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# OPPORTUNITIES FOR IMPROVING END-USE ELECTRICITY EFFICIENCY IN INDIA

Prepared By:

Steven Nadel
American Council for an Energy Efficient Economy

S. Gopinath
National Productivity Council, India

Virendra Kothari
Innotem Services Private Limited

Energy Planning and Policy Development Project, 936-5228
International Development and Energy Associates, Inc.
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## EXECUTIVE SUMMARY

### INTRODUCTION

This report is a component of the Indian Power Sector Assessment being conducted by the World Bank in coordination with the Government of India and bilateral donor agencies. This report examines opportunities and barriers to improved end-use efficiency in India.

In recent years, power demand in India has grown by approximately 9% per year. To sustain this level of growth, the power sector in India has accounted for 15-19% of five-year plan outlays. Virtually all of this money has been spent on supply-side resources (power plants and transmission lines). However, as a result of severe resource constraints being faced by the Indian government, Plan outlays are not keeping pace with the growth of the Indian economy and therefore expenditures of 15-19% of Plan funds will not be sufficient to meet projected power needs. As a result, it is increasingly unlikely that reliance on supply-side resources alone can bring demand and supply into balance.

As an alternative to reliance on only supply-side resources, this report examines opportunities to reduce electricity demand by promoting efficiency improvements at the end-use (customer) level. The cost of these efficiency improvements per unit of power saved is usually less than the cost to build a new power plant (and almost always less than the cost to build <u>and operate</u> a new power plant), thereby having a greater impact on India's power balance for each Rupee spent. This is not to say that efficiency improvements alone can meet India's future power needs. While the efficiency potential is substantial, power needs are greater still. Rather, the most efficient use of resources, and perhaps the only viable strategy for bringing power demand and supply into balance, is to pursue a mixed strategy of end-use efficiency improvements, supply-side efficiency improvements (improvements to existing power

plants and transmission/distribution systems), and new supply-side resources.

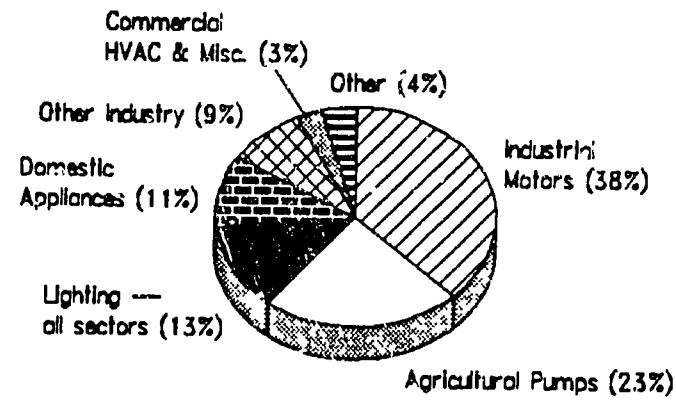
In investigating opportunities for end-use efficiency, we began our work by investigating current and projected electricity use patterns in India, and building upon this base, then estimated the amount of cost-effective efficiency measures that are available. We next examined barriers to achievement of these efficiency opportunities, and existing efforts in India, and elsewhere, to overcome these barriers and achieve significant efficiency savings. Finally, building upon existing program efforts, we examined policy options that can be pursued in India to significantly increase the rate at which end-use efficiency is improved in India. The results of each of these tasks are discussed in the paragraphs below.

**ELECTRICITY CONSUMPTION PATTERNS IN INDIA**

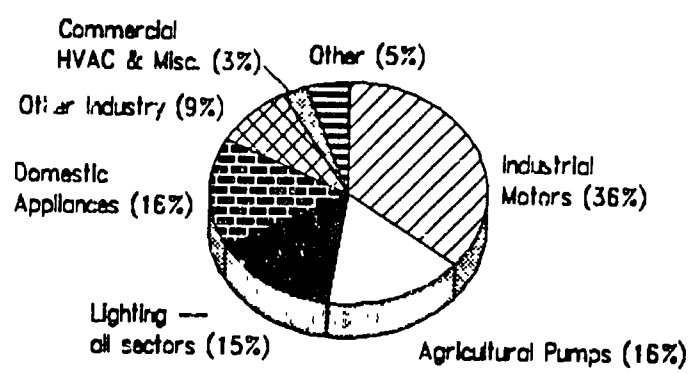
Our analysis began by examining current levels of electricity consumption in India, and how this consumption is divided among the different end-uses. End-use breakdowns were based on studies that have been prepared in India in recent years, supplemented with data from other countries. In many cases the available data were very limited, and thus the end-use estimates are subject to a considerable degree of uncertainty. This analysis, which is summarized in Figure ES-1, found that the largest electricity end-uses are industrial motors (38% of all electricity use), agricultural pumps (23%), lighting (13%), and domestic appliances (11%).

We next examined projected future trends in electricity use and adopted two forecasts for further analysis -- a high case and a low case. The high case is based on the Central Electricity Authority's Thirteenth Electric Power Survey and projects average growth in electricity use of approximately 10% per year over the 1989/90 to 2004/05 period. The low case is based on the Advisory Board on Energy's Case I forecast, and projects an average annual growth rate of almost 7% over the same period.

Figure ES-1. Distribution of Electricity End Use -- All Sectors




1989/1990




2004/2005

The final step in this analysis was to estimate how electricity use in 2004/05 will be divided among the different end-uses. This analysis is also summarized in Figure ES-1 and shows that end-use shares in 2004/05 will generally be similar to that at present, except that the share of total electricity use consumed by domestic appliances will rise to 16% (due to increases in the proportion of families owning appliances) while the share consumed by agricultural pumps will decline to 16% (due primarily to limitations on the amount of water available).

**OPPORTUNITIES FOR EFFICIENCY IMPROVEMENTS**

For each of the major electricity end-uses we examined opportunities for cost-effective efficiency improvements. A total of 27 efficiency measures were examined. For each measure we examined measure cost per kW saved and per kWh saved. Whenever a measure costs less per kW than a new power plant (approximately Rs 23,500/kW for a baseload plant and Rs 12,900/kW for a peaking plant) and/or less than short-term or long-term marginal generation costs (approximately Rs 1.1/kWh and Rs 1.9/kWh respectively), a measure is likely to be cost-effective in India. In addition to examining measure cost-effectiveness, we also examined the amount of savings that are available in India if each measure is widely used. The results of these analyses are summarized in Table ES-1.

This analysis shows that all of the efficiency measures examined cost less per kW than new power plants, and cost less per kWh than marginal operating costs. If all measures examined are implemented wherever cost-effective and technically feasible, forecasted electricity use and peak generating requirements in 2004/05 can be reduced by approximately 20%. The average capital cost of these measures is only Rs. 3,800/kW -- substantially less than the cost of both baseload and peaking power plants. The majority of savings are due to a limited number of measures, and thus promotion of these measures should be a priority for future program efforts. These priority measures include improvements to new and existing

Table ES-1. Cost-Effectiveness and Savings Analysis for 27 Conservation & Load Management Measures

| Measure | Rs/kW | Rs/kWh | Energy Savings Possible in 2004/05 (GWh) | | Savings as a % of Projected GWh Sales | | Peak Generation Savings Savings Possible in 2004/05 (MW) | | Savings as a % of Projected Generating Capacity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low-case | High-case | Individual | Cumulative | Low-case | High-case | Individual | Cumulative |
| TLD lamp | 0 | 0.00 | 3,324 | 5,331 | 0.66% | 0.66% | 1,140 | 1,828 | 0.60% | 0.60% |
| Centrif. refrig. compressor | 3,200 | 0.09 | 872 | 1,398 | 0.17% | 0.84% | 200 | 321 | 0.11% | 0.71% |
| Improved arc furnaces | 3,400 | 0.13 | 1,242 | 1,998 | 0.25% | 1.09% | 311 | 500 | 0.16% | 0.87% |
| Meter agricultural pumpsets | 4,700 | 0.18 | 3,985 | 6,385 | 0.80% | 1.88% | 1,275 | 2,043 | 0.67% | 1.54% |
| Incand. to fluor. fixture | 2,200 | 0.19 | 8,227 | 13,202 | 1.64% | 3.52% | 5,808 | 9,319 | 3.06% | 4.60% |
| HPSV lamp & ballast | 3,800 | 0.20 | 1,263 | 1,989 | 0.25% | 3.78% | 442 | 696 | 0.23% | 4.83% |
| Motor rewinding, etc. | 7,400 | 0.25 | 10,214 | 16,369 | 2.04% | 5.81% | 2,918 | 4,677 | 1.54% | 6.37% |
| High efficiency motors | 8,400 | 0.25 | 3,860 | 6,186 | 0.77% | 6.58% | 1,103 | 1,767 | 0.58% | 6.95% |
| Air compressor O&M | 7,300 | 0.26 | 1,682 | 2,695 | 0.34% | 6.92% | 505 | 809 | 0.27% | 7.22% |
| HVAC effic. improvements | 7,000 | 0.28 | 2,465 | 3,974 | 0.49% | 7.41% | 822 | 1,325 | 0.43% | 7.65% |
| Two-speed motors | 9,700 | 0.29 | 3,792 | 6,077 | 0.76% | 8.17% | 1,083 | 1,736 | 0.57% | 8.22% |
| High effic. new pumpsets | 7,300 | 0.30 | 9,086 | 14,558 | 1.81% | 9.98% | 3,060 | 4,904 | 1.61% | 9.84% |
| Moderate effic. refrig. | 12,600 | 0.32 | 3,232 | 5,182 | 0.65% | 10.63% | 738 | 1,183 | 0.39% | 10.23% |
| Membrane chlor-alk process | 12,500 | 0.32 | 1,704 | 2,741 | 0.34% | 10.97% | 379 | 609 | 0.20% | 10.42% |
| Room A/C EER 9 | 4,000 | 0.33 | 1,105 | 1,777 | 0.22% | 11.19% | 737 | 1,184 | 0.39% | 10.81% |
| Circular fluorescent lamps | 3,700 | 0.37 | 2,859 | 4,588 | 0.57% | 11.76% | 2,018 | 3,239 | 1.06% | 11.88% |
| Optimize industrial pumps | 11,200 | 0.38 | 3,113 | 4,995 | 0.62% | 12.38% | 889 | 1,427 | 0.47% | 12.35% |
| Optimize industrial fans | 12,200 | 0.41 | 2,450 | 3,925 | 0.49% | 12.87% | 700 | 1,121 | 0.37% | 12.71% |
| More efficient fan | 6,300 | 0.42 | 2,779 | 4,446 | 0.55% | 13.42% | 1,556 | 2,490 | 0.82% | 13.53% |
| Improved aluminum smelters | 17,600 | 0.46 | 3,366 | 5,406 | 0.67% | 14.10% | 748 | 1,201 | 0.39% | 13.93% |
| Electronic Ballast | 11,200 | 0.47 | 7,479 | 11,995 | 1.49% | 15.59% | 2,564 | 4,112 | 1.35% | 15.28% |
| High effic. refrigerator | 20,000 | 0.50 | 3,667 | 5,880 | 0.73% | 16.32% | 837 | 1,342 | 0.44% | 15.72% |
| Variable speed drives | 17,200 | 0.62 | 11,140 | 17,852 | 2.22% | 18.54% | 2,674 | 4,285 | 1.41% | 17.13% |
| Compact fluorescent lamp | 6,800 | 0.67 | 3,311 | 5,313 | 0.66% | 19.21% | 2,337 | 3,750 | 1.23% | 18.36% |
| Agrig pumpset rectification | 16,900 | 0.77 | 7,950 | 12,738 | 1.59% | 20.79% | 2,678 | 4,291 | 1.41% | 19.77% |
| Efficient evap. cooler | 10,100 | 0.79 | 455 | 728 | 0.09% | 20.88% | 303 | 485 | 0.16% | 19.93% |
| Storage cooling | 13,300 | -- | -- | -- | -- | -- | 604 | 972 | 0.32% | 20.25% |
| TOTAL | | | 104,624 | 167,727 | 20.88% | 20.88% | 38,430 | 61,616 | 20.25% | 20.25% |

agricultural pumping systems, metering of agricultural pumpsets, use of fluorescent fixtures instead of incandescent fixtures in new construction, improved operations and maintenance practices in the industrial sector, and the development and promotion of efficient end-use equipment including motors, variable speed drives, compact and circular fluorescent lamps, electronic ballasts, and domestic refrigerators and other appliances.

**BARRIERS TO ENERGY EFFICIENCY IN INDIA**

There are many barriers to implementation of cost-effective energy efficiency measures in India. Among the major barriers are the following:

1. Many end-users are unaware of opportunities to improve energy efficiency.

2. Even where end-users are aware of efficiency opportunities, they are unlikely to make efficiency investments that cost more than minimal amounts. On the other hand, failure by end-users to invest in efficiency measures with modest cost obligates utilities to invest in new power plants with much higher costs.

3. Electricity prices in India do not generally cover the full costs of electricity production. End-users do not use electricity efficiently because they pay only a portion of the full cost. This is particularly a problem in the agricultural and domestic sectors.

4. Some end-users lack the capital to finance efficiency investments. Also, there is a shortage of foreign currency which can be used to finance imports of efficient equipment or the machinery and raw materials needed to produce efficient equipment in India.

5. Implementing efficiency projects takes time that many end-users do not have, and can disrupt day-to-day operations.

6. Many of the most promising efficiency measures are not widely available in India. Many efficient devices are not produced in India. Due to high import duties, availability of models produced overseas is very limited. For devices that are produced in India, availability and use are restricted by limited production capacity, quality control problems, the high cost of imported components, and a vicious circle in which limited

availability leads to high cost which leads to limited demand.

7. Problems with power quality in India obligate manufacturers and end-users to produce and use equipment that can withstand large voltage fluctuations. This equipment is often less efficient than equipment designed to operate in a narrower voltage band.

8. Some of the energy-saving equipment produced in India is of poor quality, which decreases the energy-savings, and makes end-users reluctant to make efficiency investments.

9. Small-scale manufacturers produce a substantial share of end-use equipment, but these firms often produce equipment that is low in cost and low in efficiency. Larger firms are restricted from entering these markets, and small-scale firms often lack the resources and interest to improve their products.

10. As in other countries, end-users have an aversion to taking risks associated with new technologies, or new uses of old technologies. Many energy efficiency measures fall into these categories.

11. Many decision-makers are biased towards large visible projects they can show-off. While some energy efficiency measures meet this criteria, many other measures, such as operations and maintenance measures, and small equipment improvements are relatively invisible.

12. The presence of a large used-equipment market which delays the retirement of inefficient equipment.

13. A shortage of skilled staff in India needed to identify, install, and maintain energy-efficiency measures.

## EXISTING PROGRAMS AND POLICIES TO IMPROVE EFFICIENCY IN INDIA

Governments and organizations in India have undertaken a number of programs and policies to improve electricity efficiency in India including information and education programs, income tax incentives, excise and customs duty relief, sales tax reductions, energy audit schemes, subsidies for equipment finance, agricultural pumpset rectification efforts, and equipment efficiency standards.

While laudable, these efforts have generally been limited, and as a result, have had limited effect. For example, reductions in

taxes and duties emphasize measures to conserve oil and to produce renewable energy. Only a few measures to save electricity are eligible. Similarly, energy audit and pumpset rectification programs have served only a limited number of customers due to limited availability, and financing programs have been even more limited. Furthermore, financing programs require substantial paperwork and usually involve only a limited interest subsidy. Experience in other countries indicates that most loan programs have disappointing participation rates, and that other forms of financial incentive are usually more effective. Also, experience around the world indicates that information and education programs will generally have limited impact unless offered in combination with financing and other program services. Likewise, equipment efficiency standards in India apply to only a few types of equipment, are usually voluntary (manufacturers are not required to comply), and frequently they specify only modest efficiency improvements.

While efforts to date have been limited, they have resulted in some energy savings and, perhaps more importantly, they provide a useful foundation upon which to build for the future. For example, pumpset rectification programs can be expanded. Utility-operated education programs can be expanded to include technical and financial assistance. Equipment efficiency standards can be expanded, strengthened, and made mandatory. Efforts to promote local production of quality, efficient equipment can build upon efforts now underway in India.

## POLICY RECOMMENDATIONS

In developing our recommendations, we decided not to develop a long "laundry list" of detailed program and policy recommendations. Such lists have been compiled in India before, and we do not seek to replicate them. Instead, we chose to concentrate our analysis and recommendations on a few initiatives that could have a significant effect on the level of efficiency investment in India. These recommendations are as follows:

1. Prepare and implement "least-cost" plans.

2. Expand efforts to promote the production of high efficiency technologies in India, including advanced technologies.

3. Expand existing programs and start new programs to improve the efficiency of agricultural pumps, lighting systems, and industrial facilities.

4. Implement institutional modifications to increase the priority accorded electricity conservation efforts and to improve the coordination of these efforts.

Each of these recommendations is discussed briefly below.

**Least-Cost Utility Planning**

In most of the world, including India, utilities concentrate on building new power plants, and limit conservation activities to public education efforts. However, investments in many conservation and load management measures are less expensive per kW than new power plants. In order to decide the best mix of new power plants and conservation and load management programs to pursue, many utilities in the U.S., as well as other countries, are conducting a "least-cost planning process" in which the cost of new generating facilities, supply-side efficiency improvements, and end-use efficiency measures are all examined, and the mix of resources which can meet future power needs at the lowest cost are selected. Experience in other countries suggests that implementation of a least-cost plan can save many millions, if not billions, of dollars by substituting low-cost efficiency improvements for some of the most expensive new power projects.

In order to establish least-cost planning in India, some technical assistance might be needed from experts who have participated in previous least-cost planning processes. Least-cost planning efforts should begin at the Central Electricity Authority and at a few of the more progressive State Electricity Boards. Only over time can all utilities be expected to undertake such a process. In the long-term, the Government of India, or multilateral

financial institutions could require preparation of a least-cost plan, before providing financing for utility projects, be they power plants or conservation programs. As part of their least-cost planning processes, utilities will need to decide which conservation and load-management programs are most suitable for India. The best way to learn which programs are best is to conduct pilot programs. For example, a pilot lighting program is now being planned in Bombay.

**Promote High Efficiency Technologies**

Many of the efficiency measures with the greatest savings potential involve technologies that are routinely produced in other countries in the world, but not in India. Examples include circular fluorescent lamps; compact fluorescent lamps; improved efficiency refrigerators, air conditioners, evaporative coolers, and fan motors; and storage cooling systems. In addition, a few technologies that are produced in India could benefit from improvement. Examples include electronic ballasts (which suffer from quality control problems) and variable-speed drives (where costs are high).

If these technologies are to realize their savings potential, a major effort needs to take place to promote the widespread production, availability, and use of these products. Components of such a strategy include: (1) research, development, and demonstration projects with an emphasis on adapting technologies developed overseas to the Indian context; (2) technical and financial assistance to manufacturers so they can produce the equipment; (3) selective reductions in import duties, both on the manufacturing equipment needed to produce products domestically, and on limited quantities of actual products, so that a sufficient market can be established to make domestic manufacture attractive; (4) mandatory efficiency standards for selected equipment; and (5) purchases of efficient equipment by government agencies and institutions to help create a market for this equipment within India.

## Expand Efficiency Programs in High-Priority Areas

Many of the largest opportunities for saving electricity fall in three areas: agricultural pumping; lighting in all sectors: and improved operations, maintenance and equipment selection in the industrial sector. These three areas should receive priority attention.

### *Agricultural Efficiency Programs*

Agricultural pumps represent one of the largest efficiency opportunities in India. Pumpset rectification programs operated by the Rural Electrification Corporation and individual states have shown that the energy use of existing pumpsets can be reduced by 30% or more at low cost. Similar savings are possible if only high efficiency equipment is used in new installations. Furthermore, pumpset electricity use is not metered, and thus farmers have no incentive to use them efficiently. To tap into these opportunities, all pumpsets should be metered, existing rectification programs should be greatly expanded, and efficiency standards for new pumps should be strengthened.

### *Lighting Efficiency Programs*

Lighting efficiency measures account for approximately 35% of the available demand savings identified by this project, and approximately 40% of these savings are available from just one measure -- use of fluorescent fixtures instead of incandescent fixtures. Accordingly, extensive efforts should be made to encourage customers to install fluorescent fixtures instead of incandescent fixtures when new lighting systems are installed. Possible approaches that can be used include: (1) offering domestic customers a special low rate for the first few kWh -- just enough to operate two 20-watt fluorescent lamps; additional kWh would be charged at a significantly higher rate; and (2) provide fluorescent fixtures to customers at subsidized prices, so that fluorescent fixtures cost no more than incandescent fixtures. The first

approach has been successfully used in Thailand; the second approach would have a capital cost substantially less than even peaking power plants.

*Industrial Efficiency Programs*

Nearly 40% of the energy savings and over 25% of the available peak generating capacity savings identified in our research involve improvements to industrial motors and processes. These savings fall into three general groups -- low-cost operations, maintenance, and equipment optimization measures; new production equipment in key electricity-intensive industries (aluminum, chlor-alkali, and steel); and use of more efficient equipment in motor systems.

To encourage the first group of measures, expanded training, information, and technical assistance programs are needed, building on current efforts in this area. Another way to promote these measures is to encourage firms to hire energy managers who would be responsible for identifying energy waste within their plants and for developing solutions. While a number of Indian manufacturers have energy managers, most do not.

The second group of measures involve a small number of firms. These firms often have technical expertise, but lack the capital needed to fund these improvements. Financial assistance in the form of low-cost and/or long-term loans for efficiency improvements could be of great benefit to these firms. Given the amount of money required, assistance from multilateral development banks will probably be needed.

The third group -- improvements to motor systems -- involve nearly all industries in India. While a few of these industries have the information, technical expertise and capital to implement these measures, most do not. This group of measures may be the most difficult of the three groups to implement. Achieving these savings will require a combination of information, technical assistance, and financial assistance. Since many small firms are

involved, loans may be too complex to administer -- partial grants (perhaps 50% of measure cost) may be preferable. This approach has been very successful in China.

## INSTITUTIONAL MODIFICATIONS TO IMPROVE ELECTRICITY CONSERVATION EFFORTS

In order to successfully implement the recommendations discussed above, strong leadership and extensive coordination will be needed in the Center and in each state. At present, responsibility for electricity conservation activity is diffused among many government departments and agencies, and is not generally accorded high priority by the leadership of their respective agencies.

Many of our recommendations flow from our first recommendation --to develop and implement a least-cost planning process. At the Center, power planning is coordinated by the Central Electricity Authority (CEA). CEA is responsible for developing the National Power Plan and for working closely with the states on their individual plans. In a companion report to this report, demand forecasting and investment planning issues were investigated. The principle recommendation of this review was that a new post be created in CEA at the Member level, to be known as the Member (Energy Efficiency). We endorse this recommendation. Similar steps should be undertaken at each State Electricity Board.

While CEA can coordinate preparation of least-cost plans in India, implementation of the plans will require money. The major source of funds used by State Electricity Boards for capacity expansion is the Power Finance Corporation (PFC). Since demand-side programs are essentially another form of capacity expansion, the PFC is the logical organization to fund SEB demand-side efforts. PFC in turn could obtain funds from the World Bank and the Asian Development Bank. In order to implement this mandate, PFC will need to develop expertise in the development and implementation of demand-side programs. We recommend that a unit be established within PFC for this purpose.

A substantial number of energy efficiency efforts are now underway in India and this number is likely to grow significantly in future years. While these programs will likely be administered by many different agencies and organizations, there is a danger that efforts will not be planned as an integrated whole, with the result that some important efficiency measures are missed entirely, while other measures are the subject of duplicative efforts. In order that resources be most efficiently and usefully spent, we recommend that an All-India electricity conservation program be established, whose charge is to coordinate planning and administration of the many programs that will be offered by different organizations and agencies.

To some extent, the mission of the electricity conservation program is similar to that of the Energy Management Center (EMC). EMC is new and it is too early to say for sure how well it will be able to carry out its mission. However, a recent review of energy-efficiency agencies in a number of countries, including India, found that autonomous agencies like EMC are unlikely to have a major impact because they are too far removed from key decision-makers in the government. In order to remedy this deficiency, EMC should be brought personally under the charge of the Secretary of the Department of the Power. At the same time, consultation with other relevant government agencies should be increased and the input of universities, SEBs, and private industry should be actively sought. A program of this type has been established in Brazil, and early results are highly encouraging.

**ACHIEVABLE SAVINGS FROM THESE POLICY INITIATIVES**

The policies recommended here can have a substantial impact on future power needs in India, but given the many barriers that must be overcome, achieving all of the conservation potential identified by our research will be close to impossible. Accordingly, we developed a rough estimate of the amount of savings that could be achieved by 2004/05 if our recommendations are implemented.

Overall, we estimate that peak generating needs can be reduced by approximately 12% by 2004/05. This amounts to just over half of the cost-effective technical potential identified in our research (see Figure ES-2). To achieve half of the available cost-effective savings over a 14 year period is ambitious, but less than recent estimates of the achievable conservation potential made in the U.S.

If 12% savings are achieved, peak generating requirements will be reduced by 22,000-36,000 MW (depending on which demand forecast is employed), saving approximately Rs. 25,000-40,000 crores in capital costs (Rs. 250-400 billion).*

**CONCLUSION**

A concerted effort to improve end-use efficiency in India is a critical element in any strategy for India's power sector. India cannot build its way out of its current power shortage -- the cost of the power plants that would be required is more than India can afford. End-use efficiency investments offer the opportunity to acquire "saved power" at a cost substantially less than new power plants. Thus, efficiency investments offer an opportunity to stretch available funds, for they provide more kW and kWh for each Rupee spent.

In this report, we recommend four strategies to tap into this efficiency "gold mine" -- least-cost utility planning; expanded efforts to promote the production in India of high-efficiency technologies; expanded programs to improve the efficiency of agricultural pumps, lighting systems and industrial facilities; and institutional modifications designed to increase the priority accorded electricity conservation efforts and to improve the coordination of these efforts.

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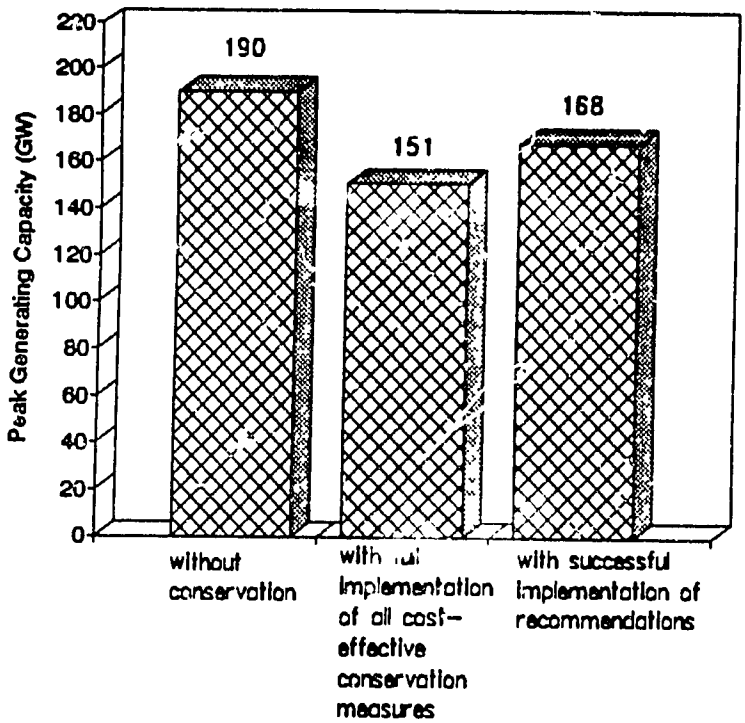
* A billion is a thousand million.

Figure ES-2. Technical and Achievable Conservation Potential for 2004/2005 -- Low-Case Forecast.



In order to implement these recommendations will require the active participation of many parties including the Government of India (who will help establish, operate, and finance many of the programs), State Electricity Boards (who will prepare and implement least-cost plans), State governments (who can assist in the establishment and operation of the programs), multilateral development banks (who can provide financing to implement least-cost plans and to establish production facilities for high efficiency equipment), and bilateral donor agencies and the new multilateral Global Environment Facility (who can provide technical and financial assistance). Establishing a successful end-use efficiency program, one that will have a significant impact on future electricity needs in India, will require a substantial committment by each of the parties listed above. Without a concerted effort by all parties, efficiency improvements are likely to be modest, and India's power problems could well become worse.

# Chapter 1
# INTRODUCTION

## BACKGROUND

The power sector in India has grown considerably in the four decades since independence in 1947. Utility generating capacity increased from 1,712 MW in 1950/51[1] to 59,588 MW in 1988/89 as a result of the high priority placed on the power sector by Indian planners. In addition, captive generation capacity (on-site generators in homes and businesses) has grown substantially. Between 1950/51 and 1988/89, total gross generation of electricity by utilities and non-utilities increased from 7 to 236 TWh (billion kWh), recording an average annual growth rate of about 10%. In recent years, there has been a slight decrease in the growth rate. Total gross electricity generation doubled between 1980/81 and 1988/89 corresponding to a 9% rate of growth (Centre for Monitoring Indian Economy, 1990).

Despite this rapid growth, the power sector continues to be the bane of the Indian energy sector, with demand exceeding supply and consequently severe peak demand and energy shortages being experienced by the economy. During 1989/90, the all-India power availability deficit was 7.9%.[2] However, there were wide variations at the regional and state levels, with the deficit in the state of Karnataka being as high as 23.4% (Centre for Monitoring Indian Economy, 1990).

The projections made in the Thirteenth Electric Power Survey (CEA, 1988) indicate that by the end of the Ninth Five Year Plan in 1999/2000 the public utilities would be required to meet a peak load requirement of 112,000 MW and an energy generation requirement

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[1] Refers to Indian fiscal year which begins April 1 and ends March 31.

[2] The power availability deficit is an estimate of lost electricity sales due to voltage reductions and involuntary service interruptions.

of 594 TWh. These projections represent an annual growth rate of approximately 10% per year. In order to meet this projected demand, an extremely ambitious program for planned capacity additions will be needed. Historically, the power sector has accounted for 15-19% of total Plan outlays (Centre for Monitoring Indian Economy, 1990). However, as a result of severe resource constraints being faced by the Indian government, Plan outlays are not keeping pace with the growth of the Indian economy and therefore expenditures of 15-19% of Plan funds will not be sufficient to meet projected power needs. Thus, estimates for planned capacity additions in the Eighth Plan (expected to start in 1992/93) have been revised successively downwards from 48,000 MW in the original formulation to 38,000 MW in a later formulation, and further to about 26,000 MW recently.

The response to the chronic power shortages in India has been poor quality of service including voltage and frequency fluctuations and involuntary load shedding because of power cuts imposed by the utilities, whether pre-announced or abrupt. Clearly, this is not an acceptable solution and neither can this practice be a long-term response. Increased efficiency of electricity end-use (reducing the amount of energy used) and load management (shifting energy use from peak to off-peak periods) are two approaches which have the potential of being important and cost-effective strategies to mitigate or eliminate the shortfall between electricity demand and supply as well as to complement supply capacity additions. These approaches are equally, if not more, important in the context of the high energy intensity of the Indian economy.

The World Bank, in association with bilateral donor agencies, is conducting a series of comprehensive studies on the Indian power sector. One of the components, involving the participation of the United States Agency for International Development, is this study on end-use efficiency of electricity use. The objectives of the study are to identify important factors constraining end-use efficiency and to suggest how constraints might be eased and how such initiatives could complement expansions in supply capacity.

The study has been conducted jointly by a team of Indian and U.S. consultants -- National Productivity Council (NPC) and Innotem Services Private Limited (INNOTEM) from India and the American Council for an Energy-Efficient Economy (ACEEE) from the United States.

**TECHNICAL APPROACH AND METHODOLOGY**

Although electricity is used in all sectors of the economy, its consumption in different sectors takes place in different end-uses and equipment, and with different efficiencies. Thus an end-use analysis approach was used for this study. The methodology followed for each sector broadly consists of the following elements:

- Develop a list of end-uses and major equipment types;
- Estimate and analyze current electricity use for each sector in total and disaggregated by end-use/equipment type;
- Estimate and analyze forecasted electricity use for each sector in total and disaggregated by end-use/equipment type;
- Develop a list of major energy-conservation and load-management options for each end-use and sector;
- Conduct a technical and economic assessment of each option;
- Identify constraints to adoption of efficiency measures;
- Review current programs and policies to promote energy conservation and load management in India;
- Building on current programs and policies in India and in other countries, identify strategies to overcome constraints;
- Identify and evaluate policy options;
- Develop recommendations, including steps that can be taken by the Government of India, state governments, the World Bank, and bilateral donor agencies.

Following the above methodology, the study was organised into a series of tasks, as follows:

- Task 1: Analysis of current and projected electricity use patterns in India;
- Task 2: Review of major opportunities to improve end-use efficiency;
- Task 3: Identification of constraints to adoption of efficiency measures and strategies to overcome these constraints;
- Task 4: Review of major energy conservation programs and policies in India;
- Task 5: Development of policy options;
- Task 6: Field interviews with end-users, equipment manufacturers, industry associations, electric utilities, financial institutions, government agencies, government officials, and other energy experts;
- Task 7: Evaluation of policy options;
- Task 8: Preparation of draft report;
- Task 9: Review of draft report by experts;
- Task 10: Preparation of final report.

Each member of the study team was primarily responsible for specific tasks although close interaction among all members was maintained throughout the study. Tasks 1 and 4 were carried out by INNOTEM, Tasks 2 and 3 by NPC, and Task 6 by NPC and INNOTEM jointly. ACEEE was responsible for Task 7, for the Task 2 economic analysis of conservation and load management opportunities, and for overall direction of the project. The report preparation tasks involved the participation of all team members.

**ORGANIZATION OF REPORT**

This report is organized into six chapters, roughly corresponding to the different tasks discussed above. Following this introductory chapter, Chapter 2 discusses present and projected electricity use patterns in India, with a particular focus on use at the sector and end-use level. Chapter 3 discusses some of the major opportunities to improve efficiency of electricity use in

India, including an analysis of measure economics, current technology status, and the savings that are available from each measure on a country-wide basis. Chapter 4 discusses the barriers which thus far have limited the adoption of efficiency measures and identifies options for overcoming these barriers. Chapter 5 addresses current programs and policies to promote energy efficiency and load management in India. Finally, Chapter 6 builds on the findings of each of the previous chapters to discuss programs and policies that can be pursued in India, to overcome the many barriers identified, and substantially increase the amount of conservation and load management achieved over the Eighth, Ninth, and Tenth five-year plan cycles (the present through approximately 2004/05). This chapter includes discussions of programs and policies pursued in other countries which could be adapted to India, and includes some rough estimates of the savings in India from the recommended programs and policies. Two appendices include detailed analyses on several of the issues discussed in the main body of the report.

## Chapter 2

## ELECTRICITY CONSUMPTION BY SECTOR AND END-USE

### TRENDS IN ELECTRICITY CONSUMPTION

Between 1980/81 and 1987/88, total electricity purchased from public utilities increased from 82,367 GWh (million kWh) to 146,206 GWh, corresponding to an average annual increase of 8.5%. Detailed data on electricity sales over this period is provided in Table 2-1. In addition, a significant amount of electricity (approximately 16,000 GWh in 1989/90 -- CEA, 1988) is provided by captive generation (self-generation).

Sales of electricity by sector over the 1980/81 to 1987/88 period is also summarized in Table 2-1. These data show that the industrial sector accounts for the largest share of electricity sales followed by the agriculture and domestic sectors. However, the share of the industrial sector has been declining gradually, while the shares of the agriculture and domestic sectors have been increasing. In 1980/81, the shares of the industrial, agricultural, and domestic sectors were 58%, 18% and 11% of All-India electricity sales respectively. By 1987/88, these shares had changed to 49%, 24% and 15% respectively. The shares of the other sectors (commercial, traction [railway] and other), have been relatively stable.

Growth rates exhibited by the various sectors between 1987/88 and the preceding 2, 5, 10 and 15 years are summarized in Table 2-2. The agricultural sector exhibits the highest growth rate followed by the domestic sector. Compared to the overall growth rate, the growth rate of the industrial sector has been consistently lower, while the growth rates of all the other sectors have been comparable.

Table 2-1
Trends in Electricity Sales

| Year | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88P |
|---|---|---|---|---|---|---|---|---|
| **Electricity Sales, GWh** | | | | | | | | |
| Total | 82,367 | 90,245 | 95,589 | 102,344 | 114,068 | 122,999 | 135,952 | 146,206 |
| Industrial | 48,069 | 53,064 | 52,967 | 57,094 | 63,019 | 66,980 | 70,297 | 71,361 |
| Agriculture | 14,489 | 15,201 | 17,817 | 18,234 | 20,960 | 23,422 | 29,444 | 34,814 |
| Domestic | 9,246 | 10,440 | 12,092 | 13,235 | 15,506 | 17,258 | 19,323 | 21,498 |
| Commercial | 4,682 | 5,194 | 5,846 | 6,561 | 6,937 | 7,290 | 7,772 | 8,754 |
| Traction | 2,266 | 2,505 | 2,633 | 2,710 | 2,880 | 3,082 | 3,229 | 3,699 |
| Others | 3,615 | 3,842 | 4,234 | 4,511 | 4,765 | 4,967 | 5,887 | 6,080 |
| Public Water Works | 1,534 | 1,674 | 1,757 | 1,828 | 2,065 | 2,106 | 2,561 | |
| Public Lighting | 749 | 813 | 836 | 934 | 1,052 | 1,096 | 1,210 | |
| Misc.Non-Indust'l. | 1,332 | 1,355 | 1,641 | 1,749 | 1,648 | 1,765 | 2,116 | |
| **Share, %** | | | | | | | | |
| Industrial | 58.4 | 58.8 | 55.4 | 55.8 | 55.2 | 54.5 | 51.7 | 48.8 |
| Agriculture | 17.6 | 16.8 | 18.6 | 17.8 | 18.4 | 19.0 | 21.7 | 23.8 |
| Domestic | 11.2 | 11.6 | 12.6 | 12.9 | 13.6 | 14.0 | 14.2 | 14.7 |
| Commercial | 5.7 | 5.8 | 6.1 | 6.4 | 6.1 | 5.9 | 5.7 | 6.0 |
| Traction | 2.8 | 2.8 | 2.8 | 2.6 | 2.5 | 2.5 | 2.4 | 2.5 |
| Others | 4.4 | 4.3 | 4.4 | 4.4 | 4.2 | 4.0 | 4.3 | 4.2 |
| Public Water Works | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.9 | |
| Public Lighting | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | |
| Misc.Non-Indust'l. | 1.6 | 1.5 | 1.7 | 1.7 | 1.4 | 1.4 | 1.6 | |

p: provisional

Source: Central Electricity Authority, "Public Electricity Supply -- All India Statistics -- General Review," New Delhi, various issues.

Table 2-2
Average Percent Annual Growth Rate in Electricity Sales

| | Total | Domestic | Commercial | Industrial | Traction | Agriculture | Others |
|---|---|---|---|---|---|---|---|
| Up to 1987/88 over period of: | | | | | | | |
| 2 years | 9.03 | 11.61 | 9.58 | 3.22 | 9.55 | 21.92 | 10.63 |
| 5 years | 8.87 | 12.20 | 8.41 | 6.14 | 7.04 | 14.34 | 7.50 |
| 10 years | 7.76 | 12.16 | 7.05 | 5.29 | 4.88 | 13.16 | 7.44 |
| 15 years | 7.55 | 11.31 | 7.94 | 5.44 | 4.80 | 12.54 | 7.68 |

## BASELINE SECTORAL ELECTRICITY CONSUMPTION ESTIMATES

The starting point for the study was the establishment of a baseline electricity consumption pattern for each sector as a whole and for the major end-uses and generic equipment categories within each sector. The sectoral estimates are presented and discussed in this section, while the end-use estimates are provided in the following section.

The only primary source for national level data on electricity consumption is the annual statistical compilation, "Public Electricity Supply -- All India Statistics -- General Review," published by the Central Electricity Authority (CEA). However, there is considerable delay in the publication and availability of this compilation. The most recent edition available was the 1986/87 issue (CEA, 1990) which also contained provisional estimates of 1987/88 electricity consumption. However, during the course of the study, it was decided that 1989/90 was to be taken as the base year for all sectoral and end-use estimates. Hence, sectoral estimates for 1989/90 were determined based on a regression analysis of historical trends. A detailed description of the analysis procedure is provided in Appendix A.

In addition to estimating sectoral electricity sales by utilities in this manner, we also made an adjustment for captive generation. This adjustment was based on the estimated value of 16,118 GWh for net captive generation in 1989/90 as given in CEA's Thirteenth Electric Power Survey (CEA, 1988). Since captive generation takes place predominantly in the industrial sector, the entire amount was allocated to the industrial sector.

We also considered making an adjustment for electricity that is used but not paid for (theft). Traditionally in India, theft is included as part of transmission and distribution (T&D) losses. We attempted to find good data on the extent of theft, so we could include stolen electricity in our end-use breakdowns. Unfortunately we could not obtain good data, and thus were forced

to follow the traditional approach of including stolen electricity as part of losses.

The resultant estimates for electricity consumption in 1989/90 are summarized in Table 2-3 and Figure 2-1. Due to the simple analysis procedures employed, and the lack of data for 1988/89 and 1989/90, these estimates should be considered approximate, rather than exact.

**FORECASTED SECTORAL ELECTRICITY CONSUMPTION ESTIMATES**

A similar exercise was carried out to determine projected energy use patterns for the year 2004/05. The forecasts given in the Thirteenth Electric Power Survey (CEA, 1988) formed the basis of these projections. While this forecast is somewhat dated and suffers from a number of limitations, more recent data, such as that contained in the forthcoming Fourteenth Electric Power Survey, was not available to us.

A discussion of the assumptions and the methodology employed by CEA in arriving at the forecasts would be out of place here, but certain aspects of the methodology do require mention. For the period from 1986/87 to 1990/91, forecasts were developed based on detailed consideration of the number of consumers in different sectors and electricity consumption per consumer. Beyond 1990/91 and up to 1994/95, CEA made sectoral or category-wise forecasts by extrapolating energy consumption in different categories on the basis of trends during the period from 1986/87 to 1990/91. Beyond 1994/95, for the period from 1995/96 to 2004/05, no forecasts of end-use electricity consumption are provided by CEA, and the forecasts for generating requirements (at the power plant level) were projected on the basis of anticipated growth rates during 1986/87 to 1994/95.

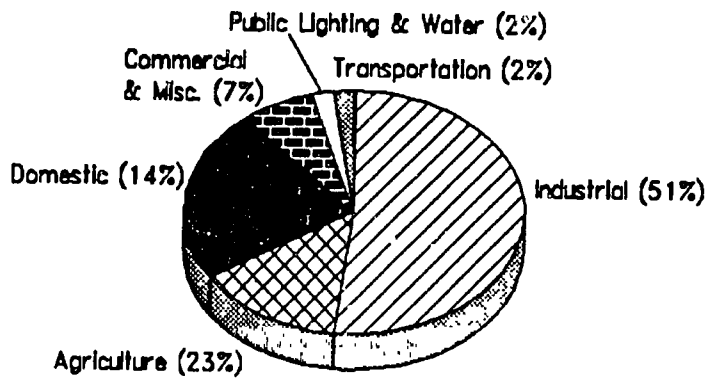
Sectoral estimates for 2004/05 for the purposes of this study were therefore determined based on a regression analysis of the forecasted sectoral electricity consumptions from 1986/87 to

Table 2-3
Estimated 1989/90 Purchased and Total Electricity Consumption

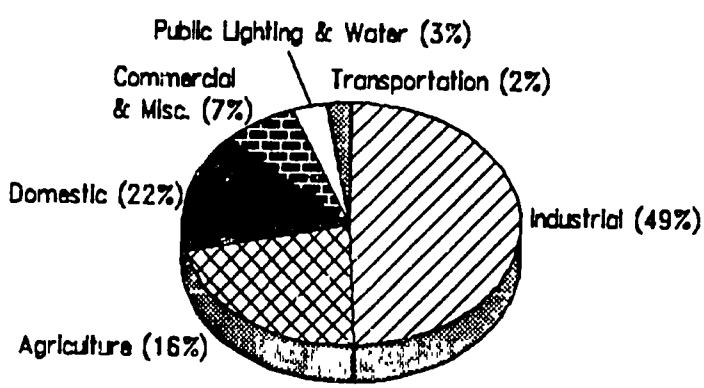
| | Purchased | Total |
|---|---|---|
| Electricity Consumption, GWh | | |
| Total | 175,000 | 191,100 |
| Industrial | 81,600 | 97,700 |
| Agriculture | 44,400 | 44,400 |
| Domestic | 27,600 | 27,600 |
| Commercial | 10,100 | 10,100 |
| Traction | 4,100 | 4,100 |
| Others | 7,200 | 7,200 |
| Public Water Works | 3,100 | 3,100 |
| Public Lighting | 1,600 | 1,600 |
| Misc.Non-Industr'l. | 2,500 | 2,500 |
| Share, % | | |
| Industrial | 46.6 | 51.1 |
| Agriculture | 25.4 | 23.2 |
| Domestic | 15.8 | 14.4 |
| Commercial | 5.8 | 5.3 |
| Traction | 2.3 | 2.1 |
| Others | 4.1 | 3.8 |
| Public Water Works | 1.8 | 1.6 |
| Public Lighting | 0.9 | 0.8 |
| Misc.Non-Industr'l. | 1.4 | 1.3 |

Notes: Totals may not sum due to rounding.
Electricity that is stolen is not included in these figures.

Figure 2-1. Distribution of Electricity Use by Sector.




1989/1990




2004/2005

1994/95. Details on the analysis are provided in Appendix A. The results of the regression analysis are summarized in Table 2-4, which provides calculated forecasts of sectoral electricty use over the 1989/90 to 2004/05 period at five year intervals.

As mentioned earlier, the CEA only forecasts generation requirements beyond 1994/95. These estimates are also shown in Table 2-4, together with the calculated ratio of total consumption to public utilities' generation. This ratio shows an increasing trend, which, if true, would imply any or all of the following factors: reduced auxiliary consumption, reduced transmission and distribution losses, and increased captive generation. However, it seems unlikely that any of these factors would explain the entire increase; more likely, much of the increase is just a manifestation and result of flaws in the forecasting methodology.

