

# An Analysis of Maharashtra's Power Situation

*This paper analyses Maharashtra's data on demand, supply and load shedding. The trends in the hourly load variation and seasonal variation of average energy and peak shortages in Maharashtra (2005-07) are analysed and used to make short-term projections and recommendations. The projected average energy and peak shortages in the state for 2007-08 are 2,600 MW and 4,500 MW, respectively. Demand side management and captive generation can be used to reduce the quantum of load shedding. The possible impact of augmenting generation from installed captive capacity and a few DSM options like efficiency for residential lighting and solar water heaters has been quantified. It is estimated that the average energy and peak shortage for 2007-08 can be reduced to 680 MW and 2,000 MW using these selected options.*

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Since 2005, Maharashtra's power sector has been unable to meet electricity demand. The state utility has been resorting to load shedding to bridge the gap between supply and demand. Several parts of the state have eight to 10 hours of load shedding. Load shedding results in disruption of life-style, loss of production and causes inconvenience to consumers. Naturally this is a contentious and controversial issue. However there is a lack of analysis based on data, to support different viewpoints.

Conventionally, power systems are designed to maintain equilibrium between demand and supply. Hence most of the theory of optimal operation, dispatch and planning assume this equilibrium. In Maharashtra, load shedding has persisted for the last two years and is expected to continue for some more time. The Maharashtra State Electricity Distribution Company Ltd (MSEDCL) estimates that shortages will persist till 2010-11. The optimal operation of a power sector under shortages is a difficult problem. This requires an analysis and understanding of the data on shortages.

This paper attempts to analyse Maharashtra's data on demand, supply and load shedding. We try to answer the following questions: (1) What is the quantum of load-shed? How has it varied during 2005-07? (2) What are the shortages/load-shed by different consumer classes? (3) What are the other short-term options? (4) What is the expected shortage during 2007-08? Can load shedding be reduced during 2007-08?

The analysis provided in this paper intends to highlight the issues related to Maharashtra's power situation and hopefully will result in improved decision-making.

## Energy and Peak Demand Trend and Quantification of Shortages

### Quantification and Trend of Energy Demand

The demand for electricity varies during the day and over the year. Typically most Indian utilities have a morning peak and evening peak, with evening peak higher than that of morning peak because of residential and commercial lighting load.

Figure 1 shows a daily load profile for the state utility (earlier Maharashtra State Electricity Board), for a typical day when there was no load shedding.

An analysis of the hourly pattern report for each day (for the last two years) available from the state load dispatch centre (SLDC),<sup>1</sup> Kalwa, has been carried out to generate profiles for the monthly average energy demand and study the seasonal variation in demand.

The Maharashtra power system is bifurcated into two systems: that of Mumbai, served by Reliance and Tata Power; and the rest of the state served by the MSEDCL. (BEST is a distribution company with no generation of its own, that receives electricity from Tata Power.) Thus, in Maharashtra, the state demand consists of MSEDCL demand, Tata Power demand and Reliance demand as given by equation (1).

$$\text{MSEDCL Demand} + \text{Tata Power Demand} + \text{Reliance Demand} = \text{Maharashtra State Demand} \quad \dots(1)$$

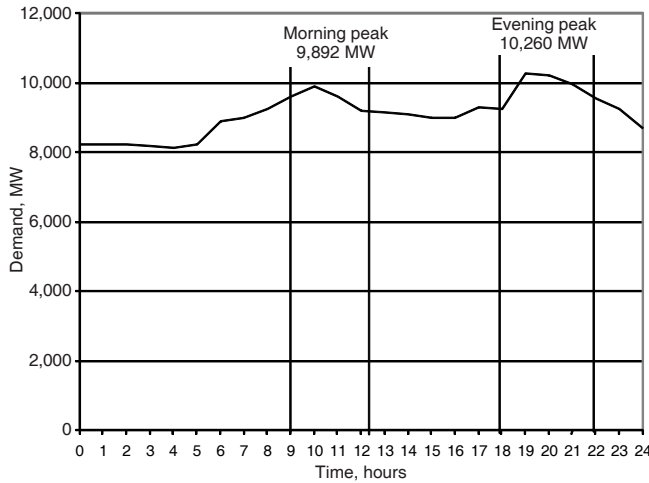
In a normal situation, there is a balance between supply and demand. However, at present, supply is not sufficient to meet demand and there is load shedding by MSEDCL. Hence the unrestricted MSEDCL demand can be obtained by adding the MSEDCL supply to the load shed as shown in equation (2).

$$\text{MSEDCL Supply} + \text{MSEDCL Load Shedding} = \text{MSEDCL Demand} \quad \dots(2)$$

Figure 2 shows the seasonal energy demand variation from April 2005 to March 2007. It shows a wide variation in seasonal energy demand. From Figure 2, the annual average unrestricted energy demand for 2005-06 is 10,028 MW whereas the annual average unrestricted energy demand for 2006-07 is 10,438 MW (growth of 4.1 per cent). Figure 2 shows that the shortages are less in July, August and September while the energy shortage is significant in the months of December, January and February. The variation in monthly energy demand shortage from April 2005 to March 2007 and the percentage energy demand shortage with respect to unrestricted demand in the respective months is given in Table 1. The difference between the two curves represents the monthly load shed also shown in Table 1.

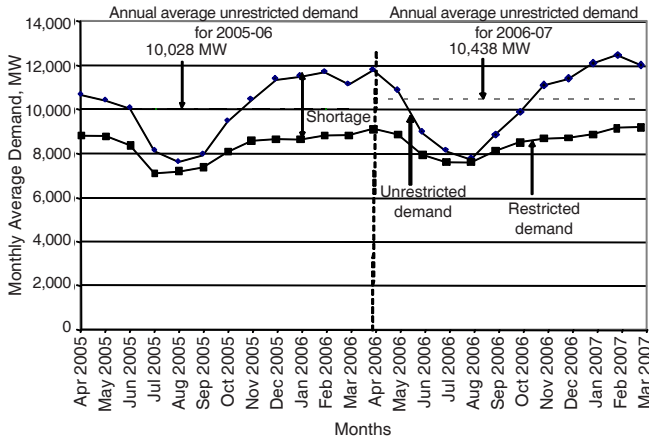
Energy demand shortage in 2005-06 is 17.6 per cent of MSEDCL unrestricted demand whereas energy demand shortage in year

**Figure 1: MSEB's Load Profile without Load Shedding (November 8, 2000)**



Source: Sreedhar (2004).

