Validation of electricity demand projections

Final report

Prepared for **MSEB**

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Introduction

The power sector of Maharashtra has undergone enormous transformation over the last few years, so has been the entire position of demand and supply of electric power in Maharashtra. Over the period, most of the demand growth projections appeared to be highly optimistic and did not materialise. A few studies indicated that demand of certain consumer categories remained virtually stagnant. A number of previous studies on demand projections for MSEB, including projection made by MSEB itself, proved to be inaccurate. In last couple of years, however, MSEB has faced huge peak demand shortages (to the tune of 2000 MW). This prompted MSEB to re-look the various demand projections.

In the report we have discussed the demand projection conducted by the Godbole Committee in 2001, forecast results after considering certain deviations from the assumptions made by Godbole Committee, followed by the MSEB's own projection in 2002. Finally, we have discussed the methodology and analysis that TERI has undertaken to forecast the future scenario of power demand in MSEB region.

Demand Projection: Godbole Committee

In 2001 a Godbole Committee submitted a report on MSEB, which included study of physical and financial performance of MSEB along with demand projection of the future growth pattern in MSEB system. The Committee projected demand for electricity in the MSEB system over the next 10 years, with the help of the past growth in demand for power in the state, MSEB's own projection for future demand, and other similar demand projections and studies conducted. The sequence of capacity additions over the late 90s was also taken into account to obtain a better understanding of the nature of demand. The Committee analysed past trends and then forecasted the demand. This has been discussed in the later sections.

Past Trends

The demand growth of the past has been much lower than the forecast and was unevenly distributed across different categories of users. The maximum growth in demand was in the domestic and commercial consumption, which was concluded by the Committee by looking into the load curve of Maharashtra. The *gross energy requirement* for 2000-01 has been 58,929 MU, of which 22941 MU accounted for technical and commercial losses. The gross energy requirement between 1995-2000 increased at a CAGR of about 5.9% p.a. The committee pointed out that this increase is much lower than estimates made by MSEB earlier projections.

Projection of Electricity Demand

The Committee projected the energy demand for individual consumer categories for next 9 years. The steps involved are classified below:

1. Apportionment of Commercial Losses and unmet demand of Various Consumer Categories was made.
    - In 2000-01 the T&D losses estimated by MSEB was 38.89%, the Committee assumed technical and commercial losses to be 21% and 18% of energy input respectively.
    - The commercial loss was believed to be highest in industrial/powerloom areas, and in rural pockets.
    - The domestic consumers of the urban/semi-urban areas also have sufficiently high commercial losses.

- The estimated commercial losses for the year 2000-01 were apportioned on a proportionate basis amongst all categories.
- *The Committee expected MSEB to reduce commercial losses from the level of 18% in 2000-01 to 5% by 2009-10.*
- The unmet demand of 3% (1400 MU) in 2000-01 has also been apportioned to each consumer category in proportion to their respective consumption during 2000-01.

2. Application of appropriate Growth rates over the Projection Period

- Category wise consumption growth rate (as calculated by MSEB) was applied to the base demand after adjusting for apportionment of commercial losses and correction of unmet demand over the projection period.

The Committee also concluded that, with adequate investment in T&D, the technical losses could be reduced to a level of 16% by 2009-10.

Godbole Committee's Projection

A complete break-up of the billable energy demand, commercial and technical losses and energy input in the MSEB system over 10-year period is provided below in Table 1.1. (in MU)

Table 1.1: Projection of Category Wise Energy Demand

Consumer Category	2002	2006	2010	CAGR
Domestic	7,963	12,853	18,457	9.8%
Commercial	1,624	2,395	32,10	7.9%
Industrial LT	2,037	2,963	39,97	7.8%
Adjusted Agricultural	9,001	12,494	15,586	6.3%
H T Industry	14,810	18,100	22,277	4.6%
Total Consumption	40,081	55,975	71,859	6.7%
Gross Energy (MU)	63759	77400	92476	4.2%

It may be highlighted here that gross energy requirement was worked out after considering a loss reduction over the years in the system. This is the reason that CAGR for total consumption works out to be 6.7%, whereas for gross energy requirement it works out to be 4.2%.

Projection of Peak Demand

Peak demand for the next 9 years has also been calculated based on the gross energy input into the system, using the system load factor of 72%.
The peak demand in MW during the projection period is shown in table 1.2 below.

Table 1.2: Projection of Peak Demand

	2002	2006	2010
Demand at Bus Bar (MU)	63759	77400	92476
Annual System load factor	72%	72%	72%
Peak Demand at bus bar (MW)	10109	12272	14662

The Committee acknowledged that, few things, which could have significant impact on the demand, are not taken into account during projection.

1. It was assumed that in the metered areas there is reduction in consumption and the entire extent of commercial loss is converted into billed demand in those areas. This is likely to be overestimation.

2. The time of day metering is likely to result in high tariff for peak power consumers. But this would encourage them to shift the load and to make investment in energy efficient system. This would alter the pattern of demand and affect the peak demand projections made.

Deviation from the Godbole assumption

Projections made by Godbole Committee, if modified fairly, would be very similar to the MSEB projection, which we have discussed later in the section.

