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Measurement of Relative Efficiency of State Owned Electric Utilities in INDIA Using Data Envelopment Analysis

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Abstract

In this paper two different DEA models were applied to evaluate the relative efficiency of State Owned Electric Utilities (SOEUs) in India. The DEA method was applied to find the overall efficiency, Technical Efficiency and Scale Efficiency. The Most Productive Scale Size (MPSS) is calculated for the scale inefficient utility. The results and discussions of this paper can be used to assist the authorities to pave the way for the improvement in technical and scale efficiency.

Keywords: Benchmarking, Relative Efficiency Measurement, Data Envelopment Analysis, CCR Model, BCC Model, Most Productive Scale Size

1. Introduction

This Paper presents a case study in which Data Envelopment Analysis [1],[2] is applied to evaluate the relative efficiencies of the 29 State Owned Electric Utilities in India. The purpose of this study is to identify the efficient / inefficient SOEU through the development and use of DEA model and to suggest the possible way of improving the overall efficiency, technical efficiency and scale efficiency. Efficiency measurement is an important issue in power delivery. Measure of relative efficiency was motivated by several factors like cost efficiency, operational efficiency, managerial efficiency etc., among which this paper is confined to *operational efficiency measurement* of SOEU's by using DEA.

The Indian power sector commenced an era of reforms and restructuring since the year 1991, with the opening of the sector to Independent power producers. The Indian Government made a vision of "Power to all" by the end of the year 2012 and the projected installed capacity is around 2,12,000 MW which is twice the current value. To achieve such a greater capacity the Indian government has initiated a lot of reforms like APDRP (Accelerated Power Development and Reform Programme), DRUM Distribution Reform, Upgrades and Management) etc,. At this juncture, the knowledge of the operational efficiency of the various SOEU's will help the personnel to refine their ideas for better operation.

The participation of private sector in the distribution sector has been already initiated. There are three private companies already available in Karnataka and two private companies in Maharashtra (Tata Power Company and Reliance Power Company). Lot more initiatives have been taken for the participation of private distribution utilities. In this changing environment there is an urgent need for detailed analysis of various SOEUs performance using standard benchmarking techniques; a process that can reveal finer mechanisms causing inefficiencies. The analysis presented in this paper will help to review the performance of SOEU so that lessons from the failure can be taken note of and effective steps be taken to mitigate the shortcomings. This analysis is also useful because presently the main focus of the reform programme is to make SOEUs efficient and commercialize these entities.

The objective of the present analysis is to develop a benchmark based on the comparison of the operation of similar SOEUs and analyze the inefficiencies of the existing utilities in the policy context of making them efficient. The rest of this paper is organized as follows. Section 2 reviews the related literature. Section 3 discusses about the Brief Scenario of Indian Electricity Industry. Section 4 discusses about the Data Envelopment Analysis and the mathematical background of the DEA methodology. Section 5 discusses about the selection of inputs/outputs and the factor analysis. Section 6 discusses about the results and analysis. As a conclusion, section 7 follows the results and analysis.

2. Literature Survey

The previous studies that have used DEA to investigate the relative efficiency of the power industry are now described. Fare *et al* [5] used DEA model to assess the relative efficiency of electric utilities in which an output (net generation) and three inputs (fuel, labor and capacity) are considered. Charnes *et al* [6] measured the management efficiency of regulated electric co operatives in which three outputs (net margin, total kWh sales and total revenue received) and eleven inputs (operational expenses, maintenance expenses etc) are considered for anlaysis. Miliotis [7] evaluated the efficiency of 45 EDDs of Greek Public Power Corporation. This research considered eight factors such as served customers, network length etc for analysis.

