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# AN EVALUATION OF THE BIOENERGY SYSTEMS AND TECHNOLOGY PROJECT OF THE AGENCY FOR INTERNATIONAL DEVELOPMENT BUREAU FOR SCIENCE AND TECHNOLOGY OFFICE OF ENERGY

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# INTRODUCTION

This report summarizes the findings of an intensive evaluation of the Bioenergy Systems and Technology (BST) Project of the Office of Energy, Bureau of Science and Technology. The evaluation team reviewed in detail the activities of the project staff in Washington and, to the extent possible without travel to the field, in AID recipient countries. These activities include workshops, technical consultancies to the field, and the preparation and publication of state-of-the-art reports, a bioenergy handbook and a quarterly bioenergy newsletter.

The BST project, originally named the Bioresources for Energy Project, was approved in October 1979, reauthorized in August 1980, and has been administered by the Office of Energy using a Participating Agency Service Agreement (PASA) with the United States Department of Agriculture (Forest Service and the Office of Science and Education). On the basis of the experience gained during the first 18 months of work, the Energy Office redesigned the project to provide more direct support for mission activities and to emphasize the importance of viewing bioenergy production as the product of an integrated system that involves the identification and production of feedstocks as well as the design and adaptation of conversion technologies. This redesign was undertaken after careful consultation with the regional bureaus of the Agency and responds to their concern that the original project placed too much emphasis on the preparation of "state-of-the-art" reports and too little on direct mission support.

The overall conclusion of the evaluation team is that the BST project represents a sound and appropriate allocation of AID resources in the energy

field. The mix of activities included in the revised project is appropriate, given our expectation about the future demand for assistance, and is a logical redirection based on the knowledge and experience gained in the first phase. The project will, in the future, stress direct field support more heavily, and this will be conducted within a structured framework designed by the Energy Office to promote the design of coherent, economically viable biomass energy projects. The evaluation team endorses this new emphasis.

Although we feel the management of the project can still be improved--see our recommendations, at the end of this report--the PASA arrangement appears to be an effective means of securing technical specialist for the work of the Agency. The success of the Office of Energy, after early instability in project leadership, in hiring a qualified bioenergy specialist who can devote full time to the management of the project augurs well for continued improvement.

## EVALUATION OF PROJECT ACTIVITIES

The Bioenergy Systems and Technology project has initiated a number of activities as part of its mandate to assist USAID field missions in identifying and developing appropriate bioenergy projects. Both field activities and technical reports have been evaluated.

### FIELD ACTIVITIES

The evaluation team reviewed reports of field activities and interviewed, by phone or in person, representatives of all the regional bureaus. In addition, the team sent a cable requesting comments on project sponsored activities to those countries in which technical assistance was provided.

In general, our conclusion is that the field support activities have been productive and effective in providing technical assistance of a wide variety. The project has been well-received and there is every reason to expect an increase in demand for support activities in the biomass area.

### BUREAU COMMENTS

The Africa Bureau reported that very little work had been done in African countries under the auspices of the Bioenergy Systems project. The reasons given were very general in nature, but reflected a feeling on the part of that Bureau that the kinds of technologies and bioenergy systems in which the

Africa Bureau has been interested have been ones that are less sophisticated and technologically complex than those encompassed by the S&T/EY project. "They are not interested in the same things we are," was the view of a representative of that Bureau. An exception to this was the work of Kjell Christophersen in assisting in the design of work on the cultivation of a native species in arid zones. This work was praised, although the Bureau complained that it took more than a year to obtain agreement from the S&T/EY office to provide the assistance. Although it is true that many biomass technologies use resources or conversion processes that currently are inappropriate for extensive use in Africa, it is the opinion of the evaluation team that the Africa Bureau has underestimated the usefulness of the bioenergy project to African missions and, if more fully informed of available support, will find many ways to use the services the project makes available.

The Latin American and Caribbean Bureau expressed considerable satisfaction with the project both under former and current management. Relative to other S&T/EY projects the BST has perhaps been the most used and the ost useful to LAC Bureau. It was felt, however, that there remains a need for greater communication and coordination. LAC, for example, has yet to receive a copy of the trip report of Dr. Beinhart's attendance to a central American regional biomass seminar during 1981. Also some of the earlier field support was poorly coordinated with LAC and therefore led to less than optimal projects. Time and staff constraints in both LAC and ST/EY have made collaborative action less than desired, but both are attempting to move in the right direction. For the above reasons, and because biomass still represents 50% of the primary energy used in most LAC countries, this Bureau felt very strongly that the project should be continued, reinforced, and better integrated with activities in S&T/FNR.

The Asia Bureau reported broad support for the project and the orientation of the new project paper citing several instances of successful field support activities. The single complaint of that Bureau is that the state-of-the-art papers had not been distributed to them despite repeated requests for copies.

The Near East Bureau also reported favorable impressions concerning the project and its activities in the field, although the representative from that Bureau stated that, to the best of his knowledge, the project had not been used extensively by the Bureau or the countries in the region.

## TECHNICAL CONSULTANCIES

Various forms of technical assistance were provided in eight countries at the request of their respective field missions. These involved consultancies on the feasibility of bioenergy projects and the development of bioenergy programs. Reports have been issued for each of these visits.

Although it is possible to evaluate the quality of these reports in a number of ways, the most meaningful measures of their usefulness concern (1) whether the in-country program was served and (2) whether the goals of the overall BST project were advanced.

