Chapter - 6

DATA ANALYSIS AND INTERPRETATION – II: PERFORMANCE EVALUATION AND PRODUCTIVITY CHANGE

Performance evaluation, slack estimation, target setting and productivity change of the power plants are undertaken to achieve the objectives detailed at § 4.2.2 and § 4.2.3. The criteria adopted for selection of DMUs and variables (inputs and outputs), profile of DMUs, descriptive statistics of performance parameters, technical efficiencies (TE) and productivity change of the power plants are discussed in this chapter. TE of the plants are estimated using Data Envelopment Analysis (DEA). Distribution of TE, technical and scale efficiencies (SE), ranking of power plants, excess consumption of inputs as input slacks, and benchmarking for performance are further analysed. The influence of categorical variables like average age and average unit capacity, geographical regions and management structures are further investigated using DEA and Post hoc Games Howell test. The total factor productivity changes (TFPCH) of the power plants are estimated using Malmquist Productivity Index (MPI) and further decomposed into technical change (TECHCH) and efficiency change (EFFCH).

6.1 DMUs and Variables

DEA is applied to evaluate the relative performance of power plants by comparing their actual performance with the industry leaders and to explore the possibility of contraction of the current input levels without deteriorating the present output levels. In DEA literature homogenous production units consuming identical inputs to produce similar outputs are called Decision Making Units (DMU). While the number of DMUs depends on the objective of the study, higher number of DMUs has higher probability of capturing the high performance units determining the efficiency frontier (Cooper *et al.*, 2007). As a rule of thumb, number of DMUs should be larger than the product of number of inputs and outputs and the sample size should be at least 2 to 3 times larger than the sum of number of inputs and outputs (Ramanathan, 2005; Cooper *et al.*, 2007).

Selection of inputs and outputs has been a challenging task in performance modeling using DEA. Selection of inputs and outputs is purely subjective and there is no specific rule for determining the inputs and outputs. However experts recommend that attempt should be made to capture all inputs and outputs relevant for the objectives of the study. An exhaustive list of variables should be compiled initially and qualitative and quantitative filtration techniques like correlation, expert advice etc. applied to eliminate redundant and less important ones. One way of classifying the factor as input or output is to check whether DMUs recording higher performance in terms of that factor is considered more efficient or not. if, yes then the factor is normally classified as an output. Otherwise it is classified as an input (Ramanathan, 2005). Inputs are defined as resources utilized or conditions affecting the performance of the DMUs, outputs are produced by the DMUs.

Based on this consideration, electricity generated is considered as output and installed capacity, coal consumption, auxiliary consumption, generation loss due to PM and FO are considered as inputs. Even though DEA can handle multiple inputs and multiple outputs, inclusion of too many parameters have the tendency to skew the performance levels resulting in too many DMUs in the efficient frontier. For the present study having five inputs and one output, minimum no of DMUs should be 18.

Performance data of thermal power plants is expressed in ratios. Since the scale information is lost on ratios, to account for the scale of operation, the performance parameters are converted to yearly aggregates through appropriate translations. Power generation during a year is obtained by multiplying the PLF of the plant with the capacity of the plant and 8760 running hours during a year (24 hours a day for 365 days).

6.2 Profile of DMUs

For evaluating the relative performance of the power plants, 74 coal fired power plants were selected. The rationale for selecting the plants has been outlined at § 4.3. The profile of DMUs is detailed in Table 26.

Table 26 : Profile of DMUs

Sector	Operator	Eastern	Northern	Southern	Western	Total
Central	DVC	4				4
	NTPC	4	6	2	2	14
	Total	8	6	2	2	18
Private	CESC	4				4
	REL				1	1
	TORR POWER				2	2
	Total	4			3	7
State	APGENCO			4		4
	BSEB	1				1
	CSEB				2	2
	DPL	1				1
	GSECL				4	4
	HPGCL		2			2
	IPGPCL		2			2
	JSEB	1				1
	KPCL			1		1
	MAHAGENCO				7	7
	MPGPCL				4	4
	OPGC	1				1
	PSEB		3			3
	RRVUNL		2			2
	TNEB			4		4
	TVNL	1				1
	UPRVUNL		5			5
	WBPDC	4				4
	Total	9	14	9	17	49
Total		21	20	11	22	74

The study considers 74 coal fired power plants, being managed by 23 operators and located in four geographical regions. While there are 49 plants in State Sector, 18 plants are in Central Sector and remaining seven in Private Sector. Installed capacities of these plants are about 60 GW out of total of 62.7 GW commissioned (95.7%) till FY04. For smoothing exceptional good or bad performance of a plant during a particular year, performance data over five years (FY04 to FY08) is considered for the study. A plant in a different year is considered as a distinct DMU. Thus 74 plants during five years are considered as 370 DMUs.

6.3 Descriptive Statistics

The number of variables relevant for the study has already been outlined at § 4.5. Secondary data from thermal performance reviews (TPR, 2004; TPR, 2005; TPR, 2006; TPR, 2007; TPR, 2008) published by CEA is used for performance evaluation. Descriptive summary of the dataset is detailed in Table 27.