We have modified 2 assumptions that were considered in the study

1) T&D losses were assumed to reduce by 17% during 2002-2010. We have assumed no reduction in T&D losses from 38.89%.
2) Considering load factor of 68% instead of 72%.

With these assumptions and taking the same figures for total consumption as projected by Godbole Committee, we have estimated the energy required and the peak demand.

Table 1.3 represents energy demand and peak demand as estimated by making adjustment in losses and load factor and by using total consumption figures forecasted by Godbole Committee.

Table 1.3: Projection after considering deviation from assumption made by Godbole Committee: Energy Demand and Peak Demand

Year	Godbole forecast of total consumption	Loss reduction assumed by Godbole	Godbole forecast of total energy requirement	Assuming losses of 38.89%	Peak demand at the load factor of 68
2002	40081	37%	63759	65588	11011
2003	43880	35%	67215	71805	12054
2004	47827	32%	70443	78264	13139
2005	51874	30%	73866	84886	14250
2006	55975	28%	77400	91597	15377
2007	59864	26%	81150	97961	16445
2008	63690	25%	84754	104222	17496
2009	67674	24%	88514	110741	18591
2010	71859	22%	92476	117590	19740

Power Demand and Supply Position in 10th (2002-2007) and 11th (2007-2012) Plan as prepared by MSEB

MSEB projected future electricity demand in the 10th and 11th Plan periods based on energy scale data for the previous 15 years, and on CAGR for energy demand that was 3.7%, derived from the energy billed at various categories of consumers. However, according to MSEB this method of projection suffered from some **inaccuracies**, which are listed below:

- Sale of power to the agricultural consumer was uncertain as consumption of many agricultural consumer was unmetered
- Expected T&D loss reduction by 2% every year was not achieved in reality so the forecast energy demand was lower than actually experienced by the grid in 2002-03.

Considering the fact that data on agriculture consumption and T&D losses is not reliable, MSEB also projected the demand by using the data for last 5 years on the electricity demand at the bus bar i.e. energy fed at bus bar of MSEB system adjusted for frequency correction and load shedding. In this case the CAGR of energy demand was 5.83%. Various factors that formed the basis of the projection are as follows:

- Energy demand at bus bar
  - energy generated by MSEB Power Station is net off for auxiliary Consumption at 7%
  - energy purchased from Central Sector at the bus bar
  - frequency correction applied to the total energy (1+2)
  - Loss due to load shedding is added in the above frequency correction energy demand
  - the demand worked out for past five years as above is used to derive CAGR
- Peak demand at Bus bar
  - MSEB Power Station MW total is net off for auxiliary consumption by 7% to arrive at the demand at bus bar at the time of maximum peak recorded
  - MW assistance form central sector at the time of maximum peak recorded
  - load shedding recorded at the time of maximum peak is then added
  - frequency correction is then applied to the total peak load (1+2+3)

- The demand worked out for the past four years is used to derive CAGR

Methodology adopted for peak load demand

The methodology adopted by MSEB for peak load demand are categorised here:

- Forecast was based on the peak load demand experienced for the last 4 years.
- CAGR of peak load demand for past 4 years was 6.43%. This was applied for arriving at peak load demand for the years of the 10th Plan.
  - This CAGR gave comparatively the best-fit analysis for prediction of earlier demand.
  - Same CAGR was applied to all the years of 11th Plan
- A gross figure of 7% was attributable to auxiliary consumption by power station—thermal, hydro, gas together. Using the criteria, the gross MW at the grid base was obtained, and to this load shedding recorded at the peak time was added.
- The projection was therefore basically on the "ZERO" load shedding criteria.

A tabular presentation of peak demand projection (May 2003) and peaking shortfall with the installed capacity of 12146 MW in the 10th Plan

Table 1.4: Projection for Peak Demand and Peaking Shortfall

Year	Peak demand projection (MW)	Peaking Shortfall (MW)[1]	Total installed capacity (MW)	Peaking capacity available at Bus bar	Short fall in peaking capacity (MW)(C2-C5)	Additional Installed capacity required
2002-03	11211	2058	12188	9153	2058	2766
2003-04	11933	2779	12188	9153	2779	3735
2004-05	12700	3546	12438	9767	2932	3941
2005-06[2]	13517	4363	13298	10494	3022	4062
2006-07	14387	5232	14974	11805	2580	3468

1 If no capacity addition takes place

2 With execution of power projects by MSEB at Parli, Paras, and Uran, and availability of additional power from NTPC & NPC and expected commissioning of restructured CIPCO IPP.

Scenario for the 11th Plan

For the 11th Plan first the peak demand and the peaking shortfall as projected by MSEB (with no capacity addition) is tabulated. Then taking into consideration the future demand projections and available firmed up capacity addition options considered for the MSEB system, the energy and power deficit scenario as developed by MSEB is reported.

Table 1.5: Projection of peaking shortfall (with no capacity addition)

Year	Peak Demand (MW)	Peaking shortfall (MW)
2007-08	15313	6157
2008-09	16298	7141
2009-10	17346	8189
2010-11	18462	9304
2011-12	19650	10491

The report indicated that MSEB doesn't have any sanctioned project for the time being, but there are many projects on the pipeline whose implementation has to start during 10th Plan period, so that the capacity benefit is available in the 11th Plan. MSEB needs to sanction loans and financial support to expand the generating capacity for meeting the growing power demand.