The forecast described above is an extension of CEA's forecast in the Thirteen Electric Power Survey. This forecast assumes rapid economic growth (explicit GNP growth rates are not provided in the forecast), with even more rapid growth in electricity demand -- an average growth rate of 10% per year. This electricity growth rate is significantly higher than India has sustained at any point in the past 15 years (see Table 2-2). Growth rates of this magnitude have been sustained for a 15 year period by only a few countries. Examples include South Korea, Thailand, Indonesia, Brazil, and Taiwan over the 1970-1986 period (Meyers and Campbell, 1990). Thus, while a growth rate of this magnitude may be possible, it likely represents an upper-bound scenario.

In order to balance this upper-bound scenario, we also sought to develop a lower-bound scenario. For this purpose, other official forecasts of electricity consumption in 2004/05 were reviewed, namely those made by the Advisory Board on Energy (ABE, 1985) and the Energy Demand Screening Group set up by the Planning Commission (1986). These forecasts are summarized in Table 2-5. The two cases in the ABE forecast correspond to a rate of growth in gross

Table 2-4
Forecasted Electricity Consumption

| Year | 1989/90[e*] | 1994/95[e] | 1999/00[f] | 2004/05[f] |
|---|---|---|---|---|
| Electricity Consumption, GWh | | | | |
| Total | 191,100 | 308,500 | 500,700 | 803,000 |
| Industrial | 97,700 | 162,200 | 256,400 | 397,100 |
| Agriculture | 44,400 | 54,300 | 83,700 | 127,700 |
| Domestic | 27,600 | 51,500 | 95,400 | 174,900 |
| Comm, Misc, Non-Industrial | 12,500 | 23,300 | 37,200 | 58,300 |
| Traction | 4,100 | 7,200 | 11,800 | 18,600 |
| Public Lighting | 1,600 | 2,700 | 4,300 | 6,800 |
| Public Water Works | 3,100 | 7,200 | 12,000 | 19,600 |
| Utility Generation | 240,200 | 384,800 | 593,800 | 919,100 |
| Consumption/Generation | 0.80 | 0.80 | 0.84 | 0.87 |
| Share, % | | | | |
| Industrial | 51.1 | 52.6 | 51.2 | 49.5 |
| Agriculture | 23.3 | 17.6 | 16.7 | 15.9 |
| Domestic | 14.5 | 16.7 | 19.0 | 21.8 |
| Comm, Misc. Non-Industrial | 6.6 | 7.6 | 7.4 | 7.3 |
| Traction | 2.1 | 2.3 | 2.4 | 2.3 |
| Public Lighting | 0.8 | 0.9 | 0.9 | 0.8 |
| Public Water Works | 1.6 | 2.3 | 2.4 | 2.4 |

e*: 1989/90 estimate based on historical trends (Table 2-3)
e: estimates as given in Thirteenth Electric Power Survey
f: forecasted values based on trends from Thirteenth Electric Power Survey

Notes: Totals may not sum due to rounding.
Electricity that is stolen is included under utility generation and is not included in the other figures.

Table 2-5
Other Forecasts of Electricity Consumption in 2004/05

| Sector | Advisory Board on Energy Case I | Case II | Energy Demand Screening Group |
|---|---|---|---|
| Electricity Consumption, GWh | | | |
| Industry | 302,000 | 366,000 | 367,000 |
| Household | 96,000 | 107,000 | 145,610 |
| Agriculture | 42,000 | 45,200 | 45,200 |
| Transport | 8,920 | 11,670 | 11,670 |
| Others | 52,080 | 62,130 | 59,770 |
| Total | 501,000 | 592,000 | 629,250 |
| Share, % | | | |
| Industry | 60.3 | 61.8 | 58.3 |
| Household | 19.2 | 18.1 | 23.1 |
| Agriculture | 8.4 | 7.6 | 7.2 |
| Transport | 1.8 | 2.0 | 1.9 |
| Others | 10.4 | 10.5 | 9.5 |

Note: Others includes Commercial, Miscellaneous and Non-Industrial, Public Lighting, and Public Water Works and Sewage.

Sources: Advisory Board on Energy, 1985 and Energy Demand Screening Group, 1986.

domestic product (GDP) at constant prices of 4% and 5% per annum compounded over the 1985-2005 period. Without going into details of the assumptions behind the forecasts, we elected to use Case I forecast of the ABE to represent our lower-bound scenario, because it shows the slowest growth rate of the forecasts examined. This forecast projects total electricity consumption in 2004/05 to be about 500,000 GWh, representing an average annual growth rate over the 1989/90 to 2004/05 period of 6.6% (slightly lower than the growth rate in India over the past 15 years -- see Table 2-2).[3]

The upper- and lower-bound forecasts used in this study represent a large range of uncertainty. The difference between these two forecasts (803 TWh in 2004/05 versus 501 TWh) amounts to 300 TWh -- an amount approximately 50% greater than total electricity use in India in 1989/90. The two forecasts are illustrated in Figure 2-2, which also includes historical and estimated data for the 1980-1990 period.

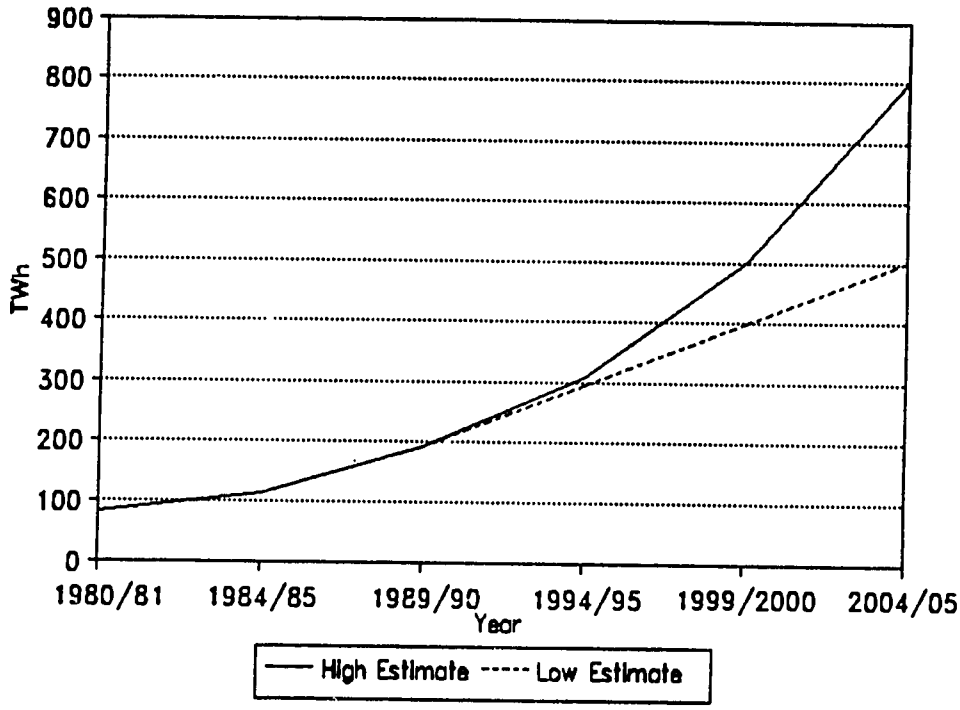
**BASELINE END-USE ELECTRICITY CONSUMTIONS ESTIMATES**

Since the focus of this study is on end-uses, a list of end-uses and major equipment types in all sectors was prepared at the outset of the study. These are given below:

- Industrial sector
  - Lighting
  - Mechanical drive

[3] In electing to use the ABE forecast for our lower-bound estimate, we only used the ABE forecast of All-India electricity consumption. This figure was then allocated to the different sectors based on the percentages derived for the upper-bound forecast. We did this because the ABE forecast projects that 60% of All-India electricity sales in 2004/05 will go to the industrial sector, a significant increase from the 51% share in 1989/90 (although a modest increase from the 55-56% level prevailing at the time the ABE forecast was prepared). As discussed previously, the recent trend in India is for the industrial proportion of All-India electricity sales to decline slightly; in line with the allocations in the upper-bound forecast.

Figure 2-2. Electricity Sales in India — 1980/1981 to 2004/2005.



        - Pumps
        - Compressors
        - Fans and blowers
        - Other
    - Process heat
        - Electric arc furnaces (steelmaking)
    - Electrolytic processes
        - Aluminium
        - Chlor-alkali
    - Other

    - Agricultural sector
        - Irrigation pumps

    - Residential sector
        - Lighting
        - Space cooling/ventilation
        - Fans
            - Ceiling fans
            - Table fans
        - Evaporative air coolers (desert coolers)
        - Air conditioners
    - Refrigerators
    - Television
        - Black & white TV sets
        - Color TV sets
    - Other

- Commercial sector
    - Lighting
    - Heating, ventilating and air conditioning (HVAC)
    - Other

- Transport sector
    - Electric Traction

Existing studies, literature references, and results of surveys that have been carried out in the past were reviewed to obtain disaggregated data at the end-use level or to develop a basis for performing the disaggregation. In addition, a series of interviews was carried out with equipment manufacturers, major end-users, and other experts, to gather additional inputs for this analysis. However, no new primary data were generated in this study.

The basic approach that was used to estimate disaggregated end-use electricity consumption was to derive estimates of equipment population, typical daily or annual operating hours, and typical electrical rating (Watts) or typical annual electricity

consumption, and thereby calculate end-use consumption. However, severe data problems were encountered during the process of deriving these estimates. The major problem was unavailability or very limited availability of data. Among the limitations of available data at disaggregated levels are poor quality of data, inadequate or insufficient data, and poor statistical design in the case of surveys. Due to these limitations, the estimates described below should be considered approximate, and subject to a considerable degree of uncertainty.

Descriptions of the data inputs and methods to derive each of the end-use estimates are provided in Appendix A. Results of the analysis are summarized in Table 2-6 and Figure 2-3.

In the industrial sector, electric motors are the dominant end-use, accounting for nearly 75% of sector electricity use. Other significant end-uses are lighting (9% of sector electricity use) and aluminum smelting (8%). In the agriculture sector, nearly all electricity is used by irrigation pumps. In the domestic sector, the largest end-use is fans (34% of sector use), followed by lighting (28%) and refrigerators (13%). Cooling equipment (air conditioners and evaporative coolers) account for an estimated 11% of sector electricity use. In the commercial/miscellaneous sector the two major end-uses are lighting and HVAC, accounting for an estimated 60% and 32% of sector electricity use, respectively.

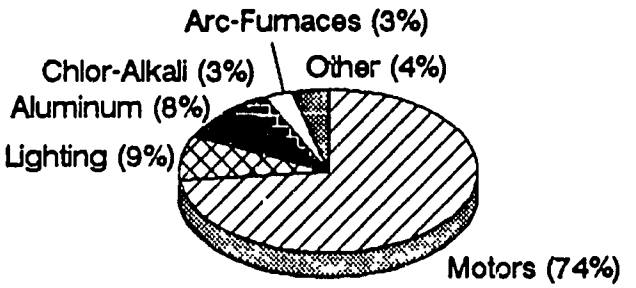
When all the sectors are combined, the largest end-use is industrial motors -- 38% of All-India electricity use. Agricultural pumps account for an estimated 23% of nationwide electricity use, following by lighting (14%), domestic appliances (11%), and other industrial end-uses (9%). HVAC and miscellaneous uses in the commercial sector amount to approximately 3% of nationwide electricity use while all other end-uses total 4% of

Table 2-6. Estimated Electricity Use by End-Use -- 1989/90

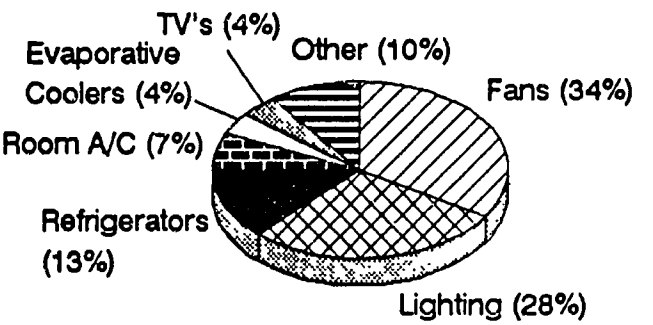
| End-Use | % of GWh Use in Sector | Use in 1989/90 (GWh/yr) Total | Use in 1989/90 (GWh/yr) By End-Use | % of All-India Use Total | % of All-India Use By End-Use |
|---|---|---|---|---|---|
| .Industrial | | 97,700 | | 51.1% | |
| Motors | | | | | |
| Pumping | 14.1% | | 13,800 | | 7.2% |
| Fans | 8.3% | | 8,100 | | 4.2% |
| Air compressors | 3.6% | | 3,500 | | 1.8% |
| Refrigeration | 3.6% | | 3,500 | | 1.8% |
| Other | 44.1% | | 43,100 | | 22.6% |
| Lighting | | | | | |
| Incandescent | 0.3% | | 300 | | 0.2% |
| Fluorescent | 6.7% | | 6,500 | | 3.4% |
| Mercury vapor | 1.2% | | 1,200 | | 0.6% |
| Sodium vapor | 0.8% | | 800 | | 0.4% |
| Electric arc furnaces | 2.8% | | 2,700 | | 1.4% |
| Electrolysis | | | | | |
| Chlor-Alkali | 3.0% | | 2,900 | | 1.5% |
| Aluminum | 8.0% | | 7,800 | | 4.1% |
| Other | 3.6% | | 3,500 | | 1.8% |
| Agricultural | | | | | |
| Pumps | 100.0% | 44,400 | 44,400 | 23.2% | 23.2% |
| Domestic | | 27,600 | | 14.4% | |
| Lighting | | | | | |
| Incandescent | 26.73% | | 7,400 | | 3.9% |
| Fluorescent | 1.27% | | 300 | | 0.2% |
| Refrigerators | 12.5% | | 3,500 | | 1.8% |
| Fans | 34.3% | | 9,500 | | 5.0% |
| Evaporative coolers | 4.2% | | 1,200 | | 0.6% |
| Air conditioners | 7.1% | | 2,000 | | 1.0% |
| Televisions | 3.9% | | 1,100 | | 0.6% |
| Other | 10.0% | | 2,800 | | 1.5% |
| Commercial & Misc Non-Ind'l | | 12,600 | | 6.6% | |
| Lighting | | | | | |
| Incandescent | 9.3% | | 1,200 | | 0.6% |
| Fluorescent | 49.1% | | 6,200 | | 3.2% |
| Mercury vapor | 1.1% | | 100 | | 0.1% |
| Sodium vapor | 0.4% | | 100 | | 0.1% |
| HVAC | 32.0% | | 4,000 | | 2.1% |
| Other | 8.0% | | 1,000 | | 0.5% |
| Public lighting | | 1,600 | | 0.8% | |
| Incandescent | 11.8% | | 200 | | 0.1% |
| Fluorescent | 58.2% | | 900 | | 0.5% |
| Mercury vapor | 13.6% | | 200 | | 0.1% |
| Sodium vapor | 16.4% | | 300 | | 0.2% |
| Transportation | | 4,100 | 4,100 | 2.1% | 2.1% |
| Public water works | | 3,100 | 3,100 | 1.6% | 1.6% |
| TOTAL | | 191,100 | 191,100 | 100.0% | 100.1% |

Note: Totals may not sum due to rounding.

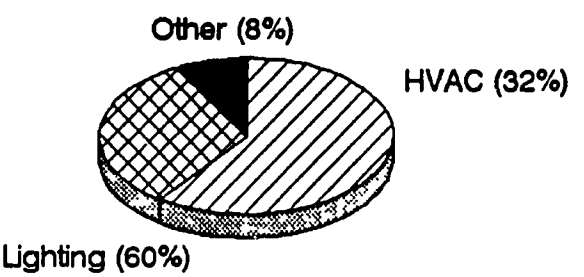
Figure 2-3. Distribution of Electricity by End-Use -- 1989/1990




Industrial




Domestic




Commercial/ Miscellaneous

electricity use. These figures are illustrated in Figure 2-4. Interestingly, over 70% of electricity use is for motors including industrial motors, agricultural pumps, and domestic and commercial appliances and equipment.

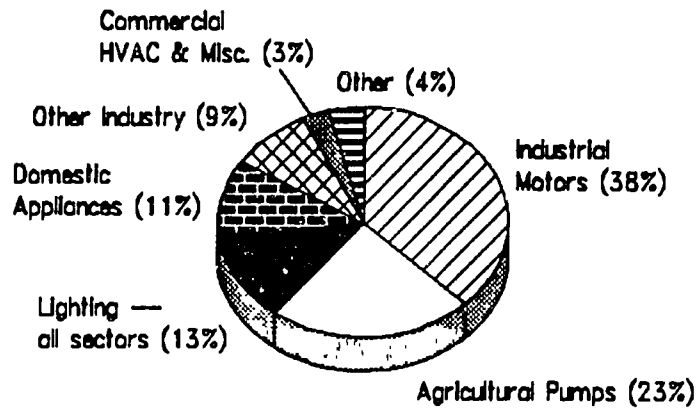
**FORECASTED END-USE ELECTRICITY CONSUMPTION ESTIMATES**

Given our reliance in this study on electricty-use forecasts developed by others, and given the paucity of end-use data in India, the estimates for end-use electricity consumption in 2004/05 were made based on simple and reasonable assumptions, and no attempt was made to obtain or generate the detailed data and assumptions that would normally be made when developing forecasts. In general these forecasts are based on current trends, and assume that no radical transformation of the Indian economy takes place during the 1990-2005 period.

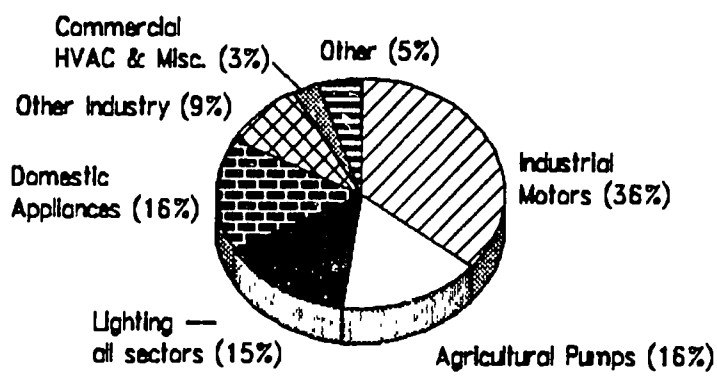
For the industrial sector, motors constitute the largest single end-use, and the shares of other end-uses are comparatively small. Since no radical changes in the mix and output of manufacturing industries are expected up to 2004/05, no significant changes are expected in the shares of the end-uses. Accordingly, the end-use allocations estimated for 1989/90 are also assumed to hold true in 2004/05. Similarly, in the agriculture sector, irrigation pumps are the dominant end-use, and we project they will be equally dominant in 2004/05. In the commercial sector, due to lack of adequate data, the end-use shares are assumed to be the same as in 1989/90.

Only in the residential sector was there sufficient data to develop a new end-use allocation for 2004/05. For this analysis, production trends over the 1970-1999 period were examined to estimate growth rates in equipment saturations. This production trend analysis, which was based on data compiled by the Center for Monitoring Indian Economy (1987 and 1991), revealed the growth rates to be approximately 6% for ceiling fans and table fans, 5%

Figure 2-4. Distribution of Electricity End Use -- All Sectors.




1989/1990




2004/2005

for room air conditioners, 15% for refrigerators, 30% for black & white TV sets, and 20% for color TV sets. The high growth rates for refrigerators and TV sets are probably due to their recent emergence as necessary rather than luxury consumer durables especially in middle-class households, and also due to a low starting base. It is unlikely that these growth rates can be sustained in the long run as the market saturates. Thus, a lower growth rate of 10% was assumed. Desert coolers (evaporative coolers) were assumed to grow at the same rate as fans, i.e. 6%.

These growth rates were applied to current energy consumption levels to obtain 2004/05 estimates. Electricity use by "other" equipment (e.g., water heaters, clothes washers, stereos, etc.) was assumed to double to 20% of total sector energy use, in line with other equipment use in present-day Egypt (Turiel et. al., 1990). We also assumed, in the absence of better data, that equipment operating hours and electrical ratings would remain at 1989/90 levels (average equipment size can be expected to grow somewhat, but these size increases are assumed to be offset by modest market-driven efficiency improvements).

The resulting domestic-sector end-use estimates are summarized in Table 2-7. The total for the sector lies near the lower-bound scenario. The end-use proportions for all sectors, as shown in Table 2-8, were then applied to both scenarios. Table 2.8 summarizes the end-use breakdown in 2004/05 for the high case while Table 2-9 provides analagous data for the low-case. These end-use allocations are also illustrated in Figure 2-1.

In summary, due to a paucity of data, and to an assumption that profound changes in the Indian economy will not take place over the next decade and a half, our end-use allocation for electricity use in 2004/05 is very similar to our allocation for 1989/90.

Table 2-7
Residential Equipment: Estimated Stock
and Electricity Consumption, 2004/05

| Equipment | 1989/90 Stock (million) | Growth Rate (%/yr) | 2004/05 Stock (million) | 2004/05 GWh | % of Sector GWh |
|---|---|---|---|---|---|
| Lighting | | 7 | | 25,604 | 24.5% |
| Ceiling fan | 61.2 | 6 | 146.7 | 25,667 | 24.6% |
| Table fan | 15.3 | 6 | 36.7 | 1,541 | 1.5% |
| Room A/C | 0.9 | 5 | 1.9 | 4,927 | 4.7% |
| Air cooler | 5.0 | 6 | 12.0 | 3,307 | 3.2% |
| Refrigerator | 7.6 | 10 | 31.7 | 17,118 | 16.4% |
| B&W TV | 20.9 | 10 | 87.3 | 3,141 | 3.0% |
| Color TV | 5.5 | 10 | 23.0 | 2,206 | 2.1% |
| Other | | | | 20,878 | 20.0% |
| Total | | | | 104,389 | 100.0% |

Note: Stock means the total number of devices in use.

Source: Appendix A.

Table 2-8. Projected Electricity Use by End-Use -- High Case

| End-Use | % of GWh Use in Sector | Projected Use in 2004/05 (GWh/yr) Total | Projected Use in 2004/05 (GWh/yr) By End-Use | % of All-India Use Total | % of All-India Use By End-Use |
|---|---|---|---|---|---|
| Industrial | | 397,100 | | 49.5% | |
| Motors | | | | | |
| Pumping | 14.1% | | 56,000 | | 7.0% |
| Fans | 8.3% | | 33,000 | | 4.1% |
| Air compressors | 3.6% | | 14,100 | | 1.8% |
| Refrigeration | 3.6% | | 14,100 | | 1.8% |
| Other | 44.1% | | 175,100 | | 21.8% |
| Lighting | | | | | |
| Incandescent | 0.3% | | 1,200 | | 0.1% |
| Fluorescent | 6.7% | | 26,600 | | 3.3% |
| Mercury vapor | 1.2% | | 4,800 | | 0.6% |
| Sodium vapor | 0.8% | | 3,200 | | 0.4% |
| Electric arc furnaces | 2.8% | | 11,100 | | 1.4% |
| Electrolysis | | | | | |
| Chlor-Alkali | 3.0% | | 11,900 | | 1.5% |
| Aluminum | 8.0% | | 31,800 | | 4.0% |
| Other | 3.6% | | 14,300 | | 1.8% |
| Agricultural | | | | | |
| Pumps | 100.0% | 127,700 | 127,700 | 15.9% | 15.9% |
| Domestic | | 174,900 | | 21.8% | |
| Lighting | | | | | |
| Incandescent | 23.4% | | 40,900 | | 5.1% |
| Fluorescent | 1.1% | | 1,900 | | 0.2% |
| Refrigerators | 16.4% | | 28,700 | | 3.6% |
| Fans | 26.1% | | 45,600 | | 5.7% |
| Evaporative coolers | 3.2% | | 5,600 | | 0.7% |
| Air conditioners | 4.7% | | 8,200 | | 1.0% |
| Televisions | 5.1% | | 8,900 | | 1.1% |
| Other | 20.0% | | 35,000 | | 4.4% |
| Commercial & Misc Non-Ind'l | | 58,300 | | 7.3% | |
| Lighting | | | | | |
| Incandescent | 9.3% | | 5,400 | | 0.7% |
| Fluorescent | 49.1% | | 28,600 | | 3.6% |
| Mercury vapor | 1.1% | | 600 | | 0.1% |
| Sodium vapor | 0.4% | | 200 | | 0.0% |
| HVAC | 32.0% | | 18,700 | | 2.3% |
| Other | 8.0% | | 4,700 | | 0.6% |
| Public lighting | | 6,800 | | 0.8% | |
| Incandescent | 11.8% | | 800 | | 0.1% |
| Fluorescent | 58.2% | | 4,000 | | 0.5% |
| Mercury vapor | 13.6% | | 900 | | 0.1% |
| Sodium vapor | 16.4% | | 1,100 | | 0.1% |
| Transportation | | 18,600 | 18,600 | 2.3% | 2.3% |
| Public water works | | 19,600 | 19,600 | 2.4% | 2.4% |
| TOTAL | | 803,000 | 803,000 | 100.0% | 100.0% |

Note: Totals may not sum due to rounding.

Table 2-9. Projected Electricity Use by End-Use -- Low Case

| End-Use | % of GWh Use in Sector | Projected Use in 2004/05 (GWh/yr) Total | By End-Use | % of All-India Use Total | By End-Use |
|---|---|---|---|---|---|
| Industrial | | 247,800 | | 49.5% | |
| Motors | | | | | |
| Pumping | 14.1% | | 34,900 | | 7.0% |
| Fans | 8.3% | | 20,600 | | 4.1% |
| Air compressors | 3.6% | | 8,800 | | 1.8% |
| Refrigeration | 3.6% | | 8,800 | | 1.8% |
| Other | 44.1% | | 109,300 | | 21.8% |
| Lighting | | | | | |
| Incandescent | 0.3% | | 700 | | 0.1% |
| Fluorescent | 6.7% | | 16,600 | | 3.3% |
| Mercury vapor | 1.2% | | 3,000 | | 0.6% |
| Sodium vapor | 0.8% | | 2,000 | | 0.4% |
| Electric arc furnaces | 2.8% | | 6,900 | | 1.4% |
| Electrolysis | | | | | |
| Chlor-Alkali | 3.0% | | 7,400 | | 1.5% |
| Aluminum | 8.0% | | 19,800 | | 4.0% |
| Other | 3.6% | | 8,900 | | 1.8% |
| Agricultural | | | | | |
| Pumps | 100.0% | 79,700 | 79,700 | 15.9% | 15.9% |
| Domestic | | 109,100 | | 21.8% | |
| Lighting | | | | | |
| Incandescent | 23.4% | | 25,500 | | 5.1% |
| Fluorescent | 1.1% | | 1,200 | | 0.2% |
| Refrigerators | 16.4% | | 17,900 | | 3.6% |
| Fans | 26.1% | | 28,500 | | 5.7% |
| Evaporative coolers | 3.2% | | 3,500 | | 0.7% |
| Air conditioners | 4.7% | | 5,100 | | 1.0% |
| Televisions | 5.1% | | 5,600 | | 1.1% |
| Other | 20.0% | | 21,800 | | 4.4% |
| Commercial & Misc Non-Ind'l | | 36,400 | | 7.3% | |
| Lighting | | | | | |
| Incandescent | 9.3% | | 3,400 | | 0.7% |
| Fluorescent | 49.1% | | 17,900 | | 3.6% |
| Mercury vapor | 1.1% | | 400 | | 0.1% |
| Sodium vapor | 0.4% | | 100 | | 0.0% |
| HVAC | 32.0% | | 11,600 | | 2.3% |
| Other | 8.0% | | 2,900 | | 0.6% |
| Public lighting | | 4,200 | | 0.8% | |
| Incandescent | 11.8% | | 500 | | 0.1% |
| Fluorescent | 58.2% | | 2,400 | | 0.5% |
| Mercury vapor | 13.6% | | 600 | | 0.1% |
| Sodium vapor | 16.4% | | 700 | | 0.1% |
| Transportation | | 11,600 | 11,600 | 2.3% | 2.3% |
| Public water works | | 12,200 | 12,200 | 2.4% | 2.4% |
| TOTAL | | 501,000 | 501,000 | 100.0% | 100.0% |

Note: Totals may not sum due to rounding.

# Chapter 3

# OPPORTUNITIES TO IMPROVE ELECTRICAL END-USE EFFICIENCY

## INTRODUCTION

While the projections of future electricity use and demand discussed in the previous chapter appear staggering, these estimates generally assume that the efficiency of electricity use in India will be largely unchanged from present-day levels. However, much of the equipment in India is less efficient than equipment used in other countries, and even equipment in developed countries can benefit from efficiency improvements.

In this chapter, some of the major opportunities to improve end-use efficiency are explored. While there are hundreds of efficiency measures which can, and are, being applied in India, in this chapter we concentrate on 27 measures (or sets of measures) which provide particularly large opportunities for savings. This discussion has two objectives -- to examine the current status of promising efficiency measures in India, and to provide a first-cut estimate of the cost-effective technical savings potential in India from efficiency measures.

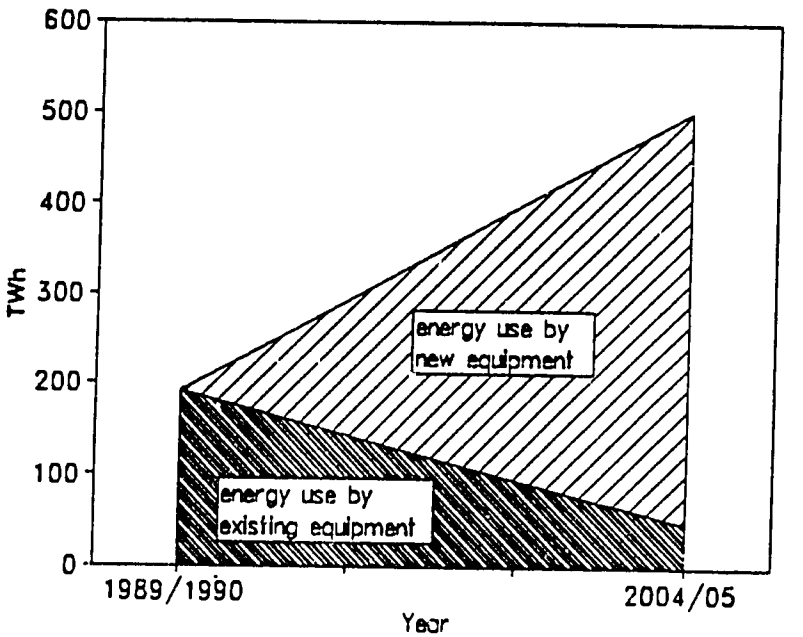
The technical savings potential is the amount of energy that can be saved if all measures which are technically feasible are implemented. However, not all measures which are technically possible are cost-effective. Hence, we further limit our analysis to measures which are cost-effective to Indian society as a whole (meaning that the benefits of the measure to society are greater than the costs of the measure to society -- details are discussed below). However, there are many reasons why cost-effective, technically viable measures are not implemented, and thus the achievable efficiency potential is generally lower than the cost-effective technical potential. In Chapter 6 we make a rough estimate of the achievable efficiency potential.

Both the estimate of cost-effective technical savings potential in this chapter, and the estimate of achievable savings potential in Chapter 6 are for 2004/05 -- a period far enough into the future for significant savings to be made, but near enough to be of concern to policy-makers today.

As discussed in Chapter 2, electricity use in India is projected to grow by a factor of 2.6 (low case) to 4.2 (high case) during the 1989/90 - 2004/05 period. Thus, the majority of electricity use in 2004/05 will be attributable to equipment purchased between now and 2004/05 (see Figure 3-1). Since so much new equipment is being purchased, our analysis emphasizes the purchase of efficient equipment whenever new equipment is needed (including replacement of existing equipment as well as purchase of equipment for new applications). At these times, the cost of the efficiency improvement is the difference in cost between standard-efficiency equipment and high-efficiency equipment. For a few measures, primarily low-cost operations and maintenance-type measures, we assume that efficiency improvements must be made on a retrofit basis. In these cases, the full cost of the measure is used in our analysis.

As noted above, in undertaking this analysis of the potential for efficiency savings, we take a societal perspective. The societal perspective considers not only the costs paid and benefits received by the end-user, but also costs paid and benefits received by other parties, such as central and state governments who collect excise taxes whenever equipment is purchased, and who subsidize electricity prices for many end-users. In order to examine efficiency measure costs from the societal perspective, we examine the cost exclusive of excise taxes, sales taxes, and import duties, because monies paid in taxes and duties are offset by compensating benefits -- the services provided when the revenues are spent. Likewise, in examining the benefits of energy and power savings, we value these benefits at the full cost to produce this power, and not the subsidized cost paid by many end-users.

Figure 3-1. Electricity Use by New & Existing Equipment -- Low Case




This simplified analysis illustrates that even in the low-growth case, new equipment accounts for the majority of electricity use over the 1989/90 - 2004/05 period. This analysis assumes that existing equipment has an average remaining life of 20 years, and hence that 75% of existing equipment will be replaced over the 15 year analysis period. Also, growth in electricity sales is assumed to be due to new equipment, and not to increased use of existing equipment.

For each measure examined in this chapter, we assess measure economics using two approaches.

First, we calculate the cost of the measure per saved kilowatt (kW) of peak generating capacity. This calculation is done using the following formula:

$$\text{Rs/kW} = \frac{\text{Measure cost}}{(\text{Average kW savings}) * (\text{Peak coincidence factor}) * (\text{T\&D/Capacity utilization factor})}$$

Measure costs and average kW savings are unique for each application. In the sections that follow, we provide some typical examples. These costs are taken for a 20-year period -- for measures with shorter lives, discounted equipment replacement costs are included in the calculations. Peak coincidence factor is the proportion of equipment that is actually operating during India's period of peak demand (5-9 pm during weekday evenings). These factors are based on very limited data from India, supplemented with data from overseas. The T&D (transmission and distribution)/Capacity utilization factor is an adjustment for T&D losses, and for power plant utilization factors. For these calculations we assume 20% T&D losses, and an average 60% capacity factor. These estimates are conservative in light of recent Indian experience. For example, in 1987/88, average T&D losses were 21.5% and average power plant utilization was 42.5% (including 53.2% for thermal plants) (TERI, 1989).

To illustrate the use of this formula, assume an efficiency measure with a capital cost (net of taxes) of Rs. 1000 and an average installed life of ten years. The cost of the measure, for the 20-year analysis period, is Rs. 1386 (Rs. 1000 initial cost plus Rs. 386 discounted replacement cost in year ten assuming a 10% real discount rate -- all costs are in Rupees and reflect conditions in 1991). If the measure saves 1 kW on average, and has a peak coincidence factor of 60%, then the cost per kW is Rs. 1155 (Rs.

1386 cost / (1 kW average savings * .6 coincidence factor * 1.2 T&D factor * 1/.6 capacity factor)).

Cost per kW numbers for efficiency measures can be compared to the cost of new power plants. For example, a companion report to this analysis (IDEA, 1991) estimated the cost of a new baseload plant in India at Rs. 22,000/kW and a new peaking plant at Rs. 12,000/kW. These costs were estimated before the Rupee was devalued in July, 1991. As a result of the devaluation, these costs increase to approximately Rs. 23,500 and Rs. 12,900 respectively.[1] For efficiency measures that primarily save at the time of the evening peak, a measure is likely to save capital if its cost per kW is less than Rs. 12,900. Likewise, for measures that save throughout the day, capital savings are likely whenever cost per kW are less than Rs. 23,500.

While such comparisons provide useful insights into measure economics, given the uncertainties inherent in the data, particularly the estimates of peak coincidence factor, care must be taken not to impute too much validity into this analysis. Where measures clearly have lower capital costs than new power plants, capital cost savings are likely. But when the cost of efficiency measures and power plants are within approximately 20% of each other, more detailed analysis is needed before conclusions can be drawn.

A further limitation to cost per kW values is that they include no credit for power plant operating cost savings -- an efficiency measure which saves 1 kW and operates for 4,000 hours each year has much higher kWh savings than a similar measure that operates only 1,000 hours each year. Savings in kWh translate into savings in

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[1] As a result of devaluation, the exchange rate rose from Rs. 21/U.S. $ to Rs. 26/$. Gadgil and Januzzi (1989) cite a presentation by Dr. John Besant-Jones of the World Bank that foreign exchange accounts for approximately 30% of power plant cost in India. Accordingly, the devaluation leads to a 7% increase in power plant cost (.7 + .3(26/21)).

fuel and other operations and maintenance costs. In order to account for these cost savings, we calculate a second measure of cost-effectiveness -- cost of conserved energy (CSE). Cost of conserved energy is the levelized average cost of a measure per kWh saved. It is calculated with the following formula:

$$\text{CSE (Rs/kWh)} = \frac{\text{Measure cost * Capital recovery factor}}{\text{Annual kWh savings}}$$

Measure costs are primarily initial costs, but where on-going costs are substantial, we also include them in the analysis. The capital recovery factor can be thought of as the annual payments on a loan used to finance an efficiency measure, assuming an interest rate equal to the discount rate, and a loan term equal to the measure life.[2] In our calculations, we assume a 10% real discount rate (*real* means excluding the effects of inflation -- the real rate is lower than the *nominal* rate charged by banks because the nominal rate includes an allowance for inflation).

The CSE can be compared to societal marginal costs to estimate the cost-effectiveness of efficiency measures. In a companion report to this study, RCG/Hagler, Bailly, Inc. (1991) estimates that the long-run marginal cost of electricity generation for four typical State Electricity Boards (SEBs) in India range from Rs. 1.77/kWh to 2.02/kWh.[3] This means that over the long-term, efficiency

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[2] Typically CRF is calculated using the loan payment formula in a computer spreadsheet program. The full formula for CRF is: $(d(1+d)^n)/((1+d)^n-1)$ where d is the discount rate and n the measure life. Thus, for a measure with a 10 year life, the CRF is 0.16, assuming a 10% discount rate. Note that since the CRF varies with measure life, no additional adjustment is needed in the CSE formula for measures with short measure lives.

[3] These costs are at the end-user level, and hence should be compared to kWh savings at the end-user level. For this reason, an adjustment for T&D losses is not included in the CCE formula, since the T&D loss factor reflects kWh savings to the utility, not kWh savings to end-users. Also, these marginal costs were calculated prior to the recent devaluation of the Rupee. Thus, these marginal costs can be expected to increase somewhat, to reflect the impact of the devaluation on equipment and fuel costs.

measures with a CSE of less than Rs. 1.77-2.02 will be cost-effective.

However, long-run marginal cost estimates are based on the implicit assumption that power demand and power supply are in balance, and therefore a kWh saved means one less kWh that needs to be generated. While such an analysis may be appropriate for India in the long-term, over the short-term, demand and supply are not in balance, so a kWh saved will be immediately resold to someone else. With this in mind, the short-run marginal value of a kWh saved can be conservatively approximated by looking at the marginal revenues from additional kWh sales. In India, it is the industrial sector that usually faces load curtailments and voltage reductions first, and thus the short-run marginal value can be approximated by the average revenues per kWh from industrial customers. In the RCG/Hagler, Bailly study, these figures range from Rs. 0.92/kWh to Rs. 1.27/kWh. Thus, over the short-term, efficiency measures can save Indian utilities money whenever the CSE is less than approximately Rs. 0.9-1.3/kWh.[4]

In interpreting CSE data calculated in this report, it is important to keep in mind that CSE calculations represent typical cases, and that individual applications will vary considerably. Accordingly, when CSE figures are substantially less than Rs. 0.9-1.3/kWh, short-term cost-effectiveness is likely, but when CSE figures are

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[4] This figure is conservative because it values additional kWh at the average price, when in fact the value may be much higher. For example, some customers purchase captive generators to provide additional power at a cost per kWh in excess of Rs. 2. Other customers reduce production. For example, a study by the National Council for Applied Economic Research (1985) found that in the early 1980's production losses in industry due to power shortages were in excess of $2 billion annually, or about 1.5 percent of GNP. If be divide this figure by the estimated power availability deficit during the same period (approx. 10,000 GWh/year -- TERI, 1989), the value of lost production is approximately $0.20/kWh of power deficit (about Rs. 5/kWh at <u>current</u> exchange rates).

near these threshold values, more detailed analysis needs to be performed.

In the sections below, we discuss our analysis of the 27 different measures we examined in depth. Our analysis begins with a discussion of lighting efficiency measures, across all sectors. We then turn to sector-specific measures, beginning with the industrial sector, proceeding to the agriculture sector, and ending with the domestic and commercial sectors.

In discussing individual measures, or sets of measures, we review current equipment efficiencies in India, and opportunities to improve these efficiencies, including measures that are presently available in India, as well as measures which are now used overseas and which could be produced in India given sufficient encouragement. Our discussion also covers measure costs and savings, and reports the cost per kW and the CSE of each measure. The actual calculations are summarized in Table 3-6 near the end of this chapter.

In addition, for each measure, we estimate the proportion of applications in 2004/5 for which each measure is suitable. Few efficiency measures are technically feasible and cost-effective for all applications and hence an estimate of the number of appropriate applications is needed to develop a reasonable estimate of the savings potential. For example, if a measure involves the purchase of a high-efficiency refrigerator instead of a standard refrigerator, if the high efficiency refrigerator is available in India today, and if 80% of the refrigerators in use in 2004/05 are purchased after 1991, then the percent applicable factor will be 80%. The measure is not applicable for the 20% of refrigerators which will not be replaced. For measures that do not involve new equipment, based on discussions with industry experts, we estimated the proportion of applications in 2004/05 for which a measure is likely to be technically feasible and have a CSE of less than the long-run marginal costs discussed above.

In some cases, more than one measure is analyzed that affects the same end-use. In these cases, the measure with the lowest CSE is generally assumed to be adopted first, and the savings, cost, and percent applicable factors for subsequent measures assume that the first measure is in place. In a few cases, one type of equipment may be most appropriate for some applications and another type of equipment more appropriate for other applications. For example, two-speed motors have a lower CSE than variable-speed drives, but cannot be used in all speed-control applications. In these cases we allocate the available market among the competing technologies based on professional judgement.

This analysis draws heavily from a companion report, *Review of Power End-Use Efficiencies*, prepared by the National Productivity Council (1991) as part of this project. Readers desiring detailed information on the measures discussed here should refer to the full NPC report. In addition to drawing on information from the NPC report, we also draw from a recent study prepared for the Asian Development Bank on end-use efficiency in India (Dutt, 1991), and on a variety of other reports prepared in India and overseas.

**LIGHTING**

Lighting systems account for approximately 13% of total electricity consumption in India (see Chapter 2). In India, four different types of lighting systems are widely used -- incandescent, fluorescent, mercury vapor, and sodium vapor. Estimated lighting electricity use by sector and system type for 1989/90 is summarized in Table 3-1.

As can be seen in this table, over 80% of incandescent lighting energy use is in the domestic sector, over 90% of fluorescent energy use is in the industrial, commercial, and miscellaneous sectors, and over 60% of mercury and sodium vapor lamp energy use is in the industrial sector.

Table 3-1

Lighting Electricity Use by Sector and Lamp Type (TWh)

| Sector | Lighting System Type | | | | |
|---|---|---|---|---|---|
| | Incan-descent | Fluor-escent | Mercury Vapor | Sodium Vapor | Total |
| Domestic | 7.4 | 0.3 | 0.0 | 0.0 | 7.7 |
| Commercial & Misc. | 1.2 | 6.2 | 0.1 | 0.1 | 7.6 |
| Industrial | 0.3 | 6.5 | 1.2 | 0.8 | 8.8 |
| Public Lighting | 0.2 | 0.9 | 0.2 | 0.3 | 1.6 |
| Total | 9.1 | 13.9 | 1.5 | 1.2 | 25.7 |

Source: Table 2-6.

For our analysis of energy-saving opportunities, we examined six lighting conservation measures, including three directed at incandescent lamps, two directed at fluorescent lamps, and one directed at mercury vapor lamps. These measures are:

1. Replace incandescent lamps with fluorescent tube fixtures.
2. Replace incandescent lamps with circular fluorescent lamps.
3. Replace incandescent lamps with compact fluorescent lamps.
4. Replace "TL" fluorescent tubes with "TLD" fluorescent tubes.
5. Install electronic ballasts when conventional ballasts wear out.
6. Use high pressure sodium lamps and ballasts instead of mercury vapor lamps and ballasts.

We focus on these measures because they have the largest savings potential of the many different lighting efficiency measures which can be used in India. In addition to these measures, there are many other opportunities to reduce lighting energy use, including improved efficiency incandescent lamps, improved efficiency lighting fixtures, and lighting controls such as occupancy sensors and daylight dimming systems.[5] Each of the six featured lighting conservation opportunities are discussed following Table 3-1.

## Incandescent Lamp Replacements

A conventional Indian 60 Watt incandescent lamp (often called a "GLS" lamp, for General Lighting Service) puts out approximately 720 lumens of light, making for an efficiency of 12 lumens/watt (TERI, 1990). Fluorescent lamps are much more efficient, with efficiencies of 50-80 lumens per watt for products produced in India, and efficiencies as high as 90 lumens per watt for products produced in developed countries. In addition to efficiency advantages, fluorescent lamps generally have longer lives than incandescent lamps; the rated life of fluorescent lamps in India

[5] For information on some of these other measures in a developing country context, please see Geller, 1990.

is approximately 5000 hours, compared to 1000 hours for incandescent lamps. Furthermore, recent developments in phosphor technology allow fluorescent lamps to put out nearly the same color of light as an incandescent lamp, albeit at a cost premium. These phosphors are widely used overseas, but are not presently used in lamps produced in India.

For our analysis of fluorescent substitutes for incandescent lamps, we examined three measures -- new fluorescent fixtures, ballasted circular fluorescent lamps, and compact fluorescent lamps.

