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Economic Benefits of Reducing Maharashtra's Electricity Shortage through End-Use Efficiency Improvement

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With the assistance of
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Environmental Energy Technologies Division

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Table of Contents

Table of Tables

Table of Figures

Preface

In recognition of the role that energy efficiency can play to ameliorate India's energy vulnerabilities, the US Agency for International Development, Office of Environment, Energy and Enterprise, New Delhi, initiated the Energy Conservation and Commercialization (ECO-II) Program in August-September 2003. ECO-II was established in consultation with the Indian Bureau of Energy Efficiency (BEE). Maharashtra was identified as a focus state for the development of demand-side management (DSM) planning and implementation activities. The International Institute for Energy Conservation (IIEC) was contracted to implement the ECO-II initiative with a focus on public buildings, municipal water pumping and street lighting, and domestic water heating. IIEC also provided training for building institutional capacity of the Maharashtra Energy Development Agency (MEDA). At the request of the Energy Department of the Government of Maharashtra, a Strategic State Energy Conservation Action Plan was developed. The plan identifies eleven energy efficiency programs, for implementation by government agencies and utility companies in the state.

This LBNL study was designed to complement the aforementioned ECO-II activities. One of ECO-II's goals is to develop parameters for an energy conservation fund to support the implementation of energy efficiency measures in the state. Through a techno-economic analysis the LBNL study provides a sound analytical rationale for the use of public funds to support end-use energy efficiency improvement. The study estimates the economic benefits of selected end-use energy efficiency investments in the residential, commercial, industrial, and agricultural sectors to consumers, utility companies, government, and industry. Increased energy efficiency permits utility companies to meet their demand obligations, and electricity-short businesses to increase production, which can result in higher tax payments to governments at all levels. The analysis estimates the reduction in the state's fiscal deficit through the implementation of such measures.

Abstract

India is faced with electricity shortages that have persisted for many years. End-use electricity efficiency improvement offers the least expensive way to reduce these shortages. In Maharashtra, which is a relatively well off industrialized state, the economic potential for cost-effective end-use efficiency improvement is large enough to eliminate the state's electricity shortage. Increasing its use in subsidized consumer categories (agriculture, residential, and municipal) can reduce subsidy payments. The resale of thus saved electricity to electricity-short businesses can increase their production and generate additional revenue for the Maharashtra State Electricity Board (MSEB). Curtailment of electricity to businesses lowers their economic output, and reduces their tax payment to governments at all levels. Restoring electricity supply to such businesses can increase their production and tax payments. Such increased tax revenue has the potential to reduce Maharashtra's fiscal deficit by more than 15%. A demand-side management (DSM) program targeted at (1) short-term efficiency improvement (lighting, agricultural pump rectification, motor rewinding, variable speed drives, etc.) can provide immediate relief, and (2) long-term efficiency improvement (appliance standards, solar water heating, new agricultural pumps, efficient motors, etc.) can together place the electricity system on a more reliable footing. A combination of MSEB, Maharashtra Electricity Regulatory Commission, Maharashtra Energy Development Agency (MEDA), and/or a newly formed public-private partnership may be needed to pursue rebate, third party billing, and information dissemination programs for this purpose.

1 Introduction:

The rapidly growing Indian economy is vulnerable to disruptions in the supply of energy. India currently produces only one-third of its oil demand, possesses limited natural gas reserves, and faces chronic electricity shortages. The rising demand for these two fuels is expected to be met through imports from foreign sources, which will worsen the country's vulnerability to volatile prices in a tightening world oil market. The inability of the electricity grid to supply reliable power, particularly to business consumers, has prompted increased use of captive power generation that often uses diesel fuel. These vulnerabilities are being addressed through diversification of energy imports, the development of indigenous energy sources, and, last but not least, reducing the intensity of energy use of the Indian economy. In this report, we focus on ways to stretch the existing electricity supply capacity by making energy use more efficient. The increased efficiency will permit utility companies to meet their demand obligations, and permit electricity-short businesses to increase production that will result in higher tax payments to governments at all levels. More efficient use of energy thus has the potential to reduce the nation's vulnerability in both the imported fuels and electricity markets.

With a total generation capacity in excess of 100 GW, India has one of the world's largest electricity supply systems that spans the breadth of the country. The Indian government has carried out many legislative and regulatory reforms since the mid-1990s which involve establishment of independent electricity regulatory commissions and increased participation of the private sector in generation and distribution of electricity. As a consequence of these reforms in the electric power sector, and also in the overall economy, the productivity of electricity use has increased since 1991, and electricity use per unit of economic output has remained relatively unchanged since then. Despite these reforms, and the large generation capacity, electricity shortages are endemic throughout the country. The Ministry of Power's annual report (2002-03) notes that there was a power shortage of about 10 GW or 12.2% of the peak demand, and an energy shortage of 41.7 GWh or 9.1% of the requirement during that year. Shortages of this magnitude can significantly constrain industrial activity, reduce economic growth, and/or require businesses to utilize more expensive back-up generation. Reduced economic output also means that these businesses pay less tax revenue to governments at all levels. The Indian central and state governments are faced with fiscal deficits that are made worse by the reduced economic growth caused by the lack of electricity service to businesses.

It is clear then that an increase in electricity supply could have substantial tax revenue benefit to the government. Increasing the supply of electricity would require higher investment in generation of electricity, and possibly for its transmission and distribution. Part of the reason for the electricity shortage, however, is the lack of access to capital for cash-strapped electric utility companies that are unable to generate adequate revenue to cover their costs of supply. Improving end-use electricity efficiency in this context can offer a much less expensive alternative for providing the desired electricity service (Sathaye and Roy, 2005). We test this hypothesis by analyzing the electricity shortage in Maharashtra, India's most industrialized state, and estimate the economic benefits to the consumer, the utility company, and the state government. We examine the role of energy efficiency as a means to reduce and possibly eliminate electricity shortages, reduce vulnerability to disruptions in the energy markets, increase economic output, employment, and tax revenue which would thereby reduce government fiscal deficits. We conclude that the economic benefits of improving end-use efficiency, to consumers, the state utility company (Maharashtra State Electricity Board (MSEB)), and the government, are sufficiently large to warrant initiation of an immediate program to alleviate current and long-term electricity shortage in the state.

2 Maharashtra Background:

The population of the state of Maharashtra was 101.3 million on 1 March 2004. The state accounts for 13% of India's GDP, and for 19% of its industrial output. It is relatively better off than most other Indian states with an income per capita of Rs. 24,248 (US $508)[1] in 2001-02. The state's fiscal deficit has worsened since the mid-1990s, and as a proportion of the Gross State Domestic Product (GSDP), it increased from 2.0% in 1993-94 to 5.6% in 2003-04 (RE). Likewise, the state's overall debt now stands at 25.2% of its GSDP, which is up from 12.7% in 1995-96. Faced with financial challenges, the

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[1] July 04 US $ exchange rate, 47.692. (Economic Survey 2003-04, Planning Commission, Govt. of India.)

state government is pursuing a program of fiscal reforms in understanding with the central Ministry of Finance to achieve fiscal sustainability in the medium term.

2.1 Electricity Supply

The electricity generation in 2002-03 and installed capacity on 31 March 2003 in Maharashtra are shown in Table 1. The state has generators within its boundaries, and also purchases electricity from two other sources, the National Thermal Power Corporation (NTPC) and the Nuclear Power Corporation (NPC). The latter accounted for about 20% of the electricity supply to the state. Five major entities are engaged in the generation of electricity in the state. Of these, MSEB, Tata Power and Reliance account for 97% of the state's generation. Thermal generation accounts for almost 75% of the in-state generation.

Table 1. Electricity generation and capacity, Maharashtra (2002-03)

Type of generation	**Capacity (MW)**	**Generation (GWh)**
Thermal	8,075	52,204
Hydro	2,878	5,534
Natural gas	1,820	5,043
Nuclear (state's share)	190	1,158
Sub-total (in state)	***12,963***	***64,740****
MSEB	*75%*	*75%*
Tata power	*14%*	*16%*
BSES (reliance)	*4%*	*6%*
Dabhol Power Corp. (not used since May 2001)	*6%*	*0%*
Tarapur	*1%*	*2%*
Non-conventional		*1%*
State's share of NTPC/NPC	***2,189***	***15,799***
Total	**15,152**	**80,539**

Source: Economic Survey of Maharashtra, 2003-04.
Note: * -- includes 801 GWh from other sources

The growth rate of installed capacity in the state has declined over the past 40 years, and during the past decade (1991-2001) capacity increased at an annual rate of 4.9% per year. More importantly, the state currently is not able to make use of the 2400 MW of capacity from the Dabhol Power Corporation (DPC). And, due to MSEB's tenuous financial situation, the state has added only three major power plants over the past few years (1998-99: 250 MW Koyna, 1999-00:750 MW Koyna, 2000-01: 400 MW

Khaperkheda), and planned to add 250 MW at Parali and 250 MW and Ghatgar in 2004-05.[2]

2.2 Electricity Demand and Revenue:

Statewide, and within MSEB service area, the industrial sector accounts for the largest share of the total electricity consumption (Table 2), which is followed by the domestic sector statewide, but by the agriculture sector in the MSEB area. The average revenue realized from the agriculture sector in 2002-03 was only Rs. 1.50 per kWh, which was much lower than the average cost of electricity supply at Rs. 3.26 per kWh. Furthermore, this revenue realization has declined since the government has provided farmers electricity free of charge since summer 2004. Commercial and industrial customers clearly pay much higher rates compared to the average cost of supply. Domestic, agriculture, public lighting, and public water works consumers enjoy lower rates, which are subsidized, in part, by the other customers.

In 2002-03, MSEB had a deficit of Rs. 254.7 crores or about 1.9 percent of the total revenue, excluding subsidy, of Rs. 13,447 crores. The deficit was only half that of the prior year, but nevertheless reflects the poor financial situation of the utility company. Its inability to raise adequate revenue also reflects poorly on its capacity to borrow funds for investment in future power generation plants and the sorely needed modernization of the transmission and distribution system (T&D) system.

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[2] 10th National Electricity Plan, Central Electricity Authority, India

Table 2. Consumption of electricity, Maharashtra (2002-03)

Type	**Statewide (GWh)**	**%**	**MSEB (GWh)**	**%**	**MSEB average revenue realization (Rs./kWh)**
Domestic	12,267	*24.6*	7,411	*19.1*	2.8
Commercial	4,669	*9.3*	1,643	*4.2*	4.6 (non-domestic)
Industrial	18,156	*36.4*	15,593	*40.3*	4.0 (high tension) 3.6 (general motive power)
Agriculture	10,642	*21.3*	10,202	*26.3*	1.5
Public lighting	666	*1.3*	576	*1.5*	3.1
Railways	1,748	*3.5*	1,012	*2.6*	3.8
Public water works	1,416	*2.8*	1,387	*3.6*	2.8 (urban) 1.1 (rural)
Misc.	381	*0.8*	1,014	*2.4*	
Total	**49,945**	***100.0***	**38,837**	***100.0***	**3.26***

Source: Economic Survey of Maharashtra, 2003-04.
Note: * -- Average cost of power supply

2.3 Electricity Shortage

Until 1998-99, there was sufficient generation capacity to meet MSEB’s peak demand for electricity. Since then, however, peak demand each year has exceeded the available system capacity. In 2003-04, peak demand amounted to 13,279 MW, which required the shedding of 2,367 MW of load.

MSEB has made efforts to reduce its transmission and distribution losses. During 2003-04, it reported a T&D loss of 34.2% compared to 38.6% the year before and 39.2% in 2001-02, part of which was reduction in technical losses. Further reductions of technical T&D loss, estimated to be about 22%, would reduce the shortage and the need for additional generation capacity.

3 Approach

In this analysis, we explore the potential for the use of energy efficiency as a means to reduce Maharashtra’s electricity shortage. This requires that we estimate the load shed by MSEB, and the cost-effective potential for energy efficiency improvement, by consumer category.

Since only aggregate data were available on the shed load, we developed a procedure to allocate it by urban and rural areas and by customer category, which relied on interviews with MSEB dispatch staff and their published load shedding plan for the state.

We estimated the energy efficiency potential for selected efficiency measures and/or end-uses, such as lighting, refrigerators, electric motors, agricultural pump sets, solar water heaters, and variable speed drives. Costs of these measures were estimated through market surveys. Typically, three types of potentials have been reported in the literature – technological, economic, and market potential. Market potential refers to the actual penetration level of the technology in the market. Economic potential refers to the penetration potential at an economic cost of the measure without taking into account various types of market failures. We estimated the economic potential of the measures first from the consumer perspective, and added transaction costs that might be incurred to overcome some of the market failures. We also reduced the economic potential to reflect the impact of market failures that might limit the penetration of energy efficiency measures. These adjustments to the economic cost and potential values thus gets us closer to the market potential.

We match the energy efficiency potential and the load shed by customer category, and thus establish an economic basis for a program to potentially eliminate the shortage. Electricity saved by subsidized customers can be utilized by those high tariff customers who are not receiving adequate electricity supply, provided the system capacity is adequate to support the additional load. We estimate the amount of saved electricity that MSEB may be able to resell to such high tariff customers. This has two consequences. It reduces MSEB’s subsidized load, which reduces its revenue loss, and increases its supply to high tariff customers, which increases its revenue.

