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An Indo-US Programme on Electric Power Technology Assessment

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Preface

For several decades now India has suffered acutely from a chronic problem of energy shortage. Per capita power consumption in India tends to be among the lowest in the world, and the problems of limited installed capacity have been compounded by those of transmission, distribution and economic and social policy. India's fossil fuel reserves are either poor in quality (as with coal) or very low in quantity (as with oil and gas). To obtain reliable power on a secure basis is therefore a major problem in the country.

To make a detailed analysis of different technology options and associated policies that may be relevant to India, an Indo-US Programme on Electrical Power Technology Assessment was started in the year 1998, in collaboration with and partial funding support from the Carnegie Mellon University. As part of this Programme several important areas have been identified, and four in particular relating to clean coal technologies, biomass option and transmission and distribution have already been addressed.

These studies concluded the first phase of the project. To consolidate the position and to chart a course for the rest of the project, a meeting of experts from the US and India was held in Warwick during 24-26 September 1999. The theme of the

meeting was the energy scenario in India, and the available options in terms of technology as well as policy regarding regulation, pricing etc. This report is an account of the discussions and recommendations that emerged from this meeting. The meeting provided a valuable forum for exchange of ideas and sharing of experience between the experts of the two countries.

This project would have been difficult to complete without the support received from Carnegie Mellon University. I am happy to acknowledge this support. I hope that this report will serve to highlight technology and policy options that should be considered seriously if we are to accelerate the process of reliable and secure energy supply in India in coming years.

R. Narasimha
Director, NIAS

Introduction

This project was initiated by Carnegie Mellon University (CMU), USA and the National Institute of Advanced Studies (NIAS), Bangalore in the year 1998. A preliminary meeting of energy experts chaired by Prof. A. Ramachandran, Honorary Visiting Professor, National Institute of Advanced Studies, Bangalore and Prof. V. S. Arunachalam, Distinguished Service Professor, Carnegie Mellon University (CMU) representing the US side was held at NIAS on 11 March, 1998 to discuss the details and identify topics that need to be addressed in the joint study. The outcome of this meeting is summarised in Annex-A.

During the course of the study, NIAS brought out the reports indicated below, which formed the basis for discussions between the two groups of experts (India-US) held at Warwick University, UK during 24-26 September 1999.

1. **Advanced Coal Technologies for Power Generation in India**
Prof. Ajit K. Kolar and Prof. V M K Sastri
2. **A Biomass option for Enhancing Energy Security**
Prof. H. S. Mukunda
3. **Distribution of Electrical Power**
Prof. D. P. Sengupta
4. **Status of Electric Power Transmission in India and Possible Technological Development**
Mr. S. Parameswaran

S. Rajagopal

The topic on 'Oil & Gas' could not be addressed due to time constraints and will be included in the second phase.

The final report on the meeting held at Warwick is attached as Annex-B. It can be noted from the report that the deliberations contain references to existing technologies, policies, funding arrangements etc. in addition to some innovative approaches. The group did recognise the fact that several recommendations now made, for example participation by the investors (IPPs), regulatory regime for improving the quality of power as well as ensuring effective management have been made earlier by other expert groups and are either under implementation or under active consideration of the government. Nevertheless, the groups felt the need to reiterate these in order to strengthen and support such recommendations.

In a review meeting held at NIAS on 17 March 2000, it was decided that the final report on the Warwick meeting should be in two parts - one relating to the actual deliberations at Warwick (Annex-B) and the second on the recommendations that flow out of the deliberations (Annex-C). It was also decided that the collaboration with CMU should be further pursued and as a step towards this a meeting in the near future should be organised with the concerned scientists at CMU.



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Annex-A : “Energy for the Future”

A meeting to discuss the topic of “Energy for the future” was held at NIAS on 10-11 March 1998. Several experts drawn from academia, public sector institutions, government and non-governmental organisations deliberated on the status of electric power in India, the available technology options, policy needs etc. It was recommended at the end of the meeting that the following points need to be looked into:

- (1) The fact that many participants referred to several reports on energy and also lack of their implementation seriously, could mean that those reports may not have addressed the right issues or they addressed only the technological issues not giving due consideration to social and political aspects which could have come in the way of their implementation. A holistic approach to energy issues is therefore necessary.
- (2) Policy and technology options are strongly linked and it is not right to consider one without the other. While the Indo-U.S. group could discuss openly the technology issues, the policy initiatives can come only from the Indian group which will be aware of specific problems relating to acceptability and implementation.

