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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, the University entered into a collaborative program with the National Institute of Advanced Studies (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 Carnegie Mellon and NIAS generated a number of documents on various issues as background materials. 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 September 24th to 26th, 1999. About ten 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 utilizing 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 needs India needs electric power from all sources. Beyond commercially available technologies, we recommend collaborative technology and pilot plant programs for advanced coal utilization 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 pumpsets.

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 minimized, 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 State Electricity Boards (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 enacted specifically to address the needs of the agricultural sector. Deregulation of the power sector appears to be the enabler for efficient generation and competitive utilization of electricity. It is recommended that the US share its experience with India in these areas.

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 programs 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 the collaboration between the US Dept. of Energy and other institutions with their counterparts 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. The experiences in India would 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.

Groups Reports

I. 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

- 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. This 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
- 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 restrictions on sources and type of capital. Such decisions are best left to the investor.

II. Technology

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

Objective: To improve the current per annual capital consumption of about 350 kWh to 1,000 kWh. This must be done in an affordable and environmentally appropriate manner.

In the **short term**, the key need is to improve the efficiency and operation of the existing power system. This must involve:

- 1) Improvements to the reliability and efficiency of current generation stations;
- 2) Reductions in the transmission and distribution "losses" (which include theft);
- 3) Improvements in efficiency of end use devices, especially in the agricultural sector (which accounts for over 30 percent of India's electricity consumption).

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

- 1) Low-cost electric power metering at the customer end of the wire (e.g., using card meters) together with related data acquisition and storage;
- 2) A project to adapt efficient motor and pump technology for agricultural water pumping;
- 3) Demonstrate the application of thyristor technology to reduce losses and improve power quality;
- 4) To improve distributed power generation for use in villages and remote areas, a project to demonstrate the viability and stand-alone performance of biomass gasification systems in conjunction with combined-cycle power generation using microturbines;
- 5) To improve the reliability and efficiency of existing large central station power generation facilities, a project to implement modern monitoring diagnostics;
- 6) Assess the technological options for repowering on a case by case basis. In some cases repowering can offer a cost-effective means of improving the efficiency and capacity of existing power plants.
- 7) Demonstration projects for flue-gas conditioning and upgrading electrostatic precipitators is recommended. The problem of particulate emissions from power plants in India remains as one of the most important environmental issues and would be addressed by this recommendation.

To improve the environmental performance of existing power plants, policies and technologies should be implemented to reduce the ash content of domestic coals burned in India. A technology for coal cleaning is readily available and commercially demonstrated, but institutional barriers still prevent its widespread adoption in India;

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

- 1) Adopt new environmental performance standards for advanced technologies that are consistent with the environmental control capabilities of such systems. In particular, if future coal use in India is to expand as projected, new environmental standards will be needed to help protect the health of India's citizens;
- 2) Re-assess the feasibility and cost of alternative large-scale power generation technologies such as integrated gasification combined cycle (IGCC) systems and pressurized fluid bed combustion (PFBC) 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;
- 3) Create a national power grid operating at voltages greater than today's 400 kV to reduce regional imbalances and allow more efficient overall operation;
- 4) This group strongly underscores the need to support long-term technology research and development on all aspects of electric power generation, transmission and end-use. The worldwide trend toward privatization and competition in the electric power sector may compromise the ability of the power industry to successfully carry out long-term R&D.

III. Policy Issues

The current institutional arrangements in the power sector, and the incentives faced by institutions and people working in that sector, result in seriously inefficient and economically dysfunctional behaviors.

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:

1. Strategies must be developed to get operating companies (SEBs) 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:
 - a) States 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 organization with flexibility in raising capital.
- This would allow SEBs to concentrate on optimizing non-agricultural load.
- Would allow these new entities to focus on best solutions for local loads

Such separate entities will facilitate:

- decentralization,
- more efficient usage, and
- more responsiveness to the needs of agricultural customers.

Removing SEBs from obligation to serve such users without receiving adequate compensation for the services, will create value for SEB owners.

- b) States could institute "power stamp" programs 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

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

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 privatization. Such debt restructuring must be conditional, based on satisfactory price rationalization, 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 center include:

- 1) Develop a mechanism to coordinate the ministries of coal, oil and gas, and power. This is needed to promote coal washing, reducing the shipping of useless ash and rock overloading 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.
- 2) Promote the Ministry of Power to merge and streamline the many separate organizations with overlapping and ambiguous responsibilities related to electric power;
- 3) 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;
- 4) Separate the planning and operating portion of the central high-voltage grid from the financial portion of the system, and arrange for the grid to be open to investment by the private financial community;
- 5) 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;

- 6) 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;
- 7) In order to promote conservation and more efficient use of electricity, mandate efficiency labeling of all electric appliances and institute minimum performance standards for appliances. To encourage competition and innovation, such standards should be stated in terms of a performance objective, not any particular design requirement;
- 8) Develop and institute appropriately protective environmental standards for all generation technology;
- 9) 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");
- 10) Those appointed in power-related organizations 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:

- 1) Tariffs should be made closer to marginal cost, and for large customers (and for all bulk power sales) made time dependent;
- 2) Lower cost interruptible tariffs should be created;
- 3) Rate-of-return regulation should be phased out in favor 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;
- 4) All restrictions and fees should be dropped on those who want to build their own "captive" power generation;
- 5) Power companies should be required to connect, and to make take-or-pay agreements with captive generators at time-of-day rates approved by regulatory authorities;
- 6) Power sales between utilities and states should be allowed and facilitated.

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 experiences from other countries that have succeeded. Hence, the need for policy experiments.