Golany *et al* [8] assessed the operating efficiency of power plants in Israel Electric Corporation in which four outputs (generated power, operational availability, deviation from operational parameters and SO_2 emissions) and three inputs (installed capacity, fuel consumption and manpower) are considered. Puneet Chitkara [24] used DEA to find the operational efficiency of Indian Power Plants. Kaoru Tone and Miki Tsutsu [25] applied DEA for the decomposition of cost efficiency for Japanese-US electric utility companies where they used three input factors (Capital cost, Number of employees, Fuel consumption) and three cost input data (Total capital cost, Total Labor cost and total fuel cost) and one output (Net electricity power sales). Chyan Yang and Wen-men Lu [22] assessed the managerial performance of Taiwan Power Company where five input factors (Employment expenditure, operating expenditure, total assets, length of distribution network and transformer capacity) and three output factors (number of customers, quantity of energy sold and energy loss rate) were considered for the analysis. Raul Sanhueza *et al* [27] used DEA to determine the distribution added value for the Chilean Electric Utilities where five input factors (Distribution added value, total km line length etc) and three output factors (Total energy sold, coincident power during peak hours and number of customers) are considered. Athanassopoulos *et al* [9] developed data envelopment scenario analysis for setting targets to electricity generating plants in the U.K. This study considered four outputs (electricity produce, plant availability, accidents incurred and generated pollution)and three inputs (fuel, controllable costs and capital expenditure). Sueyoshi [10] explored a marginal cost based pricing system using the DEA approach to examine the tariff structure of nine electric power companies in Japan. This research considered the output of 11 electricity sales and three input prices.

Park *et al* [11] measured the operating efficiency of the 64 conventional fuel plant in South Korea in which he consided an output (net electrical energy output) and three inputs (fuel consumption, installed power and labor). Pahwa *et al* [26] applied DEA to measure the 50 largest electric distribution utilities in the U.S. In this research three outputs (distribution system peak load, retail sales and retail customers) and five inputs (distribution system losses, distribution lines etc) are considered. Tripta Thakur [29] used DEA for the benchmarking study for the Indian Electric Utilities where he used three input factors (Total cost, number of consumers and distribution line length) and an output (Energy sold)

In this paper, the operational efficiency of 29 State Owned Electric Utilities in India are evaluated using DEA where three input factors (Installed Capacity, Circuit km and % T&D losses) and Two output factors (Number of consumers and Quantity of Energy Supplied) are considered for analysis

3. Brief Scenario of Indian Electricity Industry

Electricity is one of the most vital infrastructure inputs for economic development of a country. The demand of electricity in India is enormous and is growing steadily. The vast Indian electricity market, today offers one of the highest growth opportunities for private developers. Since independence, the Indian electricity sector has grown manifold in size and capacity. The generating capacity under utilities has increased from a meagre 1362 MW in 1947 to 112058 MW as on March, 2004. Electricity generation, which was only 4.1 billion KWh in 1947 has risen to a level of over 558.134 billion KWh in 2003-2004. In its quest for increasing availability of electricity, the country has adopted a blend of thermal, hydel and nuclear sources. Out of these, coal based thermal power plants and in some regions, hydro power plants have been the mainstay of electricity generation. Oil, natural gas and nuclear power accounts for a smaller proportion. Thermal plants at present account for 70 percent of the total power generation, hydro electricity plants contribute 26 per cent and the nuclear plants account for the rest. Of late, emphasis is also being laid on development of non-conventional energy sources i.e. solar, wind and biomass.

The structure, ownership pattern and regulatory setup of the Indian power sector have witnessed radical changes especially in the past few years as part of the ongoing reform program with the establishment of independent regulators, corporatisation, unbundling and the advent of privatization in some States

To have an easy access and control, the Indian Power Sector is divided into five regions viz., Northern, Eastern, Western, Southern and North-Eastern Regions. Each state has its own utility previously known as State Electricity Boards. With the introduction of new Electricity Act 2003, Indian power sector is undergoing drastic reformation such as envisaging new National Electricity Policy (NEP), Rationalization of Tariffs, Restructuring of the SOEU's and the provision for new regulatory regime. Each state has the freedom to set up its own regulation and there will be State Electricity Regulatory Commission and each SERC will be centrally coordinated by CERC.

As on March 2005, twenty two states namely, Orissa, Haryana, Andhra Pradesh, Uttar Pradesh, Karnataka, West Bengal, Tamil Nadu, Punjab, Delhi, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Himachal Pradesh, Assam, Chatisgarh, Uttaranchal, Goa, Bihar, Jharkhand, Kerala and Tripura have either constituted or notified the constitution of SERC. Eighteen SERCs viz. Orissa, Andhra Pradesh, Uttar Pradesh, Maharashtra, Gujarat, Haryana, Karnataka, Rajasthan, Delhi, Madhya Pradesh, Himachal Pradesh, West Bengal, Punjab, Tamil Nadu, Assam, Uttaranchal, Jharkhand and Kerala have issued tariff orders.