With one exception, the responses from the field to a cabled inquiry have been positive. The cable from Rabat, Morocco, reported that the consultancies provided by S&T/EY were useful in the development of a PID, and praised a study of charcoal conversion and combustion technologies. A cable received earlier (before the request from the evaluation team) from Indonesia noted the high quality and helpfulness of the biomass team that assisted in the development of a renewable energy lab.

The single exception was a critical cable received from the mission in the Dominican Republic. The mission staff encountered difficulty in working with a team sent to that country to assist in the preparation of a project paper, and noted that this contrasted sharply with very productive and helpful technical support received from S&T/EY in the past. The evaluation team reviewed this instance carefully and has concluded that the problems involved, including personality conflicts, poor timing, language problems and incomplete communications between Washington and the field, are unlikely to recur for the same reasons in the future.

The extent to which BST project objectives were served can be inferred from action taken on the basis of the consultancies and from the reports' organization, scientific content, consistency and apparent suitability given local, social and cultural issues and host nation national priorities. In terms of these criteria, the results are uneven as described below.

Costa Rica: A Preliminary Review of Biomass Energy Options in Costa Rica and the National Alcohol Fuel Program.

J. L. Jones,

October 31 - November 8, 1980.

The current major component of the biomass energy program in Costa Rica is the production of ethanol to replace petroleum fuels in transportation. Jones recognizes that agronomic and political issues outside of alcohol conversion are important and probably controlling. He also notes several biological and nonbiological renewable energy approaches which may be suitable for development. In addition, he mentions that a comprehensive study was in progress to estimate the costs and benefits of the alcohol fuels program.

Subsequent to this report (but not necessarily as a consequence), Costa Rica has taken a strong interest in biomass energy forms other than ethanol. These include work on biogas, charcoal, and gasifiers.

Ecuador I: Biomass for Energy in Ecuador;
An Assessment. G. Beinhart, J. F. Henry,
November 17 - December 4, 1980

This consultancy concerned the production and use of fuelwood, crop residues, manures, and municipal wastes as bioenergy sources.

The report demonstrated sensitivity to organizational and cultural problems and provided a fine technical overview. Problems with the biogas effort were frankly described and lead to a second visit to aid in this area.

Ecuador II: Biogas Program Assessment and Planning in Ecuador.
R. T. Skrinde, J. A. Brautigan
March 17-31, 1981.

Siting, sizing and operating problems in the biogas program were covered and comprehensive recommendations were provided for enhancing and expanding the project - a thorough and probably effective consultancy.

Although no formal follow-up reports were made for these two projects, the Ecuadorian government was sufficiently impressed with the quality of the second consultancy to request additional work from this contractor. We also understand that the government of Ecuador, through INE, has constructed more than a dozen digesters and is considering further expansion.

Morocco: Biomass for Energy in Morocco.

P. E. Hoekstra, K. A. Christophersen, J. L. Jones,

July 12 - August 2, 1980.

This study covered forestry and agricultural biomass generation and conversion for energy as well as some design considerations for the proposed Renewable Energy Center.

Some odd disparities occur between sections of the report concerning costs and economics. As part of a summation of equipment costs for biomass production, figures are quoted to the nearest dollar. When conversion processes are described, it is suggested that small metal cooking stoves can be purchased and installed in urban Morocco "for less than $1,000". The cost of retrofitting a gasifier on a large vehicle is estimated at $5,000-$10,000. Certainly better figures are available.

Based on this effort, some work on portable charcoal kilns has been initiated, a World Bank loan for reforestation has been requested, and a project paper on forestry prepared.

Indonesia: Puspiptek Energy Resources Laboratory - Assessment of Biomass Program and Facilities.

R. T. Skrinde, P. E. Hoekstra, A. Talib, K. H. Vause,

November 3 - 24, 1980.

In this report plans and projects for this new laboratory were covered including identification of technical and economic problems.

If anything, the program proposed is too broad. With the apparent thrust toward solving rural and transmigration problems, inclusion of research on flash pyrolysis, methanol, and continuous fermentation to ethanol seem

ill-advised if technical personnel and resources are at all limited. The development of thousands of small-scale ethanol plants for rural areas could probably occupy the efforts of this laboratory entirely, if this remains a direction pursued by the Indonesian government.

Apparently, constructon of this research facility has not yet begun.

Tunisia: Agricultural and Biomass Energy Assessment for Tunisia.
H. Waelti, T. R. Miles,
December 8 - 19, 1980.

This report concerns the determination, collection, and use of data on agricultural energy consumption. It appears to be complete and cohesive and appears to meet the requirements of the request.

USAID work in Tunisia is now being phased out.

Sri Lanka: Investment Analyses of Fuelwood Plantation in Sri Lanka.
E. L. Medema, C. R. Hatch, K. A. Christophersen,
March 1981.

This report covers investment feasibility for a fuelwood plantation of *Eucalyptus camaldulensis* on various soils with different planting and management techniques.

Although the economic analyses are scrupulously derived, the social advantages or disadvantages of taungya farming are ignored. Perhaps this consideration will be included by the government of Sri Lanka.

Findings from this study will be used to solicit a World Bank loan for charcoal energy plantations. The approach used in this study will be used in other countries by the Asia Bureau.

Dominican Republic: Woodfuel Production and Conversion to Energy in the Dominican Republic.

P. E. Hoekstra, A. K. Chatterjee,

June 19 - July 10, 1981.

This report proposes small- and large-scale woodfuel planting trials as well as examination of charcoal production and gasification.

It is well organized, provides a rational approach and appears to meet the requirements outlined in the mission request.

This effort was not well received by the mission (see comments above); however, much of the report was directly transferred to the Mission Energy PP to be obligated soon.

Panama: Implementation of the Wood-Fueled Steam Electric Plant at Yaviza.