- (3) Working groups to look into specific energy sources and problem areas will have to be constituted. These groups will provide a report after in depth review of the problems and issues involved. This report will be presented to an Indian group (similar to the present group), final report should emerge based on the discussions of this Indian group, and may be presented to the US counter-parts. This report will form the basis for further Indo-U.S. deliberations.

In the light of the above recommendations, a small group meeting was held on 11 March 1998 at NIAS identifying the themes for the working groups. It was decided that the first four topics would be taken up for study in the first phase of the project.

1. Working Group 1 - Clean Coal Technologies
2. Working Group 2 - Renewable Energy: Biomass
3. Working Group 3 - Transmission and Distribution
4. Working Group 4 - Oil and Gas
5. Working Group 5 - Energy Services, Upgradation and Refurbishment of Equipment
6. Working Group 6 - Energy Conservation
7. Working Group 7 - State Electricity Boards (SEBs) and Related Problems, Preparation of Draft Guidelines
8. Working Group 8 - New Energy Sources - Fuel Cells
9. Working Group 9 - Energy Economics
10. Working Group 10 - Photo-voltaic & Wind Power

Annex B: Electric Power for India: A US-India Bilateral Study [Meeting at Warwick, 24-26 September 1999]

1. Among the many factors that restrict economic growth in India, the absence of adequate and modern infrastructure is seen as critical. This is especially so when it comes to electric power. In spite of having one of the largest generating capacities in the world, 93,000 MW, the per capita consumption of electricity remains very low (only about 350 kWh per year), compared to over 900 kWh for China and 14,000 kWh for the United States. There is a wide range of performance across power plants, and the transmission and distribution losses are over 20%. In spite of India's ambitious plans to increase production, the annual growth in capacity remains modest and not adequate to provide for the desired increase in economic growth. The utilities are burdened with debt and new technologies to improve efficiency and availability are not being adequately pursued. Innovative policies that would free electricity producers from subsidizing various sectors of the Indian economy are not in place. To facilitate greater consumption of electricity will require aggressive steps in all sectors of the power industry. To double India's generation capacity would require some ten years and an annual investment of over 3% of the gross domestic product. In addition to capital, India would require the newest and most efficient technologies, not only in production but also in

transmission, distribution, storage and consumption. Technology alone is not enough. Innovative and effective policies must be enacted to ensure that management of generated power is made efficient and free from pressures from various quarters that affect pricing, usage and distribution and debilitate the industry today.

Even with efficient usage of power, the growth in consumption will mandate a large increase in installed capacity. Domestic savings alone will be inadequate to meet the requirements of capital for this sector. To attract global capital at competitive prices, India must have in place appropriate regulatory and market environments that would assure potential investors of the viability of their investment.

For a number of years, CMU has been engaged in studies on electric power in India. These studies have included an analysis of the viability of nuclear power in India for meeting its power requirements, a scenario for the development of natural gas pipelines across the Indian subcontinent, and a report with recommendation on the pricing and regulatory environment for generators of power. There is also an ongoing program to study the feasibility of biomass-based electricity for rural consumers using gasifiers and advanced technologies such as microturbines.

About two years back, supported by the US Department of Energy, CMU entered into a collaborative programme with NIAS in Bangalore to initiate a bilateral dialogue on electric power in India between professionals in India and the United States. In this dialogue, it was proposed to discuss various options available to India in technology, policy, and finance. Before structuring this dialogue, both CMU and NIAS generated a number of documents on various issues as background material. Though this meeting was delayed for some months due to reasons beyond the University's control, the collaborators of this project used the time to discuss various options in technology available both in the United States and in India.

The first joint meeting was held at the University of Warwick campus in UK on 24-26 September, 1999. Nine delegates from India and ten from the United States, drawn from universities, government, research institutions, and industry participated in the discussions. After formal presentations on various issues that ranged from problems in utilising Indian coal in power stations to US experience in deregulation and changes in the power sector, the delegates formed three separate working groups on technology, policy, and finance to recommend various options for consideration by both the US and Indian policy makers.

In the following section, we present a brief summary of the recommendations of these working groups.

To meet its power requirements, India needs electric power from many sources. Beyond commercially available technologies, we recommend collaborative technology and pilot plant programmes for advanced coal utilisation and for renewable technology options. We consider that renewable technologies hold the key for meeting the burgeoning power needs from rural areas. We also recommend collaborative development of robust and low-cost power meters, as well as efficient agricultural pump sets.