Over the past years, financial performance of SOEU's have deteriorated, resulting in large accumulated losses. There is now a movement towards estimating and monitoring AT&C (Aggregate commercial and technical) losses in the country. The aggregate technical & commercial (AT&C) losses are in the range of 50%. High technical losses in the system are primarily due to inadequate investments over the years for system improvement works, which has resulted in unplanned extensions of the distribution lines, overloading of the system elements like transformers and conductors, and lack of adequate reactive power support. The commercial losses are mainly due to low metering efficiency, theft & pilferages. One must also give due weight to the fact that in the pursuit of the social objective, utilities may not have encouragement to innovate and look for improvements. However the financial and operational performances suggest the necessity for a detailed technical and financial appraisal of the SOEU's in order to reveal the underlying inefficiencies and the extent of scope for improvement in the new reformed regime.

4. Research Methodology

4.1 Introduction

Data Envelopment Analysis is relatively a new data oriented approach for evaluating the performance of set of peer entities called Decision Making Units (DMU) which convert inputs to outputs. It is a popular benchmarking method; a multifactor productivity analysis model for measuring the relative efficiencies of a homogeneous set of DMUs. It is a nonparametric estimation approach for generating the efficiency frontier that is derived from the DMU. These DMU's may be hospitals, universities, schools, Air force wings, business firms etc. As this requires very few assumptions, DEA has also opened up possibilities for use in cases which have been resistant to other approaches because of the complex unknown nature of relations between the multiple inputs and multiple outputs involved in DMU's. DEA is an excellent and easily usable methodology for modeling operational processes for performance evaluations. DEA's empirical orientation and the absence of a need for the numerous priori assumptions that accompany other approaches have resulted in its use in a number of studies involving efficient frontier estimation in the governmental and nonprofit sector, in the regulated sector and in the private sector.

The technique was suggested by Charnes, Cooper and Rhodes [1] and is built on the idea of Farrell. To regulate the electrical power most of the countries have adopted benchmark regulations using model of efficient firm concept. It corresponds to a company whose investments are economically adapted to demand and operates under an optimal operation plan. To design an efficient firm the regulator must specify the production technology with which the service will be delivered, the price of inputs and the cost of assets involved. With all these presumed data, it is possible to define an efficient production frontier used as the comparison benchmark for the group of companies. The efficiency is measured using the ratio of aggregated output to the aggregated input. Following Charnes et al, a DMU is said to be efficient if it is not possible to increase (decrease) the level of output (input) without increasing the use of at least one other input or decreasing the generation of at least one other output. This definition has the same concept as that in the Koopmans Pareto optimality that all the non dominated entities have the highest efficiency score. The DMU's that lie on the efficiency frontier are efficient in the DEA model. In contrast, the entities that do not lie on the efficiency frontier are regarded as inefficient.

DEA is a linear programming method that can deal with multiple inputs and multiple outputs simultaneously, yet DEA does not require the assignment of predetermined weights to the input and output factors. In this study, two DEA models were applied. CCR model developed by Charnes *et al* [1] and the BCC model developed by Banker [2]. In particular CCR model is the basic model which produces Constant Returns to Scale (CRS) efficiency frontier. The relative efficiency evaluated for the CCR model is the overall efficiency score and the efficiency of the DMU's are set to be lie between 0 and 1.