**Figure 2: Variation of Monthly Average Energy Demand for MSEDC**



2006-07 is 18.3 per cent of MSEDC unrestricted demand. The restricted and unrestricted average energy demand and percentage growth in restricted and unrestricted energy demand in 2006-07 over 2005-06 for the state, MSEDC and Mumbai are given in Table 2. Since, in Mumbai there is no load shed, the restricted and unrestricted energy demands are the same.

### Quantification and Trend of Peak Demand

Until 1998-99, there was sufficient generation capacity to meet Maharashtra's peak demand for electricity [Phadke et al 2005]. Since then, however, peak demand each year has exceeded the available system capacity. The estimated shortage in supply provided by MSEDC is given in Table 3.

During February 2007 the shortage specified by MSEDC was 5,700 MW. An examination of the detailed monthly demand indicates that this shortage occurred only during five hours in the entire month. The average shortage in February 2007 was 3,344 MW. In order to obtain estimates of the energy and peak shortages it is necessary to analyse the annual load duration curve.

A graph showing the variation of the load on the system during 24 hours of the day is known as a daily load curve. A

daily load duration curve can be obtained by rearranging the load elements of daily load curve in descending order. This provides an idea of the duration of the time when the load on the system is greater than a specified amount. In a similar fashion the monthly load duration and annual load duration curve can be computed. Figure 3 shows a sample load duration curve.

Since there are uncertainties in the load shedding estimates, the peak shortage should not be quantified based on instantaneous load shedding data or data for a particular hour. A methodology for quantification of peak shortage has been proposed in this

**Table 1: Variation in Monthly Energy Demand Shortage from April 2005 to March 2007**

For MSEDC	Monthly Average of Unrestricted Demand (MW)	Monthly Average of Energy Supplied (MW)	Monthly Average of Load Shedding (MW)	Percentage of Load Shed
April 2005	10,668	8,785	1,883	17.7
May 2005	10,405	8,775	1,630	15.7
June 2005	10,047	8,359	1,688	16.8
July 2005	8,104	7,108	996	12.3
August 2005	7,616	7,182	434	5.7
September 2005	7,916	7,375	541	6.8
October 2005	9,442	8,060	1,382	14.6
November 2005	10,431	8,562	1,869	17.9
December 2005	11,357	8,637	2,720	23.9
January 2006	11,502	8,617	2,885	25.1
February 2006	11,705	8,798	2,907	24.8
March 2006	11,147	8,819	2,329	20.9
April 2006	11,804	9,101	2,704	22.9
May 2006	10,862	8,842	2,019	18.6
June 2006	8,937	7,948	989	11.1
July 2006	8,096	7,607	489	6.0
August 2006	7,724	7,589	135	1.7
September 2006	8,851	8,104	748	8.4
October 2006	9,864	8,499	1,365	13.8
November 2006	11,106	8,658	2,449	22.0
December 2006	11,395	8,697	2,699	23.7
January 2007	12,103	8,849	3,253	26.9
February 2007	12,489	9,145	3,344	26.8
March 2007*	12,024	9,179	2,845	23.7

\* The average is only for March 1-12, 2007.

**Table 2: Restricted and Unrestricted Energy Demand for 2005-06 and 2006-07**

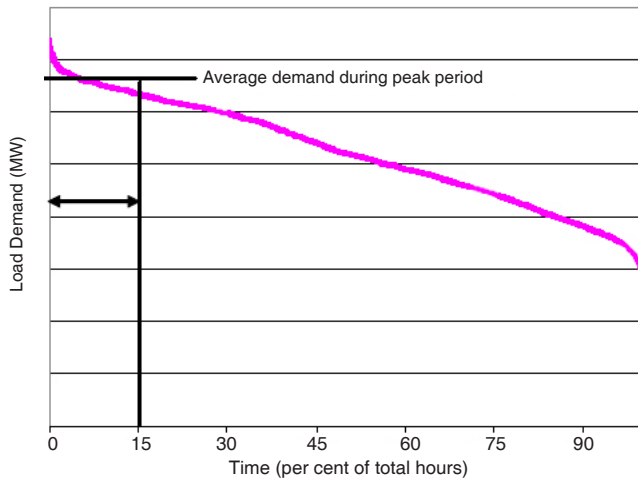
Year	MSEDC Average Energy Demand (MW)		Mumbai Average Energy Demand (MW)	State Average Energy Demand (MW)		Average Energy Shortage (MW)
	Restricted	Unrestricted		Restricted	Unrestricted	
2005-06	8,252	10,028	1,759	10,011	11,788	1,777
2006-07	8,513	10,438	1,837	10,351	12,275	1,924
Growth (per cent)	3.17	4.1	4.44	3.40	4.12	8.30

**Table 3: Demand Supply Scenario at the Time of Peak Demand (In MW)**

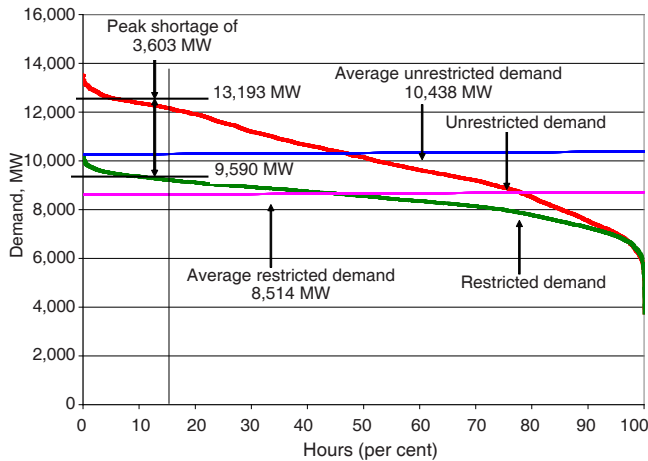
	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07 up to February 6
Demand	10,119	11,425	11,357	12,749	14,061	14,749
Availability	9,103	9,004	9,315	9,704	9,856	9,049
Shortage	1,016	2,421	2,042	3,045	4,205	5,700

Source: MSERC (2007).