R. A. Benavides, C. Bliss, A. Mayta, R. Miller, R. Rollins,

July 8 - 24, 1980.

This report covers the final preprocurement phase of this project. Although poorly organized and clumsily written, it appears complete. Concern for possible sulfur dioxide problems from wood-burning seems odd.

WORKSHOPS

Three workshops have been held during the past 2 years.

Bioenergy: April 16 - 18, 1980, Washington, D.C.

The workshop included 28 developing country participants and 38 U.S. specialists and invited guests. It covered biomass production and conversion with special emphasis on developing country applications.

It was both well organized and well received.

Data Management: July, 1980, McLean, Virginia.

This workshop focused on instructions for the state-of-the-art reviews and the terms of a contract for a data management handbook.

The success of this meeting can be judged from the quality of the reviews and handbook.

Charcoal: March, 1982, Acesita Florestal, Brazil.

The workshop addressed thoroughly all aspects--physical, social, environmental, and economic--of charcoal production in Brazil; and it appears to have been well received by the participants. Florestal deserves considerable credit for having taken care of numerous organizational details and the protocal necessary to the success of the workshop. Coupling the presentations with field visits was particularly helpful, although the schedules may have been overly ambitious. Also, material needed for the workshop was not sent to participants in advance of the meeting; and useful cross-fertilization could have been facilitated by specifying a uniform format for the presentations by country participants of their respective countries' experiences and programs.

The ability of the workshop proceedings to focus on the main issues and problems of the subject will be critical to the success of follow-up activities.

## HANDBOOK AND STATE-OF-THE-ART REPORTS

A series of fourteen State-of-the-Art reports have been prepared, and an additional ten are in preparation. The completed reports cover several major bioenergy conversion technologies, while those in progress will provide some surveys of current biomass production in developing countries as well as selected case studies, market studies, and project evaluations.

Based on the fourteen completed reports, a "Bioenergy Conversion Handbook for Developing Countries," was written. This is intended to provide basic information about bioenergy suitable for AID missions and interested parties in host countries. Detailed critiques of the Handbook and completed State-of-the-Art reports are presented in Appendices A and B of this evaluation.

With a few exceptions, the reports were found to be technically sound and should be useful sources of information about bioenergy conversion technologies. The Handbook provides a good summary of the reports' contents, but inadequacies in the reports were generally carried over to the Handbook. In addition, the utility of the Handbook could be improved through some additions and analyses, as described below.

Gasifiers. Pyrolysis gasifiers that minimize char and pyrolytic oil production were not considered. Such gasifiers are under development* and may be useful as multi-feedstock gasifiers suitable for producing medium energy gas or as the first step in methanol synthesis.

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*See OTA, "Energy from Biological Processes," Vol II, page 154; John A. Coffman, Wright-Malta Corp., Ballston Spa, New York 12020, 518-899-2227.

Boiler Derating. A crucial factor determining whether and how much a boiler converted to gasified biomass must be derated is the energy content of the biomass derived gas. Conventional air-blown gasifiers (and those using coal or charcoal) generally produce a gas with less than 150 BTU/SCF, and significant boiler derating is necessary. Advanced air-blown wood and herbage gasifiers, however, can produce a gas approaching 200 BTU/SCF, for which little or no derating may be necessary. These latter gasifiers are not fully proven in commercial practice, but they should be mentioned along with the significance of the fuel gas energy content.

Grasses and Crop Residues. These bioenergy sources are generally ignored as feedstocks, although their chemical properties make them highly suitable for gasification. Also crop residues are currently used for cooking, and some residues may become attractive for energy conversion (if fertilizers are available to replace the nutrients in the residues and sufficient residue is left in the field to protect the soil from erosion). Finally, high yield grasses have the potential for higher yields in energy farms than short rotation trees (because of grasses' higher leaf index); grasses require as little as one tenth the time between initial planting and the first harvest that trees do (thereby reducing up-front capital outlays and minimizing losses in case of pest infestation); and grass farms are more easily converted to other crops or superior grass hybrids (because of the less tenacious root system). These advantages are partially offset by the higher bulk and poorer physical handling properties of herbage (relative to wood or charcoal), but a balanced treatment should include bioenergy from plant herbage.

Methanol Synthesis. The handbook should include systems for methanol synthesis using pyrolysis gasifiers (which minimize char and oil production). The potential for serial prefabrication of methanol plants (such as that being developed by International Harvester*) should be included.

Diesel Engines. Diesel engines retrofitted for fuel gas/diesel dual fuel use do not necessarily have to be derated. In fact, the diesel injection must be limited, as part of the retrofit, to prevent excessive power (and therefore engine wear) when the dual fuel engine is at full throttle. If the fuel gas is of reasonably consistent quality, then the diesel injection can be tailored to local peak power needs. Of course, this approach reduces the fraction of diesel fuel displaced.

Energy Primer. It may be useful to provide an energy primer in the Handbook. This primer should identify the major types of biomass suitable for energy: wood, grasses, and crop residues. It should also survey the end use energy needs: cooking, building heating, boiler fuel, process heat, stationary engines, transportation. By describing the constraints on fuel types imposed by various end uses, one can progress naturally to a consideration of appropriate conversion technologies to couple the biomass with the energy need.

Technology Development Primer. It may be useful to briefly describe the various stages involved in developing a technology: proof of concept, bench scale unit, process development unit, pioneer commercial scale process unit, and commercial unit. The various technologies should then be characterized

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according to their state of development, potential time frame for the availability of commercial units, and major risks in the development.