4.2 Mathematical formulation of DEA models:

4.2.1 CCR Model

Let as assume that there are ***n*** DMUs to be evaluated. Each DMU consumes varying amounts of ***m*** different inputs to produce ***s*** different outputs. Specifically, ***DMU***j consumes x_{ij} amounts of input i and produces y_{rj} amounts of output ***r***. As per the definition of relative efficiency, this is the ratio of weighted sums of outputs to weighted sums of inputs. In mathematical programming parlance, this ratio, which is to be maximized forms the objective function for the particular DMU with a set of normalizing constraints (one for each DMU) reflects that this ratio of every DMU, must be less than or equal to unity.

$$Max h_0(u,v) = \sum u_r y_{r0} \Big/ \sum v_r x_{io}$$

Subject to $\sum u_r y_{rj} \Big/ \sum v_i x_{ij} \le 1$ for j =1,….n

$u_r, v_i \ge 0$ $\forall$ i and r.

where u_r and v_i are the weights of the input and output, y_{ro} , x_{io} are r^{th} output and i^{th} input of DMU_o

Using Charnes-Cooper transformation, transforming (u,v) to (μ,ν),

$$\text{Max } z = \sum_{r=1}^{s} \mu_r y_{ro}$$

Subject to

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \nu_{ij} x_{ij} \le 0$$

$$\sum_{i=1}^{m} \nu_i x_{io} = 1$$

$$\mu_r, \nu_i \ge 0$$

For which the LP dual problem is

$$\theta^* = \min \theta$$

Subject to $\sum_{j=1}^{n} x_{ij} \lambda_j \le \theta x_{io}$ i = 1,2,….. m

$$\sum_{j=1}^{n} y_{rj} \lambda_j \ge y_{ro} \quad r = 1,2,\ldots\ldots s$$

$\lambda_j \ge 0$ j = 1,2…….n θ unrestricted

4.2.2 BCC Model

The BCC model produces a variable returns to scale (VRS) efficiency frontier and evaluates both technical efficiency and scale efficiency. Thus the overall efficiency can be decomposed into technical efficiency and scale efficiency. Technical efficiency is the efficiency of converting inputs to outputs, while scale efficiency recognizes that economy of scales will not obtained at all scales of production and there is only one Most Productive Scale Size (MPSS) where the scale efficiency is 100%.. Therefore the DMU is said to be efficient if and only if it is both technical and scale efficient..

Thus the dual DEA program for considering the VRS model is as follows

Min θ_m

Subject to $\boldsymbol{Y}\lambda \ge \boldsymbol{Y_m}$

$\boldsymbol{X}\lambda \le \boldsymbol{\theta X_m}$ and

$\sum_{n=1}^{N} \lambda_n = 1$ λ≥0, θ free

In general, DEA programs incorporating the additional convexity constraint to take into account variable returns to scale are called BCC DEA model. The variable λ introduced into the convexity constraint also brings out the value of increasing or decreasing returns to scale.

If $\sum_{n=1}^{N}\lambda_n = 1$, then the reference DMU is expected to exhibit constant returns to scale.

If $\sum_{n=1}^{N}\lambda_n < 1$, then the reference DMU exhibits Increasing returns to scale and

If $\sum_{n=1}^{N}\lambda_n > 1$ then the reference DMU exhibits decreasing returns to scale.

4.2.3 Most Productive Scale Size

The CCR efficiency is the overall efficiency which also takes into account the scale efficiency. For the DMU which are scale inefficient, it is an indirect measure that they are not operating on the Most Productive Scale Size. If the present scale of operation of the DMU does not lead to 100% scale efficiency, then the scale size of every inefficient DMU to be operated will be identified by the calculation of MPSS.

Identifying the Most Productive Scale Size is complex for any DMU when dealing with multiple inputs and multiple outputs. Banker has proved that MPSS for a given inefficient firm can be obtained using the following relationship.

$$\left(X_{i,m}^{MPSS}, Y_{i,m}^{MPSS}\right) = \left[\theta_m^* \frac{X_{im}}{\sum_{n=1}^{N}\lambda_{nm}^*}, \frac{Y_{jm}}{\sum_{n=1}^{N}\lambda_{nm}^*}\right]$$

5. INPUT AND OUTPUT FACTORS

This paper uses samples of 29 SOEUs in India. Each of the SOEU is treated as decision making unit (DMU) under DEA analysis. The data of Inputs and outputs are taken from the TEDDY (TERI Energy Data Directory and Yearbook 2004/05). In selecting the inputs / outputs for evaluating the operational efficiency of DMU, a great care is taken as the success of evaluation depends on the data availability and quality. No universally applicable rational template is available for the selection of variables. However, in general, the inputs must reflect the resources used and the output must reflect the service levels of the utility and the degree to which the utility is meeting its objective of supplying electricity to consumers. In particular, this paper aims in evaluating the performance based on the operational efficiency; the service output is measured by the number of consumers. The product output is measured by the quantity of the energy supplied. The resources to produce the outputs considered are Installed Capacity (in MW), Distribution line length (in km), T & D losses (in %).

