X D-AAW-545-A
52684

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
AID/M/SER/OS/ANE

GOVERNMENT OF INDIA

ALTERNATIVE ENERGY RESOURCES DEVELOPMENT PROJECT
(MID-TERM EVALUATION AND FOLLOW-ON)
PROJECT NO. 386-0474

Submitted by

M.D. SCHLESINGER
JEAN-FRANCOIS HENRY

ENERGY/DEVELOPMENT INTERNATIONAL
1015 18th Street, N.W.
Suite 802
Washington, D.C. 20036

e/di
ENERGY / DEVELOPMENT INTERNATIONAL

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
AID/M/SER/OS/ANE

GOVERNMENT OF INDIA

ALTERNATIVE ENERGY RESOURCES DEVELOPMENT PROJECT
(MID-TERM EVALUATION AND FOLLOW-ON)
PROJECT NO. 386-0474

Submitted by

M.D. SCHLESINGER
JEAN-FRANCOIS HENRY

ENERGY/DEVELOPMENT INTERNATIONAL
1015 18th Street, N.W.
Suite 802
Washington, D.C. 20036

TABLE OF CONTENTS

Page

EVALUATION ABSTRACT

The Alternative Energy Resources Project is a collaborative effort between the U.S. Agency for International Development and the Government of India. Four main components of the project included Biomass Production, Biomass and Coal Conversion, Energy Efficiency and Information Exchange. Ultimate goals are to reduce Indian dependence on imported oil, to reduce deforestation and to increase energy efficiency in industry and transportation. Many of the goals were met but most of the more promising ones require continuing support.

Coal Research and Development

The most advanced projects concern the fluidized bed combustion of high ash coals and the removal of fly ash while the gas is still hot and under pressure. This clean gas is then ready for conversion to electricity or used for process steam generation. Design and operability of the hot gas clean-up system will be of value to fabricators of these specialized vessels. Feeding coal in the form of a water slurry is also part of this six part coal development program. Most of the program will continue with or without USAID support.

Biomass/Efficiency/Information Projects

Small gasifiers and film solar collector projects achieved technical objectives and appear ready for commercialization under other AID initiatives. Demonstration of 100 KW gasifier to be initiated soon; recommendations made to enhance usefulness of project. Energy modeling project provides useful tool for energy policy analysis. Low-head hydro project seriously lagging: immediate action required. Thin film solar materials project ongoing; dissemination should be initiated. Focus of Energy Efficiency project not quite appropriate. Biomass production project initiated recently.

Lessons

- Role and objectives of technologies investigated should be clearly defined.
- Close monitoring of projects needed.
- Dissemination/interaction with private sector should be expanded.
- Coordinate field activity with institutional needs.

SUMMARY OF EVALUATION FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Purpose of Activities Evaluated

The Alternative Energy Resources Development (AERD) project is a collaborative effort between the U.S. Agency for International Development (USAID) and the government of India (GOI) through its Department of Non-Conventional Energy Sources (DNES). The project includes four components: biomass production, biomass and coal conversion, energy efficiency and information exchange.

The ultimate goals of the project were to reduce India's dependence on imported oil, to reduce deforestation, and to increase industrial efficiency.

Purpose of the Evaluation and Methodology Used

Several projects were established under a 1982 proposal and most were initiated during the next three years. The program ended officially in mid-1986 but was extended until 1988 for various reasons such as the late arrival of equipment or late start. A technical review is specified in the proposal and the submitted draft report of 30 January 1987 fulfills that requirement. Each project was visited and a series of questions was asked of each principal investigator and his staff. Basically, the responses revealed a proper selection of criteria and objectives, some constraints, the level of management and the degree of completion. Seeing the physical state of the projects and combining that with the discussion, provided the team with a sense of commercial potential or the need for further research.

Findings and Conclusions

Coal Conversion - Research and Development

Only one project is nearing commercial application, the fluidized bed combustion system. The approved design of the 30 MWe AFBC represents the next step in the development sequence. Smaller sizes, up to about 15 MWe, are already used commercially. Near term developments are the pressurized combustion unit and the solids recycle system where improved combustion is expected. Another near term system is the operation of a high temperature/high pressure vessel for the removal of particulate matter from a product gas stream.

The other projects in this overall coal utilization program are of long range or academic interest -- dense media cyclones, the preparation of coal-water mixtures and cold gas clean-up. These might be considered under a technology development program both as a research project or an incubator for new ideas.

Biomass Production, Biomass Conversion, Energy Efficiency and Information Exchange

The biomass production project was designed to provide the research and development (R&D) support for the implementation of reforestation projects by reinforcing the R&D capabilities of two biomass centers, the National Botanical Research Institute (NBRI) and the Madurai-Kamraj University/Bharathidasan University (MKU/BU). As the scope of work was developed, the objectives of the project evolved from their original intent to short-term, field oriented, support for reforestation to longer term, academically oriented, basic research on species selection, plant stress, and others. The project was finally initiated in early 1987, with the current emphasis on fundamental research, it is feared that the on-going reforestation projects will not benefit much from the planned research activities.

The biomass conversion component included three subprojects dealing with the design, contruction and field testing of small (5 HP about) gasifier -- engine-pump sets aimed at replacing diesel operated units providing irrigation. The projects were completed on schedule and have achieved their technical objectives. The economic analyses conducted as part of the projects are preliminary; the availability of diesel fuel and electricity at subsidized prices and the scarceness and cost of biomass fuels suggest that, in the present economic context, this technology will not be competitive for the application considered. If these economic issues can be resolved, the technology could be commercialized; several manufacturers are, or could be, interested in commercializing small gasifiers.

The energy efficiency component was designed to promote various aspects of energy efficiency in industry through interactive workshops and visits involving representatives from Indian and U.S. industries. The project is on schedule and will be concluded in the near future. The project has been successful in establishing contacts between Indian and U.S. industries involved in energy management. It is, however, felt that the U.S. experience in providing complete energy efficiency services by specialized companies and its potential translation in the Indian energy/economic context has not been explored sufficiently.

The information exchange component included a variety of projects. Two subprojects dealt with the construction and testing of thin-film solar collectors based on the Brookhaven National Laboratories (BNL) concept. Potentially, this concept could result in higher performance and lower cost for flat plate solar collectors. These projects are on schedule and have, so far, achieved their technical objectives. The projects however lack a clear view of the market it will or could address; marketing studies and dissemination efforts, which were part of the scope of work have been disappointing. Although current tests are encouraging, the technology is not quite ready for commercialization.

The low head hydro project included two subprojects: the testing of a U.S. made turbine in parallel with some other turbines and the design, construction and testing of a load management controller. The turbine testing project is behind schedule but installation of the U.S. made turbine is planned for the next six months or so. If successful, this project should open the way to generating an appreciable amount of electricity from irrigation canals across the country. The load management controller project is way behind schedule, having been plagued by a variety of administrative, organizational and technical problems. The approach is conceptually attractive but raises questions regarding its economic and practical feasibility.

The 100 KW gasifier project is a worthwhile project aiming at evaluating the potential of gasification as a source of captive power for regional industries. Initiation of the project has unfortunately been delayed for several years; indications are that final approval for start-up may be received shortly.

The energy modeling project was completed on time and has provided a useful tool for energy policy analysis. Once the data base has been updated to 1985-86, it is hoped that the model will be used to evaluate the economic implications of various strategies for the use of non-conventional sources of energy.

Several projects have suffered from administrative, organizational, monitoring, dissemination and customs-related problems. There is an urgent need for improving these aspects in order to make projects more effective.

Recommendations

Coal Conversion Projects

When considering near term commercialization, only one coal project can qualify -- the Atmospheric Pressure Fludized Bed Combustion system. The USAID part of this project was to study the reactions that take place in the freespace above the fluidized bed. USAID will be well advised to maintain close contact with this project as well as with its pressurized version.

The next two projects that will be advantageous to U.S. technology are the Injection Variations and Combustion of Coal-Water-Mixtures and the High Temperature/High Pressure Gas Clean-up System now under construction. About three to five years will be needed to prove the commercial advantage.

Other components of this project are of long-term and academic interest.

Biomass Production, Biomass Conversion, Energy Efficiency and Information Exchange

The small gasifier, thin film solar collector, energy modeling and energy efficiency projects are, or will be shortly completed. No further support is needed to complete these projects.

The small gasifier and thin film solar collector projects are in serious need of systems/market (techno-economic) analyses to define their most promising applications within the Indian energy context.

The energy modeling software developed by TERI is currently being updated to the years 1985-86 without further funding from USAID. Once this upgrading has been accomplished, it is strongly recommended that DNES make full use of this software model to analyze and assess the economic implications of various renewable energy strategies.

It is recommended that an energy conservation project be undertaken through an Indian institution with the support of a U.S. contractor to explore practical approaches to conservation within India's context.

Recommendations for the 100 KW demonstration gasifier project include: implementation of energy conservation in the industries considered, involvement of the U.S. manufacturer of the gasifier and collection and analysis of complete operational data.

The low-head hydro project has been seriously lagging; immediate action is required to bring the project on track. A 15 month, no cost or minimal cost, extension should be considered provided a realistic and enforceable schedule is agreed upon by all interested parties.

General

DNES and USAID:

Although both organizations are obviously dedicated to make their joint projects successful and good personal relationships have been established between individuals in both organizations, there is a need for:

- Better coordination of the monitoring of projects: agreed upon schedules, chart of scheduled accomplishments or deliverables (PERT charts), periodic (regular) reviews, follow-up action by both parties,
- Better definition of the objectives of the individual projects undertaken: techno-economic analyses including sensitivity analyses, as well as resource and social aspects, of the impact of the projects should be used to evaluate and initiate projects,
- Simplification of customs formalities for importing equipment needed for projects,
- Improvement of dissemination efforts, and
- Improve the effectiveness of the process of project approval and initiation.

Lessons Learned

For multimillion dollar projects, it is desirable to have someone in-country who can follow the progress of the work.

It is also reasurring to all concerned that their work is important and that someone cares. Another important focal point is an individual who can coordinate contact between the field teams and the Government of India and the USAID bureaucracies, not an easy job.

There is probably equipment in the field where personnel are not fully trained to operate or the equipment has only limited application. A pre-purchase screening is needed by someone who understands the project requirements.

Some specific points include:

- Role and objectives of technologies should be clearly defined.

- Close monitoring of projects is needed.
- Dissemination/interaction with private sector should be expanded.
- Coordinate field activities with the institutional context.

ACKNOWLEDGEMENTS

The review team owes its success to many people at USAID*, DNES** and Indian personnel in the field. At USAID, the briefings by the U.S. personnel were vital but the day-by-day guidance provided by Mr. Padmanabhan was extraordinary. My (M.D. Schlesiger) counterpart for travels within India was V. Raghuraman, of the National Productivity Council, surely one of the most knowledgeable men in India. He was known everywhere and had a broad grasp of India's status. R&D personnel in the field, from Dhanbad to Trichy, were most cooperative and forthcoming with information and frank discussions. It was all much appreciated and made our evaluation possible.

Several counterparts provided much appreciated help during my (J.F. Henry) visits and field trips: Dr. J. Gururaja (DNES), Prof. H.S. Mukunda (IIS), V. Raghuraman (NPC), Prof. K.S. Rao (GEDA), and Dr. D. Das (AHEC). The research and technical personnel at all institutions and sites visited were most helpful, cooperative and frank in our discussions. Their contribution to this evaluation effort is gratefully acknowledged.

---

* Owen Cylke
Thomas J. Nicastro
Peter W. Amato
Jadvinder Kaur

** J. Gururaja
J.R. Meena

1.0 INTRODUCTION

In 1982 a project was proposed to expand India's technical capacity to exploit its alternative energy resources and to develop selected technologies to a stage of application. Several collaborative subprojects were developed to transfer relevant technical knowledge to alternative energy development. The goals were to:

- Reduce Indian dependence on oil imports.
- Reduce deforestation.
- Increase energy efficiencies in the transportation and industrial sectors.

These broad goals were approached in the following technical areas:

- Biomass production and conversion.
- Coal conversion.
- Energy efficiency in industry and transportation.
- Information exchange.

India has a growing need for fuel supplies and food as its population increases and poverty reduction is realized. The Government of India places a high priority on these goals and has committed substantial funding to their implementation. Both private and public sector organizations will be involved with the ultimate goal of commercializing viable technologies.

This report traces some of the background of the project and is an evaluation of its progress. Specifically, the authors look at the original objectives of the alternative energy resources projects, discuss the accomplishments and assess the need for future work and possible follow-on financing by USAID.

Review of the sub-projects keeps in view some important related attributes that go beyond technical accomplishments. For example,

- Were there constraints that may have inhibited the attainment of objectives?
- The success of institution building efforts.
- United States private sector involvement.

- Technology transfer from U.S. organizations and the effectiveness of study tours.
- Future collaborative ties with U.S. counterparts.

The Government of India identified areas for joint aid with the U.S. Agency for International Development for the utilization of coal and biomass. Focus was primarily on advanced and efficient technologies, six on coal conversion and three on biomass.

Coal Conversion Projects

1. Evaluation of the Freeboard Performance in a Fluidized Bed Combustor
2. Scale-up of AFBC Boilers
3. Coal-Water Slurries
4. Coal Preparation
5 Hot Gas Clean-up
6. Cold Gas Clean-up

Biomass Conversion Projects

1. Development of a Village-level Gasifier Utilizing Charred Agricultural Residue
2. Utilization of Producer Gas in Small Engines (3-5 HP)
3. Development and Field Implementation of Wood Based, Gasifier/Engine Systems (5-30HP)

Other areas of concern, more broadly related to the above, involved biomass production (how much is available for substitution), energy efficiency (reduce waste) and information exchange (introduce the latest technology for adaptation by industry).

The role of the United States was to provide technical assistance, train Indian engineers in the U.S. and equip the cooperating laboratories with state-of-the-art instruments. To accomplish the above goals, several engineers visited the United States to gain first-hand experience in the operation and maintenance of the equipment they will receive. These professionals also participated in meetings concerning equipment design and with experts in their field of interest. Other sources of needed information came from technical society conferences and, of course, personal contacts with whom correspondence will doubtless continue. Beside the U.S. laboratories, visiting engineers spent time with vendors who are providing equipment for development purposes. In the future, these companies may also provide full scale plants.

Initial budgets for the present cooperative program amounted to $1,118,200 for coal and $705,800 for biomass. Proposals have already been prepared for selected projects that may be continued under the present program.

2.0 BACKGROUND

2.1 Project Development

India has extensive reserves of coal and limited reserves of oil, gas and hydropower. Coal reserves are estimated to be 85 billion tons. At the current production rate of 114 million tons per year and a projected 1990 estimate of 260 million tons per year, these reserves should last about 75 years. This limited time period could be extended through more efficient utilization methods of the resource from mine to the busbar to the consumer.

Current Indian production reported in Oil and Gas Journal is 630,000 bpd and 700 million cfd for oil and gas respectively. A large fraction of the natural gas goes to fertilizer production, ammonia and urea, and new plants are under construction. To sustain its goals of economic development, the Government of India (GOI) must purchase about 2 million tons of crude oil a year, the cost of which consumes a significant portion of India's export income. Like many other countries, India is searching for indigenous resources that might replace the costly imports, albeit in a less convenient form.

Although commercial forms of energy -- coal, oil, gas, hydroelectric power -- play the major role in providing India's energy needs, non-commercial forms of energy -- fuelwood, agricultural and animal wastes -- still constitute the primary fuel for the cooking and heating needs of many urban and rural households. This situation has resulted in severe deforestation and the diversion of agricultural and animal wastes from their traditional function of fertilizer and soil amendment agent, thereby increasing the dependence on fossil fuel imports.

Over the years, the GOI has initiated and supported a number of programs aimed at decreasing the dependence on imported oil through the development of alternative energy sources -- solar, coal and biomass. A large fraction of India's proven coal reserves contains 30 to 50% ash. Conventional power plants find difficulty with these coals due to wear, erosion and flame stability. Recent combustion technology, such as fluidized-bed combustion, has the potential of using these low calorific value coals with fewer problems. In the long term, fossil fuels will be replaced by other resources, the principal candidate being biomass. For biomass to fill this role, a sustained program of resources management and reforestation is necessary to stop deforestation in the near term and insure sufficient renewable resources in the long term through the use of rapid growing species.

In 1983, a cooperative effort -- The Alternative Energy Resources Development Project -- between the Government of

India and the United States was approved. The overall objective of the project was to expand India's capability of exploiting its energy resources to a stage of application. Over a three year period, from about mid-1983 to about mid-1986, several collaborative projects were to be developed to reduce India's dependence on oil imports, to reduce the rate of deforestation and to increase efficiency in the transport and industrial sectors. Through meetings between technical experts from both countries, projects were selected and means through which a mutual transfer of knowledge could take place, were adopted. The project has now been in existence for about three years and significant achievements have been recorded.

In the original proposal, an independent evaluation is called for. The present report describes the conclusions reached by the evaluation team and provides some suggestions regarding further activities.

2.2 Components and Subprojects

To achieve the goals of the Alternative Energy Resources Development (AERD) Project, several collaborative subprojects designed to transfer technical knowledge in the field of alternative energy development were conducted in four technical areas.

The four components, or technical areas, selected for the AERD project are: biomass production, biomass and coal conversion, energy efficiency, and information exchange. The four components, their subprojects and participants are briefly reviewed below. Table 2.1 summarizes the characteristics of the various components and subprojects.

2.2.1 Biomass Production

Biomass production is a crucial element in India's energy future. In the short term, it is imperative that measures be taken to stop deforestation and to provide sufficient quantities of woody biomass to support the needs of the rural and urban users of this nonconventional resource, while, in the long term, it is essential that sufficient wood biomass be available to substitute for and reduce the need for imported fossil fuels. The GOI has recognized the key role of woody biomass in the country's energy future and has established two biomass research centers, one at the National Botanical Research Institute (NBRI) in Lucknow and the other at Madurai-Kamraj University (MKU) in Madurai, with the objective of promoting result-oriented development work and of

Table 2.1. Summary Description of the Alternative Energy Development Project.

COMPONENTS:	Biomass Production	Biomass/Coal Conversion		Energy Efficiency	Information Exchange
SUBPROJECTS:		Biomass	Coal		
	1. Production of wood biomass on sub-standard soils	1. Gasifier using charred residues.	1. Freeboard performance	1. Efficiency in industry	1. Field Test of polymer film solar collector
	2. R&D studies of woody biomass species on arid marginal lands; lab/plantation approach	2. Producer gas in small engines	2. Scale-up of AFBC boilers		2. Energy modelling
		3. Wood-based gasifier/engine	3. Hot gas clean-up		3. Low-head hybrid micro-hydel system
			4. Cold gas clean-up		4. 100KW biogasification system
			5. Coal/water slurry		5. Thin film technology
			6. Coal beneficiation		
PARTICIPANTS:	1. NBRI (India) 2. MKU/BU (India) WI (US)	1. IIT (India) 2. IIT (India) 3. JSEI (India) PETC (US)	1. BHEL (India) 2. BHEL (India) 3. BHEL (India) 4. RRL (India) 5. CFRI (India) 6. CFRI (India) PETC (US)	AIEI (now CEI-India) NAS (US)	1. STEC (India) 2. TERI (India) 3. AHEC (India) 4. GEDA (India) 5. STEC (India) 1/2/5. BNL (US) 3/4. BU (US)
FUNDING: *	2.3	0.9	2.5	0.7	0.6
TIME FRAME:	1987-1989	Apr. 84-End 86	1983-1986	Sep. 84-Mid 87	1986-1988

* Funding: Approximate - Millions of U.S. dollars including host country contribution.

accelerating demonstration projects. In addition to the activities pursued at these biomass centers, other activities include forest surveys, establishment of an Institute of Forest Management (IFM), research programs at State Forest Departments, Agricultural Universities and various institutes as well as State social forestry projects.

The biomass production components of the AERD Project will include two subprojects: Production of Woody Biomass on Substandard Soils to be conducted at the NBRI and Development Studies of Woody Biomass Species on Arid Marginal Lands - Lab cum Plantation Approach to be performed by Madurai Kamraj University/Bharathidasan University (MKU/BU). These subprojects are designed to reinforce the capabilities of the two biomass centers through collaborative activities with U.S. teams and/or individuals. The U.S. collaborative activities will be coordinated by Winrock International (WI).

A detailed implementation plan and schedules have recently been proposed; the project duration is 36 months starting in early 1987.

2.2.2 Biomass and Coal Conversion

This component addresses the problems of conversion of biomass through the generation of producer gas (gasification) and the use of this gas in internal combustion engines and of the utilization of low quality Indian coals through fluidized bed combustion technology and various methods of coal treatment.

The biomass conversion part of this component focusses on the development and field testing of small (range of 3 to 5 KW) gasifier-engine sets designed to provide mechanical power for irrigation. Agricultural machines and captive power generation consume 35 to 40% of the total diesel fuel oil sold in India. There are about 3.6 million diesel engine-pump sets in India today; their size ranges from 3.7 to 15 KW. The number of units is expected to increase each year. It is expected that biomass gasifiers will replace a significant number of diesel operated units, thus saving substantial amounts of diesel fuel.

The biomass subprojects included in this component are:

1. Development of a Village-Level Gasifier Using Charred Agricultural Residues

This subproject is conducted at the Indian Institute of Technology (IIT), New Delhi, Department of Chemical Engineering.

2. Utilization of Producer Gas in Small Horsepower Engines

This subproject aims at improving the performance of small (3 to 5 HP) diesel engines operated in a dual-fuel mode. In the last phases of the project, subprojects 1 and 2 will be combined and field-tested as a single gasifier-engine-pump set. This subproject is conducted at the IIT, New Delhi, Department of Mechanical Engineering.

3. Development and Field Implementation of Small Wood-Based Gasifier-Engine Systems (5 to 30 HP)

This subproject concentrates on the utilization of untreated (except for sizing and moisture content) woody biomass. The subproject is conducted at the Jyoti Solar Energy Institute (JSEI), now Sardar Patel Renewable Energy Research Institute (SPRERI), Vallabh Vidyanagar, Gujarat. The subprojects were initiated in April 1984 and are scheduled to be completed by the end of 1986.

The coal conversion part of the component includes the six following subprojects:

1. Coal Beneficiation.

Indian coals contain a large amount of mineral matter that mechanically and economically place burdens on a combustion system. Methods to reduce the ash content of coal are obviously desirable, but, in addition, improved beneficiation can make other coal resources available such as rejects from a coal preparation plant. Cyclones are known in coal cleaning systems but are usually for particles larger than 28 mesh (0.6 mm). Indian coals require finer grinding to separate the coal from the non-combustible mineral matter. Cyclones provide the centrifugal force used to concentrate the less dense coal.

This project is underway at CFRI, Dhanbad.

2. Rheology, Stability and Combustion of Coal-Water Mixtures (CWM).

The complexity of non-Newtonian systems, wherein fluid flow is influenced by suspended solids, provides a unique set of problems. The hydrophobic properties of coal require the control of additives and the presence of a relatively large amount of water can influence the flame properties when the coal burns. However, a slurry system is a safe and efficient way to transport coal.

Basic work on this project is being conducted at the Central Fuel Research Institute (CFRI) at Dhanbad. Combustion testing will be done at BHEL-Trichy.

3A. <u>Evaluation of Freeboard Performance in a Fluidized Bed Combustor.</u>

Parameters to be evaluated are heat transfer, dust loadings, combustion efficiency and gaseous emissions. These data will be the basis for the design of small commercial boilers, i.e., up to 30 MWe.

This research is being done at Bharat Heavy Electrical Ltd. at Trichy (BHEL-T).

3B. <u>Atmospheric Fluidized Bed Combustor (AFBC) Scaleup.</u>

A 150 ton of steam per hour unit was designed and the drawings, specifications, and scaleup details were prepared. The final design was reviewed by engineers at TVA in the U.S.

This work was also done at BHEL, Trichy.

4. <u>Hot Gas Cleanup.</u>

The purpose of this project was to design and build a fully automated test rig and to evaluate the performance of high temperature filters for the removal of particulate matter. Hot separation will result in significant savings in equipment and reduce heat losses.

This work is being done at the corporate R&D laboratories of BHEL at Hyderabad (BHEL-H).

5. <u>Cold Gas Cleanup and Separation.</u>

Cold gas cleanup is primarily for the sorption of pollutants in process gas streams as well as particulate removal. Both adsorptive and membrane technologies will be used. Adsorption can take place on materials such as charcoal or silica gel. Membranes can control the diffusion of gases across polymer films.