By 2006-07 the maximum possible addition of installed capacity will be only 2785.5 MW and there will be a shortfall of 3468 MW. A load shedding of 3468 MW will be extremely detrimental to economic progress of the State, 1000 MW of peak load shedding can be considered tolerable. So additional efforts necessary to meet worsening situation, private sector should be encouraged to come in for additional capacity generation at affordable rates. The Board finally resolved to set up a high level Steering Committee to continuously and effectively monitor the capacity addition program of MSEB.

Table 1.6: Comparison of Godbole projection, MSEB projection, with Actual figures.

	CAGR for Gross Energy and peak demand	Peak demand at bus bar in 2002 MW	Gross energy requirement MU, 2002
Godbole Committee projection (2002-10)	4.2%	10109	63759
MSEB's projection	6.43%	10019	64393
Actual (2000-01)	5.9%	11211	58929

2 Methodology adopted by TERI

The studies conducted till now on electricity demand in Maharashtra has used past Compounded Annual Growth Rate (CAGR) to forecast the demand. However, CAGR has inherent shortcoming of total dependence on the first and the last observation.

Ideally, with changing lifestyle and emergence of alternative fuels and technologies (in energy supply and end-use), it has become imperative to use sophisticated econometric and hybrid modeling techniques that could capture the effect of factors such as prices, income, population, technology and other economic, demographic, policy and technological variables. However, such an exercise is lengthy & exhaustive in nature requiring past time series data for at least 30 years on various variables.

In this study we have obtained the energy demand forecast using *Autoregressive Integrated Moving Average (ARIMA)* method popularly known as, Box-Jenkins approach to economic modeling and forecasting. The emphasis of this forecasting method is on analysing the probabilistic or stochastic properties of economic time series. Unlike the regression models, in which a dependent variable, Y (t) is explained by k regressors X1, X2, X3,……,Xk, in the Box – Jenkins type time series models Y(t) might be explained by past , or lagged , values of Y itself and stochastic error terms. The method is very useful to incorporate the effect of reforms on energy requirement since it gives more weightage to the latest lag values, that is the post reform values.

Same method is applied to forecast the future peak demand. It may be stated here, it is not advisable to use trend or time series analysis for peak demand projections because of following factors that influences peak demand:

1) Change in load factor would effect the projections
2) Time of day tariff and penalty clauses, that would encourage to shift the load
3) Change in the pattern of supply would improve the load curve
4) Energy conservation measures

An Autoregressive (AR) Process

Let Y (t) represent energy requirement at time t. If we model Y (t) as

$$(Y(t) - ø) = a1\,(Y(t-1) - ø) + U(t)$$

Where ø is the mean of Y and where U (t) is an uncorrelated random error term with zero mean and constant variance, then we say that Y (t) follows a first order autoregressive process, or AR (1), stochastic process. Here the value of Y at time t depends on its value in the previous time period and a random term; the Y values are represented as deviations from their mean value. In other words, this model says that the forecast value of Y at time t is simply some proportion of (= a1) of its value at time (t-1) plus a random shock or disturbance at time t; again the Y values are expressed around their mean values. In general,

$$(Y(t) - ø) = a1\,(Y(t-1) - ø) + a2\,(Y(t-2) - ø) + \ldots\ldots + a(p)\,(Y(t-p) - ø) + U(t)$$

Where Y(t)is a pth order autoregressive, or AR (p) process. In pure AR models, only the current and previous Y values are involved; there are no other regressors. In this sense, we say that the " data speak for themselves."

A Moving Average (MA) Process

The AR model just discussed is not the only mechanism that may have generated Y. Suppose Y is modelled as follows:

$$Y(t) = \mu + ß0\,U(t) + ß1\,U(t-1)$$

Where μ is a constant and U, as before, is the stochastic error term. Here Y at time t is equal to a constant plus moving average of the current and past error terms. Thus, in the present case Y follows a first-order moving average, or an MA (1) process. More generally,

$$Y(t) = \mu + ß0\,U(t) + ß1\,U(t-1) + ß2\,U(t-2) + \ldots\ldots\ldots + ß(q)\,U(t-q)$$

An Autoregressive and Moving Average (ARMA) process

It is likely that Y has characteristics of both AR and MA and is therefore, ARMA. Thus, Y (t) follows an ARMA (1, 1) process if it can be written as

$$Y(t) = C + a1.\,Y(t-1) + ß0\,U(t) + ß1\,U(t-1)$$

Because there is one autoregressive and one moving average term. Here, c represents a constant term.

The Box – Jenkins (BJ) Methodology

Now the question is: looking at a time series, such as the Energy Requirement, how does one know whether it follows a purely AR process (and if so, what is the value of p) or a purely MA process (and if so, what is the value of q) or an ARMA process (and if so, what are the values of p and q). The BJ methodology helps in answering t he preceding question. The method consists of four steps:

Step 1. **Identification.** First step is to find out whether the series is stationary or not. In a non-stationary model Box-Jenkins model is not applied. The next step is to find out appropriate values of p and q to find out the lag factor. Correlogram and partial Correlogram are used for this purpose.