Without losing generality, the annual data for the year 2005 was used for this study. The use of annual data can reduce the influence of seasonal problem. For the validation of the data used for the development of DEA model, the assumption of "isotonicity" (ie., an increase in input should not result in a decrease in any output) is examined. Regression analysis on the selected input and output factor is a useful procedure to examine the property of isotonicity. If the correlation between the selected input and output factor is positive, these factors are isotonically related and can be included in the model. It is observed that the selected input and output factors for this study shows positive correlation between them except for the % T& D Losses. As this is the loss attribute, this data has to be considered as negate. An overview about the key characteristics is presented in Table 1. Table 2 indicates the value of correlation between the input and output factors. In addition, according to, Joe Sarkis, the number of DMU's should be at least twice the number of inputs and outputs. In this study the number of DMU is twenty nine, which is twice the number of input and output.

6. OPERATIONAL EFFICIENCY ANALYSIS

In this study, CCR model, with constant returns to scale (CRS) is applied to evaluate the overall efficiency. In addition, the BCC model, with variable returns to scale (VRS), is used to evaluate the technical and scale efficiencies. Both the dual linear programming formulations are run for every DMU. The combined results of the CCR model, BCC model, Peer units for the inefficient DMU and the Slacks in the Inputs are given in Table 3. The analysis of the slack variable shows the way for the improvement for the inefficient DMU. The input slack values represent the needed reductions of the corresponding input factors to become an efficient DMU. For example, Arunachal Pradesh requires decrease of 53.26 MW in its installed capacity, 3683.55 km in circuit length and 0.3289 in percentage T&D losses. Based on the results of the CCR model it is observed that 7 SOEU's are relatively efficient and the overall efficiency score is equal to 1. The average efficiency score of all SOEU's is 0.7739. This implies that the utilization of the resources among the utility is only 77%. Among the inefficient utilities Arunachal Pradesh, Sikkim and Uttranchal shown very low efficiencies with an average efficiency score of 35% which needs improvement in both technical efficiency and scale efficiency.

The BCC model is used to evaluate the technical efficiency and scale efficiency. Some of the DMUs which are inefficient in CCR model now becomes efficient in BCC model. The results of BCC model can show the major sources of inefficiencies among the 22 SOEU's and also provide possible directions of improvement for the overall efficiency for each utility. In the BCC model, four utilities which shown inefficiency in their CCR model became relatively efficient which modifies the frontier line. For example, Maharashtra has the CRS efficiency score of 96.31% and it becomes efficient in the VRS model with an efficiency score of 100%. The Efficiency Score analysis ie. the overall efficiency, technical efficiency and Scale efficiency is given in Table 4. The ten SOEU's viz., Arunachal Pradesh, Goa, Himachal Pradesh, Karnataka, Maharashtra, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura have technical efficiency scores higher than scale efficiency scores. The SOEU that has the scale efficiency less than 1 is called as scale inefficient. This implies that the inefficiency of the SOEU's is primarily due to the scale inefficiency. A scale inefficient DMU that exceeds the Most Productive Scale Size (MPSS) will present decreasing returns to scale. Alternatively, a scale inefficient DMU that is smaller than MPSS will present increasing returns to scale.

For example, in Table 4, Goa and Himachal Pradesh are having technical efficiency higher than the scale efficiency. These two SOEU's can increase their operation scales to improve their overall efficiency because they present IRS. On the other hand, Maharashtra should decrease its operation scale because it presents DRS. The inefficiency in the twelve inefficient (but with high scale efficiency score) SOEU's (Assam, Bihar, Chattisgarh, Haryana, Jammu & Kashmir, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh, Uttranchal, West Bengal) are mainly due to technical inefficiency. To increase the overall efficiency these SOEU's should improve technical efficiency of resource allocation and utilization in order to improve the overall efficiency. Hence it is for the policy makers and the government to further scrutinize the actual scope for feasibility of increasing the operation scale by taking into account the actual conditions on the field.