This research is underway at the Regional Research Laboratory at Hyderabad (RRL-H).

The subprojects were initiated between 1982 and 1984 and were scheduled to be completed by the end of 1986. Because of unavoidable delays, some projects received additional funding for their continuation and extension.

The Pittsburgh Energy Technology Center (PETC) under a Participating Agency Service Agreement (PASA) is managing these biomass and coal cooperative projects; its Indian counterpart is the Department of Non-Conventional Energy Sources (DNES - GOI).

2.2.3. Energy Efficiency

The original project paper proposed a U.S./Indian technical exchange program dealing with energy efficiency in industry and transportation. Both sectors are heavy users of imported commercial fuels and, based on U.S. and Indian experience, it was felt that energy efficiency improvements were possible, cost effective and could result in short and medium term energy savings.

For both sectors, a program of technical collaboration was planned with the purpose of comparing experience and increasing the awareness of Indian industrial managers of the energy control, energy management, traffic control, engine technology, transportation planning, and other technologies available in the United States.

The Association of Indian Engineering Industries (AIEI) -- now renamed the Confederation of Engineering Industries (CEI) -- and the National Academy of Sciences (NAS) were selected as the Indian and U.S. representatives, respectively, for the implementation of this project component. Both institutions have wide access to public and private representatives of industry in their respective countries and it is anticipated that through their collaborative efforts, an effective channel for energy efficiency technology transfer will be established.

Contract negotiations with NAS were concluded in 1984. The agreed-upon scope of work focussed on energy efficiency in industry, the original transportation subproject being abandoned.

A first visit to India by NAS representatives took place in 1985. During the visit, an approach of interactive workshops was defined to achieve the goals of the program. Activities proposed under the program included three visits/workshops in India, a visit/workshop in the U.S. and the transfer of some software. No formal program plan was established for these activities. The series of activities mentioned above will be considered as the subproject pursued under the energy efficiency component and will be the object of the review presented in Section 4.

2.2.4 Information Exchange

One of the functions of the Indian Commission for Additional Sources of Energy (CASE) is to provide a data bank on all aspects of new and renewable energy sources. The purpose of this data bank is to disseminate technical information and to provide guidance to potential users of renewable energy systems. To achieve these objectives it was originally proposed to develop a formalized link between CASE and information sources in the United States through

Department of Energy (DOE) sources, possibly the Solar Energy Research Institute (SERI) or other acceptable alternatives.

As the project evolved, the original intent of technical data transfer was modified to support five specific subprojects. The subprojects included in this component are:

1. <u>Field Test of Polymer Film Solar Collectors</u>

This subproject called for the testing of the advanced flat plate solar collectors developed at Brookhaven National Laboratory (BNL) under climatic conditions prevailing in India. The BNL design offers the double advantage of high performance and potential significant reduction in installed cost. Tests were conducted at the Solar Thermal Energy Center (STEC) facility at Dundahara, Haryana, with the collaboration of BNL.

2. <u>Development of a National Planning Model for Non-Conventional Energy</u>

This subproject called for the development of a national planning model which will enable government policy makers to analyze and evaluate the impact of non-conventional energy technologies on the overall economic picture of the country. The work was conducted at the Tata Energy Research Institute (TERI), New Delhi, with the collaboration of BNL.

3. <u>Low-Head Hybrid Micro-System</u>

This subproject involved the development of a micro processor controlling system for automatic and efficient management of loads connected to low-head turbine plants, training of Indian scientists in electronic load control systems, setting-up a facility for the design of electronic controllers and the procurement of a low-head U.S. made turbine to the tested, in parallel with other units, at a site under development in Kakroi. The Indian investigator is the Alternative Hydro Energy Center (AHEC), Roorkee University, Roorkee; its U.S. counterpart is Boston University (BU), Boston, MA.

4. <u>One Hundred Kilowatt Gasification System</u>

This subproject calls for the installation of a demonstration biomass gasification plant of 100 KW capacity for captive power generation. The system will be linked to a dairy plant and to an oil mill complex. The demonstration will take place at Junagahd, Gujarat, under the management of the Gujarat Energy Development Agency (GEDA).

5. Thin Film Technology

This subproject is a follow-on to the earlier collaborative project (see Section 2.2.4.-1 above) between the Solar Thermal Energy Center (STEC) and Brookhaven National Laboratory (BNL). Its purpose is to develop materials characterization capabilities, provide training in systems design capability and evaluate the current and projected capability of Indian industry for producing the materials required for thin polymer collectors of the BNL design. The work will be conducted by STEC with the collaboration of BNL.

2.3 Evaluation Methodology

The overall purpose of the evaluation task is to determine whether the original objectives of the AERD project have been met, to determine whether some mid-term corrections to the original scope of work are warranted, and to assess if any of the subprojects merits USAID further financial support.

2.3.1 Approach

The Scope of Work for the evaluation team calls for a review of each of the subprojects included under the four components of the AERD project. For each subproject, a number of aspects of the subproject will be reviewed and discussed. A standard format for reviewing the subprojects will be followed whenever possible. This format is shown in the next section.

USAID is currently implementing a new six year project, the Energy Research and Enterprise (ERE) project which will support selected research and technology development proposals while seeking to create an institutional environment for relevant technology innovation in the energy sector. Some of the subprojects included in the AERD project could be candidates for further development under the proposed ERE project and have, therefore, been evaluated with this potential in mind.

Before leaving for India, the evaluation team familiarized itself with the project, its components and subprojects, through briefings, meetings and conversations with U.S. representatives involved in the implementation of the project.

In India, the team attempted to contact U.S. and Indian representatives involved in the project. Several site visits to various subprojects were also undertaken. A list of contacts and visits made during the evaluation process is shown as Appendix A.

In India, the evaluation team coordinated its activities with those of a World Bank team involved in assessing the potential for commercialization of renewable energy technologies.

2.3.2 Format for the Evaluation of Subprojects

The format adopted for the evaluation of subprojects includes twelve headings each covering a particular aspect of the subproject considered; for each topic, some typical questions raised during the evaluation are mentioned.

a. Project Description and Selection Criteria

Brief description of project and reasons for its selection.

- Were selection criteria reasonable?
- Are selection criteria still valid?
- Does project address short/long term energy problems of India?
- Could another technology, at the same scale, achieve similar results?

b. Progress to Date

Summary of progress at time of evaluation.

c. Attainment of Objectives

- Were objectives of subproject clearly defined?
- Were stated objectives of subproject achieved?
- Were objectives of component achieved through this subproject?
- Were overall objectives of project achieved through this subproject?

d. Barriers and Constraints

- Were there barriers/contraints which prevented attainment of objectives?
- Were actions taken to overcome barriers/contraints?
- Could other actions have been taken to overcome barriers/contraints?

e. Procurement Efforts

- Did subproject call for transfer of equipment (data, software,)?
- Did transfer take place?
- Were there problems/delays in transfer?
- Reasons for problems/delays.
- What actions were taken to overcome problems/delays?

f. Management Effectiveness

- Were goals and schedules of subproject clearly defined?
- Was support provided (budget, financing, information, data, training, specialized personnel, etc.)?
- Was contact maintained with subproject personnel?
- Was interaction with other subprojects established and encouraged when needed and justified?
- Did management personnel follow-up on requests for intervention from the subproject?
- Was there too much/too little management intervention?

The management effectiveness of DNES and of USAID will be reviewed.

g. Effectiveness of U.S. Technology Transfer

- Did U.S. organizations involve the private sector?
- Has this resulted in expanding access to U.S. technology?
- Will contacts/interaction be maintained after conclusion of project?
- Are licensing/manufacturing/export agreements likely to result from technology transfer activities?

h. Relevance of Technology Selected

- Is technology appropriate for Indian energy sector?
- Can technology be replicated without USAID technical/financial assistance?
- Does capability to operate/maintain exist?
- Are there perceived barriers to commercialization (other than economic factors considered under j. below)?
- Are approaches available to overcome perceived barriers?

i. Relevance of Collaborative Effort and Study Tours

- Was U.S. contribution to collaborative effort (subproject) appropriate? too much? too little?
- Should another approach have been chosen?
- Were study trips, visits and training in U.S. effective? too little? too much?
- Was there reluctance from U.S. organizations to participate in study trips, visits, etc.?

j. Economic Viability of Technology

- Are data available to make valid economic evaluation?
- Based on data available, does technology appear viable?
- What further data are needed to perform reliable economic evaluation?
- Is economics a serious barrier to commercialization?
- What approaches are available to overcome economic barriers?

k. Institution Building Efforts

- Did the program result in increasing the technical capability of the institution involved?

- Will this increased capability be maintained after termination of the program?
- Will the increased capability be used and contribute to further development in the area of non-conventional energy?

1. Utility and Importance of Effort -- Recommendations

- Positive/negative impacts of project without follow-on activities.
- Are objectives still relevant?
- Should further activities be supported?
- Recommendations for further involvement.

3.0 PROJECT ASSESSMENT

This chapter presents detailed assessments of the various subprojects actively pursued at the date of this evaluation.

3.1 Biomass Production

Information regarding this project could only be obtained a few days before the end of the stay in India. The evaluation is based on conversations with Dr. O.P. Vimal, DNES, and Dr. C.R. Hatch, USAID, and on a review of the program plan submitted in October 1986 by Winrock International, the U.S. contractor selected.

a. Project Description and Selection Criteria

The original intent, expressed by the GOI and AID, was to reinforce the capability of two biomass research centers, NBRI and MKU/BU, to provide support for the on-going reforestation projects i.e. provide research support for short-term objectives.

As the project evolved, and largely because of the academic perspective of the institutions involved, the project evolved into a fundamental research project addressing various aspects of forestry (nursery operations, plant stress, etc.). These problems must certainly be addressed but they are long-term objectives which do not address the immediate needs of current social forestry programs.

One of the major problems faced in this case is that the institutions involved have little contacts and few channels to interact with field people engaged in forestry programs; like most academic research institutions, the two Indian institutions involved have little interest in pursuing the practical implications of their research efforts.

b. Progress to Date

The project was initiated recently and training activities of Indian personnel have been initiated.

c. Attainment of Objectives

In its current form, the project will not achieve the original objectives of AERD (see a. above).

d/e. No comments at present.

f. Management Effectiveness

Project discussions were initiated in 1982. Delays occurred in developing the project, mostly because of the transfer of the proposed activities from CASE to the newly formed DNES.

The work plan calls for annual progress reports to be issued by the two Indian institutions. Based on the experience gained from other projects, it is suggested that more frequent (quarterly or at least semi-annual) reports be requested. It is recognized that scientific research cannot be kept on a tight and predictible schedule, but reports identifying progress, problems, delays, etc. are needed to insure effective monitoring of the projects.

g,h,i,j: No comments at present.

k. Institution Building Efforts

The projects should increase the capability of the institutions involved for conducting long-term fundamental research. Some means should be found to orient this capability towards nearer term objectives.

l. Utility and Importance of Effort - Recommendations

There is little doubt that the project, as originally conceived, could provide much needed support to social forestry or other reforestation projects. In its current proposed form, with emphasis on long-term research, the project will not have its intended impact in the near-term.

Recommendations include:

1. Improve the proposed monitoring procedures by requesting quarterly progress reports. This should be initiated by WI with the support of AID and DNES.

2. Establish contacts between field people (social forestry group, etc.) and the research institutions. The objective is to suggest research topics of a fundamental nature which could be of immediate interest to the field people. This is not an attempt at restricting academic freedom but rather of focussing fundamental research on topics of immediate interest. Such interaction could be

established by creating work groups meeting periodically to exchange ideas and identify problems. WI should play an active role in this process.

3.2 Biomass/Coal Conversion

The three biomass subprojects are reviewed in Sections 3.2.1. to 3.2.3; the reviews of the coal conversion projects are presented in Sections 3.2.4 to 3.2.9. Whenever possible, the format proposed in Section 2.3.1. will be followed.

3.2.1 Development of a Village-Level Gasifier Utilizing Charred Agricultural Residues

a. Project Description and Selection Criteria

A prototype system was to be developed wherein charred agro-wastes, a gasifier and a gas clean-up unit are integrated into a simple, reliable, field-operated piece of equipment. The project called for this system to fuel a 5 HP diesel engine driving an irrigation pump.

This subproject was selected for a number of reasons: availability of substantial quantities of agricultural wastes, availability of a technology for converting these wastes into charred fuel of reliable quality, increasing number of small diesel pumping units indispensible for maintaining and expanding agricultural output, and increasing demand for imported fossil fuel by the agricultural sector. Despite the recent stabilization of world oil prices which may reduce the drain on India's financial resources in the short-term, the long-term focus of the project, i.e., to reduce dependence on imported fuels and switch to indigeneous resources is still valid.

Gasification of wood, charcoal, coal or other materials is an old technology which has proven its usefulness, among other, during the Second World War in Europe where hundreds of thousands of units were used for years. The technology has limitations, start-up time, low quality gas, etc., but given the emphasis placed in India on the replacement of fossil fuels, it is a promising option for numerous applications, from low power rural to larger industrial applications. The current gasification projects, sections 3.2.1, 3.2.2, 3.2.3 and 3.4.4, aim at exploiting this alternative technology.

Other technologies which could achieve the same objective of providing dispersed, small scale, mechanical power include photovoltaic sets or biogas operated engines. Photovoltaics appear to be much too expensive in the foreseeable future to be a realistic candidate for the application considered. Biogas production from animal wastes and its use in engines is a demonstrated technology. Few rural families, however, appear to own enough cattle to generate enough biogas for their basic daily needs (lighting, cooking-usually the prime objective of biogas) and for pumping power.

b. Progress to Date

At the onset of the project, a detailed program plan including clearly defined objectives and schedules was established. Essentially all the objectives were achieved within the timeframe proposed.

A small down-draft gasifier was developed and operated at the Chemical Engineering Department of ITT, New Delhi. The feed material is charred biomass. The design incorporates considerable flexibility, such as,

- The throat and reduction zone are a single piece for easy replacement and maintenance,
- Tuyere openings are at two levels and proper adjustment can control the length of the fire zone,
- The combustion and reduction zones are insulated to maintain gasifier internal temperature,
- The use of horizontal and vertical grates eliminates choking and reduces pressure drop,
- An additional ash removal port is provided,
- A shaking grate facilitates ash removal

The gasifier operates on briquetted and charred biomass. About 70 percent replacement of diesel fuel is possible with compression ignition (diesel) engines. After laboratory testing and improvements to remedy the problems noticed, a field trial unit was fabricated and integrated with an engine-pump set (developed under the second biomass subproject - see Section 3.2.2.) and field tested.

Table 3.1 summarizes the main achievements of this subproject. The technical work is of very good quality and well documented through periodic workshop reports. The field unit tested is a laboratory prototype/demonstration unit which lacks engineering sophistication. This was illustrated during the site visit when some operational problems occurred -- loosening of producer gas inlet pipe from engine, water seepage from cooling tower to engine.

The economic evaluation document provided is somewhat simplistic. Obviously not enough data are available for a full economic review, but a sensitivity analysis evaluating

Table 3.1 Biomass Conversion Subproject: Development of Village-Level Gasifier Using Charred Agriculture Wastes - Progress to End 1986

Fuel Specifications.

Gasifier Design/Development/Operation (Laboratory).

Fabrication/Testing of Field Trial Unit (Integration with engine developed in second biomass subproject).

Field Operation of Commercial Unit (Gasifier-engine-pump).

- Engine: 5HP
- Cumulated Operating Hours: 120
- Diesel Replacement: 67 to 72%
- Char Consumption (dual mode): 1.2 Kg/KWH
- Diesel Consumption (dual mode): 0.33 l/KWH
- Diesel Consumption (diesel only): 1.1 l/KWH (At Rs. 4/l = Rs. 4.4/kWh = $.33/KWH)
- Operator: Local farmer (trained and supervised)

Documentation Manuals:

- Engineering Drawings (not completed)
- Operation/Maintenance Procedures (not completed)
- Environmental/Safety Procedures (not completed)
- Economic Analysis (completed)

Socio-Economic Impact Assessment (not completed).

Training and Visits in the U.S.

Transfer of Equipment from the U.S.

Yearly Workshops in India.

Final Report (in preparation).

the impact of the major cost parameters (capital costs, interest rates, depreciation period, fuel costs) could have helped in defining the range of economic viability of the system. One assumption is particularly questionable: it is assumed that agrowastes have zero cost. Agrowaste, if truly unused, may have zero intrinsic value but they must be collected and converted to charcoal. Even if the farmer performs these tasks himself, the diversion of his time from other activities has a cost.

The unit is operated in a sugar cane growing area -- potential residues are cane, leaves and/or bagasse -- but is operated on charred corncobs. This "mixed" situation results from the fact that corncobs were used in laboratory experiments and that no ready-made method was available for charring and briquetting sugar cane residues. This should be explored.

Although a comprehensive final report will be issued shortly (under preparation by A. Talib, Mitre Corporation), training and other documentation manuals were not prepared. These would be useful.

During the site visit, the data recording procedures were reviewed with Dr. H.S. Mukunda (IIS-Bangalore). Some modifications were suggested and will be implemented:

- provide a scale to weight input fuel,
- provide a funnel to avoid fuel losses during loading,
- record total diesel fuel consumption from beginning to end of each pumping period (integrated value),
- improve water seal to avoid leaks to engine, and
- repair/improve flexible joint between gasifier and engine.

The overall impression conveyed by the subproject is very positive and the dedication and enthusiasm of the participants is obvious.

c. Attainment of Objectives

The subproject had clearly defined objectives and, with minor exceptions, these objectives were achieved within the timeframe allocated for the project.

The subproject contributed to achieving the objectives of the component -- biomass conversion -- in that it provided an apparently viable method for replacement of diesel fuel by renewable waste materials. The subproject also contributed to achieving the overall objectives of the AERD project by providing a mean for reducing dependence on imported fuels while providing an alternative for generating the mechanical power needed for irrigation.

d. Barriers and Constraints

No major barriers prevented the project from achieving its objectives. Some minor problems were recorded, such as minor delays in the transfer of imported equipment from the US, delay in securing the needed inert gas for operating the analytical equipment and some organizational problems during the integration of this subproject with the second subproject (see Section 3.2.2). All these problems were solved through the combined efforts of the parties involved and none resulted in serious delays for the project.

e. Procurement Efforts

The subproject called for the transfer of specialized equipment from the US to India to reinforce the analytical capability of ITT in analyzing and documenting its work. Some delays were recorded in this transfer. In retrospect, the U.S. contractor responsible for the transfer had the difficult task of securing, shipping and importing specialized equipment on very short notice. Most problem appear to have resulted from lengthy and complicated import regulations. These were straightened out through the intervention of DNES. It could be suggested that for future projects, some special, simplified import procedures should be set up with the appropriate authorities to facilitate the import of specialized equipment essential for the successful completion of collaborative projects.

f. Management Effectiveness

Generally speaking, the subproject received adequate support from both DNES and USAID: financing of the project, organization of study tours, workshops and visits, and intervention on special occasions, such as the import of equipment, were provided in time and as needed.

g. Effectiveness of U.S. Technology Transfer

The visits and training sessions in the US did involve university and research centers involved in gasification. In contrast to other technologies, such as fluidized bed combustion, there are relatively few private entities actively engaged in small scale gasification of biomass. It is hoped that contacts established during this program between Indian research groups and U.S. similar groups will be maintained. No significant licensing or manufacturing agreements are expected to result from the program.

h. Relevance of Technology Selected

The technology selected is capable of providing an important fraction of the energy required for irrigation using indigeneous resources. The technology can probably be scaled-up from the basic 3 to 5 HP level common to irrigation systems to 10 to 15 or even more HP; at that level, the technology could satisfy the basic needs of small communities for electricity and mechanical power.

The unit demonstrated in this subproject was designed and built in India with local resources and personnel; there is little doubt, therefore that the technology could be replicated without further technical help from USAID. The field operation of the unit was conducted by a farmer, after appropriate training and it seems, therefore, that the potential exists for commercializing the technology.

The subproject, however, included only one experimental unit. Before engaging in an extensive dissemination effort, it is recommended that further demonstration, precursor to commercialization, be undertaken. Such larger scale demonstrations could probably be part of an Energy, Research, and Enterprise (ERE) project, should some manufacturer be interested in the technology, which appears to be the case.

i. Relevence of Collaborative Effort and Study Tours

The PETC management team showed much dedication and enthusiasm for the project. This has been acknowledged on numerous occasions by their Indian counterparts. A few supplementary visits by U.S. personnel may have been useful at some critical stages of the projects, but these were not included in the budget.

Visits and training sessions in the U.S. were well organized and effective. U.S. organizations involved in these activities were very supportive of the project and its goals.

All Indian scientists interviewed who were involved in these sessions expressed their satisfaction; it was mentioned that a somewhat longer stay (1 week) at the University of California, Davis (Prof. J. Goss) laboratory would have been welcomed in view of the abundance of information to absorb.

j. Economic Viability of the Technology

The preliminary economic analysis made by IIT suggests that a gasifier operated 1,500 hours/year could pay for itself in approximately two years. This appears optimistic in view of the comments made in Section 3.2.1.b above (zero fuel cost for example) and in view of the fact that standard irrigation needs appear to be closer to 1000 hours/year than to 1,500 hours.

As of now, the economic analyses can only be considered as preliminary because many characteristics of the system are not sufficiently defined and neither are some of the costs involved. Further data should be gathered on useful life of the systems, maintenance costs, spare parts costs, unit cost for large scale production, charred fuel costs and its regional variation, etc. A large scale demonstration project such as was mentioned in Section h above could answer these questions.

k. Institution Building Efforts

Through this subproject, IIT, Chemical Engineering Department, has increased its research capability in the area of biomass fuel characterization and gasifier development. The department is involved in other biomass conversion projects (stoves, char preparation,...) which could also benefit from the increased analytical capability. The scientists trained in the U.S. have now received appointments at the University, thereby ensuring that the expertise gained will be maintained in the future.

l. Utility and Importance of Effort - Recommendations

The project has demonstrated that a gasifier system using charred agricultural wastes can be effective in providing irrigation power and in replacing a significant fraction of the diesel fuel previously used for this purpose. Fabrication and field testing of a unit has shown that the technology can be implemented using local resources and personnel.

The experience gained so far from the demonstration unit, however, is limited: economics, infrastructure needs, social impacts among others are not clearly defined. An attempt at immediate commercialization could result in less than optimal success and disaffection and disinterest by potential users because of the potential negative impact of some of the unresolved issues. Two follow-up activities are suggested: extend field testing of the unit to at least several hundred hours and explore the problem of preparation of a suitable fuel based on local wastes. The latter task should include material and energy balances and careful record of labor time as described in Chapter 5.

3.2.2 Utilization of Producer Gas in Small (3-5HP) Utility Engines

After a laboratory/development phase, this project was integrated with the gasifier described in Section 3.2.1 to conduct field trials of a complete gasifier-engine-pump set. Although the two subprojects were conducted in two different departments of IIT, their evolution paralleled each other to a large extend and, therefore, some of the comments made in evaluating the first subproject apply in the present case. In those instances, the reader will be referred to the appropriate paragraph of Section 3.2.1.

a. Project Description and Selection Criteria

Small compression ignition engines (3-5 HP diesels) were to be modified for efficient utilization of producer gas. The engineering studies evaluated performance, emissions and materials compatibility; standardized procedures for the testing of fuels, gas and engines and for modifying engines were to be developed. A field trial unit to be integrated with the gasifier developed under subproject 3.2.1 was to be built and tested.

This project was selected for essentially the same reasons as project 3.2.1 (see Section 3.2.1.a).

b. Progress to Date

Essentially all the objectives stated in the original detailed work plan have been achieved within the timeframe of the project.

Testing procedures for fuel, producer gas and engine were developed. Engine modifications for conversion from diesel to dual-fuel operation were optimized and standardized and a field unit was tested. Unfortunately, only about 120 hours of actual field testing were logged.

Table 3.2 summarizes the main achievements of this subproject. Comments similar to those made about Table 3.1 apply in this case.

Data is also currently generated regarding lubrication oil degradation and engine wear.

c. Attainment of Objectives

See Section 3.2.1.c.

As indicated above, unfortunately, only about 120 hours of field tests were possible within the timeframe of the project. Although these have clearly demonstrated that this system is viable, longer periods of testing are necessary to fully evaluate the technical performance of the system.

d. Barriers and Constraints

See section 3.2.1.d.

e. Procurement Efforts

See Section 3.2.1.e.

Table 3.2 Biomass Conversion Subproject: Utilization of Producer Gas in Small Engines - Progress to End of 1986.