*New Fluorescent Fixtures*

The majority of incandescent fixtures in use in India in 2004/05 will be fixtures that have yet to be installed. In new applications, the most cost-effective alternative to the incandescent fixture is a fluorescent tube fixture. While the initial cost of a new fixture is high (typical cost of Rs. 160 for a fluorescent fixture; including fixture, ballast, starter, lamp, and installation, versus Rs. 30 for an incandescent fixture), operating costs are far lower and lamps need to be replaced less often. Compared to 60 Watt incandescent lamp, a 20 Watt fluorescent tube puts out approximately 40% more light. Relative to 75 and 100 Watt incandescent lamps the fluorescent lamp puts out 10% more and 25% less light respectively (TERI, 1990). If we use a 75 Watt incandescent as the basecase, switching to a 20 Watt fluorescent fixture saves 41 Watts (60 watts for the incandescent minus 20 watts for the fluorescent tube minus 14 watts for the fluorescent ballast). If we assume each lamp operates an average of 1700 hours per year (the energy-use weighted average for incandescent lamps across all sectors as shown in Appendix A), and estimate the peak coincidence factor for incandescent lighting across all sectors at 60%, the capital cost of a new fluorescent fixture is Rs. 2200/kW saved. Assuming a 15 year life for the fixture (and ignoring the fact that one fluorescent tube costs slightly less than five incandescent bulbs), the CSE is Rs. 0.19/kWh. We estimate that this measure is appropriate for most

new fixtures in India, representing approximately 50% of the incandescent fixture stock in 2004/05.

*Ballasted Circular Fluorescent Lamps*

Ballasted circular fluorescent lamps feature a fluorescent tube bent into a circle, with a fluorescent ballast incorporated into a adapter that inserts into a standard incandescent lamp socket. A 22 Watt ballasted circular fluorescent supplies over 800 lumens of light. Thus, substituting a 22 Watt fluorescent for a 60 Watt incandescent reduces electricity use by 63% (the 22 Watts includes the ballast), while increasing light output slightly. Circular fluorescents are lower in cost than compact fluorescent lamps (described below), but bulkier, which limits the number of fixtures they fit in. Circular fluorescents are reportedly now being imported into India. At current exchange rates ($1 = Rs. 26) the cost is approximately Rs. 150 including lamp, ballast, and base, but excluding taxes and duties (Sathaye, 1991). While these products are not presently produced in India, introducing production into India should not present any technical difficulties as the technology is similar to fluorescent tubes.

Ballasted circular fluorescent lamps are particularly appropriate as a retrofit replacement for incandescent lamps. In the U.S., ballasted circular fluorescent lamps have a rated life of 10,000 hours. If we assume a 7,000 hour life for India (due to the impact of voltage fluctuations) and 1,700 operating hours per year (the same as for the previous measure) then the average life will be four years. With this average life, a ballasted circular fluorescent lamp will replace nine standard incandescent lamps (750 hour typical life), which at Rs. 10 per incandescent lamp, results in a present value savings over four years of Rs. 75. Thus, the net cost of a ballasted circular fluorescent is only Rs. 75 (Rs. 150 initial cost minus Rs. 75 incandescent cost). If we estimate the same peak coincidence factor as above (60%), a ballasted circular fluorescent has a capital cost of about Rs. 3,700/kw. The CSE is Rs. 0.37/kWh. We previously indicated that 50% of

incandescent lamp applications are appropriate for new fluorescent tube fixtures. We estimate that an additional 15% of incandescent lamp energy use is appropriate for ballasted circular fluorescent lamps. The remaining applications cannot either accommodate the size of a circular fluorescent or operating hours are insufficient (significantly lower than the 1700 hours/year assumed here) for the circular fluorescent to be cost-effective).

*Compact Fluorescent Lamps*

Compact fluorescent lamps are more efficient and smaller in size than circular fluorescent lamps, but also more expensive. A 16 Watt compact fluorescent lamp (including ballast) puts out about the same amount of light as a standard 60 Watt incandescent lamp, representing an energy savings of nearly 75% over the incandescent lamp. Compact fluorescent lamps can come with adaptors which fit into incandescent lamp sockets, or they can plug into fixtures designed for use with compact fluorescent lamps. Due to their small size, compact fluorescents can be fit into many (though not all) fixtures designed for incandescent lamps. Compact fluorescent lamps are not presently produced in India, although several manufacturers are reportedly considering opening up production lines in India. In the meantime, compact fluorescents are imported into India in small quantities, and proposals for increased imports have been submitted by several companies (Mamak, 1990). We estimate that compact fluorescent lamps would primarily be used in the residential sector, although they will also be appropriate for some applications in the commercial and industrial sectors.

A study by Lawrence Berkeley Laboratory (Gadgil and Jannuzzi, 1989) estimated that compact fluorescents could be imported to India at a cost of Rs. 135, exclusive of taxes and duties. If we adjust this cost for the difference in exchange rate since the study was done (an increase from Rs. 15/U.S. $ to Rs. 26/U.S. $), then the cost of a compact fluorescent is Rs. 235. This price is also in line with a Rs. 200 price quoted in a 1990 study (TERI, 1990). As with the ballasted circular fluorescent lamp, a compact fluorescent

can be expected to last 7,000 hours in India (Mamak, 1990) and displace nine regular incandescent bulbs. Subtracting the present value cost of nine incandescent lamps over four years (assuming 1,700 average operating hours per year), the net cost of the compact fluorescent is Rs. 160 and the capital cost works out to Rs. 6,800/kW saved. The CSE is Rs. 0.67/kWh.

Compact fluorescents are more costly per kWh saved than new fluorescent fixtures or circular fluorescent lamps. Thus compact fluorescents will be limited to incandescent applications for which these other products are not suitable. Since compact fluorescents are smaller than the other fluorescents, they can be used in more applications, although even compact fluorescents are too big for all applications. Furthermore, some applications have very low operating hours, for which compact fluorescents will not be cost-effective. With these factors in mind, we estimate that compact fluorescents are appropriate (technically viable and cost-effective) for 15% of incandescent lamp applications. This is in addition to the applications for which new fluorescent fixtures and circular fluorescent lamps are most appropriate.

## Improving Fluorescent Lamp Efficiency

In India, the most common fluorescent lighting system is a 40 Watt fluorescent tube plus a 12-15 Watt magnetic ballast. 40 Watt fluorescent tubes are standard throughout the world. Magnetic ballasts are also common, although in other countries a ballast to control one 40 Watt lamp typically consumes about 8 Watts (Philips Lighting, 1988). The reason for the higher consumption in Indian ballasts vary from product to product, and may include use of aluminum wire (aluminum wire is a less efficient conductor of electricity than copper), poor quality lamination materials, and poor stamping of laminations. In addition to low efficiency, most Indian ballasts suffer from another problem -- low power factor. The power factor of a typical Indian ballast is .5 to .6 (TERI, 1990). The lower the power factor, the higher the losses in distribution circuits, including those on the utility grid and

those within customer facilities. Most of the losses occur on the utility side of the meter, and thus low power factor presents a major burden to utilities, but is usually of limited consequence to end-users.

For our analysis of efficiency improvements to fluorescent lighting systems, we examined two measures -- "TLD" lamps and electronic ballasts. These measures apply to all of the fluorescent lamp energy use reported in Chapter 2, and also to the new fluorescent tube fixtures discussed above.

*"TLD" Lamps*

The standard "TL" fluorescent tube used in India uses 40 Watts of power. Tubes half this length use 20 Watts. For the past few years, several Indian manufacturers (Philips, Laxman, and Prakash) have made "TLD" lamps which use only 36 Watts (18 Watts for the shorter tubes), yet provide the same light output. The TLD lamps are thinner than the TL lamps. The major disadvantage of the TLD lamp is that it will extinguish when voltage drops to 155-165 volts, whereas TL lamps will not extinguish until voltage drops to 130 volts (Mamak, 1990). Philips reports that 40% of their fluorescent lamp sales are TLD lamps (Mamak, 1990), although another recent analysis estimated that only 12% of All-India fluorescent lamp sales are TLD lamps (TERI, 1990). In Western Europe, TLD lamps dominate fluorescent lamp sales, and TLD lamps are increasingly being used in developing countries. For example, by the end of 1991, fluorescent lamp manufacturers in Egypt plan to produce only TLD lamps (Turiel et al., 1990). In discussions around India, some lighting industry officials reported that TLD lamps are actually less expensive than TL lamps (because they use less materials), while others claimed that TLD lamps cost slightly more. For our analysis, we assumed TLD lamps cost the same as TL lamps, and therefore the cost per kW and the CSE are zero. Over the long-run, as voltage variability problems are solved, this measure should be appropriate for all fluorescent lamp applications.

*Electronic Ballasts*

Electronic ballasts use power electronics, instead of an electromagnet, to regulate power supply to the fluorescent lamps, thereby eliminating power losses at the magnet. A typical electronic ballast draws only 1-3 Watts, representing an 85% saving compared to 14 Watt conventional ballasts (the power used by the lamps is not affected). In addition, many electronic ballasts have a high power factor (greater than 0.9), although we could not obtain sufficient data to estimate the amount of energy that would be saved from the improved power factor.

Several small manufacturers produce electronic ballasts in India, although these products reportedly suffer from quality control problems which can dramatically shorten their life. HMT, a major lamp producer, has recently applied to the Government of India for permission to produce an electronic ballast. This ballast will reportedly have a life of 15-20 years (HMT, 1991). Electronic ballasts in India range in cost from approximately Rs. 200 to Rs. 300, substantially more than the Rs. 60 cost of a conventional ballast (NPC, 1991; TERI, 1990). If we assume an incremental cost for an electronic ballast of Rs. 190, and further estimate a peak coincidence factor of 60%, the capital cost of upgrading from a standard to an electronic ballast at the time of ballast replacement is Rs. 11,200/kW saved. Assuming a 15 year ballast life (based on the HMT estimate reported above), the CSE is Rs. 0.47/kWh.

Over the long-run, as the quality of Indian electronic ballasts improves, and as existing ballasts need replacement, this measure should be appropriate for nearly all fluorescent fixtures in India. Since not all ballasts will be replaced between the time when electronic ballasts are widely available in India, and 2004/04, we estimate that electronic ballasts will be technically and economically feasible for 75% of applications in 2004/05.

## Improving Mercury Vapor Lamp Efficiency

Mercury vapor lamps are less efficient than other types of high intensity discharge lamps such as sodium vapor lamps. For example, a 250-watt mercury vapor lamp produced in India puts out approximately 13,000 lumens of light. This is approximately half the light output of an Indian 250-watt high-pressure sodium lamp (TERI, 1990). In most applications, mercury vapor lamps can be replaced with high pressure sodium lamps, resulting in an energy savings of approximately 40% (for example, a 150-watt high-pressure sodium lamp can be substituted for a 250-watt mercury lamp, with a modest increase in light output). Even greater savings are possible through the use of low-pressure sodium lamps, although these lamps provide an extremely yellow light which is not suitable for many applications.

High-pressure sodium lamps are produced by several Indian manufacturers. These lamps require a high-pressure sodium ballast that is also produced in India.[6] The cost of a new 150 Watt high pressure sodium lamp and ballast in India is approximately Rs. 1480, Rs. 515 more than a mercury lamp and ballast (NPC, 1991). If we estimate ballast life at 10 years and the peak coincidence factor for mercury vapor lamps to be 70% (they are extensively used for exterior lighting), the capital cost of a high pressure sodium lamp and ballast installation is Rs. 3,800/kW saved. The CSE is Rs. 0.20/kWh. These figures are conservative because they assume that lamp replacement costs are the same for both sodium and mercury. In actuality, sodium lamps should have lower replacement costs because they have a rated life three times longer than mercury lamps produced in India (15,000 hours versus 5,000 hours -- TERI, 1990), which more than compensates for the 2.2 times higher cost of replacement sodium lamps (NPC, 1991).

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[6] High pressure sodium lamps designed to run on mercury vapor ballasts are produced abroad, but these provide less than half the savings of a high pressure sodium lamp/ballast combination.

Over the long-run, this measure should be appropriate for nearly all applications of mercury-vapor lamps in India. Initially, high-pressure sodium lamps could not be used in all applications due to poor color rendering. However, in recent years high color rendering sodium lamps were introduced into India, and thus this obstacle no longer remains.

## INDUSTRIAL SECTOR

### Motors

Industrial motors account for approximately 38% of total electricity consumption in India (see Chapter 2). Electric motors are used to power many different types of equipment including fans, pumps, air compressors, refrigeration compressors, and production machinery. For our analysis of opportunities to reduce motor energy use, we examined eight different measures. These measures do not capture all motor system efficiency opportunities, but they represent a good start. The eight measures are:

1. Improved motor rewinding, sizing, and maintenance
2. High-efficiency motors
3. Two-speed motors
4. Variable-speed drives
5. Optimize industrial pumps
6. Optimize industrial fans
7. Air compressor operation and maintenance improvements
8. Centrifugal refrigeration compressors

*Improved Motor Rewinding, Sizing, and Maintenance*

In India, as well as other countries, motor efficiency in the field is often lower than the tested efficiency of a new motor in the laboratory. Reasons for the difference are many and include oversizing of motors, phase-imbalance, poor rewinding of motors (replacement of the wire windings on a motor when the original

windings wear-out),[7] and less than adequate motor maintenance. For example, a recent study on motors in the U.S. estimated that total motor energy use could be reduced by 5-12% by correcting for these problems (Nadel et al., 1991).

In India, a field survey conducted by TERI (1988) found that the efficiency of motors in the field ranged from 4-13% lower than manufacturer ratings for new motors. The discrepancy was highest for small motors and lowest for large motors. For a typical mid-size motor (20 hp), the motor in the field consumed 7% more power than its rating when new. Several other estimates have also been made of the energy savings available in India from improved motor rewinding, sizing, and maintenance. NPC (1991) estimates that motor energy use on average can be reduced by 2-3% due to improved repair and rewinding practices, plus some additional savings that are possible from proper motor sizing. Savings of 16% have been estimated by Ashok Gadgil at Lawrence Berkeley Laboratory for a combination of measures including improved motor sizing, power factor correction, correcting core damage from improper rewinds, phase balancing, maintenance measures, and use of high efficiency motors (Dutt, 1991). Since high-efficiency motors save approximately 2-5% (discussed below), Gadgil estimates that the remaining measures will save 12-13% or so.

For our analysis we use a typical 20-hp motor with an efficiency, when operating properly, of 88.5%. Due to problems with sizing, maintenance, phase balance, and rewinding, we estimate the motor uses 7% more energy than its rated efficiency would indicate. The 7% figure comes from the TERI study noted above and is slightly lower than the midpoint of the range estimated above for both India and the U.S. If we estimate that the typical motor operates for

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[7] During the rewinding process the motor is heated in order to loosen the "glue" that helps hold the windings in place. Research in the U.S. has found that whenever the core of the motor is heated above 260-340 degrees Celsius, damage occurs which can reduce the efficiency of the motor by approximately 2% (Nadel et al., 1991). In India, motors are commonly heated in open fires, where high temperatures, and core damage are likely.

2,500 full-load hours/year (from Appendix A), and operates, on average, at 60% of full load, then 4,200 part-load hours can be inferred.

The incremental cost of these measures, relative to standard practices, are usually very low (Nadel et al., 1991; Dutt, 1991). If we estimate that these measures on average have a simple payback of one year (the incremental cost of the measure is equal to the value of one year of kWh savings at Rs. 1/kWh), and that the average life of these measures is five years, the capital cost of these measures is Rs. 7,400/kW, and the CSE is Rs. 0.25/kWh. Based on the U.S. experience, and our observations in India, we estimate these measures are applicable to 80% of the Indian motor stock.

High-Efficiency Motors

The efficiency of motors produced in India varies somewhat from manufacturer to manufacturer. In particular, some of the small-scale manufacturers who make only small motors produce motors with lower efficiencies than manufacturers in the organized sector. In addition, several manufacturers (Siemens, Crompton Greaves, Kirloskar, and Jyoti) produce two lines of motors -- a standard-efficiency line and a high-efficiency line. Data on motor efficiencies in India are summarized in Table 3-2. Data for motors produced in the U.S. are also shown for comparison.[8] As can be seen in this table, high-efficiency motors produced in India are from 2-5% more efficient than standard-efficiency motors. Standard-efficiency motors produced in the organized sector in India appear to be of comparable efficiencies to U.S. standard motors. High-efficiency motors produced in India are approximately 0.5 efficiency point less efficient than their U.S. counterparts due to the use of better-quality steel in the U.S. high-efficiency motors.

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[8] It appears that the same testing procedures are used in India and the U.S., both based on IEEE Standard 112- Method B. Thus, efficiency data should be comparable.

Table 3-2

Efficiencies of Indian and U.S.
Standard and High Efficiency Motors

| Motor Size (hp) | Indian Motors | | U.S. Motors | |
|---|---|---|---|---|
| | Standard | High Effic. | Standard | High Effic. |
| 1 | 71-73 | | 76.8 | 84.0 |
| 1.5 | 74-75 | | | |
| 2 | 76 | | 81.1 | 85.3 |
| 3 | 79 | | 81.4 | 88.8 |
| 4 | 80 | | | |
| 5 | 81.5-85 | | 83.9 | 89.0 |
| 7.5 | 84-87 | | 84.7 | 90.8 |
| 10 | 85-87 | 90.5 | 86.4 | 91.0 |
| 12.5 | 86-88 | 90.5-91.0 | | |
| 15 | 87-89.5 | 91 | 87.1 | 92.0 |
| 20 | 87-89.5 | 92 | 88.3 | 92.7 |
| 25 | 90-90.5 | | 89.7 | 92.9 |
| 30 | 90-91 | | 90.4 | 93.2 |
| 40 | 90.5-92 | | 90.6 | 93.6 |
| 50 | 90-92.5 | 93.5 | 91.5 | 93.8 |
| 60 | 91-93 | 94.0 | 91.8 | 94.4 |
| 75 | 91.5-93.5 | 94.5 | 92.1 | 94.6 |
| 100 | 92-94 | 94.5 | 91.9 | 95.0 |
| 120 | 92.5-94.5 | 95.0 | | |
| 125 | | | 92.1 | 95.1 |
| 150 | 92.5-94.5 | 95.0 | 93.1 | 95.4 |
| 170 | 92.5-93.5 | 95.2 | | |
| 200 | | | 94.0 | 95.6 |
| 220 | 93-95.5 | | | |
| 250 | | | 94.3 | 95.6 |
| 270 | 95-95.5 | | | |

Note: All data are for (three-phase, four pole) totally enclosed, fan-cooled motors.

Sources:
* Indian data from NPC, 1991. Only companies in the organized sector are included.
* U.S. data from Nadel et. al., 1991. This is an average for eight different manufacturers.

Use of high-efficiency motors in India can reduce motor electricity use by 2-5%. Examination of the U.S. data for motors less than 10 hp shows that even greater savings are possible in small motors (Indian manufacturers do not produce high-efficiency small motors, due to expectations of limited purchaser demand). Indian manufacturers have produced high efficiency motors for only a few years. Discussions with manufacturers indicate that high efficiency motors probably account for less than 1% of motor sales in India today.

A primary reason for the low sales of high-efficiency motors is that they cost more than standard efficiency motors -- Indian manufacturers estimate that high efficiency motors cost 25-35% more than standard-efficiency motors (NPC, 1991). Part of the increased cost is import duties on low-loss silicon steel which is used in the cores of high efficiency motors. A standard 20-hp motor (efficiency of 88.5%) costs approximately Rs. 18,600 (including excise duty and typical discounts), a high-efficiency motor (92% efficient) costs about 30% more -- Rs. 24,200. The incremental price of the high-efficiency motor is thus Rs. 5,600. Using these assumptions, plus assumptions on the operating hour and percent of full load made for the previous measure, the incremental capital cost of a high-efficiency motor is Rs. 8,400/kW saved (assuming a 60% coincidence factor). If the motor has an average life of 30 years, the CSE is Rs. 0.25/kWh.

High-efficiency motors are not appropriate for all applications. For some specialized applications, high-efficiency motors are not commonly made. For applications with very limited operating hours, high-efficiency motors may not be cost-effective. Also, for some applications, multi-speed motors are more appropriate. Furthermore, high-efficiency motors primarily make sense when an existing motor wears out and must be replaced. Some existing motors will remain in place beyond 2004/05. With these factors in mind, we estimate that over the next 15 years, high efficiency motors will be technically feasible and cost-effective for approximately 55% of motor applications, including a much higher

proportion of new applications, and a lower proportion of existing applications.

*Motor Speed Control*

Motor efficiency is generally highest when motors operate within about 50% of their rated load. However for many applications, the load placed on a motor varies over time. For example, a motor in a commercial cooling system generally operates at full-load during the hottest days of the year, but at other times, the load placed on the motor is significantly lower, varying with the outdoor temperature and humidity. In addition, for some applications, such as fans and pumps, the load varies with the cube ($V^3$) of the air or water velocity. Thus, when the velocity is reduced by 20%, the load on the motor is reduced by 50%. For applications where the load varies with time, some means of speed control is usually employed. Traditionally speed is controlled with fluid couplings, eddy-current couplings, throttles, and guide vanes, but these controls are inefficient because speed is varied by introducing friction, thereby wasting energy. A far more efficient way to vary speed is at the motor itself, either through use of a multi-speed motor, or with a variable-speed drive.

*Multi-Speed Motors*: Multi-speed motors generally contain two (or more) sets of windings, which allow the motor to operate at two (or more) different speeds. Use of a multi-speed motor allows gross changes in motor speed to take place at the motor, with fine tuning left to traditional speed-control devices such as guide vanes. Multi-speed motors provide a fairly low-cost approach to motor speed control. In India two-speed (and even three-speed) motors are produced by several manufacturers. These motors typically cost from 30-80% more than a similar-sized single-speed motor. Savings vary depending on the application but savings of 8-10% are typical (NPC, 1991). For a typical application involving a 30 hp motor, incremental capital costs relative to a single-speed motor are approximately Rs. 9,700/kW, and the CSE is Rs. 0.29. These calculations, which are relative to a 90%-efficient single-speed

motor, assume 9% savings and a Rs. 20,850 incremental cost (55% more than a single-speed motor of the same size). Other assumptions are the same as those made above for high efficiency motors.

Multi-speed motors are not appropriate for all motor applications. First, not all applications need variable speed. Second, multi-speed motors are typically larger than one-speed motors, so physical space limitations may apply.[9] Third, for some applications, variable speed drives (VSDs -- discussed below) offer additional cost-effective savings, and thus are technically preferable. With these factors in mind, we estimate that motors accounting for approximately 25% of motor energy use can benefit from multi-speed motors.

*Variable Speed Drives*: Variable speed drives (VSDs) are electronic devices that are placed between the motor and the power supply. VSDs can continuously vary the speed of a motor from 100% down to very low speeds. In many applications they provide significantly higher savings than multi-speed motors (for example, one study in the U.S. estimated average savings in appropriate applications to be 22.5% (Miller et al., 1989)). In addition to energy savings, VSDs offer a number of other advantages including improved equipment lifetimes (due to the soft-start capability incorporated into many VSDs), better process control and product quality, isolation of motors from the power line (providing limited protection from power failure and line voltage problems), and operation at higher speeds than standard line frequencies allow (Baldwin, 1989).

Variable-speed drives are manufactured by six companies in India -- BHEL, NELCO, Siemens, Hirel, Asea, and Larsen & Toubro. These

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[9] In the U.S. and other developed countries, a special type of two-speed motor is produced called a pole-amplitude-modulation (PAM) motor. PAM motors are approximately the same size as single-speed motors and cost about the same as conventional two-speed motors (Nadel et al., 1991).

companies generally import electronic components into India, and then assemble them into a drive. VSDs are presently fairly expensive in India, and as a consequence are primarily used with large motors. VSD costs in India range from Rs. 2,500-10,000/kW in the 10-400 kW range, and for slip power recovery systems with ratings above 1,000 kW, costs range from Rs. 1,200-1,500/kW (NPC, 1991).

For illustrative purposes, we examine a 250-hp VSD (186 kW) operating 5,000 hours each year. A high-efficiency motor is assumed (95% efficiency). At a VSD cost of Rs. 5,000/kW, and a peak coincidence factor of 60%, the capital cost is Rs. 17,200/kW saved, assuming the 22.5% typical savings noted previously. Assuming a ten-year life for the VSD (common for electronics of this type), the CSE is Rs. 0.62/kWh. Prices have been steadily dropping in the U.S. (Nadel et. al., 1991), and further price reductions are likely.

We estimate that VSDs are appropriate for motors representing approximately 30% of Indian motor use. This figure is in addition to the 25% of applications for which we estimate two-speed motors are appropriate.

*Optimize Industrial Pumps*

As noted in chapter 2, an estimated 20% of industrial motor energy use is for pumps. Other estimates place the proportion as high as 40% (NPC, 1991). In addition to industrial pumps, water supply and sewage disposal plants, and auxiliaries in power plants are other major pump applications (irrigation pumps in the agriculture sector are discussed later). There are a number of opportunities to improve the efficiency of pump systems, including use of high efficiency pumps, minimizing friction losses in the piping network, and derating/replacement of oversized pumps. Analysis by NPC (1991) indicates that except for the small-scale sector, pump efficiencies have increased by 5-10% in recent years. Thus, as existing pumps are replaced, efficiencies should increase.

According to the NPC analysis, high-efficiency pumps often cost the same as less efficient pumps, and if there is a cost premium, it is modest (on the order of 5-10%). Much larger savings are available on average by minimizing piping-friction losses. NPC estimates a potential for average savings of 15-20%, and provides an example of a typical application with a simple payback of less than three years (NPC, 1991). The NPC analysis also estimates that savings of 5-10% are generally possible by derating or replacing oversized pumps.

Combining this entire package of measures, we conservatively estimate that 70% of industrial pump systems in India can benefit from cost-effective efficiency improvements and that average savings in these systems will total 15%, with an average simple payback of three years. Applying these assumptions to a typical 20-hp pump operating at an average of 60% of full-load for 4,200 hours/year, and further assuming a 60% peak coincidence factor and a 70% basecase pump efficiency (which incorporates the motor efficiency improvements discussed above), we calculate a capital cost of Rs. 11,200/kW saved. Assuming a pump life of 20 years yields a CSE of Rs. 0.38.

*Optimize Industrial Fans*

As noted in Chapter 2, fans and blowers account for over 10% of industrial motor use. As with pumps, there are many opportunities to improve the efficiency of fan systems including high-efficiency fans, replacement of oversized impellers and fans, and reduction of friction losses. NPC (1991) explores these opportunities in-depth. Their analysis indicates that even greater efficiency improvements are possible in fan systems than in pump systems, because in addition to savings from reduced friction losses, and derating/replacement of oversized fans, substantial efficiency improvements are possible from high efficiency backward-curved fan systems (10% savings typical when replacing radial fans, 20% savings when replacing forward-curved fans). If, for illustrative purposes, we assume 20% savings are possible in 70% of

applications, with all other assumptions the same as discussed above under pumps,[10] the capital cost of the efficiency improvements is Rs. 12,200/kW saved, and the CSE is Rs. 0.41/kWh.

*Air Compressor Operations and Maintenance Improvements*

Many factories have compressed air systems that provide air for cleaning and industrial process applications. Compressors are typically located at central locations and supply lines carry the compressed air throughout the plant. Compressed air systems are notorious for air leakage, leading to energy waste. In addition, some systems operate at higher pressures than needed, and maintenance of compressor systems is often less than adequate (for example, air filters are not cleaned). Furthermore, some compressors are oversized, or are inefficient. NPC (1991) found that energy savings of 20-40% are possible at low cost. Assuming 30% energy savings, a one-year simple payback period, an average measure life of five years, and the basic operating assumptions made above for pumps and fans, the cost per kW is Rs. 7,300/kW and the CSE is Rs. 0.26. We estimate that these measures are applicable to compressors representing 75% of compressor electricity use in India. Additional savings are possible from improved compressor controls, and from use of staged compressors in a facility.[11] We did not conduct a detailed analysis of these measures.

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[10] The assumption of a three-year average simple payback period for fan efficiency measures is probably conservative, as NPC's analysis shows many measures with simple paybacks of approximately one year. Only in the case of measures to reduce friction losses in ducts are longer simple payback periods common.

[11] With staged compressors, when air requirements are low, a small compressor is used; when requirements increase, a medium-sized compressor is used; and when requirements are large, both compressors are used together. Such a system allows better matching of compressor power to the load, thereby avoiding part-load operation of compressors (as discussed previously, part-load operation can result in considerable energy waste).

## Centrifugal and Screw Refrigeration Compressors

Refrigeration compressors are used extensively in industry to preserve food and for other processes requiring cold temperatures. Most compressors in India are reciprocating compressors. A typical new reciprocating compressor in India has an efficiency of 1.05-1.10 kW/ton of refrigeration. Centrifugal compressors have much better efficiencies. For example, one Indian company, in cooperation with a Japanese manufacturer, is selling centrifugal chillers with efficiencies of 0.60-0.74 kW/ton (NPC, 1991). A third type of compressor -- the screw compressor -- is also available. While not quite as efficient as the centrifugal compressor, these units are available in smaller sizes than centrifugal compressors, allowing more applications to be served. In the U.S., 100-ton screw compressors with efficiencies as low as 0.66 kW/ton are available (Block, 1991).

For a typical 200-ton compressor, an efficiency improvement from 1.05 kW/ton to 0.70 kW/ton can be expected by switching from a reciprocating to a centrifugal or screw compressor. A centrifugal compressor of this size will cost approximately Rs. 400,000 more than a reciprocating chiller (NPC, 1991). Assuming load and coincidence factors of 70%, and a measure life of 20 years, the capital cost is Rs. 3,200/kW and the CSE is Rs. 0.09/kWh.

This measure is not appropriate for all compressors -- some compressors are large enough that use of centrifugal chillers is common. Other compressors are too small for even a screw compressor to serve the load. With these factors in mind, we estimate that this measure is appropriate for 35% of industrial refrigeration loads in India.

Additional savings are available from use of improved efficiency compressors in applications for which a change in compressor type is not possible or justified. We did not examine the costs and savings of these improvements.

## Electric Arc Furnaces

Electric arc furnaces are used to manufacture specialty steels and to manufacture steel from scrap metal. Electric arc furnaces account for nearly 3% of industrial electricity use in India and approximately 1.4% of total electricity use in India (see Chapter 2). Electric arc furnaces are employed both in mini-steel plants located throughout India that rely almost exclusively on electric arc furnaces, and in foundry plants which use electric arc furnaces alongside more traditional steelmaking processes.

Electricity costs are one of the major costs of operating an electric arc furnace, so users are conscious of the need for energy conservation. Many conservation measures are in widespread use in India today including scrap segregation, improved melt-down practices, and standardization of tapping temperature (NPC, 1991).

Still, many additional techniques are available to improve electric arc furnace efficiency, techniques which are not widely used in India. NPC, in its companion to this report (NPC, 1991), examined eleven different measures to improve the efficiency of electric arc furnaces in India. NPC's findings are summarized in Table 3-3.

By way of reference, electric arc furnaces consume 600-900 kWh/ton of product. Thus, if all the measures listed in Table 3-3 are implemented, electricity savings of over 50% could result. However, not all measures will be suitable for all furnaces. Therefore, for our analysis, we assume an average savings of 30% at a cost of Rs. 5 million for a 10 ton furnace. We estimate these savings can be achieved in 60% of the electric arc furnaces in India. Other key assumptions needed for our analysis include an assumed energy consumption of 800 kWh/ton, an average "tap time" (time for each batch of steel) of 200 minutes, and an assumed annual operating hours of 4,000 hours for each furnace (these figures are based on data reported in NPC, 1991). Finally, we estimate that 50% of electric arc furnaces are on at the time of

Table 3-3
Measures to Improve Electric Arc Furnace Efficiency in India

| Saving Measure | (kWh/ton) | Approx. Cost ($10^6$ Rs) | Notes |
|---|---|---|---|
| Oxygen assisted melting | up to 75 | 1.0-2.0 | |
| Oxyfuel burner | up to 50 | 1.0 | Needs water cooled panels & computer controls for best results |
| Scrap preheating | 30-40 | 6.0 | Best suited for a shop with more than one furnace as cost can be spread among several furnaces |
| Use burnt lime | 70-100 | NA | Needs installation of a lime kiln or purchase of burnt lime. Some energy is consumed in the process to make burnt lime. |
| Power factor correction & control | NA | NA | |
| Ladle furnace | 10-15 | 4 | Also improves product quality and productivity. Cost given here is for a new ladle furnace. The difference in price between a new electric arc furnace and a new ladle furnace is much lower. |
| Eccentric bottom tapping | 10-15 | NA | |
| Foaming slag practices | up to 40 | NA | |
| Computerized control & automation | up to 50 | NA | |

Notes: Costs are for a 10-15 ton electric arc furnace.
NA = not available.

Source: NPC, 1991.

system peak -- either on the grid or on auxilary generation equipment. Based on these assumptions, the capital cost of these improvements is 3,400/kW saved and the CSE Rs. 0.13/kWh.

**Chlor-Alkali Processes**

The chlor-alkali industry uses electrolysis to produce chlorine and related products from brine (saltwater) solutions. In India, the chlor-alkali industry accounts for approximately 3% of industrial electricity use and 1.5% of total electricity use (see Chapter 2).

Three basic processes are used throughout the world to produce chlorine -- the mercury amalgam process, the diaphragm process, and the membrane process. In India, approximately 90% of chlor-alkali production is with the mercury process, 7% with the diaphragm process, and 3% with the membrane process. In India, the mercury process uses the most electricity (nearly 3400 kWh/ton produced, including auxilaries) and the diaphragm process uses slightly less electricity (approximately 3000 kWh/ton). The membrane process is the most efficient (electricity use as low as 2500 kWh/ton), but has higher capital costs than the other processes. In addition to electricity, all three processes require some fuel; the diaphragm process uses the most fuel, the mercury process the least fuel (NPC, 1989). Several other considerations also affect the selection of the best process including environmental and health concerns and foreign-currency concerns. Mercury is highly toxic and the use of mercury cells has been banned in several countries (Streicher and Geller, 1990). The mercury process requires extensive imports of mercury, a drain on India's foreign currency reserves (Raghuraman, 1989).

Considering all of these factors, conversion of mercury and diaphragm cells to the membrane process is a viable option. Relative to the mercury process, the membrane process saves approximately 880 kWh/ton and reduces environmental, health and foreign currency concerns, but requires slightly more fuel. Relative to the diaphragm process, the membrane process saves

approximately 500 kWh/ton, and reduces fuel consumption. In addition, relative to both the mercury and diaphragm processes, the membrane process improves product quality, reduces consumption of chemicals, and improves plant operations through benefits such as fast restarting after power interruptions and stable caustic concentrations after power fluctuations (NPC, 1991).

Since India currently has a very large chlor-alkali capacity, including substantial excess capacity (NPC, 1991), our analysis emphasizes the conversion of existing chlor-alkali plants to the membrane process. For our analysis, we assume that a baseline 100 ton per day (TPD) plant consuming 3300 kWh/ton is replaced with a membrane plant consuming 2500 kWh/ton at a capital cost of Rs. 2.5 million/TPD (NPC, 1991). Since existing plants are likely to require extensive improvements in order to remain operational in 2004/05, we assume a net cost of Rs. 2.0 million/TPD. The plant operates for 7200 hours/year (NPC, 1989) and this use is spread evenly throughout the day and year. Capital cost per kW saved is Rs. 12,500, and the CSE Rs. 0.32/kWh. This measure is appropriate for nearly all existing chlor-alkali capacity -- we estimate a 95% applicability factor.

## Aluminum Smelting

Aluminum production is very energy intensive -- energy costs account for 40-45% of the costs of manufacture. India today has seven smelters located in five different plants -- two in the public sector and three in the private sector. With the exception of the National Aluminum Company (NALCo), set up in 1987-88, the other units have old smelters with technology and energy consumption inferior to other current technology. Estimates of the average energy consumption of Indian aluminum plants range from 14,000 to 18,000 kWh/metric tonne, with the most-likely figure approximately 16,000 kWh/tonne. The NALCo plant uses 12,800 kWh/tonne -- approximately 20% less than the Indian average (Raghuraman, 1989).

In the low-case scenario discussed in Chapter 2, electricity use for aluminum production is projected to increase by 70%. If we assume this increase will all be due to new plants, and we further assume that 50% of current production capacity (much of the portion not served by NALCo) also needs replacement by 2004/05, then 85% of the production capacity in place in 2004/05 will be in new plants. Based on the NALCo experience, we assume an average savings of 20% relative to the norm of 16,000 kWh/tonne. In the absence of good data, we estimate a five-year average payback, at an electricity price of Rs. 1/kWh. This is the same assumption made by Geller (1991) in his analysis of conservation opportunities in Brazil. If we assume a 80% load and peak coincidence factor, the capital cost is Rs. 17,600/kW saved, and the CSE is Rs. 0.46/kWh.

## AGRICULTURAL SECTOR

### Pumps

In the past ten years, electricity use for irrigation pumps has grown by over 13% per year. Pumpsets now represent over 20% of electricity use in India. While many pumpsets are very wasteful users of electricity, there is much that can be done to improve their efficiency. In this report, we analyze three efficiency measures:

1. Metering of agricultural pumps
2. Rectification of existing agricultural pumps
3. New high efficiency pumpsets

In addition to these measures, we briefly discuss one other measure -- use of diesel pumpsets.

### Pump Metering

Presently in India agricultural pumpsets are not metered --users pay a set fee based on pump size, regardless of how many hours the pump operates. Needless to say, such a system provides no incentive to limit pump operating hours nor to improve pump

efficiency, and as a result, reports from the field indicate that considerable energy and water waste results. If pump electrical use were metered, and customers billed on the basis of their kWh use, considerable savings would likely take place.[12]

For our analysis, we assume that installing meters would reduce electricity use by 5%. This figure is based on estimates provided by Indian experts. This estimate is much lower than the approximately 15% savings achieved in the U.S. when rental housing tenants are billed for their electricity use (prior to meter installation, a set charge for electricity was included in the rent, regardless of actual electricity use) (Rosenberg, 1984; NYPSC, 1989).

For our analysis, a few other assumptions are needed. Cost of the three-phase meters is estimated to be Rs. 250, based on information provided by BHEL, a meter manufacturer. These costs are increased to Rs. 400 to allow for labor costs associated with installation. The typical motor is assumed to be a 4-kW motor operating 1,000 full-load hours/year, with a peak load coincidence factor of 16% (these assumptions are documented by NPC (1991) based on a review of the literature). Based on these assumptions, the capital cost of agricultural metering is Rs. 4,700/kW saved. If we assume a 20 year meter life, the CSE is Rs. 0.18. These costs are based only on initial costs, and do not include the cost of periodic meter readings. Meter reading costs will raise the cost per kWh

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[12] Agricultural electricity prices in India are highly subsidized, with an average cost per kWh in 1987/88 of Rs. 0.15/kWh (TERI, 1989). A number of observers have suggested that if agricultural electricity were priced at the cost of service (greater than Rs. 1/kWh), substantial electricity conservation would result. However, ending agricultural subsidies is a highly charged political issue, and is unlikely to happen in the near future. Our proposal is based on keeping the average electricity price at or near current levels, but charging customers for each kWh they use. Once meters are installed, additional pricing strategies could be tried. For example, an increasing block rate could be used under which small users of electricity (primarily small farmers) pay a low charge per kWh, and larger users of electricity pay higher charges.

somewhat, but given the very low capital costs involved, even if our estimate of costs is off by a factor of four, installing agricultural meters is likely to be cost-effective to utilities. This measure is appropriate for all agricultural pumps.

**Rectification of Existing Agricultural Pumps**

The typical pumpset features an inefficient pump, linked with a belt to a motor, and foot valves and return and supply pipes with high friction losses. As a result of path-breaking research in Gujarat, a standard package of retrofit measures for existing pumps has been developed including replacement of the existing foot valve, return, and supply lines with low friction equivalents (for example, PVC pipe is used for the return and supply lines), and replacement of the existing pump and motor with a new monoblock pumpset (pump and motor are a single unit). This retrofit package reduces electricity use by 30-50%, at a cost of approximately Rs. 9,000 (NPC, 1991). In assessing this measure we assume that meters are in place, and hence operation is reduced to 950 full-load hours per year. If we assume the same typical pump size and peak coincidence factor as for the analysis of metering, and estimate a 15-year average pump life, the cost per kW saved is Rs. 18,900 (based on 35% savings). The CSE is Rs. 0.77/kWh. As pumpsize increases, the cost-effectiveness of this package increases dramatically. For example, Dutt (1991) calculates a CSE of Rs. 0.20/kWh for the same package, assuming an average pump electricity use approximately five times greater than is assumed here.

Most of the cost of this retrofit package is for the new pumpset. If only the foot valve and return and supply pipes are replaced, the cost drops to approximately Rs. 1,150, with typical savings of 18-27% (NPC, 1991). Assuming the midpoint of this savings range, the capital cost of this package is approximately Rs. 4,900 per kW saved, and the CSE Rs. 0.20.

We estimate that this package of retrofits is appropriate for approximately 30% of pumpsets that will be in place by 2004/05.

Most of the remaining pumpsets will be new units for which the next efficiency measure is most appropriate.

**New High-Efficiency Pumpsets**

If agricultural electricity use grows by 80% during the 1989/90 to 2004/05 period, as estimated for the lower-bound case in Chapter 2 (or 190% growth in the upper-bound case), the majority of pumpsets in use in 2004/05 will be units that are purchased and installed after 1989-90 (including a combination of new applications and replacement of worn-out pumpsets in existing applications). If at the time these systems are purchased and installed only efficient equipment is used, savings of approximately 20% can be achieved relative to the typical system being purchased today (NPC, 1991). The extra costs of the more efficient pump system are modest -- perhaps Rs. 2,000 for a typical 4-kW system. Assuming operating hours and other parameters as for pumpset rectification, the cost per kW for these savings is only Rs. 7,300/kW, with a CSE of Rs. 0.30/kWh. We estimate that this package is appropriate for nearly all new pumpsets, which will represent approximately 60% of the pumpset stock in 2004/05.

**Diesel and Wind Pumpsets**

The analysis above assumes that use of electrical pumpsets will grow rapidly. If agricultural electricity prices remain highly subsidized, as at present, electrical pumpsets are the lowest cost system for farmers to purchase and operate. However, if electric, diesel, and wind pumpsets are all subsidized to the same degree, then diesel and wind pumpsets may be less expensive than electrical pumpsets to own and operate, and substantial electricity savings could result (Dutt, 1991, citing previous work by Ramesh and Natarajan, and Srivastava and Sharan).

## DOMESTIC SECTOR

In the domestic sector, major end-uses are fans, lighting, refrigerators, and cooling equipment. Efficiency opportunities for

lighting were discussed previously. In this section we discuss opportunities for improving the efficiency of refrigerators, fans, air conditioners, and air coolers.

**Refrigerators**

Refrigerators in India appear to be among the most inefficient in the world. Interviews with manufacturers indicate that a typical new 165 liter Indian refrigerator uses approximately 540 kWh per year (NPC, 1991). Older models use considerably more (TERI, 1991a). In comparison, an average Brazilian model of about 225 liters uses 410 kWh/year, while a new Korean 200 liter model uses approximately 240 kWh/year (Meyers et al., 1990).[13] Experience in Korea during the 1980's illustrates the type of efficiency improvements that are possible in refrigerators. During this period the typical 200 liter model produced in Korea decreased from 672 kWh/year (similar to models produced in India a few years ago) to 240 kWh/year. These improvements were achieved by reducing the wattage of the anti-sweat heater, use of more efficient compressors and fans, and use of more and better insulation. This data is summarized in Table 3-4.

Even greater efficiency improvements are possible. For example, in response to a competition sponsored by the Swedish government, Electrolux agreed to produce two different 290 liter combination refrigerator/freezers -- one with a 210 kWh/year consumption, and one with a 313 kWh/year consumption (Department of Energy Efficiency, 1991). Since Indian units are smaller, and do not include a large freezer compartment, the Swedish work indicates that Indian units with annual consumption of less than 150 kWh/year are possible.

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[13] There are differences in appliance testing procedures from country to country, and thus differences in the tens of kWh may not be significant. However differences of several hundred kWh/year are likely to be significant, regardless of the testing procedures used.

Table 3-4

Progress in Improving Refrigerator Efficiency in Korea

| Year | kWh/year (200 liter model) |
|---|---|
| 1980 | 672 |
| 1981 | 456 |
| 1982 | 336 |
| 1983 | 312 |
| 1984 | 288 |
| 1985 | 264 |
| 1986 | 240 |
| 1987 | 240 |

Notes: Data are for the simple average of models produced during the year. It is unclear what test procedure was used to develop this data.

Source: Korean Electric Power Corporation, as reported in Meyers, et al., 1990.

In addition to poor efficiency, Indian refrigerators suffer from another problem -- poor power factor. The Tata Energy Research Institute measurements of Indian refrigerators has shown power factors in the 0.5-0.7 range (Natarajan, 1991). Low power factors result in excessive distribution losses.

In this context, we examined two efficiency measures:

1. Moderate-efficiency refrigerators
2. High-efficiency refrigerators

We could not obtain sufficient data to estimate the energy savings from power factor correction.

*Moderate Efficiency Refrigerators*

For this analysis, we assumed that Indian manufacturers improve the efficiency of new units to levels common in today's Brazilian models (that is, to an annual consumption of approximately 410 kWh/year). In order to accomplish these improvements, manufacturers could use foam instead of fiberglass insulation (a transition that has recently begun in India, under the marketing name "Puf"), increase the thickness of insulation (thicknesses of 6 cm and more are common in developed countries), use high efficiency compressors, increase evaporator surface area, and use tighter door seals. Not all of these improvements would need to be incorporated in each model -- incorporation of all of these improvements would likely exceed the 410 kWh target.

The cost of these improvements is likely to be modest. For example, visits to appliance stores in Brazil found that retail prices of high-efficiency models are practically equal to standard-efficiency models (Geller, 1991). However, in order to be conservative, based on experience in the U.S. in the early 1980's (Geller, 1985), we assume an incremental cost of $20 (Rs.520). If we further assume that power consumption for refrigerators is equally divided among all hours of the year, then the capital cost of this measure is Rs. 12,600/kW saved. Assuming a 25-year average

refrigerator life, the CSE is Rs. 0.32/kWh. This measure is appropriate for all new Indian refrigerators. Assuming about three years to make the necessary manufacturing changes, approximately 75% of the refrigerators installed in 2004/05 can take advantage of this change.