India needs large amounts of capital for many years to build its new generation and distribution capacity. Capital follows appropriate technology and good investment environments. We recommend the institution of totally transparent policies for investment, and the availability of all required information needed for the flow of capital. The number of stages for getting the necessary approvals should be minimised and the entire approval process speeded up. Other changes needed in the power sector include unbundling and the setting up of independent regulatory bodies. Multilateral institutions should be encouraged to support such infrastructure projects.

Innovative policy changes will have to be considered if SEBs are to become commercially viable. This may involve developing pricing and other options that free the SEBs from having to carry the losses accrued due to past subsidies. New policy options should be pursued specifically to address the needs of the agricultural sector.

Indian engineers and other professionals in the electric power industry do not generally go for higher education. We strongly recommend continuing education to these professionals. We suggest that the US universities and other institutions that have experience in the area of electric power collaborate with Indian universities to develop such programmes in India. It is suggested that at least a few initial contingents of such professionals be provided opportunities for study and training in the US, focusing not only on power technology but on issues of finance, management, and regulation as well.

We also suggest that the collaboration between the US Dept. of Energy and other institutions with their counter-parts in India should be broad-based, and not centered on a single technology or policy. Electric power is an ideal arena for cooperation between India and the United States. Helping India find solutions to its electric power problems are of importance to the US. Development and demonstration of new, efficient and sustainable technologies that are also economically competitive will address concerns about global warming and climate change though this would be of secondary concern vis-a-vis auguments generation. The experience in India could have great impact in determining which technologies will be used by other developing countries such as China, Brazil, and Indonesia, countries that will soon be the largest power producers in the world.

Energy and electric power are issues too important to be left to normal channels of bilateral collaboration. More vigorous and focused cooperation between the two countries, not unlike that which ushered in the Green Revolution, is urgently needed to enable India to sustain and improve its recent impressive rates of economic growth and improvements in human welfare.

I. Technology

Technology covers electricity generation, transmission and distribution (T&D), and end usage.

Objective

To increase the current annual per capita consumption of about 350 kWh to 1,000 kWh in a period of about 10-15 years. This must be done in an affordable and environmentally appropriate manner.

In the short term (about 10 years), the key need is to improve the efficiency and operation of the existing power system. This must involve.

Improvements to the reliability and efficiency of current generation stations, reductions in the transmission and distribution “losses” (which include theft), improvements in efficiency of end use devices, especially in the agricultural sector (which accounts for over 30 per cent of India’s electricity consumption).

India should undertake several technology demonstration projects, which may include the following:

- Low-cost electric power metering at the customer end of the wire (e.g. using card meters) together with related data acquisition and storage;
- A project to adapt efficient motor and pump technology for agricultural water pumping;
- Application of thyristor technology to reduce losses and improve power quality;
- Improvement of distributed power generation for use in villages and remote areas, to demonstrate the viability and stand-alone performance of biomass gasification systems in conjunction with combined-cycle power generation using microturbines;
- Improving the reliability and efficiency of existing large central station power generation facilities, by implementing modern monitoring diagnostics;
- Assessment of technological options for repowering on a case-by-case basis. In some cases, repowering can offer cost-effective means of improving the efficiency and capacity of existing power plants.
- Flue-gas conditioning and upgrading electrostatic precipitators to address the problem of particulate emissions from power plants;

- Coal Beneficiation programme which is in its nascent stage in India must be accelerated and enhanced in its scope and implementation. Technology development for obtaining ash content lower than presently prescribed must be encouraged.

With regard to longer-term priorities, the panel recommends:

- Legislate and implement new and compatible environmental performance standards to promote adoption of the best available advanced technologies to protect the health of Indian citizens and meet international obligations consistent with national priorities.
- Re-assess the feasibility and cost of alternative large-scale power generation technologies such as integrated gasification combined cycle systems and pressurised fluid bed combustion systems. At the present time, the cost of these cleaner and more efficient systems is still generally prohibitive. Thus, their feasibility for use in India should be carefully examined relative to competing options for electric power generation. Incentives to reduce the cost of these systems through early demonstration also should be considered.
- Create a national power grid operating at voltages greater than today's 400 kV to reduce regional imbalances and allow more efficient overall operation.
- The Group strongly underscores the need to support long-term technology research and development on all aspects

of electric power generation, transmission and end-use including environmental, energy conservation and economic aspects. The world-wide trend toward privatisation and competition in the electric power sector may compromise the ability of the power industry to successfully carry out long-term R&D.

II. Policy Issues

Objective

The need for evolving suitable policy initiatives to support efficient operations relating to our transmission and distribution of electric power.