Development of Test Procedures (fuels, gas, engine).

Development and Standardization of Engine Modifications (intake, fuel system, regulation/control).

Testing/Optimization of Modified Engines (short/long term).

Fabrication/Testing of Field Trial Unit (Integration of modified engine with gasifier developed in first biomass conversion subproject).

Field Operation of Demonstration Unit (gasifier-engine-pump)*

Documentation Manuals

- Engineering/Assembly Drawings (not completed)
- Retrofit/Operation/Maintenance Procedures (not completed)
- Environmental/Safety Procedures (not completed)
- Economic Analysis (see project 3.2.1)

Training/Visits in the U.S.

Transfer of Equipment from the U.S.

Yearly Workshops in India.

Final Report (in preparation)

* Summary Operational Characteristics for the set are shown in Table 3.1.

f. Management Effectiveness

See Section 3.2.1.f.

g. Effectiveness of U.S. Technology Transfer

See Section 3.2.1.g.

h. Relevance of Technology Selected

See Section 3.2.1.h.

i. Relevance of Collaborative Effort and Study Tours

See Section 3.2.1.i.

j. Economic Viability of the Technology

See Section 3.2.1.j.

k. Institution Building Efforts

Through the collaborative effort, IIT, Department of Mechanical Engineering, has increased its capability for fuel/engine testing: the diagnostic equipment and training received, combined with existing test engines, created a nucleus capable of conducting effective engine-related studies.

It should also be noted that, by being involved in field trials, both the Department of Chemical Engineering and the Department of Mechanical Engineering have gained insight and experience in transfering technology from their academic environment to the real life environment.

l. Utility and Importance of Effort - Recommendations

See Section 3.2.1.l.

At present, no follow-up work is envisioned except collaboration with the Chemical Engineering Department, if follow-up work is conducted there, on an as-needed basis.

3.2.3 Development and Field Implementation of a Wood-Based Gasifier/Engine System (5 to 30 HP)

a. Project Description and Selection Criteria

A reliable wood-based gasifier and gas clean-up system was to be developed and the clean gas fed to 5 and 30 HP compression ignition engines. Field trials were to be made in rural areas. This subproject is meant to capitalize on the experience in gasifier technology accumulated at the Jyoti Solar Energy Institute (JSEI) over the years. Besides the technical development, a socio-economic impact assessment was planned. It would establish a profile of the village selected for the field trial, determine the availability of wood fuel in the region and quantify the economic and social benefits to be derived from the gasifier/engine set.

This project was selected for the same reasons as the other gasifier project (Sections 3.2.1. and 3.2.2.): increasing number of diesel-operated irrigation pumps and desire to decrease the dependence of the agricultural sector on imported fuels.

In view of the current deforestation problems and of the difficulty and cost of obtaining wood fuel in some areas of the country, the selection of a wood-based technology could be regarded as unwise. The project must, however, be looked at in the broader context of progressive substitution of wood for fossil fuels through the implementation of "energy forests" which, if successful, will provide significant amounts of wood fuel. This subproject thus complements the subprojects conducted under the Biomass Production component of the overall AERD project.

The work was conducted at the JSEI, now renamed Sardar Patel Renewable Energy Research Institute (SPRERI), in Vallabh Vidyanagar, Gujarat, and at the close-by site of Johr; the U.S. counterpart was the PETC team.

b. Progress to Date

A small demonstration unit installed at the village of Johr runs a 3.7 kW diesel engine-pump set. It is a down-draft system with an output of 12 N cubic meters/hr. (about 400 cfh). The combustion zone operates at about 1,100 degree Centigrade and the outlet gas is cooled at about 125 deg. C. The cleaned gas is fed to a 5 HP Field Marshall engine that operates at 1,500 RPM and has a pump output of 15 l/s (about 200 gpm).

The farmer who operates this gasifier-engine unit was trained in its operation and maintenance by the JSEI and keeps a log of all inputs and outputs. The system uses wood blocks (about 5 cm x 1.5 cm dia.), moisture content about 10% (estimates) prepared by the farmer. Over 1,000 cumulated hours of well documented operation have been accumulated. A preliminary economic analysis has been performed.

Table 3.3 summarizes the main accomplishments of the subproject.

Table 3.3 Biomass Conversion Subproject: Development and Field Implementation of Small Wood-Based Gasifier Engine System - Progress to End of 1986.

Fabrication and Testing of Field Trial Unit.

Training of Personnel.

Field Operation of Trial Unit

- Engine: 3.7 KW
- Commulated Operating Hours: 1,100
- Diesel Replacement: 70% (about)
- Wood Consumption: 3.4 kg/hr
- Diesel Consumption (dual mode): 0.27/hr.
- Diesel Consumption (diesel only): 0.9 l/hr.
- Operator: Local farmer (trained and supervised)

Documentation Manuals:

- Engineering Drawings.
- Operation/Maintenance Procedures.
- Safety Procedures
- Cost and Economic Analysis
- Environmental Impacts

Training and Visits in the U.S.

Transfer of Equipment from the U.S.

Yearly Workshops in India

Final Report (in preparation)

The development work is of very good quality and well documented. The field unit tested is more engineered than that tested in the other programs (Sections 3.2.1 and 3.2.2.); this probably reflects the field experience gained previously by SPRERI while conducting a gasifier project under a Ford Foundation grant. Start-up time of the units was about 5 to 10 minutes from the time of lighting the fuel to switching to dual-fuel operation.

The socio-economic document is somewhat limited in scope. Because only one unit was tested, the impact of gasifiers on the social structure of the village cannot really be evaluated. The proposal called for an evaluation of wood availability in the area which is missing. The economic analysis, while taking into account fuel delivery and preparation costs, does not include a sensitivity analysis. Further, the amounts assigned to capital recovery and interest do not appear to be correct (the method of calculation is not provided.)

During this visit, it was agreed to provide the farmer with a scale in order to obtain more reliable fuel input data.

The original proposal included the development of systems ranging from 5 to about 25 HP. Due to budgetary constraints the project was limited to 5 HP units.

The overall impression from the projects is very favorable: there is a concern for engineering and much dedication to the project.

c. Attainment of Objectives

The subproject had clearly defined objectives; essentially all the technical objectives have been achieved and well documented. The socio-economic analysis originally planned was not fully completed; this is mostly due to the fact that the subproject included only one demonstration unit from which it is impossible to derive significant statistical data.

The subproject contributes to achieving the objectives of the component -- biomass conversion -- in that it provides an apparently viable method for displacing significant amounts of diesel fuel through the use of a renewable resource potentially available in many parts of the country. The subproject also contributes to achieving the overall objectives of the AERD project by providing a method for reducing dependence on imported fuels while offering an alternative method for generating the mechanical power needed for agricultural development. As noted above, the full benefit of the technology will only be reached when a reliable supply of wood fuel can be secured.

d. Barriers and Constraints

No major barriers prevented the project from achieving its technical objectives. Some problems were recorded, such as delays in the transfer of imported equipment from the U.S. These problems were resolved through the efforts of the parties involved without interfering seriously with the outcome of the project.

Delays were incurred in obtaining the gas for calibration. Some shipments reached the site with some parts of the equipment missing. The contents were apparently not checked by the procurement subcontractor (checking would have resulted in further delays because of unpacking and repacking).

e. Procurement Efforts

The situation was the same for this project as was the case for the other subproject (see Section 3.2.1.e.). Added to this was the problem of missing components mentioned under d. above.

f. Management Effectiveness

The same comments that were made in Section 3.2.1.f. also apply in this case.

g. Effectiveness of U.S. Technology Transfer

See Section 3.2.1.g.

h. Relevance of Technology Selected

The technology selected is capable of providing an important fraction of the mechanical energy required in agriculture (irrigation, small mills, etc.) as well as electricity in dispersed locations.

The unit demonstrated in this subproject was designed and built in India, in fact improved on previously developed Indian technology, using local resources and personnel; there is little doubt, therefore, that the technology could be replicated without further technical help from USAID. The unit was operated by an enthusiastic and dedicated farmer, after appropriate training and under supervision, as needed. It seems therefore that the potential exists for commercialization.

The subproject included only one experimental unit. Before engaging in an extensive dissemination effort, it is recommended that further demonstrations be conducted; this could probably be achieved through ERE programs.

Finally, it must be stressed that this technology can be considered relevant only if sufficient amounts of wood fuel are available; its dissemination should thus occur in parallel with an expansion of woody biomass production capability.

i. Relevance of Collaborative Effort and Study Tours

See Section 3.2.1.i.

j. Economic Viability of the Technology

The preliminary economic analysis of the performance of the demonstration unit indicates that, at current prices for wood and diesel fuel (Rs. 0.4/kg and Rs. 3.58/l respectively), operating the engine on wood fuel (dual mode) would cost Rs. 0.70/KWH of shaft power versus Rs. 1.07/KWH for diesel fuel only. These estimates assume a gasifier cost of Rs. 20,000 amortized over 10 years (1,000 hours of operation per year). Gasifier operation does not appear to be competitive with electricity, when available, or is only marginally competitive. This is because electricity for agricultural uses is heavily subsidized. This situation was recognized by the farmer operating the experimental gasifier, in that he switched to electrical pumping of water when electricity was available at attractive prices.

A similar analysis made by the evaluation team (see Appendix C) suggests that, under the conditions assumed in the previous analysis, the gasifier will not be competitive with diesel fuel. The main difference between the two analyses is that the evaluation team uses a conventional capital recovery formula while the project analysis appears to use only a yearly interest charge on the capital.

These preliminary analyses must be considered with caution; many elements of the analysis are still ill-defined -- cost of gasifier under large scale production conditions, cost of wood fuel when adequate supplies will be available through short rotation forestry, actual lifetime of the system, maintenance requirements after long periods of use, etc. The analyses also suggests that the economic viability of the system is probably quite site specific; areas where electricity is available under current supported rates are not good candidates for the technology, for example.

k. Institution Building Efforts

Prior to implementing the project under review, the JSEI had already been involved in the development and operation of gasifiers. Through the subproject, the capability of the JSEI has been increased through the transfer of analytical equipment and techniques and through the training received and experience gained by the staff involved in the project. The JSEI can be be relied upon to provide effective support for the further development of gasifier technology both in India and in other Developing Countries.

1. Utility and Importance of Effort - Recommendations

The project has demonstrated that a gasifer system using wood fuel can be effective in providing power for irrigation and in replacing a significant fraction of the diesel fuel previously used for the purpose. Fabrication and field testing of the unit has shown that the technology can be implemented using local resources and personnel.

The experience gained so far is very encouraging but is limited: economics, infrastructure needs, social impacts, among others, are not clearly defined. These data can probably be generated through ERE initiatives.

Most economic studies show that wood fuel is a major component of operating costs. The cost of wood for the unit tested is high (about Rs. 500/metric ton or Rs. 0.50/kg). To this cost, transportation costs of Rs. 0.013/kg and preparation (of wood blocks) cost of Rs. 0.32/kg must be added. As performed now, wood preparation is done manually. If the technology is to progress, mechanical or semi-mechanical wood preparation processes must be established. It is recommended that a small research effort be undertake along these lines.

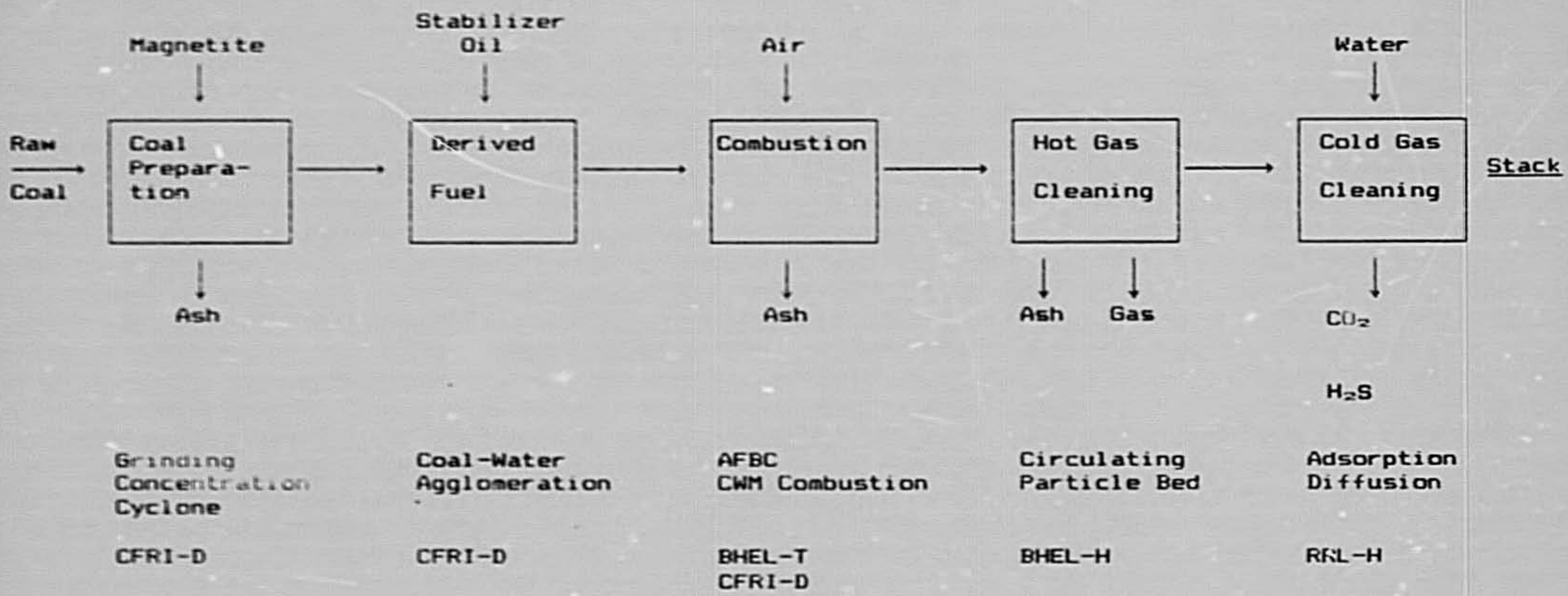
Coal Conversion Projects

As was already mentioned, there are six subprojects pursued as part of this fossil fuel combustion investigation. The emphasis changed little from the projects in the 1982 proposal and the overall objective remained the same, namely that India become self-sufficient in energy to develop all forms of indigenous energy resources. The USAID/GOI program can provide significant support for the ultimate goals, both in technology transfer and a source for equipment not available from local vendors.

When the fossil fuel components are organized, the composite shows a range from the mine to the power plant. To preserve the continuity of thought, the various subprojects are discussed in the logical order shown in Figure 1.

The Central Fuel Research Institute of Dhanbad (CFRI-D) is a distinguished laboratory with a long history of accomplishment in all phases of coal research. Much of the equipment is of recent vintage and capable of maintaining its position in coal technology. Infrastructure is also in place for coal analysis, petrography, geology and operating personnel. Enthusiasm of the staff for its project is obvious and the staff is anxious that continued financial report will be available.

Figure 1. FOSSIL FUEL MODEL



Equipment in place was observed and open discussions were held in the field. Ultimately, the review team sat down with the principal investigators to go over a set of questions derived from the interests of AID personnel.

Besides a review of the two projects under the fossil fuel program, one of us (MDS) has a long standing interest in the conversion of coal into liquid fuels and chemicals. Both methods of conversion are investigated at Dhanbad, direct liquefaction with hydrogen and indirect liquefication, the catalytic hydrogenation of carbon monoxide. One staff member, V.A. Krishnamurthy had visited the Pittsburgh Coal Research Center several years ago.

3.2.4 Beneficiation of Fine Coal on a Dense Medium Cyclone

Project Description and Selection Criteria

The addition of a finely ground solid to water produces a liquid with an apparent density greater than water itself, about 1.5 times heavier in this work. Thus, coal can be separated from ash because of their density difference. Centrifugal force to speed the separation is provided by a cyclone eight inches in diameter. The unique aspect of this program is that finer coal is used as compared to normal coal preparation practice. Indian coals have a very high ash content and fine grinding is being evaluated as a means to reduce the ash content of the clean coal beyond the normal methods. Improvement in ash removal could make more coking coal available to the steel industry.

Administrative approval from the Government of India was received in September 1984 and the next year was needed to acquire equipment and construct the pilot plant. Equipment from the U.S., (an 8 inch Heyl and Patterson rubber lined cyclone, particle size analyser, and the Sweco screening apparatus) were received later so that testing of the equipment could not be started until February 1986. The available data are reported in a detailed CFRI report issued in June 1986, "Beneficiation of Fine Coal in Dense Medium Cyclone" by A.K. Chakravorti. A significant change in the equipment was the reduction in the speed of the centrifugal type circulating pump, thereby reducing the particle size degradation. Before slowing down, the pump readings had to be taken quickly before the size distribution of the coal changed significantly.

The 8 inch Heyl Patterson cyclone with a 14 deg. angle was installed as received from the U.S. At a 6:1 dense medium to coal ratio the ash was reduced from 33.8% to 11 to 12.6% for 9 to 100 mesh coal. Finer coal, 7 to 200 mesh was dashed to the same level. Thirty percent ash in the feed was reduced to about 20%. The yield of clean coal, however, was much improved by fine grinding of both coal and the magnetite.

The following are responses to specific questions regarding the benefication of fine coal in a dense medium cyclone:

The criteria used to select the project were correct. Cyclones are a commercial piece of equipment but this study extends the technique to high-ash Indian coals. Finer grinding of the coals and finer particle sized magnetite place this process in a new regime. Low ash coals are in demand by the steel industry.

Progress to Date, Procurement Efforts

Overall objectives were reached, separation was effective and the product could be burned. As with many other projects, getting approval for imports caused long delays. The milestones chart in the CFRI report shows that most of the useful data taking occurred in the last few months of the project.

Technology Transfer, Relevance and Study Tour

Institution building efforts were with the Pittsburgh Energy Technology Center (PETC). Close cooperation was maintained with the coal preparation engineer who made two trips to Dhanbad. The group leader at Dhanbad made a trip to the Pittsburgh station. It is expected that commercialization will be realized in the 1990s. All the support came from PETC where coal preparation research is at a high level. Technology transfer from the coal preparation group was effective. Ideas for future work evolved from the program and a second cyclone was designed, built, and put into operation. The 6 inch cyclone more closely satisfied their needs of flexibility. Other supportive technology included the separation of magnetite and the oil agglomeration of fine coal particles. In the agglomeration technique, water is adsorbed prefentialy on ash and oil on the coal particles which then stick together or agglomerate. Mixing rate, time and other factors determine the size and strength of the final product, usually a ball with a higher heating value than the coal alone because of the added 5 to 7% of oil.

Management Effectiveness

Both DNES and USAID provided sufficient management to the cyclone project. The technology selected is relevant, especially when combined with oil agglomeration as part of the coal utilization sequence. Where appropriate, the concentration yields a more commercial product. Constraints include the availability and cost of oil, appropriate markets for the better coal and utilization of the ash.

Now that the personal ties have been established the intercommunication will continue. In anticipation of continuing the project, instruments for the determination of surface properties and flow rates have been requested.

Equipment provided for the project was appropriate and functioned properly. Although the equipment arrived late in the program schedule, experiments were completed and analyzed. Data are available in the June 1986 report.

Environmental impacts are minimal and perhaps less than those of other coal systems. Coal and magnetite are moved in water suspension and the water circuits are closed, that is, solids are floucated and the clear water is recirculated to extinction. Tailings and rejects must still be discharged, often into nearby streams. Underground disposal is possible but must take into account other mining activities and the possibility of aquifer contamination.

Recommendations

Cyclone cleaning of Indian coals should continue. Although an 8 inch cyclone was provided by USAID, the need for a six inch cyclone with a different configuration was needed. The staff took the initiative and built one. Improved cyclone design combined with a detailed petrographic analysis could indicate the limits of this method of physical coal cleaning.

The use of a cyclone for coal cleaning provides a safe and low cost way to handle finely ground coal. Dust formation and its hazards are eliminated. The coal is also available for safe transport to a fluidized bed combustor.

3.2.5 Coal Water Mixture Fuel (CWM) - CFRI D

Project Description

This multifaceted program was designed to examine the rheology, stability and combustion of coal-water mixtures (CWM). Because of the complexity of non-Newtonian systems, specialized instrumentation is needed to measure the unique characteristics of coal-water mixtures. Critical properties of CWM are viscosity, particle size distribution, stability, surface tension, surface area and pH. Equipment for these studies is available in India but some instrumentation was supplied by USAID.

Equipment suitable for preparing coal particles below 100 mesh with 60% finer than 300 mesh (50 μm) was evaluated. Both run-of-mine coal and demineralized coals were tested because of the way mineral matter is disseminated within the coal matrix. Chemical demineralization, oil agglomeration, cyclones and solvent extraction may be applied for CWM preparation and testing.

One objective reached was to achieve a high concentration of coal in the mixture and still maintain flowability and stability. At a 60% by weight concentration of Raniganj field coal in water, magnesium lignosulfate (Celex), a sodium salt of alkyl napthalene sulfonic acid (Lomar D), a coal derived stabilizer (CDS) and particle size were investigated. There was an optimum concentration for each of the additives.

Flowability of the CWM is much improved when a small amount of coal is replaced with a coal derieved stabilizer. There is cynergistic effect of CDS with Celex or Lomar D where a gel-like structure develops and the CWM does not settle, i.e., a standard rod penetrates to the bottom of the column. The significance of this test is that after standing in storage or shipment, the mass is readily repulped or suspended with little agitation. Another factor in the development of a stable system is the distribution of particle sizes. Maximum fluidity and high stability was observed when a bimodal particle size distribution was prepared by mixing finer and coarser fractions. To the $< 50\mu m$ coal they added a 75 to $150\mu m$ fraction. Improved physical properties can be explained by the arrangement of finer particles occupying the interstices leading to denser packing but their net effect is to provide improved fluidity. A related phenomenon occurs in fludized bed technology.

Millions of tons of washery refuse are polluting the Ganga and Dansodar Rivers in eastern India. This situation might be remedied by burning the combustible tailings in fludized bed. Note: anthracite culm from the Susquehana River is burned in power plants in eastern Pennsylvania.

The first phase of the CWM required a literature search and planning of an experimental procedure. This background work required the development of additives, the selection of three coal samples and a study of the operating parameters (coal concentration, flow regimes, surface properties and particle size distribution). Coal water slurries could be prepared in 30 Kg batches in existing equipment. USAID provided the Haake Viscosimeter.

Following are the responses by [illegible] staff to prepared questions:

Validity of Selection Criteri[illegible] Constraints

Selection criteria established at the beginning of the project were correct and no changes were required. Objectives for the next phase have already been outlined. Besides reaching the planned objectives, preliminary tests were made in the small fluidized bed combustion unit. In this project there were no constraints. A viscosity measuring apparatus (Haake) was installed and commissioned in January 1986 leaving sufficient time to carry out the experimental program.

Institution Building and Technology Transfer

Institutional building efforts were primarily within India since little information on CWM exists in the literature and proprietary data were not available. There was an expression that the work done up to now could provide a home for the combustion institute, an idea that have been around for some time. The argument for establishing the institute at CFRI is based on the facts that the infrastructure of coal science and analytical service are in place and there is a Coal Survey Office on site that could help in coal sampling and selection. A core group of chemical engineers and chemists could be formed readily.

Collaborative Efforts and Management

U.S. organizations provided patent literature and supplied samples of suspension agents obtained from American manufacturers. Technology transfer was thus limited to instrumentation provided by USAID via Viking Engineering. At the same time the CFRI staff felt that DNES and USAID were effective in their management of the program. Dr. Gururaja provided guidance and seemed to have confidence in the ability of CFRI investigators to carry out their work. DNES kept them informed of workshops, seminars and USAID activities relating to the CWM project.

Relevance of Selected Technology

The technology selected is relevant to the safe and convenient transportation of coal. Coal dust/air mixtures are always a potential explosion hazard, even during short transport distances when a static discharge is possible. Other technology involved the ability of stabilizers to prevent settling even at no flow conditions for a long time. The additives used are organic compounds and probably combustible in a fire box. Information on this problem was obtained at the New Technologies meeting in Honolulu (1985). Other collaborative ties established in the U.S. are also expected to continue.

Although the equipment needed for the project was received late, it was put into service effectively. Delivery delay was similar to that found in other projects, specifically the need for the Government of India to be convinced that equivalent equipment is not available domestically, a reasonable request. However, excessive delays in the program schedules can result because of the lack of a knowledgeable intermediary.