- *High-Efficiency Refrigerators*

In addition to examining modest improvements to new refrigerators, we also examined further improvements to refrigerators in order to reduce consumption to 205 kWh/year -- similar to the consumption of the much larger Swedish model discussed above, and a 50% energy saving from the previous measure. Consumption levels in this range are now being discussed in Brazil, for units sold in 1998 (Geller, 1991).

In order to achieve this consumption level, a number of technical improvements to Indian refrigerators would be needed relative to the previous measure including: improved insulation, thicker insulation, improved fan and compressor efficiencies, improved door gaskets, and increased and improved heat exchange surfaces.

An important consideration which affects the development of high-efficiency refrigerators is the pending international phase-out of CFC's -- inert gases which are commonly used as refrigerants and foam blowing agents. Analyses by the Lawrence Berkeley Laboratory indicate that work on CFC substitutes is advancing steadily, and with optimized design, the elimination of CFC's is likely to have minimal impact on refrigerator efficiency (Turiel and Levine, 1989).

Based on analyses of the costs of these efficiency improvements in the U.S. (DOE, 1989) and Brazil (Geller, 1991), we estimate the cost to be $50, which at current exchange rates is Rs. 1,300. This estimate is in line with Swedish projections which indicate that the high-efficiency models discussed above will cost 10-20% more than standard Swedish units (Department of Energy Efficiency,

1991). Based on this incremental cost, the capital cost for this measure is Rs. 20,000/kW saved, and the CSE Rs. 0.50/kWh.

As with the measure above, this measure is appropriate for all new refrigerators. However, models of this efficiency are unlikely to be widely available in India for at least five years. Accordingly, only about 50% of the refrigerator stock in 2004/05 can incorporate this measure.

**Fans**

Fans are the largest user of electricity in the domestic sector. This includes both ceiling fans and table fans. Recent analyses suggest that there are at least two major opportunities to improve the efficiency of fans in India -- more efficient fans and electronic fan speed controls.

*More Efficient Fans*

A recent analysis in Pakistan (de Almeida and Geller, 1987) found that fan efficiencies vary significantly between manufacturers, and that the more-efficient fans use approximately 20% less energy than the less-efficient fans. A review of their data indicates that the energy efficiency of Pakistani fans is similar to Indian fans. The price difference between the more- and less-efficient fan was Rs. 200.[14]

Furthermore, even the more-efficient fans can be improved. Ashok Gadgil, as cited by Dutt (1991), has investigated fan motors in India and estimates that fan motor efficiency can be improved by 10%, which would reduce the electricity consumption of the fan by 10%. Such fan motors are not presently produced in India, but it is within the technical capability of Indian manufacturers to produce them. The efficiency increase would raise the cost of the motor approximately 30%. Gadgil estimates the cost of a typical

[14] While this price is in Pakastani Rupees, the value of the Indian and Pakistani Rupee are within about 10% of each other.

fan motor to be approximately Rs. 175, and thus a 30% cost increase represents a price increase of Rs. 50.

Based on these two analyses, we estimate that the efficiency of the average new fan can be increased by 15%, at a cost of Rs. 125. Such an improvement should be appropriate for all new fans, which will represent approximately 65% of the fan stock in 2004/05 (the remaining 35% will be fans existing today). Assuming a typical fan size and annual operating hours of 70 Watts and 2,500 hours respectively (from Appendix A), a fan life of 20 years, and a peak coincidence factor of 70% yields a capital cost of Rs. 6,300/kW saved and a CSE of Rs. 0.42/kWh.

*Electronic Speed Controls*

Fans are not always operated at full speed -- many times fans are operated at "low" or "medium" speed. Most fans in India use resistance type fan speed regulators which reduces fan speed by intoducing resistance into fan circuit. This resistance results in considerable energy waste. An alternative to conventional speed controls is electronic controls, which are basically simplified versions of the variable speed drives for industrial motors that were discussed earlier. Singh and Kumar (1989) compared conventional and electronic fan speed regulators and found that relative to conventional regulators, electronic regulators reduce energy use by 10-20% when the fan is operated at low speeds. However they also found that electronic regulators now being used in India introduce harmonics into the line (they distort the electrical wave shape which in turn can affect the lifespan of the fan and utility distribution transformers) and reduce fan power factor (which increases line losses). These problems can probably be solved with the use of harmonic filters and capacitors, but we could not obtain information on how costly these improvements would be. For this reason we did not include electronic fan speed controls in our analysis.

## Room Air Conditioners

Room air conditioners are not widely used in India at present, for only the wealthy can afford them. However, air conditioner sales have been increasing, and thus in the future room air conditioners may be a significant electricity user and contributor to peak demand.

Room air conditioner efficiency is measured with an energy efficiency ratio (EER) which is the Btu of cooling output divided by the Watts of power input. The higher the EER, the more efficient the air conditioner. Bureau of Indian Standards (BIS) specifications call for an EER of 6.6-7.0 (depending on unit size) to receive BIS certification. However, certification is voluntary and many units are sold with EERs perhaps as low as 5.0. In the U.S., as a result of federal efficiency standards, EERs must exceed a level of 8.6 and units with EERs as high as 12.0 are available (ACEEE, 1991). In Thailand, units with EERs of 9.0-10.6 are also readily available (IIEC, 1990).

Based on the experience in other countries, it appears that an EER level of 9.0 can be readily obtained in India. In fact, a few such units are presently imported from overseas. Gadgil (as cited in Dutt, 1991) estimates that the efficiency of a typical 6.0 EER one ton (12,000 Btu/hour) air conditioner can be increased to an EER of 9.0 at a cost of approximately Rs. 2,000. Assuming 1,200 operating hours per year (from Appendix A), an air conditioner life of 15 years, and a peak coincidence factor of 40%, the capital cost is Rs. 4,000/kW and the CSE Rs. 0.33. This measure would affect only new units -- an estimated 65% of the room air conditioner stock in 2004/05.

## Evaporative Coolers

Evaporative coolers, commonly called "desert coolers" provide a low-cost form of air conditioning in regions with low humidity. Evaporative coolers blow warm room air across a spray of water, causing the water to evaporate, which cools the air (since the heat

required to vaporize the water is removed). In India, evaporative coolers are primarily used in the northern part of the country where relative humidity levels are generally less than 50% during the hot summer months. In Delhi alone, according to a recent study sponsored by the Energy Management Centre (EMC), there are an estimated 1.1 million coolers (Centre for Research, Planning & Action, 1990).

In addition to estimating the current stock of evaporative coolers, the EMC study cited above also examined opportunities to improve the efficiency of the coolers. This study found that a typical evaporative cooler uses about 20% more energy than a unit meeting BIS's voluntary standards, and that BIS's standards could be strengthened to a considerable degree. For our analysis, we assume a 20% energy saving relative to typical current units, at an incremental cost of Rs. 500 (NPC, 1991). Assuming a 230-watt unit operating for 1,200 hours/year (from Appendix A), a 20-year cooler life, and a 40% peak coincidence factor, the capital cost of more efficient evaporative coolers is Rs. 10,100/kW and the CSE is Rs. .79/kWh. This improvement will affect new evaporative coolers (an estimated 65% of the 2004/05 stock) but not existing coolers.

## COMMERCIAL SECTOR

In the commercial sector, the major end-uses are lighting and HVAC (heating, ventilating, and air conditioning -- including fans). Lighting improvements were discussed previously. For our analysis of HVAC efficiency opportunities we examined two measures -- a package of HVAC conservation improvements, and storage cooling systems.

### HVAC Efficiency Improvements

Many measures are available to improve the efficiency of HVAC systems including reducing heat gain into the building, improved efficiency equipment, improved controls, and use of more efficient distribution systems such as variable-air-volume (VAV) systems.

The more a building heats up, the more power an air conditioning system uses. Building heat gains can be reduced substantially through use of roof insulation, use of window coatings and overhangs which reduce heat gain, use of light-colored paint or construction materials, and orienting a building to reduce the amount of sunlight directly striking the building while increasing the amount of natural ventilation and daylight reaching the building. Specific guidelines in the Indian context have been provided by the Central Building Research Institute (Saxena, Agarwal and Chand, 1989). In addition to reducing equipment operating hours, efforts to reduce heat gain allows equipment to be downsized, resulting in additional cost savings.

The energy savings from these measures can be subtantial. For example a set of computer simulations conducted in Brazil found that by combining all the these measures, heat gains could be reduced by up to 60-75% (Alucci, 1989). Even one of these measures in isolation can result in significant energy savings. For example, NPC (1991) found that use of heat-control window film in an office building and a hotel reduced total building electricity use by 1.6%. If HVAC represents 40% of the typical building load (from Appendix A), this amounts to a 4% reduction in HVAC energy use. The simple payback on these projects ranged from 2-5 years.

The efficiency of a typical Indian water-cooled reciprocating compressor is 1.05-1.10 kW/ton. A typical unit produced in the U.S. has an efficiency of .90-.95 kW/ton -- a savings of about 14%. Savings for smaller cooling systems may be even greater.

Thermostats and other controls turn specific pieces of equipment on and off. One particularly sophisticated control, a building automation system, allows the user to reduce energy use by operating equipment in the most efficient manner. Among a wide range of functions, such systems can reduce equipment operation during unoccupied periods, optimize the distribution of cool air to the sections of the building needing it the most, and turn equipment on in stages in order to optimize operating efficiency.

Laghate and Sardesai (1989) estimate that such systems can reduce energy use in Indian commercial buildings by 10-30%. A proposal for such a system is now pending at a major international hotel -- 27% savings and a one-year payback are predicted on the proposed investment of Rs. 4 million (NPC, 1991). Less sophisticated controls are also available, which cost less, but result in somewhat lower energy savings.

Based on these and other measures, a study in the U.S. for New York State found that commercial building HVAC energy use could be reduced by about 50% with an average simple payback of approximately two years (Miller, Eto, and Geller, 1989). Geller (1991) estimates that 25% HVAC savings are possible in Brazil by 2000, and 40% savings are possible in 2010 at an average CSE of $0.012/kWh (Rs. 0.31/kWh).

We estimate that on average 25% HVAC savings can be achieved in India when new HVAC systems are installed, with an average simple payback of three years (at Rs. 1/kWh saved). For purposes of the analysis, a 20-ton rooftop air conditioner with an EER of 7.5 is used as a basecase. If we further assume a 20 year measure life, 1,800 operating hours per year, and a 30% peak coincidence factor, the capital cost is Rs. 7,000/kW saved and the CSE is Rs. 0.28/kWh.

This result is very similar to the result obtained in the Brazilian analysis.

This measure is appropriate for all new commercial buildings (approximately 70% of the 2004/05 stock) and for those existing buildings which will receive new HVAC systems between now and 2004/05. In total, we estimate that this measure is feasible for 85% of commercial buildings in use in 2004/05.

**Storage Cooling Systems**

Commercial cooling loads primarily occur during the daytime and early evening -- at night most systems are shut off. Thus, for

buildings which operate through the evening hours, such as hotels and hospitals, cooling systems contribute to peak loads. Storage cooling systems allow this load to be switched to the nighttime, thereby reducing peak demand. A storage cooling system consists of water or ice storage tanks, and a control system. During the night, chilled water from the cooling systems are fed into the storage tanks, creating ice or chilled water. During the day and early evening hours, the main chiller is shut off, and chilled water from the storage tanks is used to cool the building. In the U.S., many utilities are actively promoting storage cooling systems. The economic rationale for customers to install these systems is the use of time-of-day electrical rates (high kWh &/or kW charges during peak hours, lower charges during off-peak hours).

Storage cooling systems are presently being imported into India. Perhaps 35 systems have been installed. Systems are primarily used by hotels who want to provide cooling even during power blackouts (Block, 1991).

For our analysis on storage cooling economics in India, we assumed a 300-ton cooling system. Cost of a storage cooling system is approximately $500/ton in the U.S., and we assumed the same price in India (Rs. 13,000/ton). Experience in the U.S. indicates that on average, storage cooling systems reduce peak demand by approximately 85%, but increase kWh use by about 5% (Piette et al., 1988; Block, 1989). The peak reduction is only 85% because circulation pumps continue to operate during the peak period. KWh use increases due to the both the pumping energy needed to charge and discharge the storage tanks, and the heat gained by the stored cold water/ice (between the time of production and use). If we further assume a baseline system efficiency of 0.90 kW/ton (allowing for HVAC system efficiency improvements), 2,400 annual full-load operating hours (for buildings which operate for both the day and evening), and a peak coincidence factor of 50% for commercial cooling in buildings with evening operation, the cost per kW saved is Rs. 13,300.

These systems are appropriate for large commercial buildings which operate throughout the evening. They are also appropriate for industrial refrigeration systems which operate during the evening but not late at night (during the night the system can recharge). We estimate that these factors apply to 20% of commercial cooling and industrial refrigeration systems. Our calculations of storage cooling savings assume that commercial HVAC and industrial refrigeration efficiency improvements have previously been implemented.

**TECHNICAL POTENTIAL FOR COST-EFFECTIVE SAVINGS**

In preceding sections of this paper, specific conservation and load management measures were discussed, including illustrative calculations of the cost/kW and CSE of each measure. This section summarizes the findings from the rest of this chapter and estimates the amount of conservation and load management savings that could be achieved in India in 2004/05 if all measures are pursued.

In the preceding sections the cost/kW and CSE of each measure were reported. These calculations were produced by a spreadsheet model developed by ACEEE. This model, and the model results, are summarized in Table 3-5. With this model we examined the economics for a typical application of each measure. The unit used for analysis is described in column [a]. Basic data for each measure are inserted in columns [b], [c], [d], [f], [j], [m], and [o]. In addition, data on savings for each measure are inserted in either column [g] or [i] (given one of these values, the other can be calculated). Rationales and sources for most of this data are described in the sections above dealing with the specific measures. The data in column [o] -- the taxes included in the cost of each measure -- comes from Table 3-6. In cases where the text indicates that taxes are excluded from the cost estimates, a zero is entered in the column [0]. Additional adjustments are made to the data in column [k] (to eliminate overlap between savings estimates) and column [n] (to include repurchase costs for measures with a life

Table 3-5. Cost-Effectiveness and Savings Analysis for Conservation & Load Management Measures

| Measure | Unit Used for Analysis [a] | Base kW (without measure) [b] | Coinci-dence Factor [c] | Assumed Operating Hours [d] | Per yr (without measure) (b*d) [e] | Initial Cost of Measure (Rs) [f] |
|---|---|---|---|---|---|---|
| TLD lamp | 40 Watt | 0.054 | 60% | 3,500 | 189 | 0 |
| Centrif. refrig. compressor | 200 T | 210 | 70% | 6,100 | 1,281,000 | 400,000 |
| Improved arc furnaces | 10 T | 2,400 | 50% | 4,000 | 9,600,000 | 5,000,000 |
| Meter agricultural pumpsets | 4 kW | 4.0 | 16% | 1,000 | 4,000 | 400 |
| Incand. to fluor. fixture | 75 Watt | 0.075 | 60% | 1,700 | 128 | 130 |
| HPSV lamp & ballast | 250 Watt | 0.285 | 70% | 4,000 | 1,140 | 565 |
| Motor rewinding, etc. | 20 hp | 10.9 | 60% | 4,200 | 45,811 | 3,000 |
| High efficiency motors | 20 hp | 10.1 | 60% | 4,200 | 42,604 | 5,584 |
| Air compressor O&M | 200 hp | 128 | 60% | 4,000 | 511,543 | 150,000 |
| HVAC effic. improvements | 20 ton | 32 | 30% | 1,800 | 57,600 | 43,200 |
| Multi-speed motors | 30 hp | 14.9 | 60% | 4,200 | 62,664 | 20,850 |
| High effic. new pumpsets | 4 kW | 4.0 | 16% | 950 | 3,800 | 2,000 |
| Moderate effic. refrig. | 540 kWh | 0.062 | 100% | 8,760 | 540 | 520 |
| Membrane chlor-alk process | 100 TPD | 17,188 | 80% | 7,200 | 123,750,000 | 200,000,000 |
| Room A/C EER 9 | 1 ton | 2.0 | 40% | 1,200 | 2,400 | 2,000 |
| Circular fluorescent lamps | 60 Watt | 0.06 | 60% | 1,700 | 102 | 75 |
| Optimize industrial pumps | 20 hp | 12.8 | 60% | 4,200 | 53,712 | 33,000 |
| Optimize industrial fans | 20 hp | 12.8 | 60% | 4,200 | 53,712 | 50,000 |
| More efficient fan | 70 Watt | 0.070 | 70% | 2,500 | 175 | 125 |
| Improved aluminum smelters | 600 TPD | 500,000 | 80% | 7,200 | 3.60E+09 | 3.60E+09 |
| Electronic ballast | 40 Watt | 0.054 | 60% | 3,500 | 189 | 190 |
| High effic. refrigerator | 410 kWh | 0.047 | 100% | 8,760 | 410 | 1,300 |
| Variable speed drives | 250 hp | 117.8 | 60% | 5,000 | 588,947 | 932,500 |
| Compact fluorescent lamp | 60 Watt | 0.06 | 60% | 1,700 | 102 | 160 |
| Agrig pumpset rectification | 4 kW | 4.0 | 16% | 950 | 3,800 | 9,000 |
| Efficient evap. cooler | 230 Watt | 0.23 | 40% | 1,200 | 276 | 500 |
| Storage cooling | 300 tons | 270 | 50% | 2,400 | 648,000 | 3,900,000 |

Notes:

* Specific assumptions are generally discussed in the text.
* Calculations assume 20% T&D losses, 60% capacity utilization factor, 10% real discount rate, and $1=Rs.26.
* The adjustment for previous measures is designed to prevent double-counting of savings when measures overhap. It is equal to (1-[column l]) for each measure that is assumed to be adopted before the current measure. When more than one measure is adopted previously, column k is the product of (1-[l]) for each previous measure.
* Present value of replacement costs equals ([column f]/1.1^n) where n is the year at which the measure is replaced. Measures are replaced up to the 20th year. For measures replaced in the 15th year, only 5/15 of measure costs are used in the calculations (prorated replacement cost thru the 20th year).
* Tax information comes from Table 3-5. For the three measures for which tax information was not available (aluminum smelting, HVAC equipment, and storage cooling systems) we assumed the same rates as for industrial pumps.
* Measure costs and measure replacement costs are multiplied by (1-[column o]) before calculating Rs./kW and Rs./kWh.

Table 3-5 (continued)

| kWh Savings [g] | Peak kW Savings [h] | Gross % Savings (g/e) [i] | % Appli- cable [j] | Adjust. for Previous Measures [k] | Net % Savings (i*j*k) [l] | Measure Life (yrs) [m] | PV of Replace. Costs (Rs) [n] | Taxes as % of Cost [o] | Rs/kW [p] | Rs/kWh [q] |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 0.005 | 7% | 100% | 100% | 7% | 1.67 | 0 | 18.2% | 0 | 0.00 |
| 427,000 | 98.0 | 33% | 35% | 85% | 10% | 20 | 0 | 21.7% | 3,200 | 0.09 |
| 2,880,000 | 720 | 30% | 60% | 100% | 18% | 10 | 398,987 | 54.2% | 3,400 | 0.13 |
| 200 | 0.064 | 5% | 100% | 100% | 5% | 20 | 0 | 25.4% | 4,700 | 0.18 |
| 69.7 | 0.049 | 55% | 50% | 100% | 27% | 15 | 10 | 21.7% | 2,200 | 0.19 |
| 360 | 0.126 | 32% | 100% | 100% | 32% | 10 | 45 | 21.7% | 3,800 | 0.20 |
| 3,207 | 0.9 | 7% | 80% | 100% | 6% | 5 | 3,738 | 0.0% | 7,400 | 0.25 |
| 1,737 | 0.5 | 4% | 55% | 94% | 2% | 30 | 0 | 25.4% | 8,400 | 0.25 |
| 153,463 | 46.0 | 30% | 75% | 85% | 19% | 5 | 186,878 | 0.0% | 7,300 | 0.26 |
| 14,400 | 4.8 | 25% | 85% | 100% | 21% | 20 | 0 | 21.7% | 7,000 | 0.28 |
| 5,640 | 1.6 | 9% | 25% | 92% | 2% | 30 | 0 | 25.4% | 9,700 | 0.29 |
| 760 | 0.256 | 20% | 60% | 95% | 11% | 15 | 160 | 13.0% | 7,300 | 0.30 |
| 130 | 0.030 | 24% | 75% | 100% | 18% | 25 | 0 | 27.9% | 12,600 | 0.32 |
| 30,000,000 | 6,667 | 24% | 95% | 100% | 23% | 20 | 0 | 58.5% | 12,500 | 0.32 |
| 800 | 0.533 | 33% | 65% | 100% | 22% | 15 | 160 | 0.0% | 4,000 | 0.33 |
| 64.6 | 0.046 | 63% | 15% | 100% | 10% | 4 | 93 | 0.0% | 3,700 | 0.37 |
| 8,057 | 2.3 | 15% | 70% | 85% | 9% | 20 | 0 | 21.7% | 11,200 | 0.38 |
| 10,742 | 3.1 | 20% | 70% | 85% | 12% | 20 | 0 | 25.4% | 12,200 | 0.41 |
| 26 | 0.015 | 15% | 65% | 100% | 10% | 20 | 0 | 25.4% | 6,300 | 0.42 |
| 7.20E+08 | 160,000 | 20% | 85% | 100% | 17% | 20 | 0 | 21.7% | 17,600 | 0.46 |
| 42 | 0.014 | 22% | 75% | 100% | 17% | 15 | 15 | 21.7% | 11,200 | 0.47 |
| 205 | 0.047 | 50% | 50% | 82% | 20% | 25 | 0 | 27.9% | 20,000 | 0.50 |
| 132,513 | 31.9 | 22.5% | 30% | 90% | 6% | 10 | 74,411 | 45.7% | 17,200 | 0.52 |
| 74.8 | 0.053 | 73% | 15% | 100% | 11% | 4 | 199 | 0.0% | 6,800 | 0.67 |
| 1,330 | 0.448 | 35% | 30% | 95% | 10% | 15 | 718 | 13.0% | 18,900 | 0.77 |
| 55 | 0.037 | 20% | 65% | 100% | 13% | 20 | 0 | 25.4% | 10,100 | 0.79 |
| (32,400) | 230 | 43% | 20% | 84% | 7% | 20 | 0 | 21.7% | 13,300 | -- |

Table 3-6. **Excise Taxes, Sales Taxes and Customs Duties on Efficiency Measures**

| Measure | Excise Tax [a] | Sales Tax [b] | Customs Duty [c] | Taxes as % of Cost [d] |
|---|---|---|---|---|
| Fluorescent fixture | 11.0% | 15.0% | NA | 21.7% |
| Circular & compact fluorescent | 33.0% | 15.0% | 225.9% | 79.9% |
| Fluorescent lamp | Rs. 2.2 | 15.0% | NA | 18.2% |
| Electronic ballast | 11.0% | 15.0% | NA | 21.7% |
| Sodium vapor lamp | 11.0% | 15.0% | NA | 21.7% |
| High effic. & 2-speed motor | | | | |
| <= 7.5 kW | 27.5% | 15.0% | NA | 31.8% |
| > 7.5 kW | 16.5% | 15.0% | NA | 25.4% |
| Variable speed drive | 16.5% | 15.0% | 37.5% | 45.7% |
| Industrial pump | 11.0% | 15.0% | NA | 21.7% |
| Industrial fan & blower | 16.5% | 15.0% | NA | 25.4% |
| Electric arc furnace | 16.5% | 15.0% | 63.1% | 54.2% |
| Membrane technology | 16.5% | 15.0% | 80.0% | 58.5% |
| Aluminum smelting equip. | ? | ? | ? | ? |
| Electric motor | 16.5% | 15.0% | NA | 25.4% |
| Agricultural pumpset | 0.0% | 15.0% | NA | 13.0% |
| Refrigerator - 165 liters | Rs. 1650 | 15.0% | NA | 27.9% |
| Domestic fan | 16.5% | 15.0% | NA | 25.4% |
| Air conditioner - 1 tonne | Rs. 13200 | 15.0% | NA | 39.6% |
| Evaporative cooler | 16.5% | 15.0% | NA | 25.4% |
| HVAC equipment & controls | ? | ? | ? | ? |
| Storage cooling system | ? | ? | ? | ? |

Notes:

* Column d = 1 - 1/{[1/(1+a)]*[1/(1+b)]}
* NA = not applicable; measure widely produced in India
* ? = not available
* Sales taxes vary from item to item and state to state; 15% is an overall average.
* Information on taxes
* Duty on electronic components varies from approximately 125-175%. For the variable speed drive we assume electronic components account for 30% of VSD cost, at an average duty of 150%.
* In calculating column d for fluorescent lamps, refrigerators, and air conditioners, base costs of Rs. 35, Rs. 8,000, and Rs. 30,000 were assumed.

of less than 20 years). The formulas used to calculate data for these two columns are discussed in the notes to Table 3-5.

Based on these assumptions, the model calculates the peak kW savings (at the generation plant level, after allowing for T&D losses and capacity utilization rates), net savings (gross savings times percent applicable times the adjustment factor to eliminate double-counting), the cost per kW and the CSE.

In Table 3-5, results of the model are reported in order of CSE, starting with the lowest-cost measures and proceeding to the highest-cost measures. Conservation measures are listed first. The one load management measure (storage cooling), for which no kWh savings are obtained, is reported at the bottom. In examining the results of this model, please bear in mind that most of the assumptions are inexact and subject to a considerable degree of uncertainty. In particular, the estimates of peak coincidence factor and measure applicability factor are subject to a substantial degree of uncertainty because they are based on professional judgement and not on measured survey data.

Despite the uncertainties, the results of our analysis clearly indicate that there are large opportunities for cost-effective electricity savings in India. As can be seen in Table 3-5, all of the measures have a CSE of Rs. 0.79 or less and a capital cost of Rs. 20,000/kw or less. Since even the most expensive of these measures has a lower cost than the marginal cost of electricity production in India (Rs. 0.90 - 2.02/kWh) and a lower capital cost than a new baseload power plant (Rs. 23,350/kW), all of the measures are likely to be cost-effective.

Using the results from this model, potential All-India savings for each measure were calculated by multiplying net savings from Table 3-5, by estimates of 2004/05 energy consumption in each end-use, as summarized in Tables 2-8 and 2-9. Results of this analysis are summarized in Table 3-7. This table also includes estimates of

Table 3-7. Savings Potential in India in 2004/05 from 27 Conservation & Load Management Measures

| Measure | Projected GWh in 2004/05 for this End-Use | | Energy Savings Possible in 2004/05 (GWh) | | Savings as a % of Projected GWh Sales | | Peak Generation Savings Savings Possible in 2004/05 (MW) | | Savings as a % of Projected Generating Capacity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low-case [a] | High-case [b] | Low-case [c] | High-case [d] | Individual [e] | Cumulative [f] | Low-case [g] | High-case [h] | Individual [i] | Cumulative [j] |
| TLD lamp | 44,873 | 71,968 | 3,324 | 5,331 | 0.66% | 0.66% | 1,140 | 1,828 | 0.60% | 0.60% |
| Centrif. refrig. compressor | 8,800 | 14,100 | 872 | 1,398 | 0.17% | 0.84% | 200 | 321 | 0.11% | 0.71% |
| Improved arc furnaces | 6,900 | 11,100 | 1,242 | 1,998 | 0.25% | 1.09% | 311 | 500 | 0.16% | 0.87% |
| Meter agricultural pumpsets | 79,700 | 127,700 | 3,985 | 6,385 | 0.80% | 1.88% | 1,275 | 2,043 | 0.67% | 1.54% |
| Incand. to fluor. fixture | 30,100 | 48,300 | 8,227 | 13,202 | 1.64% | 3.52% | 5,808 | 9,319 | 3.06% | 4.60% |
| HPSV lamp & ballast | 4,900 | 6,300 | 1,263 | 1,989 | 0.25% | 3.78% | 442 | 696 | 0.23% | 4.83% |
| Motor rewinding, etc. | 182,400 | 292,300 | 10,214 | 16,369 | 2.04% | 5.81% | 2,918 | 4,677 | 1.54% | 6.37% |
| High efficiency motors | 182,400 | 292,300 | 3,860 | 6,186 | 0.77% | 6.58% | 1,103 | 1,767 | 0.58% | 6.95% |
| Air compressor O&M | 8,800 | 14,100 | 1,682 | 2,695 | 0.34% | 6.92% | 505 | 809 | 0.27% | 7.22% |
| HVAC effic. improvements | 11,600 | 18,700 | 2,465 | 3,974 | 0.49% | 7.41% | 822 | 1,325 | 0.43% | 7.65% |
| Two-speed motors | 182,400 | 292,300 | 3,792 | 6,077 | 0.76% | 8.17% | 1,083 | 1,736 | 0.57% | 8.22% |
| High effic. new pumpsets | 79,700 | 127,700 | 9,086 | 14,558 | 1.81% | 9.98% | 3,060 | 4,904 | 1.61% | 9.84% |
| Moderate effic. refrig. | 17,900 | 28,700 | 3,232 | 5,182 | 0.65% | 10.63% | 738 | 1,183 | 0.39% | 10.23% |
| Membrane chlor-alk process | 7,400 | 11,900 | 1,704 | 2,741 | 0.34% | 10.97% | 379 | 609 | 0.20% | 10.42% |
| Room A/C EER 9 | 5,100 | 8,200 | 1,105 | 1,777 | 0.22% | 11.19% | 737 | 1,184 | 0.39% | 10.81% |
| Circular fluorescent lamps | 30,100 | 48,300 | 2,859 | 4,588 | 0.57% | 11.76% | 2,018 | 3,239 | 1.06% | 11.88% |
| Optimize industrial pumps | 34,900 | 56,000 | 3,113 | 4,995 | 0.62% | 12.38% | 889 | 1,427 | 0.47% | 12.35% |
| Optimize industrial fans | 20,600 | 33,000 | 2,450 | 3,925 | 0.49% | 12.87% | 700 | 1,121 | 0.37% | 12.71% |
| More efficient fan | 28,500 | 45,600 | 2,779 | 4,446 | 0.55% | 13.42% | 1,556 | 2,490 | 0.8[illegible]% | 13.53% |
| Improved aluminum smelters | 19,800 | 31,800 | 3,366 | 5,406 | 0.67% | 14.10% | 748 | 1,201 | 0.39% | 13.93% |
| Electronic Ballast | 44,873 | 71,968 | 7,479 | 11,995 | 1.49% | 15.59% | 2,564 | 4,112 | 1.35% | 15.28% |
| High effic. refrigerator | 17,900 | 28,700 | 3,667 | 5,880 | 0.73% | 16.32% | 837 | 1,342 | 0.44% | 15.72% |
| Variable speed drives | 182,400 | 292,300 | 11,140 | 17,852 | 2.22% | 18.54% | 2,674 | 4,285 | 1.41% | 17.13% |
| Compact fluorescent lamp | 30,100 | 48,300 | 3,311 | 5,313 | 0.66% | 19.21% | 2,337 | 3,750 | 1.23% | 18.36% |
| Agrig pumpset rectification | 79,700 | 127,700 | 7,950 | 12,738 | 1.59% | 20.79% | 2,678 | 4,291 | 1.41% | 19.77% |
| Efficient evap. cooler | 3,500 | 5,600 | 455 | 728 | 0.09% | 20.88% | 303 | 485 | 0.16% | 19.93% |
| Storage cooling | 20,400 | 32,800 | -- | -- | -- | -- | 604 | 972 | 0.32% | 20.25% |
| TOTAL | | | 104,624 | 167,727 | 20.88% | 20.88% | 38,430 | 61,616 | 20.25% | 20.25% |

* Numbers in columns [a] and [b] are from Tables 2-8 and 2-9.
* Columns [c] and [d] are calculated by multiplying column [l] in Table 3-6 by columns [a] and [b] in this table.
* Columns [g] and [h] are calculated from the kWh savings (columns [c] and [d].). To calculate kW savings, kWh savings are divided by operating hours (for that measure) and the capacity factor (0.6) and multiplied by the coincidence factor (for that measure) and the T&D factor (1.2).
* The percentage savings figures assume 2004/05 sales of 501,000 GWh (low case) and 802,000 GWh (high case). Generating capacity for 2004/05 is 190,000 MW (low case) and 304,000 (high case). Generating capacity figures are based on the average ratio of GWh sales to MW peak during the 1981-88 period as reported in CEA, 1987, and an assumed capacity utilization factor of 60%.

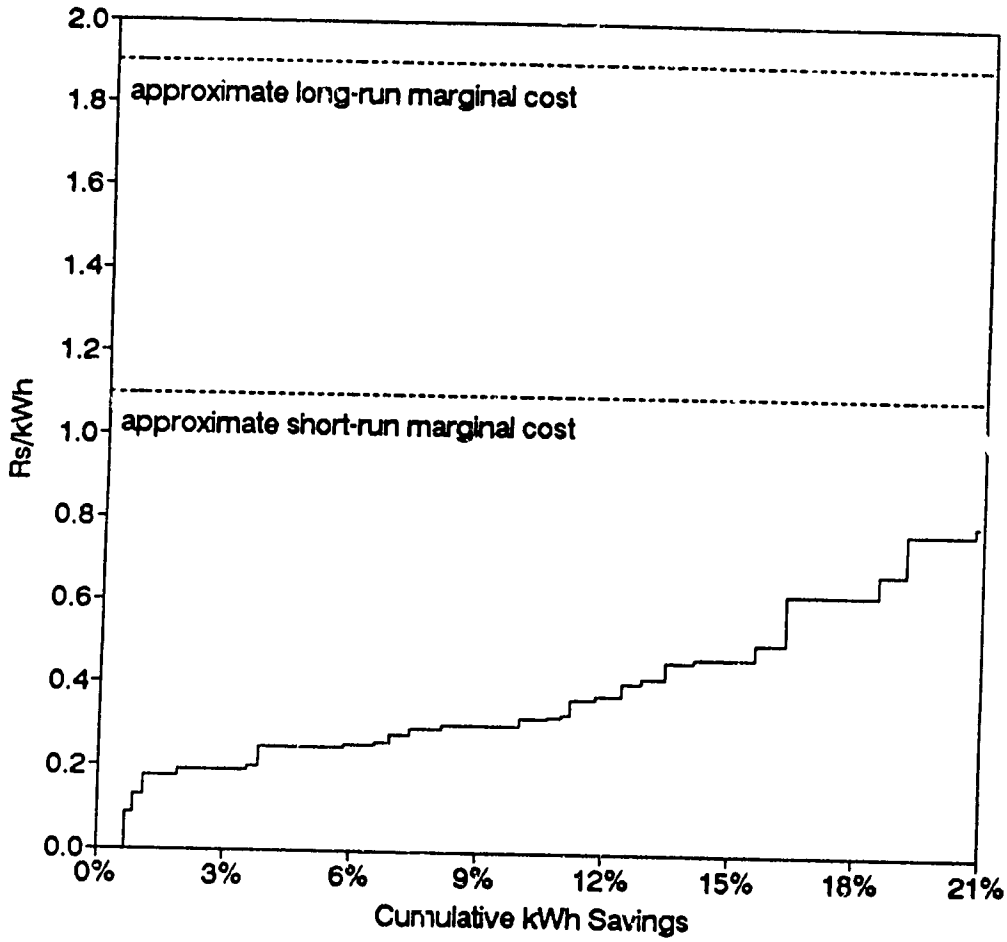
potential peak generation savings (the method used to calculate these savings is described in the notes to Table 3-7).

Overall, the 27 measures examined in this study can reduce projected kWh sales and peak generation needs in 2004/5 by approximately 20%. This estimate of available savings is probably very conservative. We only examined a limited number of measures; if more measures were added to the analysis, the savings would increase. Also, if the time horizon were not limited to 2004/05, there would be more time for the technologies considered here to penetrate the Indian market.

Another way to examine the results of our analysis is with a "conservation supply curve." Such a curve plots the amount of energy that can be saved from each measure as a function of the cost of each measure, starting with the lowest cost measures first, and proceeding to higher cost measures Figures 3-2 and 3-3 present conservation supply curves for our results, based respectively on the CSE and cost/kW of the different efficiency measures examined. These curves are derived from the data in tables 3-5 and 3-7.

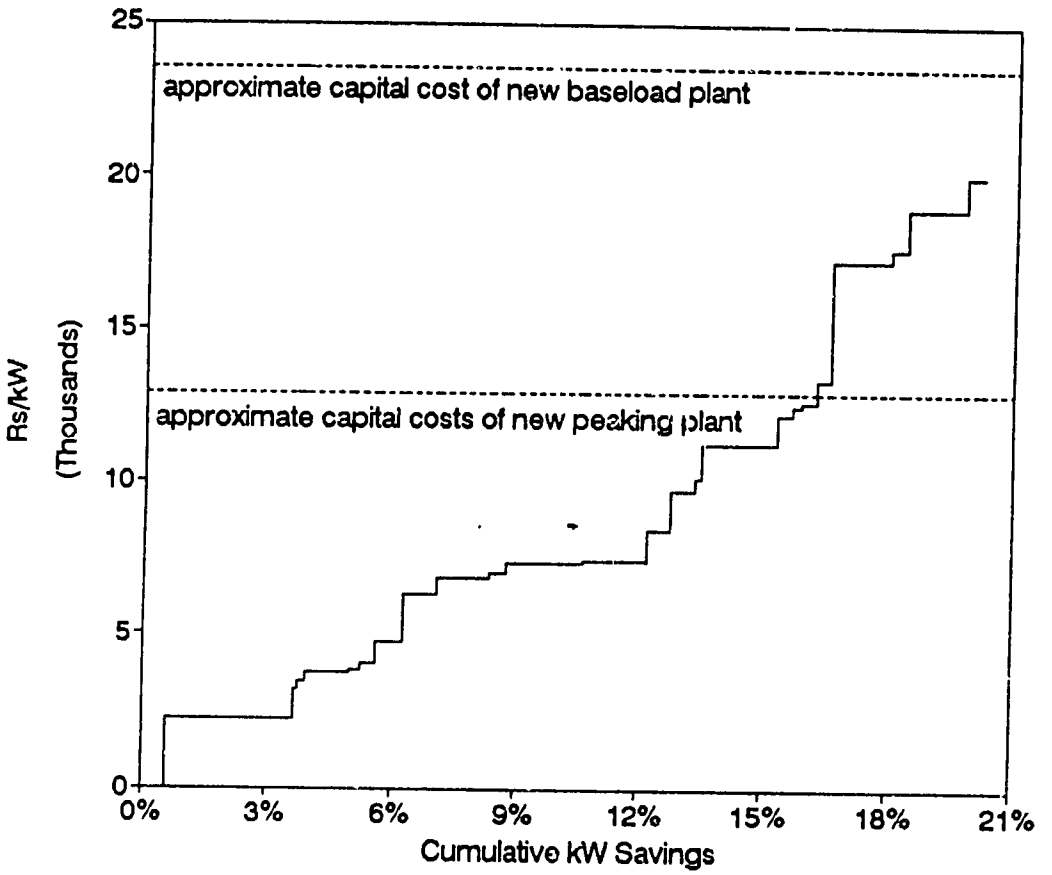
Higher savings potential have been shown in studies in other countries. For example, in a study for New York State in the U.S., Miller, Eto and Geller (1989) examined 62 efficiency measures and found a cost-effective technical savings potential from the societal perspective of 34% of GWh sales and 42% of peak demand. Studies in several developing countries have also found a cost-effective technical savings potential equal or greater than the potential estimated here. For example, Geller (1991), in his analysis of Brazil, found a savings potential of 17% of GWh sales in 2000, and 24% in 2010. Likewise, de Almeida and Geller (1987) examined the potential for savings in Pakistan's industrial and commercial sectors, and found a GWh savings potential of 30% in 2005.

Figure 3-2. Supply Curve for Conserved Electricity in India.




Note: Rs/kWh are from Table 3-5, savings are from Table 3-7.

Figure 3-3. Supply Curve for Conserved Generating Capacity in India.




Note: Rs/kW are from Table 3-5, savings are from Table 3-7.

In examining the results in Table 3-7, it is clear that several measures account for a large share of the available savings. Measures with the largest kWh and kW savings, on an All-India basis, are summarized in Table 3-8. Several trends emerge from this analysis. First, many of the measures with the largest savings relate to the agricultural sector, indicating that this sector should receive priority attention. Second, many of the measures with large savings involve advanced technology -- technology that is being used with increasing frequency in developed countries, but are not yet readily available in India. This indicates that "technology transfer" efforts should also receive attention. Third, many lighting measures tie in this list of measures with high savings, indicating that lighting across all sectors is another potential priority target. Fourth, several basic industrial operations and maintenance-type measures (motor repairs and rewinding, and industrial fan efficiency improvements) offer large savings, indicating a need to promote improved operations and maintenance efforts in industry. We return to these points in Chapter 6.

In summary, this chapter identifies potential savings in India, over the next 15 years, that can reduce kWh sales and peak generating needs by approximately 20%. This estimate is probably conservative as only a limited number of measures were examined. All of the measures discussed here are likely to be highly cost-effective relative to the capital and operating costs of power plants.

Overall, the weighted average capital cost of all measures examined is Rs. 8,800/kW (weighted based on peak savings). If we assume an average generating plant cost of Rs. 20,000/kW (since our measures will primarily displace baseload plants, but some displacement of peak plants will occur as well), then implementation of all the measures examined will save Rs. 430 billion ($17 billion U.S.) in capital costs under the low growth scenario, and Rs. 690 billion ($27 billion U.S.) under the high growth scenario.

Table 3-8. Measures with the Largest Energy and Demand Savings

| Energy savings: | Savings as a % of 2004/05 Projected GWh Sales |
|---|---|
| Variable speed drives | 2.22% |
| Motor rewinding, etc. | 2.04% |
| High effic. new pumpsets | 1.81% |
| Incand. to fluor. fixture | 1.64% |
| Agrig pumpset rectification | 1.59% |
| Electronic Ballast | 1.49% |
| Meter agricultural pumpsets | 0.80% |
| High efficiency motors | 0.77% |
| Two-speed motors | 0.76% |
| High effic. refrigerator | 0.73% |
| Improved aluminum smelters | 0.67% |
| TLD lamp | 0.66% |
| Compact fluorescent lamp | 0.66% |
| Moderate effic. refrig. | 0.65% |
| Optimize industrial pumps | 0.62% |

| Demand Savings: | Savings as a % of 2004/05 Projected Generating Capacity |
|---|---|
| Incand. to fluor. fixture | 3.06% |
| High effic. new pumpsets | 1.61% |
| Motor rewinding, etc. | 1.54% |
| Agrig pumpset rectification | 1.41% |
| Variable speed drives | 1.41% |
| Electronic Ballast | 1.35% |
| Compact fluorescent lamp | 1.23% |
| Circular fluorescent lamps | 1.06% |
| More efficient fan | 0.82% |
| Meter agricultural pumpsets | 0.67% |
| TLD lamp | 0.60% |
| High efficiency motors | 0.58% |
| Two-speed motors | 0.57% |
| Optimize industrial pumps | 0.47% |
| High effic. refrigerator | 0.44% |

However, achieving these savings will not be easy. The next chapter discusses barriers to the achievement of these savings. The last chapter discusses programs and policies that can be implemented in India to get around the barriers, and achieve a substantial share of the available savings.

## Chapter 4

## BARRIERS TO ENERGY EFFICIENCY IN INDIA

### INTRODUCTION

In the previous chapter we examined how India could cut needed generating capacity by 20% in 2004/05 through application of 27 conservation and load management measures. However, actually achieving these savings will not be easy because there are a number of constraints which hinder adoption of conservation and load management measures in India. In this chapter we discuss many of the major barriers and include examples of how specific barriers apply to individual conservation measures. At the end of this chapter we summarize how these barriers affect each of the measures examined in Chapter 3. For each barrier we also briefly discuss some possible approaches to overcoming the barrier (many of these potential solutions are discussed in more detail in Chapters 5 and 6).

The specific barriers discussed are as follows:

1. Lack of information;
2. Measure costs exceed willingness to pay;
3. Electricity prices are less than marginal costs and the cost of electricity production;
4. Limited capital, especially foreign currency
5. Hassles of implementing efficiency projects;
6. Limited availability of efficient equipment and the raw materials and components needed to manufacture efficient equipment;
7. Poor power quality and reliability;
8. Problems with equipment and material quality;
9. Small-scale manufacturing firms which produce inefficient products;
10. Aversion to taking risks associated with new technologies;

11. Bias towards visible projects;

12. Presence of a large used-equipment market which delays the retirement of inefficient equipment;

13. Shortage of skilled staff.

**LACK OF INFORMATION**

With some notable exceptions (primarily in energy-intensive industries), Indian consumers are usually unaware of opportunities to improve energy efficiency. In India, as in other countries, consumers and businesses concentrate on the services provided by energy consuming equipment (such as light or cooling) and are usually not interested in information on energy efficiency. Furthermore, information on the energy consumption or energy efficiency of equipment is frequently not available, and even when available, is rarely publicized.

Many organizations in India have attempted to address this problem through the preparation of educational materials (examples are discussed in Chapter 5). However these materials are often very general in nature and lack detailed information needed by specific types of end-users. Also, in order to affect equipment purchase decisions, information is best presented immediately before equipment purchase. Unfortunately, few mechanisms are in place to provide efficiency information at this critical time.

The solution to this problem is more detailed educational efforts, customized to each end-use segment, with an emphasis on providing information immediately before the decisions are made. Options include: energy labels on appliances, motors and pumps; and training programs for industrial energy managers on specific topics relevant to their industry. While some efforts in these areas have taken place in India, efforts to date have reached only a small portion of Indian energy users.

**MEASURE COSTS EXCEED WILLINGNESS TO PAY**

As in many countries, most Indian consumers seek to minimize the initial cost of a piece of equipment and do not pay much attention to operating costs. Thus any measure that adds to initial costs is less likely to be considered. However, some consumers will pay more for an efficiency measure that reduces operating costs. However, even these consumers generally focus on measures with a simple payback period of one to two years (meaning that additional purchase costs are offset by energy savings in only a year or two). While some efficiency measures have simple payback periods this low, many measures have a higher simple payback period, but still cost less than the cost of building and operating a new power plant. When consumers elect not to invest in these cost-effective measures, they obligate utilities to invest in new power plants with much higher costs, thereby wasting societal resources.