1. The current institutional arrangements in the power sector, and the disincentives faced by institutions and people working in that sector, result in seriously inefficient and economically dysfunctional behaviours. The problems faced by the Indian electric power sector are not fundamentally technical. What is needed is a major restructuring of institutional arrangements and incentives.

This should be undertaken through a set of major policy changes at the national level, and a series of fundamental changes at the state and local level.

For the Indian power system to become an efficient system offering adequate and reasonably priced power, two fundamental changes must occur.

First, strategies must be developed to get operating companies (State Electricity Boards) out of the middle between State governments and subsidized agricultural customers. If government wishes to subsidize some customers, those subsidies should be direct, and not undertaken in a way that leaves the power system operator trapped in the middle (delivering the power but not receiving compensation). Several mechanisms exist that could be used to make this change. The State could establish and/or fund a separate rural power authority which operating companies would bill like any other customer for agricultural supply as metered at the sub-station level. If the rural power authority did not pay its bills, the company could suspend service, just as it would for any other customer.

- Agricultural electricity supply
- Create a separate entity to fund and operate agricultural sector supply
- Quasi-governmental organisation with flexibility in raising capital

This would allow SEBs to concentrate on optimising non-agricultural load and the new entities to focus on best solutions for local loads.

The new entities will facilitate:

- decentralisation,
- more efficient usage,
- more responsiveness to the needs of agricultural customers,
- removing SEBs from obligation to serve such users without receiving adequate compensation for the services, and so create value for SEB owners.

States could institute “power stamp” programmes at the level of individually metered customers. Stamps could be used to purchase power, but if they are not all used, they could later be cashed in for rupees. This would provide individual users with an incentive to conserve power and to install more energy efficient equipment.

2. Power Systems that are able to

- put in place a mechanism for full compensation for all power delivered,
- institute rationalised marginal cost pricing (including time dependent tariffs for larger customers), and
- provide end user service

Should be relieved of their accumulated debt from past power subsidies so that they can begin to operate as normal companies, focused on their financial performance. There are several ways in which debt might be removed, including assumption by government, or sales of assets via privatisation.

Such debt restructuring must be conditional, based on satisfactory price rationalisation, efficiency measures, proper accounting, and setting up of independent power regulatory authorities.

Beyond these basic changes, elements of the changes that should be undertaken at the centre include:

- Develop a mechanism to coordinate the ministries of coal and power. This is needed to promote coal washing, reducing the shipping of useless ash and the rock overloading of the Indian rail freight system, and assure reasonable and prompt payments. This may require the formation of a ministerial committee with a clear mandate from the PM and supported by a capable executive interfacing with all the concerned ministries.
- Promote the Ministry of Power to merge and streamline the many separate organisations with overlapping and ambiguous responsibilities related to electric power.
- Begin a rolling process of privatization of the nation's coal mines so that they can begin to operate on a more rational economic basis. For those mines that are not privatized, seek and use the advice from experts who are familiar with the operations of well run foreign mines (e.g. in Australia) on how to improve the operating efficiency of Indian mines.
- Separate the planning and operating parts responsibilities of the central high-voltage grid from the financial part of

the system, and arrange for the grid to be open to investment by the private financial community.

- Give regulators, authority over entry and industry structure. Current authority covers only rates, and this is inadequate to promote the objectives of efficient and effective operation.
- End central planning of the power system. In its place give planning authority to those public entities that are actually responsible for operating the various companies involved. Ensure that there is a mechanism for coordination of planning among these companies.
- In order to promote conservation and more efficient use of electricity, mandate efficiency labeling of all electric appliances and institute minimum performance standards of appliances. To encourage competition and innovation, such standards should be stated in terms of performance objectives, not particular design requirements.
- Develop and institute appropriate protective environmental standards for all generation technology.
- Draw on the resources of existing academic organizations, and establish several interdisciplinary infrastructure institutes whose staffs have strong expertise in economics, regulatory practice and management, as well as relevant technical subjects. These institutes should offer a variety of short mid-career professional education programs for practitioners from all sectors of the Indian power industry to help, change the current planning/engineering mind set to a more business/

economic/financial mind set. The institutes should also undertake research and demonstration activities on infrastructure improvement (see discussion below of “policy experiments”).

- Those appointed in power-related organisations should have familiarity with the problems of the power sector. Their terms of appointment should be long enough to allow continuity in policy formulation and implementation.