Further Activities and Continued Involvement

Now that the coal-water-mixture project is underway some equipment limitations are apparent; the equipment received met specifications and operates properly. The desirable extension is the capability to expand the maximum and minimum viscosity readings for the second phase of the work. Based on the completed work, the proposed project has four studies:

1. Develop more effective additive systems that would allow higher concentrations of coal, improved fluidity and still maintain stability.

2. Optimize the physical parameters such as particle size distribution, concentration of additives, milling, mixing, etc.

3. Design and install a pipe loop to study the flow of CWM through a pipeline at anticipated operating conditions.

4. Design and build a facility for the continuous preparation of CWM. The dispersed coal product would be the feedstock for combustion and gasification units.

3.2.5A Coal-Water-Mixture Combustion (BHEL-T)

A normal extension of the slurry-preparation work at the CFRI is its preparation and combustion on a large scale. To this end a 0.5 m x 0.5 m fluidized bed combustion unit is under construction at Tiruchiapalli (Trichy). There is a world wide background information on coal-water slurry combustion but often as an oil substitute and with low ash coals. In India the problem to be investigated is the combustion of high ash coal and washery tailings that still contain carbon. Preliminary tests reported at the Second Annual Workshop proved that the slurries could be burned.

Factors to be evaluated in the new FBC unit are facilities for bulk preparation of CWM, pressure drop measurement, erosion testing, scale up factors and combustion performance. A separate test rig will study nozzle designs that may be suitable for atomizing and burning 400 Kg. of CWS per hour.

Recommendations

The Government of India is apparently committed to the development of fluidized bed combustion technology. Small commercial units are in operation and an objective of BHEL is to bring this technology to the power industry. It would be of advantage to USAID to support this activity and be privy to commercial developments. CWM know-how is an integral part of the combustion system.

3.2.6 Bharat Heavy Electricals Ltd. (BHEL - T)

BHEL is a large integrated corporation and the site at Tiruchirapalli has several pilot plants. The ones of particular interest were the new 1m x 1m atmospheric pressure fluidized bed combustor (AFBC) and the combustor for coal-water-slurries. Design and approval of 30 MWe plant has been completed. At the moment they are waiting for word from AID concerning financial support. Smaller commercial AFBC units are in operation, a distillery, polymer plant, cement plant, fertilizer production, paper mills and a sugar plant. Others are under construction for process steam, cogeneration and power generation.

3.2.6.1 Evaluation of the Freeboard Performance in a Fluidized-Bed Combustor and Coal Water Mixture Combustion (BHEL - T)

Project Description

An overall objective was to design, construct, commission and operate a 1 meter x 1 meter Atmospheric Fluidized-Bed Combustor (AFBC) research test facility. To be evaluated were combustion and heat transfer in the freeboard region. Specific objectives were to:

a. Gather performance and heat transfer data.

b. Determine dust loading and gas composition along the freeboard length.

c. Correlate the freeboard performance in terms of design and operating parameters.

d. Obtain combustion efficiency and carbon burnup data as a function of fuel type and size.

e. Obtain data on the SOX/NOX reactions in the freeboard and their effect on unit emissions and sorbent utilization.

This instrumented research facility will generate engineering and performance data for burning Indian coals in the AFBC system. Engineering correlations provide a basis for the design, scale-up and performance criteria of up to 30 MWe commercial AFBC units. Cost of the project was shared by BHEL and USAID. BHEL designed, constructed, and commissioned the test facility at a cost of Rs. 35 lakhs ($350,000). USAID was to provide specialized instrumentation and data acquisition systems at a cost of $300,000. The tasks outlined above were carried out between January 1984 and June 30, 1986. Work was still in progress in January 1987.

A sizable crew of engineers and technicians were required to design and build the combustion plant and more will be needed to operate the system on a round the clock basis. Of particular interest to the USAID program is the space above the fluidized bed called the freeboard region. In this volume some combustion takes place and some heat is absorbed through heat exchange surfaces. There is also some particulate entrainment and gas phase reactions. Since fewer hot spots are found in properly operated fluidized bed, the average temperatures are lower and the formulation of SOX and NOX is reduced. Looking through the observation port one can see glowing particles flying randomly in the free space. Combustion efficiency and carbon burnup are important factors in this work. This unit has a well planned data and sample acquisition system. Data is stored in a Hewlett Packard Model 3054A computer and the gas stream is analyzed automatically by a Beckman unitized system for six components. Ultimately, the computer will be used for process control as well as data acquisition and analysis.

The present design allows for expansion of the freeboard space by adding plenum sections, and changing the fluidized bed depth to cover more or less of the horizontal heat exchanger tubes in the bed. The rest of the plant will remain unchanged.

A total of 120 tons of finished components for the test facility and the subsystems are installed at Trichy. Inspection and performance testing of the individual components was completed as was the curing of the refractory and fluidization trials. Most of the items available in India were delivered during the later part of 1985. Some of the major pieces of equipment were solids feeders, fans and blowers, refractory and insulating materials.

Following is the summary of responses to the discussion questions relating to the freeboard region of the atmospheric pressure fluidized bed combustor:

Selection Criteria and Progress To Date

There was no change in the objectives since the project inception in 1982. The unit to burn coal in a fluidized bed was designed, reviewed, approved, constructed and commissioned. On the day of the review the 1m x 1m unit was in operation.

Barriers and Constraints

Delivery of equipment by Indian suppliers was slow not withstanding the spate of bad weather. Expediting was done by the staff who followed up telex messages and phone calls with personal visits in order to get import exemptions.

Management Effectiveness

One of the things deficient in most projects was the lack of a coordinator. Acquiring of compressed gases for instrument calibration was a good example. Cylinders shipped from the U.S. got as far as Tokyo but could not be loaded on Indian planes and were subsequently returned to the U.S. An alternate route was worked out ultimately.

Institution Building and Study Tours

Institution building occurred via the combustor design review. Five engineers spent four weeks in the US and visited seven places Foster Wheeler, EPRI, Babcock and Wilcox, Combustion Engineering, METC, ORNL and TVA, the latter place was doing the review of the plant for BHEL-T.

Technology Transfer

Effectiveness of U.S. organizations and technology transfer was apparent from the speed with which work was accomplished and enthusiasm of the group for this project. Input was received from several sources and applied to the design and operation. Representatives from ORNL spent considerable time on site to provide continued support to the engineers and construction crew.

DNES did not require a periodic review but when requests for assistance were made, DNES was there to assist. On one occasion the import duty was waived because of the intervention DNES.

The technologies developed provide alternate feeding systems and will prove out the equipment arrangements such as bed heights, heat transfer, combustion efficiency, etc.

Collaborative Efforts

Here is one case where continued collaboration will play a major role. There will be considerable data exchange between U.S. agencies and related Indian offices. Typical would be TVA's interest in a boiler one step ahead of their pilot plant unit.

The equipment received was certainly appropriate. It was not timely because of natural and political constraints. Overall, the unit is underway.

Environmental Impact

On the environmental side, particulate matter and ash disposal will continue to be significant problems. The follow-on program may investigate the application of a baghouse filter. If the particle size of the fly ash is increased in the FBC system, further improvement may result.

Recommendations

The atmospheric pressure fluidized bed combustion system is on the brink of operation and taking a step in the development of a commercial power component. With the technology network already developed between the U.S. and India, it will be a benefit to continue financial support and retain access to new developments and solution to potential operating problems. This research will lead to advanced technology such as solids recycling and pressurized combustion, both of which will improve efficiency.

3.2.6.2 Coal-Water-Slurry Combustion (BHEL-T)

A pilot plant is under construction for the combustion of coal-water-mixtures. The 0.5m x 0.5m fluidized bed is flexible in that the combustible feed can be under-fired or fed to the top of the bed. Residence time and better air/fuel mixing are increased by corner fired, tangential secondary air above the slurry inlet. For this unit USAID provided an on line Brookfield viscosimeter, Haake viscosimeter for laboratory use, a Philadelphia mixer for slurry agitation in the feed tank, a Wilden diaphram pump for slurry transfer, an on line Kay-Ray density meter and ceramic tips for the atomizers. Other equipment is available for droplet size measurement using diffraction of a laser beam, a hot air tap, a petrographic microscope and surface analyzer. These last two instruments are used to examine cenospheres of burned out particles and to measure surface areas which are related to activity and carbon burn-off.

A related facility is being built to burn 400 Kg/hr of atomized coal-water-slurry. Associated equipment will ball mill the coal to a fine size and prepare the coal-water-slurry for storage. Three types of atomizers were designed and fabricated. On the day of the field visit, flow tests of one burner configuration were under way. No heat recovery is planned and ash will simply collect in the combustion chamber.

Following are responses to the questions asked of each project:

Selection Criteria and Constraints

The selection criteria were correct -- there were no changes from the original proposal. Although there were some constraints that delayed the project about 6 months, the objectives were reached.

Some items were purchased in India but some of the equipment could not be identified until the project got underway. A mass flow meter needed for the experimental program has been requested.

Although there was no individual selected to coordinate the work, some ties were developed with PETC, CFRI and the RRL at Jaipur.

Collaborative Efforts and Study Tour

U.S. organizations, particularly Viking Engineering Company, were effective in procuring equipment in a short time. However, Dr. Saluja cold not deliver it because import approval had not been obtained. After eight months BHEL paid the three lacks import duty, a heavy burden on the project. Except for the support from VEC there was no one to interact with and no one on this project visited the U.S., mainly because no one is known to be working on CWS combustion in a fluidized bed.

One reason for delay in getting started was the two years the DNES took to approve the project. Why the delay occurred was not clear.

Continued Involvement

Application of the CWM technology can go beyond coal itself. There are tailing and sludges from several sources that contain recoverable energy. The technology can also be applied to the environmentally acceptable method of undesirable waste disposal such as residues from paper mills, refineries or sewage treatment. Gasification systems may also benefit from the combustion research.

It is hoped that the present ties and knowledge of the field can develop collaborative ties. Coal-water-mixtures are used for the introduction of coal into high pressure systems and previous conferences described tests made in some industrial boilers (Florida Power and Light Co.).

In reference to project delays, the procurement of equipment was appropriate and timely by coincidence. Equipment for the pilot plant is being assembled and tests will be under way within the year. A considerable amount of study has gone into burner design configuration and materials.

Environmental Impact

Environmental considerations indicate an improvement over the other forms of combustion. The lower combustion temperatures should reduce the formation of nitrogen oxides; atomization should reduce the carbon loss and particulate retention by the fluidized bed should be improved.

3.2.7 Scale up of the Atmospheric Pressure Fluidized Bed Combustor

Project Description

A 150 ton of steam per hour AFBC was designed by BHEL engineers and through USAID, the design was reviewed by TVA engineers who operate a smaller but similar fluidized bed combustor. Five suggested changes by TVA engineers were incorporated in the final design which has now been submitted for funding. Details of the changes were described as the Third USAID/GOI Workshop in December 1985.

The 150 tons per hour unit is a cooperative demonstration between USAID, DNES, BHEL and a private customer. In the design, coal containing 6% moisture and 32% ash and about 7000 BTU/Lb is the basis. USAID would provide, through several U.S. companies, pumps, filters analytical equipment, a computer control room and an oil fired start up system.

About 3 years will be required for mechanical design, manufacture, commissioning and start up. If no major delays occur, data collection can start and steam supply to the customer will begin. Output from the unit will depend on the heating value of the fuel which can be as low as 2000 Kcal/Kg (3600 Btu/Lb). Ash contents as high as 70% are considered when coal washery rejects are burned, moisture contents as high as 55% are considered for lignite or bagasse combustion.

Technology Transfer and Study Tours

This project moved ahead at a steady pace because no equipment supply was involved. Technology transfer from TVA was extensive; two TVA engineers visited BHEL and a BHEL engineer visited the TVA plant. These ties will undoubtedly continue because these in much interest in both organizations.

Environmental Impact

Environmental impacts should be similar or less than that described for the AFBC unit. The ash recovery system will be closer to power plant size and the efficiency of collection should be improved. Fluidized bed combustion of Indian coals minimizes the discharge of sulfur an nitrogen oxides.

Further Activities and Continued Involvement

Utility companies in India have not yet adopted the AFBC technology although smaller systems are used in industry. A distillery operates a 12 tph FBC boiler for cogeneration, a polymer plants are under construction. One of the new units will burn washery rejects containing 65% ash. Other AFBC units will burn bagasse or rice husks.

3.2.8 Bharat Heavy Electricals Ltd. (BHEL-H)

The Corporate Research and Development laboratories at Hyderabad are extensive and apparently encompass a wide variety of programs. Mr. R.S. Rangan presented the design features of the high pressure, high temperature system for particulate removal. There was a good exchange of information on the design and possible chemical reactions. In the afternoon we visited a pilot plant on the grounds of the Regional Research Laboratory (RRL-H) where a high pressure, fluidized bed gasifier is nearly completed. The hot gas cleanup unit will be build next to this gasifier and a slip stream will be taken as feed to the hot gas cleanup system. Foundations are being dug for the new equipment.

On the gasifier structure is a rig to study solids transport and in an adjacent building is a prototype circulation system. It will be about a year before the main separation vessel will be available so that the construction and commissioning in progress will not delay the testing program. There is a good working relationship between the RRL and BHEL engineers, both are well supervised and motivated.

USAID provided the following instrumentation: a data acquisition system - HP3497A/HP7475A, a Beckman Gas analyzer for CO, CO_2, O_2, SO_2, NO and H_2 and a Kay-Ray gamma ray level monitor.

3.2.9. Hot Gas Clean-up (BHEL-H)

Project Description

There are two main objectives in this project. One was to design and procure a fully instrumented test rig for evaluating the performance of some particulate separation systems. The other was to acquaint Indian engineers with the state-of-the-art in the U.S. Hot gas cleanup in pulverized fuel boilers and combined cycle power plants were visited.

Besides observing these high temperature and high pressure particulate removal systems being developed, the engineers discussed with their U.S. counterparts, various design features. Analysis of the operational data was to evaluate the suitability of these hot gas clean up concepts for Indian coals. These same same engineers would participate in the gas cleaning pilot plants under development.

Project cost to the Government of India (GOI) was estimated at $88,000 (130 K lakh) for manpower, travel and instrumentation available in India. USAID was to purchase eight instruments and some laboratory equipment for data acquisition, gas analysis and level indication.

Major tasks were completed as scheduled. Construction is underway and should be completed in 1987. Commissioning of the system is closely linked with the pressurized, fluidized bed gasifier.

Below are responses to the routine questions asked of each project:

Selection Criteria

The selection criteria were correct and no changes were made. However, BHEL did expand the project within their own programs. There will be cooperative testing of new equipment and increased instrumentation.

Institution Building

As will be explained later, the project came into being only in mid-1984 but has progressed rapidly. On-line monitoring is still a prime objective and some good projects not included in the original proposal to USAID are of interest to BHEL. Typical USAID projects are included in the proposal for continued support, e.g., advanced filtration methods, high temperature H_2S (hydrogen sulfide) removal, alkali vapor contamination and specialized instrumentation. Some of these problems and those from the AFBC and CWM combustion are good candidates for a Combustion Institute. There is already a list of worthwhile projects.

Constraints and Actions Taken

The primary constraint on this project was finding someone to fabricate the vessel. Solicitation for bids brought only two responsive replies. The vessel is under construction in Bombay and is scheduled for delivery in December 1987. USAID and the Government of India reached agreement on this project only in 1984. Design work was begun in 1985. Further delay was caused by the change in materials of construction and some design modifications were required.

Institution Building

Institution building efforts were primarily between BHEL-H and RRL-H. Data from this high temperature, high pressure service will be of interest to power plants especially where combined cycle technology is applied. Interest of the METC manager was concentrated on sulfur removal. This aspect does not seem to be a significant problem in India unless there is a deleterious effect of even trace quantities on downstream equipment.

Collaborative Efforts

The Department of Energy manager and consultants to the program worked hard to make effective contacts in the U.S. Since there are no government supported, related programs in the U.S. information and data were not available. When nothing is available, there is nothing to be transfered. However, this project has significant merit, not only in the field of particulate removal but also the development of high pressure, high temperature (HP/HT) vessel design and solids handing.

Apparently the staff on this hot gas cleanup project worked in isolation from DNES and AID. In fact, no one attended the project review meeting in July 1986. When assistance was needed they went directly to the DOE manager or Viking Engineering. Even before USAID decided to support the hot gas cleanup project, BHEL recognized the importance of such an apparatus. It was also stated that even if DNES and

USAID decide to discontinue their support, the work will continue under BHEL auspices. Not having access to the results of this program would mean the loss of useful data on the design and operation of dynamic high pressure, high temperature systems.

Collaborative Ties and Study Tours

Although the collaborative ties established up to now were few, there is continued interest and the BHEL staff feels free to contact those in the U.S. who may be of assistance. Two of the engineers spent a few weeks at New York University where research on high temperature solids removal by electrostatic precepitation is being studied. Trips to California and Illinois were also useful in the design of the new BHEL system. At the Institute of Gas Technology gasification plant near Chicago, much useful data were provided. Plans are underway to send other engineers to the U.S. for training. Specific sites have not yet been selected.

A one year delay occurred because of the need to redesign the internal parts of the main pressure vessel that operates at 850-900 deg. C and and about 75 psig. New bids were required even though the number of potential Indian fabrications is limited. Only two companies had facilities to do the job.

Environmental Impact

Environmental impacts are expected to range from negligable to beneficial. The ash collected would be combined with the larger quantities of ash from the main boilers on site. There is the potential for removal of alkali vapor from the effluent gases which is beneficial but a possibility exists for the reaction of alkali vapors, acid gases and water vapor with the 2 mm alumina spheres that circulate within the system. There is no assurance that these reactions will occur, but are noted for the record.

3.2.10 Cold Gas Clean-Up (RRL-H)

The Regional Research Laboratory at Hyderabad is concerned primarily with biochemical problems although coal conversion projects such as cold gas cleaning and gasification units are on site.

Project Description

The cold gas clean-up and and separation unit is a small dual function system of gas feeders, flow meters, small bore tubing with compression fittings and two separation systems. One of them is an adsorption column (27 mm x 700 mm) packed with cocoanut char, the other is a rectangular flat plate flange type holder for a semipermiable membrane insert.

A short visit was made to Lurgi gasifier nearby. This unit has a data acquisition computer provided by UNIDO.

Following are responses to the series of questions requested by AID.

Selection Criteria and Modification

The original criteria were modified to exclude the separation of particulate matter. Related work is underway at BHEL on a larger scale. With approval of the METC program manager, the objective was changed to include separation of acid gases from the gasifier product stream. The semipermeable membrane separation part was unchanged but a source of membrane material has not been found. U.S. manufacturers declined to participate in the program.

Barriers and Constraints

Overall objectives were not reached because specifications for the equipment were not finalized until September 1985. No equipment was available until late in 1986. There was a problem with import licenses from the Government of India who required a specific form, in fact, the gas chromatograph arrived on the day of our visit, January 12, 1987.

Institution Building

Considerable institution building was evident. The engineering group (3 chemical engineers and 2 mechanical engineers) and the support staff were very much involved in getting the equipment on stream. Cooperation was also underway with the BHEL group working on the high pressure system. The two techniques are conceivably complementary in that both particulate matter and acid gases are removed. When the small bench scale work is completed with a synthetic gas mixtures, a small gas stream from the Lurgi gasifier may be processed. An extension of this work could be the purification of natural gases containing carbon dioxide and hydrogen sulfide.

Technology Transfer and Management Effectiveness

U.S. organizations were helpful and effective. A telex or letter to Viking Engineering or to METC brought a rapid response. Usually requested was technical information or funds for additional material. The RRL-H staff was satisfied with the arrangement. Existing reports were provided and some information was available from the public domain, however, the adsorption of gases on charcoal and other high surface area materials is well known.

Effective management was provided by Viking Engineering Corp while DNES and USAID acted as a conduit and were aware of changes in the project status. For example, DNES asked for a project review in July 1986 and papers were presented at the second and third workshops. Reports were submitted every six months.

Continued Involvement

This limited project has a place in the broad subject of power generation; application to acid gas removal at temperatures up to 150°C. Past experience with the coal fired turbine at Morgantown, ca. 1955, is suggested as a reference to gas clean up problems.

Collaborative Efforts and Study Tours

Collaborative ties were established and attempts are still being made to acquire membrances of different types for testing. Inquiries by personnel at Viking and the Institute of Gas Technology have not yet been successful. Only one visit was made to the U.S. on this project. The coast-to-coast trip was short and much of the looked for data and materials were proprietary and unavailable. Future trips should be preplanned with initial contacts made locally to assure a proper exchange of data or information on samples. All of the needed equipment is finally on site, some it yet to assembled and placed on stream. Continuation of the program, according to the new proposals of one to five years, will probably require additional instrumentation.

Environmental Impacts

The best estimate at this time, before any experiment is made, will be the need for gas analyzers for carbon monoxide (CO) and hydrogen Sulfide (H_2S), both of which are environmental hazards. The hydrogen sulfide can be reduced to sulfur and water by known processes and the staff is aware of the potential problem of the disposal of adsorbants and membranes. High surface area materials such as activiated carbons present a handling problem to prevent fire and/or explosions.

Recommendation

This problem is primarily of academic interest but it can be a worthwhile investigation. The present objectives are a good start but the projects should evolve into a more sophisticated study.

3.3 Energy Efficiency

a. Project Description and Selection Criteria

The original project paper proposed a U.S./Indian technical exchange program dealing with energy efficiency in industry and transportation. A program of technical collaboration was planned with the purpose of comparing experiences and increasing the awareness of Indian industry managers of the technologies available in the United States.

During an initial visit to India, an approach of interactive workshops was defined by the Confederation of Engineering Industries (CEI) and the National Academy of Sciences (NAS), the Indian and U.S. institutions selected to conduct the program.

Energy conservation is certainly one of the most cost-effective methods for reducting energy demand and dependence on foreign imports, as has been very successfully demonstrated in the U.S. and many other countries. Including energy efficiency as a component of the AERD program was a good choice.

The need for energy efficiency has been recognized by the Government of India (GOI) which has established some limited incentives to encourage energy efficiency. Some Indian industries have recognized the economic advantages of energy conservation and have taken steps in that direction. The number of companies involved in such activities is increasing, but at a relatively slow pace, considering the obvious advantages that can be derived from conservation.

Some reasons for this slow progress appear to be: lack of awareness of the real economic potential of conservation (generally short term pay-back, relative low capital, etc.) by many industrialists, complexity of the bureaucratic process required to benefit from the incentives, nature of the incentives (reduction in electric consumption could bring a user into a less favorable price category, thus cancelling the benefits of conservation for example), lack of focus on conservation within the GOI (it is only recently -- January 1987 -- that a Secretary-level position for Energy Conservation has been created) and lack of an infrastructure of specialized consulting firms capable of delivering complete (audit-implementation-management-financing) conservation services.

Given a variety of federal, state and local policies and incentives, as well as original financing approaches, such as third party financing, a new service industry providing complete conservation "packages" has emerged in the U.S. in the last 10 years. Despite a relaxation of the American attitude toward conservation, conservation activities still take place, mostly through these consulting firms, because industrial managers have realized the benefits which can derive from conservation. This coordinated approach involving the private sector appears to be what is missing in India for conservation to expand.

It is felt that the objective of the program would have been better served, if the subproject had focused on the American experience in implementing conservation rather than on technical aspects which can easily be mastered by the very competent Indian engineers and scientists.

b. Progress to Date

Table 3.4 summarizes the tasks included in the program and their current status.

Three out of four workshops have been completed; the fourth is scheduled for early 1988.

All workshops were well-attended by a cross-section of Indian and U.S. engineers, industry managers, manufacturers, government and state representatives.

The first workshop dealt with strategies for improving efficiency in thermal energy use, low grade fuel, waste heat recovery, cogeneration, monitoring and controls, static power drives and possible strategies. This meeting seemed to have been somewhat academic and resulted only in an enumeration of general strategies, i.e., relax government regulations, increase awareness, etc.

The second workshop addressed the problems of improving the efficiency of electrical energy use: impact of power distribution on productivity, motor efficiency, packaged cogeneration systems and lighting were considered. Barriers to conservation and possible strategies were reviewed. A large number of private companies attended this workshop and contacts between Indian and U.S. manufacturers were established. This is attested by follow-up correspondence between U.S. and Indian manufacturers.

The workshops received wide press coverage and were attended by central and state government representatives.