Increased supply of electricity to high tariff customers would enable businesses to increase their economic output by a proportionate amount. Higher economic output would generate additional tax revenue to governments at all levels. We estimate the tax revenue using data on state tax revenue by category.

The increased economic output will provide a backward and forward stimulus to the state economy. To estimate this secondary or indirect impact on output, income, taxes, and employment, we developed an input- output table for Maharashtra. The IO table is based on a national 1997-98 table with adjustments for industries that are not located in the state. Income and employment multipliers were derived using this state IO table and used to estimate the aforementioned secondary impacts.

Section 4 below describes our estimates of the load shed by MSEB by customer category, Sections 5 and 6 describe the estimation of the cost and current potential, and consumer and MSEB economic benefits respectively, of selected measures, Section 7 describes the estimation of future energy savings, Section 8 discusses the fiscal benefits to the Maharashtra government, Section 9 notes the relevance of US state-level public benefits programs to Indian states, and Section 10 describes the conclusions and delineates areas for further work.

4 Analysis of MSEB load shedding

Since the economic and welfare loss due to electricity shortage varies by consumer category, we need to understand the distribution of the load shed by MSEB by these categories. In the case of industrial consumers, a shortage could result in loss of production or require the use of expensive backup power, while in the case of residential consumers a shortage would cause an inconvenience with no direct economic loss. Section 4.1 below describes the MSEB daily load profile, which illustrates the severity of its electricity shortage. Section 4.2 describes MSEB’s plan to implement load shedding on an organized basis, and Section 4.3 describes our procedure for the estimation of the load shed by customer category.

4.1 MSEB daily load profile

Energy efficiency measures save energy at different times of the day. For example, energy efficient household lighting typically saves energy in the late evening and solar water heaters save energy in the morning. Energy efficient measures will be most beneficial if they save energy at a time when the load is being shed.

The following charts give the load shedding pattern for the year 2001-2002 (Figure 1) and the year 2002-2003 (Figure 2). The vertical gap between MSEB supply and demand is the amount of load shed. Load shedding increased in the year 2002-03, compared to the prior year, as demand increased but the supply remained unchanged. As seen in the graphs, load is shed not just at the peak time, but for almost 16 hours a day from 6am to 10pm. Hence, any energy saved during this 16 hour period will help reduce the shortage.

Figure 1. MSEB system demand and supply for 2001-02

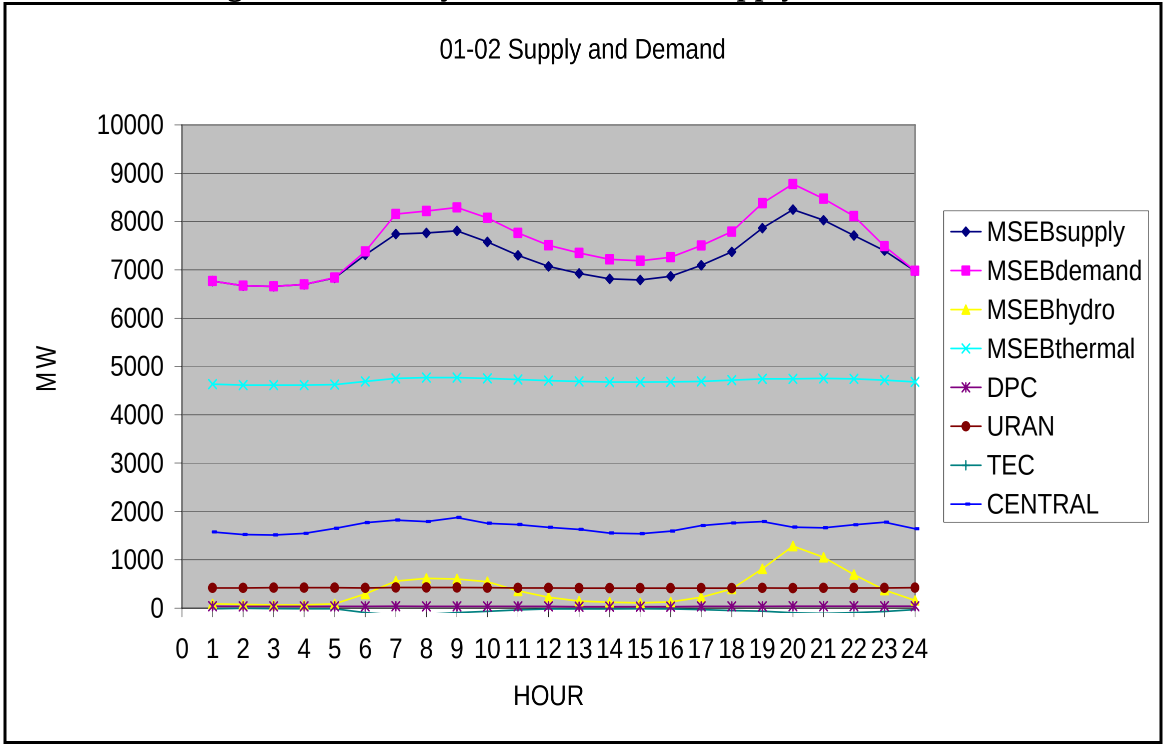
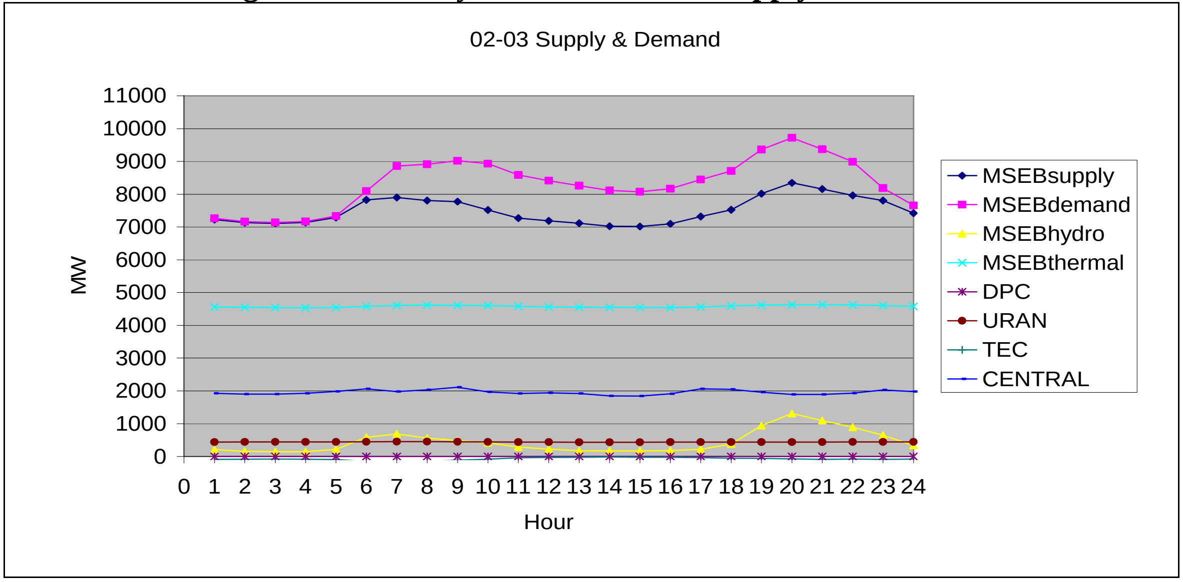


Figure 2. MSEB system demand and supply for 2002-03



4.2 Implementation of MSEB's load shedding plan [3,4]

The Regional Load Dispatch Center (RLDC) at Kalwa (Thane) is the main authority for implementing a load shedding plan in Maharashtra. RLDC estimates future electricity demand and supply for one year and prepares a load shedding plan. This plan allocates the load to be shed by urban and rural regions. On a given day, RLDC instructs operators of main substations to shed load based on this plan with certain modifications that are based on specific conditions of demand and supply prevailing on that day. Operators at main substations then plan and implement feeder-wise load shedding programs.

MSEB officials believe that about 60 – 70 % of the planned load shedding actually takes place on the ground.[5] In some cases, the substations are reluctant to implement load shedding programs because of political and social pressures. At the substation level, the load at the time when service was discontinued is reported as the shed load for the next few hours until the connection is restored. This is not a precise way of estimating the shed load as the load may change during this period. Estimating load behavior in the absence of load shedding, and then estimating and planning load shedding considering this behavior will improve load shedding plans, but this is not how it is planned and reported currently. We rely on MSEB's load shedding estimates since there is no independently monitored method that uses better data for this purpose. Each substation reports the shed hourly load to the RLDC where substation-wise data are aggregated to arrive at the total hourly load shed for the entire MSEB system.

4.3 Estimation of load shedding by customer category

We need to estimate the shed load by customer category, but MSEB does not collect data by category. Our interviews with MSEB officials indicate that some general principles are followed in load shedding to minimize the financial losses to MSEB. The

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[3] This analysis is based on informal interviews with MSEB officials responsible for the planning and implementation of the load-shedding plan.

[4] Allocation of load shedding between rural & urban consumers is based on Maharashtra State Electricity Board (MSEB) (2004). Schedule of planned load shedding http://www.msebindia.com/consumer/merc_arcieve.shtm. (accessed on August 19th , 2004 (20.50 PST)
Load shedding allocation principles based on interviews with MSEB officials – primary information from Dr. Sunil Kulkarni, Chief Engineer, Kalwa Load Dispatch Center. Also based on interviews with Girish Sant and Shantanu Dixit, Prayas Energy Group, Pune.

[5] ~ 60 % in the period April to September and ~ 70 % in the period October to March

general principles are as follows. Load shedding is avoided for high tariff industrial and commercial consumers of MSEB. As the Maharashtra Industrial Development Corporation (MIDC) areas have high concentration of industry, load is rarely shed in these areas. Load shedding is also generally avoided for high tension (HT) consumers as most of these are large industrial or commercial consumers. Load shedding is generally avoided in major cities such as Pune, Nagpur, and Aurangabad since these cities have high concentration of commercial consumers.[6] Although commercial consumers pay a high tariff, load shedding for these consumers is difficult to avoid since they are often on the same feeders as residential consumers. A majority of the load shedding is done in rural areas where the load mainly consists of agricultural pumping.

By considering MSEB's load shedding plan, the hourly shed load reported for the MSEB system, and information given by MSEB officials, the load shedding by different categories of consumers is estimated as follows:

As the load is rarely shed in Mumbai, load shedding for the MSEB system is equivalent to that for the Maharashtra power system. Industrial production capacity is thus not affected in Mumbai but it is curtailed in the rest of the state. This has implications for the procedure used to estimate sales tax revenue, which is described in Section 8.

MSEB's load shedding schedule (available on MSEB's web site) indicates a plan for the hours and amount of load to be shed in rural as well as urban areas (Table 3). A ratio of urban to rural load to be shed can be worked out from this plan. This analysis shows that about 82% of the load is shed in rural areas while the remaining 18% is in urban areas. Hence we estimate that out of the total shed load of 7,836 GWh in 2002-03, 1,436 GWh were shed in urban areas and 6,400 GWh in rural areas.

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[6] The electricity situation in the state had deteriorated by 2004-05 such that even Pune was experiencing 3-hours per day load shedding.

Table 3. MSEB's load shedding plan

Time block	**MW**	**Hours**	**MW-hr/ day**
Rural load shedding plan			
5.00 to 5.30	890	0.5	445
5.30 to 11.00	2005	5.5	11028
11.00 to 11.30	2005	0.5	1003
11.30 to 17.00	2005	5.5	11028
17.00 to 17.30	2005	0.5	1003
17.30 to 23.00	2005	5.5	11028
23.00 to 23.30	1115	0.5	558
Total rural			**36090**
% of the total load shedding			**82%**
Urban load shedding plan			
8.30 to 11.30	900	3	2700
11.30 to 14.30	900	3	2700
14.30 to 17.30	900	3	2700
Total urban			**8100**
% of the total load shedding			**18%**

The next step is to estimate the amount of load that is shed by each category of consumer in urban and rural areas. The total shed load is allocated to different categories of consumers on a pro-rata basis of the consumption subject to load shedding in each consumption category. The consumption subject to load shedding is calculated from the total consumption of each category by making two corrections. First, MIDC consumption is removed from HT and LT industry consumption since MIDC load is rarely shed. Next a certain ratio (which is based on the information given by MSEB officials) is applied to this corrected consumption to arrive at the consumption subject to load shedding. For example, for the domestic category, this ratio is 100% indicating that all the domestic consumption is subject to load shedding. For HT industry, this ratio is assumed to be 50% indicating that only half of the non-MIDC HT industry consumption is subject to load shedding. The total shed load is then allocated to different consumption categories on a pro-rata basis of the consumption subject to load shedding in each category of consumption. Table 4 shows the key steps in this process

Table 4. Consumer category-wise load-shedding allocation (2002-03)

Consumer category	Consumption (GWh)	Consumption excluding MIDC areas (GWh)	Percentage eligible for load shedding (%)	Consumption subject to load shedding (GWh)	Load shed by category (GWh)	Load shed by category as % of the total shed load (%)
C 1	**C 2**	**C 3**	**C 4**	**C 5=C 4*C 3**	**C 6[+]**	**C 7**
Urban						
Domestic	4912	4912	100%	4912	614	43%
Commercial	1231	1231	100%	1231	154	11%
L. T. industry	2317	1764	80%	1411	176	12%
H. T. industry	6480	4932	50%	2466	308	21%
Agriculture and irrigation	721	721	100%	721	90	6%
Street lights	312	312	100%	312	39	3%
Railway traction	666	666	0%	0	0	0%
Railway non-traction	56	56	0%	0	0	0%
Public water Works	611	611	50%	305	38	3%
Military	256	256	50%	128	16	1%
Total urban	17562	15461		11875	1436	18.3%
Rural						
Domestic	2498	2498	100%	2498	963	15%
Commercial	412	412	100%	412	159	2%
L. T.	875	666	100%	666	257	4%
H. T.	5920	4506	50%	2253	868	14%
Agriculture and irrigation	9481	9481	100%	9481	3653	57%
Street lights	264	264	0	0	102	2%
Railway traction	277	277	0	0	0	0%
Railway non-traction	12	12	100%	12	0	0%
P.W.W.	776	776	50%	388	150	2%
Military	31	31	50%	16	6	0%
Mula pravara	631	631	100%	631	243	4%
Total rural	21177	19555		16760	6399	81.7%
Total (rural + urban)	38739	35016		28635	7835	

5 Estimating the cost of energy efficiency measures

There are many measures to increase the end-use efficiency in the electricity sector. In this report, we focus on measures that are widely used in each consumer category and are likely to have a significant potential for efficiency improvement. These include lighting, refrigeration, water heating, motors, variable speed drives, and agricultural pump sets. Air conditioning is a rapidly rising end use, where energy efficiency improvement could make a difference in the future but its use in the residential sector is limited at present to the highest income households. Improvements to some of these end uses, such as lighting and pump rectification, would have immediate benefits, and others will provide a longer-term benefit, both enhancing the supply system reliability.