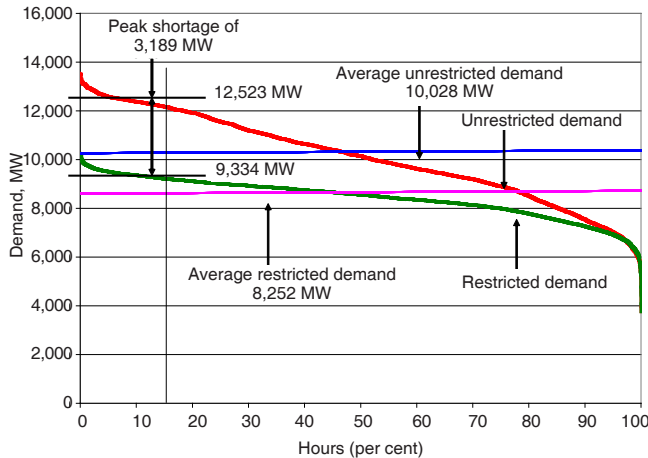
**Figure 3: A Sample Load Duration Curve**



**Figure 4: Annual Load Duration Curve for MSEDCL for 2006-07**



**Figure 5: Annual Load Duration Curve for MSEDCL for 2005-06**



**Table 4: Restricted and Unrestricted Peak Demand for 2005-06 and 2006-07**

Year	MSEDCL Peak Demand (MW)			Mumbai Restricted/ Unrestricted Peak Demand (MW)	State Peak Demand (MW)		
	Restricted	Unrestricted	Shortage		Restricted	Unrestricted	Shortage
2005-06	9,334	12,523	3,189	2,261	11,214	14,487	3,272
2006-07	9,590	13,193	3,603	2,374	11,581	15,216	3,635
Percentage growth	2.7	5.4	13.0	5.0	3.3	5.0	11.1

section by utilising the hourly demand data from SLDC. In order to quantify the peak shortage of MSEDCL for 2006-07, annual load duration curves are constructed for restricted and unrestricted demands. From these load duration curves, the average value for the highest load hours (15 per cent of the total hours) is taken as the peak load. Thus, the peak load is calculated for the restricted and unrestricted load duration curves for 2006-07 and the difference gives us the peak shortage for 2006-07. For 2006-07, the restricted peak demand is 9,590 MW and unrestricted peak demand is 13,193 MW, which gives us a peak shortage of 3,603 MW as shown in Figure 4. Similarly for 2005-06 restricted peak demand is 9,334 MW, unrestricted peak demand is 12,523 MW and peak shortage is 3,189 MW as shown in Figure 5.

The peak shortage in 2005-06 is 25.5 per cent of MSEDCL's unrestricted peak demand whereas peak shortage in 2006-07 is 27.3 per cent of MSEDCL's unrestricted peak demand. The data for the state, MSEDCL and Mumbai is given in Table 4.

In Table 4 it is seen that the peak shortage for the state and MSEDCL is different even though there is no load shedding for Mumbai; this is because the peak demand of MSEDCL and peak demand of Mumbai occur at different times.

Figure 6 shows the seasonal variation in restricted and unrestricted monthly peak demand from April 2005 to March 2007. In July, August and September the peak shortage is relatively less while the peak shortage is significant in January, February and March.

Figure 7 shows the variation of the monthly energy and peak demand shortages during 2005-07. It is seen that the energy and peak shortage follow similar trends. All the above estimates are dependent on the accuracy of the load shed statistics. We believe that there is a need to improve the methodology for quantifying this.

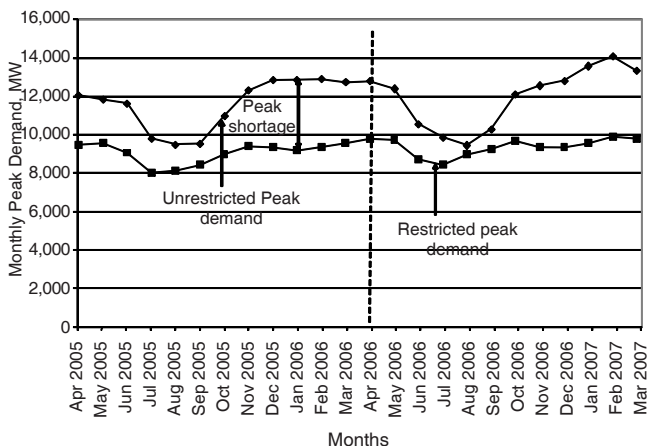
## Analysis of Load Shed Plan and Fairness of Load Shedding

### Load Shed Plan

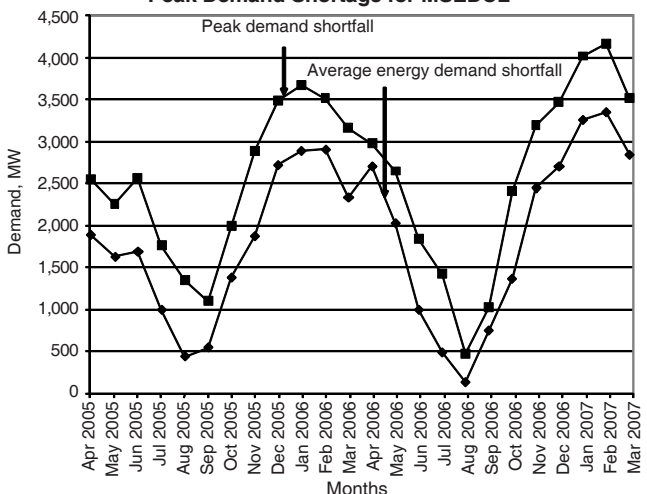
The State Load Dispatch Centre (SLDC) at Kalwa is the main authority for implementing the load shedding plan in Maharashtra. The load shedding plan allocates the load to be shed by urban and rural regions. On a given day, SLDC instructs operators of main substations to shed the load based on this plan 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 programmes.

