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# PROJECT ASSISTANCE COMPLETION REPORT

## ALTERNATIVE ENERGY RESOURCES DEVELOPMENT PROJECT

## (386-0474)

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## I. INTRODUCTION

Realization of India's goals of employment generation and poverty alleviation requires rapid, rural-based growth. Prospects for growth, however, critically depend on the future availability and cost of energy supplies. The development of alternative energy sources is an important element in poverty reduction because of the impact of rising fuel prices on the incomes of poor households. Over the past quarter of a century, energy consumption has grown almost twice as fast as India's GNP, with the share of oil in commercial energy consumption also increasing. To achieve sustained high growth rates, India must find ways simultaneously to reduce the energy-intensity of economic expansion in all sectors and augment supplies of energy alternatives to conventional energy sources.

Although India produces about 40 percent of its petroleum requirements, in 1980 oil imports absorbed about 80 percent of its foreign exchange earnings. The Government of India (GOI) was moving ahead with oil exploration and expansion of capacities in coal mining and power generation, but costs were staggering and lead times long. At the same time, traditional non-commercial energy supplies (firewood, agricultural and animal waste), which accounted for 40 percent of total energy use, were coming under increasing pressure due to progressive deforestation and land degradation.

The GOI assigned a high priority in its sixth five-year plan (1978-83) to alternative energy resource development, particularly forestry, biogas plants and solar energy research and development. USAID authorized the Alternative Energy Resources Development Project (AERD) in June 1982 to address the problems, such as deforestation and a heavy oil dependence, which resulted from the increase in the demand for energy and was designed to support India's own alternative energy resource development efforts.

## II. PROJECT GOAL AND PURPOSE

The goals of the AERD Project were threefold: (1) to reduce deforestation; (2) to reduce expenditures on energy supplies; and (3) to increase efficiency of energy use. The purposes were: (1) to expand India's technical capacity to develop alternative energy resources; and (2) to develop selected energy technologies to the application stage.

The purposes were to be achieved through several collaborative subprojects designed to transfer technical knowledge in the field of alternative energy development. Subprojects were to cover the areas of: (1) biomass production by supporting the development of the research capabilities and programs of two

Indian biomass (biological products that can be used as fuel) research centers; (2) coal and biomass conversion, concentrating on testing systems for the production of producer gas, gasification of wood, charcoal, and crop residues; (3) energy efficiency in industry and transportation by supporting a U.S.-India technical exchange program; and (4) information exchange by supporting the information collection and dissemination function of the Commission for Additional Sources of Energy (CASE). The subprojects were to be implemented through the collaboration of U.S. and Indian public and private sector organizations. Support of Biomass production (energy plantation) programs and coal conversion technologies (gasification) were to be the major emphasis of the Project since they offered the prospects of near-term solutions to a diminishing supply of firewood and a lower cost alternative to oil.

## III. PROJECT HISTORY

The AERD Project with cumulative funding of $13 million (GOI contribution of $5 million and AID contribution of $8 million) was a collaborative effort between USAID and the GOI through its Department of Non-Conventional Energy Sources (DNES). Although originally planned as a four-year project, it was extended to ten years divided into two Phases: Phase I covered the period from June 1982 to June 1988; and Phase II began in July 1988 and ended with the project completion in June 1992.

Because of implementation delays caused by a change in the designated GOI implementing agency from the Commission for Additional Sources of Energy (CASE) to the newly formed Department of Non-Conventional Energy Sources (DNES), the Project was initially extended from July 1986 to June 1988. The Project was further extended to December 1990 in order to support the follow-on, Phase II coal conversion subprojects and to complete the two biomass production subprojects. A final extension of 18 months was granted due to contracting delays in the Phase II coal conversion and renewable energy subprojects and to facilitate the completion of these subprojects.

The start-up delays caused by the shift to DNES were resolved in early 1984, and since that time implementation accelerated rapidly with the rate of disbursement increasing by 500 percent between April 1984 and April 1985. An additional $3 million in grant funds ($2 million in September 1986 and $1 million in May 1991) was authorized to the original funding of $5 million to support expanded activities in the innovative coal conversion and renewable energy fields.

In the first phase of the Project, nine subprojects in the area of coal and biomass conversion, five subprojects in the area of information exchange, as well as four workshops and two study missions in the area of energy efficiency were



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successfully completed. In addition, two subprojects in biomass production were initiated (see Attachment B for a list of Phase I subprojects). A mid-term evaluation of the Project, conducted in January 1987, found that most sub-projects were well selected with regard to Indian capabilities and the potential impact of and prospects for the technologies. Most subprojects had attained their technical objectives as well as the project objectives of advancing India's capability of increasing the use of non-conventional energy sources to displace oil dependency. A Project Assistance Completion Report was also prepared on Phase I of the Project in November 1989 (see Attachment D). It noted that the program had met most of its goals. Some selected parts were poised for continued Research and Development (R&D) activity, in particular the larger fluidized bed combustion unit which was ready for operation and expansion to a larger scale.

The mid-term evaluation report commended the usefulness of the Project, its impact on development of new technologies and the increasing awareness it had created in India concerning energy problems and their possible solutions. The report strongly recommended follow-on activities in all project components. The major activities carried out under the four project components are highlighted below.

**Biomass Production**

In India, where agriculture and forest resources are vast, the use of biomass as a source of energy has high potential. It can be used as a source of energy directly, or can be converted into a liquid or gaseous fuel, and can be used as feed stock. The original intent of this component was to support India's programs in biomass production by reinforcing the capability of two biomass research centers - the National Botanical Research Institute (NBRI) at Lucknow and Madurai Kamraj University/Bharathidasan University (MKU/BI) at Madurai. As the Project evolved, and largely because of the academic perspective of the institutions, the component became a fundamental research project addressing various aspects of forestry. Two subprojects were designed to reinforce the capabilities of the two biomass centers through collaborative activities with U.S. teams/individuals. The two subprojects, Production of Woody Biomass on Substandard Soil conducted at the NBRI and Development Studies of Woody Biomass Species on Arid Marginal Lands performed by MKU/BU, which were initiated during Phase I of the Project were continued during Phase II.

**Biomass and Coal Conversion**

This major component of the Project addressed the problems of conversion of biomass through gasification and supported several subprojects in the area of utilization of low quality coals. India has one of the largest coal reserves in the developing world, but the coal is of low quality with a high ash content. This



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component was designed to help advance Indian knowledge by evaluating coal conversion technologies of near term interest. A program of technical personnel exchanges and professional development was envisioned. The Department of Energy, Pittsburgh Energy Technology Center (PETC), in the U.S. was responsible for managing and implementing the coal subprojects, and six subprojects were designed and conducted in coal conversion during AERD's first phase.

In addition, three subprojects were conducted in biomass conversion during Phase I. The subprojects involved the development and field testing of three biomass conversion technologies that could significantly decrease India's dependence on imported oil. The technical work in the three subprojects was conducted in joint collaboration between U.S. and Indian engineers.

In November 1988, at the request of the GOI, USAID supported the visit of a U.S. definitional team to assist the mission in identifying and developing follow-on subprojects under the AERD Project. Based on their recommendations, six more subprojects in the area of coal technology and one subproject in the area of renewable energy were approved for implementation during the second phase of the Project (see Attachment C for a list of the Phase II subprojects). Some of the Phase II coal subprojects were designed to improve power generation and the life expectancy of the power plants through the modernization and rehabilitation of the existing plants as well as through establishment of a sophisticated fuels test facility. Thus, improvements in the availability of power would foster economic growth and development in the rural areas resulting in a potential increase in incomes of the rural poor.