Step 2. **Estimation.** Having identified the appropriate p and q values, the next stage is to estimate the parameters of autoregressive and moving average terms included in the model.

Step 3. **Diagnostic checking.** Having chosen a particular ARMA model, and having estimated its parameters, we next see whether the chosen model fits the data reasonably well, for it is possible that another ARMA model might do the job well. That is why considerable skill is required to choose the right ARIMA model.

Step 4. **Forecasting.** One of the reasons for the popularity of the ARIMA modeling is its success in forecasting. In many cases, the forecasts obtained from this method are more reliable than those obtained from traditional trend analysis.

Time Trend Method

Another method used for building forecasting model is the time trend method. Here the dependent variable is regressed over variable time with various degrees. Further, the trend model could follow a linear trend or a polynomial trend.

A linear trend model: $y_t = \beta_1 t + \varepsilon_t$

Here the time variable t is known as the trend variable. Trend means a sustained upward or downward movement in the behaviours of the variable. If the slope coefficient is positive then it is an upward trend in y, where as if it is negative it is a downward trend in y.

A second order polynomial trend model: $y_t = \alpha + \beta_1 t + \delta t^2 + \varepsilon_t$

It is a class of multiple regression models, and is called a *quadratic function* in t, or more generally, a second-degree polynomial in time.

The general k^{th} degree polynomial time trend regression may be written as:

$y_t = \alpha + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \ldots\ldots.. + \beta_k t^k + \varepsilon_t$

The Box Jenkinson and time trend method is reliable for forecasting, only in the short and medium term, till 2006-07.

3 Demand projections

Energy Demand

Total Energy demand is arrived by incorporating following components:

1) Energy demand at the bus bar
2) Units lost due to frequency disturbance
3) Units lost due to load shedding

To certain extent, this methodology of arriving at the total energy demand represents unrestricted demand as it incorporates load shedding and frequency disturbance. While estimating total energy demand at the bus-bar a reduction of 1% in the supply is considered due to

–Reduction in demand due to some technical loss reduction

–Decrease in consumption due to metering and introduction of meter tariff especially in case of agricultural consumption

Box-Jenkins method is used to obtain the electricity demand in the MSEB system for the period 2004-2012[1].

Following steps were carried out:

1. Identification

The series for which future values need to be forecasted should first be identified, as to whether it is stationary, and also the correlogram of the series should be generated.

Identification involved two steps

Unit Root Test

Test for unit root is carried out to find out whether the series is stationary or non-stationary[2]. The unit root test showed that the series is in levels, with intercept and no lag is stationary.

Correlogram Specification

Both the ACF and PACF showed exponential decay, and the lag at various levels of both ACF and PACF was significant. This specification led us to choose various models for projections, which are discussed in the next section.

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1 Time trend and ARMA models are best to forecast the demand for the short and medium term (i.e. up to 2006-07) and not for long term projections (2011-12).

2 If the series is non-stationary then the mean and the variance will not be constant over time and the forecast based on that series would be spurious.

2. Estimation

While forecasting the energy demand, we have attempted various models, in order to obtain a best fit with high R^2, stationary series, significant t-statistics and least deviation from actuals in the past.

Model 1: ARMA (1,1) with constant

$y_t = \alpha + \beta_1 y_{t-1} + \delta_1 \mu_{t-1} + \varepsilon_t$

Fitting the regressed model we have the following representation:

$$y_t = 277941.0 + 0.9878\, y_{t-1} + 0.6821\, \mu_{t-1}$$
$$(0.19087) \quad (12.738) \quad (0.0466)$$
$$R^2 = 0.9842$$

Durbin-Watson statistic = 2.4

The model is stationary with quite a high R^2, implying the equation is a good fit. The t-statistics for the coefficient of y_{t-1} is highly significant, implying this variable has a significant impact on the movement of the dependent variable. The value of Durbin-Watson statistic is in the range of 2, which implies there is no first order auto-correlation.

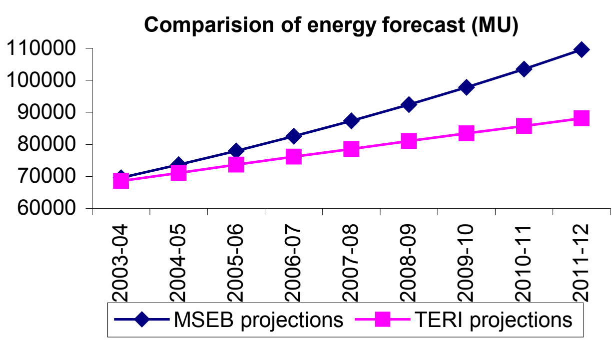
However, the t-statistics for the coefficients of constant and error term are not significant meaning that these variables don't have significant contribution in explaining the equation (or rather the movement of y_t). Further, the value of constant is high, which means the curve has a huge drift.

The forecast obtained using this model is reported below along with the MSEB Projection. A comparison of the projection made by this model and MSEB is shown in table 3.1 and graph 3.1.