Table 27: Descriptive Statistics of Performance Parameters

	N	Minimum	Maximum	Mean	Std. Deviation
Output					
Generation	370	412.30	301908.60	62394.89	56578.03
Input					
Capacity	370	50.00	3260.00	811.35	622.11
PM	370	.00	82.77	8.77	10.64
FO	370	.06	62.75	10.64	11.84
SCC	370	.46	1.28	.74	.13
APC	370	5.34	18.14	9.55	1.98

It is observed that the capacities of the power plants vary from 50 MW to 3260 MW. There is wide fluctuation in the performance parameters like PM figures varying from 0% to 82.77%.

6.4 Technical Efficiencies (TE)

Based on the approach discussed earlier and using input oriented DEA with variable return to scale, the relative performance level through technical efficiencies with constant (TE_{CRS}) and variable (TE_{VRS}) return to scale, scale efficiencies, peers, return to scale properties along with input and output slacks of coal fired power plants are evaluated using multi stage approach of Coelli (1996).

Continuing the discussion started while framing the second objective at § 4.2.2, it is observed that a hypothetical plant can be carved out of the linear combination of 77.9% of DMU-198 (Ramagundam STPP during FY06) and 22.1% of DMU-237 (Dahanu during FY07) could generate the electricity generated by DMU-73 (Vindhyachal during FY04) having lesser installed capacity; consuming lesser coal and auxiliary power; and reduced generation loss. The hypothetical plant could have an installed capacity of 2136 MW, require 9.69 MT of coal, 1.06 BU of auxiliary power and possible generation loss to the tune of 1.359 BU and 0.154 BU towards PM and FO. TE_{CRS} and TE_{VRS} of Vindhyachal are estimated to be 0.870 and 0.989 respectively. Excess consumption of inputs is the difference between the figures for the actual plant and hypothetical plant and performance targets for the actual plant are the figures of the hypothetical plant. Dahanu and Ramagundam STPP are the peers for Vindhyachal and their practices can be emulated by Vindhyachal for performance improvement. Ranking of the plant is decided after evaluating the TE of other plants.

While the TE_{CRS} of other plants in different years (DMUs) varied from 42% to 100%; TE_{VRS} varied from 51% to 100% and SE between 42% and 100%. Average TE_{VRS} varied between 55.8% and 100% with mean of 83.29%. The TE of as many as 174 DMUs (47%) and 37 plants (50%) lie below the mean TE level. As many as 50 DMUs occupy the efficient frontier defined by the operational parameters Capacity, PLF, SCC, APC, PM and FO during the five year period. Some of the DMUs were actually the same plant in a different period reducing the efficient DMUs to 16. While two plants are VRS efficient during all the five year period, no plant was found CRS efficient during all the five years.

6.4.1 Distribution of TE Scores

Distribution of TE scores is detailed in Table 28 and shown in Figure 12.

Table 28 : TE in Different Bands

VRS TE	No of DMUs	% of DMUs	FY04	FY05	FY06	FY07	FY08
Up to 0.6	17	4.59	1	5	3	4	4
0.6 to 0.7	35	9.46	9	5	7	7	7
0.7 to 0.8	86	23.24	21	21	16	12	16
0.8 to 0.9	105	28.38	22	19	24	22	18
0.9 to 1.0	77	20.81	16	16	13	14	18
1.0	50	13.51	5	8	11	15	11

It is observed that 105 DMUs i.e. about 28% of the DMUs have the TE scores between 80% and 90%. 50 DMUs different years have TE scores of 1.0 out of which 15 DMUs have TE scores of 1.0 during FY07.

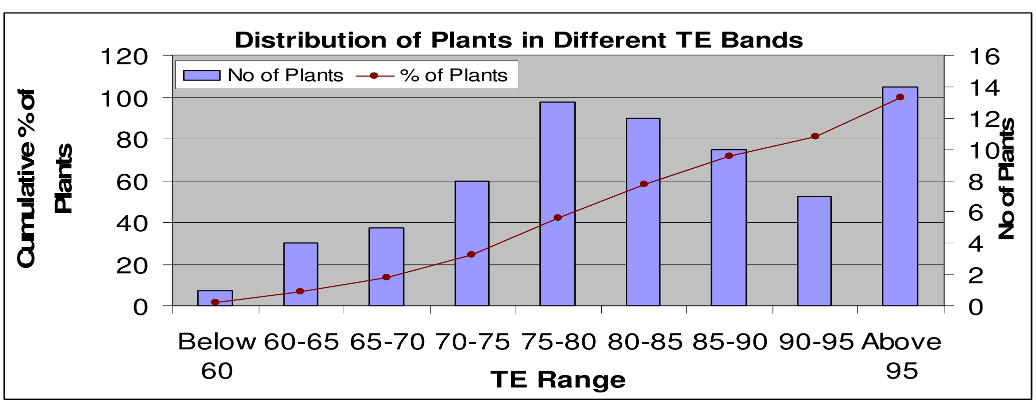

Figure 12 : Distribution of Plants in Different TE Bands

6.4.2 *Average Technical and Scale Efficiencies*

Average TE_{CRS} and TE_{VRS} and Scale Efficiencies (SE) of the plants are shown in Figure 13. It is observed that the TE_{VRS} varies between 0.558 and 1.0; TE_{CRS} varies between 0.525 (Plant 7, Barauni) and 0.999 (Plant15, Dahanu). Average SE of plants vary between 0.607 and 1.0.