For the residential sector, we analyze the use of compact florescent lamps (CFLs) for lighting, energy efficient refrigerators, and solar water heaters (Table 6). In the commercial sector, the focus is on CFLs and refrigerators, in the agricultural sector, on agricultural water pumping, and in the industrial sector, on motors and variable speed drives. In the following discussion we present the methodology used for calculating the cost of conserved energy, and the cost of conserved peak capacity.

5.1 Methodology

Table 5 gives the details of formulas used to calculate the CCE and the cost of conserved peak capacity (CCP). The first column alphabetizes the row parameters and the last column displays the equation. For example Row C – Equipment life (years) is calculated by dividing equipment life (hours) in row B by usage in hours per year (in row A), and hence the equation for C displays B/A.

The methodology used for calculating the cost of conserved energy and the cost of conserved peak capacity can be described as follows: The additional cost of an energy efficient technology (energy efficient technologies) compared to a conventional energy technology (CET) is the incremental capital cost (Row D). This is also the purchase cost or investment needed for improving energy efficiency using that technology. The capacity of energy efficient technologies and CET are chosen in such a way that they have the same useful output (heat, light, mechanical power, etc.). The energy efficient technologies saves a certain amount of energy every year over its lifetime. The cost of conserved energy is obtained by dividing the annualized incremental capital cost for the energy technology by the energy saved annually as shown in Row O, and the cost of conserved peak capacity is shown in Row P.

Table 5. Method for calculating the cost of conserved energy (CCE) and capital cost of conserved peak (CCP) capacity

Index	Parameter	Equation
A	Usage (Hours/Yr)	
B	Equipment Life (Hours)	
C	Equipment Life (Years)	B/A
D	Incremental capital cost (Rs.)	
E	Transaction costs (% of capital cost)	
F	Total Investment (Rs.)	D*(1+E)
G	Discount rate	
H	Capital Recovery Factor (CRF)	C/(1- (1+C)^(-B))
I	Annualized capital Cost (Rs./Yr)	F*H
J	Load Saving while in operation at end user (Watts)	
K	T & D losses	
L	Annual Energy Savings at the bus bar (kWh/Yr)	J*B/(1-K)
M	Peak coincidence factor	
N	Peak load saving at the bus bar (Watts)	J*M/(1-K)
O	Cost of Conserved Energy (CCE) (Rs/kWh)	L/I
P	Capital Cost of Conserved Peak Capacity (CCP)	F/N

For example, an 18W CFL gives the same amount of light output (lumens) as a 60W incandescent lamp, hence if CFLs are used instead of conventional incandescent lamps, 42W of power is saved while the CFL is in operation. This power saving will reduce the power shortage, or displace supply side resources if the power is saved at the time when there is no power shortage. A peak coincidence factor captures this aspect and is equal to the probability that the energy efficient device will be operating when the system is short of power. Expected load saving is the product of the load saved while in operation and the peak coincidence factor. The cost of peak power saved is calculated by dividing the incremental capital cost by the peak load saving. As there are T & D losses in the system, one unit of energy (or power) saved by the end user saves more than one unit of energy (or power) at the bus bar. This effect is taken into account while calculating the bus bar cost of conserved energy and the cost of conserved peak capacity.

5.2 Data and parameter assumptions

The calculation of CCE and CCP requires data on the price, efficiency, and usage of the efficient and conventional technologies. We collected data on retail as well as wholesale prices for most of the technologies through either telephone or in-person interviews with manufactures and dealers (wholesale as well as retail). (See Appendix 1 for details on sources of information) Based on these interviews, we estimate that the wholesale price of the efficient technologies is typically 20 to 40 % lower than its retail price. Although an individual consumer pays the retail price, large utility or government purchases for efficiency programs are likely to be at the wholesale price. Data on usage and efficiency of the technologies were obtained from manufactures, dealers, and secondary sources such as reports, and journal articles. In the following discussion, we describe the data and parameter assumptions separately for each technology considered in this study.

5.2.1 Residential Sector

We focus on three end-uses, lighting, water heating and refrigeration, in this sector. For each end-use we assess the cost of one representative energy efficient technology. For lighting, we evaluate the use of CFLs, for refrigeration, the use of efficient refrigerators, and for water heating, the use of solar water heaters. We collected data on retail and wholesale costs of these technologies during August 2004 through in-person or telephone interviews with retail stores, dealers, and manufacturers in the mid-size city of Pune, Maharashtra. The data are thus indicative of the technology costs borne by urban dwellers, but are not comprehensive in their representation of Maharashtra state. End-use efficiency and retail market price data for the residential sector are reported in Table 6.

Replacement of incandescent lights with CFLs

An 18 W CFL gives the same light output (lumens) as a 60 W incandescent bulb saving 42 W of power. CFLs are rated to last between 7,000-10,000 hours compared to an incandescent bulb which is rated for 750-1000 hours. Prices of CFLs in India have dropped significantly in the past few years partly as a result of increased competition in the Indian market. There are a variety of CFL brands, local as well as imported, of varying quality, that are available in the market. The retail price of a CFL ranges from as low as Rs. 20 for an 18 W Chinese unbranded bulb up to Rs. 260 for a comparable Philips brand. Local brands such as Orpat are also popular and an 18 W CFL costs Rs. 160.

There is a significant difference between wholesale and retail prices of these bulbs. For example, retail price of an 18 W Philips CFL is Rs. 260 while the wholesale price is Rs. 220. For our analysis, we take the price of Philips CFL as it is the most popular, and a proven brand. We make a conservative assumption of 8000 hours as the life of the CFL. The retail market price of a 60 W incandescent bulb is about Rs. 8 each, and eight incandescent bulbs will be replaced during the life time of a CFL. The incremental capital cost of using a CFL instead of an incandescent bulb is obtained by subtracting the net present value of eight incandescent bulbs replaced over a period of five years (a CFL will last about five years given average hours of operation per year) from the price of a CFL. Many studies (IEI-CMIE (2000), SRC (1995), USAID (1991)) have found that residential light bulbs are used for 4 hours mostly from 6.00 pm to 10 pm in the evening; hence we calculate a usage rate of 1460 hours per pear. Figures 1 and 2 show that the system is short of capacity during this period, which results in a high peak coincidence factor of 0.9. The use of a CFL results in an annual electricity saving of 46 kWh/year.

Energy efficient refrigerators

The average electricity consumption of a 165 liter direct cool refrigerator sold in the Indian market is about 1 kWh per day (365 kWh per year). A commercially available energy efficient refrigerator (made by Videocon) consumes about 0.65 kWh per day (237 kWh per year), and retails for Rs. 300 – 550 more depending upon the brand of the conventional refrigerator (BEE, 2004). The higher cost and electricity consumption of a refrigerator is consistent with that reported from analysis of specific improvements for a typical refrigerator. We assume an incremental first cost of Rs. 550 for an energy efficient refrigerator.[7,8] Refrigerators operate continually and cycle throughout the day. Harrington (2004) reports a compressor activation rate of 38% for Indian refrigerators. Since the refrigerators cycle throughout the day, the peak coincidence factor for refrigerators is equal to the number of hours of power shortage in the day divided by the total number of hours which is 0.66 (16 hours of power shortage/24 hours in a day). The use of an efficient refrigerator results in an annual electricity saving of 125 kWh/year.

Replacement of an electric water heater with a solar water heater

Electric water heaters draw significant amount of power (2.25 kW models are the most popular in the state based on interviews with retailers (Appendix 1)), and constitute most of the morning peak demand. Solar water heaters (SWH) can save electricity on at least the 250 non-monsoon days in a year. To calculate their energy savings, we assume that the water requirement per family is 100 liters per day with an incremental temperature of 15 degree C. This results in an electricity consumption of 581 kWh/year, which can be eliminated by the use of a SWH. The purchase price of a 100 liter per day SWH unit is Rs. 20,000. Electric water heaters are mostly used during the morning, and they consume electricity during the morning peak time. Hence we estimate a peak coincidence factor of 0.9.

5.2.2 Commercial Sector

For the commercial sector, we consider two energy efficiency measures — replacement of incandescent bulbs with CFLs, and energy efficient refrigerators (Table 6). For these two measures, estimates of incremental capital cost are the same as the residential sector, but estimates of usage and peak coincidence factor are different. For lighting, we assume usage of 6 hours per day. We also assume a lower peak coincidence factor of 0.8 as some of the consumption may happen off peak at night for applications such as security and street lighting, billboard illumination, etc. Cost estimates and assumptions for energy efficient refrigerators are the same as in the case of the residential sector.

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[7] These data are consistent with those estimated by Bhatia (1999), as reported by Harrington (2004) for a variety of direct-cool refrigerator models of 165 liter capacity.

[8] Consumer costs only. Not intended for programs so no wholesale cost estimate.

Table 6. Data on selected energy efficiency measures in the residential and commercial sectors

	Residential						**Commercial**	
	Lighting		**Water heating**		**Refrigerators[3]**		**Lighting**	
Measure/ technology	**Incandescent lamp**	**Compact fluorescent lamp**	**Geyser**	**Solar water heater**	**Conventional[1]**	**Higher efficiency[1]**	**Incandescent lamp**	**Compact fluorescent lamp**
Power requirement per unit. (W)	60	18	2,250	0	110	72	60	18
Measure life (years or hours)	1,000	7.3 yrs. or 8,000 hrs.	15	15	10	10	1,000	3.7 yrs. or 8,000 hrs.
Usage (hours/year)	1,095	1,095	NA	NA	38%[2]	38%[2]	2,190	2,190
Retail market price (Rs./Unit)	8	260	3000	20,000	8,000	8,550	7.1[4]	225[4]
Annual electricity use (kWh/year)	65.7	19.7	581	0	365	240	131.4	39.4
Peak Coincidence Factor	0.9	0.9	0.9	0.9	0.66	0.66	0.8	0.8

Note:
1: Direct cool refrigerator of 165 liter size.
2: Percentage refers to the compressor activation rate of the refrigerator.
3: Data applies to both residential and commercial sectors
4: Wholesale market price

5.2.3 Agricultural sector

In the agricultural sector, we focus our attention on small agricultural pump sets (APS), which constitute majority of the agricultural electricity consumption (Table 7). Many studies (Patel and Pandye, 1993) have found that the efficiency of agricultural pumping systems (APS) in India is dismally low. The several technical reasons for inefficiency include—oversized pump sets, undersized pipes, high friction foot valves, and substandard models of pumps. As the electricity tariffs for farmers are very low (in some states, including presently in Maharashtra, electricity supply is free for farmers), neither the farmer nor the pump dealer has an incentive to install efficient APS. Farmers also lack access to credit and information about the efficiency of pump sets and its impact on costs (Sant and Dixit, 1996).

We consider three different sets of energy efficiency measures— (1) purchasing an energy efficient pump set instead of a conventional one at the end of the pump life, (2) rectification (retrofitting) of the existing APS by replacing pipes and the foot valve, and (3) replacement of the existing pump with an energy efficient pump.

Cost effectiveness of these measures varies depending on the situation. For example, if the existing pump is not that old and is of a standard brand (hence is likely to be more efficient) then pump replacement may not be cost effective. Other measures such as pipe and foot value replacement may result in larger efficiency improvement at a lower cost. It is important to avoid blanket replacement of the entire APS as some programs have done and target energy efficiency measures taking the current situation into consideration.