USAID contracted with PETC for five of the six subprojects, and these five began implementation in September 1989 with Oak Ridge National Laboratory (ORNL) providing the technical assistance. Of the five, Bharat Heavy Electrical Limited (BHEL) was the Indian implementing agency for four subprojects. The fifth subproject, An Environmental Study of the Coal Resource Cycle, was implemented by Tata Energy Research Institute (TERI). Two of the subprojects originally proposed (Characterization of Indian Coals and NOx Emissions) were combined by building one test facility for both NOx/SOx emissions and for fuel characterization based on U.S. experts' strong recommendations that one facility would be more useful and cost effective. This combined sixth subproject, Integrated Coal Gasification Combined Cycle, was implemented through a buy-in to an AID/W contract with Bechtel Inc. USA and was completed successfully.

**Energy Efficiency**

The original project paper proposed a U.S./Indian technical exchange program dealing with energy efficiency in industry and transportation. For both sectors, a

program of technical collaboration was planned with the purpose of comparing Indian and U.S. experiences and increasing the awareness of Indian industrial managers of the technologies available in the U.S. The Confederation of Engineering Industry (CEI) and the National Academy of Sciences (NAS) were selected as the Indian and U.S. agencies, respectively, for the implementation of this component. These two organizations were chosen because both had wide access to public and private representatives of industry in their respective countries, and it was anticipated that they could establish an effective channel for energy efficiency technology. The contract negotiations, concluded in 1984, resulted in a scope of work focused on improving energy efficiency in industry and interactive workshops. According to the mid-term evaluation report of the AERD Project, the energy efficiency component was well run, contributing to the establishment of numerous contacts between U.S. and Indian public and private sector representatives.

**Information Exchange**

At the start of the AERD Project, India already had large numbers of scientists and engineers in a variety of institutions who were working on alternative energy technologies and related areas. These professionals were capable of benefiting from information on current developments in the U.S., and from joint workshops with their U.S. counterparts. This component was originally conceived to help support the information collection and dissemination function of the DNES by developing a formalized link between DNES and information sources in the U.S., but as the project evolved, the original intent was modified to support five specific subprojects under Phase I (listed in Attachment B). In addition Indian scientists were deputed to a number of energy conferences, seminars and workshops in the U.S. for interaction with their counterparts. A total of 100 participants were sent to U.S. under this program.

Also under the Information Exchange component, under Phase II of the Project, the Photovoltaic Test Facility activity was implemented by DNES and was considered one of the most important activities for meeting overall AERD objectives. The purpose of the subproject was to accelerate availability and adoption of reliable and economic photovoltaic modules and systems for remote power and other end-user applications by establishment of a test facility for photovoltaic systems and modules. The test facility was intended to develop confidence in the photovoltaic product, to enhance expertise in the photovoltaic system design and operation, to encourage support of private sector development and to lead to recognition and widespread use of the technology. The test facility was expected to support further commercialization of photovoltaic technology. The solar photovoltaic test facility subproject which was executed through the Sandia National Laboratories (SNL) of the U.S. Dept. of Energy commenced implementation in August 1990 and was completed on June 30, 1992.

## IV. PROJECT STATUS AND ACCOMPLISHMENTS

The AERD Project has proven very successful, providing the GOI with a vehicle to experiment with new technologies and increasing the awareness of energy problems and possible solutions in India. Aside from the new technologies which were developed, the Project has been successful in establishing excellent working arrangements between U.S. and Indian institutions which will certainly continue beyond the life of the project.

### Biomass Production

The production of woody biomass was envisioned such that although emphasizing the non-commercial sector, the methodologies developed in this project could be applicable to the production of woody biomass for India's pulp and paper industries, construction industries, and commercial bio-energy conversion facilities. The two subprojects began implementation during Phase I, and the U.S. training of Indian scientists was completed. Activities that remained to be implemented included training of a second group of Indian scientists, procurement of laboratory equipment and U.S. technical assistance to the two research centers.

During Phase II, the two bio-mass subprojects initiated during Phase I were completed. The U.S. technical assistance was provided and the training of Indian engineers was completed. In addition, a national workshop on Nursery Technology was held at Madurai. The laboratory equipment for the two research institutes was procured, shipped and installed. The installed equipment is being used by the two institutions for their work in the area of business production.

### Biomass and Coal Conversion

Six coal conversion subprojects were successfully completed during Phase I and the achievements included the following:

1. A key achievement of the coal conversion component has been a newly designed and constructed test facility to evaluate the combustion and heat transfer in the freeboard region of a fluidized bed combustor. The facility, commended for its sophistication, is extensively utilized by Bharat Heavy Electricals, Ltd. (BHEL) to determine key design parameters in commercial Fluidized Bed Combustion (FBC) systems.

2. A final design, with arrangement drawings and equipment specifications, of a Atmospheric Pressure Fluidized Bed Combustion (AFBC) unit enhanced BHEL's capability in offering utility size AFBC units.

3. A high pressure test facility to evaluate hot gas cleanup devices was erected which led to the introduction of the granular bed filter in a demonstration plant on integrated coal gasification combined cycle (IGCC) at BHEL.

4. A pilot plant was installed at the Central Fuel Research Institute (CFRI) to study the beneficiation characteristics of coking coals.

5. Long-term R&D in the areas of cleaning gaseous effluents from coal gasification processes was implemented at the Regional Research Laboratory.

6. The three biomass conversion Phase I subprojects provided critical inputs that have assisted key Indian institutions in utilizing bio-fuels for power/mechanical operations. They resulted in the design and fabrication of: (1) a small gasifier and gas cleanup subsystem for converting preprocessed agricultural residues into producer gas; and (2) an engine intake system for producer gas dual-fuel operations. The subprojects provided an apparently available method for replacement of diesel fuel by renewable waste materials and contributed to overall AERD objectives by providing a means for reducing dependence on imported fuels while providing an alternative for generating the mechanical power needed for irrigation. In addition, the small gasifiers were ready for commercialization and the biomass gasifiers were expected to replace a significant number of diesel operated units, thus saving substantial amounts of diesel fuel.

In order to facilitate interaction between U.S. and Indian personnel and institutions involved in the AERD Project, five workshops, held in New Delhi, and two study tours to the U.S., were completed during the first phase under this project component. The workshops provided a forum for technical exchanges between U.S. and Indian participants, for assessing the status of subprojects and encouraging U.S. specialists to discuss with their Indian counterparts the direction and course of the program. The study tours included site visits by Indian scientists and engineers to U.S. facilities actively involved in their respective areas of research. During the first phase of this component, 31 engineers and scientists were trained in the U.S.

Six subprojects under Phase II were completed and resulted in:

- The establishment of a sophisticated fuel evaluation test facility (FETF). The FETF, set up in collaboration with PETC is a unique facility which incorporates testing features to cover almost every aspect of the evaluations required. The FETF at Trichy is a versatile fuels test facility and is thermally rated at 3.0 million BTU/hr. It is the first such facility in Southeast Asia. The FETF enhances the capability of BHEL to understand and solve fuel

related performance problems in the existing boilers, thereby improving the availability and reliability of power plants. Prior evaluation of the performance characteristics of the fuel will help BHEL incorporate appropriate systems for combustion, heat absorption and pollution abatement at the design stage itself and guarantee the performance more closely. Testing fuels in the FETF is cheaper, quicker and more flexible than testing in a commercial boiler. BHEL is continuing to provide funding for the operation of the facility after AID assistance has been completed. With the opening of the Indian power sector to private investment, FETF could serve as a user facility for testing, screening and evaluating coals for private power project developers as well.

- The demonstration of power plant life assessment methodology and technology in Indian utilities and the dissemination of knowledge to Indian utilities through a pilot project in one utility and the conducting of workshops and visits of staff from the Electric Power Research Institute (EPRI) to BHEL and Indian utilities, and visits of BHEL staff to U.S. utilities.

- A workshop on residual life assessment of thermal power plant equipment was held which helped disseminate U.S. experience on power plant life extension which was of use to the Indian power sector.

- Advanced Diagnostic Instrumentation for field evaluation of remaining life estimation of power plant components procured and supplied to the Indian institution.

  (The life extension activities initiated under AERD will be continued through the EMCAT Project where a model life assessment study covering all areas of the power plant will be conducted.)