While the Average TE_{CRS} of only one plant (Plant 15, Dahanu) is 1.00, it is above 0.95 for seven plants (52, 11, 30, 51, 54, 50, 68). Substantial gaps between average TE_{CRS} and average TEV_{RS} is observed indicating existence of scale inefficiency. Many of the DMUs which are technically efficient during different years are because of relaxation in their scales of operation and are not truly efficient. Two plants (Amarkantak and TORR Power AEC) which operate at very low scale size (50MW and 60MW) are VRS efficient in all the five years but the average SE of these power plants are only 0.607 and 0.969, it indicates in absence of any better plant in this scale, the plants may considered efficient.

6.4.3 *Ranking of Power Plants*

Ranking of the power plants based on individual performance parameters and the technical efficiency scores averaged over a five year period spanning FY04 to FY08 is detailed in Annexure – I. The correlation between the average rank based on individual performance parameters and TE_{CRS} and TE_{VRS} is explored using Pearson's Correlation Coefficient and shown in Table 29.

Table 29 : Correlations of Efficiency Scores

		AvgRank	CRSTE	VRSTE	SCALE
AvgRank	Pearson Correlation	1	.964(**)	.857(**)	.059
	Sig. (2-tailed)		.000	.000	.618
	N	74	74	74	74
CRSTE	Pearson Correlation	.964(**)	1	.876(**)	.081
	Sig. (2-tailed)	.000		.000	.494
	N	74	74	74	74
VRSTE	Pearson Correlation	.857(**)	.876(**)	1	-.212
	Sig. (2-tailed)	.000	.000		.070
	N	74	74	74	74
SCALE	Pearson Correlation	.059	.081	-.212	1
	Sig. (2-tailed)	.618	.494	.070	
	N	74	74	74	74

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson correlation coefficient between Average ranks of operational parameters and TE_{CRS} as well as TE_{VRS} is found to be 0.964 and 0.857 respectively and is significant at 0.01 levels. Thus the DEA based ranking is highly correlated with the average ranking which is adopted for multi criteria ranking (Jacobs *et al.*, 2004). The rank correlation between average rank and scale efficiency is only 0.059 and not significant.

Figure 13 : Average Technical and Scale Efficiencies During FY04 to FY08

6.4.4 Slack Estimation

Input oriented DEA models aim at minimizing inputs levels without compromising the output level. In the current study, the possibility of achieving the current level of power generation with lesser levels of one or more input variables like Installed

Capacity, Coal consumed, Auxiliary Power Consumed, Generation loss due to PM and FO is explored. Based on the actual performance of other plants, DEA calculates the targets for the less efficient plants. Besides the targets, DEA also suggests a set of plants called peers, whose performance can be benchmarked to achieve the set targets and guide focused techno-managerial intervention for performance improvement.

It is found that the current level of electricity generation achieved out of the 60 GW of installed capacity can be realized from only 49 GW, indicating about 11GW of unutilized generating assets. The slack estimated by CIIGBC (2005) and Subramaniam (2010) are 12 GW and 4 GW respectively. Even though it is not possible to contract the installed capacity, efficient utilization of the available resources has the potential to generate about 18% more electricity generated by these plants.

Generation loss on account of PM can be reduced by 48.4% i.e. The current PM level of 7.5% can be pruned to about 3.9% enhancing the availability by additional 4%. Recently Kukde working group has recommended for adoption of improved planned maintenance practices (CEA, 2008). As per the recommendation, the average planned maintenance duration of 51 days/year and 63 days/year in respect of 210MW units and 500MW units can be brought down to 28 days/year. In fact the PM level of Dahanu plant during the period of study (FY04 to FY08) has remained below 3%. During the year 2005-06, Paras plant maintained PM figures of 0% and FO of 1.06%.

FO slack is found to be 80% which at current all India 9% level translates to about 7.2%. Infusion of improved operation and maintenance practices can help substantial reduction of generation loss being encountered currently; can bridge the demand supply gap and enhance the reliability of the power system. Ideally the FO should be zero, but based on the best practice frontier which has been achieved by few plants; techno-managerial intervention has the potential to bring it to sub 1% level. The present dataset reveals that as many as 23 DMUs in State, Central and Private sector have achieved below 1% FO level during FY04 to FY08. CIIGBC (2005) had estimated that average FO of 8.84% could be brought down to 4.44% through benchmarking.

Coal slack is estimated to be about 14.3%, which at current consumption level of about 320 million tonnes per annum translates to the tune of 46 million tones. The resulting savings would result lower cost of generation of electricity, reduced CO2 emissions and save scarce natural resources. The savings could be used by starved power plants and make use of their generation assets lying idle because of short supply of coal.