Purchasing an energy efficient new pump instead of a conventional one:

This measure applies to new purchases. Many companies sell low cost brands of pumps with substandard quality. As the electricity tariff is low (currently free to Maharashtra farmers), electricity consumption and efficiency is generally not considered as a criterion in a farmer's pump selection process. Dealers have an incentive to sell oversized pumps with maximum head and as a result, often an inappropriate size and type of pump gets selected. Patel and Pandye (1994) have shown that appropriately selected standard quality pumps can save between 30 to 40% of the used energy. We assume a conservative 25% efficiency improvement. Pumps that meet the ISI mark (such as Kirloskar) cost 30 to 50% more than substandard quality pumps. For a 5 horsepower ISI mark pump, a farmer would have to pay an incremental cost of Rs. 3000 to Rs. 4000 per pump (based on market survey of pump dealers in Pune, Maharashtra listed in Appendix 1). Use of an efficient pump can decrease electricity consumption by 1,119 kWh/year.

Table 7. Data on selected energy efficiency measures for agricultural water pumping

	New pump purchase		Pump rectification		Pump replacement	
Measure/ technology	**Conventional new pump**	**Efficient new pump**	**Existing pump**	**Pump after rectification**	**Existing pump**	**Efficient new pump**
Power requirement (W/ Unit)	3.7 (5 hp)	3.7 (5 hp)	3.7 (5 hp)	3.7 (5 hp)	3.7 (5 hp)	3.7 (5 hp)
Load while in operation (W)	3.7	2.8[1]	3.7	2.6[2]	3.7	2.2[3]
Measure life (years) (yours)	10	10	10	10	10	10
Usage (hours/year)	1,200	1,200	1,200	1,200	1,200	1,200
Retail market price (Rs./Unit)	7,000	10,000	0	2,500	0	10,000
Peak coincidence factor	0.25	0.25	0.25	0.25	0.25	0.25
Annual electricity use (kWh/year)	4476	3357	4476	3133	4476	2686

Note:
1: 25% power and electricity savings
2: 30% power and electricity savings
3: 40% power and electricity savings

Pump rectification (retrofitting)

Patel and Pandye (1994) have found that in the case of most pump sets, undersized pipes are used. This greatly increases the frictional losses as frictional resistance is inversely proportional to the square of the diameter. In many cases, high friction foot valves are used. Replacing the existing undersized pipes with appropriate size pipes and replacing high-friction with low-friction foot values can improve efficiency of APS by 30 to 40 % (Sant and Dixit,1996, Patel and Pandye, 1994). We assume an efficiency improvement of 30%. The cost of such rectification is around Rs. 2500; this cost is very sensitive to the length of the piping. Our estimate is for a replacement of a 50 meter pipe which results in a saving of 30 % for a 5 hp pump. Rectification can decrease electricity consumption by 1,343 kWh/year.

Pump replacement

In some cases, the efficiency of an existing pump is so low that it is worth replacing it with a new energy efficient one. This low efficiency could be the result of a combination of factors like a substandard quality pump, inappropriate size and make, multiple motor rewinding, and older vintage. Efficiency improvements of the order of 40% are possible through this measure. In this case, the incremental capital cost is around Rs. 10,000 for a 3.5 kW (5 HP) pump. We assume that 50% of the existing pumps are worth replacing. Pump replacement can decrease electricity consumption by 1,790 kWh/year.

Load shedding is extensive in agricultural areas and the sector seldom gets power during the day; hence most of the APS consumption is during the nighttime. We estimate that 75 % of the APS consumption happens during the 8-hour (10 pm to 6 am) off-peak period, and only 25 % of the consumption is on peak, which results in a peak coincidence factor of 0.25.

5.2.4 Industrial sector

Measures for improving energy efficiency in the industrial sector include use of energy efficient motors, variable speed drives, efficient lighting, appropriate sizing of motors, pumps, drives, pipes, etc. We focus our attention on energy efficient motors, variable speed drives, and efficient lighting as they are likely to have the largest potential savings (Table 8).

Energy efficient motors

Motors consume a majority (about 70%) of the electricity used in the industrial sector. We obtained data on the incremental savings and cost from dealers of major brands in India (refer to Appendix 1 for the list of contacted dealers). Energy efficient motors can save between 2% to 8% of the energy used by conventional motors and these cost between 5% to 15 % more. This option is considered only in the case of new purchases as in most cases it is not economical to replace an existing motor with an energy efficient one. We estimate the average saving as 5% at an average incremental cost of Rs 8,000 based on the incremental savings and capital cost for different sizes of energy efficient motors weighted by motor sizes in the market. A detailed study of HT industry electricity consumption conducted by the Indira Gandhi Institute of Development Research (IGIDR) (IGIDR, 1991) estimates that on average industrial motors are used 6,000 hours a year, and we make use of this estimate. We estimate that a new high efficiency motor can decrease electricity consumption by 3,000 kWh/year/motor.

Table 8. Data on selected energy efficiency measures in the industrial sector

	Purchase new motors		**Variable speed drives**		**Lighting**	
Measure/ technology	**Conventional new motor**	**Efficient new motor**	**Conventional drive**	**Variable speed drive**	**Incandescent lamp**	**Compact fluorescent lamp**
Power Requirement (kW or W/ unit)	10	9.5	1	0.7	60	18
Load while in operation (kW or W/ unit)	10	9.5	1	0.7	60	18
Measure life (years) (hours)	10	10	10	10	1000	1.3 8000
Usage (Hours/year)	6,000	6,000	6,000	6,000	6,000	6,000
Incremental market price (Rs./Unit)	35,000	43,000		6,000	7.1[1]	225[1]
Peak coincidence factor	0.7	0.7	0.7	0.7	0.7	0.7
Annual electricity use (kWh/year)	60,000	57,000	6,000	4,200	360	108

Note: 1: Wholesale market price

Variable speed drives

Variable speed drives have a large potential for saving energy and can save between 30% to 40 % of the motor electricity consumption. In recent years, the prices of variable speed drives have dropped substantially, and they now cost around Rs. 6,000 /kW. Data on cost and energy saving potential of variable speed drives were obtained from major dealers in India (refer to Appendix 1 for the list of dealers contacted).

Average usage was assumed to be 6,000 hours per year (same as industrial motors). The IGIDR HT industry survey shows that 70 % of the industrial consumption occurs during the 16 hour (6 am to 10 pm) period, which results in a peak coincidence factor of 0.7 for energy efficient motors and variable speed drives. We estimate that variable speed drives can decrease electricity consumption by 1,800 kWh/year/motor.

Energy efficient lighting

The main option considered here is the replacement of incandescent lights with CFLs. Estimate of the retail price is the same as that for the residential sector. Since an industry may be able to purchase lamps at the wholesale price, we use these prices in estimating the cost of conserved energy in this sector. Usage and peak coincidence factor are assumed to be the same as those for energy efficient motors and variable speed drives. Due to the potentially high usage rates, the electricity savings from lighting are estimated to be 252 kWh/year.

6 Estimation of net benefits

Energy efficiency measures will result in benefits to the consumer, society (government), and in some circumstances, which we discuss below, to the utility company. We discuss the direct benefits to each of these three stakeholders, and the indirect or secondary benefits to the government. The indirect benefits arise because of increased economic output in industries that supply or consume products from businesses that are affected by the electricity shortage.

6.1 Benefits to the consumer

A consumer benefits if he can save electricity at a cost that is less than the electricity tariff. The cost of electricity saved is also known as the cost of conserved energy (CCE) (see Equation 1). Electricity savings reduce the probability of load shedding, which in turn reduces the probability that a consumer will experience a loss of electricity supply. Residential consumers experience a welfare loss due to this cut in supply, but businesses see a loss of production and/or resort to backup generation to make up for this reduction. We estimate the lost economic output due to load shedding.

The capital cost (purchase price) per kW of each end-use technology may be compared with that of building a new power plant. A typical coal power plant in India costs between Rs. 32,000 to Rs. 40,000 per kW (Sathaye and Phadke, 2005). All the energy efficiency measures that we report in Table 9 cost much less than that, even after including a transaction cost and assuming a conservative high purchase price of the energy-efficient technology. The electricity savings in Table 9 are based on the data shown in Tables 6, 7, and 8. The CCE computed using these data is also shown in Table 9, and these values may be compared with the average electricity tariff paid by consumers.[9] In all instances, except in the agricultural sector where farmers enjoy free electricity and solar water heating, which is expensive, the CCE is lower than the tariff. These and other energy efficiency measures are thus economically attractive from an end-user perspective.

Table 9. Cost of energy efficiency technologies from a consumer perspective

End-use device	**Incremental purchase cost**	**Electricity savings**	**Lifetime**	**Discount rate (real)**	**CCE**	**Electricity tariff (2003-04)**
	(Rs./kW)	**(kWh/ yr/unit)**	**(years)**	**(%)**	**(Rs./ kWh)**	**(Rs./ kWh)**
Residential						
CFL (Lighting)	6,072	46.0	7.3	25	1.72	2.79
Refrigerators	15,820	127.8	15	25	1.23	2.79
Solar water heater	8,311	580.7	10	25	9.02	2.79
Commercial Lighting	5,431	98.6	3.7	20	1.02	3.91
Refrigerators	15,820	127.8	15	20	1.23	3.91
Agriculture IPS						
New unit	3,539	1,119	10	20	0.70	0.00
Rectification	2,458	1,343	10	20	0.49	0.00
Replacement	8,802	1,790	10	20	1.75	0.00
Industrial						
Motors	17,600	3,000	10	18	0.58	3.00
Variable Speed Drives	22,000	1,800	10	18	0.73	3.00
Lighting	5,431	270.0	3.7	18	0.80	3.00

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[9] The CCE should ideally be compared with the marginal electricity tariff, which would be higher than the average values shown in Table 9. Since the CCE is lower in all non-agricultural cases, except for solar water heaters where it is three times higher, the conclusion that energy efficiency measures are cost effective for the selected non-agricultural measures would still hold.

6.2 Benefits to MSEB

In estimating the benefits to MSEB, we first analyze the case in which consumers implement energy efficiency measures on their own. From Table 9 it is clear that the CCE is less than the tariff for residential, commercial and industrial customers for most end-uses, and hence it is in the consumers' own financial interest to implement the selected energy efficiency measures. The impact on MSEB of this implementation is different depending on whether the measures are implemented on- or off-shortage hours. If energy is saved during the hours of shortage, MSEB can sell this saved energy to its most valued consumers to the extent these customers are short of electricity. Table 4 shows that the load shed in the commercial and industrial sectors amounted to 1922 GWh in 2002-03. Any electricity saved by subsidized customers, residential, agricultural, municipal lighting, public works, etc., can be resold to this extent to C&I customers in the short run. If energy is saved during on-shortage hours, then

MSEB revenue increase = Revenue from selling the saved energy to the most valued consumer – revenue loss as a result of decreased sales because of energy savings

If energy is saved during off-shortage hours, then

MSEB revenue increase = Avoided marginal cost of generation - revenue loss as a result of decreased sales because of energy savings

In the longer run, energy savings will reduce future growth in demand, and will reduce the need for building new capacity. Taking this growth in demand into consideration means that much more of the saved electricity can be sold to C&I customers in the future (see Table 10, Col. 7 discussion below). As shown in this analysis, the annualized cost of peak capacity saved is much lower than annualized cost of building new capacity.

Table 10 shows the economic impact on MSEB if consumers were to increase their penetration of energy efficiency measures as shown in Table 9. In the short-term MSEB would avoid its short-term marginal cost of generation (SRMC). Using data for Nasik and Kawas power plants, we estimate the SRMC to be Rs. 1.96 per kWh of generation or Rs. 2.47 per delivered kWh; the latter accounts for 22% T&D loss, and this cost when adjusted for the peak coincidence factor may be compared against the CCE.

The peak coincidence factor reported in Tables 6, 7, and 8 for each energy efficiency measure shows the percentage of consumption that occurs during the shortage hours and otherwise. We adjust the avoided short-term cost of delivered supply using this factor and report it in Table 10. Among the subsidized sectors, it is clear that the CCE (Col. 2) for agricultural improvements is lower than the MSEB short-term cost of supply (Col. 3). A utility program in this sector would thus be warranted just on this financial and economic basis.

Column 4 shows the average electricity tariff by sector. MSEB would lose customer revenue at this rate due to reduced electricity use, which would be offset by the avoided short-term cost of supply. Column 5 shows the cost to MSEB taking these factors into account. It shows that MSEB would lose revenue in the short term in all sectors, except agriculture.

Column 6 shows a similar analysis, except that we use the average cost of supply for MSEB of Rs. 2.83. The former figure was stipulated by MERC for the calculation of subsidy for the residential sector. Figures in Column 6 show that MSEB would benefit by increased penetration of energy efficiency measures in the residential and agricultural sectors.