An examination of the unrestricted load profiles over the years shows a change in the load profile shape. This indicates that the load shed estimate for some of the hours is higher than the actual. This is reflected in an increase in the unrestricted load factor (defined as ratio of average demand to the unrestricted peak

**Figure 6: Variation of Monthly Peak Demand for MSEDCL**



**Figure 7: Variation of Monthly Energy and Peak Demand Shortage for MSEDCL**



demand) in the MSEDCL system. This is not seen in the Mumbai system (see the Appendix).

At present MSEDCL estimates the load shed to be equal to the load on the feeder at the time when the service is discontinued (feeder switched off). This is reported as the constant load shed for the next few hours until the connection is restored [Phadke et al, *ibid*]. This is not a precise way of estimating the shed load as the load may change during this period. The load on any feeder normally varies during the day depending on the type of load connected to it. If a feeder is switched off for several hours, the actual load that is shed varies during this time period. In order to estimate this, it would be necessary to incorporate the variation in load by obtaining data on the feeder on another day (during a similar period) when there is no load shedding.

A bottom up approach based on actual load profiles of feeders that are being switched off should be followed for a better understanding of load shed data that will result in improved system operation.

### Fairness of Load Shedding

The economic and welfare loss due to electricity shortages varies by consumer categories hence it is important to understand the distribution of load shedding by MSEDCL by these categories.

Based on the principles specified by the Maharashtra Electricity Regulatory Commission (MERC), MSEDCL prepares a load shedding plan and gets it approved from MERC. As per the MERC principles, the entire load shedding programme is formulated by evaluating different consumer segments, viz, rural, urban and industrial conglomeration and other urban based on a parameter called distribution collection loss (DCL) efficiency. DCL efficiency is calculated after giving 70 per cent weightage to the distribution losses in the segmented groups and 30 per cent to the efficiency of collection of revenues against the total power sold. However, a difference of 3 per cent is considered for rural areas in DCL calculations as the technical losses are generally higher in the rural areas owing to higher lengths of distribution system. As per the DCL efficiency, each of the three customer segments has been divided into four further groups A, B, C and D. The group with the lowest DCL efficiency is penalised with more load shedding hours (in this case D will be the most and A will be the least). The ranking of the consumer segments based on the distribution collection losses is shown in Table 5.

In addition to the DCL efficiency, the total load to be shed is apportioned to the three consumer segments based on the contribution of the respective segments to the total load under the utility. As per MSEDCL statistics of May 2005, 45 per cent of the load caters to the requirement of rural areas, 27 per cent to industries, MIDCs and water works (non-sheddable loads) and 28 per cent to other urban areas. The ratio of apportionment between the three segments varied from 2:3:7 (as per May 18, 2006 MERC directives) to 1:1.4:2.8 in early 2007. However an upper ceiling of hours of load shedding for a particular segment and a particular group (A, B, etc) is specified by MERC that should not

**Table 5: Ranking of Consumer Segments Based on Distribution Collection Losses (Per cent)**

Groups	Weighted Average of Loss and Collection Efficiency Level (DCL 70/30)		
	Rural	Major Urban	Other Urban
Group A	0 to 28	0 to 25	0 to 25
Group B	>28 to 38	>25 to 35	>25 to 35
Group C	>38 to 53	>35 to 50	>35 to 50
Group D	Above 53	Above 50	Above 50

Source: MSEDCL, 'Load Shedding Protocol'.

**Table 6: Load Shedding Hours of MSEDCL**

Region	Urban and Industrial Conglomerations	Other Regions	Agriculture Dominated Regions	
Groups	Hours	Hours	Hours	Hours
(a) Formulated in July 2005				
A	1	2	5	
B	2	4	8	
C	2	4	8	
D	2	4	8	
Region	Urban and Industrial Conglomerations	Other Regions	Agriculture Dominated Regions	Anticipated Load Relief
Groups	Hours	Hours	Hours	MW
(b) Formulated in May 2006				
A	2.5	4.5	11	3,500-4,500
B	3	5	11.5	
C	3.5	5.5	12	
D	4	6	12	

be violated. The consumer segment-wise and group-wise hours of load shedding carried out to meet the existing system demand are given in Table 6.

As per the hourly load relief data of MSEDCL the total load shed in MW and data in MWh by the three segments of customers (urban and industrial conglomeration, other region and agriculture dominated areas) has been calculated as per the proposed load shedding programme of MSEDCL dated July 1, 2005 (Table 6a), and tabulated in Table 7. This analysis is for the earlier load shed plan for the period 2005-06 for which data is available.

The total load shared by three consumer segments as in Table 8. The percentage share of load shed by the three consumer segments is given in Table 9. It is seen that according to the plan, rural areas shed about 33 per cent of their demand, major urban areas shed about 7 per cent of their demand while other urban areas shed about 16 per cent of their demand, as per the MSEDCL data for July 1, 2005.

MSEDCL should provide reports of actual loads shed by individual consumer classes. Since the load on a feeder varies during the day it may be worthwhile to study the impact of load shedding on a few individual feeders of each of the categories. There is an uncertainty involved in computation of the load shed (especially if it persists for a period of several hours).

## Short-Term Measures to Avoid Load Shedding

### Utilisation of Installed Captive Capacity in the State

A captive power plant is a generation plant set up by an industrial/commercial unit for supplying power primarily for its own consumption. Under this scheme, a threshold level is prescribed for the industry's own consumption from the captive units and capacity in excess is permitted for sale into the grid. However due to economic barriers the installed captive capacity in the state is underutilised. This underutilised installed captive capacity can be used to reduce load shedding in the state.