Table 3.1: Comparison of projections: ED (MU)

Year	MSEB projections	Model 1	Difference
2003-04	69599	68570	-1.5%
2004-05	73661	71119	-3.5%
2005-06	77960	73637	-5.5%
2006-07	82510	76125	-7.7%
2007-08	87326	78583	-10.0%
2008-09	92422	81010	-12.3%
2009-10	97816	83408	-14.7%
2010-11	103525	85777	-17.1%
2011-12	109567	88117	-19.6%
CAGR	5.84%	3.27%	

Graph 3.1: Comparison of MSEB Projection and Forecast using Model 1: ED



Model 2: AR (1)

$y_t = \beta_1 y_{t-1} + \varepsilon_t$

Fitting the estimated model we have:

$y_t = 1.056\, y_{t-1} + \varepsilon_t$

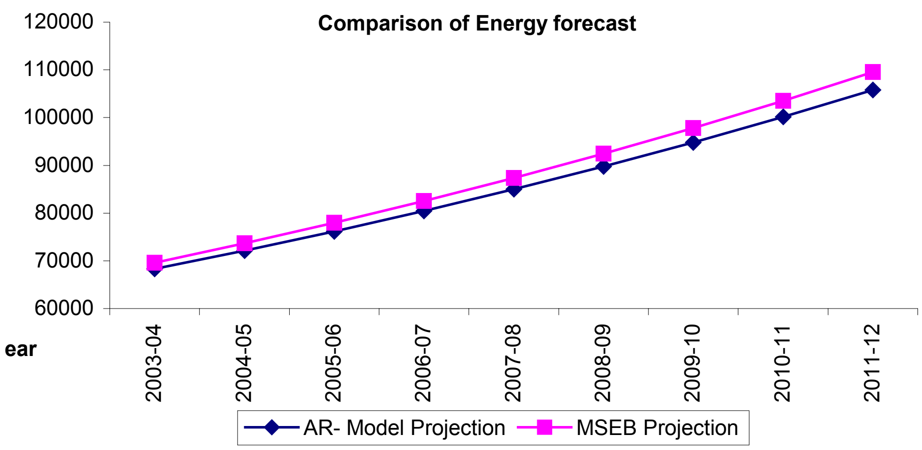
(118.93)

$R^2 = 0.9796$ Durbin-Watson Statistic = 1.6

The R^2 is significant with D-W statistics being quite low, but it is above the upper bound (d_u) at 0.05 level of significance, (which is obtained from Durbin-Watson d-statistic table), implying that there is no autocorrelation, and the t-statistic of the coefficient is also significant.

Though this model is a good fit, but the AR process of the estimated equation was found to be non-stationary[3]*, and the forecast with non-stationary model would be spurious.* A graphical comparison of the forecast using this model and MSEB projection is shown in graph 3.2.

Graph 3.2: Comparison of MSEB Projection with forecast using model 2: ED



[3] A non-stationary series do not have a constant mean and variance over time, and the forecast based on that series will be spurious.

Model 3: ARMA

$y_t = \beta_1 y_{t-1} + \delta_1 \mu_{t-1} + \varepsilon_t$

Fitting the above model after running the regression we have:

$y_t = 1.06\, y_{t-1} + 0.61\, \mu_{t-1} + \varepsilon_t$

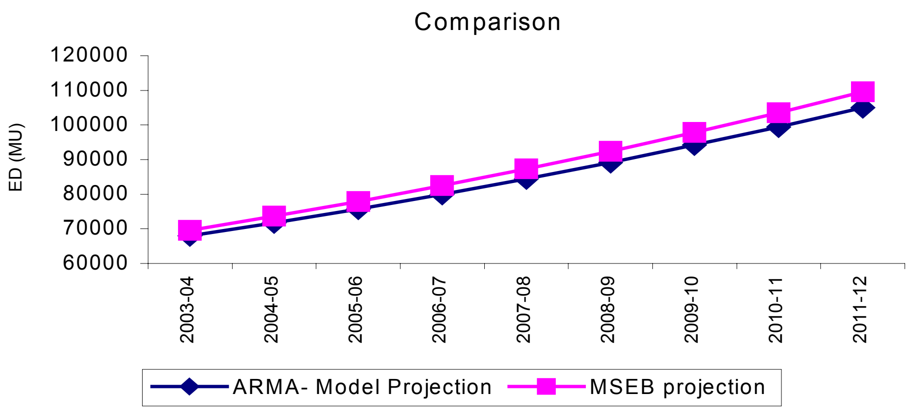
(81.18) (2.57)

$R^2 = 0.984$

Durbin-Watson Statistic = 2.25

Here again, R^2 is high and t-statistic is significant, but AR process is non stationary. The comparison of the MSEB's projections and the estimated energy demand using this model is shown in the graph 3.3.

Graph 3.3: Comparison of MSEB Forecast with forecast using Model 3



Model 2 and Model 3 being non-stationary, there are high chances that the forecast would be an over estimate and spurious. Therefore, the model is not recommended for forecasting.

Model 4: Time trend model:

$y_t = \alpha + \beta_1 t + \delta t^2 + \varepsilon_t$

The original series of MSEB (1991-2003) is regressed on time period, of order one as well as two, along with a constant. Therefore, the model is polynomial of order 2 in time.