Auxiliary Power Consumption (APC) slack have been found to be 18.4% indicating APC at the current level of about 40BU can be brought down by 18.4% resulting in a savings of 7.2 BU of electricity. CIIGBC (2005) estimated that all India average APC of 8.57% could be brought down to 7.53% through benchmarking.

6.4.5 Benchmarking for Performance Improvement

Benchmarking of industry best practices has been practiced for performance improvement in many sectors. Electricity regulators world wide also use performance benchmarking for the performance improvement of electricity utilities (Jamshab and Politt, 2000). DEA carves out hypothetical DMUs from the linear combination of other DMUs, whose performance is better than individual DMUs and recommends a set of peers who are the sources of best practices (Vercellis, 2009) and whose performance can be emulated for productivity gains. The frequency of occurrence of a plant as a peer in different years is shown in Figure 14.

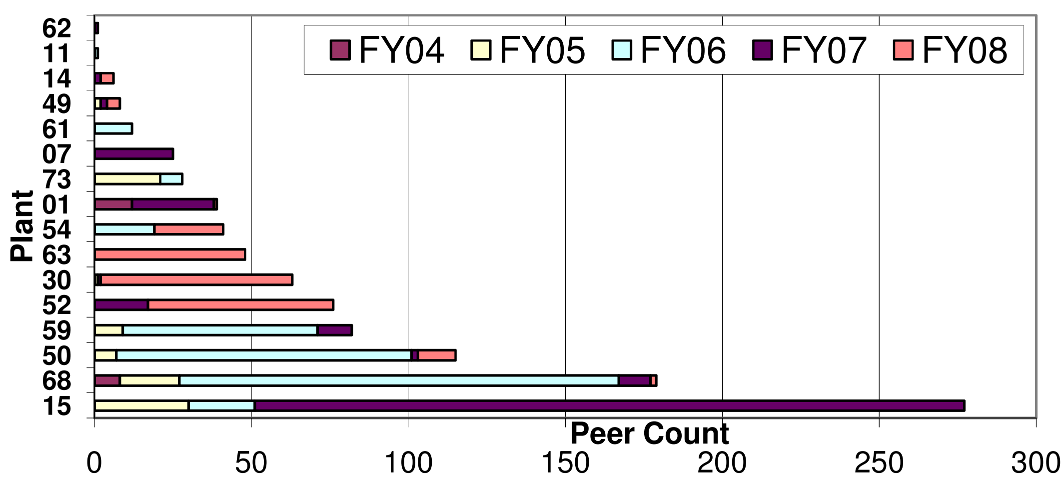

Figure 14 : Frequency of Occurrence of a plant as Peer in Different Years

A plant in different years is treated as a different DMU. For as many as 277 DMUs, it is possible to create hypothetical DMUs from the linear combination of plant-15 (Dahanu) and other plants which consumes less input and produces at least the same output as that of the real DMU. The peer count of plant-15 is highest. It is observed that plant-15 in the year FY07 is viewed as a peer by as many as 226 other DMUs. DMUs in FY06 and FY07 appear as reference units very often while those in FY04 and FY05 appears less frequently.

6.5 Influence of Categorical Variables

In addition to the set of controllable variables discussed earlier, certain other variables like geographical location in which the plant is located, the management structure, average unit size of the power plant, age of the units etc. seem to affect the performance of the power plants. The influence of such variables is investigated by analyzing the variance of TE_{VRS} and TE_{CRS} across these variables through ANOVA.

6.5.1 Variation of Technical Efficiency with Average Age and Unit Capacity

To study the influence of average age and unit capacity on the plant performance, the null hypothesis $\mathbf{H_{6\_1}}$ that "Technical efficiencies of the plants do not vary across different age and capacity groups" is tested using two-way ANOVA. Average unit capacities were categorized into 6 groups. Category-1 : 30 to 110 MW; Category-2: 110 to 210 MW; Category-3: 210 MW; Category-4: 250 MW; Category-5: 250 MW to 500 MW; and Category-6: 500 MW. Based on the average age of units, plants were divided into 6 bands. Category-1: 0 to 5 years; Category-2: 5 to 10 years; Category-3: 10 to 15 years; Category-4: 15 to 20 years; Category-5: 20 to 25 years; and Category-6: above 25 years. To test the above null hypothesis, two-way ANOVA of TE_{CRS} with unit capacity and age as factors was carried out. Since the scales of operation is already considered while evaluating $TE_{VRS,}$ it will not be proper to evaluate the impact of unit capacity which is an indicator of scales of operation with $TE_{VRS,}$ therefore instead of TE_{VRS} is considered. The results of ANOVA are detailed in Table 30.