- BHEL equipped to conduct baseline monitoring of NOx and SOx emissions in coal fired power plants through technical assistance from U.S. companies and provision of monitoring equipment.

- Quantification of emissions from operating power plants and relating them to plant design and operating practices has helped in development of control strategies for pollution abatement in India.

- Design review of the slagging combustor at BHEL and modifications to the combustor and auxiliary equipment recommended to enable slag formation. Diagnostic hardware instruments necessay for measurement and analysis to determine slag characteristics procured and supplied.

The end result of the coal subprojects resulted in the following benefits:-

An extensive data base on coal conversion and poilution control measures tailored for the Indian power sector was generated. Aside from providing a necessary base for GOI policy in the area of pollution abatement, the data generated through measurements in the facilities established will help the U.S. private sector in the selection of the most appropriate technologies and products for the Indian power sector. The work carried out under the subproject an Advanced Diagnostic studies for Prediction of Life Expectancy of Existing power plants will help promote U.S. technologies and equipment for life extension of Indian power plants. Power plant extension has been identified as one of the priority areas for implementation by the GOI during the eight five year plan (1992-93). Renovation and modernization of coal fired power plants in an area targetted for immense investment and growth in India.

**Energy Efficiency**

Four workshops on energy efficiency were held in India and were attended by over 400 Indian participants. The workshops included a cross section of Indian and U.S. engineers, industry managers, manufacturers and government and state representatives. Because a large number of private companies attended, good contacts between Indian and U.S. manufacturers were established. Also, an energy conservation mission of 20 senior officials from the Indian private sector visited the U.S. with the objective of discussing and evolving new areas for U.S./Indian cooperation in energy efficiency and allied fields, and exploring business and trade potential in energy efficiency technologies & systems. These objectives were largely met through a well conceived program organized by NAS. In addition, a cogeneration technology mission comprised of 11 senior officials from the GOI and Indian private sector under the auspices of CEI visited the U.S. This mission was extremely successful in that the CEI was able to develop a series of recommendations and an action plan for promoting cogeneration in India, based on the U.S. experience. The recommendations were widely circulated within both the GOI and the private sector.

**Information Exchange**

This component established mechanisms for the exchange of information on a systematic basis and for the organization of workshops on relevant topics. Further, this component successfully supported five subprojects, and additionally about 100 Indian scientists attended energy conferences and seminars in the U.S. This component also supported a special study and two workshops on non-utility power generation in India.

The five Phase I subprojects under this component resulted in:

- the commercialization of polymer film collectors by the private sector aided by Brookhaven National Laboratory (BNL). BNL's design offered the double advantage of high performance and a potential significant reduction in installation costs;

- the objective of increasing the Solar Energy Center's (SEC) analytical capability was achieved and Indian scientists were introduced to a new approach to solar technology;

- the development of a National Planning Model for Non-Conventional Energy enabling government policy makers to analyse and evaluate the impact of non-conventional energy technologies on the national economy;

- the development of a microprocessor controlled system for automatic and efficient management of loads connected to low head turbine plants;

- the establishment of a facility for the design of electronic controllers and procurement of a low head U.S. made turbine; and

- a thin film technology subproject which was a follow-on to the earlier collaborative project on polymer film collectors between the Solar Energy Center (SEC) and BNL. The subproject developed the material's characteristic capabilities and evaluated the current and projected capability of Indian industry to produce the materials for thin polymer collectors of the BNL design.

In addition, non-utility power generation workshops to disseminate the findings of the study on cogeneration of power in India which focused on Maharastra and Gujarat were successfully organized in India involving the participation of over 100 senior GOI/private sector officials.

This Solar Photovoltaic Test Facility subproject which was also implemented under this component was completed in Phase II as originally planned. The equipment specifications were finalised after detailed discussions and all needed equipment was procured and supplied. The training provided to DNES personnel who will be responsible for operation of the facility was designed to provide a solid background in field testing and trouble shooting and instrumentation of systems. A two week visit by SNL personnel to India provided an in-depth perspective on the status of equipment, planned activities of DNES for the use of the facility and the status of the photovoltaic activities in India.

This subproject has the capacity to have a tremendous impact on the state-of-the-art in photovoltaic technology in India. As the network of private organisations grows to aid in the distribution of the technology, this facility will play a major role in the success of photovoltaics. DNES will have the capabilities to aid product manufacturers make improvements on their products and guide the evolution of the photovoltaic technology. This facility is the shining star of the PV technology, a resource for all of the states to avail themselves of, as duplication of these resources is very expensive. The future of this facility's possible contributions to photovoltaics in India looks very bright.

**Relevance of Collaborative Effort and Study Tours**

Visits and training sessions in the U.S. were well organized, and effective and the U.S. organizations were very supportive of the Project and its goals. Indian scientists, engineers, private and public sector officials gained experience, training, and valuable contacts through the various study tours and workshops supported by this Project. The effectiveness of U.S. organizations and the technology transfer was apparent, for instance, in the speed with which work was accomplished and the enthusiasm of the group for the evaluation of freeboard performance in a fluidized bed combustor project. Also, representatives from ORNL spent considerable time on site to provide continued support to the engineers and construction crew. The PETC management team also showed dedication and enthusiasm for the Project which was acknowledged on numerous occasions by their Indian counterparts. In addition, the exchanges of scientists from SEC and BNL were very fruitful and effective in the polymer film solar collectors subproject. A close working relationship was built up with PETC and SNL as they were keen to consolidate a technology development presence in India (since India, as the fifth largest coal producer, has the potential to become a significant market for U.S. energy technology). It is expected that this collaboration will continue, as considerable data exchanges are expected between U.S. agencies and related Indian agencies.

**Institution Building**

Several institutions have, or will benefit from the Project, by having enhanced their research capability and by establishing themselves as credible research centers. Some examples include: the Chemical Engineering Department at Indian Institute of Technology (I.I.T.), Delhi, has increased its research capability in the area of biomass fuel characterization and gasifier development. This increased analytical capability will benefit the other biomass conversion projects in which it is involved. The scientists trained in the U.S. under the biomass production component have received permanent appointments at the two Indian universities ensuring that their expertise will be maintained in the future. Under the biomass conversion

component, the Department of Mechanical Engineering at I.I.T., Delhi, 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. By being involved in field trials, both the Department of Chemical Engineering and the Department of Mechanical Engineering have gained insight and experience in transferring technology from their academic environment to a real life environment. The Sardar Patel Renewable Energy Research Institute (SPRERI), already involved in the development and operation of gasifiers, increased its capability through the transfer of analytical equipment and techniques and the training and experience gained by the staff involved in the AERD Project. In the coal conversion subprojects, the Central Fuel Research Institute received support from PETC through the exchange of experts, technology transfer and ideas for future work. The BHEL Corporate Research and Development Laboratories benefited from engineer's visits to the U.S. The Energy Efficiency subprojects enhanced the capabilities of the CEI, a private industry association representing about 2,000 industries having good relations with government agencies, and contacts with other industrial groups. In addition, the DNES, TERI, the Alternative Hydro Energy Center (AHEC), Gujarat Dairy Development Corporation (GEDA), and the SEC all benefited from enhanced capabilities due to their involvement in the various subprojects. Under Phase II of the Project, the institutions that were recipients of the technical assistance and training were Bharat Heavy Electricals Ltd., Research and Development group at Trichy and the Department of Non-Conventional Energy Sources (DNES). More than 20 engineers from these two organisations were trained under the coal projects through PETC and under the test facility project through SNL. Engineers of BHEL were exposed to the latest developments in the U.S. in these areas. Through their association with the technical community in India, PETC and SNL have established an excellent working relationship with the key energy sector agencies in India which will be continued in the future.

### Sustainability

All of the private and public sector collaborating institutions involved in the R&D activities in this project enhanced their research capabilities in the four targeted areas. This enhanced capability plus the collaborative associations formed among the institutions will continue beyond the life of the Project. In addition, BHEL as well as DNES are committing increased resources to project produced or assisted facilities, and it is fully expected that its corporate commitment to R&D will continue well beyond the termination of USAID assistance.