The Most Productive Scale Size for the inefficient DMU is tabulated in Table 5. The value of MPSS in the parenthesis showed against the actual value gives the clear idea about its scale of operation. For example, Arunachal Pradesh has installed capacity of 179.4 MW whereas the MPSS calculated for this specific input is 1038.19 MW. Therefore, to become an efficient unit it has to raise the installed capacity to 1038.9 MW. Assam has total circuit length of 78612 whereas the MPSS calculated is 50628.18 km. Therefore it has to reduce its circuit to 50628.18 km to become as efficient unit. Chattisgarh actually has a T& D loss of 42.6 % for a circuit length of 120208 km whereas the MPSS calculated for T & D loss is around 49.81% for a circuit length of 1147435.6km. As this is the loss attribute it is not technically advisable to increase the loss to 49.81%. Moreover when the circuit length decreases then the loss attribute also has to decrease. At this juncture, the Operating Manager has to decide about the technical viability also.

7. Conclusion

This study makes an effort to measure relative efficiency of the SOEU's of the Indian Power Sector using a Frontier tool viz.,Data Envelopment Analysis. From the results of this study it is observed that there is a existence of inefficiency in 22 SOEUs. The findings of the slack variable analysis in CCR model provided the improvement directions for the inefficient districts when compared with other districts. Further more most of the inefficient DMUs suffered from scale inefficiency rather than from technical inefficiency. A majority of the SOEU does not seem to operate on the optimum level of operation. In particular 19 SOEUs presented increasing return to scale which need to increase their scale of operation. Alternatively, Maharashtra exhibited decreasing returns of scale which need to downsize its scale of operation. The knowledge of MPSS helps to know about the scale of operation of the individual DMU with respect to the individual inputs and outputs. To improve the performance, a number of policy measures such as encouraging competition, unbundling and restructuring can be considered.

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Table 1. Summary Statistics for the Data

Parameter	Mean	Median	Std.Deviation	Max	Min
Installed Capacity(MW)	4099.841379	2077.1	4415.59492	17182.3	102.7
Circuit km	215568.4828	100464	239809.1447	707037	5156
%T & D Losses	38.13448276	39.3	13.08926157	65.2	16.7
Number of Consumers (in Lakhs)	45.16931034	21.49	55.15127967	198.6	0.6
Quantity of Energy Supplied (GWh)	12326.70759	7157.48	14058.17649	51823.9	125.01

Table 2. Input / Output Correlations:

Variable	Installed Capacity (MW)	Circuit km	% T & D Losses	Number of Consumers (in Lakhs)	Quantity of Energy Supplied (GWh)
Installed Capacity(MW)	1	0.926268853	-0.374842659	0.927913676	0.988578193
Circuit km	0.926268853	1	-0.387146885	0.940012764	0.890973283
% T&D Losses	-0.374842659	-0.387146885	1	-0.45796782	-0.365538555
Number of Consumers (in Lakhs)	0.927913676	0.940012764	-0.392683722	1	0.903436179
Quantity of Energy Supplied (GWh)	0.988578193	0.890973283	-0.365538555	0.903436179	1