The visit by Indian representatives to the U.S. included some site visits (GM plant, Pepco, etc.), an audit seminar, review of PURPA and a visit to the Energy Management Technology Exhibit in Atlanta.

The reports provide short summaries of presentations and discussions -- which is probably sufficient, as little new ground was broken. The reports also contain unnecessary material (sample: "The University (Georgetown U.) has a

Table 3.4 - Energy Efficiency Subproject - Tasks and Status

Tasks	Status
Organization meeting	completed
Workshop on Termal Energy Efficiency (January 86 - New Delhi)	completed
Workshop on Electrical Energy Use (May 86 - Bombay, Bangalore)	completed
Energy Mission to USA (October 86 - Washington, DC, Atlanta, GA)	completed
Workshop on Energy Management Systems	Planned; early 1988
Reports	completed (for completed tasks).

sprinkling of ivy-covered halls and is steeped in tradition that dated back to a time when cows grazed where the U.S. capital now stands.).

Tasks and reports were delivered but the project as a whole gives an impression of being superficial.

c. Attainment of Objectives

The defined objectives of the project were achieved. However, as discussed in Section 3.3.a. the overall objective of making India benefit from the U.S.'s experience in implementing energy conservation has been missed. Promoting U.S./India technology transfers in energy conservation systems should occur after channels for implementation have been established, i.e. after a conservation market exists.

d. Barriers and Constraints

None

e. Procurement Efforts

None

f. Management Effectiveness

Despite the fact that energy conservation is not part of its mandate, DNES kept informed and attended the working sessions. USAID's support was recognized.

g. Effectiveness of U.S. Technology Transfer

As mentioned above many contacts between Indian and U.S. manufacturers were established. Possible U.S. to India, and India to U.S. transfer of specific technologies were explored. These contacts, particularly regarding U.S. to India transfers, will most probably not be maintained if the basic issue of devising practical ways of large scale implementation of conservation in India is not solved.

h. Relevance of Technology Selected

This aspect has been addressed in Section 3.3.a.

i. Relevance of Collaborative Effort and Study Tours

All activities were well organized and planned as is illustrated by the answers to the evaluation forms circulated by NAS. The forms also included suggestions, by Indian participants, for topics to be discussed, activities to be undertaken, etc.

Table 3.5 - Field Test of Polymer Film Solar Collectors Subproject - Scope of Work and Status

Items	Status
Visit of STEC scientists to U.S.	completed
Visit of BNL scientists to India	completed
Procure/deliver/install	
• Collectors	completed
• Diagnostic equipment	completed
Test Collectors	completed
Evaluation of data	completed
Final report	Partially completed
Workshop/Identify Applications	Not completed
Commercialization study	completed

j. Economic Viability of the Technology

As was demonstrated by numerous examples, energy conservation is probably the most cost-effective method of reducing dependence on fossil fuels. Pay-back periods of two years or less are not unusual.

k. Institution Building Efforts

CEI is a private organization representing about 2,000 engineering industries. Its functions include promotion of its members' activities, representation, lobbying, etc. In the absence of a clearly identifiable government body responsible for conservation, the selection of CEI was reasonable: CEI has good relations with government agencies, contacts with similar industrial groups and is interested in conservation for its member industries. Although nationally represented through its regional offices, CEI only represents a narrow segment of the industry and it is not clear if, in the long run, it is the best vehicle for promoting conservation.

Currently, few institutions are engaged in conservation activities: the National Productivity Council and the Petroleum Conservation Research Association provide audit services, but no follow-up services and a few engineering firms provide conservation engineering services.

Could an option be to induce an institute such as TERI to create a Tata Institute for Energy Efficiency? Such an independent institution could represent the industrial/commercial sectors in general and through their access to government policy-makers promote conservation effectively.

l. Utility and Importance of Effort - Recommendations

The project was useful in that it brought conservation to the attention of industrialists, manufacturers and government representatives. However, as stated above, it did not address the real problem.

A demonstration of a conservation program in a chosen industry, identifying the problems and constraints inherent to the Indian context and exploring realistic approaches, should be initiated. This is discussed in Chapter 5.

3.4 Information Exchange

This section describes the status of a variety of subprojects included in the Information Exchange Component of the AERD project.

3.4.1 Field Test of Polymer Film Solar Collectors

a. Project Description

The subproject called for the testing of advanced flat plate solar collectors, developed at Brookhaven National Laboratory (BNL), under climatic conditions prevailing in India.

The BNL design offers the double advantage of high performance and potential significant reduction in installed cost (typically, the installed cost of a collector of standard design in the U.S. is about $30 per square foot, while the estimated cost of collectors of improved design is about $5 per square foot). Efficiency and projected costs of the film collectors are more favorable than those of current Indian-made collectors. Successful development of this new technology could therefore help greatly the Indian solar industry.

The tests were conducted at the Solar Thermal Energy Center (STEC) facility at Jundahara, Haryana, with the collaboration of BNL. The project was initiated in mid 1983 and concluded in December 1984.

Subsequently the project was extended in 1985 to support a special study on commercialization of polymer film collectors.

b. Progress to Date

Table 3.5 shows the items included in the scope of work and their degree of completion.

Most technical aspects of the program were completed. BNL collector tests indicate that efficiency is about 13% higher than that of average collectors of Indian design despite the harsh environment, particularly heavy dust, which it was feared, could have reduced performance due to erosion of the film surface.

Since the end of the project, the collectors have been kept exposed to the environment and are tested every six months for about one week each time. So far, after about two years of longevity testing (four experiments), a degredation of about 2% of the original performance has been noted.

As a spin-off of this subproject, the STEC staff has designed a thin film collector based on the BNL concept using only materials made in India. Preliminary tests indicate that this design is about 5% more efficient than the BNL collector. Major improvements include better insulation of the back and sides of the collector and a collector plate having better flow and heat transfer characteristics.

A summary report covering about 2 months of testing was prepared in the form of a paper presented at the U.S.-India Binational Symposium workshop on Solar Energy Research and Applications, National Science Foundation - DNES, Roorkee, August 1985. A final report and techno-economic feasibility analysis of potential applications, called for in the scope of work, were only partially completed. The final report is frankly disappointing. The 80 page report contains 30 pages of copies of equipment manufacturers pamphlets. The training received by the Indian scientist (over about 3 weeks) is described in a one page listing of his activities. About 25 pages deal with introduction, generalities, photos and data print-outs. About 12 of the remaining pages are devoted to a superficial discussion of applications for solar system (including cooling systems) and to the conclusions. A total of about 12 pages describes the accomplishments of 18 months of work: no attempt is made at describing methodologies, problems, difficulties, data processing techniques or the improved capability of STEC as a research laboratory.

An addendum to the final report devoted to the commercialization of the BNL collector indicates that contacts have been established and pursued with an Indian company interested in the concept. A detailed final report would have been very valuable as a tool for training new personnel and as an instrument for dissemination of the technology.

The special commercialization study was completed but is rather vague and superficial; the background on U.S. solar industry could have been better documented, the method for surveying Indian solar systems is not described, the estimates of payback periods are not documented and, finally, no comments are made concerning the Indian manufacturers interested to purchase sample collectors (would they be interested in a joint venture, under what terms, etc.).

Finally, the workshop planned for Delhi was not held. It could be argued that presentation of a paper at another workshop has exposed the technology. However, a special workshop, with invitation to all manufacturers, would have had a greater impact.

c. <u>Attainment of Objectives</u>

The objectives of the project were well defined. The technical aspects were achieved and have contributed to the objectives of increasing STEC's analytical capability and of introducing Indian scientists to a new approach to solar technology.

The reporting and dissemination aspects did not reach their objectives.

d. Barriers and Constraints

Better compliance with the objectives might have been achieved had a subcontractor specializing in market development been selected to conduct the commercialization study and organize the planned workshop.

e. Procurement Efforts

The project called for the delivery of experimental BNL collectors and of diagnostic equipment for standardized testing of collectors. No problems were encountered in providing and delivering the equipment.

f. Management Effectiveness

The goals of the project were achieved and schedules adhered to. Being a DNES center, STEC received all necessary support from its sponsor. STEC also acknowledged having received good support from USAID.

Both institutions, however, should have made sure that all tasks of the project had been completed.

g. Effectiveness of U.S. Technology Transfer

The private sector was not involved in this subproject as the collector tested was a prototype developed by a U.S. National Laboratory. Contacts and interactions have been maintained between STEC and BNL.

The commercialization report indicates that a U.S. manufacturer could be interested in establishing a joint venture in India.

h. Relevance of the Technology Selected

The technology selected is relevant to the efforts of STEC to develop and promote solar technology for India. The question of the relevance of solar energy in general is more difficult to assess.

The selected technology can be replicated and improved upon, as has been already shown by STEC, without USAID support.

i. Relevance of Collaborative Effort and Study Tours

The subproject called for exchange of scientists between STEC and BNL. More visits took place from the U.S. to India than vice-versa because, at the time, the Indian team included a very limited number of scientists. These exchanges were very fruitful and effective as is indicated by letters exchanged between BNL and DNES in mid 1984.

j. Economic Viability of the Technology

Experience in several countries, in particular in the U.S., has shown that the economics of solar domestic hot water or space heating are at best marginal. For this reason, most commercialization programs needed government subsidies and incentives to penetrate the market. Similarly, at present, the Government of India tries to encourage the installation of solar domestic hot water systems through subsidies ranging from 30 to 80% of the cost, depending on the end-users.

Current prices for solar family hot water systems start at about Rs. 5,500 (quote by manufacturer - Danfoss (India) Ltd.). This system (100l - input/output temperatures: 17/60°C) will provide about 50% of a family's need, or the equivalent of about 890 KWH/year. Financed at 12% over 5 years, the system will cost the family about Rs. 1,470/year. For the family to break even in 5 years, electricity should cost Rs. 1.64/KWH (Rs. 1468/894 KWH), which is well above the current price of electricity to residential customers. Through the thin film technology, STEC projects, that the cost of similar family system could be brought down to about $300 or say Rs. 3,800, and maybe less. At that price, under the same assumptions as above, the 5-year break-even cost of electricity would be Rs. 1.13/KWH, much closer to the current price for electricity.

This "back of the envelope" analysis does point to the fact that much cost reduction and/or performance improvements are needed for the technology to be economically attractive on its own merits.

Looked upon on a more global way, every KW of electricity displaced by a solar system, reduces the demand for new generating capacity, an element which should be taken into account.

To further evaluate the viability of the technology, realistic field data should be collected by monitoring the water and electricity consumptions of families with and without solar systems. Such activities should probably be undertaken by an interested manufacturer as part of his marketing strategy, perhaps under a new USAID initiative.

k. Institution Building Efforts

The project has increased the capability of STEC for pursuing solar-related research by providing STEC with a solar collector testing station not available previously. Further, the project has initiated research activities in the field of thin-film collector technology, thereby establishing STEC as a forward looking institution in the field.

Had the dissemination efforts (report/workshop) been fully completed, they would have enhanced the status of STEC among the Indian solar community.

1. Utility and Importance of Effort - Recommendations

The thin film collector has the potential of seriously improving the techno-economic prospects for solar thermal energy generation. The project has brought STEC in a position to conduct quality research and has confirmed the hopes placed in the BNL design.

Attempts should be made to compensate for the lack of dissemination efforts during this program by increasing such efforts during the follow-up program.

3.4.2 Development of a National Planning Model for Non-Conventional Energy

a. Project Description and Selection Criteria

The objective of the subproject was to develop an analytical planning model for non-conventional energy in India capable of assessing the mutual interactions between energy and economic variables. The model is meant to enable the Government of India to plan for energy use in different sectors and evaluate the impact of various energy policies.

At the time the project was initiated, energy policy analysis was conducted sporadically by various committees and there was a need for a comprehensive model of the Indian energy sector whereby energy policies could be evaluated within the framework of the overall economic development of the country.

The project was conducted by the Tata Energy Research Institute (TERI) with the collaboration of the Brookhaven National Laboratory (BNL).

b. Progress to Date

The project was initiated in 1983 and concluded in 1985. During this period, TERI developed its (TERI) Energy Economy Simulation and Evaluation Model (TEESE) based on the Brookhaven Energy Economy Assessment Model (BEEAM). TEESE includes simplified mathematical expressions for the energy flows in the economy and accounts for losses and conversion and end-use efficiencies within the overall framework of the Input/Output model for the Indian economy.

The model was established for the base year 1978-1979. Currently, TERI, under the auspices of the Advisory Board on Energy (ABE), is updating the model to the 1984-85 period and introducing some refinements such as disaggregation of some sectors in sub-classes, division of end-users by income categories, etc. Examination of preliminary runs of this updated version shows that the impact of some oil policies (level of import/export, full/partial use of domestic refineries for example) on the overall economics can be quantified. Under the current agreement between TERI and the ABE, results from the ongoing 1984-85 analysis cannot be released without the ABE's approval. It is probable that once the updated model is operational, DNES could request runs of specific cases to evaluate the impact of non-conventional energy policies.

TERI also supports the efforts of five independent institutions in developing regional energy models.

All tasks included in the program -- data gathering, training, modeling, sample cases and final report -- have been completed.

The final report, delivered to DNES but apparently not to USAID, described the mechanics of the model in precise mathematical form. It is too rigorous for lay people not familiar with the matricial formulation used. Some introductory remarks and general comments about the utilization of the model, written in practical terms, would have been useful. A pamphlet issued by TERI fills somewhat this gap.

The work and the team responsible conveys an impression of high competence and professionalism.

d. <u>Barriers and Constraints</u>

No major problems seemed to have hindered the completion of the subproject, although some aspects of the collaborative efforts did not appear to be completely satisfactory (see Sections 3.4.2.e and 3.4.2.i below).

e. <u>Procurement Efforts</u>

The project called for the transfer of an IBM (series 80 - 1M byte - hard disk) system. Some delays in procurement occurred probably due to U.S. Department of Commerce regulations regarding the shipping of electronic equipment. Further, the equipment did not function properly when received, creating delays while securing replacement parts. This could be due to the recent introduction of the equipment on the market. Unfortunately, BNL did not test the equipment before shipment, nor provide the opportunity for the Indian scientist to familiarize herself with the equipment while at BNL.

f. <u>Management Effectiveness</u>

A fairly detailed work plan was developed early in the project which was adhered to with minor variations. TERI expressed its satisfaction for the support provided by the USAID mission during the project.

g. Effectiveness of U.S. Technology Transfer

The subproject did not involve the private sector. Only BNL and its associated International Energy Studies group were involved in the collaborative effort. In view of the comments made in Section 3.4.2.i., it is improbable that an active collaboration will be maintained between BNL and TERI. This is unfortunate because TERI is expanding the scope of the model beyond BNL's original form and feed-back would have been benefical to BNL or other U.S. researchers.

h. Relevance of Technology Selected

The subproject has provided a very useful tool for energy policy evaluation. The TEESE has been adopted by the Advisory Board on Energy (ABE) and by the Gas Authority of India, Ltd., as their model for economic analysis. DNES has expressed its intention of using the TEESE model for its evaluation of non-conventional resources. Although the conclusions derived from models are only as good as the data assumptions used as inputs, if used with caution, the development of the TEESE model is timely and relevant for India's energy planning efforts.

i. Relevence of Collaborative Effort and Study Tours

The subproject involved the training of an Indian scientist at BNL. The involvement of BNL in this activity was apparently minimal and certainly less than TERI expected. This could be due to overcommitment on the part of BNL's Principal Investigator (V. Mubayi) to a variety of projects.

j. Economic Viability of the Technology

Not Applicable.

k. Institution Building Efforts

There is no doubt that the subproject has enhanced TERI's capability for evaluation of energy policies and programs. As indicated above, other institutions will also benefit from the capability. TERI has already built on the original model and shows all intentions of pursuing the development of more refined models.

l. Utility and Importance of Effort - Recommendations

The importance of the subproject's accomplishment has already been stressed; no follow-up support appears necessary for the model to be used.

Energy utilization, both conventional and non-conventional, does raise environmental and social problems: increased utilization of low quality coal may result in intolerable pollution, increased use of biomaterials for energy production could divert the resource from its traditional use and create social/environmental problems, etc. It is suggested that the possibility of including environment and social costs and benefits be considered.

3.4.3 Low Head Hybrid Micro-Hydel System

a. Project Description and Selection Criteria

This project was designed to help develop economically viable and technically feasible integrated energy systems using low-head hydro electric turbines as a primary renewable energy source. The main inputs expected from the AERD program included the development of a prototype microprocessor for electrical load management, development of various commodity producing systems, purchase and delivery of a prototype turbine for low head applications and training (the detailed scope of work is reviewed below - Section 3.4.b). The project is conducted by the Alternative Hydro Energy Center (AHEC) at Roorkee University, Roorkee; its U.S. counterpart is Boston University (BU), Boston, MA.

A survey of India's hydroelectric potential resources suggested that about 5,000 MW of capacity could be tapped. Of this capacity, about 3,000 MW appears to be available at low-head (less than about 3 m drop) sites along irrigation canals. Low-head systems could provide electrical power to villages located along these canals for lighting, irrigation, water pumping and local industries but their economic viability is limited by high capital costs (often twice that of large hydro systems) and a low load factor (20 to 40%) due to the low demand by the end-users. The approach pursued by the AHEC, under the sponsorship of DNES, is to attempt to lower the capital cost through improved civil works designs, use of most suitable turbines and diversion of surplus power, when available, to secondary loads designed to convert the surplus power to commodities which are needed and can be sold within the local economy.

The AHEC is currenty developing an irrigation canal site at Kakroi where four 100 KW turbines will be tested in parallel; one of these will be a U.S.-made Essex turbine provided under the AERD project, the others are an Indian-made unit (BHEL), an Austrian (Voess-Alpine) unit and probably a Swedish-made unit. Power will be sold to the grid or distributed to neighboring villages. The U.S. participation in this project will therefore help AHEC in establishing a valuable data base comparing turbine performance, operating and maintenance costs and other data needed to perform techno-economic evaluations of future sites.

The other facet of the U.S. contribution involves the development of a micro-controller designed to automatically switch surplus power to a variety of "dummy" or secondary loads. The secondary loads considered under the project include fertilizer synthesis, water distillation, generation of hydrogen and oxygen through electrolysis and preparation of briquetted fuel. The choice of these loads is questionable (see Section 3.4.3.j).

The U.S. involvement under AERD fits well with the stated goals of AHEC and DNES.

It should also be noted that an alternative approach to load management is also considered by AHEC; this would involve a low head system providing base load needs, complemented by a biomass gasification unit providing peak demand as needed. AHEC has developed and is testing a gasifier for this purpose and may install such a unit at the Kakroi site.

b. Progress to Date

Table 3.6 describes the items involved in the scope of work and indicate their current status. The table shows clearly that many tasks, or subtasks, have not been or are only partially completed. What is particularly distressing is that many of the tasks involving technology transfer and the training of Indian scientists associated with this transfer have not been completed. A number of reasons are responsible for the lagging progress; they are discussed in Section 3.4.3.d. below.

Apart from the development of the Kakroi site which appears to proceed reasonably well, the remainder of the project gives an impression of disarray and helplessness.

c. Attainment of Objectives

The objectives of the project were defined in rather general terms; at various stages of the project, scheduling charts appear to have been proposed but there is no indication that these schedules have been reviewed to account for delays and problems.

As indicated previously, many of the stated objectives of the project have not been achieved, particularly those involving constructive interaction between Indian and U.S. scientists. So far, the subproject has not contributed significantly to the overall objectives of the AERD project.

d. Barriers and Constraints

Since its inception, the subproject has been plagued by a number of technical and administrative delays. Table 3.7 shows the chronology of events as they appear to have taken place since the beginning of the project; some dates and event

Table 3.6 - Low Head Hydrid Micro-Hydel System Subproject
Scope of Work and Current Status

Items	Status
1. Prototype micro processor controller development	Partially Completed
2. Laboratory testing of prototype:	
- in U.S.	Status Unknown
- in India	Not completed
3. Installation/Commissioning of prototype	Not completed
4. Help design/setting up facility for development of similar controllers in India	
- Equipment procurement	Completed
- Training/assistance	Partially completed
5. Procurement of U.S. made turbine	
- Procurement/shipment	Completed - Unit in Bombay
- Installation Specifications	Not supplied
- Installation assistance by manufacturer	Not completed
6. Training of AHEC scientists	
- Controller development	Incomplete
- Secondary load	Incomplete
- Civil Engineering	Completed
7. Support for preparation of manual	Incomplete
8. Hiring of consultants	Ongoing as needed
9. Site preparation (By AHEC)	Partially completed

Table 3.7 - Low-Head Hybrid Micro Hydel System Subproject. Approximate Sequence of Events

Date (approx.)	
Early 1982	Initiation of Low-Head project under Technologies for the Rural Poor (TRP) project.
Mid 1982	Principal Investigator leaves Colorado State University (CSU) for Boston University (BU).
Late 1982	Decision to purchase prototype Schneider engine.
Mid 1983	Controller sent to India - sent back to BU for modifications.
Mid 1983	Schneider engine prototype tested in California.
Mid 1984	Controller sent to India - sent back for modifications/redesign.
End 1984	End of AERD project.
Mid 1985	Extension of AERD subproject to end 1986.
Mid 1985	Abandon Schneider engine due to unsatisfactory performance (tests by Korean licensee).
Mid 1985	Start civil work at Kakroi site.
Late 1985	Selection and order of Essex turbine.
Late 1986	Controller ready for shipment.
Late 1986	Protocol of tests of controller requested by AHEC from BU - no response as yet.
Late 1986	Installation specification for Essex turbine requested by AHEC from BU - no response as yet.
End 1986	End of AERD project.
Early 1987	Essex turbine delivered in Bombay.
Early 1987	Kakroi site partially ready: BHEL turbine installed, Voess-Alpine turbine partially installed.

description may be approximate but they are probably close enough to reality to identify the major roadblocks which prevented the subproject from reaching its objectives. Four major roadblocks can be identified:

- Transfer of the Principal Investigator from Colorado State University (CSU) to Boston University (BU). Negotiations of an agreement with BU under AERD and the move of the principal investigator from CSU to BU certainly resulted in a less than fully productive period. In retrospect, it might have been preferable to keep the project at CSU and assign a new principal investigator, particularly in view of the fact that at the time of the transfer BU was not (and probably is not as now) fully equipped to test the controller.

- Selection of the prototype Schneider turbine. This system was selected on the basis of its high claimed efficiency. Tests conducted in California indicated that the system was not as efficient as claimed and that the design had flaws. Further testing by the Korean licensee/ manufacturer confirmed this and the system was rightly abandoned in favor of a more conventional, more reliable, design (Essex turbine). This situation resulted in a delay of at least two years in the procurement of a turbine for the Kakroi site. It is not clear how the Schneider turbine was selected originally, but its unusally high claimed efficiency combined with less than convincing performance in California should have raised questions as early as mid 1983. A small panel of experts could have been called in at the time, which probably would have advised caution and selection of a more reliable turbine. Enthusiasm for an apparently revolutionary design may have overtaken caution in this case.

- Development of the controller. This element of the subproject has been seriously lagging throughout the project. The reasons for this are not clear but could be that too many sophisticated functions were included and that the goals may have been somewhat unrealistic for a first attempt at a prototype controller. On several occasions, the prototype was tested and rejected for lack of satisfactory performance. A careful review of the goals could have been done at those times and less complex objectives defined, which, while not necessarily providing a fully developed prototype, might have provided a "proof of concept" of the approach of automatic load management.

- Interaction and management. In contrast to some other projects (gasifier projects for example -- Section 3.2) for which clearly defined objectives and timetables were established early in the project and during which periodic reviews of achievements and revision of the plans took place through joint meetings of the U.S. and teams involved, this project appears to have lacked this kind of constructive interaction and management. Several situations (referred to above) occured when the opportunity and the need, for this kind of interaction existed, but unfortunately nobody assumed the leadership required. This could be due to a lack of definition of the respective roles of the parties involved. In recent months from about October 1, 1986 on, reminders that the project was due to end by December 31, 1986 and that progress reports were due, were sent to BU by USAID and AHEC.

Independently of the work pursued under AERD, the development of the Kakroi site, which is necessary for the testing of turbines, is a complex enterprise involving AHEC at Roorkee (4 hours by car from the site), State agencies responsible for waterways and power generation and the engineering firm doing the work. All parties involved have done a very credible job but the administrative problems encountered should be documented so as to be able to streamline operations when further projects are undertaken.

e. Procurement Efforts

The subproject called for the transfer of laboratory and field equipment (turbine). Most of the equipment has been shipped and received. Some potential problems could have occured at customs because the description of the equipment shipped did not reach AHEC on time.

f. Management Effectiveness

The problem of management and interaction at the level of the Indian and U.S. counterparts have been described in Section 3.4.3.d. above; they can be summarized as a lack of initial planning (tasks/schedules), lack of periodic reviews and overall lack of clearly defined leadership.