The fitted regression equation is:

$y_t = 32079 + 2259.2\, t + 51.299\, t^2 + \varepsilon_t$

(26.396) (5.256) (1.594)

$R^2 = 0.99$ Durbin Watson= 1.6

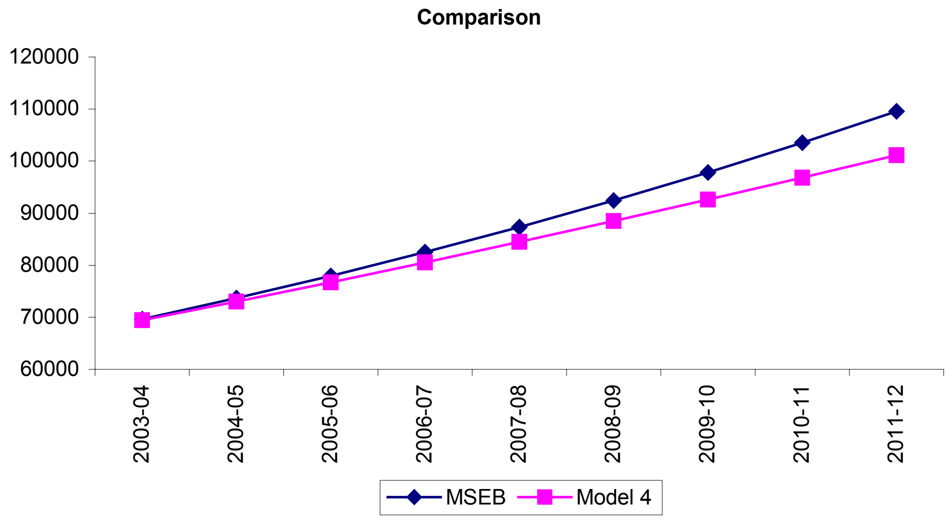
This model has a high R^2 and significant t-statistics for most of the coefficient. The forecasted series is stationary at levels with no lags, and there is no autocorrelation.

The forecasted value is shown in table 3.2 and graph 3.4 along with the comparison of MSEB and model 4 projections:

Table 3.2: Comparison of Projections: ED (MU)

Year	MSEB	Model 4	Deviation
2003-04	69599	69424	-0.3%
2004-05	73661	73032	-0.9%
2005-06	77960	76742	-1.6%
2006-07	82510	80553	-2.4%
2007-08	87326	84466	-3.3%
2008-09	92422	88481	-4.3%
2009-10	97816	92597	-5.3%
2010-11	103525	96814	-6.5%
2011-12	109567	101134	-7.7%

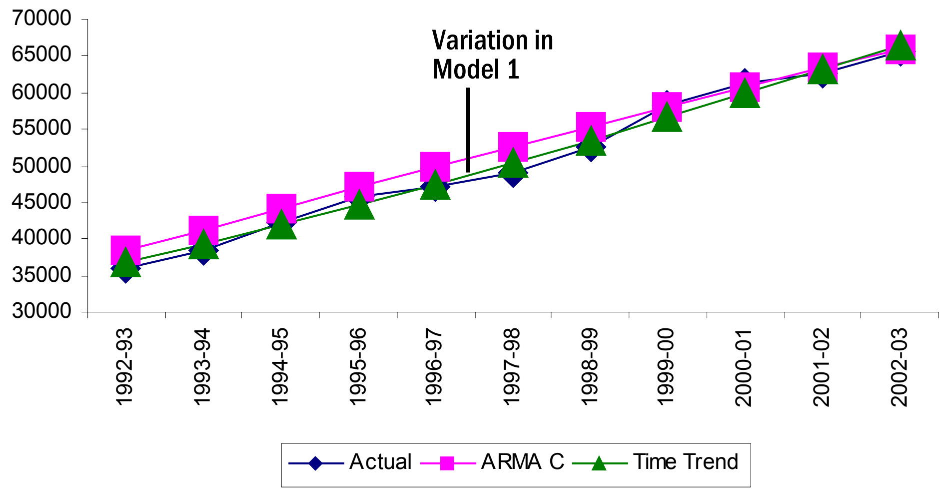
Graph 3.4: Comparison of MSEB Forecast with forecast using Model 4



Choosing the final model

Among all the four models that we have estimated so far, only the ARMA C model and the time trend model was stationary with high R^2. However, the forecast obtained from time trend was having least deviation from the actual curve. This is depicted in the diagram below.

Graph 3.5: Comparison of Energy Demand: Actual, Model 1, Model 4



The graph shows that for the initial 8-9 years the variance of the fitted ARMA C model from the actual energy demand curve was quite significant, but gradually it merged with the actual demand curve. Whereas the fitted time trend line has merged to the original demand curve for the entire time period.

Below, a tabular comparison of the two best-fit models is provided, in terms of variance, t-statistics, R2, and autocorrelation. This also supports the choice of time trend model as the best forecasting model for the short and medium term.