In addition to general consumer reluctance to invest in efficiency, there are a number of other constraints which limit consumer willingness to invest money in efficiency improvements.

First, efficient equipment often carries a cost premium beyond the cost of the efficiency improvement itself. For example, efforts to improve equipment efficiency are often reserved for high quality pieces of equipment, and thus the user must pay for both the quality and efficiency improvement, presenting a steep first-cost barrier. This is the case with evaporative coolers and room air conditioners where low-quality, low-efficiency equipment produced by the small-scale sector competes with higher quality, higher efficiency equipment produced by the organized sector (although not all equipment produced by the organized sector is of higher efficiency). Furthermore, excise duties can contribute to the price disparity. For example, the excise duty on room air conditioners (Rs. 13,200 for a 1 ton model -- see Table 3-6) is equal to the pre-tax price of the product. If it costs Rs. 2,000 to increase the EER to 9.0 (including price markups in the

distribution chain), then the extra cost to consumers is Rs. 4,000 -- the Rs. 2,000 cost of the improvement, plus Rs. 2,000 tax (Dutt, 1991).

Second, even for efficiency measures proven abroad, the cost in the Indian context is often higher because of limited production quantities in India and/or use of imported components which drive up costs.

When production quantities are limited, there are few economies of scale, and thus the cost per unit is high. High prices lead to low demand, creating a vicious circle which makes it difficult for prices to fall. In many industries, India has many small manufacturers, instead of a few large manufacturers as in many other countries. Reasons for this development are many and include: (a) a poor transportation infrastructure in India, which makes it difficult to produce goods for the entire country out of one plant; (b) capacity licensing restrictions, used by the government to match production to planned demand, but which also restrict capacity expansion;[1] (c) incentives provided by many states to build small plants in backward areas; and (d) restrictions on capacity expansion in some areas, such as Bombay, in order to control environmental problems. While each of these policies have many desirable effects (economic development in backward areas and environmental protection for example), they also have some undesirable side effects.

Imported components are expensive for two reasons: the shipping costs involved and import duties. Shipping costs may add 20% to the cost of a measure. Import duties vary widely from product to product (see Table 3-6), and can raise component costs from as little as 10-20% to 200% or more. While duties are often designed to protect Indian manufacturers, at times, high duties even apply

[1] In July, 1991, the Government of India eased many of these restrictions for most industries. Restrictions still apply to selected industries, among them the appliance industry (TERI, 1991b).

to equipment that is not manufactured in India. For example, the import duty on membrane chlor-alkali technology is 80%.

Third, in some regulated sectors of the economy (primarily intermediate products such as steel, petroleum, and selected chemicals), prices are fixed by the government using complex formulas, many of which are cost-plus based. Some goods are uniformly priced, but the price of others may vary according to the age of the plant producing the product or according to the category of the customer. Overall, costs are far higher than their equivalents in world markets. This cost-plus approach provides no incentive to public sector firms to reduce energy costs (Padmanabhan, 1991). This system of price regulation has been largely eliminated from some industries in recent years, including cement, aluminum, and pulp and paper, but remains in place in other industries (Baldwin, 1991).

Fourth, some equipment purchases are made by people who do not pay the electricity bills. Examples of this situation include commercial building developers (who decide what efficiency measures to incorporate in a building, while tenants pay the electricity bills), and operating departments in some industrial facilities (who chose equipment, while bills are paid out of a central account and are not traceable to individual operating departments). Equipment purchasers who do not pay operating costs have little incentive to consider efficiency improvements.

There are a number of possible solutions to the problem of measure costs exceeding willingness to pay. First, government and industry can work together to develop markets for efficient technologies, so that there is a sufficient market in India to produce equipment on a large scale. Likewise, government and industry can work together to ensure that production capacity is done at sufficient scale to take advantage of economies of scale. Second, consumers can be educated about life-cycle cost economics, and how paying a little more at first can save a lot over the life of a piece of equipment. Third, industries can allocate operating and capital

costs to individual departments so that those who purchase equipment also pay the operating costs (such a step is reportedly occurring in some Indian firms). Third, financing (loans) can be offered to end-users (although experience in many countries indicates that only a minority of end-users will take advantage of the loans -- see Appendix B). Fourth, utilities can offer financial incentives to encourage efficiency measures, with the amount of incentive dependent on the amount of money the utility saves by reducing demand (this approach is becoming widespread in the U.S., and is also discussed in Appendix B). Fifth, excise taxes and import duties can be reduced or waived for efficient equipment. For example, the Indian Electrical and Electronics Manufacturer's Association (IEEMA) has recently recommended such a step for energy efficient motors (IEEMA, 1990). Sixth, electricity prices can be modified so they send clear price signals on the value of energy savings (this issue is discussed further below).

**ELECTRICITY PRICES ARE LESS THAN CONSTRUCTION AND OPERATION COSTS**

Electricity prices in India are generally less than the cost of electricity production (average cost) and substantially less than the cost to build and operate a new power plant (marginal cost). This situation is illustrated by a recent analysis by RCG/Hagler, Bailly, Inc. (1991) which examined electricity revenues/kWh and compared these revenues to the average and marginal cost of producing this power. The average revenue/kWh (approximately Rs. 0.6-0.9/kWh) was significantly less than the average cost of production (approximately Rs. 1.0-1.25/kWh) and substantially less than the marginal cost of production (which averaged Rs. 1.8-2.0/kWh). An illustrative sector by sector example from this study is summarized in Table 4-1. As can be seen in this table, the underpricing problem is particularly acute in the agriculture and domestic sectors, and is not a major issue for high tension industrial customers. This underpricing causes consumers to place little value on saving energy.

Table 4-1. Comparison of Electricity Prices and Long-Run Marginal Costs in Maharastra, 1990/91.

| Customer Class | Revenues/kWh | Long-Run Marginal Cost |
|---|---|---|
| Domestic | Rs. 0.55 | Rs. 2.28 |
| Commercial | 1.03 | 2.08 |
| Industrial | | |
| Low tension | 0.92 | 1.67 |
| High tension | 1.27 | 1.28 |
| Agriculture | 0.09 | 1.89 |
| Railway | 1.15 | 1.36 |
| Other | 1.15 | 2.08 |
| TOTAL | 0.88 | 1.77 |

Source: RCG/Hagler, Bailly, Inc., 1991.

In most states, agricultural electricity is not only underpriced, it is unpriced. In these states electricity use by agricultural customers is not metered; instead customers pay a fixed fee each time period based on the power rating of the equipment. A 10 hp pump that runs continuously is charged no more than a 10 hp pump that runs one hour a day. In this situation, farmers have no incentive to conserve.

Problems with retail electricity pricing also constrain efficiency investments for several other reasons. First, most customers pay for electricity based on total kWh use over a certain period, with no distinction between use during peak periods (when electricity is more expensive to produce) and off-peak periods (when the cost of production is lower). This lack of proper price signals discourage load management actions. Second, with the exception of large industrial customers, most customers do not pay be poor power factor. Poor customer power factor increases transmission and distribution losses, thereby raising the cost per kWh delivered. Since most customers are not penalized for poor power factor, they have little incentive to purchase high power factor equipment. This is particularly a problem in the agriculture, domestic, and commercial sectors.

The obvious solution to these problems, is to reform electricity pricing, although the political barriers to pricing reform are formidable.

**LIMITED CAPITAL AND FOREIGN CURRENCY**

Capital is in tight supply in India, so even consumers who want to invest in efficiency may not have the capital available for these investments. This is particularly a problem in the domestic and small-scale sectors, but even large industrial firms often devote most of their available capital to their core business (e.g., making steel) and limit efficiency investments to an arbitrary, small pool of money. Also, capital is generally more available for facility expansion than for modernization because of more liberal

debt to equity requirements used by some programs which finance expansion (Padmanabhan, 1991).

India has limited foreign currency with which to pay for imported equipment and materials. This problem applies to all sectors of the economy, and not just to efficiency investments. In addition to a general shortage of foreign currency, in an effort to limit the outflow of scare currency reserves, the Government of India places a variety of restrictions to limit imports. Examples of these restrictions include import duties (discussed previously), restrictions on the amount of material that can be imported (unless a product is covered by an Open General License, a specific application must be submitted for each import transaction, and applications can be denied), and denying licenses to Indian firms to manufacture equipment in India which requires extensive use of imported components. These restrictions hinder efficiency improvements because they limit the availability of efficient equipment.

In July of 1991 the Government of India took a number of steps to ease these problems including easing restrictions on foreign investments in high-priority industries. Among the industries included are the electric motor and electric furnace industries (TERI, 1991b).

Even with these changes, foreign currency is likely to remain in tight supply. While some restrictions on the spending of foreign currency are probably needed to protect foreign currency reserves, by restricting foreign currency expenditures for efficiency improvements, the need for power plants increases. As a result, more capital is needed to finance power plants, including capital to pay for imported components used in these power plants. It would be useful to conduct a study to see whether foreign capital could be saved by easing foreign currency related restrictions on efficiency measures. If foreign capital would be saved, then these restrictions should be eased, at least on a temporary basis (i.e.,

long enough for domestic production of efficient technologies to be established).

## HASSLES IN IMPLEMENTING EFFICIENCY PROJECTS

Implementing efficiency measures can involve extensive hassles for customers. For example, it takes time to research efficiency measures and oversee their installation. The time involved is likely to be particularly large for a first project; with subsequent projects the lessons learned on the first project can help shorten the time involved. Most people are busy enough that new time commitments appear uninviting. This problem is not limited to efficiency measures, but pertains to any new undertaking. Some large firms have hired energy managers and other staff who quickly master the process of implementing efficiency projects. But for small firms who must assign efficiency projects to staff without specialized training in the energy efficiency field, the hassles of implementing efficiency projects can be formidable.

Another major hassle is that when measures are installed, it may disrupt normal operations. This is particularly a problem in industrial facilities where an entire production line may need to be shut down in order to replace a single piece of equipment.

Each of these problems has a potential solution. For example, technical assistance can be provided to end-users to reduce the time and other hassles of implementing efficiency projects. Also, large industries that do not have a full-time energy manager can be encouraged to hire one. Likewise, equipment installations can be scheduled during periods of planned shutdown -- for example, the annual shutdown period in many industrial facilities, or during nights and weekends in commercial facilities.

**LIMITED AVAILABILITY OF EFFICIENT EQUIPMENT AND COMPONENTS**

As noted in Chapter 3, many types of efficient equipment are not readily available in India. Examples include compact fluorescent lamps, circular fluorescent lamps, and efficient refrigerators, room air conditioners, and evaporative coolers.

While this equipment can be imported, transportation costs and import duties often raise the costs to unacceptable levels. For example, the import duty on compact fluorescent lamps is 226% (see Table 3-6). Indian manufacturers are often reluctant to produce new equipment until they are assured that there will be sufficient consumer demand, but consumer demand cannot be established until products are available.

Another reason for limited availability of efficient equipment is that the raw materials and components needed to produce efficient equipment are sometimes not readily available. For example, discussions with motor manufacturers indicate that better quality materials such as cold-rolled non-grain oriented steel and properly enameled winding wire are not readily available indigenously. The difference between domestic production and demand must be imported, which adds to costs, particularly when import duties are high. Other components that are frequently imported include high efficiency phosphors for fluorescent lamps, discharge tubes and sintered aluminum dioxide powder for high pressure sodium lamps, and electronic components for electronic ballasts and variable speed drives.

Furthermore, at times, the Government of India restricts imports of materials or restricts licenses for production within India. For example, copper wire has lower electrical losses than the aluminum wire used in most Indian motors and ballasts, but domestic copper production is not sufficient to meet to demand and copper imports are restricted in order to limit the outflow of hard currency. Likewise, several Indian firms have applied to manufacture compact fluorescent lamps in India, but the

applications have yet to be approved. With the recent easing of licensing requirements for most industries, this problem may largely disappear.

Even when efficient equipment is produced in India, it can be difficult for an end-user to purchase this equipment. For example, high efficiency motors are rarely stocked by dealers. If a user wants a high efficiency motor, the motor must be specially ordered, which typically adds a delay of one to two months. Since most users cannot afford such a delay, high efficiency motors are rarely requested. This creates another vicious circle -- efficient equipment is not stocked because there is no demand, but there is no demand in part because efficient equipment is not stocked (this problem also exists in many other countries, including the U.S. -- Nadel et. al., 1991).

These problems are not easily solved. One possible solution is for government and industry to identify products and materials meriting high priority attention, and through a combination of direct purchases (purchases by the government and utilities for use in their own facilities), selective duty waivers (waiving duties on a limited quantity of product -- just enough to interest Indian industry to produce these products domestically) and other policy interventions, develop a market for these products.

**POOR POWER QUALITY AND RELIABILITY**

In India, voltage can deviate by 30% or more from the nominal 230 volt value of the Indian electrical system. Fluctuations are particularly great in rural areas. These voltage fluctuations are due to a shortage of generating capacity during peak periods; in order to stretch available capacity, voltages are reduced. In addition, power outages are also widespread, including both planned and unplanned outages. Planned outages (called "rostering") generally involve cutting power to large customers, usually with several hours advance notice.

These power quality and reliability problems impede efficiency measures in several ways. First, some equipment operates less efficiently at low voltages. For example, rectifiers used in chlor-alkali plants use 1-4% more energy at low voltage than at normal voltage (NPC, 1991).

Second, some efficient equipment cannot be used at low voltages. For example, high pressure sodium lamps do not operate at very low voltages. As a result, in rural areas where low voltages are common, the penetration of high pressure sodium lamps for streetlighting and other purposes is limited.

Third, due to voltage variability, electrical components must be made more robust, and more robust components are often less efficient. For example, in designing fractional horsepower motors for refrigerators, manufacturers are compelled to trade off efficiency for improved reliability at low voltage (NPC, 1991). Even where designing equipment to withstand wide voltage fluctuations does not hurt efficiency, it can add to costs. For example, electronic ballasts can be designed to withstand large voltage variation, but the resulting designs are likely to be more expensive than designs for a stable voltage environment.

Fourth, to deal with low voltages, some end-users oversize equipment. For example, a pumping load may require a 5 hp motor under normal voltage conditions, but under low voltage the 5 hp motor will not supply enough power to meet the load. Therefore the user selects a 10 hp pump which can lead to extra energy use if pump operating hours are not cut in half or if inefficient speed controls are used to slow down the motor during periods of full voltage.

Fifth, power stabilizers (voltage regulators) are often used by end-users to reduce voltage fluctuations at individual pieces of equipment, but these stabilizers consume energy.

Sixth, some industrial managers do not take conservation actions for fear that reductions in use will lead to a reduction in their electricity quota. Under rostering programs, large customers are often given a quota for the amount of power they can use during peak periods. If electricity use is reduced through conservation, the quota can be reduced as well. Thus, some industrial managers hold potential conservation measures in abeyance, saving these actions for some future time when the power they represent is needed elsewhere in the plant.

The solution to these problems, improved power quality and reliability, can likely be achieved only in the long-term as a result of many years of effort to bring electricity demand and supply into balance. One possible option for the short-term is to reward customers who implement significant conservation and load management actions by limiting the number of planned power outages they receive. For example, if a customer reduces electricity use by 30%, the customer could be exempt from planned outages.

**PROBLEMS WITH EQUIPMENT AND MATERIAL QUALITY**

While most measures have proven reliable in use, there have been some problems. For example, electronic ballasts sold in India have unacceptably high failure rates (TERI, 1990b). To date these ballasts have been manufactured by small firms who have not worked out all the engineering details (two larger, established firms -- HMT and APR -- have recently announced plans to try to enter the electronic ballast business). Similar problems have been reported for energy-saving motor controllers (NPC, 1991).

In addition to problems with equipment failure, many types of electronic equipment now marketed in India suffer from other problems. For example, the electronic ballasts sold in India have a high harmonic content (they distort electric wave forms) and can cause radio frequency interference problems (they interfere with radio reception). Both of these problems have been solved in

somewhat to product cost. [illegible] solving these problems adds

The solution to these problems are improved engineering of products and improved quality control in the manufacturing process. Options to spur these improvements include increased manufacturer interest in these issues (for example, good quality control will be needed in order to take advantage of export opportunities), increased government attention to these issues (including direct government purchases of quality equipment and efforts by the Bureau of Indian Standards to develop standards for products for which no standard presently exists, such as electronic ballasts), and end-user education (on how to specify and recognize high quality products).

## THE SMALL-SCALE SECTOR

Small-scale manufacturers play a very important role in the Indian context. Many types of energy-using equipment are manufactured predominantly by small-scale companies, including ballasts, lighting fixtures, small electric motors and pumps, domestic fans, room air conditioners, and evaporative coolers. Small-scale companies often use manual assembly, and hence are an important source of employment for India's large workforce. Furthermore, small-scale companies are often well organized politically, and thus receive special protections from the government. For example, production of ballasts and lighting fixtures are largely reserved for the small-scale sector (exceptions mainly pertain to large firms who manufactured ballasts and fixtures before the regulations reserving these products to the small-scale sector went into effect).

India's reliance on the small-scale sector affects equipment efficiency in several ways. First, quality control is generally not very good in the small-scale sector, and energy efficiency usually suffers as a result. Rarely does a small-scale firm meet BIS standards. Second, small-scale firms compete primarily on

price. In an effort to minimize costs, efficiency considerations are generally ignored. Third, the organized sector (large-scale firms), in an effort to compete with the small scale sector on price, often scrimp on product quality and efficiency.

Options for dealing with these problems are several. First, technical assistance can be provided to small-scale firms to improve the quality and efficiency of their products. Experience in countries throughout the world indicates that as a country becomes more developed, consumers increasingly demand improved product quality. Thus, if small-scale firms want to remain competitive over the long-term, product quality will need to increase. Second, in cases where the small-scale sector cannot produce equipment of the efficiencies desired, allow the organized sector to enter the market. For example, while ballasts are generally reserved for the small-scale sector, it is very difficult for small scale firms to make reliable electronic ballasts. Thus, it makes a lot of sense to allow large firms to make electronic ballasts.

**AVERSION TO TAKING RISKS ASSOCIATED WITH NEW TECHNOLOGIES**

Most end-users are reluctant to invest in new technologies, until they have been proven to work in the local context. To the extent measures are unproven in India, most end-users will not adopt them. This problem can be addressed through demonstration projects on promising technologies, incentives for "early adopters" of promising technologies, and development and dissemination of case studies on successful installations of new technologies.

**BIAS TOWARDS VISIBLE PROJECTS**

Many facility managers and utility managers have a bias towards visible projects, such as a new advanced production line or a new power plant (Reddy, 1990). Efficiency projects are rarely large and showy -- instead efficiency projects are generally made up of many small measures which are not especially impressive to look at. Often, for example, the efficiency improvement may be hidden within

an existing piece of equipment. Furthermore, many efficiency measures do not involve hardware changes at all, but instead involve operational changes which are invisible to most observers.

This is not an easy problem to solve. What is required is to change the attitudes of managers so that the efficient use of resources is valued instead of the visible use of resources. This problem is common in many countries and is not unique to India. One option that is used by several companies in the U.S. is to provide year-end bonuses to industrial and utility executives based on progress made towards specified efficiency goals.

**USED EQUIPMENT MARKET DELAYS RETIREMENT OF INEFFICIENT EQUIPMENT**

In India there is a very extensive market in used equipment. Broken equipment is usually repaired, and is only retired when no further repairs are possible. The main concern in this market is how well equipment operates; efficiency considerations rarely enter the picture. Due to this market, equipment in India has a very long in-service life, which means that it will take many years for inefficient equipment to be retired.

There are several things that can be done to address this problem. First, efforts can target the new equipment market, since new equipment today becomes the used equipment of tomorrow. Saturation rates for many types of electrical equipment are growing rapidly, so that by 2005 the majority of equipment in place will be equipment produced during the 1991-2005 period. Second, programs can be offered to promote the early retirement of particularly inefficient pieces of equipment. For example, several utilities in the U.S. will buy inefficient appliances from customers, and then destroy the equipment so that it does not reenter the market. It costs these utilities less to buy and destroy the equipment than it costs to build power plants to service these inefficient loads (Nadel, 1991a).

## SHORTAGE OF SKILLED STAFF

A final constraint that hinders efficiency efforts in India is a shortage of skilled manpower to identify, install, and maintain efficiency measures. In particular there is a shortage of people who can take a systems approach to efficiency issues, meaning they examine the entire system and recommend the package of improvements that best optimizes the system as a whole. The number of engineers and technicians in India who are experienced in efficiency issues is small relative to the need for these people. For example, there is a shortage of experienced electrical technicians who can maintain variable speed drives (NPC, 1991). Likewise, skilled private sector energy auditors and efficiency consultants have been in short supply (Padmanabhan, 1991). Similar shortages exist in the areas of lighting design and industrial energy management. While training programs do exist, these efforts are generally small relative to the need.

In order to address this problem, training programs can be expanded, including classroom-based programs and in-the-field programs. Also, as demand for energy efficiency services grow, employment opportunities will grow, which provides a strong impetus for students to seek training in these areas.

## BARRIERS SPECIFIC TO INDIVIDUAL MEASURES

While many of the barriers discussed above apply to many different efficiency measures, for each efficiency measure only some barriers are of primary importance. In Table 4-2 we summarize which barriers apply to the individual efficiency measures examined in Chapter 3. This summary is based on an in-depth treatment of these issues prepared by NPC (1991) as part of this project. Readers desiring a detailed discussion on how specific barriers apply to specific efficiency measures should refer to the NPC report.

Table 4-2. Major Barriers to Adoption of 27 Conservation and Load Management Measures

| Measure | Lack of Info | High Cost | Low Electric Prices | Limited Capital and Foreign Currency | Hassles of Implement. Projects | Limited Avail. of Equip. & Raw Mat'l | Poor Power Quality and Reliabil. | Equip. and Material Quality | Small-Scale Sector | Risks of New Technol. | Bias Towards Visible Projects | Used Equip. Market | Shortage of Skilled Staff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Circular fluorescent lamps | X | X | X | | | X | X | | | X | X | | |
| Compact fluorescent lamp | X | X | X | X | | X | X | | | X | X | | |
| Incand. to fluor. fixture | | | X | | | | X | | | | X | | |
| TLD lamp | X | | | | | | X | | | X | X | | |
| Electronic ballast | | X | | X | | X | X | X | X | X | X | | |
| HPSV lamp & ballast | X | X | | | | | X | | | X | X | | |
| Motor rewinding, etc. | X | | | | X | | | X | | | X | X | X |
| High efficiency motors | X | X | | | X | X | | | X | X | X | X | |
| Multi-speed motors | X | X | | | X | | | | | | X | | X |
| Variable speed drives | X | X | | X | X | X | X | X | | X | | | X |
| Optimize industrial pumps | X | | | | X | | X | | | | X | X | X |
| Optimize industrial fans | X | | | | X | | X | | | | X | X | X |
| Air compressor O&M | X | | | | X | | | | | | X | | X |
| Centrif. refrig. compressor | X | X | | | X | | | | | | | | |
| Improved arc furnaces | | X | | X | | X | X | | | | | | |
| Membrane chlor-alk process | | X | | X | | X | X | | | | | | |
| Improved aluminum smelters | | X | | X | | X | X | | | | | | |
| Meter agricultural pumpsets | | X | X | | X | | | | | | X | | |
| Agrig pumpset rectification | X | X | X | | X | | | | | | X | | X |
| High effic. new pumpsets | X | X | X | | X | | X | | X | | X | X | X |
| Efficient evap. cooler | X | X | X | X | | X | | | X | | X | X | |
| Room A/C EER 9 | X | X | X | X | | X | | | X | | X | X | |
| Moderate effic. refrig. | X | X | X | X | | X | | | | | X | X | |
| High effic. refrigerator | X | X | X | X | | X | | | | | X | X | |
| More efficient fan | X | X | X | | | X | | | X | | X | X | |
| HVAC effic. improvements | X | X | | X | X | X | X | | | X | X | | X |
| Storage cooling | X | X | X | X | X | X | | | | X | | | X |

## DISCUSSION

The barriers to efficiency improvements are extensive, but for each barrier there are a variety of options to overcome the barrier. Significant efforts to overcome these barriers have already begun. In Chapter 5 we discuss many of these efforts. In Chapter 6, we discuss which of the many options discussed in this chapter should become priorities for implementation.

## Chapter 5

## REVIEW OF EXISTING POLICIES AND PROGRAMS RELATING TO ENERGY EFFICIENCY

### INTRODUCTION

This section provides an overview of various policies and programs relating to energy efficiency that exist currently in India. In addition, a number of new initiatives are discussed. The review covers policies and programs for all forms of energy and is not limited to just those dealing with electricity use -- mainly for two reasons. First, there are very few policies and programs that are related specifically to electricity end-use. Second, and more importantly, the experience with all such policies and programs, irrespective of the energy source, provides a useful background to the types of measures that have been adopted and implemented in India as well as insights and lessons for future policy directions.

This review outlines policies and programs of the government as well as efforts being undertaken by other agencies, organizations and institutions, such as state electricity boards, state energy development agencies, and financial institutions. We cover efforts to encourage energy conservation through various fiscal and non-fiscal measures and other provisions. The review is not intended to be exhaustive or comprehensive, since this was not possible within the constraints of the study; rather, the intent is to provide the reader with an adequate feel of the various dimensions and aspects of energy policies and programs in India.

The Department of Power functions as the nodal point for facilitating the implementation of a coordinated strategy on energy conservation. The thrust of the strategy being followed at present is on the promotion of energy conservation in energy-intensive sectors by assessing the efficiency of energy use through energy audits, fixing specific energy consumption targets and evolving action plans for reducing the level of energy consumption per unit

of production, and monitoring the targets. The strategy also promotes energy-savings measures and technologies through demonstration projects, fiscal incentives and setting performance standards for electrical equipment. The other important elements are undertaking studies to evaluate specific technical and policy options, training professionals to create a cadre of energy managers and auditors, and educating consumers through publicity campaigns to create mass awareness on the need and benefits of energy conservation (Department of Power, 1990).

The existing policies and programs can be categorized broadly into tax incentives and duty reliefs; schemes and subsidies for energy audits; schemes and subsidies for equipment finance; agricultural pumpset programs; equipment standards; research, development and demonstration programs; monitoring of energy consumption; training; and information dissemination. Brief descriptions of each of these follow.

## TAX INCENTIVES AND DUTY RELIEF

Four different types of tax incentive and duty relief schemes are presently used in India: income tax incentives, excise duty relief, customs duty relief, and sales tax relief. Each are discussed below:

### Income Tax Incentives

For certain specified energy saving devices and systems, 100% depreciation is allowed for income tax purposes. Specific items covered are listed in Table 5-1. As can be seen, most of the items do not pertain to electricity use, although a few electricity-saving items are listed including electric load monitoring systems, demand controllers, heat pumps, and electronic motor controls such as VSDs.

Available evidence indicates that these incentives have had only a marginal impact (Padmanabhan, 1991). The accelerated depreciation facility requires that the depreciation also be

charged in a company's balance sheet -- a very significant expense that can erode firm profits in the year the expense is charged. As a result, it appears that the incentive primarily is used by highly profitable firms who can afford to expense equipment in a single year. For example, a study by the National Council of Applied Economic Research (1987) of purchasers of eligible equipment found that only 25% of the 196 industries surveyed had used the accelerated depreciation facility.

**Excise Duty Relief**

A number of renewable energy devices are exempted from payment of excise duty. The particular devices covered are largely those listed in section H of Table 5-1.

**Customs Duty Relief**

A number of renewable energy devices are fully exempt from all customs duties. In addition, a number of energy-saving devices are partly exempted from customs duties. Specific equipment covered is listed in Table 5-2. As with the devices receiving income tax incentives, only a few electricity-saving devices are listed including heat pumps, load demand controllers, photocell controls for streetlights, and microprocesser controls for the aluminum and chlor-alkali industries.

**Sales Tax Relief**

Sales tax exemptions have been granted by various state governments and union territories for a number of different renewable energy and energy saving devices. A compilation of these concessions has been prepared by the Petroleum Conservation Research Association (undated). Devices receiving exemptions are generally a subset of the devices listed in Tables 5-1 and 5-2.

Table 5-1. Energy Saving Devices for Which 100% Depreciation is Allowed

A. Specialized boilers and furnaces
   1. Ignifluid/fluidized bed boilers
   2. Flameless furnaces
   3. Fluidized bed type heat treatment furnaces
   4. High efficiency boilers (thermal efficiency greater than 75 per cent in case of coal fired boilers and 80 per cent in case of oil/gas fired boilers)

B. Instrumentation and monitoring systems for monitoring energy flows
   1. Automatic electric load monitoring systems
   2. Digital heat loss meters
   3. Microprocessor based control systems
   4. Infra-red thermography
   5. Meters for measuring heat losses, furnace oil flow, steam flow; electric energy and power factor meters
   6. Maximum demand indicator and clamp-on power meters
   7. Exhaust gases analyzer
   8. Fuel oil pump test bench

C. Waste heat recovery equipments
   1. Economizers and feed water heaters
   2. Recuperators and air preheaters
   3. Heat pumps
   4. Thermal energy wheel for high and low temperature waste heat recovery

D. Cogeneration systems
   1. Back pressure pass out, controlled extraction, extraction-cum-condensing turbines for cogeneration along with pressure boilers
   2. Vapor absorption refrigeration systems
   3. Organic Rankine cycle power systems
   4. Low inlet pressure small steam turbines

E. Electrical equipment
   1. Shunt capacitors and synchronous condenser systems
   2. Automatic power cut off devices (relays) mounted on individual motors
   3. Automatic voltage controller
   4. Power factor controller for AC motors
   5. Solid state devices for controlling motor speeds
   6. Thermally energy-efficient stenters (which require 800 or less kilo calories of heat to evaporate one kilogram of water)

F. Burners
   1. 0 to 10 per cent excess air burners
   2. Emulsion burners
   3. Burners using air with high pre-heat temperature (> 300 °C)

Table 5-1 (continued)

G. Other equipment
   1. Wet air oxidation equipment for recovery of chemicals and heat
   2. Mechanical vapor recompressors
   3. Thin film evaporators
   4. Automatic micro-processor based load demand controllers
   5. Coal based producer gas plants
   6. Fluid drives and fluid couplings
   7. Turbo-chargers/super-chargers

H Renewable Energy Devices

   1. Flat plate solar collectors
   2. Concentrating and pipe type solar collectors
   3. Solar cookers
   4. Solar water heaters and systems
   5. Air/gas/fluid heating systems
   6. Solar crop driers and systems
   7. Solar refrigeration, cold storage and air-conditioning systems
   8. Solar stills and desalination systems
   9. Solar power generating systems
   10. Solar pumps based on solar-thermal and solar-photovoltaic conversion
   11. Solar-photovoltaic modules and panels for water pumping and other applications
   12. Wind mills and any specially designed devices which run on wind mills
   13. Any special devices including electric generators and pumps running on wind energy
   14. Bio-gas plants and bio-gas engines
   15. Electrically operated vehicles including battery-powered or fuel-cell-powered vehicles
   16. Agricultural and municipal waste conversion devices producing energy
   17. Equipment for utilizing ocean waste and thermal energy
   18. Machinery and plant used in the manufacture of any of the above items

Table 5-2. Energy Saving Equipment Exempted from Customs Duties

Wholly Exempted:

A. Solar energy equipment
   1. Black continuously plated solar selective coating sheets (in cut lengths or in coils), fins and tubes
   2. Vacuum tube solar collectors
   3. Concentrating solar collectors
   4. Stirling engine

B. Wind energy generation equipment
   1. Wind-operated electricity generators
   2. Wind-operated battery chargers

Partially Exempted:[1]

1. Flameless furnaces for reheating and heat treatment applications
2. High velocity recirculating furnaces for reheating and heat treatment applications
3. Low excess air burners (below 10% excess air)
4. Fuel oil emulsion burners
5. Regenerative burners for applications in forging and heat treatment furnaces
6. Self-recuperative burners (burners using pre-heated air)
7. Flat-flame burners
8. Heat pipes for extracting heat from low temperature fluids and gases
9. Heat pumps for space heating, water heating, cooling applications
10. Free ball bucket steam traps with no links/hinges
11. Automatic microprocessor based load demand controllers for efficient load management
12. Microprocessor based combustion control system for boilers
13. Light sensitive time switches for street light controls
14. Microprocessor based automatic anode over-potential controllers in caustic, chlorine and aluminum industries
15. Microprocessor based universal programmable timers for continuous and batch processes, such as in tire industry and rayon industry
16. Heat recovery system imported by cooperative dairy plants
17. Machinery for the manufacture of instruments, appliances or equipments which function with the aid of non-conventional forms of energy

In addition, all the items exempted from payment of excise duty are also exempted from the whole of the additional customs duty.

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[1] These items are exempted from payment of customs duty in excess of 35 per cent ad valorem and the whole of the additional customs duty. Customs duties levied on imports are basic or standard duty, auxiliary duty, and additional or countervailing duty. Each of these is specified separately.

## ENERGY AUDITS

### Energy Audit Programs

The Department of Power funds energy audit studies in industrial and commercial units which are carried out by consultants. Up to 1989/90, energy audits (preliminary and detailed) were completed in 140 industrial units and 3 government buildings. New audits were initiated in 10 industrial units and 6 residential/commercial buildings in 1989/90. Follow-up action on the measures suggested in the earlier energy audit reports was pursued with the concerned organizations (Department of Power, 1990).

An energy audit and conservation project financed by the Government of India and the United Nations Development Program (UNDP) was initiated in 1989/90 by the Department of Power. Under this three-year project, which is being managed by the Energy Management Centre, four energy audit buses have been deployed for undertaking comprehensive energy audit studies in the industrial, transport, commercial and residential sectors. Within the industrial sector, the sub-sectors that have been specified are paper, textiles, chemicals and pharmaceuticals, food and food processing, glass and ceramics, engineering, and the small-scale sector. The buses are fully equipped with measuring instruments and data processing facilities and are being operated by regional organizations (lead agencies) in four different regions in the country.

The expected outputs of the project are:

- Reports on technical and policy standards for national conservation activities, and evaluation of institutional and legislative energy conservation frameworks in other nations;
- energy audit training manuals for each sector;
- 45 energy conservation audit reports covering 35 units in manufacturing, 5 in transport, and 5 in the residential/commercial sectors;
- study tours, fellowships, technical seminars, and a national energy conservation workshop (Department of Power, 1990; Energy Management Centre, 1990a).

Another energy audit bus program, financed by the Government of India and the Commission of European Communities, was recently initiated by the Department of Power. Three buses are being operated by lead organizations in different regions under this three-year program which is also being managed by the Energy Management Centre. Initially, the operation of the buses will be subsidized but the aim is to eventually become fully self-supporting (Energy Management Centre, 1990b).

Some State Electricity Boards also provide energy audit services, especially to industrial consumers. For example, the Gujarat Electricity Board formed an Energy Conservation Cell in 1982 and has since carried out preliminary walk-through audits in over 150 units (Lele and Raval, 1990; Lele, 1991).

The Petroleum Conservation Research Association (PCRA) provides free energy audit and energy consulting services to industrial users. Preliminary audits are conducted for users consuming more than 1,000 tons oil equivalent (TOE) annually (of all forms of energy, but with petroleum products being the major share). About 40-45 such audits are conducted every year, and so far about 150 audits have been done. For industries consuming about 250-1,000 kilolitres of oil per year, a diagnostic study/survey is carried out. About 2,300 such surveys have been done so far, and 200-225 surveys are done annually. Services are also provided to even smaller users, consuming about 100-250 kilolitres per year, but only housekeeping types of measures are considered. About 200 such studies are done every year, and more than 1200 have been completed so far (Bhatnagar, 1991).

**Subsidies For Energy Audits**

At the national level, two energy audit subsidy schemes are in operation. These schemes are administered by the Industrial Development Bank of India (IDBI) and the Petroleum Conservation Research Association (PCRA).

The Energy Audit Subsidy (EAS) scheme of the IDBI was launched in June, 1988. Under this scheme, assistance is available to financially sound industrial undertakings which have been in operation for at least five years. Subsidies cover up to 50% of the cost of preliminary and detailed energy audits. The maximum subsidy available for a preliminary audit is Rs. 10,000 or 0.01% of the company's gross fixed assets, whichever is lower. For a detailed audit, the limit is Rs. 100,000 or 0.05% of gross fixed assets, whichever is lower. The energy audit must be carried out by NPC, PCRA, one of the Technical Consultancy Organizations promoted by the national financial institutions, or an approved energy consultant on the panel of IDBI (IDBI, undated).

As of January, 1991, 166 proposals for energy audits, both preliminary and detailed, of 140 companies had been sanctioned under this scheme by IDBI for a total amount of Rs. 3.82 million. Of this, Rs. 2.15 million had been disbursed for 96 audits in 77 companies (Subramanian and Anantapadmanabhan, 1991).

The PCRA scheme offers subsidies up to 50% of the cost of conducting an energy audit subject to a maximum amount of Rs. 25,000 per industrial unit. The study must be carried out by an energy audit consultant approved by PCRA. The subsidy is payable after acceptance of the energy audit report by the industrial unit and PCRA, and subject to a written commitment by the industrial unit to implement recommendations that will result in realization of 50% or more of the energy savings potential identified in the report (PCRA, undated). However, only 3-4 audits have been conducted so far under this scheme. The program has not yet reached the stage where PCRA has monitored the implementation of recommended measures and realization of the 50% of the potential savings target (Bhatnagar, 1991).

Subsidy schemes for energy audits are also in operation at the state level. For example, the Gujarat Energy Development Agency (GEDA) operates an Energy Audit Study Subsidy Scheme under which

50% of the cost of the energy audit study up to a maximum of Rs. 20,000 is provided as a subsidy (Pandya, 1991). The scheme, which includes industries, offices, hotels, shopping complexes, hospitals, institutions, and hostels, was launched in 1983 and expanded in 1986 to cover medium and small-scale industries.

Over 60 industries have so far been audited under GEDA's scheme. A recent survey of industries audited under the scheme showed that most units had implemented short-term measures which required little or no investment and could be implemented immediately. The main reasons for not implementing energy conservation measures were financial constraints and, in some cases, complexity of plant. To make the scheme more effective, GEDA is considering certain modifications to provide for post-audit monitoring of energy consumption over a period of 3-12 months to study the results of energy conservation measures implemented by the units (Pandya, 1991).

Similar schemes are operated also by state level energy development agencies in some other states, such as Maharashtra.

**SUBSIDIES FOR EQUIPMENT FINANCE**

Subsidies for equipment finance are available under a number of schemes whose details are given below.

The Equipment Finance for Energy Conservation (EFEC) scheme of IDBI was launched together with the Energy Audit Subsidy scheme in June, 1988. This scheme is handled by IDBI jointly with the Industrial Finance Corporation of India (IFCI) and the Industrial Credit and Investment Corporation of India (ICICI). Under the scheme, financial assistance is available to financially sound industrial undertakings which have been in operation for at least five years. The assistance is in the form of reduced interest loans for installation of equipment for effecting energy conservation including plant and machinery, miscellaneous fixed assets, erection and installation charges, technical know-how fees,

and fees for designs and drawings. However, the assistance is available only for installation of equipment affecting energy conservation in existing plants/processes and not for expansion or diversification of production capacities even though these may result in energy conservation (IDBI, undated).

An energy audit (preliminary and detailed) is a pre-requisite for applying for assistance under the scheme. The assistance is limited to 90% of the cost of the project subject to a maximum of Rs. 50 million, or 5% of gross fixed assets of the company, whichever is lower. The loan carries an interest rate of 15% with a rebate in interest linked to the amount of energy savings actually achieved on a sustainable basis by the project. A rebate of 2% in the interest rate is allowed if the savings due to the scheme are more than 10% of the average specific energy consumption for the last three years. For energy savings between 5-10%, a 1% rebate is allowed. The rebate on the interest amount due in a particular quarter is based on the savings achieved in the previous quarter.

The loan recipient's contribution is required to be a minimum of 10% of the cost of the project. The portion of the energy audit cost borne by the loan recipient is also treated as part of the recipient's contribution. Repayment of the loan begins after two years and must be completed in three years thereafter -- a total of 12 quarterly installments. At the option of the borrower, interest can be funded for a period of two years on a simple interest basis, with repayment of funded interest spread over the five year period.

As of January, 1991, 14 proposals from 13 companies had been sanctioned under this scheme for a total amount of Rs. 491.8 million, of which IDBI's share was Rs. 282.0 million. Of this, Rs. 158.4 million had been disbursed by IDBI for 11 schemes in 10 companies. The total project cost of the 14 sanctioned proposals was Rs. 602.5 million (Subramanian and Anantapadmanabhan, 1991).

Until the end of 1990, financial assistance for energy conservation projects was also available from financial institutions at concessional terms under their Soft Loan Scheme for Modernization under which term loans up to an overall limit of Rs. 50 million at a reduced interest rate of 11.5% were available. An analysis by IDBI indicates that out of about Rs. 8,250 million sanctioned under this scheme during the period from June, 1989 to December, 1990, about Rs. 1,170 million was for what could be considered energy conservation schemes (Subramanian and Anantapadmanabhan, 1991). This could perhaps be one reason for the somewhat poor response to the EFEC scheme.

A boiler modernization scheme is operated by PCRA under which soft loans are provided for replacement of existing, inefficient oil-fired boilers of up to 50 tons/hour capacity by new efficient boilers having efficiency of 80% or greater for oil and 75% or greater for coal boilers. The loan interest rate is 11.5-12% with repayment in 3-5 years (PCRA, undated). Under this scheme, 62 boilers had been replaced as of March, 1991 (Bhatnagar, 1991).

At the state level too, similar schemes are in operation in some states. For example, the Gujarat State Financial Corporation (GSFC) offers loans for modernization including energy conservation equipment at reduced interest rates.

GEDA operates an Interest Subsidy Scheme under which it provides a subsidy on interest due on loans taken from government or government approved national and state level financial institutions such as scheduled banks, IFCI, IDBI, ICICI, and GSFC. The subsidy is either a 6% interest rate, or half of the rate customarily charged by the participating financial institution, whichever is less. The subsidy is for a period of 2 years with a maximum interest subsidy of Rs. 50,000, i.e. Rs. 25,000 per year (Pandya, 1991).

The Department of Non-Conventional Energy Sources provides a subsidy for specified solar thermal systems and devices for installation in solar thermal extension programs. For solar water heating, air heating, and desalination systems, and solar timber kilns and dryers, a subsidy of 50% is available to government public sector enterprises and 33-1/3% to private sector industrial units.

The financial institutions also provide loans at a concessional interest rate of 12.5% for projects which involve the manufacture and installation of renewable energy systems and also for purchases of renewable energy devices. The items eligible under this scheme are similar those listed in Section H of Table 5-1.

**AGRICULTURAL PUMPSETS**

Rectification of electric pumpsets is being carried out by many State Electricity Boards with funding from the Department of Power and the Rural Electrification Corporation. Some State Energy Development Agencies, e.g. GEDA, are also funding rectification programs. The Petroleum Conservation Research Association also funds rectification of diesel pumpsets by selected state agencies (Bhatnagar, 1991).

A program for rectification of 25,000 electric pumpsets was initiated in 1985/86 (Department of Power, 1986). Another demonstration scheme for rectification of 15,000 pumpsets in the states of Haryana, Madhya Pradesh and Gujarat was implemented beginning in 1987/88 (Department of Power, 1988). In 1988/89, demonstration projects for partial rectification of 20,000 pumpsets and complete rectification of 500 pumpsets were begun (Department of Power, 1989).

The Rural Electrification Corporation (REC) provides financing to State Electricity Boards for rectification of electric pumpsets in REC project areas under its Energy Conservation Program. During

1989/90, about 22,000 pumpsets were rectified under this program (Rural Electrification Corporation, 1990). REC is also providing professional guidance to farmers about the installation of energy efficient pumping systems, and certifying the efficiency of pumpsets installed in eight states covering 80,000 new agricultural pumpsets (Department of Power, 1989).

The National Bank for Agricultural and Rural Development (NABARD) has been asked to formulate measures to ensure that bank loans are given only for installation of those pumping systems which conform to standard specifications (Department of Power, 1987). State governments have been advised to ensure that power connections are given only for pumpsets which conform to standard specifications (Department of Power, 1988).

PCRA's rectification activities were started in 1983/84. About 3,700 diesel pumpsets have been rectified to date; currently, about 1,100-1.200 pumpsets are being covered every year (Bhatnagar, 1991).

**EQUIPMENT STANDARDS**

A concerted effort to review existing standards with energy efficiency aspects was initiated by the Bureau of Indian Standards (BIS) following the establishment of a Coordination Cell for Energy Conservation in BIS in 1986. The work undertaken by BIS indicates that out of about 13,000 Indian Standards in force, about 200 deal directly with energy efficiency aspects. These standards are being examined to attempt, wherever possible, one or more of the following measures (BIS, 1987a):

- Upgrading existing limits on energy efficiency;
- Preparing system specifications and equipment selection guides;
- Marking/labelling of energy efficiency or energy consumption parameters on the equipment nameplate;

- Introducing mandatory certification;
- Developing standards in new areas.

Indian standards which contain provisions dealing with energy generally stipulate one or more of the following -- maximum energy consumption, minimum efficiency, maximum energy losses, or other criteria which have a direct or indirect bearing on energy consumption. There are a large number of standards in areas that indirectly aid energy conservation. Also, apart from product specifications, there are other types of standards which can also help to achieve energy efficiency. These include:

- Guidelines on selection of energy efficient equipment;
- Guidelines for system design and proper matching of components;
- Codes of practice for proper equipment installation and maintenance.

A brief review of energy related provisions in Indian standards for various electrical equipment follows (BIS, 1987a; BIS, 1987b). All of these standards are voluntary. Products that comply with the standards receive BIS certification. Non-complying products can also be sold, but without BIS certification.

**Motors**

The standards for induction motors specify the minimum value of the product of efficiency and power factor for motors of different sizes and also include a provision to mark energy consumption on the rating plate. A new standard for energy efficient motors was issued in 1989 which lays down minimum efficiency values for motors up to 37 kW.

**Agricultural Pumps**

Standards for pumpsets for agricultural purposes specify the pump efficiency; these values are increased periodically. Recognizing the need for proper sizing and matching of all components of the

entire pumping system, a standard on recommended pumping system design practices was issued in 1984 and later revised.