This leadership could have been assumed by DNES and/or USAID. Unfortunately, until very recently, neither organization has taken necessary steps to untangle what can only be characterized as a mess.

g. Effectiveness of U.S. Technology Transfer

A U.S.-made turbine was transfered for comparative testing with Indian and other foreign units. So far, no direct contact between AHEC and the U.S. manufacturer appear to have taken place. Despite requests from AHEC, installation specifications and drawings have not been sent, which has prevented AHEC from preparing the site for turbine installation. A visit by a U.S. technician is planned for the installation and commissioning of the turbine which will establish a direct link between the U.S. manufacturer and AHEC. Once the system is operational, the Indian team is quite qualified to operate the system.

Depending on the outcome of the comparative tests, further contacts between the U.S. and Indian manufacturers may be pursued.

i. Relevance of Collaborative Effort and Study Tours

A civil engineer received training at CSU. This stay was very successful and has resulted in the incorporation of improved designs for the civil works of projects carried by AHEC. There are indications that this contact will be maintained and result in fruitful exchanges of information.

As indicated above, little interaction appears to have taken place between AHEC and BU during the design and development of the prototype controller. Equipment was sent to AHEC, but without the necessary training, its usefulness is limited. A study tour by professor D. Das, which was to include controller design activities at BU, proved disappointing because BU's laboratory was not operational at the time.

j. Economic Viability of the Technology

Two major applications appear feasible for the technology: low-land generation along canals which may be within a reasonable distance of the grid and generation of power for isolated villages (mostly in hills).

In the first case, access to the grid, the low-head unit could provide free or low cost electricity to a group of villages and sell the remainder to the local power authority at a predetermined price. This option is being considered for the Kakroi project where the State Power Agency has offered to purchase power at Rs. 0.8 /KWH. It has been argued that a generating capacity of a few hundred KW may not be of interest to utilities; however, if a series of low-head plants are installed along a canal (every 10 to 15 Km for example), the total capacity may reach several MW, a level of capacity which may be of interest to the local grid.

It is obviously too early to make completely realistic projections of the economics of the system; indeed, one of the main objectives of the Kakroi and other project sites is to generate the data base needed for such analysis. However, preliminary analysis (see Appendix C) suggests that, on the basis of prices quoted for Kakroi, the return on the investment could be attractive for an investor (situation comparable to that projected for wind mill farms in Gujarat).

The case of villages in hills is less clear. Conceptually, producing commodities saleable on the local market is a good idea. However, the market for some of the commodities (hydrogen/oxygen, distilled water) is limited in isolated rural areas. Further, if sufficient biomass is available to manufacture briquettes, why not use a gasifier which price per KW installed is lower than that of turbines. Similarly, the cost of fertilizer produced from electricity will be very high (28 gr production/3 KWH) and requires a source of phosphate in the proximity of the site. Some more basic "dummy" loads more appropriate to the village environment may have to be considered (water pumping storage, hot water, driers, storage of food, etc.). The needs may not be sufficient to absorb the full extra capacity. The economics are complex and unclear and may in fact suggest that the concept of maximum load utilization may not be practical in the context considered.

k. Institution Building Efforts

The delivery and planned installation and operation of the Essex turbine will contribute to AHEC's goal of developing a data base of turbine performance and economics which will help in future development of the low-head hydro resource in the country.

The other facet of the program, i.e. controller development, which should have resulted in establishing a capability for the development of electronic micro-controllers has not been achieved.

l. Utility and Importance of Effort - Recommendations

In view of the large resource available and of the encouraging preliminary economics, this subproject is certainly relevant.

Should the USAID involvement stop at this stage, an important element of the subproject (electronic control) would be missing. Apart from creating a feeling of frustration on the part of the Indian scientists involved, it would also delay the establishment of an important component of AHEC research capability.

It is therefore suggested that this subproject be granted an extension of about 15 months under AHEC; consultation with AHEC indicates that this time frame would be sufficient to complete the work, provided BU can be made to adhere to a strict schedule. More detailed recommendations are presented in Chapter 5.

3.4.4 100 KW Gasifier Engine Generator System

a. Project Description and Selection Criteria

The subproject calls for the installation of a demonstration biomass gasification plant of 100 KW capacity at Junagadh, Gujarat. The unit will provide electrical power to two local industries, the Junagadh Dairy of the Gujarat Dairy Development Corporation (GDDC) and the adjacent oil mill complex of the Gujarat Cooperatives Oil-Seed Growers Federation (GROFED). The gasifier will use groundnut shells, a captive resource, the surplus of which must currently be disposed of.

The objective of the experiment is to test a 100 KW unit under field conditions, gain experience in gasifier operation, gather techno-economic data to evaluate the viability of the technology and replicate the system in other industries. The proposed system is intended to provide all the electrical power necessary to the two industries, the surplus power will be absorbed by the grid.

The project was selected as exemplifying one of the potential applications for gasifiers, i.e., captive power generation, captive resources and industrial users subjected to power shortages. If successful, the demonstration will provide very valuable data about the potential of gasifiers in local industrial situations.

The principal investigator will be the Gujarat Energy Development Agency (GEDA); the end-user recipients of the generated power, the dairy cooperative and the oil mill complex, will collaborate on the effort by providing biomass fuel, man power and space for installation. The overall management will be provided by DNES. A U.S. manufacturer will provide the gasifier/engine/generator set and other equipment.

b. Progress to Date

The project still awaits official authorization to proceed.

c. Attainment of Objectives

The main objective of the project is to gather and evaluate techno-economic data. This task will be accomplished by GEDA. The proposal does not identify clearly which data will be collected, equipment needed or procedures to be followed. A carefully designed evaluation plan should be laid-out before initiation of the project to ensure that the maximum possible information is gathered.

d. Barriers and Constraints

The project was proposed and approved, in principle, in 1985. Since then several difficulties concerning the selection and procurement of the equipment were encountered:

- originally, GEDA proposed to procure the equipment,
- end of 1985: GEDA suggested USAID procure the equipment,
- early 1986: specifications were prepared by a U.S. contractor (TVA)
- May 1986: decision is taken to search negotiated bids for R&D equipment
- end 1986: GEDA proposes to do the procurement expecting to negotiate a lower price
- early 1987: authorization to proceed is expected shortly from the Indian Department of Economic Affairs.

Initiation of the project has been delayed for a number of reasons.

The attempt at selecting a U.S. manufacturer willing to provide equipment responding to the specifications proved fruitless; this step could have been avoided by involving a knowledgeable U.S. consultant in the initial discussions who could have confirmed that no U.S. manufacturer is prepared to deliver fully commercial equipment in the hundred KW capacity range. The PETC team responsible for the gasifier projects under AERD included such specialists. Switching back and forth the responsibility for procurement between GEDA and USAID also proved time consuming.

Finally, as all other projects, this project requires the authorization of the Indian Department of Economic Affairs to proceed. To request this authorization, a budget must be submitted which requires a preliminary (unofficial) round of bids, which must be followed by a final round of bids once the project is authorized. These procedures imposed by the Indian government can probably not be simplified, but some streamlining of the preliminary steps should be considered.

e. Procurement Efforts

Described in Section 3.4.4.d. above.

f. Management Effectiveness

The proposal calls for the creation of a monitoring committee including representatives and experts from the parties involved, i.e. DNES, USAID, GDDC and GROFED to supervise and review the progress.

Clearcut objectives and schedules as well as responsibilities will have to be established for the committee to be effective.

g. Effectiveness of U.S. Technology Transfer

The gasifier unit will be provided by a U.S. manufacturer. Apart from the installation and commissioning of the unit, the proposal does not indicate that further links with the U.S. manufacturer will be maintained (see Section 3.4.i. below).

h. Relevence of Technology Selected

As indicated earlier, the technology appears promising for the context in which it is tested. If the demonstration is conclusive, it will facilitate commercialization.

i. Relevance of Collaborative Effort

The fact that the U.S. manufacturer can only provide a R&D or precommercial gasifier unit suggests that the manufacturer could benefit from the data generated during the demonstration. The proposal does not mention this collaborative aspect. It is suggested that the manufacturer be involved in the design of the testing and data gathering procedures and that a mechanism be established whereby the manufacturer will be kept informed of the progress of the demonstration.

j. Economic Viability

The fact that the gasifier should provide uninterrupted power to the two industries may be enough of an economic advantage to justify this kind of captive power plant. The low cost of the fuel and high usage factor also suggest that the unit could be competitive with grid power.

k. Institution Building Efforts

A successful demonstration will reinforce DNES and GEDA's capability for implementating industrial gasifier applications.

It is recommended that the project be pursued, with the proviso that clearly defined plan of action and data gathering procedures be established and that the U.S. manufacturer be involved in the demonstration.

3.4.5 Thin Film Collector Technology

a. Project Description and Selection Criteria

The first project dealing with solar energy -- Field Test of Polymer Thin Film Collectors, Section 3.4.1 -- indicated that the advanced design for flat plate solar collectors proposed by BNL had definitely better cost and performance characteristics that the average collectors currently produced in India. The development and, ultimately, commercialization of the technology could have a very favorable impact on India's solar thermal energy industry.

The present project is a follow-up of the original project. Its objectives are to advance the technology and applications of thin film collectors by establishing the capability of thin film materials testing and of hot water system designing and by promoting the technology through workshops and information exchange.

b. Progress to Date

Table 3.8 lists the tasks included in the scope of work and indicate their degree of completion.

The detailed work plan has been completed. Although it does not identify time frames for completion of the various tasks, if one assumes that the proposed exchanges of scientists indicated on the schedule correspond approximately to training and set-up activities, the plan should permit completion of the program if schedules are adhered to. Although USAID had insisted on quarterly progress reports in its Revised Statement of Work (January 86), no mention is made of these in the Work Plan submitted and the first quarterly report due has not been submitted to USAID.

The project was initiated in August 1986 and is due to be completed at the end of September 1987. Work is ongoing on all tasks; the status reported in Table 3.7 is based on records of correspondence between BNL and USAID and on conversations with DNES-SEC.

Items c, d, and e cannot be evaluated at present.

f. Management Effectiveness

DNES and BNL, through numerous cable requests, have expressed concern about the delay in the approval process for the current project (Phase II). This delay was motivated by

Table 3.8 Thin Film Technology Subproject
Scope and Current Status

Tasks	Status
1. Detailed Program Plan	Completed
2. Experimental Test Facility	
- Set up	Early 1987
- Training	Planned
- Tests	Not completed
3. Design of Hot Water Systems	
- Hardware/Software	Early 1987
- Training	Planned
- Design Studies	Not completed
4. Workshop/Information Exchange	Not completed
5. Equipment Procurement	Partially completed

USAID's insistence on focussing the program on objectives compatible with BNL's expertise and compatible with DNES/SEC's goals of promoting solar thermal energy. In the long run, these delays may be benefical because there is a better chance to reach the objectives of a well-defined program than those of a broad, all-encompassing project.

Items g, h, i and j cannot be evaluated at present.

k. Institution Building Efforts

If successfully completed, the project will largely increase SEC'S capability to conduct quality research. The ties with BNL will also be enhanced.

The full benefit of the program, i.e. to establish SEC as a leader and innovator in solar technology among India's solar community, will only be achieved if the Information Dissemination (including workshops) task is emphasized. This is essential because such an opportunity was missed in the first program.

l. Utility and Importance of Effort - Recommendations

If successful, the program will provide data which should enable DNES and a panel of experts to evaluate the potential of thin film collectors in India.

It is recommended that dissemination efforts be undertaken as soon as possible. A first step could be to send a letter/pamphlet to all known manufacturers of collectors, describing the thin film collector (advantages, performances, estimated costs, etc.) with an enclosed return card by which the manufacturers could express their interest and request more information. For those manufacturers having expressed interest, a second step could be to offer one free (or nominal cost) collector for testing. The offer would be tied to the manufacturer's agreement to send back performance data, comments, suggestions, etc. by completing a test form designed by DNES. Such an approach (or some variation of it) would have several advantages: it would involve the manufacturers, it would establish a dialogue between DNES-SEC and the private sector, it would provide some field exposure and data, and, some useful suggestions may be provided by the manufacturers which could be analyzed and evaluated during the project. It would also show that DNES/SEC "means business" and is confident that the technology it promotes is superior to current systems. Such a plan would require a certain investment on the part of DNES, but it is felt that the potential benefits in terms of future commercialization outweight the cost.

4.0 OVERALL PROJECT ACCOMPLISHMENTS

This chapter attempts to provide an overview of the AERD project and its subprojects. The first section deals with biomass, energy efficiency and information exchange subprojects, the second with coal related subprojects.

4.1 Biomass Production, Biomass Conversion, Energy Efficiency and Information Exchange Subprojects

This subsection attempts to rank the subprojects on the basis of fourteen categories: to the twelve categories suggested to the evaluation team, a documentation/ dissemination and environmental categories were added. The purpose is not to make comparisons between projects. This could be unfair to some projects because of extraneous circumstances, but, rather, to provide an overall profile of performance of the projects as a whole. It is hoped that this review will provide constructive suggestions for improving the efficiency of future projects.

A ranking system from 0 to 5 is used:

0 : Not done
1 : Poor
2 : Not Satisfactory
3 : Fair/Satisfactory
4 : Good
5 : Very Good

NA: Not Applicable (project not started or partially completed)

A low ranking indicates problems in the category considered; for instance, a low ranking under "Barriers" or "Procurement" indicates that problems hindered the development of the project or prevented satisfactory procurement.

Table 4.1 presents the summary evaluation of the individual projects.

The following general comments can be made:

- Project Selection: Most projects were well selected -- prospects for the technologies, potential impact, Indian capabilities. Two exceptions: energy efficiency which does not address the real problem and hydro load management which appears too optimistic and not quite realistic. Better definition of the projects should have taken place during the initiation phase of the projects. A third project, biomass

TABLE 4.1 SUMMARY EVALUATION OF PROJECTS

	Project Selection	Progress	Attain- of object.	Barriers and constraints	Procurement	Management effective.	US Tech Transfer	Relevance technology	Collab. Efforts Tours	Economic Viability	Institut. Building	Utility Importance Effort	Document tation Dissemination	Enviromental
1. Biomass Production														
1.1 Biomass Production (NBRI-MKU/BU)	2.5	NA	(2)	NA	NA	(2)	NA	(2)	NA	NA	3	(2.5)	NA	4
2. Biomass Conversion														
2.1. Gasifier (Charcoal - IIT)	4.5	4	4.5	4	3	3	4	4.5	5	3.5	4	4	3.5	2.5
2.2. Producer Gas Engine (Charcoal - IIT)	4.5	4	4.5	4	3	3	4	4.5	5	3.5	4	4	3.5	2.5
2.3. Gasifier (Wood - SPRERI)	4.5	4.5	4.5	4	2.5	3	4	4.5	5	3.5	4	4	4	2.5
3. Energy Efficiency														
3.1. Energy Efficiency (CEI)	2	3.5	2	5	NA	3	2	2	5	4	2	2	4.5	3.5
4. Information Exchange														
4.1. Thin Film Polymer Solar Collectors (STEC)	3	3.5	3.5	2.5	4	2	4	3.5	4	3.5	2.5	3.5	2	3
4.2. Energy Modeling (TERI)	4.5	4.5	4.5	5	2.5	2.5	2.5	4.5	2	NA	4	4	2.5	NA
4.3.a. Low-Head Dydro -(AHEC) - Turbine	4.5	3	(3.5)	1	2.5	1	2	4.5	2	3.5	3	4	NA	3
4.3.b. Low-Head Hydro - (AHEC) - Load Management	2.5	1	1	1	2.5	1	0	2	1	2	1	2	1	3
4.4. 100 KW Gasifier Demo (GEDA)	4.5	NA	(3.5)	1	2	1	2	4.5	2	3.5	NA	4	NA	2.5
4.5. Thin Film Solar Collect. Technology (STEC)	3	3	(3.5)	NA	3	NA	(4)	3.5	(4)	3.5	NA	3.5	NA	3

Ranking: 0: Not Done
1: Poor
2: Not Satisfactory
3: Fair/Satisfactory
4: Good
5: Very Good
NA: Not Applicable

production, is also ranked somewhat low; this reflects the concern by the team that, under its current definition, the project may not achieve its original goal of providing the near-term research support needed to develop and implement short rotation forestry projects.

- Progress: Most projects have attained their stated technical objectives, with the exception of the hydro load management project which is seriously lagging, the 100 KW gasifier which is not approved as yet and the biomass production project which has just been initiated. The reasons for this are considered under other headings.

- Attainment of Objectives: Most projects have attained the overall objectives of advancing India's capability of increasing the use of non-conventional energy to displace petroleum derived fuels (ranking between parenthesis refer to unfinished projects which, if successful, could attain these objectives). Energy efficiency hydro load management and biomass production in its present form are exceptions.

- Barriers and Constraints: Several projects faced serious problems which hindered their progress. The low head hydro projects and the 100 KW gasifier projects suffered from a variety of administrative and organizational problems, many of which could have been avoided through effective management, better background information and a well defined chain of responsibilities. The marketing aspects of the thin film collector project could have been better served had a subcontractor specializing in market analysis been selected.

- Procurement Efforts: All projects have had to deal with the complex and frustrating formalities of Indian customs. Although the equipment imported, being for research purposes, should not be subjected to the standard inquiries of whether it can be secured in India or not, many delays have resulted from the administrative roadblocks that have to be overcome to import research equipment in the country.

Most projects encountered procurement problems: poor documentation of shipments, poor documentation of equipment characteristics, missing or broken parts, lack of testing of equipment prior to shipment, and others. Some of these have compounded the general problem of customs clearance alluded to above.

In several cases, it turned out that, after delivery of the research equipment, the required calibration gases were not available in India. A serious oversight, which resulted in the said equipment being idle for much of the project period. The problem was further amplified when it turned out that the U.S. carrier landing in India refused to accept compressed gas bottles as freight; a foreign carrier had to be identified and the necessary waivers obtained before the calibration gases could be shipped from the United States.

It must be recognized that the U.S. procurement subcontractors often have the difficult task of purchasing and shipping specialized equipment on short notice. However, some of the above mentioned problems could have been avoided had some firm purchasing contracts specifying the subcontractor's responsibility -- timely documentation, follow-up requests, checking/testing before shipment, interface with supplier, etc. -- had been established.

- Management Effectiveness: Some projects received appropriate support (1.1 to 1.3, 2.1 and to a certain extend 3.2). Once these projects were initiated, the U.S. and/or Indian teams involved appear to have "carried the ball" insuring that objectives, schedules and budget were respected. In those instances the role of DNES/AID was limited to providing the financial and general administrative support needed.

Two projects, thin film collector and energy modelling, although successful technically, could have received more attention regarding their dissemination. The energy modelling project submitted a final report to DNES (apparently not to AID) which is too technical for effective dissemination. The thin film collector projects did not complete the dissemination part of the project: a planned workshop was not organized and the reports are of poor quality. USAID made attempts to improve the quality of the reports but without success. Some means should be found to improve this situation -- final payment could be delayed until all deliverables have been received, reviewed and approved by DNES/AID as is standard practice with most U.S. government contracts.

The hydro project (2 subtasks) and the gasifier demonstration project give the impression of having been initiated and then abandoned to their own fate. Several opportunities presented themselves at which point review/reorganization/updated planning of the projects could have occurred. These opportunities were not seized. Many of the difficulties were of an administrative/organization nature (structuring of program, selection of equipment, procurement, etc.), areas in which it is felt DNES/AID should have stepped in more forcefully. More pressure should also have been applied to the U.S. contractor (BU) responsible for the hydroproject and, retrospectively, the decision of transferring the project from CSU to BU can be questioned. Inputs from an independent panel or individual could probably have avoided some delays.

Finally, delays were encountered in initiating the follow-up thin film collector project. These delays resulted from AID's desire to focus the project on well defined objectives, a good management decision. Some time might have been saved had AID stated more clearly from the start the framework within which it would consider a follow-up project.

- U.S. Technology Transfer: Several projects have resulted in effective transfer; most of these projects do not involve the private sector -- they are mostly R&D technologies developed in universities or laboratories -- but the links established will probably provide feedback to the U.S. entities involved.

Two projects (low-head turbine and gasifer demo) involve the U.S. private sector. These are ranked low in the evaluation because the plans, as they stand now, indicate little involvement of the U.S. companies other than delivering and commissioning the equipment. An effective feedback mechanism to the U.S. private sector should be established.

- Relevance of Technology Selected: Most of the technologies selected appear to offer good potential for implementation and for contributing to the goals of the AERD project.

The relevance of the load management controller project, although conceptually valid, is questionable; the objectives appear somewhat far fetched and unrealistic. As indicated before, the energy efficiency project could have addressed more relevant aspects of energy conservation.

- Collaborative Efforts and Tours: Very good comments were made about the collaboration received from the U.S. contractors for the small gasifiers, solar and energy efficiency projects.

The energy modeling effort seems to have suffered from over commitment of the U.S. contractor (BNL already heavily committed to the thin film collector project).

The suppliers of the turbine and gasifier demo units should be brought into the collaborative efforts as was pointed out before.

The collaborative support received from BU (load controller) has been minimal and raises again the questions of selection of the contractors and of monitoring of the projects.

- Economic Viability: All projects except load management, appear to be reasonably viable economically at present. Much data needs to be collected before more reliable assessments can be made.

- Institution Building Efforts: Several institutions have, or will, benefit from the project by having enhanced their research capability and by establishing themselves as credible research centers.

The energy efficiency project has confirmed CEI's interest in conservation (in general) but it is not clear whether CEI is the best vehicle for promoting conservation programs (except among its own members).

- Utility and Importance of Effort: Most projects have suffered from inappropriate documentation and/or dissemination efforts. This reduces the potential benefits of the project, particularly regarding the building of institutions. As suggested above closer monitoring of this aspect of the projects should be provided.

In an attempt to better monitor projects, AID requested that quarterly progress reports be submitted (thin film collector technology). No trace of such report was found; the problem of enforcing the terms of the agreements is raised again.

- Environmental: The gasifier projects, particularly wood based, do raise the issue of overuse of an already scarce resource if dissemination is attempted before reliable sources of wood fuel such as energy plantations, are established and productive. The products of gasification (ash, carbon dioxide, water) have essentially no effect on the environment as they are recycled in successive crops of energy plantations.

The other technologies considered, if properly implemented, have little or no impact on the environment.

Overall, most projects have been reasonably successful. The less successful projects point to some problems which should be addressed (see Chapter 5).

4.2 Coal Projects

4.2.1 Fulfillment of Project Objectives

Annual workshops, periodic reports and site visits were instrumental in keeping all projects moving ahead and close to the milepost schedules established. Officials from both the United States and India were explicit in their praise of this program. The projects pursued were carefully selected from several possibilities to assume both countries of mutual benefit.

Selection Criteria and Progress to Date

Objectives established were reached with rare exception having to do with import approvals which take time due to administrative delays. The U.S. manufacturers were prompt in making equipment available for export and U.S. export approvals were obtained quickly. Technology transfer and private sector involvement were much in evidence. Personnel from each country spent considerable time at facilities of interest to them and were able to contribute to each others know-how. Study tours were of particular benefit because of the variety of facilities made available to the engineers. Visits were to government and private facilities and some individuals attended professional meetings. Some of the chemists and engineers are members of professional societies in the U.S. and some were given the opportunity to attend meetings and meet with colleagues. These visits reconfirmed old ties and established new ones. A summary of the Coal Development Projects is shown in Table 4.2.

Recommendations

The USAID/GOI program met most of its goals and some selected parts are poised for continued R & D activity. In particular, the larger fluidized-bed combustion unit is ready for operation to prove the experience gained with smaller systems in the U.S. and in India. The technology seems ready for expansion to larger scale where it will be determined that the extrapolated data is applicable or not. Because of the experience and background of the individuals involved, a high degree of success is anticipated.

Accomplishments of the program are the result of continuous monitoring and the ability of the prime contractor, Viking Energy Corporation (VEC) to make appropriate local arrangements in India. The importance of the ability to work with local officials cannot be overemphasized. After careful review and analysis it is apparent that parts of the proposed new program, based on past successess, is ready for continued support.