Generic Economics. Although economics are very site and country specific, some generic features of bioenergy economics would be helpful to guide the readers. Some areas that might be included are:

- Historical economic problems with wood hydrolysis (see OTA, "Energy from Biological Processes," Vol II, page 167-9).
- Gasifiers. Air blown gasifiers, because of their simplicity, tend to be the cheapest. Oxygen gasifiers may be the most complex (because of the oxygen plant), but pyrolysis gasifiers (that minimize char and oil production) are larger. Mass production of small units can reduce costs.
- Trade-offs between cost of densification or charcoal production and transport cost. (see OTA, "Energy from Biological Processes," Vol II, page 152 for one such analysis.)
- Optimum size of biomass conversion facilities (ibid, page 151 for some of the considerations).
- Economy of Scale. Some potential users of bioenergy cannot take advantage of a potential economy of scale, simply because they do not use a lot of energy (e.g., small industrial users) or fuel delivery infrastructures do not exist. This often improves the relative economics of bioenergy versus other options.
- Existing markets or cultural patterns. In some cases, the economics may be dominated by the presence of existing makets or cultural attitudes, rather than considerations of investment costs, energy efficiency, etc.

- Other. A careful consideration of other factors influencing economics in the developing countries could provide several useful insights for planners.

Biomass Resource Base. The Handbook should include a description of the general parameters which determine present and potential bioenergy production (e.g., grain crop yields, fertilization, rainfall, soil type, etc.). This could include tables of residue factors (tons of crop residue produced per ton of grain) for various crops and quantitative examples of biomass production under varying conditions. It should be emphasized that experimental crop yields are almost always higher than is obtained in practice. Realistic estimates of potential future crop yields and time scale for development could be estimated and procedures for estimating current resorces described.

U.S. Case Studies. The Handbook might include a few more case studies from the U.S. sugarcane bagasse use for electricity and steam in Hawaii, grass as a boiler fuel in Kentucky*, and applications in the forest products industry are some possible examples.

## Conclusion

Despite the number of comments, it was clear that a great deal of effort and thought has gone into the current draft of the Handbook. The overall structure is sound and the Bioenergy Index (pg. 10) is an excellent idea, which should be given continued attention as the Handbook is revised. The basis for a very useful document is there; and with the suggested changes it should serve its intended purpose well.

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## BIOENERGY SYSTEMS REPORT

The first issue of the quarterly "Bioenergy Systems Report," dealing with anaerobic digestion, was the final document reviewed for this evaluation. The presentation was concise and to the point, but some brief comments may serve as a guide for improving future issues.

The Report was mostly descriptive with no analysis of relevant issues. For example, why are digesters economically sound in developing countries but perhaps less so in developed countries? What are the prerequisites for success and where should one look for potential applications of the technology? This type of critical analysis can serve the important function of directing attention, at an early stage, in the "right" direction and thereby avoiding disappointments and misunderstandings.

Technical words, such as "mesophilic bacteria," crept into the text; and these terms may alienate some of your audience.

Other comments relate to omissions of various technical considerations (e.g., removal of $H_2S$ for cooking with metal stoves or pots), but perhaps go beyond the intended scope of the Report. In general this seems like a good medium to inform people about bioenergy and attract interest. Of particular importance to the latter goal was the mention of numerous current applications and projects using anaerobic digestion.

## PROJECT MANAGEMENT

As we noted in the introduction, the management of the BST project suffered during the first 18 months because of a lack of technically trained supervision and frequent changes in project management. This has been corrected, and the prospects are excellent for a rapid improvement in overall project management

The PASA arrangement with the Department of Agriculture is a flexible instrument for acquiring a team of technical specialists, and the evaluation team feels it makes sense to continue with this administrative mechanism. However, it is important that the Office of Energy exert greater direct and continuous management control over the work of the PASA team and participate actively in the selection of the members of that team and their selections of short-term consultants. Only in this way can the Office of Energy assure that the work of the PASA team responds directly to the needs of the Agency and its missions. To achieve this goal, it is also important that the office do its best to incorporate the PASA team members in the everyday activities of the Office so that they can more readily understand the way A.I.D. works and follow the nuances of current activities. There are a number of ways, many of them listed in the "recommendations" section, by which this can be accomplished.

An issue that arose several times in our review of the BST project is the appropriate division of labor between the Office of Energy and the Office of Forestry, Environment and Natural Resources. A clear resolution of the roles of the two offices in the provision of development assistance is important to the smooth working of the S&T Bureau. In the judgment of the evaluation team,

the division that exists now is an appropriate and efficient one, but it is a subtle one that is not clearly understood by many in the agency. Put simply, the Energy Office biomass project focuses on conversion technologies and biomass resources that are primarily (often exclusively) oriented toward the production of energy. This means that its interest extends to the production of biomass resources only when those involve what might be called "dedicated feedstocks," such as plantations of trees dedicated to charcoal production. In contrast, the FNR Office concerns itself with the management and production of trees in a broader multiple-use context. One of the conclusions of our review is that the agency currently does not have a project that adequately covers the promotion and provision of technical assistance, from the S&T Bureau, for multiple use management of forests, grasslands, and shrublands that includes fuel as a significant byproduct, and we strongly urge that the FNR Office move to fill this gap as quickly as possible. There is clear support for such an initiative in the regional bureaus. FNR and S&T/EY should coordinate their activities to help ensure that the energy product of multiple use management has a market and is considered in the BST project.

## RECOMMENDATIONS

A principal conclusion of this evaluation is that the Bioenergy Systems and Technology Project is basically sound and serves an important role in AID's assistance to developing countries. There are several areas, however, where a better definition of responsibilities or a modification of procedures could improve the efficiency of the operation, increase the chances of introducing viable bioenergy systems, and provide valuable information to AID field missions and host countries to assist in their planning.