## Lighting Equipment

Standards for tungsten filament general service lamps, tubular fluorescent lamps and high pressure mercury vapor lamps specify the minimum rated lumen output and the maximum electricity consumption in watts. There is also a provision for marking of the rated wattage. Standards for slim diameter fluorescent tubes, mercury blended light lamps, halogen lamps, and electronic ballasts are under development. A code of practice for interior illumination provides guidelines on the choice of light sources and the most-economic designs will also consider the optimum illumination levels necessary for different occupancies and tasks. An Illumination Engineering Handbook covering good lighting engineering practice is currently under preparation.

## Residential Sector Equipment

Six standards cover fans. Of these, three standards -- for ceiling, table and pedestal fans -- specify minimum limits of air delivery and the service value, defined as air delivery per unit watt of electricity consumption, as a function of fan size. These types of fans account for the vast majority of electric fans. Three other standards -- for ventilating, air circulating and railway carriage fans -- specify maximum electricity input and minimum air delivery. The standards also stipulate the power factor of the fan, and require the electrical input in watts to be marked on the nameplate.

The standard for evaporative desert coolers covers air delivery and cooling efficiency requirements and specifies maximum power consumption limits. It also covers tests for verifying the parameters declared. An amendment to the standard for room air conditioners was issued in 1987 specifying the maximum power consumption for different capacity ratings and requiring that the rate of energy consumption be declared on the name plate.

The standard for domestic refrigerators was amended in 1987 to stipulate the maximum energy consumption over a 24 hour period under standard test conditions and to require that this value be marked on the name plate.

For some electrical appliances such as hot plates, kettles and jugs, water boilers, and coffee percolators, the standards specify minimum thermal efficiency limits. For stationary storage-type electric water heaters, the standard specifies maximum standing losses per day. The rated electrical input must be marked on the nameplate. Additionally, other performance parameters such as mean water output temperature, time to heat water, etc. are required to be marked on the nameplate or given in the instructions accompanying the water heater. The standard also gives recommended electric input rating values for various capacities of stationary storage-type electric water heaters.

Standards for monochrome and color television sets specify maximum power consumption.

### Other Standards

The standards for transformers limit maximum losses under no-load and full-load conditions. Another standard provides guidance on proper selection and use of shunt capacitors to improve the power factor of electrical equipment for low and medium voltage installations.

## RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAMS

A number of organizations conduct R,D&D programs and projects. In this section a few examples are described.

The Tata Energy Research Institute (TERI) is a private sector research organization founded in 1974 with financial support from the Tata companies. TERI conducts research on eight broad fronts: energy policy and planning; rural energy; forestry; renewable

energy technologies; energy conservation; biotechnology; computer applications; and training and information dissemination. Over the years TERI has conducted extensive research on electricity use patterns and conservation opportunities in India including studies on domestic appliances, lighting, and electricity pricing (TERI, 1991c).

The Petroleum Conservation Research Association, in addition to the energy audit programs described previously, conducts studies on fuel oil conservation in the industrial and transport sectors. It also has an R&D program to develop fuel-efficient devices and additives. Examples of R&D projects include successful efforts to develop improved kerosene and LPG stoves. PCRA is funded by a small tax on the Indian petroleum industry.

Research studies on technical and policy issues related to energy efficiency are also regularly conducted by NPC including work for the Government of India, World Bank, and bilateral donor agencies.

Energy efficiency demonstration projects have been initiated by the Department of Power. For example, a number of demonstration projects on energy conservation methods and technologies were conducted in 1989/90. These include a model project in a cement plant, three projects on rectification of inefficient agricultural pumpsets, two systems improvement projects in electricity distribution networks, a project on development of fuel-efficient bus-bodies and chassis, six projects on energy conservation through solar water heating, and a project to evaluate the performance of new electrical equipment such as electric meters, street light controllers and electronic chokes (Department of Power, 1990).

An innovative scheme conceived by the United States Agency for International Development (USAID) was begun in 1987 to provide funds for supporting technology innovation and development. This scheme, called Program for Acceleration of Commercial Energy

Research (PACER), is being implemented by the Industrial Credit and Investment Corporation of India (ICICI) (PACER Secretariat, 1990).

PACER promoted the development of goal-oriented and market-responsive technological innovations in the Indian energy sector through financial assistance to consortia of manufacturers, research institutions and/or end-users. It provides promotional assistance and finance in the form of a conditional grant for meeting part of the project cost which will absorb some risk inherent in technology development. If the project succeeds, the promoters repay twice the grant; if it fails, the grant is written off. The liability for payment occurs when the technology is commercialized.

Currently, thirteen consortia R&D projects and nine research studies have been approved. These cover product/process development in energy conservation, power generation through renewable sources of energy, and supporting analytical studies on management and policy in the Indian power/energy sector (Seshadri, 1991).

## MONITORING OF ENERGY CONSUMPTION

To ensure efficient use of energy in the major energy consuming sectors of the economy, periodical monitoring of energy consumption in these sectors vis-a-vis desirable national and international norms is being done by the Energy Conservation Cell in the Department of Power. Specific energy consumption targets for certain energy intensive industrial units are laid down and their performance monitored and reviewed. It is intended to achieve 5% reduction in specific energy consumption by 1989/90, 15% by 1994/95 and 30% reduction by 1999/2000 with reference to the specific energy consumption level for 1987/88 (Department of Power, 1989 and 1990).

**TRAINING**

Training programs for industrial personnel are being conducted by many government and private organizations. Many of these are organized with the financial support and sponsorship of the government through the Department of Power, Department of Personnel and Training, and the Energy Management Centre. For example, training programs initiated/conducted by the Department of Power in 1989/90 included 10 training programs on energy audit and energy conservation for industrial personnel, 5 training courses for cement industry personnel, and a one-week training program on industrial energy management for senior managers/engineers (Department of Power, 1990).

In the agricultural sector, the Rural Electrification Corporation has been funded by the Department of Power to provide training and guidance regarding energy conservation in agricultural pumpsets to officers and field level functionaries of State Electricity Boards, Agricultural Departments of State Governments, and banks (Department of Power, 1988 and 1990).

A project has been undertaken by the Department of Power for preparation of a document on education and training needs in the energy sector (Department of Power, 1990).

Other major training efforts are conducted by the National Productivity Council (NPC). NPC conducts over 700 training courses and seminars each year, of which a significant portion are on energy efficiency issues. Most of these efforts target industrial personnel. Funding for these efforts has come from the Energy Management Centre, the Industrial Development Bank of India (IDBI), and the Petroleum Conservation Research Association (PCRA). In addition to these short-duration training efforts, NPC sponsors a two-year (post) graduate training program on Energy Management for engineers.

## INFORMATION DISSEMINATION

Information dissemination in the form of publications, brochures, posters, stickers and other publicity to create mass awareness on the need for and benefits of energy conservation are being carried out by many government departments and organizations such as the Department of Power, Energy Management Centre, Petroleum Conservation Research Association, Department of Coal, State Electricity Boards, industry associations, and private organizations. Media campaigns and advertisements in newspapers, magazines, radio and television have also been organized. Apart from these direct activities, campaigns have also been conducted by the Department of Power through other organizations such as the Bureau of Indian Standards, the Railways, the Development Commissioner (Small Scale Industries) and the Confederation of Engineering Industry (Department of Power, 1989).

Several organizations publish journals reporting on energy efficiency issues. Prominent examples include the *Energy Management Journal* (published by NPC), *TIDE* and *Energy Policy Issues* (both published by TERI). In addition, NPC, TERI, and PCRA publish many research and policy reports on energy efficiency issues.

A National Energy Conservation Week was organized during February, 1989 (Department of Power, 1989). In 1989/90, 12 states were sanctioned funds by the Department of Power to organize Energy Conservation Weeks in major cities (Department of Power, 1990).

## NEW INITIATIVES

In addition to the many on-going activities discussed above, a number of new initiatives currently in the planning and start-up stages also deserve mention.

Perhaps most prominent of these new initiatives is the Industrial Energy Conservation Project now being planned by the Government of

India, the World Bank, and bilateral donor agencies. Under the project, the World Bank will loan approximately $250 million in foreign currency to IDBI and ICICI. Approximately the same amount of funds, in local currency, will be provided by IDBI, ICICI, and Indian government agencies and institutions. Additional grant funds will be provided by bilateral donor agencies from the U.S. and Europe. The majority of funds will be used to finance energy conservation improvements in Indian industries, at subsidized interest rates. Some funds will be used to finance customs duty reductions on energy-saving equipment and to fund technical assistance and institutional development work designed to further energy efficiency policy in India (World Bank, 1990).

A start-up initiative that has the potential to have a major role in promoting energy efficiency initiatives in India is the Energy Management Centre (EMC). EMC is a semi-autonomous agency within the Department of Power that was formed in 1989 with the support of the European Economic Community. EMC was established to provide an overall strategic vision, supported by quantitative analysis, of what needs to be done to improve energy efficiency in the Indian economy (EMC, 1989). In some ways, EMC is envisioned as an organization which will help coordinate the activities of the many organizations working on energy efficiency issues in India.

The Energy Management Consultation and Training (EMCAT) project is a $20 million grant provided by USAID to the Government of India for a six year period. The project has two components: improving the efficiency of India's electric power generation, transmission, and distribution system; and improving end-use efficiency in India. Funds will be used for training, technical assistance, studies, and purchase of equipment. Project activities will include work in power sector investment planning, private sector energy consulting, loan portfolio design, information dissemination, and policy dialogue. Work on the power supply component will be directed by the Power Finance Corporation, while work on the end-use efficiency component will be directed by IDBI (USAID, 1990).

The Bombay Efficient Lighting Large-Scale Experiment Project (BELLE) is a joint effort of Bombay Electric Supply and Transport (BEST -- a local electric distribution company), Philips India (a lighting manufacturer), and the Indira Gandhi Institute of Development Research (IGIDR). A major problem which hinders the use of compact fluorescent lamps in India is their high initial cost. BELLE will seek to overcome this barrier by leasing compact fluorescent light bulbs to domestic customers in Bombay for approximately Rs. 4.50/month -- less than the value of the monthly electricity savings provided by the bulbs. The lease payments will be sufficient to pay off the cost of the bulbs in four years. The program is modeled after similar programs in the U.S. and will be the first hardware-oriented electricity conservation program in India that targets the domestic customer class (Gadgil, 1990).

Lighting energy savings are also being addressed by another initiative -- a taskforce on lighting issues formed by the Department of Power. The taskforce, which includes government and private sector representatives, is developing recommendations to promote lighting efficiency in India. Among the options being discussed are efforts to promote compact fluorescent lamps and electronic ballasts, and programs to improve the efficiency of street lights and lighting systems in government buildings (Mamak, 1990).

## DISCUSSION

Indian organizations have launched a substantial number of efforts to improve energy efficiency, and additional promising efforts are in the planning and start-up stages. These efforts have probably had some impact on energy consumption patterns in India, but perhaps more importantly, they provide an important foundation upon which to build much larger efforts. In the next chapter we provide some recommendations on high priority initiatives that can build on existing efforts and provide dramatically increased energy savings.

# Chapter 6

# POLICY RECOMMENDATIONS

## INTRODUCTION

Preceding chapters have discussed opportunities to improve efficiency in India, barriers to efficiency improvements, and program and policy efforts to date that seek to overcome the barriers and achieve efficiency improvements. In addition, research was conducted on electricity conservation efforts in other countries, both developing and developed (the results of this research is summarized in Appendix B). This chapter draws all these different pieces of information together, and recommends several policy initiatives that could help India to achieve a substantial share of the available efficiency opportunities.

In making our recommendations, we have not developed a long "laundry list" of detailed program and policy recommendations. Such lists have been compiled in India before, and we do not seek to replicate them. Instead, we choose to concentrate our analysis and recommendations on a few initiatives that could have a dramatic effect on the level of efficiency investment in India.

## SUMMARY OF RECOMMENDATIONS

Based on the analysis of where major efficiency opportunities lie, and based on the experience in other countries, we have four principal recommendations to suggest -- recommendations that build upon the substantial amount of work to promote efficiency that has already taken place in India. These recommendations are as follows:

1. Prepare and implement "least-cost" plans.

2. Expand efforts to promote the production of high efficiency technologies in India, including advanced technologies.

3. Expand existing programs and start new programs to improve the efficiency of agricultural pumps, lighting systems, and industrial facilities.



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4. Implement institutional modifications to increase the priority accorded electricity conservation efforts and to improve the coordination of these efforts.

Each of these recommendations, and the rationale for each of these recommendations, is discussed below. We also discuss several suggestions that fall under these four headings.

**PREPARE AND IMPLEMENT LEAST-COST PLANS**

In most of the world, including India, utilities concentrate on building new power plants, and limit conservation activities to public education efforts. However, as discussed in Chapter 3, investments in conservation and load management measures are usually less expensive per kW than new power plants. In order to decide the best mix of new power plants and conservation and load management programs to pursue, many utilities in the U.S., as well as other countries, are conducting a "least-cost planning process."

Least-cost utility planning (LCUP) is a planning process that many electric utilities go through in order to determine the best mix of new power resources (e.g., new power plants and conservation programs) which can be used to meet future power requirements at the lowest possible cost. A LCUP process consists of several steps:

1. Develop a forecast of future electricity needs.

2. Examine the costs and amount of power available from different options for improving power availability, including new power plants (coal, hydro, natural gas, and renewable energy), improvements to existing power plants and transmission lines, and electricity conservation and load management programs.

3. Rank the different options in terms of cost per unit of energy generated or saved (including all operating costs over the project's lifetime).

4. Beginning with the least-expensive projects first, continue down the list until enough projects are included to meet projected future needs.

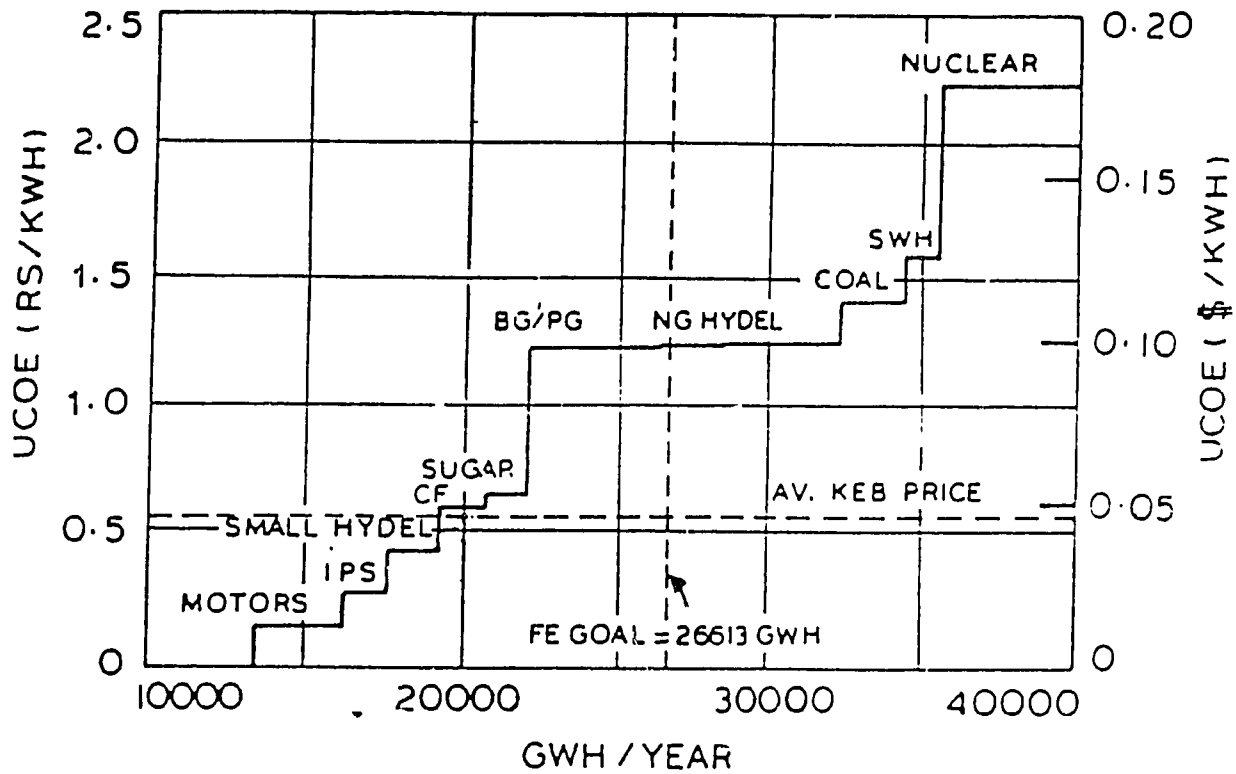
5. Change a few key assumptions, such as fuel prices and the rate of peak demand growth, to see if the ranking of projects changes significantly when key assumptions are changed. If this is the case, develop a new "least-cost" list of those projects that are most likely to have low costs under a wide variety of different assumptions.

Least-cost utility planning is most widely used in the U.S., but in recent years, LCUP has begun to be practiced in Canada, Australia, and Sweden. LCUP efforts have also begun in other European countries, and in Costa Rica, Jamaica, Malaysia and Thailand.

In India, a group of analysts have developed a least-cost plan for the state of Karnataka (Reddy et al., 1991). The planners examined a variety of demand and supply options including energy-efficient motors, improved pumpsets (IPS), compact fluorescent bulbs (CF), solar water heaters, cogeneration from bagasse in sugar factories, biogas- and producer-gas-based generation sets, small hydel (hydro) plants, large hydel plants, and centralized natural gas, coal, and nuclear generating stations. The different options were ranked in terms of cost per kWh, cost per kW, and the amount of electricity available from each option. A plan was then put together starting with the lowest cost option and continuing with higher cost options until sufficient sources were included to meet projected demand in 1999/2000. The least-cost plan included all of the conservation measures examined, as well as power generation from sugar, small hydel, biogas, producer-gas, and natural gas (see Figure 6-1). Relative to a plan previously prepared for the state of Karnataka which emphasized large-scale coal, hydel, and nuclear plants, the least-cost plan was projected to reduce capital costs over the planning period by approximately 60% (saving Rs. 15,000 crores [150 billion]), while providing greater rural electrification, irrigation, and employment.

The Karnataka least-cost plan has yet to be implemented, but in the U.S. many public-sector and private-sector electric utilities are both preparing and implementing least-cost plans. An example of one such plan is described in the case study on the next page.

Figure 6-1. Karnataka Least-Cost Supply Curve




This curve shows the cost of the different demand-side and supply-side options in Rs/kWh along the left axis, and the amount of energy available from each source along the bottom axis. Options are ranked in terms of Rs/kWh, starting with the lower left corner and continuing to the upper right corner. The new resources needed over the plan period are indicated by the dotted vertical line in the middle of the graph. Items to the left of this line are the items that were incorporated into the Karnataka least-cost plan.

In order to establish least-cost planning in India, some technical assistance might be needed from experts who have participated in previous least-cost planning processes. These experts are usually based overseas. Bilateral agencies can finance the work of these experts, as they work with Indian utility officials to prepare a least-cost plan. During this process, it is essential that most of the work be done by Indian officials -- the best way to learn least-cost planning is to immerse oneself in the process.

Initially, least-cost planning efforts should begin with a few State Electricity Boards and at the All-India level, probably under the auspices of the Central Electricity Authority (CEA). Only over time can all utilities be expected to undertake such a process. In the long-term, the Government of India, or multilateral financial institutions could require preparation of a least-cost plan, before providing financing for utility projects, be they power plants or conservation programs. Such a policy is now pursued by many states in the U.S.

As part of their least-cost planning processes, utilities will need to decide which conservation and load management programs are most suitable for India. Many of the different program approaches used in other countries are described in Appendix B. However, the best way to learn which programs are best for India is to conduct pilot programs. An example of such a pilot program -- the BELLE Project -- is described in Chapter 5. Other pilot programs using other approaches need to be undertaken throughout India in order to provide critical information on how best to promote conservation and load management in India.

Financing for these pilot programs, as well as for preparation of least-cost plans, can come from a number of sources including State Electric Board funds, the Power Finance Corporation (for example, end-use efficiency efforts are listed as an eligible activity in PFC's power plant modernization program), and bilateral donor agencies. For example the least-cost planning efforts in Costa Rica

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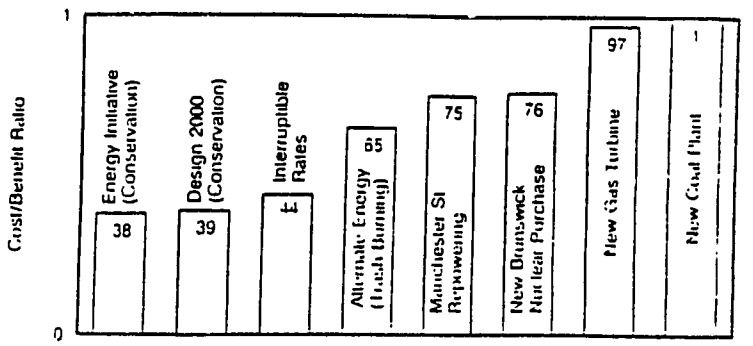
CASE STUDY: NEW ENGLAND ELECTRIC LEAST-COST PLANNING PROCESS

The New England Electric System (NEES) is a private electric company serving three states in the northeastern U.S. NEES has been preparing least-cost plans since the mid-1980's.

For its 1990 least-cost plan, NEES examined 69 options, including 11 new power plants, 7 opportunities to purchase power from other power companies, 11 cogeneration and alternative energy projects, 9 transmission line improvement projects, and 31 conservation and load management programs. As in the Karnataka study, most of the least-expensive power options were conservation programs (see figure below).

Projects were assessed for a basecase scenario and five alternative scenarios (e.g., a high growth scenario and a scenario with reduced natural gas availability). After examining the least-cost plan for each scenario, NEES selected the mix of power supply options that would best minimize costs across the range of scenarios. The chosen resource mix calls for 4,419 MW of additional power by 2008, of which 32% will come from conservation and load management programs, 28% will come from cogeneration and alternative energy facilities, 28% will come from new natural gas-fired power plants, and 12% will be purchased from a Canadian hydroelectric plant and other facilites.

As a result of this planning process, NEES expects to invest $600 million in conservation and load management programs over the 1990-99 period (1990 $), but compared to a strategy based only on building new high efficiency coal-fired power plants, the conservation and load management programs will save NEES $1 billion more than the programs will cost.




This figure summarizes the results of the economic analysis comparing different power supply and conservation options. A cost-benefit ratio less than 1.0 means an option is less expensive than a new coal plant

Source: NEES, 1990.

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and Thailand, mentioned above, are being funded in-part by U.S. and Canadian bilateral agencies.

**PROMOTE HIGH-EFFICIENCY TECHNOLOGIES IN INDIA**

Many of the efficiency measures with largest savings potential involve technologies that are routinely produced in some countries but not in India. Examples include circular fluorescent lamps; compact fluorescent lamps; improved efficiency refrigerators, air conditioners, evaporative coolers, and fan motors; and storage cooling systems. In addition, a few technologies that are produced in India could benefit from improvement. Examples include electronic ballasts (which suffer from quality control problems) and variable speed drives (where costs are high).

If these technologies are to realize their savings potential, a major effort needs to take place to promote the widespread production, availability, and use of these products. Components of such a strategy could include:

1. Research, development, and demonstration projects (RD&D) with an emphasis on technology adaptation (to adapt foreign technologies to the Indian market);

2. Technical and financial assistance to manufacturers so they can produce the equipment;

3. Selective reductions in import duties, both on the manufacturing equipment needed to produce products domestically, and on limited quantities of actual products, so that a sufficient market can be established to make domestic manufacture attractive;

4. Mandatory efficiency standards for selected equipment.

5. Purchases by government agencies and institutions.

Each of these components are discussed below.

## Research, Development, and Demonstration

Indian manufacturers, along with universities and government agencies, conduct some R&D to develop new products. However, it appears that efforts to improve equipment efficiency are not generally a high priority for R&D efforts. The Government of India, with support from bilateral donor agencies, should promote R&D to develop efficient technologies in India, with a particular focus on the measures with the largest opportunities for energy savings (listed above). In a program of this type, cost-sharing grants could be made to companies to fund R&D on targeted efficiency measures. The PACER project (described in Chapter 5), is a useful first step in this area, but greatly expanded efforts are needed.

In addition to funding standard research and development work, assistance should be provided to demonstrate and test equipment in the field. For example, quality control problems with electronic ballasts might have been avoided in India, if adequate attention had been paid to field-testing efforts. The usefulness of demonstrations and field testing is illustrated by the Brazilian experience with electronic ballasts, discussed in the case study on the next page.

Not all RD&D efforts need to take the form of cost-sharing grants. Other, creative approaches can also be tried. For example, as noted in Chapter 3, the government of Sweden recently held a competition asking manufacturers to submit bids for the most efficient refrigerator they could produce. The winning bidder received a guaranteed order for at least 500 refrigerators, plus a reward of $180-270 for each unit (Rs. 4,860 - 7,020). In addition, the winning manufacturer benefits from extensive publicity associated with the program. Several manufacturers submitted bids, with the winning bid including a unit with an energy consumption of 0.53 kWh per liter per year (approximately 85% more efficient than the typical unit built in India today) (Department of Energy Efficiency, 1991).

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CASE STUDY: DEVELOPMENT OF ELECTRONIC BALLASTS IN BRAZIL

In 1985, researchers at the University of Sao Paulo first studied the possibility of producing electronic ballasts in Brazil and conducted some experiments with different circuits. This project was funded by CESP, the Sao Paulo state utility. CESP then funded further development leading to production of about 50 prototype units in 1986-87. The goal was to use domestic components to the maximum degree and also to simplify the circuit design. Laboratory tests indicated that the performance of these prototypes was comparable to that of high-frequency electronic ballasts produced in industrialized countries.

In 1988, CESP attempted to transfer the technology to a private company. A manufacturer was selected to make 100 electronic ballasts for a demonstration project with help from the university researchers. The company (Begli) is a medium-sized manufacturer of electronic equipment. Subsequently, PROCEL (the national electricity conservation program) funded Begli to produce 350 units for a demonstration of electronic ballasts and reflective fixtures. These demonstration projects helped Begli to improve its fabrication process and improve product quality. The demonstrations were successful, and Begli began selling electronic ballasts on a limited scale for special applications (for example, high-security areas where an electronic ballast is preferred over a conventional ballast due to reduced risk of fire).

In 1990, Begli obtained the right to mass-produce electronic ballasts. In mid-year, the company began producing and marketing a full product line at attractive prices. Also, other ballast companies were considering purchasing electronic ballasts from Begli for resale.

This example shows the value of relying on researchers for early technology development but then working with a private company. Also, it shows the importance of slowly scaling up production, conducting demonstrations and field testing, and supporting R&D in a promising area for a number of years.

Source: Geller, 1991.

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While many RD&D efforts will involve the organized sector, with the intention of assisting with the RD&D needed to produce equipment for the first time in India, similar efforts should also be undertaken to assist small-scale industries to improve the efficiency of their equipment. As noted in Chapter 4, the efficiency of equipment in the small-scale sector often lags equipment efficiency in the organized sector. By assisting small-scale producers to produce more efficient equipment, they will be better able to compete with the organized sector over the long-term. Assistance can include training programs, technical publications and software, and customized technical assistance provided by industry experts.

**Technical and Financial Assistance to Manufacturers**

Along with R&D assistance, in some cases it will be useful to provide manufacturers with technical and financial assistance to build production lines for high efficiency equipment. Technical assistance can be provided by technical experts, including those in-country as well as those from overseas. Bilateral donor agencies can finance foreign technical experts, but fees for Indian technical experts may need to be subsidized by the Government of India.

In order to build new production lines, capital is needed. In some cases private firms have the requisite capital available, but in other cases, assistance with financing may be needed. In particular, in order to encourage manufacturers to produce efficient equipment, concessionary loans can be provided for selected projects that are critical in terms of reaching efficiency targets in India. Such loans could be provided by Indian development banks, using capital borrowed from the World and Asian Development Banks.

**Selective Reductions in Import Duties**

Many efficient products not presently produced in India are still subject to high import duties. For example, the import duty is

226% for compact fluorescent lamps (see Table 3-6). When import duties are this high, it is difficult to establish a market, and until a market is established, Indian manufacturers are reluctant to build domestic production facilities.

Similarly, import duties on efficient production equipment, and on equipment needed to produce efficient products, can also be quite high. For example, the import duty is 80% for membrane chlor-alkali equipment, and 63% for electric arc furnaces (see Table 3-6). These high duties on production equipment discourage Indian manufacturers from improving the efficiency of their production processes, and from starting up production lines for efficient products.

In order to address these problems, the Government of India should take two steps. First, duties for efficient products not produced in India should be lowered or eliminated for a limited period of time. This will allow a market to become established in India, providing a strong incentive for domestic production to begin. Second, duties should be reduced or eliminated for production equipment needed to improve the efficiency of production processes in India, or to produce efficient products domestically.

## Equipment Efficiency Standards

In several countries, including the U.S., Canada, and Taiwan, governments have required manufacturers to meet efficiency targets (some of these efforts are described in Appendix B). Standards are most commonly set for residential appliances (particularly refrigerators and air conditioners), but in the U.S. fluorescent ballast standards are in place as well. Standards can either take the form of laws that manufacturers must meet, or can take the form of agreements between manufacturers and the central government. The latter approach has been taken in Japan and Germany, and agreements are now being negotiated in Brazil (these efforts are also described in Appendix B).

In order to establish efficiency standards, standardized testing protocols must be established, and all equipment tested. In India, BIS has established testing protocols for many types of equipment. The next step would be to require manufacturers to test each model they produce, and to publish the information in a directory, and perhaps on a label which is placed on each model sold. In Brazil, such a testing and labeling program appears to have prompted several manufacturers to drop their least-efficient product lines and to introduce new higher-efficiency models (Geller, 1991). The final step in a standards program is to make achievement of specific efficiency levels mandatory.

In India, standards could be developed to require use of capacitors in ballasts and refrigerators (thereby improving power factor), and to require use of improved efficiency equipment. A likely first target for efficiency standards (as opposed to power factor standards) is refrigerators. The refrigerator population is growing very rapidly, so the next decade or so will be an ideal time to promote the most efficient equipment possible. Other likely targets are room air conditioners, evaporative coolers, ceiling fans, fluorescent lamps, electric motors and pumps, and clothes washing machines.

The Bureau of Indian Standards has extensive experience in equipment testing and standards development. However, BIS staff indicated in discussions with us that they prefer to limit their activity to voluntary stardards which include safety and quality concerns in addition to energy efficiency concerns. Therefore, a mandatory energy efficiency testing and efficiency standard program would probably need to be operated by another government agency within the Department of Power or the Department of the Environment, in close consultation with BIS.

### Purchases by Government Agencies and Institutions

Indian government agencies and institutions purchase a large quantity of energy-consuming equipment each year, including lighting systems, appliances, HVAC systems, and motors. These purchases probably amount to many millions of Rupees each year. If these government purchases were directed towards efficient equipment, it would provide a major market for energy-efficient products, thereby encouraging Indian industries to build and expand production lines, making efficient equipment more available to Indian consumers. A further benefit of such a policy would be to reduce the government's own electricity bill.

## EXPAND EFFICIENCY PROGRAMS IN HIGH PRIORITY AREAS

As was discussed in Chapter 3, many of the largest opportunties for saving electricity fall in three areas: agricultural pumping; lighting in all sectors: and efficiency improvements in the industrial sector. Therefore, we recommend that these three areas receive priority attention.

### Agricultural Efficiency Programs

Opportunities to improve pumping efficiency in the agricultural sector are very large, including metering of pumpset electricity use, recification of existing pumpsets, and use of only efficient equipment when new pumpsets are installed. Of the 20% reduction in kWh use that we estimate is possible by 2004/05, approximately 20% is from these three measures. A similar proportion of the available peak demand savings come from these measures (see Table 3-8).

#### *Rectification*

As was discussed in Chapter 5, the Rural Electrication Corporation operates a pump rectification program, as do a number of states and state electricity boards. However, the combined efforts of these different programs total perhaps 40,000 pumpsets each year. At this rate, it will be approximately 200 years before all existing

pumpsets are rectified, and given the growth rate in new, inefficient pumpsets, existing recification programs may never catch up to the need. Furthermore, many of these rectification programs focus only on foot-valves -- a very low cost measure that typically reduces pump energy use by 8-12% (NPC, 1991). As discussed in Chapter 3, 30-50% savings are possible with more extensive rectification.

Thus, while existing program efforts are an important step, these efforts need to be expanded many-fold in order to achieve even half of the cost-effective savings that are available. Accordingly, we recommend that the Rural Electrification Corporation, state governments, and State Electricity Boards (SEBs) undertake a massive program whose target is to rectify all existing pumpsets over a period of approximately 20 years. Such a program would need to serve approximately 400,000 pumpsets annually, at a cost of approximately Rs. 3,600 crores each year (Rs. 3.6 billion). However, since the capital cost of pumpset rectification is less than the cost of a new baseload power plant (see Chapter 3), savings would be significantly greater than the cost.

For SEBs, as discussed in Chapter 3, pump rectification programs are significantly less expensive than new power plants. Given the scale of such a program, it may be desirable to approach the World Bank and the Asian Development Bank for financing. Since SEBs now incur extensive losses on sales to the agricultural sector, reducing sales, and therefore reducing these losses, should be an attractive investment.

In order for a program of this scale to succeed, extensive efforts must be made to train new pump technicians in proper rectification procedures, and to train and educate farmers on how to install and operate pumps efficiently.

*Metering*

As discussed in Chapters 3 and 4, most agricultural pumps in India are not metered. Thus farmers have no incentive to improve the efficiency of their pumps, or to carefully manage pump usage. Experience in rental housing in the U.S. indicates that when meters are installed, consumption declines approximately 15%, assuming the same price levels as before. In chapter 3 we assumed savings of only one-third this level (5% savings), and still the cost per kWh saved was only Rs. 0.18.

The first step would be to conduct a pilot project to install meters on a limited number of pumps and evaluate the energy savings achieved. For this experiment, rates should be set so that with metering, the average farmer pays no more than he does at present -- efficient farmers would save money and only inefficient farmers would pay more. If the results show that substantial savings result, then meters should be installed on all agricultural pumps. One possible place to start is requiring meters on all new pumps. Over time meters can be installed on existing pumps. In India, most meters are purchased by end-users and not the utility. Given the extensive losses utilities now incur in the agriculture sector, and the likelihood that metering will reduce these costs, SEBs may want to purchase the meters and provide them to users -- according to our analysis in Chapter 3, a metering program would have a capital cost of under Rs. 5,000 per kW saved -- less than 25% of the cost of a new baseload power plant. Meters used for this program would need to be tamper-proof, in order to minimize theft of power.

*Standards for New Pumps*

The Bureau of Indian Standards (BIS) has established efficiency standards for pumps. These standards are voluntary -- manufacturers who meet the standards receive the BIS seal, but many pumps (perhaps as many as 50% -- NPC, 1989a) do not have the seal. As a first step, financial institutions which provide loans for pumpsets should issue loans only for pumpsets with the BIS seal.

Similarly, utilities could make BIS certification a condition for receiving low-cost electricity. In 1984, the National Bank for Agricultural and Rural Development issued such a requirement, but it appears that compliance is limited (NPC, 1989a). Banks and utilities should investigate procedures that would improve compliance. Furthermore, there is also considerable opportunity to gradually raise the efficiency levels needed for BIS certification. For example, NPC (1989a) found that there is an 8-15% efficiency difference between the most efficient pumps on the market and pumps that just meet BIS standards.

In addition to requiring BIS-certified pumps, the banks and utilities should require use of energy-efficient foot-valves, and low-friction supply and return pipes. For example, Punjab has required certain basic installation standards for all new tube wells (NPC, 1989a).

Finally, over the long-term, the Government of India should consider making BIS certification mandatory for all agricultural pumps. Mandatory certification would raise the efficiency of all pumps.

*Lighting Efficiency Programs*

Lighting efficiency measures account for approximately 25% of the available energy savings identified in chapter 3 and approximately 35% of the available demand savings (demand savings are higher since lights are likely to be in use during the 5-9 p.m. time period when demand usually peaks). Approximately 40% of the lighting peak savings are available from just one measure -- use of fluorescent fixtures instead of incandescent fixtures. Accordingly, extensive efforts should be made to encourage customers to install fluorescent fixtures instead of incandescent fixtures when new lighting systems are installed. An example of how this can be done is provided by Thailand. As part of rural electrification efforts, a special low rate is offered customers for the first few kWh -- just enough to operate two 20 watt

fluorescent lamps (Cherniak, 1990). As a result, approximately 80% of domestic lighting in Thailand is with fluorescent fixtures (Load Forecast Working Group, 1989). Another option to promote fluorescent fixtures is for SEBs to provide fluorescent fixtures to customers at subsidized prices. If fluorescent fixtures are provided to customers at the price of a typical incandescent fixture, the capital cost would be only Rs. 2,200/kW saved (see Table 3-5).

Lighting efficiency programs should not just be limited to fluorescent fixtures. Options for promoting the availability of circular fluorescent lamps, compact fluorescent lamps, and electronic ballasts were discussed previously. Once products are readily available, programs should be offered to promote their use. The BELLE project illustrates one possible approach. Other approaches are discussed in Appendix B. In addition two other programs worthy of pursuit are a major educational program on the advantages of TLD lamps and a program to convert inefficient incandescent public lighting fixtures to more efficient fluorescent and high pressure fixtures. Since TLD lamps cost no more than TL lamps, educational programs have a good chance to succeed.

*Industrial Efficiency Programs*

Nearly 40% of the energy savings and over 25% of the available peak generating capacity savings identified in Chapter 3 are in the industrial sector, <u>exclusive</u> of lighting improvements. These savings fall into three groups -- operations, maintenance, and equipment optimization measures (motor repair and rewind practices, optimize fans and pumps, air compressor O&M), use of more efficient equipment in motor systems (high efficiency motors, multi-speed motors, VSDs, centrifugal compressors), and new production equipment in key electricity-intensive industries (aluminum, chlor-alkali, and steel).

Each of these groups of measures offer large opportunities for savings, and each group requires a somewhat different approach.

The first group -- operations, maintenance, and equipment optimization measures -- are generally low in cost. The prime barriers to these measures are lack of information and lack of technical expertise. To overcome these barriers, expanded training, information, and technical assistance programs are needed. These programs will be similar to many efforts now underway in India, but should be greatly expanded in scope. Another way to promote these measures is to encourage firms to hire energy managers who would be responsible for identifying energy waste within the plant and developing solutions. While a number of Indian manufacturers have energy managers, most do not. Options for promoting use of energy managers include voluntary and mandatory programs. An example of one voluntary program, undertaken in the U.S., is described in the case study on the next page. Mandatory programs have been adopted in Korea (see Appendix B) and have been proposed in India (NPC, 1990).

The last group of measures -- production improvements in energy-intensive industries involve a small number of firms. These firms often have technical expertise, but lack the capital needed to fund these improvements. Financial assistance in the form of low-cost loans for efficiency improvements could be of great benefit to these firms. Given the amount of money required, assistance from multilateral development banks will probably be needed.

The middle group -- improvements to motor systems -- involve nearly all industries in India. While a few of these industries have the information, technical expertise and capital to implement these measures, most do not. This group of measures may be the most difficult of the three groups to implement. Achieving these savings will require a combination of information, technical assistance, and financial assistance. Since many small firms are involved, loans may be too complex to administer -- partial grants (perhaps 50% of measure cost) may be preferable. This approach has been very successful in China (Levine and Xueyi, 1990).

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CASE STUDY: NORTH CAROLINA ALTERNATIVE ENERGY CORPORATION ENERGY OFFICER PROJECT

The North Carolina Alternative Energy Corporation (NCAEC --a not-for-profit organization affiliated with government agencies and private electric utilities) has offered a program to train energy managers and to guarantee their salaries. NCAEC guarantees that after two years, the energy manager will save enough money to pay his salary. If the value of the energy savings are less than salary costs, NCAEC pays the difference. Thus organizations can hire energy managers at no financial risk.

In addition to guaranteeing energy manager salaries, NCAEC offers training and technical assistance to the energy managers. Training includes an initial three day workshop introducing the new energy managers to their new duties, and periodic follow-up workshops on various technical issues. Technical assistance is provided by an experienced energy manager on NCAEC's staff who reviews conservation proposals prepared by the new energy managers, makes periodic site visits, and answers questions on the telephone.

After the first two years, NCAEC found that the average energy manager saved twice his salary, and that NCAEC had to pay less than 3% of the total salaries guaranteed by the program.

Source: Emmett and Gee, 1986

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Regardless of which group of measures is involved, each program should give special attention to new production lines in both new and existing facilities. The majority of 2004/05 industrial energy use will be by production equipment that is not yet in place. It is far cheaper to make this equipment more efficient when it is first installed, than to implement retrofit measures later on.

## INSTITUTIONAL MODIFICATIONS TO IMPROVE ELECTRICITY CONSERVATION EFFORTS

In order to successfully implement the recommendations discussed above, strong leadership and extensive coordination will be needed. This leadership and coordination will be needed in the Centre, and in each state. At the present, responsibility for electricity conservation programs and policies is diffused among many government departments and agencies, and this activity is not generally accorded high priority by the leadership of their respective agencies.

Many of our recommendations flow from our first recommendation --to develop and implement a least-cost planning process. At the Centre, power planning is coordinated by the Central Electricity Authority (CEA). CEA is responsible for developing the National Power Plan and for working closely with the states on their individual plans. In a companion report, demand forecasting and investment planning issues were investigated (IDEA, Inc., 1991). The principal recommendation of this review was that a new post be created in CEA at the Member level, to be known as the Member (Energy Efficiency). We endorse this recommendation. Establishing a post (and associated staff) at this level could be used to re-orient the power sector planning process along least-cost principles, and to integrate demand-side options into the next update of the National Power Plan. Similar steps should be undertaken at each State Electricity Board. The Member (Energy Efficiency) at CEA could then offer assistance to his counterparts at the state level.

While CEA can coordinate preparation of least-cost plans in India, implementation of the plans will require money. The major source of funds for State Electricity Boards for capacity expansion is the Power Finance Corporation (PFC). Since demand-side programs are essentially another form of capacity expansion, the PFC is the logical organization to fund SEB demand-side efforts. PFC in turn could obtain funds from the World Bank and the Asian Development Bank. In order to implement this mandate, PFC will need to develop expertise in the development and implementation of demand-side programs. We recommend that a unit be established within PFC for this purpose. Initially this unit should work with SEBs on pilot programs, so that both PFC and the SEBs could gain valuable experience, but ultimately the emphasis should switch to large-scale programs.

As discussed in Chapter 5, a substantial number of energy efficiency efforts are now underway in India. Given the importance of energy efficiency, as demonstrated in Chapter 3, the number of programs are likely to grow substantially. While these programs will likely be administered by many different agencies and organizations, there is a danger that efforts will not be planned as an integrated whole, with the result that some important efficiency measures are missed entirely, while other measures are the subject of duplicative efforts. In order that resources be most efficiently and usefully spent, we recommend that an All-India electricity conservation program be established, whose charge is to coordinate planning and administration of the many programs that will be offered by different organizations and agencies.

To some extent, the mission of the All-India electricity conservation program is similar to that of the Energy Management Centre (EMC). EMC is new and it is too early to say for sure how well it will be able to carry out its mission. However, a recent review of energy-efficiency agencies in a number of countries, including India, found that as an autonomous agency, EMC was too far removed from the key decision-makers in the Indian government, and hence was unlikely to have a major impact (Reddy, 1990). In

order to remedy this deficiency, EMC should be brought directly under the charge of the Secretary at the Department of Power. At the same time, consultation with other relevant government agencies should be increased and the input of universities, SEBs, and private industry should be actively sought.

A program of this type has been established in Brazil, and early results are highly encouraging. This program is described in the case study on the next page.

Funds for an Indian electricity conservation program could be provided by the Government of India, either through general revenues, or as part of a World Bank loan. Alternatively funds could be obtained from electric utilities, either through voluntary contributions, or through a small tax on kWh sales. Such a tax could be similar to the small oil tax used to fund the Petroleum Conservation Research Association.

In establishing an Indian electricity conservation program, specific goals should be established. For example, an ambitious but achievable goal might be to reduce electricity demand by at least 10% at the end of the Tenth Five Year Plan (2004/05), with smaller goals for the Eighth and Ninth Plans. The issue of an appropriate goal is discussed further in the next section.

**ACHIEVABLE SAVINGS FROM THESE POLICY INITIATIVES**

In Chapter 3 we estimated the amount of conservation and load management that is technically achievable and cost-effective. However, as discussed in Chapter 4, there are many barriers that impede implementation of these measures. While the programs and policies discussed in this chapter will certainly help to overcome some of these barriers, achieving all of the technical conservation potential by 2004/05 will be close to impossible. Accordingly, we developed a rough estimate of the amount of savings that could be achieved by 2004/05 as a result of our first three recommendations

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CASE STUDY: BRAZIL'S NATIONAL ELECTRICITY CONSERVATION PROGRAM (PROCEL)

PROCEL, established by the federal government at the end of 1985, stimulates more efficient electricity use through technology R&D, demonstrations, education and promotion, direct installation of conservation measures, development of standards and legislation, incentives, and joint projects with utilities and other organizations. A coordinating group with representatives from various ministries and federal agencies reviews and approves PROCEL's budget and projects.

PROCEL is based at Eletrobras, the federally-owned utility holding and coordinating company. PROCEL funds conservation projects carried out by state and local utilities, universities, research institutes, and other organizations. As of early 1990, PROCEL had undertaken over 150 projects with a total budget of about $20 million. The organizations conducting the projects are providing matching funds of a similar magnitude. Some major projects, such as industrial audits or substitution of incandescent street lights involve over 15 different utilities. Except for around $1 million provided by the World Bank to help start the program, PROCEL has been funded using the internal resources of Eletrobras.