Table 30: Influence of Unit Age and Capacity on TE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.235(a)	15	.149	15.247	.000
Intercept	98.295	1	98.295	10059.115	.000
AgeTag	.199	3	.066	6.793	.000
CapTag	.260	5	.052	5.313	.000
AgeTag * CapTag	.115	7	.016	1.682	.112
Error	3.459	354	.010		
Total	242.998	370			
Corrected Total	5.694	369			

a R Squared = .392 (Adjusted R Squared = .367)

It is observed that there is significant main effect of the average unit capacity on the TE, $F(5, 354) = 5.31$, $p < .001$ and also of the average age of the units on the TE, $F(3, 354) = 6.7931$, $p < .001$. However there was a non significant interaction between the age of the unit and average unit capacity, on the TE, $F(7, 354) = 1.68$, $p > 0.01$.

Post hoc Games-Howell analysis reveal that plants of 0-5 years old are technically more efficient compared to those in 5-10 years, 10-15 years and 15-20 years by 5.76%, 6.78% and 18.51% respectively. TE_{CRS} of plants having average unit capacity of 500MW is higher compared to those in 30-110 MW, 110-210 MW, 210 MW and 250-500MW by 25%, 17%, 11% and 7% respectively. The difference in TE_{CRS} between plants having average unit capacity 250 MW and 500 MW is not statistically significant.

6.5.2 Variation of Technical Efficiency Across Geographical Locations

Indian power system is divided into five geographical regions, with no thermal power plant under operation during the period of study in the North-Eastern region; the division virtually reduces to four regions namely Eastern Region (ER), Northern Region (NR), Southern Region (SR) and Western Region (WR) (MoP, 2010). The average TE_{VRS} of plants in different geographical regions like ER, NR, WR and SR are found to be 0.793, 0.802, 0.850 and 0.897 respectively.

Several studies (Shanmugam and Kulshrestha, 2005; CEA, 2009) indicate that the performance of power plants depend on the geographical locations and analysed the performance based on geographical regions. To find if the technical efficiency of power plants depend on the geographical location of a power plant, the null hypothesis $\mathbf{H_{6\_2}}$ that "Technical Efficiency of power plants does not vary across geographical regions" is tested using one-way ANOVA of TE_{VRS} scores across four regions. The four regions were represented as ER-1, NR-2, SR-3 and WR-4. The output of the analysis listed in Table 31. The results indicate significant difference in TE_{VRS} across regions, $F(3, 369) = 6.98$, $p < 0.01$. Post hoc results further indicate that the TE of plants in SR are higher than those in ER and NR by 7.1% and 8.4% respectively.

Table 31 : ANOVA of TE_{VRS} Scores across Geographical Regions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.304	3	.101	6.978	.000
Within Groups	5.308	366	.015		
Total	5.612	369			

6.5.3 *Variation of TE across Different Sectors*

Average TE_{VRS} of plants based on different management structure like State, Central and Private Sector are 0.806, 0.849 and 0.923 respectively. To test if the TE of the power plants varies across different Sectors, the null hypothesis $\mathbf{H_{6\_3}}$ that "Technical Efficiencies of the plants do not depend on the Sector in which the plant is being managed" is tested using one-way ANOVA and the results are detailed in Table 32.

Table 32 : One-way ANOVA of TE_{VRS} across Sectors

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.977	2	.488	38.675	.000
Within Groups	4.635	367	.013		
Total	5.612	369			

The results indicate, there is significant difference in Technical Efficiencies of the plants across different Sectors. Post hoc Games-Howell results further indicate that everything else remaining same, the technical efficiency of plants in Private Sector is higher than that in State and Central Sector by 14.32% and 5.4% respectively.

6.6 Productivity Change : Trends and Determinants

Total factor productivity change (TFPCH) of 74 power plants over a five year period (FY04 to FY08) is evaluated using DEAP 2.1 software (Coelli, 1996). TFPCH is decomposed to pure efficiency change (PECH), scale efficiency change (SECH), technical change (TECHCH) to understand the contribution of scale efficiency, catch-up and innovation. Variation of productivity change across geographical regions and management structures is also analysed.

6.6.1 *Total Factor Productivity Change*

Average PECH, SECH, EFFCH, TECHCH and TFPCH are appended at annexure-1. Average TFPCH of the plants is shown in Figure 15. While the circles indicate total factor productivity changes, the radials represent individual plants.