### Reconnaissance

As outlined in the BST Project Paper, assistance to USAID field missions will occur in three stages: (1) reconnaissance to characterize more clearly the potential role of bioenergy in the host country and the nature of the field mission's request, (2) identification of appropriate bioenergy systems, and (3) preparation of a feasibility study and project plan. This appears to be a logical way to proceed and the evaluation team endorses this procedure.

The reconnaissance will clearly be a crucial step in choosing the bioenergy options best suited to the host country. Even in those cases where the field mission or host country has already decided which option they wish to pursue, every effort should be made to encourage interest in a thorough reconnaissance, in order to establish a context for later decisions.

As outlined in the Project Paper, the reconnaissance will consist of a review of the national energy needs and bioenergy resources, using this

information to determine the conversion technologies which may be appropriate. Again this appears to be the logical way to approach the problem. However, for the reconnaissance to be of greatest value, it should contain at least the following information:

- Energy Needs: quantities of charcoal, coal, wood, crop residues, grasses, biogas, residual fuel oil, distillate fuel oil and LPG, gasoline, and natural gas currently used for boiler fuel industrial process heat. building heating, cooking, transportation, and farming.
- Biomass Resources: present and potential production (under low and high management) of forest residues, crop residues, grass from pasture land and natural grasslands, energy crops, and animal manure. The quantities should be reported consistently as oven dry tons or energy equivalent or, in the case of manure and excrement, its biogas equivalent.

In most cases, some or much of this information will not be available and the reconnaissance team will not be able to conduct thorough surveys, within the budget and time frame of the reconnaissance. Therefore, default procedures should be carefully worked out to estimate these data in the absence of adequate information. The estimates should also be compared with the results of energy studies conducted by other organizations.

The biomass estimates should then be analyzed according to social, cultural, geographic (distance between resources and market), environmental, and institutional constraints, and competing uses to arrive at more realistic estimates of present and potential supplies of biomass that could be used for energy. This analysis should also provide a sense of the social and cultural issues involved and be placed in the context of the host country's national priorities and AID field mission's objectives.

With this analysis, appropriate conversion technologies can be selected for subsequent study. Care should be taken to insure that critical assumptions in the analysis are identified so that spot checks of these assumptions can be made in the next step of the assistance activities.

Finally, the reconnaissance report should include recommendations about follow-up schedules and specific decision points when identifying appropriate bioenergy systems (Step 2 of the assistance activities).

## Handbook and State-of-the-Art Reports

The handbook and related reports should be revised as described in the evaluation of project activities. Copies of the handbook and the better reports should be supplied to each bureau and mission as a reference library or for their files.

## Review and Technical Assistance

BST project should establish a technical review process to ensure that the technical information in its reports is consistent and of high quality. This could involve contracting a number of paid reviewers in each technical area, conducting workshops (with 3-6 experts) on specific subjects to review drafts or illuminate particularly difficult issues, and establishing a technical advisory panel.

## Management

In order to assure the smooth and efficient operation of the PASA mechanism in support of AID's policy objectives, it is important that the

Office of Energy exert greater direct and continuous management control over the day-to-day activities of the PASA bioenergy team. This is especially important as the Energy Office seeks to develop a coherent and structured framework for its program of assistance to the field. The physical separation of the PASA team from the Office of Energy makes this a more difficult task, but the evaluation team feels this is essential to the success of the redesigned project. It is also important that the Office of Energy participate directly in the selection of new members of the PASA team when the time comes for openings to be filled.

From our discussions with members of the PASA team and representatives of the regional bureaus, it is clear that the BST project would also benefit from a substantial increase in communication and cooperation between different parts of the AID administrative system. To begin with, it would be very helpful to members of the PASA team, for reasons mentioned earlier, to be involved in staff meetings of the Energy Office. Since that Office does not hold regular staff meetings, this would entail a change in current practice, but such a change would surely also benefit all that Office's work. Regular coordination meetings with the Office of Forestry, Environment and Natural Resources are also of critical importance as the activities of these two offices in the forestry and biomass fields grow in the future. And regular meetings with representatives of the Regional Bureaus to discuss the progress and implementation of the BST and FNR-forestry projects would also contribute to the successful management of those projects. Finally, the evaluation team feels that it would be very helpful to establish a coordinating council of Agency individuals with responsibilities and interests in the broad forestry/biomass area.

Field Visits

Teams sent to the missions should be clearly identified as AID teams first, with the home organizations of individual team members coming second. This will serve to ensure that AID is given credit for the assistance it supplies and facilitate follow-up communication between BST and host country recipients of the assistance. Wherever possible, an AID employee should also accompany the field team to the host countries to 1) help ensure that AID's objectives are fulfilled & the visits proceed smoothly, 2) provide continuity to a series of field visits and personal contacts between BST management and the recipients of BST aid, and 3) help BST evaluate the visits and implement procedural changes where needed.

Communication

Communication between the Energy Office project manager and field officers working with members of the PASA team or consultants of the Project should, in general, be more extensive after a field consultancy has taken place. In many cases a simple phone call will serve the purpose, preventing the kind of poor information flow that characterized the experience with the Dominican Republic.

Implementation Review

The evaluation team heartily endorses the plan, contained in the project Paper, to conduct an annual implementation review with representatives of the Regional bureaus in attendance.