Maharashtra shares a major portion of the total installed capacity of captive power plants (1 MW and above) of India. The prime mover-wise installed captive capacity for Maharashtra as on March 31, 2004 and its utilisation factors (UF) for 2003-04 are shown in Table 10.

In order to estimate the installed captive capacity in the state in 2007-08, prime mover-wise growth rates of installed captive capacity in India over the previous years are used. The annual compound growth rates for the three major prime movers, viz, coal (steam), diesel and gas have been worked out to be 2.9 per cent, 6.1 per cent and 10.8 per cent, respectively. Since the captive generation from hydro and wind are dependent on the weather, rainfall and wind speed, the utilisation factor of existing installations cannot be easily augmented. Hence the focus is on augmenting generation from coal, gas and diesel plants. The prime mover-wise projected installed captive capacity for year 2007-08 and the additional average captive generation that will be actual available to augment the present generation is given in Table 11.

The unit cost of power generation for the three major prime movers, thermal (coal), diesel and gas have been calculated to analyse the economical feasibility of utilisation of installed captive capacity in state. Since all the captive capacity is already

installed by industries, therefore only the variable cost of generation, i.e., fuel cost, is considered while calculating the unit cost of captive power generation. The prime mover-wise unit costs of captive power generation are shown in Table 12.

**Table 7: Load Shedding Plan for Different Consumer Segments (July 2005)**

Group	Total Load Shed (MWh)			Average Load Shed (MW)		
	Rural	Urban and Industrial Conglomeration	Other Urban	Rural	Urban and Industrial Conglomeration	Other Urban
A	1,420	431	418	59.2	18	17.4
B	16,952	932	1,596	706.3	38.8	66.5
C	11,888	142	3,056	495.3	5.9	127.3
D	10,928	434	3,592	455.3	18.1	149.7
Total	41,188	1,939	8,662	1,716.2	80.8	360.9

**Table 8: Average Load on Consumer Segments (MW), July 2005**

Group	Rural	Major Urban	Other Urban
A	284	431	209
B	2,119	466	399
C	1,486	71	764
D	1,366	217	898
Total	5,255	1,185	2,270

**Table 9: Percentage Load Shed by Different Consumer Segments (Per cent)**

Group	Rural	Major Urban	Other Urban
A	21	4	8
B	33	8	17
C	33	8	17
D	33	8	17

**Table 10: Prime Mover-wise Installed Captive Capacity in Maharashtra (as on March 31, 2004)**

	Hydro	Coal	Diesel	Gas	Wind	Total
Installed captive capacity (MW)	6	281	628	308	30	1253
Max energy available (GWh)	53	2,465	5,499	2,695	263	10,974
Actual energy consumption (GWh)	23	1,393	1,361	1,992	5	4,774
Utilisation factor (per cent)	43.1	56.5	24.7	73.9	2.0	43.5

Source: Central Electricity Authority (2005a).

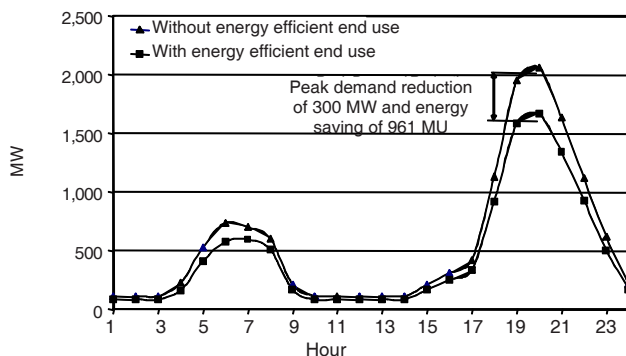
**Table 11: Additional Generation from Captive Capacity in Maharashtra (> 1MW) for 2007-08**

	Coal	Diesel	Gas	Total
Projected installed captive capacity (MW)	315	795	464	1,574
Average captive generation (MW) based on existing UF	178	197	343	718
Additional captive generation possible (MW) UF= 0.9	105	519	75	699

**Table 12: Prime Mover-wise Unit Costs of Captive Power Generation**

Parameters	Prime Movers		
	Coal	Diesel	Gas
Fuel price (Rs/kg)	2.4	34	6 Rs/sm <sup>3</sup>
Specific fuel consumption (kg/kWh)	0.697	0.188	0.345 sm <sup>3</sup> /kWh
Unit generation cost (Rs/kWh)	1.68	5.99	2.07
Additional energy available from captive in year 2007-08 (GWh)	920	4,546	657
Average total energy available (MW)		699	

**Figure 8: Load Profile for Residential Lighting Load End Use (2004-05)**



Source: More et al (2006).

The estimates computed above are for large captive plants (greater than 1 MW). There is also a potential of installed captive capacity less than 1 MW. The potential of these captive plants is taken from the manufacturer's sales statistics. The total installed capacity of the captive power plants (greater than 210 KW and less than 1 MW) in India is around 940 MW based on the manufacturer's data for the period 1990-2004 [CEA 2005b]. The projected capacity as on 2007-08 with 6.1 per cent growth rate (for diesel) is around 1,190 MW. The share of Maharashtra is taken as 7 per cent (based on share of large captive), which amounts to around 85 MW. Assuming the same utilisation factor as the large captive for diesel, the additional average generation possible is 55 MW.

### Use of Energy Efficient End Use Devices

The supply additions required to meet the projected demand require significant investments. Despite the best efforts of our energy planners, supply augmentation has not been able to match the increasing demand. It is essential that we tap the opportunities available from energy efficiency. The overall efficiency improvements are possible by improving conversion efficiency in power generation, reducing transmission and distribution losses and improving the efficiency of end use devices. A few sample options are illustrated as possible energy efficiency options to be adopted by Maharashtra.