Table 10. Economic impact on MSEB of consumers' adopting energy efficiency

End-use device	**CCE**	**MSEB short run marginal cost of supply**	**Electricity tariff (2003-04)**	**MSEB Short run net revenue**	**MSEB average revenue**	**Realized electricity revenue**
	(Rs./kWh)	**(Rs./kWh)**	**(Rs./kWh)**	**(Rs./kWh)**	**(Rs./kWh)**	**(Rs./kWh)**
Col 1.	Col 2.	Col 3	Col 4	Col 5 = Col.4-Col.3	Col 6 = Col.4-2.83	Col 7
Residential						
CFL (lighting)	1.72	0.25	2.79	2.54	-0.04	2.87
Refrigerators	1.23	0.84	2.79	1.95	-0.04	2.57
Solar water heater	9.02	0.25	2.79	2.54	-0.04	2.87
Commercial lighting	1.02	0.49	3.91	3.42	1.08	2.74
Refrigerators	1.23	0.49	3.91	3.42	1.08	2.87
Agriculture IPS						
New unit	0.70	1.85	0.00	-1.85	-2.83	2.03
Rectification	0.49	1.85	0.00	-1.85	-2.83	2.03
Replacement	1.75	1.85	0.00	-1.85	-2.83	2.03
Industrial						
Motors	0.58	0.74	3.00	2.26	0.17	2.61
Variable Speed drives	0.73	0.74	3.00	2.26	0.17	2.61
Lighting	0.80	0.34	3.00	2.66	0.17	2.61

CCE**:** Cost of conserved electricity includes a transaction cost equal to 10% of the incremental capital cost
Negative values in Columns 5, 6, and 7 indicate a cost to MSEB.

+ -- MSEB cost of supply as delivered to consumers. Short-term marginal generation cost is adjusted by T&D loss of 22% and for peak coincidence factor, which is different for each device (Tables 6,7, and 8).

*** --** Electricity revenue realized from resale of electricity to customers with electricity shortage assuming a tariff of Rs. 3 per kWh.

Column 7, Table 10, shows the increase in MSEB's revenue if the saved electricity is resold to the highest paying consumers. Energy savings occur during the shortage as well as non-shortage periods. When the savings occur during the shortage period, MSEB can resell these saved units to commercial and industrial consumers. When the savings occur during the non-shortage period, MSEB can avoid generating from some units and save on generation cost. For a particular end use technology, the fraction of savings occurring during the shortage and non-shortage periods will be determined by the shortage coincidence factor.

The benefits to MSEB can be calculated on a per kWh energy saved basis as follows:

1. *Benefits from reselling saved electricity (Column 7, Table 10) = shortage coincidence factor* resale price, which we assume to be Rs. 3 /kWh. For example, for energy efficient lighting, the benefits form reselling amount to 0.9 * Rs. 3.0 /kWh or Rs. 2.7 /kWh of saved electricity.*

2. *Benefits from avoided electricity generation (Column 3, Table 10) = (1 – shortage coincidence factor) * short run marginal cost of generation*
   *For example, for energy efficient lighting, the benefits from avoiding generation = 0.1 * Rs. 2.47 /kWh = Rs. 0.25 /kWh of saved electricity*

3. *The benefit to MSEB from residential lighting electricity use = Rs. 2.7 + Rs. 0.25 = Rs. 2.95 /kWh of saved electricity*

Our demand projections (Table 14) show that there will be adequate demand for the saved electricity from commercial and industrial consumers for the next ten years.[10] When compared with Column 2, it is clear that the realized electricity revenue exceeds the cost of conserved energy per delivered kWh for all measures, except for the case of solar water heaters.

7 Projecting future energy savings

The analysis in Sections 5 and 6 above describes the monetary benefit to consumers and MSEB per kWh of electricity savings. The benefit will materialize over a period of years with gradual adoption of the energy efficient technologies. In this section, we investigate the potential for savings over a ten year period. The projected annual energy saving and peak load reduction can form the basis for a program of energy efficiency measures in Maharashtra.

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[10] We estimate annual energy savings for all end uses considered in this analysis for the period of next ten years (Table 14). Almost all of the energy saved can be resold to either industrial or commercial consumers. During the initial period of the program (first 2 years), energy saved can be used to reduce the shortage for commercial and industrial consumers and then in the later years of the program, energy saved can be used to cater to new electricity demand. New demand in the commercial and industrial sector alone is sufficient to absorb all the energy savings. For instance, new demand from industrial and commercial consumers in the fifth year of the program is projected to be around 6,800 GWh assuming a continuation of historical 10-year growth rates. For that year, projected energy savings in the industrial and commercial sector are 1992 GWh. Hence the net new demand is 4808 GWh, which is more than the 3914 GWh energy savings projected in other sectors (except industrial and commercial) for that year. This is true for each projected year in the future for 10 years

Energy savings from the installation of energy efficiency measures will accrue over the lifetime of each measure. We assume that at the end of its life an energy efficient technology will be replaced by another equivalent measure. In this section, we estimate the energy savings and load reduction from the consumer purchase and installation of energy efficient technologies over the next ten years. In order to make this projection, we need to estimate and compare the market penetration and electricity consumption of conventional and energy efficient technologies. The approach for this estimation is described below.

7.1 Approach

In order to estimate their future impact on electricity demand, we need to estimate the penetration rate of each end-use device. Device purchases may be categorized as those for (1) replacement of existing devices at the end of their life, and (2) satisfying new consumer demand. The latter demand could arise either from the same consumer purchasing additional devices, or due to the formation of new households and/or businesses.[11] The rate of former types of purchases would be determined by the life of device. For example, the annual sales of a device with a 10 year life would be 10% of its equilibrium saturation value.

Not all eligible conventional end-use devices may be substituted by energy efficient ones. In some cases the efficient devices may not fit the rest-of-the-system at the installation site, and there may be other technological obstacles (cold starts, severe voltage fluctuation, etc.), and due to market failures (lack of information, access to credit, principal agent problems, organizational rigidities, etc.) there may be barriers to their purchase. The upper limit on their penetration will thus be less than 100% of the opportunity set.

Data on historical MSEB electricity consumption are available by consumer category, but not by end-uses. Within a consumer category, for example residential, the growth rate of electricity consumption represents that of new devices as described above. We assume that the 10-year average annual historical growth rate will be maintained in

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[11] It is of course possible that the increase in consumption may be the result of more hours of use of existing devices. Under the electricity shortage situation with no sharp increases in household incomes over the past ten years, this is unlikely to be the case.

the next ten years, and all of this consumption will be amenable to savings from new EETs, subject to the aforementioned constraints. In order to disaggregate the category-wise consumption by end-uses, we rely on historical surveys of agricultural, household and industrial sector end-use saturation.

We start with the assumption that all devices are at their equilibrium level in the base year 2002-03, and hence the annual penetration rate of each device is simply the inverse of the life of the device. Devices that have a lifetime longer than 10 years never fully get replaced, and others like incandescent lamps get fully replaced within the first 2-3 years. In parallel, new devices continue to be bought to satisfy the demand arising from expanding households and businesses. The energy saved by each energy efficient technologies is aggregated to arrive at the total energy saved annually. Since we have already estimated the peak coincidence factor and load saving for each energy efficient technologies, we can readily estimate capacity savings given the energy savings.

The potential for energy savings may be estimated from different perspectives. From a consumer financial perspective, energy efficiency measures will be implemented if the cost of saved electricity is lower than the tariff. Using this perspective would mean, however, that the potential for solar water heaters and for all agricultural measures is nil (Table 9). On the other hand, from a MSEB financial perspective, measures ought to be implemented if their cost of saved electricity is lower than that of generation. In this case, all measures, except solar water heating, would have some cost-effective electricity savings potential (Col. 8, Table 10).

In the presentation below, we estimate this MSEB financial potential for electricity savings. Our estimate is moderated, however, by the aforementioned technological factors and market failures that act as barriers to energy efficiency measure penetration. In the case of solar water heaters, the cost of saved electricity due to solar water heating is greater than the cost of generating electricity. The Maharashtra Energy Development Agency (MEDA), however, has mandated that solar water heaters be installed in new apartment complexes. Hence, we assume that 10 % of the new water heating demand is catered to by solar water heaters, and this rate remains constant over the 10-year time horizon.

Section 7.2 describes the procedure for estimating base-year electricity consumption by end use, Section 7.3 for projecting growth rates of consumption, Section 7.4 for estimating the consumption of new devices, Section 7.5 estimates the peak power saved by these devices, and Section 7.6 the total cost of energy efficiency measures. This section provides a basis for determining the costs of a program(s) to promote energy efficiency in Maharashtra.

7.2 Estimating base-year electricity consumption by end use

MSEB data show consumption by consumer category but not by end-use. Many studies have estimated consumption by end-use for each consumer category (residential, commercial, agriculture, and industry) (SRC(1995), IEI-CMIE (2000), World Bank (1997). The IEI-CMIE (2000) study reports consumption estimates by end-use at the all-India level. The most recent study that estimates end-use wise consumption for Maharashtra is by SRC consultants (SRC, 1995). This study estimates end-use consumption by consumption slab for each consumer category. We assume that for each consumption slab, the pattern of end-use consumption has remained unchanged since the study was done. The overall composition of the consumption has changed, however, as a result of consumers entering into higher consumption slabs. This assumption implies that for a given level of consumption, consumer preferences between end-uses have not altered over the 10-year period since the SRC study. This is a reasonable assumption if relative prices of appliances have not changed drastically and no new appliances with significantly high penetration have appeared in the market, which appears to be the case over the past ten years in Maharashtra. The only exception could be personal computers but their saturation is still very low, about 1.1% of the Indian population (India Times, 2005).

The slabwise consumption for the base year 2002-03 is available from MERC (Table 11). We estimate the end-use consumption for the base year by assuming the same composition of end-use consumption as the SRC study for each of the consumption slabs, and then estimating the overall composition of end-use consumption by aggregating the slab wise composition. The aggregate end use composition in the year 2002-03 is thus different than the composition in the year 1995-96. Table 12 shows the slab wise break up of consumption of different appliances for residential consumers for 1995-96, and using these proportions, our estimate of the overall end-use composition of the residential consumption in 2002-03.

Table 11. Slab-wise electricity consumption (2002-03)

Slabs (kWh/month)	GWh	Share (%)
1 to 30	4877	40%
31 to 100	4309	35%
101 to 300	1770	14%
Above 300	1310	11%

Source: MERC (2003)

Table 12. End-use share of residential electricity consumption

	Consumption slabs (kWh/month)				Overall (2002-03)
	1-30	31-100	101-300	Above 300	
Appliance	% Share of consumption				
Fluorescent tubes	14%	16%	12%	11%	14%
Incandescent bulbs	14%	12%	6%	12%	12%
Fans	30%	23%	21%	20%	25%
Air-conditioners	0%	5%	8%	11%	4%
Desert coolers	0%	0%	0%	1%	0%
Refrigerators	0%	21%	21%	16%	21%
Washing machines	0%	0%	1%	1%	0%
Toasters	0%	0%	0%	1%	0%
Geysers	5%	9%	20%	22%	10%
Televisions	14%	10%	7%	6%	11%
Immersion rods	0%	2%	1%	0%	1%
Mixer/juicers	0%	1%	1%	1%	1%
Electric ovens	2%	1%	1%	0%	1%

7.3 Projecting growth rates of end-use consumption

We use a simple approach to project the future growth rate of consumption for each consumer category by assuming that the historical growth rate of the past 10 years would prevail over the next 10 years.[12] Within a consumer category, consumption of different end uses grows at different rates. Some end use technologies such as

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[12] Other approaches, such as a logistic curve, are commonly used, but there does not appear to be a strong theoretical reason for choosing one approach over another.

refrigerators and tube lights are increasingly becoming popular, and are growing at a higher rate than others, such as incandescent lamps. We assume different growth rates for different technologies but the growth rates are selected in such a way that the average growth rate matches the historical growth rate estimated for that consumer category. For instance, based on the historical growth rate for past ten years, we project residential consumption growth at 8.5 % per annum, but the incandescent lights consumption grows at 6% per annum while that of refrigerators grows at 12%. These assumptions are consistent with historical patterns of growth of refrigerator sales and ownership data. (McNeil et al. 2005).

7.4 Estimating the electricity consumption of new end-use devices

New devices are purchased to either satisfy new consumer demand as households and businesses expand, or replace an existing one at the end of its life. The electricity consumption of new devices hence equals the consumption of these two types of stocks of new devices. The new demand is estimated as discussed in the Section 7.2. At equilibrium, the replacement rate of appliances is the inverse of the life of the appliance. The lifetime of each device is estimated from data and information obtained through an informal survey of dealers and manufacturers that are listed in Appendix 1.

7.5 Estimating the energy saved by energy-efficiency measures each year

Energy saved by energy efficiency measures each year is estimated in the following manner.

1. *Annual energy savings for an end use = Consumption of conventional stock that is to be replaced by an energy efficient technology * percentage energy savings*

2. *Consumption of conventional stock that is to be replaced by an energy efficient technology = Cumulative annual consumption of the conventional technology that is to be replaced by an energy efficient technology (we assume that if an energy efficient technology is retired, it is replaced by the same efficient technology)*

3. *Consumption of a conventional technology replaced by an energy efficient technology every year = Consumption of new appliances every year *percentage of new appliances that are energy efficient appliances every year (which is called as the penetration rate)*

Estimation of the penetration rate of EETs

The maximum saturation level (expressed as % of complete market saturation) and the time required to reach this level critically depends on the cost-effectiveness of EETs relative to the electricity tariff, and on the policies used to promote their penetration. All other things being equal, the saturation level will be higher and the penetration time will be faster for EETs that have a lower CCE. We assume the saturation level and the time required to reach it in such a way that it reflects the relative cost effectiveness of EETs. Table 13 shows the base year penetration rate, maximum penetration level, and the time required to reach it for different EETs. We assume that the penetration rate grows linearly to reach the saturation level. The base penetration rate is based on our qualitative understanding of the current popularity of EETs. Since we have pegged the saturation penetration rates and the time to reach the saturation penetration rates, the values of the base penetration rate will not affect our estimates of potential energy savings.