Coordination With Non-AID Donors

BST project should contact various non-AID donors (e.g., EEC, IDRC, IDB, SATA, IFAD, GTZ, ADB, ODA, SIDA, CIDA, FAI, IBRD, EDF, IICA, etc.) to find out about their activities in bioenergy development and to make them aware of AID's efforts and resources. This would be a useful first step towards possible cooperation or collaboration and avoidance of duplication.

## APPENDIX A

### Detailed Review of "Bioenergy Conversion Handbook"

- Tables I and III should include methanol from lignocellulosic materials (grass, crop residue, wood).

- Table III should include grass and gasoline.

- The handbook should include an overview of why anyone would want to use bioenergy and where it can fit into the total energy picture.

- Bioenergy Fuel Substitution Index:

  - Methanol and ethanol should be included as direct and indirect substitutes in all cases.

  - Low energy gas is usually less than 150 BTU/SCF. You should distinguish this from medium energy gas (about 300 BTU/SCF) because of the efficiency and derating implications with retrofits of boilers.

  - If low heat value gas is a substitute for diesel, so are methanol and ethanol.

  - This index is a very good idea and a lot of effort should be put into perfecting it.

Part A

A rationale for ordering of the technologies and where each may be appropriate should be in the introduction.

Page A-5, col. 1, para 2. The question of whether cellulosic feedstocks can be efficiently (and economicaly) converted to biogas is still very much up in the air. These biogas pretreatments are essentially the same as pretreatments for ethanol fermentation; and they have significant barriers to development.

Page A-6. Sludge is not literally a "fertilizer". Its a "soil conditioner," which is lower grade than what can be sold in the U.S. as a fertilizer.

Page A-7. Are these moisture contents percentages of dry or wet weight?

Page A-7. A figure showing boiler efficiency as function of excess air and of moisture content of feed would be useful.

Page A-8, col 2, para 2. Are you sure you want to use the term "limited scale" here? Direct combustion for steam and shaft power is very practical to a large extent in the forest product industries most everywhere.

Page A-9, col 1, para 3, line 7. Silica also causes extensive wear in boilers and gasifiers due to abrasion.

Page A-9, col 2, line 6. Don't use 3 significant digits (23,700 kg/hr). Try 25,000 kg/hr.

Page A-10, col 1, para 1. Amen!

Page A-10, col 2. "For Cooking" is a good section.

Page A-12, col 1, last para. "Liquid fraction" of a gas??? Also, you are talking about really slow and primitive gasification.

Page A-14, col 1, para 1. Also other hydrocarbons depending on the situation.

Page A-15, col 1, line 4. Biomass is finely granulated in some cases (e.g. saw dust). Mention that $O_2$ blown gasifiers have added expense of $O_2$ plant--therefore pyrolysis gasification may be cheaper.

Page A-16, col 1, par 3 and 4. What about pyrolysis gasifiers other than dual fluidized bed (which, incidentally, is no more than a concept, I believe--no hardware exists).

Page A-17, col 1, para 2. "More than 160 km" should replace "less than 161 km.

Page A-18. Mention importance of high pressure pyrolysis gasifier for methanol synthesis (i.e., the gasifier is essentially self pressurizing and, because the synthesis gas is already under pressure, only one compressor stage is needed for the ICI methanol synthesis).

Page A-20, col 1, para 3. Wright - Malta says 50% moisture feedstock is best (i.e. 100% moisture by dry weight).

Page A-23, col 1, para 2. This is wrong. There are pyrolysis gasifiers that produce only synthesis gas, (or methanol), $CO_2$, $H_2O$ and ash.

Page A-23, col 1-2. What is "large scale" and why do pyrolysis gasifiers have to be large scale?

Page A-23, col 2, last para. Not Wright-Malta.

Page A-24, col 1, para 3, line 2. Here medium BTU gas cannot be economically transported, but on page A-17, col 1, para 2, line 4 it could.

My copy has no pg. A-27.

Page A-32, col 1, para 1, line 4. There are also low temperature, low pressure acid hydrolysis processes. You should mention the concentrated acid hydrolysis and why its not likely to be economic.

Page A-32, col 2. There are high pressure, low temperature, dilute acid hydrolysis processes. (E.g., HF hydrolysis).

Page A-39, col 1, line 4. Should read "if successfully developed," rather than "when developed."

Page A-39, col 2, top. This is also geared to reducing or eliminating the consumption of expensive chemicals and energy intensive pretreatments.

Page B-1, f.f. Mobil M - gasoline should be "Mobil methanol to gasoline" or "Mobil MTG," according to Mobil.

Page B-6, col 2, para 2, line 7. Delete the reference to H/C ratio since phenol, toluene, and benzene all have low H/C ratios and are excellent gasoline blending stocks. This business about H/C ratio is a gross oversimplification of the properties that make a fuel high quality. For example, refinery reforming processes used to upgrade middle distillates to high octane gasoline always reduce the H/C ratio.

- You should also mention the reduced $NO_x$ emissions with methanol, since you mention high $NO_x$ with medium BTU gas.

Page B-7, col 1. Another problem with biomass derived gaseous fuels used in gas turbines is the potential presence of alkali metals which corrode turbine blades.

Page B-9, col 1, para 3, line 7. Gasohol can and has led to failure of some plastics, corrosion of fuel tanks, etc. This was not a problem in Brazil because ethanol has been mixed in gasoline there for decades, so all cars there have traditionally had alcohol resistant parts and servicing likewise uses alcohol resistant replacement parts.

Page B-9, col 1, para 4. Methanol in gasoline is no more toxic than ethanol in gasoline, because in both cases the gasoline itself is the dominant toxic agent.

Page B-9, col 2, top. Gas from a gasifier has to be cooled before used in an engine.