PROCEL is starting to have a noticeable impact. Program officials estimate direct savings of 1,070 GWh/yr as of 1989. The majority of the savings are from the adoption of more efficient refrigerators and lamps. Considering the full range of activities of PROCEL, including education and promotion programs, savings as high as 2,500 GWh/yr have been estimated. Saving 1,070 - 2,500 GWh/yr is equivalent to the power supplied by about 280 - 650 MW of hydroelectric capacity. Thus PROCEL has already enabled utilities to defer investing about $0.6-1.3 billion in power plants, transmission lines, and distribution facilities.

Source: Geller, 1991.

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- pursue least-cost planning, promote efficient technologies, and undertake priority programs (our fourth recommendation -- institutional reforms -- is an important foundation for our other recommendations). This estimate of the achievable conservation potential is summarized in Table 6-1.

Overall, we estimate that peak generating needs can be reduced by approximately 12% by 2004/05. This amounts to just over half of the cost-effective technical potential identified in Chapter 3. In line with the Brazilian experience, savings over the next five years or so are likely to be modest, but over the 9th and 10th Plan periods, savings should increase substantially. Additional savings are likely in the period beyond 2004/05.

To achieve half of the available cost-effective savings over a 14 year period is ambitious, but less than recent estimates of the achievable conservation potential made in the U.S. For example, a recent study for New York State estimated that as a result of implementation of least-cost plans, equipment efficiency standards, building codes (efficiency requirements for new buildings) and market-driven adoption of efficiency measures, approximately 80% of the cost-effective technical potential could be achieved by 2008 (Nadel and Tress, 1990). The estimated savings -- 27% of predicted 2008 GWh sales -- are nearly three times greater than the 10% savings estimated here. Another study, by the government-funded Oak Ridge National Laboratory, estimated that 19% savings could be achieved by 2010 as a result of utility implementation of least-cost plans. Savings from other policies were not investigated (Hirst, 1991).

**ROLES FOR THE DIFFERENT PLAYERS**

In order to reduce peak generating needs in 2004/05 by 10% through conservation and load management efforts will require the active participation of many players including the Government of India, state governments and electricity boards, the World Bank and other multilateral institutions, and bilateral donor agencies.

Table 6-1. Estimate of Achievable Conservation Potential in 2004/05

| Program/Policy | Technical Potential (% of 2004/5 Pk Gen. kW) | Percent Achievable | Achievable Potential (% of 2004/5 Pk Gen. kW) |
|---|---|---|---|
| Least-cost planning | | | 3.3% h |
| Efficient technologies | | | |
| Equipment with stds. | 4.13% a | 50% g | 2.1% i |
| Equip. without stds. | 4.02% b | 25% | 1.0% i |
| High-priority programs | | | |
| Agricultural pumps | 3.69% c | 50% g | 1.8% i |
| Lighting | 7.53% d | 33% g | 2.5% i |
| Industrial | | | |
| Operations & maint. | 2.65% e | 25% g | 0.7% i |
| Elec. intensive | 0.75% f | 50% g | 0.4% i |
| TOTAL | | | 11.7% |

Notes:

a. From Table 3-7. These are products for which efficiency standard could readily be adopted. Includes electronic ballasts, high efficiency motors, moderate & high efficiency refrigerators, more efficient fans, EER 9 room A/C, and efficient evaporative coolers
b. From Table 3-7. These are products for which it would be difficult to adopt mandatory requirements. Includes VSDs, compac & circular fluorescent lamps, and storage cooling systems.
c. From Table 3-7. Includes new pumpsets, pumpset rectification, an metering of pumpsets.
d. From Table 3-7. Includes fluorescent fixtures, TLD lamps, circular & compact fluorescent lamps, electronic ballasts, and high pressure sodium fixtures.
e. From Table 3-7. Includes motor rewinding and maintenance, fan an pump optimization, and air compressor O&M.
f. From Table 3-7. Includes the aluminum, chlor-alkali, and electri arc furnace industries.
g. Estimate by the project team.
h. Assumes 0.33% savings each year for 10 years. The leading utilities in the U.S. are saving 1%/year (Nadel, 1991b). We assume that efforts in India will be only half as effective. In addition we reduce savings by 1/3 to account for overlap with the other measures. Finally we assume that full-scale programs do no begin until 1995. Savings from pilot programs over the 1992-94 period compensate for the fact that savings of 0.33% might not be achieved during the 1995-6 program ramp-up period.
i. Technical potential times percent achievable.

For the Government of India, the first step will be to implement the recommended institutional reforms -- establishing the post of Member (Energy Efficiency) at CEA, establishing an energy efficiency unit at PFC, and drawing EMC into a senior position within the Department of Power. With these reforms in place, the Centre should pursue least-cost planning at the national level and encourage State Electricity Boards to do likewise. Other activities which should take place at the Centre include expanded efforts to promote efficient technologies (including a review of duty, licensing and other barriers to the production of efficient equipment within India and efforts to strengthen equipment efficiency testing and standards), and stepped-up programs in the areas of agricultural pumping, lighting efficiency improvements in all sectors, and modernization, operations, and maintenance improvements in the industrial sector.

State governments and State Electricity Boards should undertake similar efforts as recommended for the Centre, with an emphasis on the development and implementation of least-cost plans.

The World Bank and other multilateral institutions can provide funding for many of these efforts. In addition to the Industrial Energy Conservation Project now being discussed, areas where financing is needed include loans to: the Power Finance Corporation for utility demand-side management programs; the Rural Electrification Corporation for agricultural rectification and other agricultural efficiency improvements; and programs designed to provide financing to Indian industries to produce efficient equipment.

Bilateral donor agencies, as well as the Global Environmental Facility (a joint project of the World Bank, U.N. Development Program and U.N. Environment Program) can fund technical assistance in the areas of least-cost planning, demand-side management program design, equipment efficiency testing and standards, design and production of efficient equipment, and advanced techniques for improving energy efficiency. Funds for pilot programs,

demonstration projects, developing implementation capabilities, and planning of large-scale programs can also be provided.

## CONCLUSION

This report identifies a technical potential to reduce electricity use and peak generating requirements by 20% in 2004/05. All of the measures examined cost substantially less per kWh than short- and long-term marginal generation costs, and cost substantially less per kWh than the cost of new baseload power plants. A series of programs and policies are recommended which will build upon current efforts. If these recommendations are implemented, we estimate that peak generating requirements in 2004/05 can be reduced by 10%. The average capital cost of these savings is Rs. 8,800/kW, substantially less than the approximately Rs. 20,000/kW cost of new power plants. If 10% savings are achieved, peak generating requirements will be reduced by 22,000-36,000 MW (depending on which demand forecast is employed), saving Rs. 25,000-40,000 crores in capital costs (Rs. 250-400 billion).

If efficiency measures are not pursued to the degree suggested here, demand and generating requirements will grow more rapidly, resulting in either increased expenditures on power plants (if the funds can be found) or a worsening power deficit. Given this choice, the case for an aggressive program to promote electrical efficiency is compelling.

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## APPENDIX A

## DERIVATION OF ELECTRICITY CONSUMPTION AND END-USE ESTIMATES

### Introduction

This appendix describes the derivation of some of the estimates summarized in Chapter 2. This appendix includes three sections:

1. Derivation of 1989/90 electricity consumption estimates.
2. Derivation of 2004/05 electricity consumption estimates.
3. Derivation of 1989/90 end-use estimates.

### Section 1. Derivation of 1989/90 Electricity Consumption Estimates

The starting point of the study was the establishment of a baseline electricity consumption pattern for each sector as a whole and for the major end-uses and generic equipment categories within each sector. The sectoral estimates are presented and discussed in this section, while the end-use estimates are discussed in the last section of this appendix.

The only primary source for national level data on electricity consumption is the annual statistical compilation, "Public Electricity Supply -- All India Statistics -- General Review," published by the Central Electricity Authority (CEA). However, there is considerable delay in the publication and availability of this compilation. The most recent edition available was the 1986/87 issue (CEA, 1990) which also contained provisional estimates of 1987/88 electricity consumption. However, during the course of the study, it was indicated that 1989/90 was to be taken as the base year for all sectoral and end-use estimates. Hence, sectoral estimates for 1989/90 were determined based on a regression analysis of historical trends.

A log-linear equation of the form $\ln y = a + bt$ was fitted to historical data for each sector and for overall purchased electricity consumption. In each case, two regression fits were obtained -- based on data for 10 years and 5 years preceding 1987/88, i.e.

t = 0 corresponding to 1977/78 and 1982/83 respectively. Table A-1 shows the results of the regression analysis. The equation giving the best R squared value was then used to estimate the 1989/90 value. It was observed that the sum of all the sectoral estimates thus obtained was not equal to the estimate of total consumption obtained from the regression analysis. Each sectoral estimate was then recalculated by first determining the ratio of the sectoral estimate to the sum of all sectoral estimates and then applying this ratio to the estimated value of total purchased electricity consumption. Within the others category, shares based on historical trends were then applied to obtain the estimates for public water works, public lighting, and miscellaneous sub-categories. Table 2-3 shows the results of this exercise. The forecasted values have been rounded off to the nearest hundred GWh to avoid any implication or suggestion of accuracy of the estimates.

Finally, sectoral electricity consumption estimates for 1989/90 were obtained by making adjustments for captive generation. This was based on the estimated value of 16,118 GWh for net captive generation in 1989/90 as given in CEA's Thirteenth Electric Power Survey (CEA, 1988). Since captive generation takes place predominantly in the industrial sector, the entire amount was included in the industrial sector. The resultant estimates for electricity consumption in 1989/90 are also given in Table 2-3.

**Section 2. Forecasted Sectoral Electricity Consumption Estimates**

A similar exercise was carried out to determine projected energy use patterns for the year 2004/05. The forecasts given in the Thirteenth Electric Power Survey (CEA, 1988) formed the basis of these projections. The sectors/categories for which these forecasts are given in the survey are industrial, agriculture, domestic, railway traction, public lighting, public water works, and commercial, non-industrial and other miscellaneous loads.

While a discussion of the assumptions and the methodology employed in the survey in arriving at the forecasts would appear to be out

of place here, certain aspects of the methodology do require mention. For the period from 1986/87 to 1990/91, forecasts were developed based on detailed consideration of various factors, as mentioned in the survey. Beyond 1990/91 and up to 1994/95, sectoral or category-wise forecasts were made by extrapolating energy consumption in different categories on the basis of trends during the period from 1986/87 to 1990/91. Beyond 1994/95, for the period from 1995/96 to 2004/05, no forecasts of energy consumption are given, and the forecasts for energy requirement from public utilities (i.e. electricity generation) have been projected on the basis of anticipated growth rates during 1986/87 to 1994/95.

Sectoral estimates for 2004/05 for the purposes of this study were therefore determined based on a regression analysis of the forecasted sectoral electricity consumptions from 1986/87 to 1994/95. A log-linear equation of the form $\ln y = a + bt$ was fitted to data for each sector and the same method as described for making the 1989/90 estimates was used. The results of the regression analysis are shown in Table A-2 and the calculated forecasts at five year intervals are given in Table 2-4.

Table 2-4 also shows the estimates of sectoral electricity consumption in 1989/90 for the sake of comparison with the forecasts made for 1989/90 in the Thirteenth Electric Power Survey. The major differences are in the estimates for the industrial and agriculture sectors. However, it should be noted that the sectoral shares of the CEA forecast do not follow the trend in sectoral shares exhibited by the historical data as given in Table 2-1.

As mentioned earlier, the CEA only forecasts utility generation beyond 1994/95. These estimates are also shown in Table 2.4 together with the calculated ratio of total consumption to public utilities' generation. This ratio shows an increasing trend, which, if true, would imply any or all of the following factors -- reduced auxiliary consumption, reduced transmission and distribution losses, and increased captive generation. However, it seems unlikely that any of these factors would be the cause; more likely,

the increase is just a manifestation and result of flaws in the forecasting methodology.

It therefore would seem that the forecast of total electricity consumption in 2004/05 of about 800,000 GWh represents an upper-bound scenario. Thus, some efforts were also made to develop a lower-bound scenario. These efforts are discussed in Chapter 2.

## Section 3. Derivation of 1989/90 End-Use Estimates

Since the focus of the study was on end-uses, a list of end-uses and major equipment types in all sectors was prepared at the outset of the study. These are given below:

- Industrial Sector
  - Lighting
  - Mechanical Drive
    - Pumps
    - Air Compressors
    - Refrigeration Compressors
    - Fans and Blowers
  - Process Heat
    - Electric Arc Furnaces (Steelmaking)
  - Electrolytic Processes
    - Aluminium
    - Chlor-Alkali
  - Other

- Agricultural Sector
  - Mechanical Drive
    - Irrigation Pumps

- Residential Sector
  - Lighting
  - Space Cooling/Ventilation
    - Fans
      - Ceiling Fans
      - Table Fans
    - Evaporative Air Coolers (Desert Coolers)
    - Air Conditioners
  - Refrigeration
  - Entertainment Electronics
    - Television
      - Black & White TV Sets
      - Colour TV Sets
  - Other

- Commercial Sector
  - Lighting
  - Heating, Ventilating and Air Conditioning (HVAC)

- Other

- Transport Sector
  - Mechanical Drive
    - Electric Traction

Existing studies, literature references, and results of surveys that have been carried out in the past were reviewed to obtain disaggregated data at the end-use level or to develop a basis for performing the disaggregation. The extensive interactions which were carried out with equipment manufacturers, end-users, experts, etc. also provided inputs in this regard. However, no new primary data were generated in this study.

The basic approach that was adopted to estimate disaggregated end-use electricity consumption was to derive estimates of equipment population, typical daily or annual operating hours, and typical electrical rating or typical annual electricity consumption, and thereby calculate end-use consumption. However, severe data problems were encountered during the process of deriving these estimates. The major problem was unavailability or very limited availability of data. Among the limitations of available data at disaggregated levels are poor quality of data, inadequate or insufficient data, and poor statistical design in the case of surveys. It is important to be aware of these deficiencies since the estimates of end-use electricity consumption provide the basis for assessment and evaluation of policy options.

Brief descriptions of the data inputs and methods to derive each of the end-use estimates are given below. While the data and methods varied for different end-uses, a common and unified approach was used to estimate electricity consumption in lighting in all sectors. Hence, lighting is discussed first followed by end-uses in each sector.

**Lighting**

Table A-3 shows the various data elements used to derive estimates of electricity consumption in lighting by sector and type of

device. The number and distribution of light points, and the average watts per point, both lamp and total (i.e. lamp and ballast) were estimated based on data from a draft document prepared by representatives of the lighting industry (Development Panel for Lamps, Fittings and Components Industry, 1991) and discussions with other industry representatives (Mirchandani, 1991). The typical burning hours per year were estimated based on reported survey data (Tata Energy Research Institute, 1990), the lighting industry document and, in some cases, judgement. For each sector, a utilisation factor was estimated based on judgement to account for the number of light points in use being less than the total number of light points due to redundancy or non-operation due to fused lamps, and for some of the light points being used for less than the assumed typical burning hours per year. The product of the number of light points, average total watts/point, typical burning hours/year and the utilisation factor resulted in the electricity consumption within each sector by type of device. It can be seen from Table A-3 that among the various sectors, the domestic and industrial sectors account for large shares of total lighting electricity consumption, while among devices, fluorescent tube lights and GLS lamps consume the most electricity.

**Industrial Sector**

Within the industrial sector, the end-uses that were covered were lighting (further broken down into GLS lamps, fluorescent tube lights, HPMV lamps and HPSV lamps), motors (further broken down into pumps, compressors, and fans and blowers), electric arc furnaces used in steelmaking, aluminium electrolysis, and chlor-alkali electrolysis.

Lighting

As described above, electricity consumption in lighting in the industrial sector in 1989/90 was estimated to be 8,800 GWh (rounded off to the nearest hundred GWh), which constituted 9% of the sector's total electricity consumption. Of this, fluorescent tube lights accounted for 6,500 GWh or 74%. The shares of high pressure

mercury vapour lamps, high pressure sodium vapour lamps, and GLS lamps were 14, 9 and 3% respectively.

Motors

Electricity consumption in motors in the industrial sector was derived from a study of motor population characteristics and energy use based on 1983/84 data (Tata Energy Research Institute, 1988). The study covered 11 industries -- aluminium, cement, chemicals, engineering, fertiliser, iron and steel, jute, paper, sugar, textiles and transport equipment. These industries account for over 60% of the total electricity consumption in the industrial sector. For each industry, electricity consumption, connected load and number of motors were estimated in the study for squirrel cage, slip ring, synchronous and DC motors in different size ranges. However, for the remaining industries in the industrial sector, only the total motor electricity consumption was estimated.

For this study, detailed breakdowns were estimated first for the remaining industries by assuming that they could be represented by the composite of the breakdowns of the textile, engineering, transport and jute industries. These were added to the breakdowns for the 11 industries covered in the study to obtain total industry breakdowns. These were then pro-rated based on the ratio of electricity consumption in the industrial sector in 1989/90 and 1983/84. The results are shown in Table A-4 which indicates that motors in the industrial sector consumed 71,868 GWh or approximately 71,900 GWh in 1989/90, which accounted for about 74% of the total consumption.

Motor electricity consumption was further disaggregated to obtain estimates of consumption in pumps, compressors, and fans and blowers since these comprise the major applications of motors in industry. Since no data or estimates were available for India, this was done on the basis of data for the U.S. However, since the mix of industries is considerably different in India compared to the U.S., first the total consumption in these end-uses (i.e. pumps, compressors, fans and blowers) was estimated based on

industry-wide U.S. data (Resource Dynamics, 1986) which indicated that the consumption was 33% of motor electricity use or 23,716 GWh. This estimate was however felt to be low, and total consumption in pumps, compressors, fans and blowers is assumed to be 40% of motor electricity consumption, or 28,800 GWh. This was then further allocated among the individual end-uses based on U.S. data (Arthur D. Little Co., 1980) resulting in the following estimates for 1989/90:

| | |
|---|---|
| Pumps | 13,800 GWh |
| Compressors | 6,900 GWh |
| Fans and Blowers | 8,100 GWh |

The compressor use was then further divided into use by air and refrigeration compressors. In the absence of any good data, we assumed a 50%-50% split.

Electric Arc Furnaces (Steelmaking)

Data from a recent study indicated that the typical specific energy consumption in electric arc furnaces in Indian mini steel plants is about 800 kWh/tonne of liquid metal (Department of Scientific Industrial Research, 1988). Production of steel ingots in 1989 in mini steel plants was 3.15 million tons (Centre for Monitoring Indian Economy, 1991). Assuming a 95% liquid metal to ingot yield, and assuming production in 1989/90 to be the same as in 1989, the electricity consumption in electric arc furnaces in steelmaking was estimated to be 2,700 GWh in 1989/90. This comprised less than 3% of the industrial sector's total electricity use.

Aluminium Electrolysis

Based on data for 1984 to 1986 from a recent study, it was estimated that the typical specific energy consumption in aluminium electrolysis in Indian plants is 17,331 kWh/tonne (AC power) (Bureau of Industrial Costs and Prices, 1988). Production of aluminium ingots in 1989 was 425,000 tonnes (Centre for Monitoring Indian Economy, 1991). Assuming a 95% liquid metal to ingot yield, and assuming production in 1989/90 to be the same as in 1989, the

electricity consumption in aluminium electrolysis was estimated to be 7,800 GWh in 1989/90 or 8% of the total consumption.

Chlor-Alkali Electrolysis

Caustic soda is manufactured in India by all four process routes, namely diaphragm process, mercury process, chemical process and membrane process. Process-wise installed capacities in India in 1988 were (National Productivity Council, 1989):

| Process | Units | tons/yr | % |
|---|---|---|---|
| Mercury Amalgam | 28 | 980,500 | 84.7 |
| Membrane | 2 | 32,350 | 2.7 |
| Diaphragm | 8 | 121,450 | 10.4 |
| Chemical | 1 | 23,300 | 2.0 |

Based on the findings of a recent survey, estimated 1988 electrical energy consumption was indicated to be (National Productivity Council, 1989):

| | Unit | Mercury Process | Membrane Process | Diaphragm Process |
|---|---|---|---|---|
| Caustic Production | MT | 765,115 | 25,964 | 59,933 |
| Estimated Average Power Consumption | kWh/MT | 3,381 | 2,820 | 3,300 |
| Estimated Annual Power Consumption | GWh | 2,587 | 73 | 198 |

The total electricity consumption in 1988 was 2,858 GWh and 1989/90 consumption was assumed to be 2,900 GWh or about 3% of total consumption.

Sector Total

Table A-5 shows the consolidated estimates of end-use electricity consumption in the industrial sector in 1989/90.

**Agriculture Sector**

Irrigation pumps comprise the predominant use of electricity in the agriculture sector. Although some electricity is used in various agricultural equipment, this quantity is not known and is expected to be quite small. Hence, the consumption in pumps is assumed to

comprise the entire consumption of electricity in the agriculture sector in 1989/90 -- 44,400 GWh.

**Residential Sector**

Within the residential sector, the end-uses covered were lighting (further broken down into GLS lamps, fluorescent tube lights, HPMV lamps and HPSV lamps), space cooling and ventilation comprising of fans (further broken down into ceiling fans and table fans), evaporative air coolers (desert coolers) and air conditioners, refrigerators, and television sets (further broken down into black and white sets and colour sets).

Lighting

As described above, electricity consumption in lighting in the residential sector in 1989/90 was estimated to be 9,300 GWh. Of this, GLS lamps accounted for 8,900 GWh or over 95%, while fluorescent tube lights accounted for the remaining portion.

Within the domestic sector, lighting electricity use was also estimated separately for the urban and rural population. Table A-6 presents the assumptions and the sequence of calculations made in arriving at these estimates. Although the urban population is only 28% of the total population, urban lighting accounts for 6,600 GWh or over 70% of electricity consumption in lighting in the residential sector.

Residential Equipment

As mentioned earlier in this section, the basic approach that was adopted to estimate electricity consumption in various electrical equipment was to derive estimates of equipment population, typical daily or annual operating hours, and typical electrical rating or typical annual electricity consumption, and thereby calculate end-use consumption.

Equipment population estimates were derived from historical production data by estimating cumulative production over a time period starting from 1989/90 and going back for the number of years

corresponding to the assumed working life of the equipment. The values of equipment life were assumed to be -- fans: 20 years, room air conditioners: 15 years, refrigerators: 25 years, television sets (B&W and colour): 20 years. Only partial time series production data for these equipment could be obtained; data was available only for some or all of the following years -- 1970, 1975 and 1980 to 1989 (Centre for Monitoring Indian Economy, 1987 and 1991). The approach followed was to determine cumulative production during 1980 to 1989 and add to that a rough estimate for the cumulative production for the earlier years based on interpolation from the production data for 1970, 1975 and 1980.

The population estimates thus obtained can only be considered as rough first estimates due to a number of inherent uncertainties and necessary approximations. Except for refrigerators, all other equipment considered in this study are produced by units in the organised sector as well as the small scale sector. Since production statistics for small scale sector units are difficult to obtain and compile, official statistics -- whether from government sources or from industry trade associations -- are generally limited to data on production from organised sector units. Thus it becomes necessary to apply an "adjustment factor" to account for small scale sector production. Since there are no reliable sources nor any unique estimates available, these factors are generally based on the opinion and judgement of industry experts. Needless to say, these vary considerably, and it is also not possible to get estimates of variations in the adjustment factor over a period of time.

There is also the situation of different sources reporting different data. In this study, all data were taken from compilations for the Centre for Monitoring Indian Economy (1987 and 1991) and no attempt was made to reconcile these with data from other sources.

Due to gaps in available data for years prior to 1980, the estimates of production in those years were quick approximations.

However, since the contribution of equipment produced greater than ten years ago to total present stock of equipment is small, this would not result in severe inaccuracies.

Finally, what is really required in such an exercise is not production but net additions, i.e., production + imports - exports. In the case of India, since both imports and exports are expected to be small compared to production, they have not been considered.

Notwithstanding these caveats, the population estimates made here are believed to be adequate for the purposes of this study. However, an attempt was also made to derive alternative, independent estimates based on surveys of market penetration of consumer goods conducted by market research companies. Limited results from recent surveys were made available by two leading market research agencies (Pathfinders: India, 1987 and 1990; Indian Market Research Bureau, 1991). Based on these, the number of urban and rural households possessing a particular appliance were estimated. The total equipment population was then derived by multiplying the number of households by an assumed value for number of appliances owned per household which was estimated based on judgement. The agreement between the two sets of estimates was seen to be reasonably good. However, the estimates based upon the production data method have been adopted in this study since it was felt that there were greater uncertainties associated with the data as well as the assumptions made in the case of the estimates based on market research data.

Finally, to determine equipment energy use, estimates of typical daily or annual operating hours, and typical electrical rating or typical annual electricity consumption were obtained from limited data based on recent surveys.

Fans

Production data for fans from Centre for Monitoring Indian Economy (1987 and 1991) were adjusted by a factor of 1.33 based on an estimate that the small scale sector accounts for about 25% of

total production (Corporate Observer, 1987). The adjusted production data are shown in Table A-7. The cumulative production during 1970 to 1989 was estimated to be 102 million. The production data for fans are for general purpose fans, i.e., ceiling fans, table fans, pedestal fans, etc., and separate production figures for each type were not available. However, it is estimated that ceiling fans account for 80% of production (Corporate Observer, 1987). Table fans have been assumed to comprise the other 20%. Since fans are also used in other sectors, it was assumed that 75% of all fans would be in use in the residential sector. Based on these assumptions, the populations of ceiling fans and table fans are estimated to be 61.2 million and 15.3 million respectively. These agree reasonably well with the estimates of 63.0 and 25.0 million respectively given in Table A-9 which are derived from market research surveys.

Based on recent surveys (Natarajan, 1991), the electrical ratings were taken as 70 W and 35 W for 48" ceiling fans and 16" table fans respectively, and the average annual use as 2500 hours and 1200 hours respectively. The electricity consumption in 1989/90 was then estimated to be 10,710 GWh and 643 GWh respectively as given in Table A-8.

Evaporative Air Coolers (Desert Coolers)

For evaporative air coolers, no production data were available, nor were they covered in the consumer goods surveys conducted by market research agencies. A recent study carried out for Delhi was the only available source of information (Centre for Research, Planning and Action, 1990). The study estimated that the desert cooler population in Delhi in 1990 was 1.1 million. Since desert coolers have come into usage only recently, and their use is limited only to areas which are climatically hot and dry, i.e., in parts of north, north-west, and central India, and since they are used mainly in middle- and upper-income groups, the total nationwide population is taken to be 5 million. Based on Natarajan (1991), the electrical rating for a typical air cooler with an 18" fan was assumed to be 230 W and average annual use as 1200 hours. The

electricity consumption in evaporative air coolers 1989/90 was then estimated to be 1,380 GWh as given in Table A-8.

Room Air Conditioners

Production data for room air conditioners from the Centre for Monitoring Indian Economy (1987 and 1991) was adjusted by a factor of 3.00 based on an estimate that the small scale sector accounts for about two-thirds of total production (Puri, 1991). The adjusted production data are shown in Table A-7. The cumulative production during 1975 to 1989 was estimated to be 1.3 million. Room air conditioners are also used in other sectors; based on an available estimate, 70% of the population was taken to be in use in the residential sector (Industrial Researcher, 1990). Thus, the stock of room air conditioners in the residential sector was estimated to be 0.9 million. This agrees reasonably well with the estimate of 1.2 million given in Table A-9 which is derived from market research surveys.

Based on recent surveys (Natarajan, 1991), the electrical rating was taken as 2,170 W corresponding to a 1.5 tonne unit and the average annual use as 1,200 hours. The electricity consumption in room air conditioners in 1989/90 was then estimated to be 2,370 GWh as shown in Table A-8.

Refrigerators

Refrigerators are manufactured only in the organised sector, and production data are shown in Table A-7. The cumulative production during 1965 to 1989 was estimated to be 8.0 million. Since there is limited use of refrigerators in other sectors also, it was assumed that 95% of all refrigerators would be in use in the residential sector. Thus, the population was estimated to be 7.6 million. This agrees reasonably well with the estimate of 9.5 million given in Table A-9 which is derived from market research surveys.

Based on discussions with manufacturers (NPC, 1991), the yearly electrical consumption was taken as 540 kWh corresponding to a 165

litre unit. Refrigerators are in operation all year round, i.e. 8,760 hours. The electricity consumption in 1989/90 was then estimated to be 4,104 GWh as shown in Table A-8.

Television Sets

Production data for television sets, black & white and colour, from the Centre for Monitoring Indian Economy (1987 and 1991) are shown in Table A-7. These figures appeared to include production from all sectors and hence were not adjusted. The cumulative production of black & white TV sets during 1970 to 1989 was estimated to be 20.9 million. TV transmission in colour in India began only in 1982, and the cumulative production up to 1989 was estimated to be 5.5 million. These agree reasonably well with the estimates of 23.1 million black & white TV sets and 7.8 million colour TV sets given in Table A-9 which are derived from market research surveys.

Based on recent surveys (Natarajan, 1991), the electrical ratings were taken as 30 W and 80 W for black & white and colour TV sets respectively, and the average annual use as 1200 hours for both. The electricity consumption in 1989/90 was then estimated to be 752 GWh and 528 GWh respectively as given in Table A-8.

Sector Total

Table A-8 shows the consolidated estimates for residential sector end-uses. Since there are other end-uses which although not covered here are not insignificant, e.g., water heating, it is assumed arbitrarily that the total of all end-uses discussed above represents 90% of total domestic sector electricity consumption. The total consumption is then estimated to be approximately 33,100 GWh. This is about 20% greater than the estimated 1989/90 consumption of 27,600 GWh based on regression analysis of time series data.

Normally in such an analysis, the individual end-use consumption estimates would have been refined or scaled suitably to ensure calibration and consistency with the sectoral total consumption estimate. However, in view of the considerable uncertainties

associated with all data elements employed in this exercise, these refinements would merely be cosmetic changes. Hence, no attempt has been made to correct the end-use estimates for residential equipment.

**Commercial and Miscellaneous Sectors**

End-use shares were estimated separately for the commercial and miscellaneous sectors and the results combined. For the commercial sector we examined several estimates of end-use shares as summarized in Table A-10. Based on this analyis, plus a review of data from other countries, we estimated end-use shares for India at 50% lighting, 40% heating, ventilating, and air-conditioning (HVAC), and 10% other.

For the miscellaneous non-industrial sector we assigned all energy use to lighting because total 1989/90 estimated use for the miscelleneous non-industrial sector (2,500 GWh -- as shown in Table 2-3) is significantly less than estimated lighting energy use for the "Other" sector (4170 GWh) in Table A-3.

Finally, since 1989/90 estimated energy use in the commercial sector is four times greater than use in the miscellaneous non-industrial sector (see Table 2-3) we weighted the end-use estimates by this 4:1 ratio to obtain combined end-use shares for the commercial/miscellaneous sector of 60% lighting, 32% HVAC, and 8% other.

**Final End-Use Allocations**

When the end-use consumption figures for the industrial, residential, commercial, and public lighting/other sectors (from Tables A-5, A-8, A-10, and A-3 respectively) are compared to the estimated consumption for each sector, as summarized in Table 2-3, several differences are apparent. These differences involve consumption in the residential, public lighting, and miscellaneous non-industrial sectors. For example, estimated residential consumption for 1989/90 in Table A-8 is 5,500 GWh greater than the

estimate in Table 2-3. Estimated consumption in 1989/90 for public lighting and "other" (primarily miscellaneous non-industrial) in Table A-3 are 600 GWh and 1,670 GWh greater than in Table 2-3. In order to deal with these discrepancies, we adjusted the data in Tables A-3 and A-8 to have the same total as in Table 2-3. Adjustments were done on a proportional basis so that while the total changed, the percentage allocation among the different end-uses remained unchanged. Results of this reallocation are reported in Table 2-6.

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Table A-1
Results of Regression Analysis of Historical Trends
in Sectoral Electricity Consumption

Regression Equation: $\ln y = a + bt$

Total

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 11.05416 |
| Std Err of Y Est | 0.029649 |
| R Squared | 0.987020 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.073955 |
| Std Err of Coef. | 0.002826 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 11.37499 |
| Std Err of Y Est | 0.009975 |
| R Squared | 0.997017 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.087201 |
| Std Err of Coef. | 0.002384 |

Industrial Sector

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 10.60331 |
| Std Err of Y Est | 0.034874 |
| R Squared | 0.965227 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.053356 |
| Std Err of Coef. | 0.003325 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 10.83733 |
| Std Err of Y Est | 0.029019 |
| R Squared | 0.952539 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.062154 |
| Std Err of Coef. | 0.006936 |

Table A-1 (continued)
Results of Regression Analysis of Historical Trends
in Sectoral Electricity Consumption

Regression Equation: ln y = a + bt

Agriculture Sector

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 9.116600 |
| Std Err of Y Est | 0.065942 |
| R Squared | 0.972545 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.112262 |
| Std Err of Coef. | 0.006287 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 9.569986 |
| Std Err of Y Est | 0.064323 |
| R Squared | 0.953935 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.139944 |
| Std Err of Coef. | 0.015376 |

Domestic Sector

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 8.688493 |
| Std Err of Y Est | 0.017746 |
| R Squared | 0.998134 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.117413 |
| Std Err of Coef. | 0.001692 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 9.278126 |
| Std Err of Y Est | 0.015739 |
| R Squared | 0.995929 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.117707 |
| Std Err of Coef. | 0.003762 |

Table A-1 (continued)
Results of Regression Analysis of Historical Trends
in Sectoral Electricity Consumption

Regression Equation: $\ln y = a + bt$

Commercial Sector

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 8.235590 |
| Std Err of Y Est | 0.046240 |
| R Squared | 0.968836 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.073747 |
| Std Err of Coef. | 0.004408 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 8.615200 |
| Std Err of Y Est | 0.023888 |
| R Squared | 0.976490 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.073606 |
| Std Err of Coef. | 0.005710 |

Traction

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 7.597211 |
| Std Err of Y Est | 0.049434 |
| R Squared | 0.922838 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.048901 |
| Std Err of Coef. | 0.004713 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 7.783058 |
| Std Err of Y Est | 0.030299 |
| R Squared | 0.953447 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.065558 |
| Std Err of Coef. | 0.007243 |

Table A-1 (continued)
Results of Regression Analysis of Historical Trends
in Sectoral Electricity Consumption

Regression Equation: ln y = a + bt

Others

| | |
|---|---|
| Period | 1977/78 to 1987/88 |
| Constant | 7.930711 |
| Std Err of Y Est | 0.038428 |
| R Squared | 0.975660 |
| No. of Observations | 11 |
| Degrees of Freedom | 9 |
| X Coefficient(s) | 0.069593 |
| Std Err of Coef. | 0.003664 |

| | |
|---|---|
| Period | 1982/83 to 1987/88 |
| Constant | 8.258107 |
| Std Err of Y Est | 0.035438 |
| R Squared | 0.952278 |
| No. of Observations | 6 |
| Degrees of Freedom | 4 |
| X Coefficient(s) | 0.075684 |
| Std Err of Coef. | 0.008471 |

Table A-2
Results of Regression Analysis of
Thirteenth Electric Power Survey Projections of
Sectoral Electricity Consumption

Regression Equation: ln y = a + bt

Total

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 11.80146817 |
| Std Err of Y Est | 0.031670599 |
| R Squared | 0.987053104 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.094453294 |
| Std Err of Coef. | 0.004088656 |

Industrial

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 11.20836985 |
| Std Err of Y Est | 0.041432158 |
| R Squared | 0.975566213 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.089421911 |
| Std Err of Coef. | 0.005348868 |

Irrigation

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 10.13001818 |
| Std Err of Y Est | 0.016202387 |
| R Squared | 0.995921340 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.086478108 |
| Std Err of Coef. | 0.002091719 |

Table A-2 (continued)
Results of Regression Analysis of
Thirteenth Electric Power Survey Projections of
Sectoral Electricity Consumption

Regression Equation: ln y = a + bt

Domestic

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 9.750278633 |
| Std Err of Y Est | 0.021836917 |
| R Squared | 0.996336555 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.123005057 |
| Std Err of Coef. | 0.002819133 |

Commercial, Miscellaneous, Non-Industrial

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 9.235629594 |
| Std Err of Y Est | 0.023399827 |
| R Squared | 0.992549270 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.092249217 |
| Std Err of Coef. | 0.003020904 |

Traction

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 8.084572265 |
| Std Err of Y Est | 0.038070144 |
| R Squared | 0.980663895 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.092604805 |
| Std Err of Coef. | 0.004914834 |

Table A-2 (continued)
Results of Regression Analysis of
Thirteenth Electric Power Survey Projections of
Sectoral Electricity Consumption

Regression Equation: $\ln y = a + bt$

Public Lighting

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 7.078132454 |
| Std Err of Y Est | 0.024551855 |
| R Squared | 0.991854406 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.092538044 |
| Std Err of Coef. | 0.003169630 |

Public Water Works

| | |
|---|---|
| Period | 1986/87 to 1994/95 |
| Constant | 7.986471996 |
| Std Err of Y Est | 0.024454075 |
| R Squared | 0.993165593 |
| No. of Observations | 9 |
| Degrees of Freedom | 7 |
| X Coefficient(s) | 0.100689702 |
| Std Err of Coef. | 0.003157007 |

Table A-3
Lighting: Estimated Electricity Consumption, 1989/90

a: Number of Light Points, million

| \/Sector/Device >> | GLS[1] | FTL[2] | HPMV[3] | HPSV[4] | Total |
|---|---|---|---|---|---|
| Domestic | 140.69 | 5.63 | 0.00 | 0.00 | 146.32 |
| Commercial | 6.28 | 25.13 | 0.00 | 0.00 | 31.41 |
| Industrial | 1.18 | 19.57 | 1.89 | 0.94 | 23.58 |
| Public Lighting | 2.20 | 7.11 | 0.44 | 0.51 | 10.26 |
| Other | 1.58 | 11.06 | 0.55 | 0.24 | 13.43 |
| Total | 151.93 | 68.50 | 2.88 | 1.69 | 225.00 |

b: Average Lamp Watts/Point

| \/Sector/Device >> | GLS | FTL | HPMV | HPSV | Total weighted |
|---|---|---|---|---|---|
| Domestic | 60 | 40 | | | 59 |
| Commercial | 75 | 65 | | | 67 |
| Industrial | 100 | 80 | 150 | 200 | 91 |
| Public Lighting | 40 | 45 | 200 | 200 | 58 |
| Other | 60 | 60 | 200 | 150 | 67 |
| Total weighted | 61 | 64 | 167 | 193 | |

c: Average Total Watts/Point

| \/Sector/Device >> | GLS | FTL | HPMV | HPSV | Total weighted |
|---|---|---|---|---|---|
| Domestic | 60 | 55 | | | 60 |
| Commercial | 75 | 89 | | | 86 |
| Industrial | 100 | 105 | 175 | 235 | 116 |
| Public Lighting | 40 | 60 | 225 | 235 | 72 |
| Other | 60 | 82 | 225 | 180 | 87 |
| Total weighted | 61 | 87 | 192 | 227 | |

1) General Lighting Service lamps (incandescent lamps)
2) Fluorescent Tubular Lamps
3) High Pressure Mercury Vapour Lamps
4) High Pressure Sodium Vapour Lamps

Table A-3 (continued)
Lighting: Estimated Electricity Consumption, 1989/90

d: Typical burning hours/year

| \/Sector/Device >> | GLS | FTL | HPMV | HPSV |
|---|---|---|---|---|
| Domestic | 1400 | 1800 | | |
| Commercial | 3000 | 3000 | | |
| Industrial | 3000 | 3500 | 4000 | 4000 |
| Public Lighting | 4000 | 4000 | 4000 | 4000 |
| Other | 3600 | 4000 | 4000 | 4000 |

e: Utilisation factor

| \/Sector | |
|---|---|
| Domestic | 75% |
| Commercial | 60% |
| Industrial | 90% |
| Public Lighting | 75% |
| Other | 90% |

f: Electricity Consumption, TWh

| \/Sector/Device >> | GLS | FTL | HPMV | HPSV | Total |
|---|---|---|---|---|---|
| Domestic | 8.86 | 0.42 | 0.00 | 0.00 | 9.28 |
| Commercial | 0.85 | 4.03 | 0.00 | 0.00 | 4.87 |
| Industrial | 0.32 | 6.47 | 1.19 | 0.80 | 8.78 |
| Public Lighting | 0.26 | 1.28 | 0.30 | 0.36 | 2.20 |
| Other | 0.31 | 3.26 | 0.45 | 0.16 | 4.17 |
| Total | 10.60 | 15.46 | 1.93 | 1.31 | 29.31 |

Sources: Development Panel for Lamps, Fittings, and Components Industry, 1991; Mirchandani, 1991; Tata Energy Research Institute, 1990.

Table A-4
Industrial Sector, Motors:
Estimated Electricity Consumption, 1989/90

a: Electricity Consumption, GWh

| kW | hp | Squirrel Cage | Slip-ring | Synchro-nous | DC | Total |
|---|---|---|---|---|---|---|
| 0.75-3.75 | 1-5 | 11,750 | 102 | 2 | 192 | 12,046 |
| 3.75-7.50 | 5-10 | 7,804 | 166 | 3 | 204 | 8,178 |
| 7.50-11.25 | 10-15 | 9,022 | 273 | 0 | 177 | 9,472 |
| 11.25-15.00 | 15-20 | 8,621 | 148 | 0 | 95 | 8,864 |
| 15.00-37.50 | 20-50 | 7,181 | 1,106 | 63 | 185 | 8,534 |
| >37.50 | >50 | 13,777 | 6,305 | 2,778 | 1,913 | 24,773 |
| Total | | 58,155 | 8,101 | 2,846 | 2,766 | 71,868 |

b: Connected Load, MW

| kW | hp | Squirrel Cage | Slip-ring | Synchro-nous | DC | Total |
|---|---|---|---|---|---|---|
| 0.75-3.75 | 1-5 | 4,627 | 70 | 1 | 70 | 4,768 |
| 3.75-7.50 | 5-10 | 3,162 | 106 | 1 | 93 | 3,362 |
| 7.50-11.25 | 10-15 | 3,194 | 199 | 0 | 61 | 3,454 |
| 11.25-15.00 | 15-20 | 2,965 | 86 | 0 | 47 | 3,098 |
| 15.00-37.50 | 20-50 | 3,407 | 767 | 23 | 102 | 4,300 |
| >37.50 | >50 | 5,906 | 3,650 | 1,516 | 1,199 | 12,270 |
| Total | | 23,261 | 4,878 | 1,541 | 1,572 | 31,252 |

c: Number of Motors, thousands

| kW | hp | Squirrel Cage | Slip-ring | Synchro-nous | DC | Total |
|---|---|---|---|---|---|---|
| Total | | 3,950 | 142 | 7 | 78 | 4,177 |

Source: Tata Energy Research Institute, 1988.

Table A-5
Industrial Sector End-Uses:
Estimated Electricity Consumption, 1989/90

| End-Use | Consumption GWh | Share % |
|---|---|---|
| Motors | 71,900 | 73.6 |
| Pumps | 13,800 | 14.1 |
| Air Compressors | 3,450 | 3.5 |
| Refrigeration Compressors | 3,450 | 3.5 |
| Fans and Blowers | 8,100 | 8.3 |
| Lighting | 8,800 | 9.0 |
| GLS Lamps | 300 | 0.3 |
| Fluorescent Tube Lights | 6,500 | 6.7 |
| HPMV Lamps | 1,200 | 1.2 |
| HPSV Lamps | 800 | 0.8 |
| Aluminium Electrolysis | 7,800 | 8.0 |
| Chlor-Alkali Electrolysis | 2,900 | 3.0 |
| Electric Arc Furnaces (Steelmaking) | 2,700 | 2.8 |
| Other | 3,600 | 3.7 |
| Total | 97,700 | |

Table A-6

Residential Sector, Lighting, Urban/Rural Mix
Estimated Electricity Consumption, 1989/90

| | | Urban | Rural | Total | |
|---|---|---|---|---|---|
| Population | million | | | 815 | 1/ |
| %, population, say | | 28 | 72 | 100 | 2/ |
| Population | million | 228 | 587 | | |
| Average persons/household | | 5.45 | 5.59 | | 3/ |
| Number of Households | million | 41.8 | 105.0 | 146.8 | |
| % electrified households (1983) | | 65.75 | 14.87 | | 4/ |
| % electrified households, say | | 66 | 15 | | |
| Electrified households | million | 27.6 | 15.8 | 43.4 | |
| % of electrified households | | 64 | 36 | 100 | |
| Average GLS lamps/household | | 3.5 | 1.5 | | |
| Average GLS:FTL ratio | | 20 | 100 | | |
| Average FTLs/household | | 0.175 | 0.015 | | |
| Total GLS lamps | million | 96.6 | 41.4 | 138.0 | |
| Total FTLs | million | 4.8 | 0.4 | 5.2 | |
| % GLS lamps | | 70.0 | 30.0 | 100.0 | |
| % FTLs | | 92.3 | 7.7 | 100.0 | |
| Electricity Use, GLS lamps | GWh | 6,230 | 2,670 | 8,900 | |
| Electricity Use, FTLs | GWh | 370 | 30 | 400 | |
| Total | GWh | 6,600 | 2,700 | 9,300 | |

1/ mean of projected 1989 and 1990 population as given in Centre for Monitoring Indian Economy, 1990.
2/ based on projected urban share of 27% in 1990 mentioned in Oxford University Press, 1987, and estimate of 27% urban population in 1985 given in Centre for Monitoring Indian Economy, 1989.
3/ Office of the Registrar General, India, 1988.
4/ based on NSS 38th Round data for type of lighting as given in Centre for Monitoring Indian Economy, 1990.