## V. LESSONS LEARNED

1. The coal projects implemented through Pittsburgh Energy Technology Center (PETC) have established strong scientific and institutional linkages between

the technical communities associated with the coal industry in India and the U.S. The next step is to establish policy level linkages between key decision makers in both countries to set the pace and direction for commercial joint ventures in clean coal technologies. Continued support from U.S. Department of Energy would be very beneficial to provide India with access to the broad range of clean coal technologies developed under the USDOE clean coal technology program.

2. Environmental monitoring is still in its infancy in India, and the need for technical know-how, equipment and services are great. Opportunities for U.S. environmental consulting and service organisations are extremely bright. As a first step, it is necessary that U.S. companies obtain an in-depth exposure to Indian utility operations and local conditions before getting into full-fledged commercial ventures. Adaptation of U.S. coal and environmental technologies to Indian canditions will be the key to successful joint ventures. These lessons were clearly brought out in the two site activities that were completed under AERD in India.

3. The power plant life assessment study carried out under this project by U.S. and Indian groups was an excellent demonstration of a joint team efforts.

4. Opportunities for U.S. companies in the power sector in India are plenty and growing constantly. Several Indian and U.S. Corporations are considering setting up commercial joint ventures in the power sector. The recent liberalization policies announced by the GOI in the power sector have stimulated interest, and it is expected that many more companies will follow suit. For the first time in India, power and coal mining sectors have been opened to the private sector. Foreign technology, equipment and services are in great demand. The need for U.S. tecnologies and services in environmental, power plant modernization and efficiency improvement and coal benefication are evident.

## VI. MISSION FOLLOW-ON ACTIVITIES

### Clean Coal Technologies

Coal continues to play a dominant role in the Indian power sector, and the demand for coal in fuelling the power sector is projected to increase to over 400 million tons by the year 2000. Some of the important coal projects carried out the under AERD will be followed up through the other energy projects of the mission, viz., PACER and EMCAT. The subproject on Integrated Coal Gasification and Combined Cycle (IGCC) that resulted in a techno-economic feasibility report is being followed up under the PACER Project. A project for development and demonstration of

pressurised fluidized bed gasification (PFBG) of 150 tons per day coal output has been approved with PACER funding of $2.5 million. Based on the operation of this demonstration plant, the project proposers will scale up the gasifier and develop commercial PFBG units for power generation. Power generation through adoption of combined cycle integrated with coal gasification is perceived as a viable and effective option for the high ash Indian coals and development of PEBG technology would accelerate the process of establishment of high efficiency advanced systems suited to low grade Indian coals.

Another important activity initiated under AERD and which will be now supported under the mission's EMCAT Project is power plant life assessment. A condition assessment demonstration project at an Indian utility is being implemented under this project. The Pittsburgh Energy Technology Centre (PETC) of the U.S. Department of Energy will manage this 24 month US-India Cooperative Energy Technology Program under a Participating Agency Services Agreement (PASA) signed between AID and PETC. This program will include the training of Indian engineers in U.S. utilities, the conducting of a detailed condition assessment study under the guidance of U.S. experts, the analyzing and interpretation of field data to identify causes of failure, suggest corrective measures to prevent failures, and to extend component life and increase plant availability and efficiency. This project would establish the model for conducting future life assessment studies in Indian power plants.

**Energy Efficiency**

The energy efficiency activities implemented under AERD receive continued support through the mission's EMCAT Project. The EMCAT Project has a separate component for supporting initiatives in the field of energy efficiency with an AID funding of $6.0 million. The energy efficiency component being implemented by the Industrial Development Bank of India (IDBI), will help industrial and commercial enterprises to improve management and to install new systems to decrease energy consumption.

Cogeneration, introduction of energy service companies, energy audits and demand side management have been identified as the thrust areas for EMCAT support under the energy efficiency component. The cogeneration activities which were initiated under AERD will be one of the major areas of support under EMCAT. Preparation of detailed feasibility studies for cogeneration projects, establishment of model innovative cogeneration projects, policy studies for promotion of cogeneration and technological upgradation of the cogeneration system have been targetted for continued support.

Attachment A

## COVENANTS

1. In order to implement the subprojects under each major component of the Project, the designating entity will ensure that the work plans for each component, consistent with project objectives, are developed by the U.S. and Indian collaborating institutions about six months after AID has signed agreements with the identified U.S. institutions for collaboration.

STATUS: Work plans were provided.

2. The designated implementing entity will ensure the establishment of an adequate number of additional positions and also ensure the employment of qualified staff to fill these positions for the biomass production programs at the National Botanical Research Institute and Madurai Kamraj University with reference to AID financed activities by approximately December 1983.

STATUS: An adequate number of positions were established and filled.

3. The designated implementing entity will conduct economic and social assessments in the areas of the biomass production and conversion programs.

STATUS: Assessments have been conducted by the implementing entity.

4. The Cooperating Country/Grantee shall exercise every reasonable effort to require each person trained under the Project to work in activities related to the Project or in activities approved for financing under this Project Agreement, in India, for not less than three times the length time of his or her training program.

STATUS: This is being monitored and trainees have thus far been certified as per standard operating procedure.

Attachment B

**STATUS OF PHASE I SUBPROJECTS**

| | Status |
|---|---|
| I. Biomass Production Projects | |
| 1. Production of Woody Biomass on Substandard Soil in Phase II | completed |
| 2. Research and Development Studies of Woody Biomass Species on Arid Marginal in Phase II Lands; Lab/Plantation Approach | completed |
| II. Coal Conversion Projects | |
| 1. Evaluation of the Freeboard Performance in a Fluidized Bed Combustor | completed |
| 2. Scale-up of AFBC Boilers | completed |
| 3. Coal-Water Slurries | completed |
| 4. Coal Benefication | completed |
| 5. Hot Gas Clean-up | completed |
| 6. Cold Gas Clean-up | completed |
| III. Biomass Conversion Projects | |
| 1. Development of a Village-level Gasifier based on charred agricultural residue | completed |
| 2. Utilization of Producer Gas in Small Horse Power Engines | completed |
| 3. Development of Wood Based, Gasifier/Engine | completed |

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IV. Information Exchange Projects

| | | |
|---|---|---|
| 1. | Field test of Polymer Film Solar Collectors | completed |
| 2. | Development of a National Planning Model for Non-Conventional Energy | completed |
| 3. | Low-head Hybrid Micro-Hydel system | completed |
| 4. | 100-Kilowatt Gasification System | completed |
| 5. | Thin Film Technology | completed |

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V. Energy Efficiency

| | | |
|---|---|---|
| 1. | Four Workshops | |
| | a. Thermal Energy use in Indian Industry | completed |
| | b. Electrical Energy Use in Indian Industry | completed |
| | c. Energy Planning and Management in Indian Industry 2 workshops (at Madras & Calcutta) | completed |
| 2. | Two Study Missions to U.S. | completed |
| | a. Energy Efficiency | completed |
| | b. Cogeneration | |

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Attachment C

**STATUS OF THE PHASE II SUBPROJECTS**

| Coal Conversion Projects | Status |
|---|---|
| 1. Development of pollution control strategies for abatement of NOx emissions from coal fired power plants. | completed |
| 2. Development of slagging combustors for power utilities utilizing high ash coals. | completed |
| 3. Advanced diagnostic studies for prediction of life expectancy of existing power plants. | completed |
| 4. Techno-economic assessment of integrated coal gasification combined cycle in India. | completed |
| 5. Characterization of Indian coals for combustion and gasification. | completed |
| 6. Environmental study of coal resource cycle. | completed |

| Information Exchange | |
|---|---|
| 1. Establishment of a solar photovotaic test facility. | completed |

ATTACHMENT - D

INTERIM REPORT

# PROJECT ASSISTANCE COMPLETION REPORT

# ON

# ALTERNATIVE ENERGY RESOURCES DEVELOPMENT

# PROJECT (386-0474)

# PHASE I (JUNE 1982 - JUNE 1988)

NOVEMBER 29, 1989

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INTERIM REPORT

PROJECT ASSISTANCE COMPLETION REPORT
ALTERNATIVE ENERGY RESOURCES DEVELOPMENT PROJECT (386-0474)

1. PURPOSE

The purpose of the grant was to expand India's technical capacity to exploit its alternative energy resources and to develop selected technologies to a stage of application. The ultimate goals of the project were to reduce India's dependence on imported oil, to reduce deforestation, and to increase industrial energy efficiency.