Table 3.3: Comparison between two best models

	ARMA C	TERI projections (Time trend model)
Variance	Stationary	Stationary
t-statistics	Low	High
Constant	High	Average
R2	High	Highest

Projection arrived from the model 4 is plotted with the actual energy demand to show the level of synchronisation in the curve (Graph 6).

Graph 3.6: Comparison of Energy Demand: Actual and TERI Projection

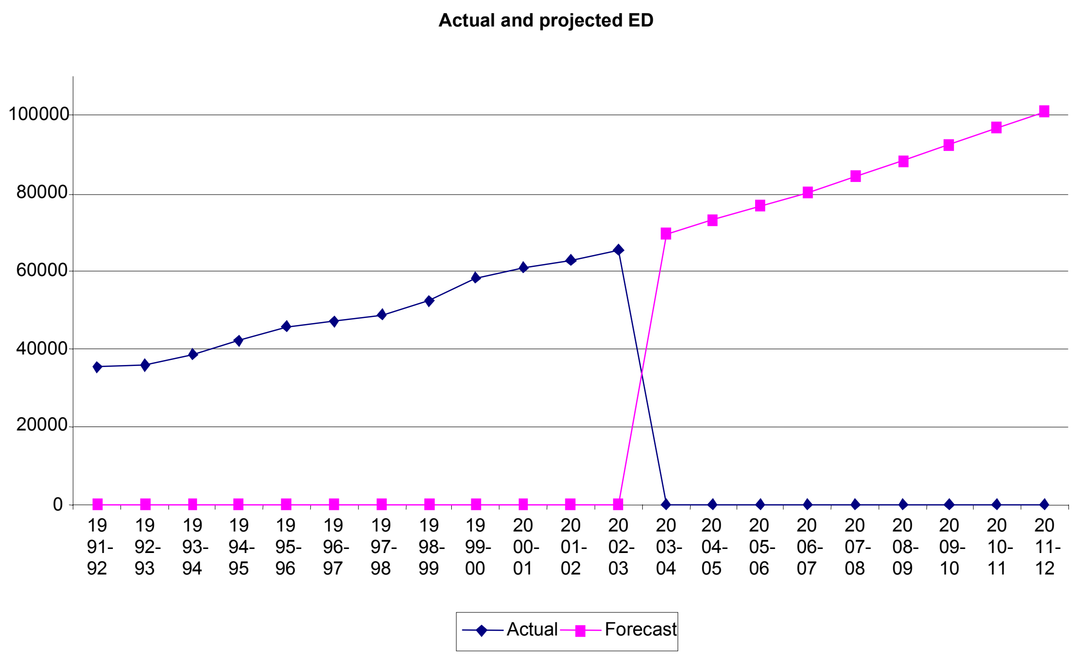


Table 3.4: Comparison of EPS, MSEB and TERI Projection of Energy Demand

	EPS Projection*	MSEB Projection	TERI Projection
2006-07	106892	82510	80553
2011-12	142911	109567	101134[4]

*** EPS Projection includes projection for the entire state of Maharashtra**

[4] Projection from time trend model and ARMA model is reliable for short and medium term and not for the long term (i.e. 2011-12)

Peak Demand

The energy requirement in the system as obtained from the time-trend model provides only a partial depiction of the system. To obtain a better understanding, the corresponding peak demand also needs to be taken into consideration. However for calculating the peak demand, knowledge of the load factor of the system is vital. Determination of the same is an intensive exercise and a separate analysis needs to be undertaken. If we calculate load factor from MSEB projection for energy demand and peak demand, implicitly, the projection has assumed a load factor of 64 to 65% (Table 3.5).

Table 3.5: Load Factor, Peak Demand and Energy Demand (MSEB Projection)

	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Energy Demand	11933	12701	13518	14388	15314	16299	17348	18464	19652
Peak Demand	69599	73661	77960	82510	87326	92422	97816	103525	109567
Load factor	67	66	66	65	65	65	64	64	64

Whereas if we calculate past load factor on the basis of the past MSEB's energy requirement and peak demand (Table 3.6), except for the year 2001-02, it is around 68% (Table 3.6).

Table 3.6: Load Factor, Peak Demand and energy Demand (MSEB Actual)

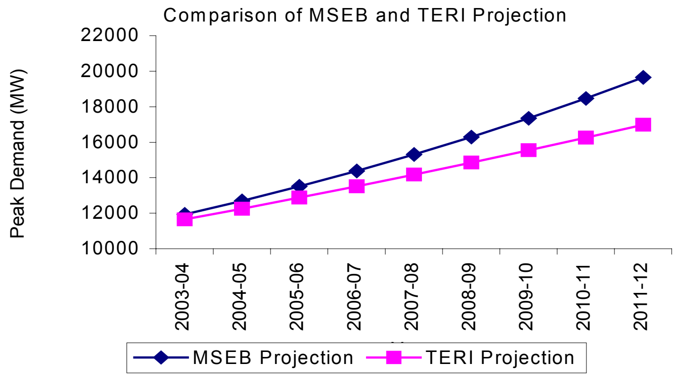
	1999-00	2000-01	2001-02	2002-03
Energy Demand	58323	61199	62715	65761
Peak Demand	9791	10209	9849	11211
Load factor	68	68	73	67

Similar load factor when applied on the demand data as calculated from time trend model, results in corresponding peak demand, which is provided in the table 3.7.

