. In Brazil, growth of a *Eucalyptus* species is being evaluated. This species has a 7-year growth cycle. In a forest occupying 40,000 hectares, annual yields initially were 23 tons per hectare. With selection the second rotation improved to 33 tons, while a third rotation produced 40 tons. The five best clones would produce 61 tons per hectare and a target of 100 tons seems reasonable. Such improvements can be conducted on a large scale, for instance, by selecting and planting superior seedlings. In addition, techniques for tissue culture cloning of trees are well developed in both the United States and Brazil.

A factor that could lead to greater emphasis on growth of trees is the possibility that the market value for wood will experience a long upward trend. Wood is considerably more valuable when processed to make lumber or paper than it is when used directly as a fuel. An important challenge for scientists is to discover and develop better methods for exploiting the chemical potentials of wood.

In terms of organic matter, wood is approximately 50 percent cellulose, 20 percent hemicellulose, and 30 percent lignin. A number of schemes are being employed to separate these components for various uses. One method is solvent extraction of the lignin followed by removal of the hemicellulose leaving the cellulose. Another is a short exposure of the wood to steam followed by explosive decompression and removal of the lignin by dilute alkali. Lignin can be used as an adhesive, and at present it commands as much as $400 a ton in this application. It can also be used as a filter in plastics and, when pyrolyzed, it forms a superior metallurgical coke.

Cellulose can be used directly as cattle feed or converted to glucose by acid hydrolysis or use of an enzyme. The enzyme method gives the highest yields and is becoming less expensive. Thus, prospects are good that large quantities of glucose derived from wood will become available. This product could be used as food for humans, as a carbon source for microbial formation of protein, or as a feedstock for fermentation processes yielding liquid fuels, chemicals, and pharmaceuticals.

For a brief period of human history oil dominated the energy and chemical scene. Wood is in the process of resuming its ancient central role, but on a broader scale as science and technology point the way to more effective production and use.—PHILIP H. ABELSON

*The conference was sponsored by Interciencia Association, Sociedade Brasileira para o Progresso da Ciência, U.S. National Academy of Sciences, Secretaria de Tecnologia Industrial-Ministério da Indústria e Comércio, Conselho Nacional de Desenvolvimento Científico e

# EMPRESA COLOMBIANA DE PETROLEOS
30 AÑOS

Bogotá, February 17th, 1982
VIG-DET-451

Mr. James W. Rowe
Executive Director
The Interciencia Association
American Association for the Advancement of Science
1776 Massachusetts Avenue, N. W.
Washington, D. C. 20036
U. S. A.

Dear Mr. Rowe :

This is to thank you and through you to the Interciencia Association and BOSTID, for the opportunity that I had to participate in the symposium - workshop " Biomass Substitute for Liquid Fuels ", held at Campinas.

This program was very useful because I had the opportunity to clarify some basic issues regarding a possible gasohol project in Colombia, by talking to the scientists present in the symposium-workshop.

Also, I was able to exchange opinions and ideas with the other Latin-american participants, on energy and environmental issues that are common to our countries.

The above, plus new valuable doubts that will have to be evaluated and clarified here in Colombia, make this symposium - workshop very useful for the planning of energy programs in my country.

Sincerely yours,

Alfredo Navarro Serrano
Head, Technological Division