**Table 13: Non-Energy Efficient and Energy Efficient End Use Devices Used for Lighting**

Sr No	Without Energy Efficient End Use		With Energy Efficient End Use		Power Saving	
	Device Type	Rating (W)	Device Type	Rating (W)	Watt	Per Cent
1	Incandescent lamp	60	Compact fluorescent lamp	15	45	75
2	Tube light with magnetic ballast	56	Energy efficient TL 5 tube light	28	28	50

**Table 14: Investment Required and Simple Payback Period for Energy Efficient Lighting Devices**

Sr No	Device Type	Operating Hours	Cost (Rs/Unit)	Unit Cost of Electricity (Rs/kWh)	Electricity Saved (kWh)	Annual Savings (Rs)	Simple Pay Back Period (Years)
1	Compact fluorescent lamp	3 hours/day	120	3.5	49	172	0.7
2	Energy efficient TL-5 tube light	8 hours/day	310 to 620	3.5	82	287	1.08 to 2.16

*Lighting efficiency:* In order to evaluate the impact of lighting end use efficiency on the state load profile, it is important to understand the present usage pattern and the reasons for the usage pattern. In the case of utilities and energy supply companies, often information is not available regarding load profiles by end use segments. In the absence of such information, it is difficult to assess the impacts and cost-effectiveness of demand side management programmes. Analytical studies can be used to estimate these load curves.

A generic model for lighting end use efficiency is developed [More and Banerjee 2006] to evolve the load profiles by using energy efficient and non-energy efficient lighting end use devices respectively, in order to evaluate the benefits in terms of energy saved and deferred peak capacity. Table 13 shows the non-energy efficient and energy efficient end use devices along with their ratings that are mainly used for lighting in domestic sector.

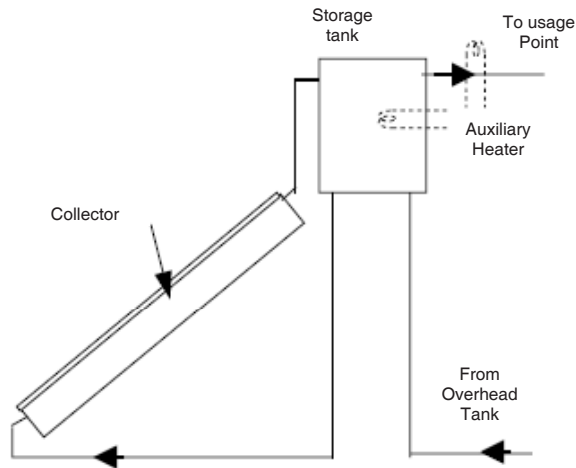
Here the load profile with energy efficient end use is constructed based on the assumption that 40 per cent of incandescent lamps will be replaced by compact fluorescent lamps (CFLs) of average power rating 14 W and 25 per cent of existing magnetic ballast tube lights are replaced by energy efficient TL5 tube lights of average power rating 28 W (according to a catalogue of the manufacturer, Philips).<sup>2</sup> The saving in demand achieved is lower because of the reduced power factor of the CFL. This correction has been incorporated in the savings estimate. In addition to reduced power factor CFLs also lead to the harmonics generation affecting power quality. However, there is little effect on a building's power quality if the CFLs comprise less than 10 per cent of the building's load. Even if the load due to CFLs is as high as 26 per cent of the building's total, the voltage distortion is less than 5 per cent [Verderber et al 1991]. Several reasonable low-cost passive circuits are available that can improve the power factor as well as suppress the harmonic distortion.

An impact of lighting efficiency programmes in Maharashtra is shown in Figure 8. It is estimated that by using energy efficient end use devices, 961 MU (GWh) of energy can be saved and 300 MW peak demand can be reduced in year 2004-05. With a compound annual growth rate of 6 per cent it is estimated that 1,145 MU of energy will be saved and 357 MW of peak demand will be reduced in 2007-08 for the state.

If information is made easily accessible and coupled with efforts to develop analytical tools/studies using the data, it is likely that a better understanding of energy usage patterns will emerge that would help in implementing effective interventions resulting in efficient energy use and great reduction in peak demand and reduction in load shedding in the most economic way. The total investment required and simple pay back period for different options of energy efficient lighting end use devices is shown in Table 14.

*Concept of life cycle costing:* If the user or the facility perceives the significant financial benefit from energy savings, it is likely to be the main driving force. One of the barriers to the adoption of energy efficiency is a procurement process that selects a

**Figure 9: Schematic of Thermosyphon Solar Water Heating System**



Source: Pillai and Banerjee (2006).

vendor based on the initial capital cost. The energy costs are not explicitly considered as it gets hidden in the overall energy bill. In many devices the operating costs predominate. Table 15 shows a sample calculation of capital costs and annual energy costs.

By modifying the procurement process in industries and commercial organisations to ensure that it is based on the minimum annualised life cycle cost we can ensure that the increase in peak and energy demand in future is moderate. This will help to reduce the future demand supply gap.

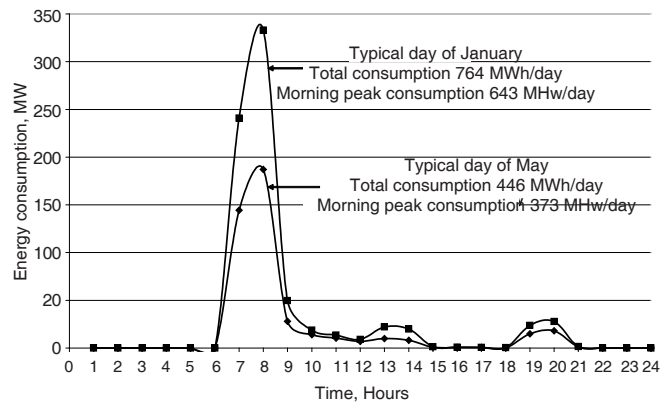
### Promoting Use of Solar Thermal Energy for Water Heating

A typical solar water heating system consists of a hot water storage tank and flat plate collector(s). The most common collector for the solar hot water is the flat plate collector, which is a rectangular box with a transparent cover, installed on a building's roof. Small tubes run through the box and the tubes are attached to a selectively coated absorber plate. The flat plate collector(s) absorb solar radiation and heat up cold water flowing through the tubes, which is collected in an insulated storage tank. In small systems, circulation of water from the tank through the collectors and back to the tank may take place automatically due to the density difference between hot and cold water (thermosyphon effect). In larger systems, a small electric pump may be required to circulate water through the collectors. Figure 9 shows the schematic of a thermosyphon solar water heating system. The auxiliary heater is installed either in the tank or at the user point for the different systems available in market.