Energy saved by the retrofitted energy efficiency measures in the agriculture and industrial sectors is estimated somewhat differently (although the logic behind assuming certain penetration rates is the same) than the above estimation procedure which applies to new purchases. In the agricultural sector, some pumps are so inefficient that it is cost-effective to replace them. We assume that about 50 % of the current stock of the pumps is in this category, and that they will be replaced over a period of 8 years. Similarly in the case of APS systems, we assume that 80 % of the current stock of APS is eligible for rectification and this replacement is done over a period of 8 years. In the industrial sector, we assumed that 30 % of conventional drives can be replaced by variable speed drives over a period of 8 years.

Table 13. Penetration rates for selected energy efficiency measures

End-use sector	Growth rate of electricity consumption (AAGR%)	Retirement rate of old appliances (AAGR%)	Base-year penetration rate* (%)	Saturation penetration rate** (%)	Years to reach saturation penetration rate
Residential sector					
Lighting (CFLs)	6%	100%	20%	80%	4
Water Heating	9%	10%	20%	50%	8
Refrigerators	12%	7%	10%	80%	8
Commercial sector					
Lighting (CFL)	8%	100%	20%	80%	4
Refrigerators	8%	7%	10%	80%	
Agricultural sector					
New pump sets	7%	7%	20%	80%	5
Rectification	7%	7%	10%	80%	8
Replacement	7%	7%	10%	50%	8
Industrial sector					
Motors	5%	10%	10%	50%	8
Variable speed drives	5%	10%	10%	50%	8
Lighting (CFLs)	5%	100%	20%	80%	4

Notes:

* Base year penetration rate: It is the fraction of newly purchased appliances that are energy efficient appliances in the base year. In the case of retrofit energy efficiency measures which apply to the existing stock of appliances (namely - rectification of agricultural pumping systems, premature retirement and replacement of highly inefficient pump sets, and variable seed drives), it is the fraction of the existing stock retrofitted or replaced in the base year.

**Saturation penetration rate: It is the maximum possible percentage of the new appliances purchased that are energy efficient appliances. In the case of retrofit energy efficiency measures which apply to the existing stock of appliances (namely - rectification of agricultural pumping systems, premature retirement and replacement of highly inefficient pump sets, and variable seed drives), it is the maximum possible fraction of the existing stock retrofitted or replaced.

Following the above procedure, we estimate the energy savings that can be achieved each year (Table 14).

Table 14. Annual energy saved by energy efficiency technologies

Year of the program	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
End-use sector					**GWh saved**				
Residential sector									
Lighting	249	689	1,155	1,272	1,380	1,497	1,624	1,762	1,912
Refrigerator	31	80	149	242	359	503	675	855	1,044
Water heating	26	55	85	119	155	194	236	464	512
Commercial sector									
Lighting	93	256	427	464	501	540	583	629	678
Refrigerators	7	17	32	52	77	107	143	180	192
Agricultural sector									
New IPS	68	205	411	686	958	1,232	1,519	1,818	2,132
Pump replacement	124	242	350	447	531	531	531	531	531
IPS rectification	124	242	350	447	531	531	531	531	531
Industrial sector									
Motors	10	26	47	75	109	150	198	258	319
VSD	104	213	328	449	575	708	847	994	994
Lighting	79	228	420	616	730	766	805	845	887
Total	**915**	**2253**	**3754**	**4869**	**5906**	**6759**	**7692**	**8867**	**9732**

7.6 Peak power saved by energy efficiency measures

The peak power saved by an energy efficiency technology = load saving when the energy efficiency technology is in use* peak coincidence factor. For each energy efficiency technology, we have already estimated the annual energy savings. The total peak load savings = (Expected peak power saved per unit of energy efficiency technology/Annual energy savings per unit of energy efficiency technology)*total energy savings achieved by that energy efficiency technology. Table 15 shows that the estimated savings are about 4,600 MW from the implementation of the selected energy efficiency measures.

Table 15. Peak power saved by selected energy efficiency measures

Year of the program	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
End-use sector	**Peak MW saved**								
Residential sector									
Cfl lighting	205	567	949	1,045	1,134	1,230	1,335	1,448	1,572
Refrigerator	5	12	23	38	56	78	105	133	163
Water heating	92	191	298	414	539	675	822	1620	1786
Commercial sector									
Cfl lighting	26	73	122	132	143	154	166	179	193
Refrigerators	1	3	5	8	12	17	22	28	30
Agricultural sector									
New IPS	10	30	61	101	141	182	224	268	314
Pump replacement	18	36	52	66	78	78	78	78	78
IPS rectification	24	48	69	88	104	104	104	104	104
Industrial sector									
Motors	1	2	4	7	10	14	18	24	29
Vsd	9	19	30	41	52	64	77	90	90
Cfl lighting	22	65	120	176	208	218	229	241	253
Total	**413**	**1046**	**1733**	**2116**	**2477**	**2814**	**3180**	**4213**	**4612**

Tables 14 and 15 show that substantial energy and capacity can be saved relatively quickly. The current level of shortages can be completely removed within a period 2-3 years depending on the policies used to promote energy efficient technologies.

7.7 Combined cost of adopting all energy efficiency measures

Using the retail purchase price of the energy efficiency measures, and based on the schedule of energy efficient technology purchases implied by the penetration rates and saturation levels shown in Table 13, we estimate the combined annual cost for adopting such measures over the ten-year horizon (Table 16). It is important to note that energy and cost savings due to these investments will continue to accrue beyond the the 10 year time horizon as these continue to operate beyond this period.

The government and utility benefit from the installation of some of these measures, and they may wish to initiate programs to promote them. For instance, since the agricultural consumer pays no electricity tariff, without a full cost reimbursement or pump performance standards, the consumer is unlikely to purchase efficient energy technologies in this sector. On the other hand, an information campaign or rebate program may suffice to persuade customers in other sectors to purchase energy efficiency measures, except solar water heating where the CCE is lower than the tariff.

Table 16. Combined annual cost* of energy efficiency measures (2004 Rs. crores)

Year		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Present value*	**Annual cost based on retail purchase price**								
Residential sector										
CFL lighting	639	125	222	235	59	54	59	64	70	76
Refrigerator	229	13	21	30	40	50	62	74	78	81
Solar water heater	720	66	87	103	118	131	145	158	305	279
Commercial sector										
CFL lighting	152	21	37	38	8	8	35	38	41	44
Refrigerator	44	3	5	6	8	11	13	16	16	5
Agricultural sector										
New IPS	308	18	37	55	74	73	73	77	80	84
Pump replacement	73	23	22	20	18	16	0	0	0	0
IPS rectification	261	83	78	72	65	56	0	0	0	0
Industrial sector										
Motors	43	3	4	6	7	9	11	13	16	16
VSD	199	35	36	38	40	42	44	46	49	0
CFL lighting	115	6	12	16	26	27	28	33	35	37
Total	**2782**	**396**	**561**	**619**	**463**	**477**	**470**	**519**	**690**	**622**

* Present value (PV) is the discounted sum of costs from years 1 through 10 for each measure at a real discount rate of 12 %.

8 Benefits to the Maharashtra government

Energy efficiency improvement can increase the state government finances in two ways. One, efficiency improvement would reduce subsidized agricultural, residential, and other loads. And, second it would increase tax revenue from businesses whose supply would no longer have to be curtailed.

8.1 Reduction in Subsidy

The current subsidy for agricultural and residential consumers is Rs. 2.83 /kWh, and Rs. 0.04 /kWh respectively. Assuming this subsidy is maintained in the future, the energy savings projected for the residential and agricultural sector (Table 14) translate into an annual reduction in subsidy, which increases from Rs. 91 crores in year 1 to Rs. 918 crores in the 9th year (Table 17).

Table 17. Subsidy Reduction in Agricultural and Residential Sectors (2004 Rs. crores)

Year	Present value*	1	2	3	4	5	6	7	8	9
Agriculture	2,381	89	195	314	447	572	649	730	815	904
Residential	36	1	3	6	7	8	9	10	12	14
Total	2,418	91	198	320	454	579	658	741	827	918

* Present value (PV) is the discounted sum of costs from years 1 through 10 for each measure at a real discount rate of 12 %.

8.1.1 Subsidy mapped to the electricity required to reduce the shortage

Table 14 shows the annual energy savings for different end uses. Some part of these energy savings occur during the daily shortage period that currently runs from 6 am to 10 pm while the remaining savings occur during the non-shortage period. Only the electricity saved during the shortage period reduces the shortage. These savings can be estimated by multiplying the total energy savings by the shortage coincidence factor, which was estimated in Section 5.

Table 18 shows the energy savings during the daily shortage in the subsidized (residential and agricultural) and non-subsidized (commercial and industrial) categories for the first three years.

Table 18. Energy savings during the daily shortage period (GWh)

Consumer category year	Year 1	Year 2	Year 3
Commercial + industrial	214	543	919
Residential + agricultural	348	901	1,507
Total	**562**	**1,444**	**2,427**

The commercial and industrial load that was shed was 1,922 GWh in 2002-2003. As Table 18 shows, energy savings in the 3rd year are estimated to be 2,427 GWh, which are large enough to eliminate load shedding to industrial and commercial consumers in that year. We estimate the reduction in subsidy due to energy savings in the residential and agricultural sectors. The present value (PV) of this subsidy reduction (assuming a 12 % real discount rate) amounts to Rs 411 crores and Rs 9 crores for the agricultural and residential sectors respectively, or a total amount of Rs. 420 crores.

8.2 Increased Commercial and Industrial Production and Tax Revenue

Load shedding results in lost economic output, which reduces the sales, excise, and corporate income taxes paid by businesses to government. Energy savings during the shortage hours can reduce the lost output. The projected electricity savings in the residential and agricultural sectors (Table 14), if resold to commercial and industrial customers, will be more than enough to cover their electricity shortage. In addition to the direct loss of output, because the affected businesses buy from and sell goods to other sectors of the economy, their output will also increase. This secondary or indirect impact will add to the taxes paid to the government.

In this section, we estimate the impact of the shortage on primary and secondary business output, and on consequent foregone tax revenue. The output impact on businesses that do not receive electricity supply depends on their level of backup generation. Since no firm data are available on the backup-generation percentage of impacted businesses, we test two scenarios in which 30% and 60% of businesses have backup generation respectively. Electricity from small backup generators costs about twice as much as grid supply. Their use will reduce business income and consequent tax revenue. We have not estimated the loss in income taxes, which are paid to the central government, since the focus here is on the state government.[13] Information about the tax situation in Maharashtra is discussed below.

8.2.1 Maharashtra Tax Revenue and Employment Impacts

Maharashtra state has run a revenue deficit which has worsened over the past 10 years, and in 2002-03 it was Rs. 9,371 crores or 30.1% of the state's revenue receipts (Economic Survey of Maharashtra, 2003-04). Its gross fiscal deficit during that year was Rs. 14,290 crores or about 4.8% of the GSDP. In 2003-04 (RE), this situation worsened and the state's gross fiscal deficit stood at Rs. 19.477 crores or 5.9% of the GSDP. The revenue deficit accounted for 65.6% of the gross fiscal deficit in 2002-03, and 46.4% the following year.[14] One way to reduce the revenue deficit is to ensure that there is adequate supply of reliable electricity to all businesses in the state. Adequate supply would stimulate increased economic output, which will result in increased tax payments to the state government.

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[13] As noted below, Maharashtra receives only a small proportion of its tax revenue from the central government.

[14] The state's debt position too has deteriorated over the past ten years, and in 2002-03 total debt as a percentage of GSDP stood at 23.4%.

The Maharashtra government levies a sales tax, stamps and registration fees, state excise duties, electricity duties, other taxes on income and expenditure, vehicle taxes, land revenue, and sundry other taxes. Table 19 shows the revenue collection for 2002-03 through the imposition of these taxes. In addition, the state receives a small amount of funds from its share of central tax revenue. We focus here on the state's own tax revenue since it accounts for about 90% of the state's total tax revenue.

Table 19. Own tax revenue of Maharashtra state (Rs. crores)

Item	**Revenue collection for the year**		
	2001-02	**2002-03**	**2003-04**
	(Actual)	**(Actual)**	**(RE)**
1) Sales tax	12,131	13,488	15,485
2) Stamps & regn. fees	2,443	2,823	3,100
3) State excise duties	1,787	1,939	2,300
4) Electricity duties	1,034	1,149	1,280
5) Other taxes on income and expenditure	986	1,032	1,020
6) Taxes on vehicles	948	941	1,025
7) Other taxes and duties on comm. & ser.	687	811	861
8) Taxes on goods and passengers	1,027	245	665
9) land revenue	261	386	338
10) Taxes on agricultural income			
State's own tax revenue (Totals 1 to 10)	**21,304**	**22,814**	**26,074**

Source: Economic Survey of Maharashtra, 2002-03.

The categories of tax revenue that would be affected by the removal of electricity shortage through energy efficiency improvements include all those listed in Table 19, except electricity duties and land revenue. Electricity duties (charged per kWh) will be affected to the extent there is a difference in the duty across sectors. Ignoring these two items[15] results in a revenue amount in 2002-03 of Rs. 21,279 crores. The total MSEB and other utility electricity sales during that year were 49,945 GWh, of which 22,825 GWh was consumed by industrial and commercial customers (Table 2).