Page B-9, col 2, bottom. To prevent excessive wear, the diesel injection must be limited because most diesels are speed governed (i.e., diesel input and biomass gas could produce too high power for the engine design). Also there is no need for derating a diesel unless you go to almost all non-diesel fuel--with dual fuel, extra diesel can be injected when peak power is needed.

Page B-9. Mention that efficiency of engines designed for methanol is at least 20% above corresponding gasoline engines.

Page B-12, col 1, para 2. Also can use pyrolysis gasification.

Page B-12, col 2, para 1. I believe International Harvester is developing a small (1/10 the scale mentioned) serial produced (prefabricated) biomass-to-methanol plant.

Page B-14, col 1, para 2. I think 1000 B/D is too conservative. Many paper pulping mills have wood inputs an order of magnitude larger than this and I think methanol plants could be at least 3,500 B/D. As you know, however, this is very site specific and generalization is hard.

Page C-201. Some analysis of existing U.S. uses of biomass energy could be useful--e.g., forest products industry, Hawaiian use of bagasse for steam and electricity, etc.

Page C-202. There are several other feasibility studies realted to the Burlington project. Contact T.B. at his office for these.

Page C-203, para 2, col 1. Not just rough and rotten wood, but also brush and thinning residues.

Comment: Some wood fueled electric generation is cheaper for Burlington than coal fired generation because (1) Burlington is a small utility and therefore cannot take advantage of potential economies of scale and (2) a coal delivery infrastructure does not exist in the area. Both could apply in developing countries.

Page C-203, col 2, "4 Related Papers. . ." There are several related papers by Chuck Hewett.

Page C-405. This project appears to be using a pyrolysis gasifier.

Page C-504, col 1, top. This is true only if the pyrolysis produces char and oil as well as a fuel gas.

Page C-702. There's a newer Emert report: "G.H. Emert and R. Katzen, "Chemicals from Biomass by Improved Enzyme Technology," presented in the symposium Biomass as a Non-Fuel Source, sponsored by the ACS/CSJ Joint Chemical Congress, Honolulu, Hawaii, April 1-6, 1980.

Page C-703, col 2, para 2, last line. Emert says there are enough such sites in the U.S. for about 3 billion gal. ethanol/yr. I don't think he'll get his feedstock as cheaply as he says or be able to sell the byproduct, however. (See OTA, "Energy from Biological Processes," Vol. II, pg. 169-170).

Page C-804. The energy used for distillation is only 1/3 of the total energy used in a typical corn to ethanol plant and an even smaller fraction in a sugarcane to ethanol plant. Therefore, this potential gain is rather insignificant (i.e., less than 15% reduction in energy consumption).

Page C-805, col 1, last para. I don't understand the logic.

Comment: Nowhere in the discussion of ethanol synthesis is there mention of the need for an analytical chemical laboratory to monitor fermentation in order to get consistently high ethanol yields.

Page D-4, D-5. Needs the following sections: commercial, industrial (steam), industrial (process heat). Needs following fuels: distillate fuel oil (rather than diesel), "other" stationary uses of petroleum (e.g. asphalt, still gas, petrochemical feedstock), and "other transportation fuels."

Page D-6, D-7. Needs:

Grasses from

- -Cropland pasture
- -Cropland haylands
- -Non-cropland pasture

Also needs some data for potential production with existing plant types but alternative management schemes (e.g. fertilizing grasses, thinning forests to maximize commercial timber production, etc.)

## APPENDIX B

### Selected Review Comments On State-of-the-Art Reports

1. Direct Combustion Systems to Produce Power From Biomass From Wood, Forest and Agricultural Crop Residue and Appendices. Nor'West Pacific Corporation, Contract No. 53-319R-0-135.

Author goes beyond his expertise when discussing drying of crop residues (OTA, "Energy from Biological Processes," Vol II, page 68). Otherwise fairly good.

2. Retrofitting Combustion Systems to Burn Biomass Derived Fuels (Solid, Liquid, and Gas). Anil K. Chatterjee, Contract No. 53-319R-0-216.

Page 31-32. His physical chemistry is wrong when calculating flue gas volumes. In fact a 220 BTU/SCF gas can have about the same amount of flue gas as with natural gas (See OTA, "Energy from Biological Processes," Vol. II, page 137, Figure 23 and T. B. Reed, et. al., "Technology and Economics of Close Coupled Gasifiers for Retrofitting Gas/Oil Combustion Units to Biomass Feedstocks," in "Retrofit '75, Proceedings of a Workshop on Air Gasification," SERI, Seattle, Wash., Feb. 2, 1979). The author apparently has ignored reactions of the type $2CO + O_2 = 2CO_2$ and $2H_2 + O_2 = 2H_2O$, in which the gas volume of the products is less than that of the reactants.

Page 35. Derating is not necessary if the gas has 200 BTU/SCF, but this requires good gasifiers.

Page 35. Author ignores pyrolysis gasifiers. It seems that more emphasis should be placed on retrofitting oil using boilers rather than natural gas burning ones, although the considerations are similar.

3. Direct Combustion Systems with Biomass Char-Oil Mixtures. Anil K. Chatterjee, Contract No. 53-319R-0-127. Apparently good, although it is beyond my expertise.

4. Assessment of Large Scale Biomass Gasification Systems for Less Developed Countries. Battelle Pacific Northwest Laboratories, E. G. Baker, D. H. Mitchell, and J. F. Williford. Contract No. 231-110-04-272.

Page 31. The author misses the point on air blown gasifiers: i.e., the need to get 200 BTU/SCF and the lack of gasifiers of this type.

Page 33-38. Note all of the pyrolysis gasifiers being developed. (See also OTA, "Energy from Biological Processes," Vol II, page 154-55.)