Proper estimation of potential of any renewable energy technology is essential for planning and promotion of technology. A methodology for potential estimation and estimate of technical potential of solar water heating for Maharashtra is proposed by Pillai and Banerjee (2006). The estimate of technical potential for solar water heating system available for Maharashtra and few of its major cities along with estimation of annual electricity savings is given in Table 16.

The load profiles for Pune representing the energy requirement

**Figure 10: Load Profile for Pune Representing the Energy Requirement for Water Heating**



Source: Pillai and Banerjee (2006).

for water heating on a typical day of winter and typical day of summer is shown in Figure 10 which clearly shows that the usage of energy for water heating is maximum during the morning peak hours (out of total energy consumption, 83 per cent to 84 per cent of energy is used during the morning peak hours between 6 am and 10 am). Thus due to use of solar water heating systems the morning peak demand of the system will be reduced.

Actual penetration of solar water heating systems is a small fraction of the reported potential. Since the maximum usage of hot water is in the morning peak hours, the morning peak

**Table 15: Comparison of Initial Cost and Annualised Life Cycle Cost (ALCC)**

Sr No	Equipment	Rating	Initial Cost (Rs)	Annual Electricity Cost	ALCC (Rs)	Cost of Electricity as Per Cent of ALCC
1	Motor	20 hp	45,000	6,00,000	6,05,720	99.0
2	EE motor	20 hp	60,000	5,02,600	5,12,700	98.0
3	Incandescent lamp	100 W	10	1168	1198	97.5
4	CFL	11 W	120	128	170	75.0

Source: Banerjee (2007).

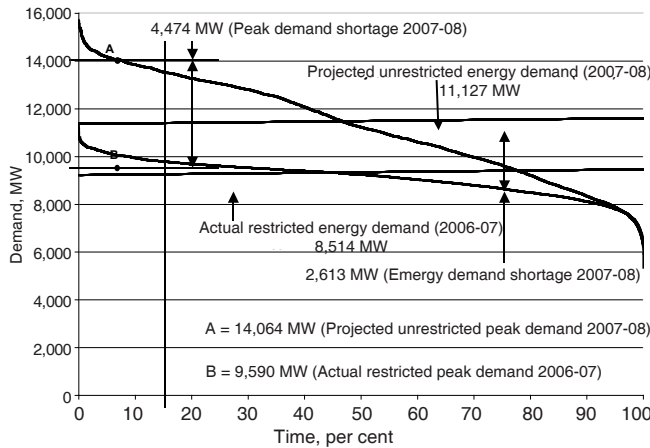
**Table 16: Technical Potential for Solar Water Heating Systems in Maharashtra**

Selected District/State	Population (million)	Per Cent Urban Population	Estimated Potential	
			Electricity Savings (GWh)	Collector Area (Million sqm)
1 Maharashtra	96.9	42.4	1,620	7.60
2 Mumbai	1.20	100	477	2.47
3 Pune	7.22	58.07	242	1.00
4 Nagpur	4.05	64.36	129	0.62

**Table 17: Different Growth Rates of Energy and Peak Demand (Per cent)**

	Energy Demand	Peak Demand	Basis
Actual unrestricted demand projection	4.1	5.4	Actual per cent growth rate in 2006-07 over 2005-06
MSEDCL projection	6.6	6.6	Growth rate considered by MSEDCL in 'Power Situation Facts and Solution'
Narasima Rao (2005)	4.3	5.8	Actual compound annual growth rate from year 1999 to 2004

**Figure 11: Energy and Peak Demand Shortage for 2007-08**



demand will reduce with increasing penetration of solar water heating systems. Thus with penetration level of 30 per cent for Maharashtra, the annual electricity that can be saved is 486 GWh, which is equivalent to an average energy demand reduction of 55 MW. Out of 486 GWh of energy consumption, around 400 GWh (~83 per cent of total energy consumption) of energy will be saved during the morning peak hours between 6 am and 10 am and the peak demand of the system will be get reduced by 298 MW for Maharashtra.

### Load Growth Projections for 2007-08

In this section, the requirement of electricity for MSEDCL for year 2007-08 is projected. The different growth rates for increase in energy and peak demand are shown in Table 17.

As shown in Table 17 the compound annual growth rates for energy and peak demand range between 4.1 and 6.6 per cent. The growth rates projected by MSEDCL are higher. These have been used for the projection. The unrestricted energy demand and peak demand for 2007-08 for MSEDCL is 11,127 MW and 14,064 MW respectively as shown in Table 18 (along with the projections for Mumbai).

*Demand supply analysis for 2007-08:* It is assumed that the energy available from the existing generation plants and the

central share during 2006-07 will also be available in 2007-08. The projected energy and peak shortages using this assumption are shown in Figure 11.

The energy demand shortage of 2,613 MW and peak demand shortage of 4,474 MW can be reduced by a variety of short-term measures. We have quantified the impact of the following short-term options:

(a) Additional generation capacity to be installed by MSEDCL as shown (Table 19). It is assumed that the plants that were expected to be commissioned till 2007 March will be available in 2007-08. (b) Augmenting generation from captive power plants in Maharashtra. (c) Energy efficient lighting. (d) Solar water heater.