4.2.2 Current Status

Extreme efforts by the personnel at each location made possible the bulk of the accomplishments. Long delays in approval of imported equipment made completion of some projects impossible or tests were made in haste to demonstrate the commitment of those involved to the projects. Extension on some projects has already been granted so that work can continue while the new funding is being organized. In the case of BHEL, the corporation has continued the support. On the day the review teams visited, all projects seemed to be underway.

4.2.3 Project Management and Design

The proposals as set out in 1982 were apparently well conceived. Only minor changes were needed to fulfill the objectives reached. Unfortunately, internal problems, similar to most countries that must import much of their goods, exist

Table 4.2

COAL DEVELOPMENT PROJECTS

	SELECTION CRITERIA CORRECT	OVERALL OBJECTIVE REACHED	CONSTRAINTS & ACTIONS TO OVER-COME	INSTITUTION BUILDING SUCCESS	EFFECTIVEN. OF US ORGAN-IZATIONS	EFFECTIVEN. OF US TECH. TRANSFER	MGMT. EFFECT. DNES/USAID	RELEVANCE OF TECHNOL. SELECTED	CONTINUATION OF TIES	EQUIPMENT PROCURFMENT TIMELY/APPRO	ENVIRON-MENTAL IMPACT
FREEBORD PERFORM. FBC	5	5	3	4	3	5	5	5	5	4	3
SCALE-UP AFBC BOILERS	5	5	0	5	3	5	3	5	5	NA	1
COAL-WATER SLURRIES	5	5	3	4	3	1	2	4	3	2	1
COAL PREPARATION	5	5	3	3	4	4	4	5	4	3	1
HOT GAS CLEAN-UP	5	2	1	2	4	0	0	5	3	3	2
COLD GAS CLEAN-UP	4	2	2	4	3	4	2	3	2	4	1

Rating 0 to 5
0=nil 3=average 5=very good

in India too. Some management was exercised locally by DNES but acquisition of material and equipment had to be provided by the contractor (VEC) and by contract monitors in the U.S. support agency (DOE). Working across several thousand miles and with only annual meetings, some delays were unavoidable. An exception to this last statement was the considerable time spent at BHEL-T by a representative from the Oak Ridge National Laboratory.

4.2.4 Technology Readiness/Application

Only one project can be considered ready for application. Design was completed and evaluated for the 30 MWe scale up. There are places where this technology is applicable. Concern was expressed at BHEL that unless the program is continued, the commercial partner may drop out. On the other hand several smaller AFBC units are already operating in widely dispersed locations in India and BHEL seems committed to continue the development. The next technology will probably be the combustion of coal-water mixtures. Burner designs with erosion resistant inserts should be proven out within the next two years. Significant testing will be completed in the burner test chamber and in the AFBC units. Finally, the high pressure/high temperature gas clean up will follow in about 3 to 5 years. There are still some questions of solids transport, stability and vessel design that must be answered.

The other three projects are nowhere near application or on a scale that has no practical significance. At least two of them, coal-water-mixtures and cold gas clean up are academic in nature. The third project has little chance of success because of the mode of ash distribution in Indian coals. Fine grinding does not significantly isolate ash from the coal matrix. Petrographic thin sections should provide the answer to this comment. Some other reasonable approach to ash removal is necessary, coal preparation technology or acid extraction are probably not the answer. The nearest scheme that seems to make sense is gasification or combustion to yield hot gases for downstream application despite the high ash burden. Plans are being considered for ash utilization with or without unburned residue.

5.0 RECOMMENDATIONS

5.1 Biomass Production, Biomass Conversion, Energy Efficiency and Information Exchange Projects

The following present some general recommendations regarding the management of projects as well as more specific recommendations concerning individual projects.

5.1.1. General

As was pointed out in Chapter 4, Section 4.1, some projects have suffered from insufficient management support from DNES/AID. Some general suggestions follow:

- Project Design and Initiation: The objectives of the projects should be clearly defined on the basis of their relevance to the Indian energy situation, economic potential and potential for implementation.

- Project Implementation and Monitoring: The first task of all projects should be to establish a detailed work plan including schedules and deadlines. A good example of this is provided by the work plan established for the small gasifier projects. Quarterly progress reports are essential to identify problems early.

Projects should be monitored regularly by DNES and AID. It is recommended that joint meetings be held regularly (quarterly) to review on-going projects. Critical path charts should be established for each project. The objective is to make contractors accountable and feel that someone is actively interested in their progress.

It is felt that some contractors have, willingly or not, dealt alternatively with either DNES or AID, creating a confusing situation. A clear chain of communication should be established between DNES and AID and contractors should be informed of this. Independently of who takes the lead in the monitoring process (DNES or AID), the other institution should receive copies of all communication to and from the contractors; this is essential if the DNES/USAID review meetings are to be effective.

As a last resort, DNES/AID can postpone funding until some identified objective has been achieved by contractors. This option has been exercised recently by USAID in regard to the hydro project (BU): a few more decisions of this type may be needed for the word to spread among contractors that they are accountable and must deliver.

It is understood that all cases are not clear-cut and that numerous unpredictable events can delay projects. There is, however, a need for closer monitoring and more active interaction with the projects.

- <u>Documentation and Dissemination</u>: This has been a somewhat weak point in many projects. Regular workshops, as was the case for the coal/biomass conversion projects, is a good idea. In the case of the biomass projects, it is felt that a wider audience should have been invited.

This dissemination function should be carried by DNES because, first, their mandate calls for the promotion and development of non-conventional energy sources, and, second, these dissemination efforts will contribute to establish DNES as an active and forward looking Department.

Some specific recommendations for DNES and USAID are as follows:

<u>DNES</u>:

1. <u>Definition of Projects</u>: There is a need for preliminary systems analyses before projects are launched. These should be a preliminary implementation plan addressing all aspects of a technology: are the resources available (biomass, building materials, etc.), at what cost, what incentives are needed to market the technology (will the GOI provide the financing, who else can, etc.). Such an analysis is obviously subject to revisions but it would focus the problems: what are the cost/performance parameters that must be matched, is the technology or the particular application attractive at all, etc. The purpose of AERD or similar projects is <u>not</u> to develop another gadget but to try to promote meaningful non-conventional energy alternatives for India.

2. <u>Initiation of Projects</u>: Launching a project requires multiple approvals from various Indian ministries and agencies. After projects are defined, see 1. above, DNES should play the lead role in getting the project(s) approved by the Indian bureaucracy. An aggressive and determined approach by DNES can only reinforce its position as a leading agency for the promotion of non-conventional resources, which, after all, is its charter.

Serious delays have been encountered in the initiation of some projects (the 100 KW gasifier project is a notable example). It is recommended that DNES assigns the responsibility of carrying individual projects through the administrative system until approval is granted to individual members of its staff. Sufficient authority and decision making powers should be delegated to these staff members for them to be effective in accelerating the process of approval of projects. After the projects have been approved, these same staff members, who by now will be familiar with the projects, would be responsible for day-to-day management of the projects and for interacting with USAID to ensure effective monitoring of the projects (see section 3 below).

3. Monitoring of Projects: Some projects have suffered from lack of consistent monitoring and critical review: the purpose is not have on-going projects, but to have on-going projects that are meaningful. Some suggestions include:

- Establish a progress chart, with deliverables and schedules (in conjunction with USAID) at the onset of a project,
- Establish a "chain of command", or, rather, a "chain of responsibilities", between DNES and USAID for each project. Who is leading, who is in charge, etc., and inform the contractors, so no games can be played.
- Request quarterly reports from all contractors. There should be no exceptions to this,
- Have quarterly reviews with USAID, and take appropriate measures if the original work plan is not adhered to.

4. Dissemination and Marketing: Several projects have not fulfilled their objective of disseminating the technology being pursued. It is imperative for DNES to ensure that positive aspects of projects are advertized: further support of projects will only happen if the "power to be" in the U.S. feel that their efforts are recognized and appreciated. Further, DNES can only establish itself as the "non-conventional energy" agency if it shows positive and meaningful contributions to Indian's energy situation. There appears to be some interest by Indian industries for some of the technologies developed under AERD and this interest should be pursued actively all across India.

5. Customs: Many delays and problems have resulted from the rigid structure of India's custom regulations. It is imperative that DNES negotiates a simplication of the procedures for importing U.S. Research and Development equipment needed by Indian institutions for pursuing AERD or similar projects.

USAID:

Many of the suggestions made for DNES do apply, mutatis mutandis, for USAID and should be implemented in parallel as many of them require the cooperation of both agencies.

1. Definition of Projects: The need to focus projects on meaningful and realistic goals has been stressed above. USAID must insist that DNES presents a realistic assessment of

projects considered for funding. It may be cost-effective for USAID to bring in a consultant in the early phases of project discussions to get an outside perspective, to help select reliable contractors/suppliers and to set realistic and achievable goals.

2. Initiation of Projects: Once a project has been defined and a decision has been taken to implement the project, it becomes DNES's responsibility to obtain the necessary clearance from the Department of Economic Affairs and any other agency involved. USAID must insist that the process of approval of projects be carried as effectively as possible. USAID could suggest timeframes for the approval of projects; if these were to be exceeded without serious reasons, such as a change of administration for example, the funds earmarked for the project would be transfered to other activities.

3. Monitoring of Projects: USAID should take the lead in establishing an effective monitoring process as outlined in section 3 above. Close monitoring is essential and, in the long run, beneficial to all parties involved; a sense of urgency for establishing and maintaining effective control of the projects must be conveyed by USAID to its Indian counterparts.

4. Dissemination and Marketing: USAID must insist that adequate and effective dissemination of the projects, as well as serious attempts at commercialization of the results of the projects, be undertaken. This is the ultimate objective of the projects sponsored by USAID and it should be emphasized and stressed with USAID's counterparts.

5. Procurement: Independently of customs regulations, some problems have been encountered with the procurement of equipment from the U.S.: missing parts, broken parts, lack of documentation, etc. USAID should tighten the terms of the agreements with U.S. suppliers of equipment to minimize such problems.

6. Staffing: The Energy Specialist, Mr. S. Padmanabhan, has been extremely effective in getting a variety of projects, some of which appeared to be drifting hopelessly, under control. The task of monitoring, reviewing and maintaining control over the existing projects is enormous; further, the new initiatives, such as ERE, planned for the near future will also require his technical expertise. It is therefore felt that the appointment of a second technical expert should seriously be considered. Alternatively, the long-term support of consultants should be considered in order to avoid the problems that have plagued some of the AERD projects.

5.1.2 Individual Projects

a. Gasification Projects

In the course of the evaluation, gasification projects other than those included in the AERD project were observed at Roorkee University (5HP), Jyoti Ltd. (manufacturer - 5 to 10 HP range) and IIS, Bangalore (5-10 HP and 100 KW). Reportedly, there are other groups actively engaged in gasification.

The units observed ranged from laboratory demonstration units tested in the field to pre-commercial/commercial units having reached variable degrees of engineering sophistication. Some observations were made:

- there seems to be little coordination/ information exchange between research groups,

- preliminary economics (see Appendix C) indicate that costs of wood and hours of utilization are critical factors. Cost of units is less critical (although capital availability is essential),

- a variety of scenarios for utilization are considered, including irrigation, village electrification, small/medium industries, associated with a variety of scenarios for fuel production, wood waste briquettes, etc., but few attempts have been made at evaluating the feasibility/economics of clearly identified scenarios or complete systems from fuel production to end-use (IIS has made such an attempt which was reviewed by the team),

- no mass/energy balances have been made and the relative merits of charcoal versus wood in terms of resource utilization has not been addressed,

- there is a need for large scale precommercial demonstrations. Such a demonstration (20 units) is currently implemented by IIS with the support of the Karnataka State Council for Science and Technology (KSCST). The project involves one week of training including teaching video tapes. The same team has built a 100 KW unit which will be tested shortly,

- several manufacturers have expressed interest in commercializing gasifiers.

Recommendations for Current Projects

- IIT projects

These projects have attained most of their objectives. It is understood that field testing and work on briquetting charred residues will be pursued for about 6 months with DNES support. The teams are capable of pursuing research on their own, no further support is recommended.

- SPRERI project

The project has reached most of its objectives and is well equiped to pursue research. No further support is recommended.

- 100 KW Gasifier Project (GEDA)

As indicated before, it is recommended that this project be implemented. It is due to be authorized and initiated shortly. Recommendations are as follows:

1. The steering committee (DNES, GEDA, GDDC, GROFED) should appoint an executive secretary responsible for daily management, monitoring, coordination and review. Similarly, GEDA should identify one person responsible for daily management data gathering/interpretation, site monitoring, etc. Direct channels of communication should be established between the AID Energy Specialist and the DNES and GEDA representatives to insure the regular/effective monitoring. A detailed work plan is essential.

Periodic, and regular, reviews and evaluation by an outside consultant should be considered by USAID.

2. Define an effective data gathering plan including all aspects of the system, fuel transportation/preparations, maintenance/repair costs, fuel characterization/preparation/consumption, etc. Define analytical methods to be used for interpretation of technical and economic data. Involve the gasifier manufacturer and a consultant in this process.

3. Establish procedures by which the manufacturer will be informed of progress and can interact with the GEDA team.

4. Make the GDDC-GROFED operations energy efficient. Because of the high capital cost of alternative technologies, systems using these technologies should be made energy efficient to reduce capital investment (in the present case, reduction of electric consumption by the facilities would result in more power sold to the grid). Further, implementing energy conservation in these industries would constitute interesting case studies to promote conservation.

Conservation should be implemented before gasifier operation is started so that the benefits of conservation can be evaluated with the current source of energy (electricity mostly). GEDA should install and document conservation measures; this should be a prerequisite for launching the project. If needed, USAID could provide the services of a U.S. consultant.

5. The option of waste heat recovery should be considered during the energy efficiency analysis suggested in (4). If this makes sense, it is recommended that after, say, one year of gasificer operation and analysis, the heat recovery system be implemented and analyzed for another 6 months to a year. This step-wise approach should permit careful analysis of each phase of the project without negative impacts on the overall management of the project. If justified and feasible, this heat recovery phase would enhance the case for energy conservation.

Recommendations for New Projects

The review presented above indicates that many activities are ongoing but that there is a lack of interaction between groups and a lack of focus on system (fuel, fuel preparation, gasifier, end-uses) design and feasibility analysis. More useful data is probably available than is apparent.

Two new activities are suggested for AID to remedy this situation and promote gasification.

1. Sponsor a review of Indian gasification projects and prospects.

This should include:

- Description of ongoing projects (data sheets for each)
- Summary of characteristics/performance
- Case studies - feasibility/economics
- Foreign activities
- Manufacturers.

This study should be conducted by a U.S. contractor and an Indian group and would constitute a reference data base for dissemination and planning purposes. Computerizing this data should be considered.

This study would also be a useful reference document for the evaluation of gasifier proposals under ERE.

2. Sponsor a Gasification Workshop

This second step, which could be organized by DNES, would bring together all research groups identified in the review, state agencies, end-users, manufacturers and foreign researchers.

b. Low Head Hydro

This project is late but is relevant. An extension of 12 months has been requested. Based on the team's observation of progress at the Kakroi site and the remaining tasks of controller delivery, testing, commissioning and training, it is suggested that a period of 15 months be granted. Some recommended actions are:

1. Grant a 15 months extension with no, or minimal, supplementary funding.

2. Extension should only be considered if a clear and definite commitment is received from BU concerning the remaining tasks. A cable to that effect has been sent by USAID.

   Similarly a clear scheduling commitment regarding the Kakroi site should be demanded from Roorkee University. A proposed work schedule was supposed to have been provided to DNES three days after the team's visit at Roorkee.

3. Establish effective channels of communication between DNES, AID, AHEC and BU for coordination/monitoring of the project and request quarterly reports.

4. Involve the U.S. supplier of the turbine in the data gathering and data analysis process.

5. The option of redefining the objectives of the load management controller should be considered. The original objective of delivering a rather complex prototype unit could be reduced to that of delivering a "proof of concept", less sophisticated unit. This option should not be discussed with BU until such time at which it is recognized that BU will not be capable of delivering the promised prototype. Such a readjustment should include a reduced level of funding.

Recommendations for New Projects

The team has expressed some reservations concerning the economic viability of low head hydro with load management in the context of isolated villages or groups of villages. Most questionable is the nature of the "dummy" loads proposed (hydrolysis, fertilizer, etc.). Although conceptually attractive, the concept does not seem to have been thoroughly discussed.

It is recommended that a feasibility analysis of the concept of load management for low-head hydro in remote areas be undertaken. The purpose is to define the situations in which the concept could be viable and identify relevant parameters (electricity, hot/cold water, shaft power needs, load profile, peak demand, potential for further needs, etc.).

Topics should include:

- Definition of representative cases.
- Energy needs (present/future), market for commodities.
- Techno-economic analysis.
- Framework within which the technology is viable.

The study should be conducted by a U.S. team and an Indian team familiar with the problems encountered in isolated villages.

c. <u>Energy Efficiency</u>

- <u>Background</u>

Some relevant aspects about energy conservation are as follows:

- Much information regarding energy consumption and fuel usage in various industries and conservation equipment available in India is available, notably through the National Productivity Council,

- Many industries are more worried about securing reliable power than about efficiency,

- The technical merit of conservation is recognized but its economic value to industries is not always recognized by industrial management spheres,

- The GOI provides some incentives for the installation of conservation measures but until recently no single entity was mandated to promote conservation,

- Several Association of Industries (Textile, Petroleum, National Productivity Council, NPC) provide audit services to their members; no support for implementation, management or financing is provided,

- A few consulting firms offer audits/recommendations to industry, but none offer complete conservation packages as is the case in the U.S.,

- Much could be gained by translating the U.S. experience in conservation implementation to the Indian context,

- There is a need for successful demonstration of conservation in Indian industries.

A proposal was submitted to USAID by Energy Environmental Engineering, Inc. (E3I). As presented, the proposal should not be considered for a number of reasons:

- the first phase -- industry surveys, audits, selection of a candidate for demonstration, etc., -- to be supported by AID does not make use of data already available in India and, as a result, is much too expensive and lengthy,

- Indian participation is limited to the installation of conservation devices; no real effort towards building an Indian infrastructure to promote conservation is apparent.

- the project proposes to transfer directly the U.S. experience (service company, third party financing, etc.) to India. For reasons discussed below, this may not be the most effective approach,

- the proposal seems to be more aimed at generating business for E3I than at resolving India's problems.

Recommendations for the Ongoing Project

One more workshop will be organized in Delhi, probably towards the end of 1987. The tentative subject is energy management systems. This is probably an appropriate topic because it may bring forward some of the procedures used in American industries to achieve energy efficiency.

Recommendations for New Projects

It is recommended that a demonstration conservation project be implemented in an industry, textile is suggested.

The project would be carried by one of the Textile Producers Association; these associations have established their credibility amongst their members, they already provide audits and they are good vehicles for disseminating the technology among their members. A U.S. contractor familiar with the complete conservation services will provide the support needed to transfer approaches used in the U.S. to the Indian context. If successful, this project could be replicated among other associations. The NPC is a private and very dynamic institution maintaining contacts with the GOI and all industries across India. They could act as catalyst to promote conservation among industrial associations.

d. Solar Projects

- Testing of Thin Film Solar Collectors

  Project concluded; following project ongoing.

- Thin Film Technology

  Project initiated and on track.

  Monitoring and dissemination must be stressed.

It is recommended that dissemination efforts be undertaken immediately by DNES. A possible approach could be:

- Send information about the encouraging results derived from the first project to all manufacturers on record. Request expressions of interest from manufacturers.

- Distribute sample collectors (free or at cost) for testing by manufacturers; comments, suggestions, and feed back will be requested in exchange.

This approach would involve manufacturers at an early stage of development, may provide useful suggestions for product development and would establish DNES as a forward looking institution in the field of solar energy.

Recommendations for New Projects

It is recommended that USAID commissions a realistic market study for solar thermal energy in India. The study should include sensitivity analysis related to a range of performance characteristics and cost. This would define ranges of economic viability for the systems considered. The study would also be useful in analyzing ERE proposals dealing with solar thermal applications.

e. Energy Modeling

Project completed and ongoing. After the model has been tested fully and improvements have been completed, environmental cost/benefits resulting from energy policies should be included in the model.

5.1.3 Priorities/Actions

The following is a tentative list of priorities for initiation/implementation of the recommendations made above (refer to above sections for actions recommended).

Immediate (January-February 87)

1. Low-Head Hydro

2. 100 KW Gasifier Demo (As soon as project approved)

3. Initiate improvement of monitoring procedures as projects 1 and 2 above develop.

Mid-Term (March-July 87)

1. Initiate Energy Conservation Demonstration
2. Initiate Solar Dissemination Programs
3. Initiate gasifier/low-head studies
4. Keep improving monitoring procedures

Long-Term (August 87 on)

1. Insure that dissemination of solar project occurs
2. Maintain close monitoring of projects

5.2 Fossil Fuels

About twenty years ago commercial power from all sources exceeded the amount of energy consumed in the commercial sector. However, recent statistics show a continued total energy growth but commercial use increased faster than the domestic consumption. The persistent growth, of course, increased the demand on both local and imported fuels with the obvious consequence of more costly imports of petroleum, deforestation and greater demand for imports of coal. Stress on the energy economy can be reduced somewhat by developing more efficient ways to apply the fuels that are consumed. The present coal utilization program can mitigate the undesirable aspects already described by demonstrating new methods of processing Indian coals. A good start has been made to apply new technology to the planned expansion and upgrading of energy production. The Government of India has an extensive program financed in small part by the United States. Of the U.S. financed segments, the projects are listed in priority order as evaluated by the review team.

Near Term Development

Fluidized-bed combustion will continue to be developed in two areas regardless of outside support. Performance of the freeboard area of the Atmospheric Fluidized-Bed Combustor (AFBC) needs to be evaluated as will be the combustion of coal-water slurries and nozzles for injecting slurries into combustion chambers. These projects provide the basis of commercially sized plants that will need major international suppliers of instruments, coal handling equipment, speciality steels, pumps, fans, etc.

Only the freeboard area is being supported by the USAID but the information gained in the combustion zone and the discharge system would also be available as part of the overall system evaluation. Fluidized bed combustion is close to commercialization on a large scale. Several small units are operating satisfactorily in plants all over India.

Scale-up design of the fluidized bed combustor to 30 MWe is completed and ready for implementation. The design is based on experience gained from smaller units and the 20 MWe unit at TVA. Costs for the demonstration plant will be shared by BHEL, DNES, and a public utility customer. Some support by USAID is recommended so that technical details derived from the project will be available to U.S. power plant designers and equipment vendors. Contacts with U.S. suppliers have already been made during the execution of the projects just completed. Some vendors already maintain offices in India.

Similar logic is applicable to the development of combustion nozzles and coal-water mixtures.

A 30 MWe power plant may be suitable for a small community that needs power for household use -- lights, radio and refrigeration. Such a plant might also be operated intermittently to provide energy only during the dark hours of the day as is done in several parts of the world. Experience at this 30 MWe level can also prepare the utility industry in India for larger systems that can serve larger communities.

Financial support from USAID for all of the proposed work is primarily for (1) training of Indian engineers at R&D centers in the U.S. Specialists and consultants in the U.S. can provide the technical inputs to the project; and (2) a bulk of the funds are needed for the purchase of instrumentation and analytical equipment from U.S. suppliers. Arrangements for travel, access to selected demonstration sites, procurement and delivery of equipment can be adequately handled by the engineering company that monitored the program reported on here. The head of this company (Dr. Saluja) has the much needed contacts both in India and the United States to coordinate and monitor the extended program.

India's financial participation will be used to support the local project personnel, fabrication of the combustor and gas clean-up systems and purchase of expendable items available domestically.

Medium Range Potential

Two projects are of interest in the near future. The hot gas, high pressure particulate removal system is of particular interest because it represents a problem of long standing. If clean hot gas is available to a combustion turbine, power generation may become a reality. Only a few parts per million of solid enough to erode turbine blades and vaporized metals can cause deposits that are damaging. The unit under construction may solve both problems by contact of the raw gas with a moving bed of alumina.

The related medium range project is the fluidized bed combustion system. Operation under pressure and applying solids recycle can improve the efficiency and the recovery of energy for steam generation. This project of pressurized combustion is not part of the USAID program just completed but the problems of freeboard performance are significant.

Long-Range Potential

Looking at the smaller segments of the program, cyclones, CWM preparation at CFRI and cold gas cleanup at RRL-H, one sees a mixed picture of research that should be pursued but with some modifications.