2. PROJECT DESCRIPTION

The Alternative Energy Resources Development Project (AERD) project is a collaborative effort between the United States 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.

3. A.I.D. INPUTS--PLANNED AND ACTUAL ('000$)

| | PLANNED | ACTUAL |
|---|---|---|
| Technical Assistance | | 3,600 |
| Commodities | | 850 |
| Training | | 1,900 |
| Others | | 650 |
| TOTAL | | 7,000 |

4. GOI INPUTS--PLANNED AND ACTUAL (in equivalent US '000$)

| PLANNED | ACTUAL |
|---|---|
| 1,750 | |

5. EXPECTED OUTPUT

15 subprojects in Biomass and Coal conversion; 2 subprojects in Biomass Production; 6 subprojects in Information Exchange; and 4 workshops on Energy Efficiency.

6. PROJECT BACKGROUND

In 1982, a decision was taken jointly by the Government of India and the United States to further strengthen the bilateral

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assistance relationship through the support of a joint research and development program in Alternative Energy Resources. The then current energy project, the Technologies for the Rural Poor (TRP) (386-0465) was half-way through its completion and its purpose was to increase Indo-U.S. collaboration in the testing and application of science and technology to India's rural development effort with special emphasis being placed on technologies appropriate to the rural setting., i.e. culture, work force and skill base, economic system, etc. The technologies under development included primarily solar energy applications for power and industrial/agricultural needs. The AERD project had a distinctly different focus from TRP in that its aim was to expand technical capabilities of Indian institutions to exploit conventional and/or non-conventional energy resources and to develop the selected technologies to a stage of practical application. The primary emphasis of this project was to develop new and advanced coal and biomass conversion technologies for the efficient utilization of coal and biomass feedstocks in India. Emphasis was also placed on promoting energy efficiency in the industrial sector and in enhancing result-oriented development work in the areas of woody biomass production. Finally the project was designed as a useful vehicle for technical interaction between Indian and U.S. energy researchers, attendance at energy workshops/conferences in the U.S., and demonstration of specific renewable technologies. To achieve the goals of the Alternative Energy Resources Development 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. Table 6.1 summarises the characteristics of the various components and subprojects which were taken up during the first phase (1982-88) of the AERD project.

On account of the late start-up of the subprojects, the PACD was extended from July 1, 1986 to June 30, 1988. During this extension, an additional funding of $2.0 million was provided to take the grant total to $7.0 million. The project was further extended for two and a half years from July 1 , 1988 to December 31, 1990. This PACD extension was necessitated by the need to support follow-on coal conversion subprojects and complete the two biomass production subprojects.

The delay in the start-up of the new coal conversion subprojects and the need to support a fresh GOI initiative in energy efficiency has compelled the DNES to request USAID to further extend the PACD from Dec. 31, 1990 to June 30, 1992.

## 6.2 SCOPE OF THIS REPORT

This interim report covers the period from project start-up (June 30, 1982) to June 30, 1988, representing the first phase of the AERD project. It provides a brief description of the completed subprojects under the four project components during the first phase. It reviews the mid-term evaluation of the project (Jan 1987) and provides the current status of the evaluation recommendations.

Between mid-1982 and early 1984 several subprojects were submitted and approved by the GOI and USAID. The details are given in Table 6.1. The following pages of this report cover subprojects that have been completed under the following three components.

| | |
|---|---|
| 1. Coal and Biomass Conversion | - 9 subprojects |
| 2. Energy Efficiency | - 4 workshops and 2 study missions |
| 3. Information Exchange | - 5 subprojects |

Note: The report being interim in nature does not purport to be either comprehensive nor conclusive. It provides an assessment of the extent to which purpose of the project has been achieved during the initial phase of the project and projections on the future directions of the project. It is to be noted that the report does not cover the biomass production component since it is currently under implementation.

## 6.3 COAL CONVERSION AND BIOMASS CONVERSION--AN OVERVIEW OF PROJECT IMPLEMENTATION AND BACKGROUND

Under a PASA with A.I.D., the Department of Energy, Pittsburgh Energy Technology Center (PETC) was responsible for managing and implementing this major component of the AERD project. The purpose of this agreement was also to obtain PETC's expertise in the areas of conversion and utilization of alternate energy resources.

The implementation plans for each of the nine subprojects under the coal and biomass conversion component were developed at the First Workshop on Alternative Energy Resources Development held in New Delhi, Nov. 7-11, 1982. The detailed technical and management workplans were approved by USAID and DNES, GOI. The technical workplans described the scope of the research, development and demonstration activities under each of the selected projects, whereas the management plans described the overall management structure and schedule for the individual collaborative projects.

6.3.1. Workshops on AERD

Five workshops were held in New Delhi, India on the program between March 1983 and March 1987 on the following dates:

| | |
|---|---|
| First Workshop | Nov. 7-11, 1983 |
| Second Workshop | Feb. 4-5, 1985 |
| Third Workshop | Dec. 5-7, 1985 |
| Fourth Workshop | March 2-4, 1988, Trichy |
| Fifth Workshop | March 9-10, 1988, Delhi |

The intent of the first three workshops was:

- to review the progress of the program during the year
- to encourage U.S. specialists to discuss with their Indian counterparts the direction and course of the program
- to assess the status of the subprojects through site visits
- to provide a forum for technical exchange between U.S. and Indian industry

The fourth and fifth workshops were focussed exclusively on the state of art of Fludized Bed Technology and its applications in the U.S. and India.

6.3.2. Study tours by Indian engineers/scientists to the U.S.

During the period August 1983 to May 1986 seventeen engineers/scientists visited the U.S. under the coal program and six engineers visited the U.S. under the biomass segment. Their program included site-visits to U.S. facilities actively involved in their respective areas of research to obtain either training and hand-on experience in the operation and maintenance of instruments, to participate in design review meetings, and technical discussions with experts in their field of interest, or to attend official conferences to update them on the current status of the technology and its future direction.

6.3.3. Expenditures

Total expenditures for the overall program on coal and biomass conversion under the PETC PASA was $1,919,000. The summary cost-sheet is shown in Table 6.2. The larger expenditure categories, each of approximately 38% of the total funding were:

Equipment supplied to Indian participating organisations ($720,555), and Technical R&D contracts ($728,064)

Almost $100,000 was spent on training of Indian engineers in the U.S. and for the workshops held in India. Individual subproject expenditures are shown in Table 6.3

6.3.4. Freeboard Performance subproject-Oak Ridge National Laboratory (ORNL) PASA

The PETC PASA for the nine subprojects expired on June 30, 1987. Of the nine subprojects, the subproject on Freeboard Performance was incomplete and under critical stages of execution. At the request of the DNES, GOI, USAID executed a buy-in to S&T/EY, AID/W PASA with ORNL to provide technical assistance to the subproject. The PASA, amounting to U.S. $376,500 was successfully executed by ORNL from September 1987 to March 31, 1989. During this period, an additional eight BHEL engineers went to the U.S. for training thus bringing the total numbers trained under the two PASA's to 31. The subproject also involved additional equipment supplies worth $130,000 under the ORNL PASA.