Each unit of electricity sold thus contributed to Rs. 9.23 worth of tax revenue to the state government in 2002-03. In other words, not providing adequate electricity to industrial and commercial consumers results in a loss of tax revenue of this magnitude. One can also estimate the marginal increase in tax revenue per kWh of electricity supplied. Between 2001-02 and 2002-03, the supplied marginal kWh generated tax

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[15] We will account for the difference in duty per kWh paid by agricultural and residential customers compared to commercial and industrial ones in the next draft.

revenue of Rs. 12.74 per kWh, which is higher than the average rate for either years. Of course, tax collections may have increased for many reasons other than the supply of electricity, so increased electricity supply will not necessarily ensure a higher tax return rate per kWh.

This average rate of Rs. 9.23 per kWh, however, needs to be adjusted to account for the uninterrupted supply of electricity to the city of Mumbai. Since Mumbai does not experience electricity shortages, a significant difference in the sales tax per kWh in Mumbai and rest of Maharashtra would lead to an over- or under-estimation of the rate for rest of Maharashtra, the area affected by electricity shortages. Data show that the rest of Maharashtra accounts for 74% of the state's GSDP and 76% of the industrial and commercial sector electricity sales (Maharashtra Economics and Statistics Directorate, 2001). Since the two percentages are close, the adjustment results in only a small decrease in the average sales tax rate to Rs. 9.10 per kWh.[16]

Load shedding in the commercial and industrial sectors results in a shortage of 1,922 GWh (Table 4). About 16% of this is in the commercial sector, 23% in the low-tension industrial, and the remaining 61% is in the high-tension sector. We illustrated in Section 5 above, that the potential for energy efficiency improvement is about 6,000 GWh, which well exceeds this shortage in the commercial and industrial (C&I) sectors. Implementation of energy efficiency measures in the non-C&I, largely subsidized, sectors, also exceeds the shortage in the C&I sectors, making enough electricity available for resale to the C&I sectors.

The increase in tax revenue to the state government from this increased supply of electricity to C&I customers may now be estimated using the average tax return per kWh. Assuming that 1922 GWh of electricity is resold to the C&I sectors, and they have no backup generation, results in an increase in their economic output that will generate Rs.

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[16] An alternative approach would have been to use the sales tax percentages in the two areas in place of GSDP percentages. Since rest of Maharashtra accounts for only 60% of the state sales tax revenue, using this method, its sales tax rate would have been Rs.7.4 per kWh (Maharashtra Ministry of Finance, 2005). However, since industry location, and not the location of sales, determines its vulnerability to a shortage, the GSDP percentage is a better measure to use for estimation of the sales tax rate per kWh. The difference in GSDP and sales tax shares indicate that rest of Maharashtra is a net exporter of goods to Mumbai, assuming that both regions' trade outside Maharashtra in the same proportion of their value added.

1,768 crores of tax revenue or about 8.3% of the affected tax revenue in 2002-03 (Table 20).

Load shedding impacts businesses in many different ways. It forces some to shut down temporarily and delay their production and delivery of products, and others to purchase backup supply either in the form of battery operated units for low power loads, and/or small generators for larger enterprises, whose power demand is higher. We do not have data on the extent to which backup generators are utilized. Anecdotal evidence suggests that indeed informal enterprises that have heavy power loads such as welders, foundries, machine shops, etc. delay production and delivery, in integrated operations where producers rely on many vendors goes awry, and fluctuating and abrupt drops in voltages lead to poorer product quality. If we assume that backup power generation is available to 30% and 60% of the customers who experience electricity shortages, then the additional tax revenue decreases to 70% and 40% of the above amount, or about Rs. 1,238 crores and Rs. 707 crores respectively (Table 20). These figures may be low since load shedding can cause a disproportionate output loss because backup generation does not turn on instantaneously, and is used for limited small power necessities. Load shedding disrupts production lines and requires that machines be reset and restarted, and even where backup generation is available, this process reduces an industry's production time.

Indirect Output and Employment Impact:

We noted earlier that increased production from the affected industries would stimulate both their suppliers and consumers to increase their output. This multiplier effect may be estimated using an input-output table. We developed an input-output table for the state of Maharashtra using the technical coefficients from the national 1998-99 table as a starting point. These coefficients were modified to reflect the industries present in Maharashtra. The resulting 43 sector input-output table and the corresponding multipliers are shown in Appendix 3.

We estimate the aggregate output multiplier for the C&I sectors for Maharashtra using the following procedure. We first estimate the output multipliers for each of the 43 sectors using an input-output table. Data are available on the value of output of the organized and unorganized industrial sectors of the Maharashtra economy. Using the distribution of output of the unorganized industries, we estimate a weighted aggregate multiplier for the unorganized sector. The value of this multiplier is 2.09. This multiplier is used to estimate the indirect output impact of increased electricity supply to the affected low- and high-tension industries. For the commercial sector, output data for the unorganized sector are not available. Here, we estimate a weighted aggregate multiplier using the output of the four commercial sectors in the input-output table. The value of this multiplier is 1.52. Using the rupee value of the amount of electricity that is not supplied to the industrial and commercial sectors (Table 4), 1284 GWh and 639 GWh respectively, yields an overall multiplier of 2.00.

We use this multiplier in estimating the indirect impact on output and taxes paid by Maharashtra industries. Using this multiplier implies that affected direct and indirect output and tax payment is twice that of industries directly affected by load shedding. We estimate the direct and indirect affected state tax revenue to be Rs. 3,530 crores with no backup generation, and between Rs. 1,410 to Rs. 2,470 crores with 60% and 30% back up respectively (Table 20). Combining this increase in tax revenue with the reduction in subsidy to residential and agricultural customers results in higher reduction in the state revenue deficit between 20.8% and 43.4% (Table 20).

We also estimate the employment impact of energy efficiency measures on the Maharashtra economy. The total employment in the Maharashtra economy was about 53.8 million in 1998-99, of which about 5.2 million persons were employed in the unorganized industrial sector. Employment per unit of output for the latter sector was 2.08 person-years per lakh rupees of output, while in the commercial sector it was lower at 1.24. Given the proportion of load shedding in the commercial and industrial sectors, the weighted aggregate multiplier is estimated to be 1.94 person-years per lakh[17] rupees of output.

The provision of electricity to the affected C&I sectors would increase employment opportunities in the state. The employment per kWh supplied to the C&I sectors may be estimated using the data on employment in these sectors, and the sectors' electricity consumption. We estimate this ratio by dividing the C&I employment data by

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[17] 1 lakh = 100,000

statewide electricity consumption in the two sectors (Table 4). The ratio is estimated to be 825 person-years per GWh of electricity consumption. Providing 1,922 GWh of electricity to the affected industries thus has the potential to generate about 1.6 million person-years worth of jobs. Again depending on the backup generation this figure would be proportionally lowered to 70% and 40% of the above value or 1.1 million and 630 thousand person-years respectively. The multiplier effect would increase the values by a factor of 1.94, to 3.1 million, 2.2 million and 1.2 million person-years respectively.

Table 20. Potential impact of energy efficiency measures on state government finances* (Rs. crores)

	Subsidy reduction*	**Tax revenue increase***			**Total subsidy reduction and revenue increase***		
		No backup	**30% backup**	**60% backup**	**No backup**	**30% backup**	**60% backup**
Agriculture	527						
Residential	11						
Total	539	1,768	1,238	707	2,307	1,777	1,246
As a % of state revenue deficit (Rs. 9,371 crores in 2002-03)	5.8%	18.9%	13.2%	7.6%	24.6%	18.9%	13.3%
Direct and indirect impact		3,531	2,472	1,412	4,070	3,011	1,951
As a % of state revenue deficit (Rs. 9,371 crores in 2002-03)		37.8%	26.4%	15.1%	43.4%	32.1%	20.8%

Note: * -- Over a three year period. Undiscounted current rupees.

9 Programs for the promotion of energy efficiency measures

Our analysis of energy efficiency measures in Maharashtra indicates that all the measures (except residential solar water heating) are cost effective from a societal perspective, residential, industrial and commercial measures are cost effective from a consumer perspective, and agricultural measures from a utility perspective. Yet, the penetration level of these measures is low compared to the potential identified through earlier surveys and that estimated in our analysis.

In the US and other industrialized countries, and in some developing countries, energy efficiency programs are being pursued to address this shortcoming. Such programs are run by utility companies, public-private partnerships, and state and federal government agencies. The rationale for these programs is that the energy efficiency gap is caused by market failures that act as barriers to the efficient use of energy. We describe this rationale and summarize the state-level US energy efficiency programs which might form a model for the state of Maharashtra and other Indian states.

Energy Efficiency Gap:

In describing the low penetration of energy efficiency measures proponents often compare a measure that is not a perfect substitute for the existing end-use technology. A key issue is whether the energy efficiency measure provides an equivalent service to the one that is being replaced. Koomey and Sanstad (1994) refer to these as hidden costs that a technology supplier may have to bear to improve the energy-efficient technology. CFLs, for example, need to meet minimum technical performance standards such as quick start at low voltages, hardening to withstand voltage fluctuations, and a smaller physical size so as to make them a close substitute to a comparable incandescent lamp.

Assuming that such technology equivalency exists, the remaining gap between the estimated and realized potential may be explained by several factors (Reddy 1991). These include principal agent problems (misplaced incentives), price acceptance by consumers and firms, complete and costless information, rational consumers, profit-maximizing firms, free entry and exit of firms, no collusion between producers, and smooth pattern of demand and supply without peaks (Sathaye and Bouille, 2001). The electricity and end-use energy efficiency markets in India and elsewhere are rarely characterized by these attributes.

A common example of the principal agent problem is the operation of a building in which the renter purchases the appliances, but the landlord pays the electricity bill. The purchaser of the equipment does not bear the direct electricity cost of its operation and has little incentive to buy an energy efficient product. In the agricultural sector in India, there is a lack of price acceptance by the farmer, and a flat or no price offers little or no incentive for energy efficiency. In the small industrial sector, consumers may not be allowed access to the electricity meter by MSEB in order to reduce the possibility of it being tampered with, thus hampering information flow about monthly electricity consumption.

Access to information about the technology, and about the availability of financing and credit may be difficult. Consumers may not be cognizant of the choices of energy efficient technologies and unable to comprehend the full life cycle cost of a low-capital cost but energy inefficient technology. The Indian market for many end-use devices, lamps, motors, pumps, etc., is getting increasingly diversified with many producers and distributors of these goods. Our indicative surveys in Maharashtra suggest that low quality goods are increasingly entering the market. Sub-standard agricultural pumps are being purchased since the farmer does not pay for electricity. Low-priced CFLs are being sold with claims of a long life, which may prove to be unwarranted. Poor performance of early CFLs may lock-out both poor and good quality CFLs in the future.

Such experiences add to the uncertainty associated with equipment performance (Hassett and Metcalf, 1993). A consumer is generally averse to bearing the risk of purchasing a new unfamiliar technology whose performance is yet to be commercially proven. But if the early experience of CFL adoption turns out to be negative, consumers may be even more averse to future purchases. A related factor is the issue of irreversibility. In some instances, the energy efficient installation may be expensive to revert to the original or another technology, which would add to the uncertainty regarding equipment performance.

Energy Efficiency Programs:

Various energy efficiency programs have been developed to address these market failures and barriers. These programs can be both voluntary and mandatory, and operated by utility companies, and national, state, and local governments. These may be categorized as voluntary programs, building and equipment energy performance standards, state market transformation programs, information, energy management financing, government procurement, tax credits, and accelerated R&D. A program may address more than one of the above market failures and barriers. The time lag between program implementation and its realized electricity savings varies depending on the targeted technologies. End-uses that have a short turnover period, such as lighting, will yield savings sooner than those with longer gestation periods. For a chronically electricity-short India, short-turnover-period technologies should be the primary candidates for implementation.

Many such programs are being implemented at the national and/or state level in the US[18]. A recent review provides information on 18 public benefits state-level energy efficiency programs that are in operation in the US (Kushler, York and Witte, 2004). These states spend over $900 million annually on the programs, and annual savings in just 12 of the states reporting evaluation data were nearly 2.8 million MWh, and power savings reported by 8 states were 1060 MW. The cost of conserved energy ranged between $0.023 to $0.044 per kWh. Electricity savings ranged from about 0.1 to 0.8 percent (mean 0.4 percent), i.e., this figure represents the percentage points shaved off electricity growth. The most common approach used by the states to fund such programs is a "public benefits charge" consisting of a small non-bypassable per kWh charge on the electric distribution service. Some states use a flat monthly fee or a charge that is embedded in the rates. The median value of the charge was just over $0.0011 per kWh.

About half of the 18 states relied principally on utility administration of the programs while the other relied on either government agencies or an independent non-profit organization (Kushler, York and Witte, 2004). For example, in California, the energy efficiency programs are administered by the utility companies with substantial direction from the California Public Utilities Commission (PUC), in New York by the New York State Energy Research and Development Administration a non-utility entity, in Michigan by the Michigan PUC, and in Arizona by the utility company. Administration of programs has evolved with more programs now being administered by non-utility entities than before. Each type of program appears to be best suited to the needs of the state and no one program administration is better than another. Blumstein et al. (2003) provide five different models and their suitability for implementation of energy efficiency programs at the state level.