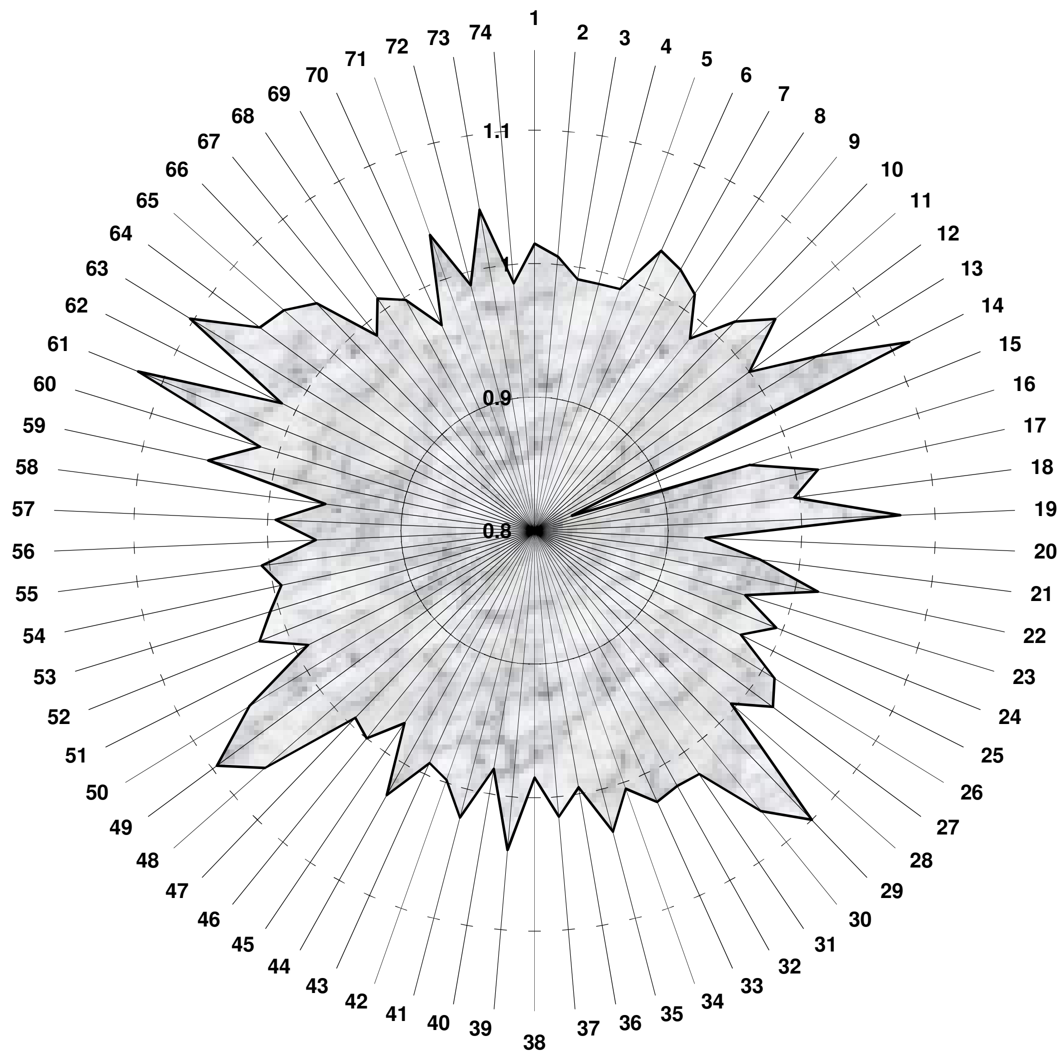

Figure 15: Average TFPCH of Power Plants During FY04 to FY08

The average TFP change of plants ranged from 0.502 to 2.166 indicating negative growth of 49.8% to positive growth of 116.6%. Out of the 74 plants, from Figure 15, it is found that while 30 plants (40.5%) recorded average negative productivity change (TFPCH <1), as many as 42 plants (56.7%) recorded productivity growth (TFPCH >1). Remaining 2 plants (2.7%) recorded no change in their TFP during the period of study. Out of the 42 Plants recording average positive TFPCH, as many as 12 Plants belong to NTPC.

On an average basis, plant-61 (South Gen) recorded maximum productivity growth of 12% per year followed by plant - 14 (Dadri) -11.4% and plant -63 (Talcher Kaniha) – 10.4%. plant - 15 (Dahanu) recorded the lowest growth of -17% per year during the period. Interestingly this plant has come out as one of the efficient units. This indicates Dahanu is loosing its superiority over the years and other plants are trying to catch-up with this unit.

Mean TFPCH is found to be 1.012 indicating growth of 1.2% per annum. The factors contributing TFP growth are EFFCH of 0.9% and TECHCH 0.2%. Year wise breakup of PECH, SECH, EFFCH, TECHCH and TFPCH are shown in Figure 16.