7.0 SUMMARY DESCRIPTION OF AERD SUBPROJECTS
Coal Conversion Component

| 7.1 Sub-Project Title | Collaborative Institutions |
|---|---|
| Evaluation of the Freeboard Performance in a Fluidized Bed Combustor (FBC) | Indian: Bharat Heavy Electricals Ltd (BHEL), Trichy, U.S.: A) Pittsburgh Energy Technology Center (PETC); B) Oak Ridge National Laboratory (ORNL) |

7.1.1 A.I.D. Grant Details

| Period of Activity | USAID* Contribution | GOI Contribution (in equivalent $)** |
|---|---|---|
| Jan '84 - June '88 | $1,061,100 | 469,100 |

* Includes $684,600 under the PETC PASA and $376,500 under the ORNL PASA

** Exchange rate: 1U.S.$ = Rs.16.507.1.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 495,166 |
| Training | 45,510 |
| Equipment | 396,852 |
| Others | 123,572 |
| Sub-project Total | 1,061,100 |

7.1.3 Summary Description and Status

The objective of the subproject was to design, construct, and operate a 1 meter square AFBC research test facility to evaluate the combustion and heat transfer in the freeboard region. The test program was specifically designed to:

a) Gather performance and heat transfer data on freeboard combustion, heat release and heat transfer rates along the freeboard height.

b) Obtain data on dust loading and gas composition along the freeboard height

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

d) Obtain combustion efficiency and carbon burn-up as a function of fuel type and size

The subproject, initiated in early 1984 was completed in mid-1988 following which long duration trials were performed on high ash content Indian coals. The final report on the subproject was submitted to USAID by the collaborating institutions in June 1989. The test facility is acknowledged for its sophistication and is extensively utilised by BHEL to determine key design parameters in commercial FBC systems.

| 7.2 SUBPROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| Scale-up of AFBC boilers | Indian: BHEL, Trichy<br>U.S.: a) PETC<br>b) Tennesse Valley Authority (TVA) |

7.2.1. A.I.D. Grant Details

| Period of Activity | USAID* Contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| Jan. '84 - April '85 | $125,003 | 30,300 |

7.2.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 98,879 |
| Training | 4,438 |
| Equipment | - |
| Others | 21,686 |
| Sub-project Total | 125,003 |

7.2.3 Summary Description and Status

The objective of the subproject was to complete the proposed design of the 30MW$_e$ (150 tonnes/hr) AFBC unit including drawings and specifications, and submit it to TVA through USAID for evaluation and verification for scale-up parameters.

The proposed design with arrangement drawings and equipment specification prepared by BHEL were forwarded to TVA in December 1984. TVA had an inhouse review of the design and two TVA engineers had preliminary discussions with BHEL engineers at Trichy during Feb. 1985. The design review by TVA was finalised in April 1985 and submitted to BHEL. Through this design, BHEL's capability in offering utility size AFBC units has been enhanced.

| 7.3 SUB-PROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| Rheology, Stability, and combustion of coal-water mixtures | Indian: a) Bharat Heavy Electricals Ltd, (BHEL), Trichy<br>b) Central Fuel Research Institute, (CFRI), Dhanbad<br><br>U.S.: a) Pittsburgh Energy Technology Center (PETC) |

7.3.1 A.I.D. Grant Details

| Period of Activity | USAID Contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| Jan '84 - Dec '86 | $76,492 | 72,700 |

7.3.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 12,135 |
| Training | 3,496 |

| | |
|---|---|
| Equipment | 51,245 |
| Others | 9,617 |
| Sub-project Total | 76,492 |

7.3.3 Subproject Description and Status

The primary objective of the subproject was the development of a process for the preparation of coal-water mix (CWM) with typical Indian coals, and characterisation of the fuel. This was the responsibility of CFRI, Dhanbad. A secondary objective, was the development of burner and suitable combustion system for utilising CWM fuel. This was the responsibility of BHEL, Trichy.

Laboratory-scale studies were conducted at CFRI, Dhanbad to prepare coal-water mixtures using coal with and without beneficiation. The rheology and stability of these fuels were investigated as a function of the rank and type of coal, additives, and particle size distribution. The combustion studies at BHEL, Trichy focussed on the combustion and erosion characteristics of the CWM fuels, pressure drop and mixing studies to obtain data for scale-up of large scale CWM preparation equipment and the combustor. The design data is an important input in large scale CWM projects.

| 7.4 SUBPROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| Hot gas clean-up and separation | Indian: BHEL, Hyderabad<br>U.S.: PETC |

7.4.1 A.I.D. Grant Details

| Period of Activity | USAID contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| July '84 - June '87 | $162,230 | 277,575 |

7.4.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 12,378 |
| Training | 8,041 |
| Equipment | 132,399 |
| Others | 9,412 |
| Sub-project Total | 162,230 |

7.4.3 Subproject Description and Status

The objective of the subproject was the setting up of a well instrumented high temperature, high pressure test facility (HTHP) to evaluate hot gas cleanup devices for use in combined cycle power generation.

By mid-1986, the HTHP facility was designed by BHEL, corporate R&D and detailed engineering drawings prepared for the fabrication of various systems, and auxiliary equipment, structures and control room and facility layout. The erection of the facility and its commissioning was completed in early 1988. Detailed testing was accomplished by mid-1988 of the Granular Bed Filter (GBF) and the HTHP. This has led to introduction of GBF in a demonstration plant on Integrated Coal Gasification Combined Cycle at BHEL, Trichy

| 7.5. | SUBPROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|---|
| | Beneficiation of Fine Coal | Indian: CFRI, Dhanbad<br>U.S.: PETC |

7.5.1 A.I.D. Grant Details

| Period of Activity | USAID contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| Sep. '84 - June '87 | $108,108 | 30,300 |

7.5.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 29,899 |
| Training | 3,221 |
| Equipment | 48,558 |
| Others | 26,430 |
| Sub-project Total | 108,108 |

7.5.3 Subproject Description and Status

Indian coals contain a large amount of mineral matter that mechanically and economically place burdens on a combustion system. However, due to inferior cleaning characteristics in Indian coals, the yield of clean coal obtained on washing, is unsatisfactory. Indian coals require finer grinding to separate the coal from the non-combustible mineral matter.

Under the subproject, a pilot plant was designed and installed at CFRI to study the beneficiation characteristics of Indian coking coals having difficult cleaning characterstics by a dense medium cyclone.

| 7.6 SUBPROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| Cold gas clean-up and separation | Indian: Regional Research Lab. (RRL), Hyderabad, U.S.: PETC |

7.6.1 A.I.D. Grant Details

| Period of Activity | USAID contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| July '84 - June '87 | $69,846 | 30,300 |

7.6.2 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 8,466 |
| Training | 3,502 |
| Equipment | 50,516 |
| Others | 7,361 |
| Sub-project Total | 69,846 |

7.6.3 Subproject Description and Status

The cold gas separation and clean-up subproject implemented at RRL, Hyderabad was undertaken with a view to allow long-term R&D to be pursued in the areas of adsorption and membrane sepration for cleaning gaseous effluents from coal gasification processes.