Table A-7
Trends in Production of Residential Equipment
(thousands)

| Year | GLS lamps | Fluorescent tubes | Fans | Room Air Conditioners | Refrigerators | TV sets, B/W | TV sets, Colour |
|---|---|---|---|---|---|---|---|
| 1970 | 143,056 | 10,722 | 2,093 | 51 | 65 | | |
| 1975 | 179,167 | 17,423 | 1,747 | 27 | 109 | | |
| 1980 | 267,917 | 27,520 | 5,305 | 75 | 279 | | |
| 1981 | 324,722 | 31,989 | 5,563 | 96 | 316 | 437 | 1 |
| 1982 | 366,667 | 33,309 | 5,417 | 92 | 354 | 570 | 70 |
| 1983 | 366,944 | 36,055 | 5,924 | 84 | 450 | 660 | 50 |
| 1984 | 364,583 | 36,506 | 6,139 | 85 | 538 | 1,000 | 280 |
| 1985 | 365,417 | 42,986 | 6,760 | 95 | 616 | 1,790 | 685 |
| 1986 | 389,167 | 49,660 | 6,968 | 119 | 585 | 2,150 | 850 |
| 1987 | 370,833 | 44,649 | 7,653 | 118 | 595 | 3,200 | 1,100 |
| 1988 | 336,806 | 49,219 | 8,667 | 117 | 961 | 4,400 | 1,300 |
| 1989 | 348,056 | 55,440 | 6,541 | 105 | 991 | 4,000 | 1,200 |
| 1990 | | | | | | | |

Source: Adapted from Centre for Monitoring Indian Economy, 1987 and 1991.

Table A-8
Residential Equipment: Estimated Electricity Consumption, 1989/90
(based on equipment population estimates from production data)

| Equipment | population (million) | W | hr/yr | GWh | % GWh |
|---|---|---|---|---|---|
| Lighting | | | | 9,280 | 26.8 |
| Ceiling Fan | 61.2 | 70 | 2,500 | 10,710 | 30.9 |
| Table Fan | 15.3 | 35 | 1,200 | 643 | 1.9 |
| Air Cooler | 5.0 | 230 | 1,200 | 1,380 | 4.0 |
| Room Air Conditioner | 0.9 | 2,170 | 1,200 | 2,370 | 6.8 |
| Refrigerator | 7.6 | 62 | 8,760 | 4,104 | 16.0 |
| B&W TV | 20.9 | 30 | 1,200 | 752 | 2.2 |
| Colour TV | 5.5 | 80 | 1,200 | 528 | 1.5 |
| Total of above | | | | 29,767 | 90.0 |
| Other, say | | | | 3,307 | 10.0 |
| Total | | | | 33,074 | |
| Estimated 1989/90 Residential Sector (Table 2.4) | | | | 27,600 | |
| Ratio, estimated total from Table 2-4/estimated total from this table | | | | 0.83 | |

Table A-9
Residential Equipment: Estimated Stock, 1989/90
(based on market research data)

| | Urban | Rural | Total | Urban | Rural | Total |
|---|---|---|---|---|---|---|
| **Households having Equipment, million** | | | | | | |
| | | | | % of Total Households | | |
| Total Households | 41.8 | 105.0 | 146.8 | 28.5 | 71.5 | 100.0 |
| Total Electrified | 27.6 | 15.8 | 43.4 | 63.6 | 36.4 | 100.0 |
| | | | | % of Electrified | | |
| **Households** | | | | | | |
| Ceiling Fan | 25.03 | 8.60 | 33.63 | 90.7 | 54.4 | 77.5 |
| Table Fan | 16.45 | 8.57 | 25.02 | 59.6 | 54.2 | 57.6 |
| Room Air Conditioner | 0.77 | NA | 0.77 | 2.8 | 0.0 | 1.8 |
| Refrigerator | 8.63 | 0.85 | 9.48 | 31.3 | 5.4 | 21.8 |
| B&W TV | 16.93 | 6.13 | 23.06 | 61.3 | 38.8 | 53.1 |
| Colour TV | 6.62 | 1.20 | 7.82 | 24.0 | 7.6 | 18.0 |
| **Equipment per Household (assumed)** | | | | | | |
| Ceiling Fan | 2 | 1.5 | | | | |
| Table Fan | 1 | 1 | | | | |
| Room Air Conditioner | 1.5 | | | | | |
| Refrigerator | 1 | 1 | | | | |
| B&W TV | 1 | 1 | | | | |
| Colour TV | 1 | 1 | | | | |
| **Stock of Equipment, million** | | | | | | |
| Ceiling Fan | 50.06 | 12.90 | 62.96 | | | |
| Table Fan | 16.45 | 8.57 | 25.02 | | | |
| Room Air Conditioner | 1.16 | 0.00 | 1.16 | | | |
| Refrigerator | 8.63 | 0.85 | 9.48 | | | |
| B&W TV | 16.93 | 6.13 | 23.06 | | | |
| Colour TV | 6.62 | 1.20 | 7.82 | | | |

Sources: Adapted from Pathfinders: India, 1987 and 1991; Indian Market Research Bureau, 1991.

Table A-10

Estimates of End-Use Shares in the Indian Commercial Sector

| | End-Use Share (%) | | |
|---|---|---|---|
| Study | Lighting | HVAC & Refrigeration | Other |
| TERI (Natarajan, 1990) | 50-60% | 35-45% | 5% |
| Desai, 1990 | 40% | 60% | -- |
| Faruqui et. al. | 43% | 32% | 25% |
| Tables 2.8 and 2-4 of this study | 48% | | |
| AVERAGE | 46.5% | 44% | 15% |
| ESTIMATES ASSUMED FOR THIS STUDY | 50% | 40% | 10% |

## Appendix B

# A REVIEW OF ELECTRICITY CONSERVATION PROGRAMS FOR DEVELOPING COUNTRIES

Steven Nadel, Howard Geller and Marc Ledbetter
American Council for an Energy-Efficient Economy

## Abstract

The growing burden of producing and distributing electricity in developing countries can be eased through investments in cost-effective measures to improve the efficiency with which electricity is used. In order to overcome the many market and institutional barriers that inhibit investments in efficiency improvements, governments and utilities should establish programs and policies to promote electricity conservation. Developing countries can turn to conservation programs used in other developed and developing countries for information on designing and implementing electricity conservation programs. Among the programs that should be considered are performance testing, labeling, and minimum efficiency standards for electric equipment, energy audits, training courses, technology development and commercialization programs, building codes, energy management requirements, electric rate incentives, rebates to purchasers of high efficiency equipment, favorable financing and tax arrangements, and least-cost utility planning. A thorough review and analysis of such programs implemented by other countries will greatly increase the likelihood that developing countries can launch successful, new electricity conservation programs.

## Introduction

Although expanding electricity use is essential for improving economic productivity and standards of living in developing countries, electricity is expensive to produce and distribute and thus should be used as efficiently as possible. There are a number of reasons why governments and utilities in developing countries should be interested in stimulating greater efficiency in electricity use:

- Increasing end-use efficiency (i.e., using better quality motors, lights, air conditioners, etc.) typically costs $300-$1000 per kilowatt (kW) saved, compared to $1500-$3000 per kW supplied from new hydroelectric or fossil fuel facilities.

- There is a large potential for cost effectively increasing the efficiency of electricity use. For example, recent studies in Brazil found electricity conservation measures can reduce electricity consumption by approximately 20% at two-fifths the cost of new electricity supply (Geller, 1990).

- Increasing end-use efficiency can help economies remain economically competitive. Worldwide production and use of energy-efficient equipment is increasing. If developing countries do not follow suit, they could become burdened with outdated products and factories.

- Slowing the pace of power plant construction will reduce adverse environmental impacts such as land inundation, disruption of local settlements, and air and water pollution.

- Efficiency programs can reduce customer electricity bills, which increases consumer satisfaction with the utility and frees up a portion of consumer income for other purchases.

Electricity conservation need not reduce economic growth nor lower standards of living. To the contrary, it can lead to greater productivity and economic growth, and higher standards of living.

Policies and programs are needed to encourage electricity conservation because numerous barriers inhibit efficiency improvements. These barriers include lack of investment capital and awareness of efficiency options, higher sensitivity to the first costs of investments than to their operating costs, lack of efficient equipment, and unfavorable financing terms.

Developing countries considering electricity conservation programs can look to a wide variety of programs that have been tried in both developed and developing countries. Although these programs generally need to be modified to suit the needs of any particular country, and not all programs are appropriate for all countries, experience with these programs offers valuable information to countries establishing new electricity conservation programs.

This paper provides a general overview of electricity conservation programs that should be considered by developing countries wishing to reduce their electricity consumption growth rates. Table B-1 lists and groups the types of programs discussed in this paper. Due to space limitations each program option is discussed only briefly and thus only a few examples from the many available are given. Also, all possible program options are not discussed here -- additional options are available, For a more comprehensive discussion of programs that can be considered by developing countries, see the report on electricity conservation prepared by the American Council for an Energy-Efficient Economy and published by the World Bank (Geller, 1986).

Table B-1
TYPES OF CONSERVATION PROGRAMS

A. Information and Education Programs
   1. Performance testing, efficiency labels and directories
   2. Energy audits
   3. Training
   4. General information

B. Equipment Development, Demonstration, and Commercialization

C. Legislation and Regulation
   1. Minimum efficiency standards and protocols
   2. Building codes
   3. Energy management requirements

D. Incentives
   1. Rate incentives
   2. Financing
   3. Leasing
   4. Rebates
   5. Shared savings
   6. Direct installation
   7. Tax credits and waivers

E. Least-Cost Utility Planning

## A. Information and Education Programs

### 1. Performance Testing, Efficiency Labels and Directories

Accurate information on the energy efficiency of equipment sold in a country is essential to any effort to promote electricity conservation. Buyers of equipment can use the ratings for comparative shopping and utilities promoting electricity conservation can use them for deciding which models of equipment to promote and what effects the equipment will have on its electric load. Public officials can use the information to track the progress that manufacturers are making in improving efficiency. Also, performance testing and labeling is necessary before minimum efficiency standards can be enacted (as discussed in section C below).

Many countries test electrical equipment for safety and product quality, but most countries do not include energy efficiency in their testing programs. Efficiency testing for performance ratings can be conducted at government laboratories or by equipment manufacturers as long as all manufacturers agree to a single, reliable method of testing. In the U.S., the federal government requires efficiency ratings for refrigerators, water heaters, air conditioners, and other domestic appliances. Manufacturers conduct performance tests and manufacturer associations oversee the program and make spot checks of ratings to assure accuracy.

Even if imported equipment has been tested and rated in the countries of origin there is usually a problem with comparing test ratings among models from different countries because there are no international testing protocols. One way to assure that equipment is tested and rated on a consistent basis is to establish a national (or regional) program for performance testing and rating of all major electrical equipment sold in a country (or region), including domestically produced and imported equipment.

Once standardized appliance efficiency testing occurs, it is possible to indicate the electricity consumption and estimated annual energy costs on models displayed in stores. The U.S. requires that most major residential appliances be labeled with such information. Directories ranking appliances by energy efficiency are published by trade and public interest organizations and distributed to consumers.

In Brazil, a program for testing and labeling the efficiency of all domestic refrigerators was begun in 1985. This program exposed manufacturers who made inefficient products, and as a result, several manufacturers improved the efficiency of some of their models. This program is being expanded to include performance testing for air conditioners, motors, and lighting products (Geller, 1990).

Testing and labeling programs also exist in Australia, Canada, Denmark, France, and South Korea (Marbek, 1990; Kim, 1983). A

national appliance testing laboratory has been built in the Philippines (Philips, 1991) and another is planned for Jamaica (Marbek, 1990). In Thailand, the International Institute for Energy Conservation (IIEC) recently published a directory of the most efficient refrigerators and air conditioners sold in the country. Due to a lack of uniform product testing in Thailand, data listed in this directory is of limited accuracy (IIEC, 1990).

2. Energy Audits

Commercial building audits can be cost-effective and lead to significant electricity savings. For example, a recent survey of commercial audit programs offered by electric utilities in the United States found that program participants reduced their electricity use by 2-8%. Programs with savings in the upper end of this range include periodic post-audit follow-up visits and financing assistance. Lighting efficiency improvements generally account for the majority of these savings (Nadel, 1990a).

Industrial audits can be performed with limited measurements or with in-depth analysis of facility efficiencies and energy flows. Worldwide experience shows that thorough training of energy auditors and offering financing for the recommended measures are critical to the success of industrial auditing programs (Gamba et al., 1986).

Energy audit programs have been established in many developing countries including Bangladesh, Brazil, Costa Rica, Ecuador, Egypt, El Salvador, Guatemala, Hungary, Honduras, India, Indonesia, Jamaica, Jordan, Kenya, Korea, Morocco, Pakistan, Panama, Philippines, Sri Lanka, Thailand, Tunisia, and Yogoslavia (Bailly, 1989; Leonard, 1989; Philips, 1991). Funds typically come from government agencies, electric utilities, loans from multilateral development banks, or grants from bilateral donor agencies. An evaluation of programs in 11 different countries found that on average 56% of recommended measures were implemented by audit recipients. Low-cost measures accounted for 86% of the measures implemented (Leonard, 1989). Energy savings achieved from these measures were not measured.

Policy makers in developing countries can encourage efficiency improvements by making an energy audit a precondition for businesses and industries to receive loans from state-owned development banks. To insure the effectiveness of such programs, development banks could offer and promote financing for recommended conservation measures. Also, public agencies could support the training and certification of energy auditors.

3. Training

In addition to training for energy auditors, training is often needed for energy managers, maintenance staff, building designers, industrial engineers, inspectors enforcing efficiency regulations, utility staff planning and operating efficiency programs, and those providing technical assistance as part of an energy conservation

program. Training programs range from simple seminars to post-graduate degree programs at a major university.

In South Korea, the national energy management association has conducted training sessions on a large scale, with a total attendance of 89,000 reported for the 1974-80 period (Kim, 1983). A training program reaching large numbers of professional energy managers is operating in the Philippines as well. Basic courses are offered through a center established by the national Bureau of Energy Utilization. More specialized seminars are conducted by the Energy Management Association, an organization of professional energy managers (Ocampo, 1984; BEU, 1986). In Sri Lanka and the Philippines, associations of energy managers regularly conduct training sessions for energy managers (Philips, 1991). In India, in addition to basic seminars offered by many organizations, a number of universities offer courses in energy management, and two institutes have set up post-graduate energy management programs (Department of Power, 1989).

In Thailand, Czechoslovakia, and Poland, training sessions have been held for utility and government officials on the concept of least-cost utility planning (this concept is discussed in Section E below). For example, in Thailand, an initial two-week seminar, involving foreign trainers, discussed analysis of electricity by end-use, and opportunities to reduce electricity use with efficiency measures. Follow-up workshops have discussed the planning and design of utility-sponsored efficiency programs. As a result of these efforts, Thai utilities are planning to offer efficiency programs in the near-future (IIEC, 1991).

In the U.S., a number of innovative training programs have been offered. For example, both California and New York State have set up specialized training programs in lighting design . The goal of each program is to train lighting designers and installers in advanced techniques for reducing electricity use while improving lighting quality (Berryman, 1990; Lighting Research Center, 1990). Pacific Gas & Electric Company and the Bonneville Power Administration (two large electric utilities) have offered in-depth training courses for architects and engineers on reducing energy use in new commercial buildings through improved building design (PG&E, 1985; Dowty, 1988).

The North Carolina Alternative Energy Corporation (NCAEC -- a not-for-profit organization affiliated with government agencies and private electric utilities) has offered a program to train energy managers and to guarantee their salaries. NCAEC guarantees that after two years, the energy manager will save enough money to pay his salary. If the value of the energy savings are less than salary costs, NCAEC pays the difference. Thus organizations can hire energy managers at no financial risk. After the first two years, NCAEC found that the average energy manager saved twice his salary, and that NCAEC had to pay less than 3% of the total salaries covered by the program (Emmett and Gee, 1986).

4. General Information Programs

Providing general energy conservation information through brochures and advertisements can raise public awareness, but may not have much impact on actual consumer behavior. Research in the U.S. has shown that information and educational programs tend to be most effective when they provide consumers with simple and specific steps to take along with estimates of how much energy and money will be saved (Stern and Aronson, 1984). General appeals to the public to save energy are usually less effective. In addition, information is more likely to be used when the information provider is respected by the information recipient (for example, when information is provided by a trusted organization in the local community) and when the information is provided face-to-face.

Another general finding is that information and educational activities work best when they are part of a comprehensive effort including technical assistance, correct pricing signals, financing, and possibly efficiency regulations. Japan has had great success in increasing energy efficiency with the government providing information, correct pricing signals, and financial incentives. Among developing countries, South Korea appears to have gone the furthest in developing educational programs that are one part of a broad, concerted, and successful conservation effort.

B. Equipment Development, Demonstration and Commercialization

Research and development activities can be used to develop new energy-saving technologies. In developing countries, some of these activities involve taking advanced technologies from developed nations and adapting them to local consumer needs and production processes. Demonstration projects apply these new technologies in factories and buildings, in order to collect case study information, and publicize the new technologies to a wide audience. Commercialization programs provide assistance to manufacturers and retailers to develop a market for the new technologies.

Probably the most comprehensive development and commercialization program in the developing world is in Brazil. In Brazil, the national electricity conservation program, PROCEL, has spearheaded work to develop more efficient refrigerators, multi-stage evaporative cooling equipment, heat pump water heaters, electronic ballasts, lighting controls, reflective luminaires, permanent magnet motors, motor speed controls, and high pressure sodium lamps. Much of the research is carried out at universities, research institutes, or utilities. In some cases, the research is oriented towards nationalizing imported components or adapting technologies to local needs.

For example, in 1985 researchers at the University of Sao Paulo began studying electronic ballasts with funding from the local utility -- CESP. In 1986-87, 50 prototype units were produced with an emphasis on using domestic components to the maximum degree possible. In 1988, CESP and PROCEL selected a

private manufacturer, Begli, to produce 450 units. These demonstration projects helped Begli to develop and improve its manufacturing process and to improve product quality. In 1988, Begli began producing units in limited quantities. By 1990, Begli was producing and marketing a full product line at attractive prices. At this time, other ballast companies were considering purchasing electronic ballasts from Begli for resale (Geller, 1990).

This example show the value of relying on researchers for early technology development but then working with a private company. It also shows the importance of slowly scaling up production, conducting demonstrations and field testing, and supporting R&D in a promising area for a number of years.

## C. Legislation and Regulation

Regulations may be desirable in situations where the unregulated market is likely to miss cost-effective energy conservation actions and investments. Efficiency regulations also can be used to increase the likelihood that planned electricity conservation will occur.

### 1. Minimum Efficiency Standards

Governments can impose minimum efficiency standards for major electricity consuming equipment, such as motors, lighting products, or air conditioners. Such standards can be relatively easy to enforce if standardized efficiency ratings are available for all models. Inspectors can fine manufacturers found producing or selling banned products.

The U.S. adopted minimum efficiency standards for residential appliances in 1987. The standards cover refrigerators, freezers, room air conditioners, central air conditioners, heat pumps, electric and gas water heaters, gas furnaces and boilers, gas ranges, and other products. In 1988, fluorescent ballasts were added to the list of regulated products. By the year 2000, the standards are expected to reduce peak summer electric demand by 29,000 megawatts (MW). These savings are in addition to what the unregulated market is expected to achieve. The expected reduction in peak demand is 27% of the growth in national peak demand from 1990-2000 as forecast by the utility industry (Geller, 1987; Geller and Miller, 1988).

In addition, a few states in the U.S. have adopted efficiency standards for commercial air conditioning equipment, electric motors, incandescent and fluorescent lamps, and incandescent and fluorescent lighting fixtures (Nadel, 1990b). The Canadian province of Ontario recently adopted efficiency standards for refrigerators and several other consumer products. The province of British Columbia is working on similar standards for appliances, and plans to include standards for electric motors as well (Kelly, 1991).

Taiwan has also adopted minimum efficiency standards for a variety of products including window air conditioners (in 1981), fans (1982), water heaters, clothes dryers, ovens and stoves (in 1983), refrigerators (1986), and large air conditioners (1987). Since the standard took effect, the average efficiency of new window air conditioners has improved by over 40%. The Energy Committee, a government agency, estimated that 795 MW of generating capacity were saved between 1981 and 1988 through appliance efficiency improvement (total installed generating capacity in 1988 was approximately 16,600 MW) (Hsueh, 1989).

Japan and Germany have induced appliance manufacturers to improve the efficiency of specific products through "arm twisting." Rather than set a minimum acceptable efficiency level, the governments set goals for improvement. The Japanese government established targets for energy efficiency improvement for various appliances in 1979, though for refrigerators and air conditioners, the targets were essentially an order. In Germany, in 1980, the government reached an agreement with manufacturers to improve the efficiency of specific products by up to 20% by 1985. The efficiency goals were voluntarily increased by the manufacturers twice in order to avoid government regulation (Wilson et. al., 1990).

In the Ivory Coast, the federal government's Bureau des Economies d'Energie (BEE) is working on developing appliance efficiency standards, beginning with air conditioners. Most air conditioners are imported, but BEE is working with one domestic air conditioner manufacturer to improve the efficiency of its air conditioners to meet the proposed efficiency standard. Reportedly, the standard itself will not involve domestic testing, but will be based on standards adopted in industrialized countries and on performance data submitted by manufacturers (Philips, 1991).

In Brazil, the government and the appliance industry are negotiating a protocol to improve the efficiency of refrigerators and freezers. The national utility proposed that all new refrigerators and freezers achieve the efficiency of the best models already produced in each class by 1993, followed by an increase of 5% per year during 1994-98. This could lead on average to new models produced in 1998 consuming about half as much electricity as new models produced in 1990. Refrigerator manufacturers agreed in principle to signing an efficiency protocol, but details were still being worked out. A second protocol is being negotiated with lamp manufacturers. It is expected that this protocol will phase-out standard incandescent lamps and set minimum efficiency levels for energy-saving incandescent lamps. A third protocol calling for production of energy-efficient motors is also under discussion. However, before the protocol can take effect, the availability of low-loss steel must be increased so that energy-efficient motors can be produced on a very large scale (Geller, 1990).

## 2. Building Codes

Regulations on the energy efficiency of new residential and commercial buildings have been implemented throughout the world. In the U.S., the federal Department of Housing and Urban Development (HUD) issued minimum standards that apply to federally-financed housing. These requirements result in new homes with up to 35% lower heating loads than those meeting basic building industry guidelines (Hirst et al., 1986). European nations such as Denmark and Sweden also have adopted stringent building efficiency regulations.

Many states in the U.S. have adopted efficiency standards for new building construction based on model standards developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). There is considerable variation in the strength of the state building codes, extent of coverage, and degree of enforcement (Collins et al., 1985). Many states revise and strengthen their codes approximately every five years.

Singapore, which uses about 32% of its electricity in commercial buildings, adopted efficiency regulations for new commercial buildings in 1979 in order to reduce electricity consumption. The standards regulate the overall thermal transfer value for air conditioned buildings, ventilation rates, indoor temperatures, and lighting power levels (Ching, 1984). Existing buildings are also required to meet efficiency standards or they are penalized on their electricity bill. These standards are estimated to have reduced electricity use in buildings by 6-10% (Chou and Ho, 1985). One of the main reasons the standards have not had a greater impact is that they do not affect solar gains, the largest cooling load in many commercial buildings. The development and analysis of more effective standards is now nearing completion. Similar standards have recently been adopted in Malaysia, and voluntary guidelines are being adopted in Indonesia, the Philippines, and Thailand (Busch, 1991).

Building efficiency standards are mandatory for new homes and commercial buildings in South Korea. They cover insulation levels in walls and ceilings and the thermal integrity of windows. Voluntary guidelines for existing residences and commercial buildings have also been enacted (Kim, 1983).

Other countries with building efficiency standards include Pakistan and Jamaica. For example, Jamaica recently adopted a code for new commercial and industrial buildings which is mandatory for government buildings and voluntary for private buildings (various inducements involving loans and permits are used to encourage private building compliance) (Ashby and Chaisson, 1991). Implementation guidelines are now being developed (Philips, 1991).

In general, the energy-saving effects of building codes are likely to depend on the training of architects, builders and enforcement officials as well as the enforcement procedures, length

of time the code has been in effect, and its complexity (Hirst et al., 1986).

3. Energy Management Regulations

A comprehensive reporting, efficiency target, and energy management program was established for larger industrial and commercial firms in the Philippines. Qualifying firms are required to set efficiency targets and report consumption quarterly to the government (Ocampo, 1984). Of the 401 companies included as of 1983, 54% were complying with the reporting procedures. In addition, larger energy-consuming firms are required to appoint full-time energy managers to plan and implement conservation programs.

South Korea also instituted a reporting scheme for larger industrial firms (Kim, 1983). Firms consuming at least 500 tons of coal equivalent per year must report on energy consumption and conservation activities annually, and they must employ an energy conservation manager. Similarly, Tunisia has a national policy requiring audits every three years for all industrial companies exceeding an average consumption of 2,000 tons of oil equivalent per year, and all commercial establishments averaging more than 500 tons of oil equivalent per year. Each of these companies is required to enter into a five-year contract with a federal energy agency on how it will implement the audit recommendations.

## D. Incentives

Subsidizing the price of electricity can act as a powerful disincentive to conserve electricity. Electricity rates that reflect the cost of providing electricity (or preferably, the marginal cost of providing electricity) can provide financial stability to utilities and the right price signal to consumers of electricity (Munasinghe and Warford, 1982). For example, in Thailand, electricity generation per unit of gross domestic product (GDP) grew at an average rate of 16%/year in the 1960s and 6%/year in the 1970s when electricity prices were subsidized. The Thai government substantially increased energy prices beginning in 1979; for example, industrial electricity prices rose 30%/year faster than inflation during 1979-82. This increase, combined with other factors, resulted in electricity generation per unit of GDP rising only 1.5%/year during 1980-82 (Kadir and Kim, 1984; Gaskin, 1985). Subsequently, Thai electricity growth per unit of GDP returned to 5.0% growth/year during 1982-86 (Meyers and Sathaye, 1988), indicating that ending price subsidies is not sufficient to overcome the many barriers inhibiting efficient use of electricity.

1. Rate Incentives

Utility rates that encourage conservation include:

o Inverted rates - rates that rise as consumption rises;

- Discount rates - lower rates that are offered to facilities meeting certain conservation requirements;

- Time-of-use rates (TOU) - rates that are higher during the utility's peak demand hours or season;

- Demand charges - charges based on a customer's highest peak demand in a billing period;

- Interruptible rates - rates, typically discounted, that require customers to reduce their use when so requested by utilities.

Many of these rate types are used by utilities in the U.S. A survey of 120 U.S. utilities indicates that 70% offer demand charges to their commercial and industrial customers, while about 50% offer time-of-use rates (Norland, 1985). More recently, TOU rates have been tested for residential and smaller commercial energy users in the U.S. A review of twelve such experiments found that TOU rates can reduce peak-period electricity consumption by up to 30% (Faruqui and Malko, 1983). As expected, larger reductions occurred when the ratio of peak to off-peak rates increased and when the length of the peak period was reduced.

TOU rates are particularly appropriate for buildings with thermal energy storage systems. For example, over 500 commercial buildings in the U.S. have ice storage systems which supply some or all of the cold air needed to cool a building during the day, allowing the central air conditioning system to be turned off. At night, when temperatures are cooler and electricity rates lower, the air conditioner is turned on in order to recharge the ice storage system for use the next day (Nadel, 1990a).

In some developing countries, including Brazil, Indonesia, Pakistan, and Uruguay, inverted rates have been implemented for low-voltage consumers (Munasinghe and Warford, 1982). In Brazil, the residential rate rises when demand exceeds 30 kWh/month, 200 kWh/month, and 500 kWh/month. Although this type of rate may not be consistent with cost of service-based rates, it can be a powerful incentive for conservation.

TOU rates are also used in several developing countries. In South Korea, TOU pricing was implemented for larger industrial customers starting in 1977. Consequently, the average load factor in Korea increased from 69% in 1976 to 78% by 1980 (Kim, 1983). In Brazil, TOU rates were implemented for high- and medium-voltage customers starting around 1982. The tariffs differentiate between peak hours (6:00 - 9:00 pm) and off-peak hours, as well as wet season and dry season. For high-voltage customers, the demand charge during the peak period is two to five times the charge during the off-peak period. It is estimated that about 2100 MW were shifted from peak to off-peak hours during 1982-87 (out of a 1987 peak of approximately 30,000 MW), and further shifts are expected (World Bank, 1989). In addition to load shifting, these

rates may lead to some reduction in absolute electricity consumption as well.

In Costa Rica TOU rates for large industrial customers were in effect for several years, but most customers were not taking advantage of the many load management opportunities available in their plants. To deal with this problem, the national utility, ICE, offered a pilot program to educate customers about load management opportunities. In the program, customers were provided with an explanation of TOU rates, data on their present load shape, a walk-through plant visit to identify potential load management measures, and referrals to experienced local load management consultants. On average, the 24 program participants reduced their peak demand by 14%. The program cost the utility $11,000, and customers $52,000, but annual savings were $312,000 for customers (due to reduced demand charges) and $200,000 for the utility (due to savings from reduced peak loads, after subtracting the cost of reduced demand charge payments from customers) (Bailly, 1989).

The feasibility of TOU pricing depends on the average amount of electricity use in the rate class under consideration, metering costs, the type of equipment being used, and ability of customers to conveniently shift some consumption to off-peak periods. The potential benefits and desirability of TOU pricing need to be evaluated on a case-by-case basis (Munasinghe and Warford, 1982; RDC, 1983).

Interruptible rates have been extensively used in the U.S. in order to reduce peak loads. For large commercial and industrial customers the most common arrangement is for the utility and the customer to agree in advance how much load the customer will shed, the duration of the reduction (6 hours for example), and how many days per month a reduction can be called for. In exchange the customer receives a large reduction in their demand charge. When an interruption is needed, the utility notifies the customer a few hours in advance and the customer sheds load by shutting off selected pieces of equipment or by starting a stand-by generator. Penalties are assessed if the customer does not shed load when requested.

Interruptible rates can also be used for residential and small commercial customers. Over 300 utilities in the U.S. pay customers a monthly fee in exchange for the right to turn off air conditioners, water heaters, and other residential appliances for a limited number of hours at times of peak electrical demand (Blevins and Miller, 1989). Typically the utility attaches a small radio control unit to each air conditioner, water heater, or other appliance in the program. When load reductions are needed, the utility operates the radio control -- no action by the customer is required.

2. Financing

Utilities are good financing sources for conservation investments because they have access to large amounts of capital

and they have ongoing financial relationships with their customers. Governmental authorities are also logical financing sources. Utility and government financing is most cost effective for large loans and for investments in equipment that are substantially more expensive than their less efficient counterparts. Loans can be provided at market or subsidized rates, however conservation financing is more likely to be successful if funds are provided at attractive terms, participation is convenient, and technical assistance is offered (Geller, 1986).

In the U.S., a number of utilities provide financing for conservation investments. The Tennessee Valley Authority (TVA) loaned out $520 million as of 1986 for investments estimated to have reduced peak demand by 1290 MW (TVA, 1986). TVA offers and aggressively promotes free energy audits and low interest loans.

Two American utilities, Wisconsin Electric and Puget Power & Light offer commercial and industrial customers a choice of a subsidized loan or a grant of comparable value. With the grant, the customer must provide the capital to finance the remainder of the investment. Both utilities found that over 90% of the customers chose the grant over the loan (Nadel, 1990a). Further research is needed to determine if customers in developing countries have a similar preference for grants over loans.

As for experience with government-sponsored financing, India, has several different programs operated by its three national development banks. These programs generally combine subsidized energy audits provided by private engineering firms with concessional rate loans (interest rates generally range from 1-4% below conventional development bank loans). As of March, 1990, the largest of the three programs had provided financing for 122 energy audits and had committed approximately $13 million in loans for energy saving equipment. In 1991, India's development banks will start a $750 million energy conservation loan program, using $250 from the World Bank and $500 million of their own funds (Sriram, 1990).

Many loan programs have suffered from limited interest on the part of potential borrowers. For example, in Thailand, financing for energy conservation projects is provided by the private Industrial Finance Corporation. Interest rates are relatively high and financing is only available for 50-60% of project costs. Consequently, the loan program has not been well-received by industrial firms (Gaskin, 1985). In Brazil, the National Development Bank started a financing program for conservation projects by industrial, commercial, and public sector enterprises in 1986. The real interest rate (after inflation) was 6-8.5%/year, considerably less than market interest rates. Unfortunately, there was little promotion of the program, complicated application procedures, substantial delays in evaluating project proposals, and low electricity prices during much of this period. As a result, relatively few loans were made (Geller, 1990). A number of other countries have had less than successful energy conservation loan

programs including Bangladesh, Jamaica, Portugal, Turkey, and Yugoslavia (Philips, 1991).

On the other hand, Hungary has had a very successful World Bank-financed industrial conservation loan program. Under the program, the National Bank of Hungary provides funds to commercial banks for a 12-year loan with a 2-3 year moritorium before payments begin. Commercial banks provide loans on the same terms to industrial borrowers. Each commercial bank conducts its own financial appraisal of conservation loan applications. Technical assessments on each application are provided by regional offices of the Energy Supervision Institute. The program involves approximately $60 million in foreign exchange. The success of the program can be attributed to good program design and to a shortage of hard currency investment capital in Hungary. Using the loan funds, companies can purchase imported equipment, albeit only for energy efficiency improvements (Philips, 1990a).

Not all financing programs in developing countries are based on loans. For example, in China, the Energy Conservation Company (ECC) of the State Energy Investment Corporation provides grants which normally cover one-third of a project's cost. Some additional funds come from federal ministries or local and provincial governments, but the bulk of the funds come from the individual companies making the energy-saving improvements. ECC has an annual budget of about $300 million, of which some goes to proven technologies and some to demonstrating new technologies (Philips, 1990b).

3. Leasing

In the U.S., a few electric utilities have leased energy-efficient equipment to customers. For example, the Taunton Municipal Lighting plant leases compact fluorescent bulbs to residential customers for $0.20 each month. If the lamp operates three hours a day, monthly electricity savings amount to approximately $0.40/month -- twice as much as the lease payments. In the event the lamp breaks or burns out, Taunton replaces it at no charge. Taunton has recently begun a similar program for commercial customers that leases a wide-array of commercial lighting equipment to customers including efficient bulbs, ballasts, fixtures and lighting controls (Desmond, 1989).

In India, a project similar to the Taunton compact fluorescent leasing program has been proposed for Bombay by a consortium of the local electric utility, a major lighting manufacturer, and a research institute (Gadgil, 1990).

4. Rebates

Several hundred U.S. utilities provide cash "rebate" payments to buyers of energy-efficient equipment. Some utilities offer rebates to sellers of efficient equipment. These programs have shown that rebates can induce thousands of customers to undertake

energy conservation actions. The most successful programs generally combine simple program procedures that are easy for customers to understand, extensive marketing, and free technical assistance (Nadel, 1990c).

Rebates are most commonly offered to commercial and industrial customers. For example, over a two year period Wisconsin Electric has provided approximately $40 million in rebates for a wide-variety of energy saving equipment including lighting, HVAC, water heating, refrigeration, and industrial process measures. The program covers improvements to both new and existing buildings. Typically the rebates cover 30-50% of the cost of each measure -- the balance is paid by the customer. After two years, the program has resulted in approximately 60 MW of load savings, at an average cost to Wisconsin Electric of less than $600/kW saved (Nadel, 1990a). Wisconsin Electric can afford this investment because by investing $40 million in conservation, it is saving much more in power plant construction and operating costs.

Air conditioners, electric hot water heaters and heat pumps are commonly included in residential rebate programs in the U.S. Rebates for efficient models are as high as $915. Many utilities provide rebates, typically $20-$100, for more efficient refrigerators, freezers and water heaters. Often, the payment depends on the efficiency and size of the product (Berman, et al., 1987).

Florida Power and Light (FP&L) is one utility in the U.S. with a variety of residential rebate programs. For example, FP&L pays between $63 and $400 to its residential customers who purchase qualifying central air conditioning systems (Berman, et al., 1987). The rebate varies according to the efficiency and size of the system. In the first three years of this program (1982-84), FP&L estimates it has reduced summer peak demand by 63 MW at a cost of about $400/kW. Based on its avoided capital and operating costs, the utility estimates that this program has a benefit-cost ratio of nearly six (Elliot, 1985).

An important point for less developed countries to consider when establishing rebate programs is that the rebate amount for equipment such as air conditioners and electric water heaters should not be greater than the extra first cost for more efficient models. Otherwise, the rebate could stimulate higher equipment saturation levels, thereby defeating the purpose of the program. Rebates might be best suited for more essential equipment, such as efficient lighting products and commercial-industrial conservation equipment. In these cases, there would be little or no incentive for increasing the saturation of electricity-consuming equipment.

5. Performance Contracting

Performance contracting programs generally involve private energy service companies (ESCo's), who contract with a utility or end-user to assess, finance and install energy conservation

measures. The ESCo takes as payment a share of the energy cost reduction.

In the U.S., over 40 ESCo's are active. Many work in tandem with electric utilities to provide energy conservation services to the utility's customers. A recent review of utility experience with performance contracting programs found that most ESCo's concentrate on the largest commercial and industrial customers and the most lucrative energy-saving measures (particularly lighting and cogeneration). ESCo's were generally not interested in working with small and medium-sized customers. Furthermore, utilities operating both performance contracting and rebate programs generally found that rebate programs achieve higher savings and are less expensive per kW saved (Nadel, 1990a).

While experiences in the U.S. with performance contracting have been mixed, in France, performance contracting has been much more successful at achieving large energy savings, at least in multifamily housing. In France, energy service companies rose to prominence after World War II in response to the need for skilled technicians to manage heating systems in multifamily housing. French energy service companies are primarily energy management companies, not financial companies. Staff are primarily engineers and technicians, not financial analysts. French energy service companies almost always are responsible for on-going operations and maintenance at the facilities they serve. Often they are paid a fixed fee, so each franc saved adds directly to their bottom line. They work in a facility over the long-term. Due to their long-term perspective and the dominance of engineers, French companies are often interested in special projects which pose engineering challenges and have long payback periods (de la Moriniere, 1989). It may be worth exploring whether the French experience in multifamily buildings can be adapted to commercial and industrial facilities in other countries.

Performance contracting programs are only just starting in developing countries. A Canadian ESCo -- Econoler -- recently opened an office in Singapore. In Indonesia, a public/private industrial conservation company, KONEBA, has set up a few shared savings arrangements. Efforts to set-up ESCo's are also underway in India and Thailand (Philips, 1991).

6. Direct installation

There are a number of barriers to implementation of energy efficiency measures besides lack of money. For example, customers often lack the time or expertise to implement measures on their own, even if attractive financing is available. Direct installation programs seek to minimize the barriers to customer participation by providing comprehensive installation services to the customer including measure identification (audit), assistance with measure installation, and financing.

In the U.S., a number of electric utilities have sponsored direct installation programs. For example, New England Electric

System (NEES) found that small commercial and industrial customers (customers using less than 20,000 kWh/month) were unlikely to participate in rebate programs due to a lack of time and expertise. To overcome these obstacles, NEES offers small commercial and industrial customers a lighting audit, preparation of a detailed work order (for measures such as electronic ballasts and compact fluorescent lamps), and installation of measures, all at no cost to the customer. Benefits to the utility (due to lower construction and operating costs) are approximately 2 1/2 times greater than the cost of the program. NEES also offers a similar program for residential customers which provides and installs a variety of conservation measures including compact fluorescent lamps, water heater insulation, and low-flow showerheads. In order to reduce marketing costs, the residential program is offered door-to-door, one block at a time (NEES, 1990).

Not all direct installation programs provide services for free. Northeast Utilities (NU), a U.S. utility, offers comprehensive direct installation services to large commercial and industrial customers, but the utility pays no more than 50% of the cost of any measure -- the customer must pay the rest (NU, 1990). Similarly, the Bonneville Power Administration offers comprehensive weatherization services to customers with electric heat. The utility provides a free energy audit, arranges for private contractors to install eligible measures (primarily insulation and energy-efficient windows), and provides a grant that covers part of the measure cost (Schick et. al., 1990).

Experience in the U.S. with direct installation programs has shown that direct installation programs generally result in higher participation rates (the proportion of eligible customers who actually participate in a program) and higher energy savings per participating customer than rebate, loan, and performance contracting programs. However, direct installation programs are generally more expensive to the utility per kWh saved than other types of programs. Still, most direct installation programs in the U.S. cost less than the cost of building and operating a power plant. Thus direct installation programs are most useful when the maximum amount of cost-effective electricity savings are desired. When lower savings are acceptable, other program approaches will generally be less expensive (Nadel, 1990c).

Only a few direct installation programs have been run in developing countries. For example, PROCEL, Brazil's national electricity conservation program, operates a direct installation program to replace incandescent street lights with mercury vapor and high pressure sodium lamps. Over 280,000 lamps were replaced during 1986-89, resulting in savings of approximately 115 GWh/year. Most of the cost of these installations is paid by PROCEL; local utilities contribute 10-20%. The goal of this program is to replace a total of 1.2 million incandescent street lights by 1994. This program is especially attractive to utilities since municipalities pay a subsidized tariff for street lighting. Lowering electricity use reduces the utility's subsidy for this public service.

The Mexican utility, CFE, has run several small demonstration programs under which compact fluorescent lamps were provided to customers for free. The bulbs for these demonstration projects were donated by manufacturers. Evaluation of these programs has not yet taken place. CFE is planning a much larger compact fluorescent direct installation program under which 3 million compact fluorescent bulbs will be given to customers in two major Mexican cities. The project will be financed with a $40 million loan and grant from the World Bank. Details of the program are now being worked out (Sturm, 1991).

In Pakistan, ENERCOM, a government-affiliated energy efficiency office, has sponsored a direct installation program to tune-up industrial boilers. Originally services were provided for free, but after a reasonable market had developed, participants were charged enough to recover program costs. A similar program is now being planned to indentify and undertake power factor improvement measures (RCG/Hagler, Bailly, Inc., 1990).

7. Tax credits and waivers

Tax credits and accelerated depreciation allowances have been used in many countries to promote energy-saving investments. For example, from 1978 to 1982, U.S. businesses could take a tax credit equal to 10% of the capital cost of energy-saving investments. Similarly, Japan allows a 7% investment tax credit on energy-saving investments plus a special depreciation allowance equivalent to 18% of the acquisition price of energy-saving measures (Furugaki, 1988). An analysis of the U.S. credit (Alliance to Save Energy, 1983) found that the credit had little impact on energy investments made by U.S. industry -- most firms who took the credit would have made the same investments if no credit were available.

A few developing countries have implemented preferential tax policies for energy-efficient equipment. In the Philippines, energy management systems, efficient motors, lighting products, air conditioning systems, and other conservation technologies are exempt from import duties. Also, the government of Barbados has removed sales tax on various energy conservation devices including efficient lighting products (Thompson, 1985). India also provides tax credits for a number of energy-saving products, and it exempts other products from sales taxes and custom duties. However, the exempted products were selected with oil conservation in mind -- few electricity saving products are on the exempted product list (Department of Power, 1989).

Thailand reduces import duties for imports of energy conservation equipment. Industries must apply to the government for the reduction. Due to the cumbersome process, from 1983-1988, only 30 factories applied for reductions. Still, the program is credited with reducing industrial energy use by about 1% (Bijayendrayodhin, 1988). Thailand is now reportedly considering

import fee reductions for entire classes of equipment, such as compact fluorescent lamps (Cherniack, 1990).

Tax credits need not only be negative. A recent report to the government of Egypt suggested that import duties be lowered for efficient products and raised for inefficient products (Turiel et. al., 1990). Import duty waivers can be particularly important for efficient products in the early stages of product development. For example, duties can be reduced on imported equipment that is needed for domestic production of efficient products. Duties can also be reduced for a limited time period (e.g., a few years), in order to develop the domestic market to the point that local manufacture is economically viable.

## E. Least-Cost Utility Planning

Least-cost utility planning (LCUP) is a planning process that many electric utilities go through in order to determine the best mix of new power resources (e.g., new power plants and conservation programs) which can be used to meet future power requirements at the lowest possible cost. A LCUP process consists of several steps:

1. Develop a forecast of future electricity needs.

2. Examine the costs and amount of power available from different options for improving power availability, including new power plants (coal, hydro, natural gas, and renewable energy), improvements to existing power plants and transmission lines, and electricity conservation and load management programs.

3. Rank the different options in terms of cost per unit of energy generated or saved (including all operating costs over the project's lifetime).

4. Beginning with the least-expensive projects first, continue down the list until enough projects are included to meet projected future needs.

5. Change a few key assumptions, such as fuel prices and the rate of peak demand growth, to see if the ranking of projects changes significantly when key assumptions are changed. If this is the case, develop a new "least-cost" list of those projects that are most likely to have low costs under a wide variety of different assumptions.

Least-cost utility planning is most widely used in the U.S., but in recent years, LCUP has begun to be practiced in Canada, Australia, and Sweden. LCUP efforts have also begun in other European countries, and in Costa Rica (RCG/Hagler, Bailly, Inc., and Oak Ridge National Laboratory, 1991), Jamaica (Conservation Law

Foundation, 1990), Malaysia, and Thailand (Cherniack and Du Pont, 1991).

New England Electric System (NEES) provides a useful illustration of a LCUP process. For this process, NEES examined 69 options, including 11 new power plants, 7 opportunities to purchase power from other power companies, 11 cogeneration and alternative energy projects, 9 transmission line improvement projects, and 31 conservation and load management programs. Projects were assessed for a basecase scenario and five alternative scenarios (e.g., a high growth scenario and a scenario with reduced natural gas availability). After examining the least cost plan for each scenario, NEES selected the mix of power supply options that would best minimize costs across the range of scenarios. The chosen resource mix calls for 3375 MW of additional power by 1999, of which 39% will come from cogeneration and alternative energy facilities, 31% will come from conservation and load management programs, 24% will come from new natural gas fired power plants, and 6% will be purchased from a Canadian hydroelectric plant. As a result of this planning process, NEES expects to invest $600 million in conservation and load management programs over the 1990-99 period (1990 $), but compared to a strategy based only on building new high efficiency coal-fired power plants, the conservation and load management programs will save NEES $1 billion more than the programs will cost (NEES, 1990).

## Conclusion

Investment in electric generating capacity, primarily from foreign loans, has been growing rapidly in many developing countries. The need to limit the growing external debt of the power sector is now recognized as an important goal by many developing country energy planners. Thus, interest in establishing much stronger electricity conservation policies and programs is growing.

Developing countries can look to the hundreds of programs that have been developed in other countries to slow growth in electricity consumption and reduce investment in expensive new electric generating capacity. A thorough review and analysis of this information should greatly increase the likelihood that an individual developing country can launch successful new electricity conservation programs that will help meet future electricity needs, while saving citizens millions of dollars.

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