Dense Medium Cyclones are used commercially but Indian coals with high ash contents and with the ash distributed throughout the particles are not easily cleaned with these systems. This research should continue but with emphasis on new methods of disassociating the ash from the carbonaceous matter. Suggested areas of investigation might include a study of the surface properties of coals and solvent action. The objective would be to decrease or eliminate the coal-ash bonds so that dispersants might induce improved separation.

Coal-Water-Slurries. Commercial additives and a coal derived material were evaluated for the preparation of stable suspensions of coal in water. These suspensions are pumpable and scable in long-term storage. When the BHEL group prepared suspensions for their experiments, the additives evaluated at CFRI were not applied. Power plant personnel don't like to do chemical processing but the possibility of a simple treatment to make the coal derived additive seems to be an interesting alternative.

Cold Gas Cleanup can be demonstrated using charcoal and semipermiable membranes. The development of such systems has merit. Hot gas cleanup is preferable for the projects now under consideration but clean cold gas may also be preferable for preparing nitrogen, hydrogen and carbon monoxide. Gases removed by adsorption and diffusion systems are often acidic and have a higher molecular weight, in particular, carbon dioxide, nitrogen oxides and sulfur oxides. Local sources of activated carbon and designed membranes for the gas systems under consideration would be of interest.

The other program worthy of consideration is the Cumbustion Institute. Several companies will be interested in combustion studies as related to fluidized beds and for burner configuration when burning high ash coals. The problems are unique and would be related to equipment provided by U.S. industries. Erosion and carbon burnout are two of the many problems awaiting resolution. Another area of research would be related to biomass which has a near term future in India.

These recommendations are an extension of those presented at the Third Annual Workshop. They are modified by the developments over the subsequent year and reflect the considerations of the review team.

BIBLIOGRAPHY

Project Paper-INDIA. Alternative Energy Resources Development. USAID/INDIA June 29, 1982. 30 pp, 15 annexes, 3 appendices.

First USAID/GOI Workshop Alternative Energy Resources and Development. Coal Conversion and Biomass Conversion. New Delhi, India, November 7-11, 1983 539pp.

Biomass and Coal Conversion Programs of the USAID/GOI Alternative Energy Resources Development Project. Trip Report to India. May 22 - June 2, 1983. 30pp.

Biomass Conversion Project Plans. USAID and the GOI First Workshop on Alternative Energy Resources and Development. New Delhi, India. November 7-11, 1983, 52pp.

Coal Conversion Project Plans. USAID and the GOI. First Workshop on Alternative Energy Resources and Development. November 7-11, 1983. 31pp.

First Workshop on Biomass and Coal Conversion Programs of the USAID/GOI Alternative Energy Resources Development Project. Report on Trip to India. November 7-19, 1983. 45pp.

Second USAID/GOI Workshop on Alternative Energy Resources and Development. Coal Conversion and Biomass Conversion. New Delhi, India. February 4-6, 1985. 427pp.

Second Annual Workshop on Biomass and Coal Conversion Programs of the USAID/GOI Alternative Energy Resources Development Project. Report on Trip to India. January 24-February 8, 1985. 46 pp.

Third Annual Workshop on Biomass and Coal Conversion Programs of the USAID/GOI Alternative Energy Resources Development Project. Report on Trip to India. December 2-17, 1985. PETC/DOE. 61pp.

Third USAID/GOI Workshop on Alternate Energy Resources and Development. Coal Conversion and Biomass Conversion. New Delhi, India. December 5-7, 1985. 54pp.

Evaluation of Proposals Submitted at the Third Annual USAID/GOI on Alternate Energy Resources Development. February 1986. PETC/DOE. 12pp.

Workshop on Thermal Energy Use in Indian Industry -- Strategies for Improving Efficiency. AIEI/NAS. 37pp.

Proposed Expansion of the Coal Conversion and Biomass Conversion Projects. The USAID/India Alternate Energy Resources and Development Program. (1986?) 16pp.

USAID/India Cooperative Coal Conversion Program. A. Kulkarni, R.P. Krishnan and D. Bienstock. Energy, Vol. 11, 1986.

Benefication of Fine Coal in Dense Medium Cyclones (USAID-GOI Project) A.K. Chankravarti. CFRI Project No. 22.0120. June 1986.

Studies on Preparation and Characterization of Coal-Water Mixture (CWM) Fuel. M. Chakraborty, T.K. Bhowmik, M. Prasad, S.K. Chanda and S. Mazumdar. CFRI Project 45.0300. June 1986.

Evaluation of Freeboard Performance in a Fluidized Bed Combustor (November 1983-June 1985) R.P. Krishnan, S. Chandrasekaran, C. Bhahaskaran, S. Shanmugam and A.V. Vasudera Murthy. July 1985. 94pp.

Proposal: 100kw Gasifier Engine Generator System for GDDC at Junagadh. K.S. Rao. Novembre 5, 1985.

Integrated Coal Gasification Combined Cycle (IGCC). An Emerging Commercial Option for the Power Industry. D.F. Spencer, S.B. Alpert and M.J. Gluckman. EPRI. Division of Fuel Chemistry Preprints. Vol. 31, No. 2, April 13-18, 1986 pp.262-269.

Fluidized Bed Combustion Technology Exchange Workshop Vol. I 345pp and Vol. II 467pp NTIS No. Conf-770447, April 13-15, 1977.

Seventh Annual International Conference on Coal Gasification, Liquifaction and Conversion to Electricity. August 5-7, 1980. University of Pittsburgh. 614pp.

Fluidization Under Pressure. M. Sciazko. UNIDO Report 1980, 37pp.

Analysis of Utility Boilers for Coal-Water Slurry Tests. R.K. Manfred and E.A. Kimel. First Annual Pittsburgh Coal Technology Conference. September 17-21, 1984. 13pp.

Fluidized Bed Combustion:

Industrial Application of Fluidized-Bed Cogeneration System. W.R. Kelly, J.M. Rourke and D.E. Mullin.
Multisolid Fluidized-Bed Combustion. H. Nack, R.D. Litt and B.C. Kim.

Energy Recovery From Fluidized-Bed Combustion. R.D. Sneyd.

Advantages of the Solids Circulation Fluid-Bed Boiler. L.S. Cohen, W.B. Johnson and M.C. Parlee.

Anthracite Culm Fired Fluidized-Bed Boiler. E.C. Lentz. Emissions Control With Fluidized-Bed, Steam Generating Systems. R. Gottko.

Chemical Engineering Progress. January 1984, pp35-67.

Using Demonstration Projects to Advance Innovation in Energy. S.R. Lefevre. Public Administration Review. Nov/Dec 1984 pp.483-489.

Organic Wastes for Fuel and Fertilizer in Developing Countries. C.G. Golusca and L.F. Diaz. UNIDO/10.410 18 February 1981 276p.

Development of Micro and Low-Head Hybrid Hydroelectric Project Under USAID Program-Bi-Annual Progress Report-July 1983-June 1984- Alternative Hydro Energy Center-University of Roorkee, Roorkee, June 1984.

Low-Head Hybrid Hydro-Electric Project, Extension Proposal - Boston University, Boston, MA - December 1985.

Technologies for the Rural Poor Project: Findings and Recommendations of AID/DNES Evaluation Team. Associates in Rural Development, Inc., Burlington, VT, January 1985.

Preliminary Report on Energy Revolution for Rural Areas under a twenty Point Program - V.K. Bansal, AHEC, Roorkee University, Roorkee, December 1986.

Annual Report 1985 - Tata Energy Research Institute (TERI), New Dehli, India.

TEESE Model - Pamphlet by Tata Energy Research Institute (TERRI), New Dehli, India.

Solar Thermal Technology Testing and Standardization - Solar Flat Plate Collectors. Solar Energy Center, DNES, Delhi.

Materials for Low-Temperature Solar Thermal Applications. S. K. Gupta, SEC-DNES, in Solar Water Heating Systems, p61-84D, Reidel Pub. Co., 1986.

Brookhaven National Laboratory Designed Collector: Performance in India. V. Mubayi - U.S.-India Binational Symposium Workshop on Solar Energy Research and Applications, NSF-DNES, Roorkee, India, August 1985.

Solar Hot Water Systems. Solar Energy Center, New Delhi, 1985.

Solar Thermal Technology Collaborative Research Program. Draft Final Report - STEC/BNL - V. Mubayi, W.G. Wilhelm. September 1985.

Commercialization of BNL Design Solar Collector in India. Addendum to Phase I Report. V. Mubayi - BNL - February 1986.

Development of a Quantitative Model for Systems Evaluation of Energy Related Technologies - Tata Energy Research Institute, New Delhi.

Economics and Promotion of Biomass Gasifiers for Water Pumping. K.S. Rao and R. Vasanthi, Gujarat Energy Development Agency, 1986.

IISC Gasifier. ASTRA. Indian Institute of Science, Bangalore, 1986.

Economics of Gasifier as Power Source. IISC, Bangalore, 1986.

Karnataka State Council for Science and Technology. Annual Report 1985-86, IISC., Bangalore, 1986.

Proceedings of the Astra Seminar, IISC, Bangalore, March 1985.

Development of Single-Pan Wood Stoves of High Efficiency, H.S. Mukunda et al., Astra, IISC, Bangalore, October 1986.

Proceedings of the Astra Seminar, IISC, Bangalore, September 1983.

The IISC Wood gasifier. Training Manual. IISC, Bangalore, 1986.

Annual Report 1985-1986. Department of Non-Conventional Energy Sources. Ministry of Energy. Government of India. 26p.

APPENDIX A - VISITS - CONTACTS

A. BIOMASS PROJECTS

Date	Organization	Individuals	Purpose
Sept. 16, 86	USAID (D.C.)	R. Ichord, R. Archer	Briefing
Oct. 3, 86	MITRE Corp.	A. Talib	Biomass Conversion
Nov. 13, 86	NAS	D. Mog	Energy Efficiency
Dec. 12, 86	USAID	R. Ichord, R. Archer	Briefing
	(NAS)	D. Mog, F. Nash	(Energy Efficiency)
	(MITRE)	A. Talib	(Bioconversion)
	World Bank		Briefing
Dec 24, 86	BNL	V. Mubayi	Thin Film Collector
Jan. 5, 87	USAID (New Delhi)	S. Padmanabhan	Briefing
Jan. 5, 87		P.W. Amato	
		O. Cylke	
Jan. 6, 87	DNES	J. Gururaja J.R. Meena	Briefing
Jan. 6, 87	NPC	V. Raghuraman	Briefing
Jan. 6, 87	BHEL	Y.P. Abbi	Briefing
Jan. 7, 87	IIT (Delhi)	P.D. Grover H.B. Mathur Staff	Gasifier Engine (Char)
	IIS	H.S. Mukunda	
	(DNES)	O.P. Vimal	
Jan. 8, 87	IIT (Delhi)	P.D. Grover H.B. Mathur Staff	Site Visit Engine (Char)

	(DNES)	K.K. Singh	
	(IIS)	H.S. Mukunda	
Jan. 8, 87	DNES	K.K. Singh	Gasifier - Discussion
	(IIS)	H.S. Mukunda	
Jan. 9, 87	TERI	R.K. Pachauri Staff	Energy Modeling
Jan. 12, 87	GEDA	K.S. Rao S.B. Patil K.S. Shah	Briefing 100 KW Gasifier
Jan. 12, 87	Jyoti Ltd.	A.C. Gupta F. Vyarawalla B.S. Vaidya M.S. Ramaprasad	Gasifier Commercialization
Jan. 13, 87	SPRERI (previously JSEI) and Site Visit	K.M. Dholakia C.S. Rao M.B. Durgaprasad	Gasifier Project
Jan. 14, 87	CEI (Delhi)	N. Srinivasan V. Raghuraman	Energy Efficiency
Jan. 14, 87	Solar Energy	S.K. Gupta	Polymer Film Technology
	Center - Site	N.P. Singh	Thin Film Technology
Jan. 14, 87	Roorkee University	D. Das	Low Head Hydro (Briefing)
Jan. 15, 87	Kakroi	D. Das	Low Head Hydro
		Project Staff	Site
Jan. 15, 87	Roorkee University	D. Das J. Gururaja	Micro Hydel System
Jan. 16, 87	Roorkee University	D. Das J. Gururaja Staff	Micro Hydel System
Jan. 16, 87	DNES	J. Gururaja S.K. Gupta J.R. Meena	Solar Projects
	DNES	O.P. Vimal	Biomass Production

Jan. 21, 87	TERI	R.K. Pachauri Staff	Energy Modeling
Jan. 22, 87	IISc	H.S. Mukunda Staff	Gasifiers Efficient Stoves
Jan. 23, 87	KSCST	S. Rajagopalan	Karnataka State Programs
	IISc	H.S. Mukunda Staff	Tests of Gasifiers and Review Training Manual
Jan. 24, 87	Institution of Engineers	S.G. Ramachandra	Energy Efficiency
	IISc	H.S. Mukunda	Gasification
Jan. 27, 87	USAID	C.R. Hatch	Biomass Production

APPENDIX B - FOSSIL FUEL PROJECTS

Itinerary - M. D. Schlesinger

January 1987

05	Arrival at Delhi	
	USAID Orientation	S. Padmanabhan Energy Specialist Dr. P. W. Amato Chief, Design and Evaluation
06	USAID	Owen Cylke, Counselor
	DNES	Dr. J. Gururaja Advisor, Energy
	National Productivity Council	V. Raghuraman, Director
	Bharat Heavy Electricals Ltd.	Dr. Y. P. Abbi, Manager
07	USAID	
	Delhi to Calcutta with V. Raghuraman	
08	Calcutta to Dhanbad Central Fuel Research Institute	Dr. R. Haque, Director Dr. M. Chakraborty, Scientist & Deputy Director
09	Central Fuel Research Institute Dhanbad to Calcutta	Samir Sen, Assistant Director
10	Calcutta to Delhi	
11	(Sunday) New Delhi	

12	Delhi to Hyderabad	
	Regional Research Laboratory	Dr. A. V. Rama Rao, Director Dr. Y. V. Subba Rao Assistant Director Dr. - Ing. R. Vaidyeswaran Distinguished Scientist (Retired)
		Dr. S. N. Reddy
13	BHEL, Corporate R & D (BHEL-H)	N. N. Ramakrishnan Senior Manager, Coal R & D S. Chakravarti R. S. Rangan
	Hyderabad to Madras	
13-18	Madras (Pongol)	
19	Madras to Tiruchirapalli	
	Bharat Heavy Electricals Ltd. (BHEL-T)	K. T. U. Malliah General Manager K. Nandakumar Deputy Manager, R & D S. Rajaram Manager Industrial Power Products Division
20	Tiruchipalli to Madurai	
	Madurai to Madras	
	Madras to Delhi	
21-30	USAID	
31	Delhi-Frankfort	
Feb 01	Frankfort - Pittsburgh	

APPENDIX C - ECONOMIC ANALYSIS

This appendix presents preliminary analyses of gasifiers and low-head hydro systems. These analysis are not final but are meant to support and illustrate some of the points made in the evaluation of projects.

1. Gasifiers

The data used was obtained from a variety of Indian sources.

Assumptions

- Capacity: 3.7 KW (shaft)
- Capital costs: gasifier-diesel-pump: Rs. 19,800-10,000
  Diesel-pump: Rs. 7,000
  Motor-pump: Rs. 8,000

- Depreciation: straight line, 10 years
- Interest: none
- Maintenance: 5% capital/year
- Operating hours: variable
- Wood cost including preparation: variable
- Diesel cost: Rs. 3.58/1
- Electricity: subsidized: Rs. 0.88/KWH
  unsubsidized: Rs. 1.33/KWH
- Operating costs: 1/2 hour per 4 h operation, Rs. 1/hour (gasifier and diesel)

Results

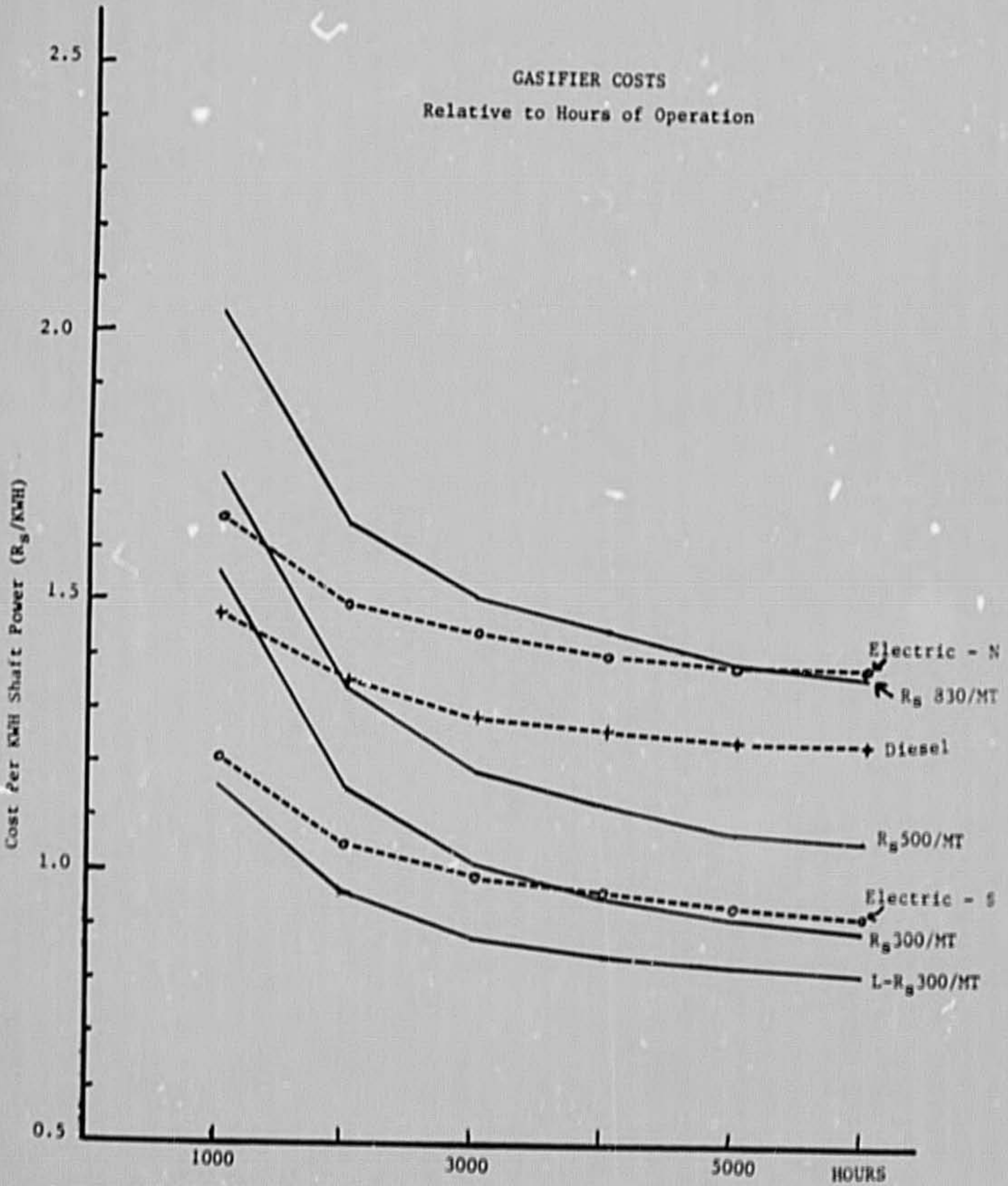
See attached figure.

Comments

- Wood fuel cost (including preparation), hours of operation and to a lesser extend capital costs are the major parameters influencing economics.

- Manual preparation of wood fuel may account for about 40% of fuel cost; little consideration has been given to this problem.

- For medium fuel cost (or Rs. 500/MT), the gasifier should operate at least about 2,000 hours/year to be competitive with diesel. Village, commercial/industrial applications are more attractive economically than irrigation (usually about 1,000 hours/year).



——— Gasifier - Fuel Cost/MT
- L = Low Cost Unit

+---+ Diesel Operation

o---o Electric - NS non subsidized
- S subsidized

Cost per KWH is less sensitive to capital cost than to fuel cost or hours of operation. Reducing the cost of the gasifier unit by half results in a 10 to 25% reduction in cost per KWH.

- Competition with subsidized electricity is almost impossible. Competition with unsubsidized electricity is attractive. This, again, suggests that commercial/industrial applications are preferable.

2. Low-Head Hydro Project

Assumptions

Rated power: 125 KW
Installed cost: Rs. 25,000/KW
Power Delivered: 100 KW
Power Sold at: Rs. 0.80/KWH
Hours: variable
Interest Rate: variable

Installation costs (1000 Rs.)

Capital		3,125	
Contingencies (10%)		313	
Interest Rate (1%)	10	12	14
Interest during Construction	722	873	1,031
TOTAL	4,160	4,311	4,469

Yearly Operation Costs (1000 Rs)

Interest Rate (%)	10	12	14
Depreciation (30 years)	139	144	149
Interest	300	388	487
M & R (2% capital)	63	63	63
TOTAL	502	595	699

Yearly Revenue (1000 Rs.)

Hours/year	2000	4000	6000	8000
Revenue	160	320	480	640

<u>Comments</u>

- Critical economic factors include capital cost, interest, operating hours per year and price of electricity.

- Under the conditions considered, the system is viable and should return a profit for interest rates of 10 to 12%.

- The minimum yearly hours of operating to break even are 6,275 and 7,400 for interest rates of 10 and 12% respectively. If the system operates 90 percent of the time, i.e. 7,880 hours per year, the "profitable" hours amount to 1,600 hours (Rs. 128,000) and 480 hours (Rs. 38,000) for interest rates of 10 and 12% respectively.

- If the installed cost is reduced by 10% (to Rs. 22,500/KW), all other things being equal, even at 14% interest the system can break even.

- If the price of electricity is raised by 10% (to Rs. 0.88/KWH -- still below the unsubsidized price of the grid), all other things being equal, even at 14% interest, the system breaks even.

- This preliminary analysis does indicate that there is a range of conditions (capital, interest, operating hours) within which a canal based low-head hydro unit serving villages and the grid can be economically viable on its own merit.

APPENDIX D - Abbreviations used in this report

1.	ABE	Advisory Board on Energy
2.	AERD	Alternate Energy Resources Development Project
3.	AFBC	Atmospheric Pressure Fluidized Bed Combustion
4.	AHEC	Alternative Hydro Energy Center
5.	AID	Agency for International Development
6.	AIEI	Association of Indian Engineering Industries
7.	BEEAM	Brookhaven Energy Economy Assessment Model
8.	BHEL	Bharat Heavy Electricals, Ltd.
9.	BHEL-H	BHEL, Hyderabad
10.	BHEL-T	BHEL, Tiruchiapalli (Trichy)
11.	BNL	Brookhaven National Laboratory
12.	BU	Boston University
13.	CASE	Commission for Additional Sources of Energy
14.	CEI	Confederation of Engineering Industries
15.	CFRI	Central Fuel Research Institute
16.	CWM	Coal-Water-Mixtures or synonym
17.	CWS	Coal-Water-Slurry
18.	DNES	Department of Non-conventional Energy Sources
19.	EPRI	Electric Power Research Institute
20.	ERE	Energy Research and Enterprise
21.	GDDC	Gujarat Dairy Development Corporation
22.	GEDA	Gujarat Energy Development Agency
23.	GOI	Government of India
24.	GROFED	Gujarat Cooperatives Oil-Seed Growers Federation
25.	IFM	Institute of Forest Management
26.	IIS	Indian Institute of Science
27.	IIT	Indian Institute of Technology
28.	JSEI	Jyoti Solar Energy Institute
29.	METC	Morgantown Energy Technology Center (US DOE)
30.	MKU/BU	Madurai-Kamraj University/Bharathidasan University
31.	MWe	Megawatts Electric (Output)
32.	NAS	National Academy of Sciences
33.	NBRI	National Botanical Research Institute
34.	PETC	Pittsburgh Energy Technology Center (US DOE)
35.	PFBC	Pressurized Fluidized Bed Combustion
36.	RRL-H	Regional Research Laboratory at Hyderabad
37.	RRL-J	RRL at Jaipur
38.	R & D	Research and Development
39.	SEC	Solar Energy Center
40.	SERI	Solar Energy Research Institute
41.	SPRERI	Sardar Patel Renewable Energy Research Institute
42.	STEC	Solar Thermal Energy Center, now SEC
43.	TEESE	Teri Energy Economy Simulation and Evaluation
44.	TERI	Tata Energy Research Institute
45.	TVA	Tennessee Valley Authority
46.	USAID	United States Agency for International Development
47.	WI	Winrock International