The research work focussed primarily on adsorptive gas separation, and gas/solid contacting techniques to remove particulate matter. A bench scale unit was designed and fabricated at RRL to carry out exploratory and process development studies to optimize gas separation methods to separate particulates, acid gases like carbon dioxide, hydrogen sulphide and organic sulphur compounds.

| 7.7 BIOMASS CONVERSION COMPONENT SUBPROJECT(S) TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| Subproject A<br>Development of a village level gasifier for irrigation pumps, based on charred agricultural residue | IIT, Delhi; PETC; MITRE Corpn. Univ. of Missouri, Univ of California |

| | |
|---|---|
| Subproject B<br>Utilization of producer gas in small horsepower diesel engines | - do - |
| Subproject C<br>Development and field implementation of small wood-based gasifier engine systems | - do -<br>Sardar Patel Solar Energy Institute, Vallabh Vidyanagar, Gujarat |

7.7.1 A.I.D. Grant Details

| Period of Activity | USAID contribution ($) | GOI Contribution (in equivalent $) |
|---|---|---|
| Subproject A<br>Jan. '84 - June '87 | 232,667 | N/A |
| Subproject B<br>Jan. '84 - June '87 | 225,219 | |
| Subproject C<br>Jan. '84 - June '87 | 234,836 | |
| Subproject(s) Total | 697,722 | |

7.5.2 A.I.D. Inputs

| Item | Amount ($) | | |
|---|---|---|---|
| | A | B | C |
| Technical Assistance | 105,788 | 105,788 | 105,788 |
| Training | 6,933 | 7,069 | 6,537 |
| Equipment | 53,668 | 46,084 | 56,233 |
| Others | 66,278 | 66,278 | 66,278 |
| Sub-project(s) Total | 232,667 | 225,219 | 234,836 |

7.7.3 Subproject(s) Description and Status

The biomass conversion component was a major component of the AERD project and involved development and field testing of three biomass conversion technologies that can significantly decrease India's dependence on imported oil. The technical work of the three subprojects was conducted in joint collaboration between U.S. and Indian engineers. The

activities accomplished by U.S. and Indian project team were as follows:

Subprojects A and B

- Designed and fabricated a small gasifier and gas cleanup subsystem suitable for converting preprocessed agricultural residue into producer gas.
- Conducted laboratory tests to obtain performance data on gasifier and gas cleanup subsystems.
- Designed, fabricated and tested different engine intake systems for producer gas dual-fuel operation
- Quantified the performance of the selected intake system with respect to maximum diesel fuel replacement and overall engine thermal efficiency
- Conducted laboratory tests to quantify the performance of the integrated gasifier-diesel engine pumpset system
- Completed over 100 hours of field performance data for the integrated system

Subproject C

- Conducted short and long term laboratory tests on small, wood-based gasifer and dual-fuel diesel engine pumpset systems
- Modified the design of the gasifier and gas clean-up systems

The three subprojects have provided critical inputs that have assisted key Indian institutions in utilising bio-fuels for power/mechanical operations.

## 8.0 ENERGY EFFICIENCY COMPONENT

| 8.1.1 SUBPROJECT TITLE | COLLABORATIVE INSTITUTIONS |
|---|---|
| 1. Workshops in Energy Efficiency | Indian: Confederation of Engineering Industry (CEI) |
| 2. Energy Conservation Mission to USA | U.S.: National Academy of Sciences |
| 3. Cogeneration Technology Mission to USA | |

8.1.2 A.I.D. Grant Details

| Period of Activity | USAID contribution | GOI Contribution (in equivalent $) |
|---|---|---|
| June '84 - Dec. '88 | $493,669 | N/A |

8.1.3 A.I.D. Inputs

| Item | Amount ($) |
|---|---|
| Technical Assistance | 135,370 |
| Training | 149,895 |
| Equipment | - |
| Others | 160,240 |
| Sub-project Total | 493,669 |

8.1.4 Subproject Description and Status

A. Workshops

The subproject supported the following three workshops in India in energy efficiency:

a) Thermal Energy use in Indian Industry: Strategies for Improving Efficiency. January 27-29, 1986, New Delhi

b) Electrical Energy use in Indian Industry: Strategies for Improving Efficiency. May 5-16, 1986, Bombay and Bangalore

c) Energy Planning and Management in Indian Industry: Lessons from U.S. experience; May 10-15, 1988; Madras and Calcutta.

The workshops had the following primary objectives:

- To consider near term applicability and benefits of using proven technologies to reduce energy costs in industry,

- To discuss long term opportunities to apply frontier technologies,

- To determine key policy and institutional barriers to the transfer of new energy technologies and to recommend strategies for overcoming these barriers,

- To consider opportunities for Indian firms to manufacture and/or market energy systems or to provide services needed to enhance energy efficiency, and

to review U.S. experience with a comphrensive approach to energy planning and management in industry, and to discuss implications of this experience for Indian industries.

The five workshops were attended by over 400 Indian participants.

B. STUDY MISSIONS TO THE U.S.

The following two study missions were organised under the subproject.

a) Energy conservation mission to USA, October 13 - 25, 1986

b) Cogeneration Technology Mission to USA, June 5 - 16, 1988

ENERGY CONSERVATION STUDY MISISON

The CEI Energy Mission to the USA from 13th to 25th October 1986 was the first focussed mission of 20 senior officials from the Indian private sector, dealing exclusively with the subject of energy efficiency. The following were the objectives of the mission:

- to review the U.S. developments in the area of Energy Management/Conservation,
- to identify possible areas for technology transfer and collaboration,
- to locate potential partners for such cooperation,
- to recommend specific action to promote Indo-U.S. linkages in the energy field,
- At the macro-level, the mission had the objective of discussing and evolving new areas for CEI-NAS cooperation in energy efficiency and allied fields. The objectives of the mission were largely met through a well-conceived program organised by the NAS.

COGENERATION TECHNOLOGY MISSION

The CEI Cogeneration Technology Mission to the USA from June 6-15, 1988 was the first, focussed mission involving 11 senior officials from the GOI and the private sector, dealing exclusively with the subject of cogeneration. The following were the objectives of the Mission:

- to study cogeneration systems and practices in the U.S.
- to discuss with manufacturers, consultants and research institutions specific technologies for cogeneration,

- to study the process of integration of cogeneration in the U.S. power system, and

- to study financial, administrative, legislative and policy/regulatory issues governing cogeneration in the USA.

The mission was extremely successful in that the CEI was able to develop a series of recommendations and action plan for promoting cogeneration in India, based on the U.S. experience. The recommendations, which were comprehensive and far reaching was circulated widely within the GOI and the Indian private sector.

9.0 INFORMATION EXCHANGE COMPONENT

The following subprojects were taken up for implementation under this component and completed.

Subproject 1: Field Test of Polymer Film Solar Collectors.

Collaborative Institutions: (Solar Energy Center, DNES and Brookhoven National Laboratory, USA).

This subproject called for the testing of the advanced flat plate solar collectors developed at Brookhoven 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 costs. Tests were conducted at the Solar Energy Center (SEC) of DNES at Dundahara, Haryana, with the collaboration of BNL. A result of the subproject was the commercialization of Polymer Film collectors by private sector.

USAID contribution

| Item | Amount ($) |
|---|---|
| Technical Assistance | 70,000 |
| Training | 7,000 |
| Equipment | 16,000 |
| Others | 47,000 |
| Sub-project Total | 140,000 |

Subproject 2: Development of a National Planning Model for Non-Conventional Energy.

Collaborative Institutions: Tata Energy Research Institute (TERI), New Delhi and Brookhaven National Laboratory (BNL), USA).

This subproject called for the development of a national planning model which will enable government policy makers to analyse and evaluate the impact of non-conventional energy technologies on the overall economic picture of the country.

USAID Contribution:

| Item | Amount ($) |
|---|---|
| Technical Assistance | 73,500 |
| Others | 13,500 |
| Sub-project Total | 87,000 |

Subproject 3: Low-Head Hybrid Micro-System

Collaborative Institutions: Alternative Hydro Energy Center (AHEC), Roorkee and Boston University, (BU), Boston, USA.

This subproject involved the development of a microprocessor 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 of a facility for the design of electronic controllers and the procurement of a low-head U.S. made turbine tested, in parallel with other units, at the project site at Kakroi, Himachal Pradesh. The subproject made slow progress in the erection and commissioning of the micro-hydel turbine. In a GOI review meeting in later 1987, it was determined that Boston University and USAID have fulfilled all contractual obligations and AHEC needs to accelerate the subproject completion.

USAID Contribution

| Item | Amount ($) |
|---|---|
| Technical Assistance | 146,119 |
| Training | 41,942 |
| Equipment | 114,303 |
| Others | 26,636 |
| Sub-project Total | 329,000 |

Subproject 4: Thin Film Technology

This subproject was a follow-on to the earlier collaborative project on Polymer Film Collectors between SEC and BNL. Its purpose was to develop material's characterisation 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.