**Table 20: Reduction in Energy Demand Shortage Due to Short-Term Options**

Parameters	Energy Demand (MW)
Average energy demand projection for 2007-08	11,127
Average energy demand supplied in 2006-07	8,514
Average energy demand shortage for 2007-08	2,613 (23.5)
Average energy demand from capacity addition in 2006-07	1,017 (9.1)
Average additional generation from captive power plants (> 1 MW)	699 (6.3)
Average additional generation from captive power plants (< 1 MW)	55 (0.5)
Average energy demand savings from lighting end use efficiency	110 (1)
Average energy demand savings from solar water heaters	55 (0.5)
Net average energy demand shortage for 2007-08	677 (6.1)

Note: Figures in brackets are in per cent.

**Table 21: Reduction in Peak Demand Shortage Due to Short-Term Options**

Parameters	Peak Demand (MW)
Peak demand projection for 2007-08	14,064
Peak demand supplied in 2006-07	9,590
Peak demand shortage for 2007-08	4,474 (31.8)
Peak demand met by capacity addition in 2006-07	1,017 (7.23)
Peak demand met by captive power plants (> 1 MW)	699 (5.0)
Peak demand met by captive power plants (< 1 MW)	55 (0.4)
Reduction in peak demand due to lighting end use efficiency	357 (2.5)
Reduction in peak demand due to solar water heaters	298 (2.1)
Net peak demand shortage for 2007-08	2,018 (14.3)

Note: Figures in brackets are in per cent.

**Table 18: Projected Unrestricted Demand for 2007-08 (MW)**

	MSEDCL		Unrestricted Demand		Maharashtra	
	Energy	Peak	Energy	Peak	Energy	Peak
Actual demand for 2006-07	10,438	13,193	1,837	2,374	12,275	15,216
Projected demand for 2007-08	11,127	14,064	1,958	2,531	13,085	16,221

**Table 19: MSEDCL's Capacity Addition Plan in 2006-07**

Project	Installed Capacity (MW)	Auxiliary Consumption (Per Cent)	Plant Load Factor (Per Cent)	Available Capacity	Ownership
Tarapur Stage – III	196	-	80	157	Central
Vindhyachal Set – 9	169	-	80	135	Central
Ratnagiri Gas Project	700	3	80	543	Central
Parali Expansion	250	9	80	182	State
Total	1,315			1,017	

Source: MSEDCL (2007).

Implementing these short-term options can reduce the average energy shortage and peak shortage (Tables 20 and 21).


## Conclusion

An analysis of Maharashtra's power situation reveals an average energy shortage of 1,900 MW in 2006-07 (18.3 per cent) for MSEDCL and a peak shortage of 3,600 MW in 2006-07. The seasonal variation in shortages has been quantified using the monthly load duration curves.

Based on the high growth projection of MSEDCL, the average and peak energy requirement in 2007-08 have been computed as 11,100 MW and 14,100 MW respectively (corresponding to state average energy and peak demand projection including Mumbai of 13,100 MW and 16,200 MW). If the actual generation remains at 2006-07 values, this will result in an average shortage of 2,600 MW and a peak shortage of 4,500 MW. The planned capacity by MSEDCL in 2006-07 should become operational by 2007-08 contributing to about 1,000 MW of energy and peak demand. The state can provide incentives to induce captive power plants to augment generation and sell electricity to the grid. This will provide an average of 750 MW of energy to the MSEDCL grid.

Lighting efficiency and solar water heaters can help reduce the need for load shedding by 165 MW. The realisation of these estimates would need policies to ensure:

- Guaranteed payments to captive power for generation to the grid: In addition for captive generators using diesel, the tax on diesel fuel may be exempt for the units sold to the grid.
- Innovative lighting efficiency programmes with agreements with manufacturers to recover capital costs from the electricity bills. Successful programmes are the Illumex project in Mexico, and Procel in Brazil and the programme adopted by Bangalore Electricity Supply Company Ltd.<sup>3</sup>
- Use of mass media to educate/inform consumers: The Bureau of Energy Efficiency has already initiated standards and labelling programme for major energy consuming appliances.
- Innovative financing and dissemination strategies for solar water heaters along with the equipment manufacturers.
- Feeder-wise strategies for energy conservation and load reduction. If the amount that can be supplied by MSEDCL is kept constant (or specified) and user groups are able to devise strategies for managing their consumption within this, they may be exempt from load shedding.

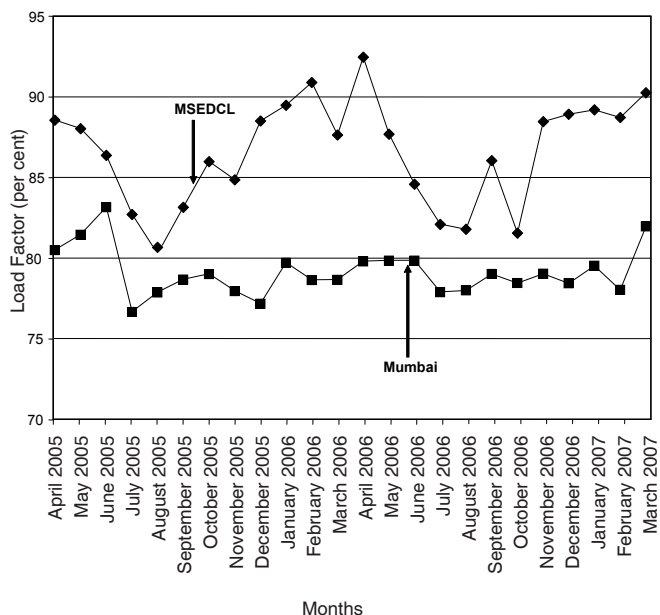
This paper quantifies the shortages and provides an analysis of options. There is a need to adopt better techniques for quantifying the shortage and understand its variation. The utility and consumers should explore options for energy efficiency and load management and minimise the need for load shedding. 

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- See 'Mexico High Efficiency Lighting Project-Post Implementation Impact Assessment', Global Environment Faculty Programme by World

Appendix: Variation of Load Factor from April 2005 to March 2007 for MSEDCL and Mumbai



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