Table 3. Efficiency Analysis

SL NO	State Owned Electric Utility	CRS efficiency	VRS efficiency	Efficient / Inefficient	PEER units	Slack in Inputs		
						Installed Capacity (MW)	Circuit km	% T&D Losses
1	ANDHRA PRADESH	100	100	EFFICIENT	1	-	-	-
2	ARUNACHAL PRADESH	29.69	90.139	INEFFICIENT	14	53.26	3683.55	0.328926
3	ASSAM	51.458	62.27	INEFFICIENT	1,14,17	548.96	38425.0	19.07
4	BIHAR	74.63	81.37	INEFFICIENT	1,8,17	326.37	80621.5	9.3
5	CHATTISGARH	86.5	89.67	INEFFICIENT	1,8,17	232.44	35328.2	5.75
6	DELHI	100	100	EFFICIENT	6	-	-	-
7	GOA	74.76	97.13	INEFFICIENT	6,14,17	118.78	3601.88	28.18
8	GUJARAT	100	100	EFFICIENT	8	-	-	-
9	HARYANA	93.394	94.88	INEFFICIENT	1,6,8,17	253.63	11722.8	2.12
10	HIMACHAL PRADESH	60.93	80.24	INEFFICIENT	6,14	704.36	29419.4	13.2
11	JAMMU &KASHMIR	60.00	66.43	INEFFICIENT	1,6,8,17	658.42	16709.3	18.199
12	JHARKHAND	100	100	EFFICIENT	12	-	-	-
13	KARNATAKA	98.74	99.64	INEFFICIENT	1,8,17	97.547	142298	0.2919
14	KERALA	100	100	EFFICIENT	14	-	-	-
15	MADHYA PRADESH	70.94	71.43	INEFFICIENT	1,8,17	1942.63	329462	12.03
16	MAHARASHTRA	96.31	100	INEFFICIENT	6,25	2178.20	26053.8	1.256
17	MANIPUR	100	100	EFFICIENT	17	-	-	-
18	MEGHALAYA	57.99	100	INEFFICIENT	1,8,17	167.14	8329.67	9.6845
19	MIZORAM	51.65	95.7	INEFFICIENT	14	56.467	10625.4	55.127
20	NAGALAND	86.283	100	INEFFICIENT	14	14.087	4546.5	54.45
21	ORISSA	67.00	68.64	INEFFICIENT	1,6,8,17	997.562	33148.9	18.84
22	PUNJAB	98.19	79.95	INEFFICIENT	1,9,17	110.937	13922.1	0.47
23	RAJASTHAN	79.47	98.84	INEFFICIENT	1,8,17	114.1	211960.5	8.97
24	SIKKIM	37.19	100	INEFFICIENT	6,14,17	72.915	3238.17	52.148
25	TAMIL NADU	100	100	EFFICIENT	25	-	-	-
26	TRIPURA	51.71	90.69	INEFFICIENT	6,14,17	118.05	6874.8	42.48
27	UTTAR PRADESH	85.94	86.07	INEFFICIENT	1,8,17	1245.57	120543.3	4.94
28	UTTARANCHAL	39.76	39.76	INEFFICIENT	1,6,14,17	1185.94	39503	29.63
29	WEST BENGAL	92.02	92.02	INEFFICIENT	1,6,8,17	443.19	15049.05	2.471

Table 4. Efficiency Score Analysis

Sl.No	State Owned Electric Utility	Overall Efficiency	Technical Efficiency	Scale Efficiency	RTS
1	ANDHRA PRADESH	1.000	1.000	1.00000	CRS
2	ARUNACHAL PRADESH	0.2969	0.9013	0.32938	IRS
3	ASSAM	0.5145	0.6227	0.82637	IRS
4	BIHAR	0.7463	0.8137	0.91717	IRS
5	CHATTISGARH	0.865	0.8967	0.96465	IRS
6	DELHI	1.000	1.000	1.00000	CRS
7	GOA	0.7476	0.9713	0.76969	IRS
8	GUJARAT	1.000	1.000	1.00000	CRS
9	HARYANA	0.9339	0.9488	0.98434	IRS
10	HIMACHAL PRADESH	0.6093	0.8024	0.75935	IRS
11	JAMMU &KASHMIR	0.6000	0.60643	0.90321	IRS
12	JHARKHAND	1.000	1.000	1.00000	CRS
13	KARNATAKA	0.9874	0.9964	0.99097	IRS
14	KERALA	1.000	1.000	1.00000	CRS
15	MADHYA PRADESH	0.7094	0.7143	0.99314	IRS
16	MAHARASHTRA	0.9631	1.000	0.96310	DRS
17	MANIPUR	1.000	1.000	1.00000	CRS
18	MEGHALAYA	0.5799	1.000	0.57990	IRS
19	MIZORAM	0.5165	0.957	0.53971	IRS
20	NAGALAND	0.8628	1.000	0.86283	IRS
21	ORISSA	0.6700	0.6864	0.97611	IRS
22	PUNJAB	0.9819	0.9884	0.99342	IRS
23	RAJASTHAN	0.7947	0.7995	0.99400	IRS
24	SIKKIM	0.3719	1.000	0.37190	IRS
25	TAMIL NADU	1.000	1.000	1.00000	CRS
26	TRIPURA	0.5171	0.9069	0.57018	IRS
27	UTTAR PRADESH	0.8594	0.8607	0.99849	IRS
28	UTTARANCHAL	0.3976	0.3976	1.00000	CRS
29	WEST BENGAL	0.9202	0.9202	1.00000	CRS