Changes that should be made in regulatory policy include the following:

- Tariffs should be made closer to marginal cost, and for large customers (and for all bulk power sales) made time dependent.
- Lower cost interruptible tariffs should be created.
- Rate-of-return regulation should be phased out in favour of a price-for-service approach, but so long as rate-of return regulation is in operation, rates paid to IPPs and other generators should be proportional to risk.
- All restrictions and fees should be dropped on those who want to build their own “captive” power generation.
- Power companies should be required to connect, and to make take-or-pay agreements with captive generators and time-of-day rates approved by regulatory authorities.
- Power sales between utilities and states should be allowed and facilitated.

3. Policy experiments

Incremental solutions are not likely to lead to great improvements, given the need for radical changes in the system. Some policy experiments should therefore be undertaken at state levels to validate the concepts. It is important that Indian experts who have all the necessary information carry out these experiments. Where appropriate, practices of other countries could be studied, and their experiences shared. Many radical initiatives of other countries are not directly applicable to India. India must evolve its own policy initiatives learning from its past practices and from experience of other countries that have succeeded. Hence, the need for policy experiments.

III. Finance and Capital

Objective

To allow the Indian Power sector to attract requisite capital at the lowest possible cost.

Capital needs of \$ 15 billion per year are likely.

- With the right laws and regulations in place, global capital markets will provide this money. Global capital is a necessity given adequate funds are not available locally in India.
- Preconditions to raise such capital are: transparent and explicit rules and regulations, time limits to close transactions, independent regulatory institutions that provide incentives. The entire power sector must transition to

incentive-based regulation, and utilities must act like business entities.

- Unbundling of services, pricing and institutions allows for greater efficiency and attracts new pools of capital.

Increasing generation capacity:

- Requires competitive bidding processes. This should be based on price per unit output, as well as other performance specifications (quantity and quality of power, fuel, social and environmental goals etc.)
- Large users and others should be able to conduct bidding processes for supply of power
- State electricity boards, or their successors, should wheel power at a reasonable fee to ensure competitiveness of industry.

Sources of capital

There should be no unduly intrusive regulations on sources and type of capital. Such decisions are best left to the investors. Nevertheless, it has to be ensured that the price of power remains competitive.

Annex-C: Recommendations

1. In the Warwick meeting (refer to list of participants – **Annex D**), the U.S. group emphasised the importance of policy issues. While agreeing that policy issues are very important, the Indian Group felt that technology issues are equally important and should not be lost sight of.
2. Both Groups strongly supported the proposal of setting up of four regional centres, one each in Bangalore, Delhi/Lucknow, Mumbai and Calcutta, to train power engineers, technicians, regulators and administrators on all issues relating to “Power, Energy and Environment”. The training should be interdisciplinary in nature, well integrated and cohesive to facilitate augmenting Indian capabilities. The faculty will be drawn from India as well as U.S., with course modules designed to suit Indian requirements. For example, the faculty for the Bangalore centre can be drawn from IISc, IIM, CPRI, National Law School etc. Such centres would ensure that a fairly large number of concerned personnel can be quickly trained, in contrast to deputations abroad of small groups of people for short periods of time, which is more expensive as well. In addition to training, the centres may also take up collection and dissemination of energy related information, development of continuing education programme modules on energy and environment, co-ordination / monitoring of energy related activities in

the region on a “watch dog” basis and acting as an advisory body on energy related matters.

3. It is important to address issues relating to transmission and distribution which have technological, political and policy constraints. In this context, as a first step technologies applicable at the point of distribution (like metering, improving quality of power etc.) will have to be looked into.

4. The power demand projections of various states are highly questionable and widely varying. Who will be responsible for demand projections - the State concerned, the central electricity authority or the IPPs is not defined. The methodology needs to be made clear. An institution with primary responsibility of projecting power demands of various states must be identified. Further the exact methodology of power demand projections must be debated, finalised and implemented by the identified institution. This will remove the present day ambiguity and confusion in this very vital aspect of power generation. There is a need to study demand projection techniques and uncertainties and evolve an appropriate methodology for power and energy grids in India. Further, issues relating to balancing investments in generation and transmission and also tariff fixation require serious consideration and study.

5. In terms of technology, priority is to be given to clean coal projects by providing enough funds for demonstration plants viable and emerging renewables like gasifiers, fuel cells etc. also require support. Technology for online monitoring of emissions and effluents is also to be addressed.

6. Normally there is a tendency to recommend a standard model of unbundling, corporatization and privatization as a solution to all situations. This may not be appropriate considering the diversity among the various States, in size, power demand etc. Alternate models for improving private sector participation need to be evolved.

7. There is need to have a clear enunciation of an energy policy by the Government of India.

The Group expressed a strong desire to continue further collaboration with CMU and as a step towards this decided to organise a conference at NIAS with CMU participation to chalk out details and an action plan.

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