USAID Contribution

| Item | Amount ($) |
|---|---|
| Technical Assistance | 98,500 |
| Training | 6,800 |
| Equipment | 45,000 |
| Others | 83,500 |
| Sub-project Total | 233,800 |

Subproject 5: Cogeneration Workshops

In 1986, a study was conducted to explore the prospects for nonutility power generation in Gujarat and Maharashtra focussing on the role of the private sector. The study was sponsored by DNES, GOI in collaboration with USAID and conducted by Hagler, Bailly & Co, a U.S. consulting firm, in collaboration with the National Productivity Council of India.

As a follow-up activity to the above nonutility power study, two workshops were held, one in New Delhi on September 28 and the other in Ahmedabad on October 1, 1987. The objectives of these workshops were to: (1) present the study results to a broad audience, including key representatives of central and state governments, utilities, industry, financial institutions, and the private sector; ii) elicit the views of workshop participants on the role of the private sector in power generation; and iii) confirm or amend the conclusions and recommendations of the study, or both. The cost of the workshops amounted to $41,000.

10. AERD--Mid-Term Evaluation and Follow-on

An mid-term evaluation of the AERD projects was completed in January 1987. The evaluation was conducted by a joint Indo/U.S. group. The U.S. group was represented by a two member team from Energy Development International, Washington under an IQC contract with USAID. The two member counterpart Indian team was nominated by the DNES.

The evaluation report commended the progress and management of the project and made several important recommendations. The following are the key recommendations and their status.

| RECOMMENDATION | STATUS |
|---|---|
| a) USAID and DNES should examine evaluation report recommendations related to new coal conversion subprojects. | Done. Six new coal conversion subprojects, based on team's recommendations, have been approved and are under implementation from August 1, 1989. |

| | | |
|---|---|---|
| b) | Set-up review committee of DNES and Roorkee University to examine subproject issues. | Completed |
| c) | Extend PACD from June 30, 1988 to December 31, 1990 | Done |

11. AERD Follow-on Projects (Phase II)

In November '88, at the request of the GOI, USAID supported the visit of a U.S. Definitional team to assist the Mission in the identification and development of follow-on subprojects under AERD. The three member U.S. team comprised of two coal experts from the U.S. Dept. of Energy, PETC and an expert on solar photovoltaics from Sandia National Laboratories. The team leader was the representative from ANE/TR/ENR, AID/W. The team recommended the following new subprojects for implementation:

A. Coal R&D

a) Development of Pollution Control Strategies for Abatement of $NO_X$ emissions from coal fired power plants.

b) Development of slagging combustors for power utilities utilising high ash coals

c) Advanced diagonistic studies for prediction of life expectancy of existing power plants

d) Techno-economic assessment of IGCC in India

e) Characterisation of Indian coals for combustion and gasification

f) Environmental study of coal resource cycle

B. Renewables

a) Solar Photovoltaic Test Facility

b) Subprojects in Energy Efficiency

11.1 Current Status of AERD Phase II

Following GOI approvals in March 1989 of the coal R&D and renewables (information exchange component) subprojects, USAID initiated the necessary documentation for contracting with U.S. collaborative institutions. A PASA with the Pittsburgh Energy Technology Center (PETC) for $1.1 million was executed in late July '89. A buy-in to the ST/EY

contract with Bechtel Inc., USA was executed in June 1989 for the IGCC subproject. The six coal subprojects are under execution.

It is anticipated that the PASA with Sandia National Laboratories for the subproject in Solar Photovoltaic Test Facility for $488,000 will be executed in January 1990.

The energy efficiency activity under the project is currently under review by DNES. In this connection, the National Productivity Council (NPC) has advised of its plans to collaborate with an U.S. institution and will be shortly proposing a collaborative program. It is anticipated that this activity will begin in July 1990.

At the time of writing this report, USAID has received a request from DNES to extend the PACD of the AERD project from December 31, 1990 to June 30, 1992. The request is under consideration.

TABLE 6.1

SUMMARY DESCRIPTION OF THE ALTERNATIVE ENERGY RESOURCES DEVELOPMENT PROJECT (PHASE 1)

| | | | |
|---|---|---|---|
| COMPONENTS: Biomass Production | Biomass/Coal Conversion | Energy Efficiency | Information Exchange |
| SUBPROJECTS | A. Biomass Conversion | | |
| 1. Production of woody biomass on sub-standard soil<br><br>2. R&D studies of woody biomass species on arid marginal lands; lab/plantation approach | 1. Development of a village-level gasifier for irrigation pumps, based on charred agri residues<br><br>2. Utilization of producer gas in small horsepower diesel engines<br><br>3. Development of wood-based gasifier/engine | 1. Workshops/study missions on energy efficiency in industry | 1. Energy modelling<br><br>2. Field test of polymer film solar collector<br><br>3. Low-head hybrid micro-hydel system<br><br>4. Thin film technology<br><br>5. Cogneration workshops<br><br>6. Participation at energy conferences/workshps in the USA |
| | B. Coal Conversion<br><br>4. Freeboard performance<br>5. Scale-up of AFBC boilers<br>6. Hot gas clean-up<br>7. Cold gas clean-up<br>8. Coal/water slurry<br>9. Coal beneficiation | | |
| PARTICIPANTS<br>1. NBRI (INDIA)<br>2. MKU/BU (INDIA)<br>1/2. WI (U.S.), AU (U.S.) | 1. IIT (INDIA)<br>2. IIT (INDIA)<br>3. JSEI (INDIA)<br>4. BHEL (INDIA)<br>5. BHEL (INDIA)<br>6. BHEL (INDIA)<br>7. RRL (INDIA)<br>8. CFRI (INDIA)<br>9. CFRI (INDIA)<br><br>1 through 9 PETC (U.S.) | 1. CEI, NAS (U.S.) | 1. TERI (INDIA)<br>2. SEC (INDIA)<br>3. TERI (INDIA)<br>4. AHEC (INDIA)<br>5. NPC (INDIA)<br><br>1/2/4 BNL (U.S.)<br>3. BU (U.S.) |
| FUNDING | | | |

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TABLE 6.2

SUMMARY OF COST FOR PETC-PASA

| Sl No | Item | Coal | Biomass | Total | Percent |
|---|---|---|---|---|---|
| 1. | PETC | | | 25,125 | 1.31 |
| | Salary | 7,804 | 1,038 | | |
| | Travel | 13,750 | 2,042 | | |
| | Others | 120 | 379 | | |
| 2. | Equipment | 564,569 | 155,986 | 720,555 | 37.55 |
| 3. | Contracts | | | 728,064 | 37.94 |
| | MITRE | - | 264 | | |
| | ORNL | 340,008 | | | |
| | UNIV. MISSOURI | | 57,462 | | |
| | UNIV. CALIF | | 66,353 | | |
| 4. | Technical Support Service | 198,525 | 122,865 | 321,389 | 16.75 |
| 5. | Training | 77,503 | 22,357 | 99,860 | 5.20 |
| 6. | Others | 24,000 | - | 24,000 | 1.25 |
| | TOTAL | 1,226,279 | 428,746 | 1,893,868 | 100.00 |

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Table 6.3: Individual Coal and Biomass Project Expenditures

PETC - PASA

| COAL CONVERSION | AMOUNT ($) |
|---|---|
| Freeboard Performance | 684,600 |
| Coal-Water Mixture | 76,492 |
| Hot Gas Cleanup | 162,229 |
| AFBC Scale-up | 125,003 |
| Coal Beneficiation | 108,108 |
| Cold Gas Clean-up | 69,846 |
| SUB-TOTAL | 1,226,278 |
| BIOMASS CONVERSION | |
| Project A | 232,667 |
| Project B | 225,219 |
| Project C | 234,836 |
| SUB-TOTAL | 697,722 |
| TOTAL | 1,919,000 |