Table 5. MPSS for the CRS inefficient DMU's

State Owned Electric Utilities	Installed Capacity (MW)	Circuit km	% T&D Losses	Number of Consumers (in Lakhs)	Quantity of Energy Supplied (GWh)
ARUNACHAL PRADESH	179.4 [1038.19]	14216 [71801.3741]	47.5 [6.412798]	1.13 [74.19]	125.01 [9093.1]
ASSAM	1130.9 [733.135]	78612 [50628.18]	39.3 [25.477]	11.77 [28.815]	1920.38 [4701.55]
BIHAR	1286.8	132126	36.7	12.5	3730.34

	[1524.54]	[81756.18]	[43.48]	[26.58]	[7933.59]
CHATTISGARH	1722 [2013.49]	120208 [114735.6]	42.6 [49.81]	22.13 [34.58]	5420.83 [8471.029]
GOA	470.7 [884.50]	14274 [26822.67]	45.1 [42.51]	3.96 [13.311]	1376.66 [4627.78]
HARYANA	3839.4 [4976.27]	177461 [230008.3]	32.1 [41.605]	39.17 [58.204]	12915.72 [19191.98]
HIMACHAL PRADESH	1803.2 [2177.08]	75315 [90931.08]	22.8 [19.01]	16.46 [53.51]	2736.92 [10315.17]
JAMMU &KASHMIR	1646.1 [1203.12]	41774 [30532.47]	45.5 [33.255]	10 [20.302]	3534.2 [7175.21]
KARNATAKA	7784.3 [10220.57]	597639 [605436]	23.3 [30.59]	128.89 [173.551]	23143.17 [31162.46]
MADHYA PRADESH	6685 [4747.928]	582757 [253591.33]	41.4 [29.403]	64.92 [91.32]	15907.83 [22450.45]
MAHARASHTRA	17182.3 [10077.92]	707037 [457401.49]	34.1 [22.06]	159.05 [110.917]	51823.9 [36140.74]
MEGHALAYA	288.2 [616.54]	15657 [30725.00]	16.7 [35.726]	1.68 [6.196]	797.02 [2939.9]
MIZORAM	116.8 [1806.29]	14798 [124923.4]	55.5 [11.157]	1.28 [74.19]	129.9 [9093.1]
NAGALAND	102.7 [3017.23]	10675 [208671.98]	55 [18.637]	1.88 [74.19]	136.25 [9093.1]
ORISSA	3023.3 [1867.23]	100464 [62047.96]	57.1 [35.26]	21.49 [29.56]	7157.48 [9846.30]
PUNJAB	6135.3 [7846.42]	287520 [356347.34]	26 [33.25]	58.36 [77.41]	22125.3 [29347.742]
RAJASTHAN	5427.6 [4468.79]	441724 [238037.4]	43.7 [35.98]	58.45 [76.19]	14691.24 [19151.58]
SIKKIM	116.1 [327.85]	5156 [14560.12]	55 [21.64]	0.6 [12.24]	182.24 [3719.6]
TRIPURA	244.5 [813.10]	14238 [47349.62]	46.4 [25.16]	2.28 [28.35]	414.26 [5151.2]
UTTAR PRADESH	8864.6 [7250.26]	494417 [355777.8]	35.2 [28.78]	88.06 [97.49]	26659.62 [29516.69]
UTTARANCHAL	1968.9 [815.96]	65583 [27179.37]	49.2 [20.38]	9.61 [25.18]	2662.15 [6976.72]
WEST BENGAL	5559.9 [5941.86]	188789 [201758.86]	31 [33.12]	47.27 [59.64]	17815.87 [22481.07]

The value in the parenthesis is the MPSS for that specific factor