Table 3.7: Comparison of Projection: PD(MW)

Year	MSEB projections	TERI Projections by applying a load factor	Difference
2003-04	11933	11655	-2.3%
2004-05	12701	12260	-3.5%
2005-06	13518	12883	-4.7%
2006-07	14388	13523	-6.0%
2007-08	15314	14180	-7.4%
2008-09	16299	14854	-8.9%
2009-10	17348	15545	-10.4%
2010-11	18464	16253	-12.0%
2011-12	19652	16978	-13.6%
CAGR	6.43%	4.8%	

Graph 3.7: Comparison of Peak Demand: MSEB and TERI Projection



Besides the above method, attempt has been made to forecast the peak demand by using Time-trend model. This has been discussed in the next section.

Model

For predicting the peak demand we have used the standard process identifying, estimating and forecasting.

We have plotted the Correlogram and applied the unit root test on the peak demand series (1992-2003). The series was stationary with zero lags and intercept. The ACF and the PACF was decaying exponentially. However, ARIMA model was not a good fit and the forecasted series was non-stationary in nature. While plotting the graph of the actual peak demand it was found that for the last three years i.e. 2001-03, there was some steep variations in the curve, which could be because of some exogenous shocks. *To avert this problem, the curve was smoothened and then regression analysis was carried out.*

The same model that was applied to forecast energy demand was applied to arrive the peak demand projections. The model was second order polynomial regression. The model was stationary with a good fit and high R^2 and significant t statistics.

The model:

$y_t = \alpha + \beta_1 t + \delta t^2 + \varepsilon_t$

Fitting the above model, we have following equation and estimates

$PD = 5386.3 + 387.68t + 6.7055t^2 + \varepsilon_t$

Where, PD= Peak Demand; T=time

Adjusted R^2 = 99%

The results of the above model are shown in the table 3.8.

Table 3.8: Comparison of Projection: PD

	MSEB Projection	Model	Deviation
2003-04	11933	11559	-3.1%
2004-05	12701	12128	-4.5%
2005-06	13518	12710	-6.0%
2006-07	14388	13306	-7.5%
2007-08	15314	13915	-9.1%
2008-09	16299	14537	-10.8%
2009-10	17348	15173	-12.5%
2010-11	18464	15822	-14.3%
2011-12	19652	16485	-16.1%
CAGR	6.43%	4.12%	

As discussed earlier, it is recommended not to project the peak demand rather it is advisable to assume a system load factor and use energy demand projections for forecasting the peak demand. If we compare the results from methods, projections arrived by applying load factor of 68 gives less deviation from actual. Following comparison is done to verify both the methods with the actual for past 4 years (table 3.9).

Table 3.9: Comparison of Two Projections: PD (MW)

Year*	Actual	By assuming 68% load factor	Deviation	Model: Regressing on time	Deviation
1999-00	9791	9496	-2.9%	9419	-3.8%
2000-01	10209	10039	-1.7%	9934	-2.7%
2002-03	11211	11177	-0.3%	11004	-1.8%

*2001-02 is dropped as an outlier in the whole series

A comparison of TERI projection of peak demand with the MSEB, and EPS projection is provided in table 3.10.

Table 3.10: Comparison of EPS, MSEB and TERI Projection of Peak Demand

	EPS Projection*	MSEB Projection	TERI Projection
2006-07	16716	14388	13523
2011-12	22348	19652	16978

* EPS Projection includes projection for the entire state of Maharashtra

In conclusion, it may be stated that the consumption analysis based on Time-Trend and Box-Jenkins model is relevant and reliable in the medium term i.e. till 2006-07, while for the long term, end-use analysis using primary survey, econometric and hybrid model incorporating various factors[5] is more reliable. The accuracy of the results could be further improved if the reliability / precision of the data obtained improves.

Lastly, one need to be cautious while planning capacity additions to meet the peak demand as it occurs for a few hours in a year. Measures like time of day tariff, shifting the pattern of supply and adopting demand side management could improve the load curve.

[5] Factors like, reform initiatives, captive power policy, electricity act 2003, industrial policy and other socio-economic factors

Annex I Final TERI projections

Year	Energy Demand		Peak Demand	
	MSEB Projection	TERI Projection	MSEB Projection	TERI Projection (68% load factor)
2003-04	69599	69424	11933	11655
2004-05	73661	73032	12701	12260
2005-06	77960	76742	13518	12883
2006-07	82510	80553	14388	13523
CAGR	5.84%	4.8%	6.43%	4.8%

Annex 2 Comparison of MSEB projection with TERI projections, and Projections after deviation from assumptions made by Godbole Committee.

Year	Energy Demand			Peak Demand		
	Adjusted Godbole Proj.	MSEB Proj.	TERI Proj.	Adjusted Godbole Proj.	MSEB Proj.	TERI Proj.
2003-04	71582	69599	69424	12017	11933	11655
2004-05	78021	73661	73032	13098	12701	12260
2005-06	84623	77960	76742	14206	13518	12883
2006-07	91313	82510	80553	15329	14388	13523