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[18] This US Department of Energy web site provides a summary description of the US state energy efficiency programs http://www.eere.energy.gov/femp/program/utility/utilityman_energymanage.cfm.

Public purpose funded energy efficiency programs in California for example that are administered by investor-owned utility companies include a Standard Performance Contracts (SPC) program, The Express Efficiency Program (EEP), and a Savings by Design Program (SDP). The SPC provides performance-based incentives for energy efficiency retrofits, including lighting, HVAC, motors, VSDs, controls, and custom projects. Incentives range from $0.05/kWh (lighting measures) to $0.14/kWh (most air conditioning and refrigeration measures) for electric energy efficiency projects. The EEP provides rebates to small- and medium-sized customers (500 kW or less) for specific energy-efficient products including lighting, air conditioning, refrigeration, motors, and natural gas-fired equipment, such as boilers. provides incentives for energy efficiency measures in new construction and major renovations. The SDP offers building owners and their design teams a range of services, including design assistance, "owner incentives" to help offset the costs of new energy-efficient buildings, and "design team incentives" to reward designers who meet ambitious energy efficiency targets.

In addition to these programs, state utility companies offer programs in their own service areas. Pacific Gas and Electric (PG&E) provides large customers (over 500 kW peak demand) rebates for replacing lighting, HVAC, refrigeration, and food service equipment with qualified energy-efficient models. Rebates can range as high as $300,000 per customer. The utility companies also offer a variety of demand-response programs that are geared towards reducing and levelizing peak loads.

In India, the Energy Conservation Act 2001 provides for the establishment of state energy conservation agencies to plan and execute programs. An agency of the state of Maharashtra, such as MEDA, and/or the utility company, MSEB, could implement public benefit programs similar to those being implemented in about 20 states in the US today. The Maharashtra Electricity Regulatory Commission (MERC) already has instituted a public-benefits electricity charge to finance renewable energy and energy efficiency programs in the state. These charges could be used to promote energy efficiency in Maharashtra either directly through MSEB, MEDA, or a new public-private partnership.

In addition to the implementation of the aforementioned public benefits energy efficiency programs, there is also a need for collection of data and analytical activities that are not occurring at the state and utility level in India. In the US such activities are routine and include the use of generation planning models, and implementation of least-cost planning that includes end-use efficiency measures. The US Federal Energy Regulatory Commission and Department of Energy, and state energy agencies, collect and/or collate annual data on individual power plant performance and attributes of other forms of energy supply. Demand-side data are collected through triennial or quadrennial surveys of households (Residential Energy Consumption Survey), commercial (Commercial Buildings Consumption Survey), and industrial (Manufacturers Energy Consumption Survey) sectors. Utility companies gather hourly data on load shapes. In India, however, utility data are only now starting to be collected to a limited extent by the more progressive states.

In India, a lighting, water pumping and solar water heating program is being investigated for implementation in Karnataka by BESCOM, and a lighting program is being designed by MSEB under orders from MERC. Based on our economic analysis, following are examples of the types of cost-effective measures activities that could be pursued in Maharashtra.

<u>Agricultural consumers</u> have highly subsidized electricity tariffs, and hence little or no incentive to undertake energy efficiency measures. As shown previously, it is cost effective for MSEB and the Maharashtra government to bear the full cost of the energy efficiency measures in agricultural pumping. For example, in the case of a program replacing two components, undersized pipes and high friction foot valves, the cost of conserved energy is Rs. 0.5 per kWh. A kWh saved in the agricultural sector saves Rs. 2.60 /kWh, which results in a net cost reduction of Rs 2.1 /kWh assuming a zero agricultural electricity tariff. The distribution of savings between MSEB and the Maharashtra government will depend upon how much of the revenue shortfall is covered through direct subsidy (from the government) and cross subsidy (from other MSEB consumer categories). The proportionally high savings per kWh warrant a strong program that includes rebates and even direct replacement of the two components.

A second example is a <u>residential program</u> that will target low-consumption households that consume 50 kWh of electricity or less per month. These are in most cases low-income consumers, who have high discount rates, and often don’t have the initial capital required to buy energy efficient end uses devices, such as CFLs. These consumers also tend not to be well educated and informed, and rarely use energy efficient appliances. MSEB could overcome the initial high cost and information barriers by a targeted leasing program for energy efficient appliances especially CFLs.[19] The cost of the CFLs could be recovered from the consumer bill over a period of time. The program could be designed in such a way that a consumer’s monthly electricity bill remains unchanged (a bill-neutral program) until the full cost of the CFL is recovered, and subsequent savings are passed on to the consumer. Beyond the benefits to the residential consumer, MSEB would benefit by reselling the saved energy to its most valued C&I consumers, and by reducing the amount of subsidy given to the low consumption (low income) residential consumers.

Utility-run energy efficiency programs can also effectively reduce the price of energy efficiency measures through their bulk procurement. Such programs would reduce various transaction costs (search costs, installation costs etc.) incurred by individual consumers. Bulk purchase has the potential to reduce the purchase cost by 30 – 40 % compared to the retail price. Since utilities are in regular contact with consumers for metering, billing, and repairs, and can collate information about their consumption patterns they could implement programs at a lower cost compared to acquisition of such devices by individual entities.

10 Conclusions

This paper analyses the economic benefits of removing Maharashtra’s electricity shortage through the use of energy efficiency measures. The analysis shows that consumers in residential, commercial, and industrial sectors benefit from the adoption of selected energy efficiency measures, except residential solar water heating. MSEB benefits because it saves the cost of supplying electricity to consumers, and realizes

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[19]. For example, average monthly bill for a 60 W incandescent bulb is Rs. 13.75 at Rs 1.91 /kWh (average tariff for consuming up to 50 units per month) * 4 hours/day * 30 * 0.06 kW). Average bill of 15 W CFL which replaces a 60 W incandescent bulb is Rs 3.43. Reduction in the bill is 10.3 Rs per month. If a 15 W CFL costs 150 Rs the cost of the CFL can be recovered in 15 months. MSEB could make a conservative estimate of the bill saving as result of using one CFL. When MSEB leases a CFL to a consumer, it could add to his/her the bill amount saved by the CFL. This will ensure that the consumer’s bill remains approximately the same. This adder will be in effect until the cost of the CFL is recovered and once the cost is recovered, the bill savings are passed on the consumer.

additional revenue through the resale of saved electricity to commercial and industrial consumers whose load is being shed. The state government benefits because lower electricity demand in the residential and agricultural sectors reduces subsidies, and resale of electricity to deprived commercial and industrial consumers increases sales tax revenue. This tax and subsidy benefit amounts to over Rs. 1,200 crores, and is magnified further due to the indirect impact on output of the Maharashtra economy. The direct and indirect magnitude of revenues is large enough to reduce the 2002-03 revenue deficits by 15% or more.

This significant potential for reducing the state's revenue deficit and improving utility finances calls for a vigorous energy efficiency program in Maharashtra using the tariff charge levied by MERC to support such activities. US state-level public-benefits programs offer alternative approaches for implementing such a program in the state. Further research is required to fully understand the economic implications and the types of programs that could be pursued. In particular, the following topics should be explored further:

- Evaluate and recommend appropriate roles for MSEB, MEDA, MERC, and other entities in the implementation of public-benefits energy efficiency programs. Other states may also be included in such an evaluation.
- Set up periodic surveys to collect data by sector on end-use electricity demand and electricity shortage by consumer category at one of the aforementioned entities.
- Institute least-cost planning models and algorithms at MERC and/or MSEB, and at similar entities in other states.
- Specify programmatic activities based on an economic analysis expanded to include other energy efficiency measures
- Train staff at ERC, SEB, utility companies, and/or other entities to implement above programmatic activities

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Appendix 1 Sources of cost and efficiency data for selected energy efficiency measures

CFLs

Survey of market prices.
Survey of Philips, Orpat, and unbranded CFLs in local stores

Solar Water Heaters

Survey of market prices
Survey of TATA BP Solar, and local brands in Pune, such as Surya systems, Energytech, etc.)

Refrigerators

Price data obtained from local dealers
Data on efficiency based on BEE (2004).*Refrigerators: Which is the 'Coolest One"?.* Bulletin of Energy Efficiency, April 2004 v.4:5

Agricultural pump sets

Price data obtained from
Kelkar Brothers: Dealer of Kirloskar Brothers LTD. Pune
Laksmi Pumps Pune

Energy efficiency motors & VSD

Data obtained from Siemens India

Appendix 2 Refrigerators

There are two main product classes for residential refrigerators in India: direct cool (manual defrost) and frost-free. Nearly all of the direct-cool models are one-door type, with a small freezer compartment within the same cabinet area as the fresh-food compartment. Likewise, the frost-free units are entirely two-door units, with two isolated compartments connected by an air passage. Traditionally, direct cool units have dominated the market, but frost-free units are gaining ground. According to a recent survey of Indian refrigerator manufacturers (IMRB 2004), direct-cool units command 82% percent of the market, with 18% held by frost-free. One source indicates, however, that sales of frost-free units are currently growing at 20% per year.[21]

The parameters necessary to assess the cost effectiveness of improved refrigerator efficiency are taken from an engineering analysis (Bhatia 1999), which evaluated the characteristics of a baseline refrigerator model and utilized a simulation software package in order to determine efficiency benefits. This analysis used cost estimates reported by Indian refrigerator manufacturers.

Table A-1 shows data collected for direct-cool refrigerators of 165-liter capacity. This capacity of refrigerator class continues to be the most popular sold. We assume that the relationship between cost increase and efficiency improvement is still generally applicable to the baseline unit on the market today.

In order to more accurately estimate energy savings of current Indian refrigerators, we estimated the daily electricity consumption from a survey of the current market (IMRB 2004). This dataset is comprehensive in terms of models currently sold, but does not have consumption data for many models. Therefore we adopt the methodology of a recent report (Harrington 2004), which estimated a compressor activation rate of 38% for Indian refrigerators currently on the market. Using this, in combination with the wattage ratings provided for current models (weighted by sales), we

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[20] McNeil M., Iyer M., Meyers S., and McMahon J. 2005. Potential Benefits from Improved Energy Efficiency of Key Electrical Products: Draft LBNL Report in progress.
The Case of India, with Extension to South Asia, the Middle East, and Africa

[21] STAT-USA Industry Sector Analysis – Refrigeration and Air Conditioning Equipment - India

determine that the baseline refrigerator uses an average of 0.98 kWh per day. Annual unit energy consumption for the baseline model is 0.98 kWh/day x 365 days = 359 kWh.

Frost-free models, almost all of which are two-door models in India, are much more energy intensive. According to a sample of models tested by manufacturers, the average consumption of a frost-free model is roughly 2.4 kWh/day, or 876 kWh per year.

The incremental costs shown in the table represent direct material and labor expenses to the manufacturer, and are not indicative of the additional price paid by the consumer, which also includes distributor and retail markups. In order to estimate these, we scale the percentage manufacturer incremental costs according to an estimate of baseline retail price. The baseline retail price for a 165 liter direct-cool (single-door) refrigerator are taken from a survey of a comparison-shopping website in India (www.compareindia.com). Price data are from a sampling of retail outlets and therefore we judge them to be competitive and potentially more representative of actual prices paid than manufacturers' suggested retail prices. The average of a sample of 17 models between 165 and 175 liters is $184 at current exchange rates.

For frost-free models, the baseline is around 220 liters, with about half of sales for units within the 220 to 250 liter range. To estimate the baseline price for frost-free models, we used a sample of 18 models from the same retail source, and found an average price of $311 for units between 220-235 liters.

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[22] Although refrigerators may not be operational during every hour of the day due to unreliability of the power supply, we assume, however that any compressor run time lost during a power outage is compensated for by the increased cooling necessary when power is restored.

Table A-1. Per unit efficiency improvement and incremental manufacturer cost for refrigerator design options (direct-cool refrigerator of 165 liter capacity)

Design number	Design	Energy savings						Incremental price	
		Unit savings	Unit savings	UEC		Δ Cost	Cum	Price	Cum
		kWh/ day	%	kWh/ day	kWh/ year	$	%	$	
0	Baseline			0.98	359			$184	$0.00
1	Gasket heat leak reduction 25%	0.05	5%	0.94	341	$2	1.3%	$186	$2.39
2	Higher EER(4.13) compressor	0.23	23%	0.76	276	$7	3.9%	$191	$7.17
3	Increase insulation thickness in door and wall by 50%	0.45	45%	0.54	196	$19	10.3%	$203	$18.94
4	Increase evaporator area by 33%	0.46	47%	0.52	190	$23	12.7%	$207	$23.36
5	Increase condenser area by 50%	0.49	50%	0.49	179	$32	17.4%	$216	$32.00

Source: Bhatia, Pankaj "Development of Energy-Efficiency Standards for Indian Refrigerators" ASHRAE Transactions: Research 199 Baseline Energy Consumption calculated from currently available models, using rated Wattage, in combination with methodology used in Harrington (2004)

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[23] Baseline design assumed to have (1) Gasket heat leak rate of 8.0 W/M – 100^{o}C, (2) Compressor EER of 3.41, (3) Wall and door insulation thickness 4.00 cm (4) Evaporator area 0.488 m^2 and (5) Condenser area 0.63 m^2; from Bhatia (1999).