Page 52. Possible extra wear on dual fueled diesel engine not mentioned.

Page 55. I would expect more energy to be lost during "gas cleanup" because the gas also must be cooled and a sizable fraction of the gas energy is sensible heat (See OTA, biomass Vol II., page 139, text and ref. 26.)

Page 57. I would say the costs are about $1/MMBTU too low (wood at $20/ODT) because of over optimistic assumptions about efficiency. Underestimation would be larger for higher wood costs.

Otherwise economics look reasonable.

Page vi. Executive summary needs cost of industrial financing for ammonia synthesis.

5. Small Scale (to 50 KW) Gas Producer - Engine System. A. Kaupp, J. R. Goss, University of California - Davis. Contract No. 53-319R-0-141.

Very good sobering report! This is a good source for someone considering conversion of engines to gasifiers.

6. Methane Fermentation of Biomass. Olympic Associates Company, Kurt Vause, Sandra Woods, and Dr. Rolf Skrinde. Contract No. 53-319R-0-124.

Part I - Narrative. Volumes I and II.

Part II - Resource Personnel

Part III - Manufacturers.

Part IV - Abstracts.

Page 46. Assumption of 10%/yr rise in fuel costs is highly questionable.

- Voluminous.
- I believe economics are unrealistic.

Vol 1, page 13. The estimate for energy from manure in the U.S. is an order of magnitude too high for cattle.

- Ditto for crop residues. The author apparently did not consider collectable residues (see OTA, Biomass, Vol II, page 67-9).

7. Ethanol From Sugar Crops: A Critical Review. Battelle Columbus Laboratories, E. S. Lipinsky, B. R. Allen, A. Bose, and S. Kresovich, Contract No. 53-319R-0-233

Good, but a general lack of sophistiction on future crop yields (See OTA, Biomass, Vol II., page 51-54 and page 91-95).

The capital investment and capital charges for a sugarcane to ethanol plant are too low, if sugarcane is available only part of the year (See OTA, Biomass, page 164-66).

8. Status of Wood Hydrolysis for Ethanol Production. FPL, Andrew J. Baker, Thomas W. Jeffries. Authorization No. 81-89

- Does not mention high pressure HF hydrolysis.

- Advantages and disadvantages treated fairly, but economics ignored (See OTA, Biomass, page 167-173).

Note also that the report includes concentrated acid hydrolysis, which was omitted from the "Handbook".

- No real analysis of the weak points of the processes is given (See OTA, Biomass, Vol. II, page 167-173).

- They tout the Madison process, but the ethanol yields (35 gal/ton) are too low to be economic except under extremely specialized circumstances.

- Otherwise very good report.

9. Production of Methanol and Its Derivatives from Biomass. Anil K. Chatterjee, Contract No. 53-319R-1-216.

Considers Mobil MTG and China Lake process, but not Fischer Tropsch. This shows bad judgement.

Does not include pyrolysis gasifier.

Does not include moving bed or entrained flow gasifiers.

The cost estimate for methanol looks about right for an $O_2$ blown system, but may be high for advanced pyrolysis gasifier systems (both because

of the lack of $O_2$ equipment and the higher yields--up to 180 gal methanol/ton of wood feedstock).

10. Pyrolysis of Wood and Agricultural Biomass. Anil K. Chatterjee, Contract No. 53-319R-0-206

Page 4, para 2, line 4. I don't think the vertical shaft pyrolyizer is necessarily best.

- The principal conclusion favoring pyrolysis to produce charcoal and pyrolytic oil is, I believe, incorrect. Charcoal production is inefficient and numerous corrosion and stability problems exist with the oil (including gum formation and acids and salts in the oil).

- Generally ignores complete gasification of feedstocks.

Page 41. In general process description, he ignores pyrolysis gasifiers designed for wet feedstock, (e.g., Wright-Malta).

Page 59 - The Bailie process is only conceptual. I don't believe any hardware exists.

Note: I must again emphasize what poor quality fuel 150 BTU/SCF gas is.

Page 70, para 2. One of the major problems was the use of MSW as a feed.

11. Biomass Fueled Heat Engines. Meta Systems, Inc., Contract No. 53-319R-0-136

Fair report. The point on "self energizing" is valid, but poorly and obscurely presented.

12. Designing Rural Cookstoves. John H. Arnold, Jr., Contract No. 53-319R-0-129

Page 25 - Agricultural residues and grasses have about 20% less energy per lb. than wood.

Page 46-51. "Stove Design Techniques"--the crucial section in the report--gives good general advice, but little specific advice. This needs a more carefully thought out technical procedure. The report states that "a general model of heat transfer. . .cannot be developed . . . but they could indicate which changes might improve performance. . ." It is just such a model--a theory to guide investigation and prediction--that could be extremely important.

The author should not discount "breakthroughs" (e.g., a doubling of efficiency) when efficiencies are so low.

Everyone says there is a need for more "thorough stove design efforts. . ." (pg. 6). Developing countries are often deficient in theory. This may be an important area where the U.S. could help.

13. Report on Rural Industries. John H. Arnold, Jr., Contract No. 53-319R-0-129

Page 134. This is exactly the point: low capital = low economic entry barrier = intensive competition = low profit, even if it is an expanding market.

Page 143. The major problem is not the "requirment. . .for experienced technical people. . ." but rather the primary need is for capital--with technical people providing the guidance to produce what is needed.

Generally very good report.

14. Executive Summary. Rural Industries and Rural Cookstoves. John H. Arnold, Jr., Contract No. 53-319R-0-129

This is okay.