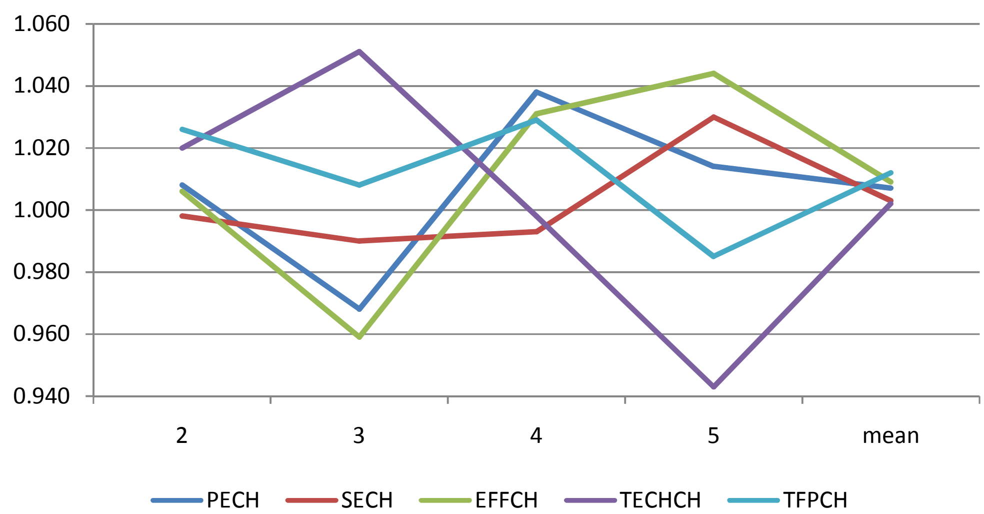

Figure 16 : Year wise Productivity Change during FY04 and FY08

While the TFP change during two periods (2 and 4) was 2.6% and 2.9%, period 3 witnessed growth of 0.8% and last period (5) recorded negative growth of 1.5%. The negative growth during the last period can be attributed to technological regress of 5.7% which was compensated by EFFCH of 4.4%.

6.6.2 *Efficiency Change*

The overall EFFCH of 0.9% per annum, when further decomposed indicates, 0.7% and 0.2% per annum due to PECH and SECH respectively. EFFCH varied from 0.741% to 1.571% during period 3 and 5 respectively by Ramagundam-B. This corresponds to regress in TE of 25.9% to progress of TE amounting to 57.1%. As many as 119 DMUs registered negative TE growth, while another 20 DMUs recorded no change. Remaining 157 DMUs recorded positive TE growth.

6.6.3 Technical Change

Positive TECHCH of 0.2% per annum is observed during the period indicating upward frontier shift. TECHCH recorded during the period range from 0.620 (Dahanu during period 2) to 1.654 (Paras during period 3). Dahanu which frequently lies in the efficiency frontier moved away from the frontier during the period. However Paras which remained away from the frontier during the four years could able to move to the frontier during the period 3. The operational performance parameters of Dahanu and Paras are listed in Table 33.

Table 33 : Performance Parameters and TECHCH of Dahanu and Paras

Plant	Year	PLF	Capacity	PM	FO	SCC	APC	TECHCH
Dahanu	2003-04	100.34	500.00	2.14	0.06	0.54	8.99	-
Dahanu	2004-05	101.35	500.00	2.09	0.19	0.54	7.51	0.620
Dahanu	2005-06	98.70	500.00	0.00	4.47	0.54	7.69	0.652
Dahanu	2006-07	101.79	500.00	2.46	0.27	0.52	7.65	1.363
Dahanu	2007-08	101.53	500.00	2.90	0.81	0.64	8.26	0.863
Paras	2003-04	82.17	55.00	9.02	1.45	0.77	10.28	-
Paras	2004-05	77.38	55.00	7.27	5.85	0.82	9.82	1.010
Paras	2005-06	87.59	55.00	0.00	1.06	0.81	10.23	1.654
Paras	2006-07	75.63	55.00	6.88	1.88	0.85	10.16	0.676
Paras	2007-08	71.31	55.00	6.33	4.28	0.94	10.60	0.997

6.6.4 Region wise and Sector wise Productivity Change

Region-wise distribution of DMUs recording positive, negative and no change in TFPG is detailed in Table 34. The results indicate more power plants in NR and ER achieved positive TFPG. Barring WR, plants in all other regions witnessed positive TFPG led by ER: 2.2% and SR: 2%. Plants in the WR witnessed negative TFPG of 0.4% during the period. Sector-wise average growth in TFP is listed in Table 35.

Table 34 : Productivity change of DMUs - Region wise Distribution

	Negative Growth	No Change	Positive Growth	Average TFPG
Eastern	7	1	13	1.022
Northern	6	-	14	1.013
Southern	6	-	5	1.020
Western	11	1	10	0.996
Total	30	2	42	

Table 35 : Productivity Change of DMUs - Sector wise Distribution

	Negative Growth	No Change	Positive Growth	Average TFPG
State	24	02	23	1.004
Central	02	-	16	1.042
Private	04	-	03	0.992
Total	30	02	42	

It is found that the plants in Central Sector achieved maximum TFPG of 4.2% followed by those in State Sector which recorded growth of 0.4%. The plants in Private Sector have recorded negative growth of 0.8% during the period.

6.6.5 Plants recording all round Productivity Growth

Twelve plants listed in Table 36; recorded all round productivity growth i.e. all indices are more than unity. While as many as six of these plants are located in Eastern Region, four lie in the Northern Region and one each in Southern and Western regions. While as many as seven plants are managed in Central Sector, 4 are in State Sector and one plant is in Private Sector. Out of the seven plants in the Central Sector, six are managed by NTPC the largest power producer in the country.

Table 36 : Plants Recording all Round Productivity Growth

Plant No	Plant	pech	sech	effch	techch	tfpch	Region	Sector	Operator
10	**Bokaro B**	1.015	1.001	1.016	1.001	1.017	Eastern	Central	DVC
11	**Budgebudge**	1.029	1.006	1.035	1.005	1.040	Eastern	Private	CESC
14	**Dadri**	1.033	1.001	1.034	1.077	1.114	Northern	Central	NTPC
19	**Farakka**	1.043	1.020	1.063	1.010	1.074	Eastern	Central	NTPC
27	**Kolaghat**	1.018	1.003	1.021	1.001	1.022	Eastern	State	WBPDC
31	**Korba West**	1.015	1.003	1.017	1.002	1.020	Western	State	CSEB
32	**Kota**	1.007	1.010	1.017	1.002	1.019	Northern	State	RRVUNL
33	**Kothagudem**	1.008	1.010	1.018	1.005	1.023	Southern	State	APGENCO
63	**Talcher Kaniha**	1.026	1.025	1.051	1.050	1.103	Eastern	Central	NTPC
64	**Talcher Thermal**	1.051	1.002	1.053	1.003	1.056	Eastern	Central	NTPC
65	**Tanda**	1.045	1.002	1.047	1.003	1.050	Northern	Central	NTPC
71	**Unchahar**	1.022	1.005	1.027	1.008	1.035	Northern	Central	NTPC

6.6.6 Productivity Change of Plants Adding Capacity

During FY04 to FY08, 13 plants have augmented their capacities. Productivity changes of these plants are listed in Table 37, indicate that barring plant - 41 (Panipat) and plant - 74 (Wanakbori), all other plants recorded reduced rate of TFPG after capacity addition.

Table 37 : Changes in Productivity Indices – With Capacity Addition

Plant No	Plant	Period	Capacity Added (MW)	PECH	SECH	EFFCH	TECHCH	TFPCH
21	**Gandhinagar**	2		0.999	1.023	1.022	0.963	0.984
		3		1.034	0.905	0.935	1.174	1.098
		4		0.965	1.073	1.035	0.939	0.972
		5	210	0.93	1.001	0.931	0.904	0.841
25	**Kahalgaon**	2		1.003	1.009	1.011	1.018	1.029
		3		1.1	1.007	1.108	0.979	1.085
		4		0.984	0.988	0.972	1.026	0.998
		5	500	0.836	0.97	0.811	0.991	0.804
35	**Mejia**	2		1.036	1.017	1.054	0.987	1.040
		3	210	1.074	0.934	1.003	1.021	1.024
		4		0.988	1.031	1.019	1.022	1.042
		5	250	1.15	0.955	1.099	0.932	1.024
41	**Panipat**	2		0.905	1.013	0.917	1.002	0.919
		3	500	1.086	0.907	0.986	1.036	1.021
		4		1.091	1.055	1.151	1.017	1.170
		5		1.001	1.002	1.003	0.989	0.991
44	**Paricha**	2		1.038	1	1.038	0.969	1.006
		3	210	0.835	1	0.835	1.15	0.960
		4		1.996	0.744	1.485	0.907	1.347
		5	210	0.714	1.342	0.958	0.891	0.854
50	**Ramagundam STPS**	2		1	1.086	1.086	1.114	1.21
		3	500	1	1.04	1.04	0.968	1.007
		4		1	0.959	0.959	1.033	0.991
		5		1	1.047	1.047	0.967	1.013
51	**Rayalseema**	2		1.001	0.998	0.999	1.015	1.015
		3		0.764	1.006	0.768	1.085	0.834
		4		1.251	0.996	1.247	0.979	1.221
		5	210	0.936	0.996	0.932	0.997	0.929
52	**Rihand**	2		0.97	0.96	0.931	1.098	1.022
		3	1000	1.013	0.979	0.992	0.963	0.955
		4		1.018	1.097	1.117	1.016	1.135
		5		1	1	1	0.984	0.984
55	**Sanjay Gandhi**	2		1.052	0.996	1.047	1.003	1.051
		3		0.933	0.992	0.925	1.01	0.934
		4		1.05	1.015	1.065	1.024	1.090
		5	500	1.088	0.969	1.054	0.909	0.957
63	**Talcher Kaniha**	2	1000	1.107	0.936	1.036	1.12	1.160
		3	500	1	1.146	1.146	0.996	1.141
		4		1	1.003	1.003	1.028	1.032
		5		1	1.025	1.025	1.059	1.085
71	**Unchahar**	2		1.043	1	1.043	1.026	1.071
		3		1.045	1.023	1.069	0.976	1.043
		4	210	1	0.965	0.965	1.038	1.002
		5		1	1.033	1.033	0.992	1.025
73	**Vindhyachal**	2		1	1.04	1.04	1.09	1.133
		3		1	1.071	1.071	0.951	1.018
		4	500	1	0.981	0.981	1.04	1.020
		5	500	1	1.031	1.031	0.98	1.010
74	**Wanakbori**	2		0.892	0.924	0.825	1.11	0.915
		3		0.954	0.994	0.949	1.003	0.951
		4		1.067	1.01	1.078	1.027	1.107
		5	210	0.965	1.03	0.994	0.987	0.981