Forecasting Generation and Utilization of Fly Ash in India

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ABSTRACT

Fly ash is an industrial waste generated at coal/lignite based thermal power plants. This waste material is utilized in numerous innovative applications across the world. In India, Ministry of Environment & Forests notification 2009 mandates to achieve 100% utilization of fly ash generated in a phased manner within five years. Various initiatives have been taken in the country to promote safe utilization of fly ash. As a result, utilization has increased from 1 million tonnes in 1994 to 100 million tonnes in 2013. Despite this impressive increase, the target of cent-percent utilization is not achieved and 73 million tonnes of fly ash remained unutilized in 2013. It leads to the following questions. Will the target of cent-percent utilization be achieved in near future if the existing trend continues? If not, what will be the gap between the generation and utilization of fly ash? An attempt is made in this study to answer these questions. For this, annual time series data of generation and utilization obtained from CEA are subjected to regression analysis to identify the underlying trend. Regression models for generation and utilization of fly ash are developed. Forecasts obtained by using the developed regression models show that if the existing trend continues, cent-percent utilization is unlikely to be achieved in near future. Thus, there is an urgent need to escalate utilization efforts in order to achieve cent-percent utilization of fly ash.

Key Words: Time series analysis, Forecasting, Regression models, Fly ash utilization, Technology management, Decision making and planning

1. Introduction

Fly ash is an industrial waste and an environmental challenge because it is known to pollute air, water and soil. Fly ash is generated during the combustion of coal/lignite for generation of electricity at thermal power plants across the world (Blissett and Rowson, 2012). Fly ash is also recognized as a valuable resource material (Kumar et al., 2005). This is because it can be utilized in numerous innovative products and applications. According to Central Electricity Authority (CEA) to promote safe utilization of fly ash Government of India commissioned a Technology Project in Mission Mode called Fly Ash Mission (FAM) in 1994 (CEA, 2014). After its approved period, i.e. 31st March 2002 it was renamed as Fly Ash Utilization Programme (FAUP), and thereafter, it was renamed as

Fly Ash Unit (FAU) providing new focus and thrust under Department of Science and Technology (DST) since May 2007 (DST, 2013). Continuous progress in research and development clubbed with continuous effort of various government and private agencies, resulted in increased utilization of fly ash year after year. Utilization of fly ash has increased from 1 million tonnes (MT) in 1994 (DST, 2013) to about 100 MT in financial year (FY) 2013 (CEA, 2014). This denotes about 10000% increase in utilization in about 19 years. Despite this impressive increase in utilization, the target of cent-percent utilization could not be achieved, and there remains over 73 MT of unutilized fly ash in FY 2013. This is because, though the utilization of fly ash has increased, the generation of fly ash has also increased from 40 MT in the year 1994 (DST, 2013) to about 173 MT in FY 2013(CEA, 2014).

According to Ministry of Environment & Forests (MoEF) notification vide Gazette of India Notification No. 2804(E) dated 3rd Nov 2009, all coal/lignite based thermal power stations and/or expansion units in operation on or before the date of MoEF's notification, are required to achieve 100% utilization of fly ash generated in a phased manner within five years from the date of notice (CEA, 2014; MoEF, 2013), i.e. by November 2014. Relating it with the data published by CEA (2014), utilization level for FY 2013 is 58% of generation. Though utilization data for November 2014 is not published yet, it is highly unlikely that cent-percent utilization could be achieved by the target schedule. It leads to the following questions. Will the target of cent-percent utilization be achieved in near future if the existing trend continues? If not, what will be the gap between the generation and utilization of fly ash? Answers of these questions are vital for strategy formulation and timely execution of action plans in order to effectively manage the problem of unutilized fly ash. Estimating the gap between generation and utilization is the first step towards strategy formulation for maximizing the utilization of fly ash (Loya and Rawani, 2015). Haque (2013a), citing World Business Council for Sustainable Development / Cement Sustainability Initiative, mentions forecast of fly

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ash utilization by cement sector in India, but forecast of collective utilization incorporating multiple applications is not provided. Haque (2013b), on the basis of India Energy Book's forecast of coal consumption, argues that generation of fly ash will increase tremendously but quantity of generation is not predicted. Referring to FAUP and Technology Information, Forecasting & Assessment Council (TIFAC), Kumar et al., (2005) mention fly ash generation is estimated to increase to about 170 MT by 2012 and 225 MT by 2017, however the basis of estimation is not shared. Bhattacharjee and Kandpal (2002) presented a 13 years forecast of fly ash generation and utilization. The results predicted the fly ash utilisation to be less than 25% of generation. The paper highlighted the need (at that time) of developing a much more aggressive strategy for fly ash utilisation. However the forecast period covered in the above study was from 1999 to 2012. There seems to be no other literature forecasting quantum of fly ash generation and utilization. Hence the above mentioned questions remain unanswered in the present scenario.

As it is highly unlikely that cent-percent utilization will be achieved within the target schedule set by MoEF, there is a need to revise the target schedule. And also there is an urgent need of suitable strategies and actions to bridge the gap between the generation and utilization. To bridge the gap between the generation and utilization of fly ash either the generation has to decrease or the utilization has to increase. Fly ash is a by-product and volume of its generation depends on production of electricity by coal based thermal power plants. Given the ever increasing demand for electricity and dependency on coal for electricity production, the generation of fly ash is highly unlikely to decrease. Thus, bridging the gap can be achieved only by increasing the utilization of fly ash. Though the quantity of fly ash generated cannot be controlled it can be predicted. Further, based on this predicted quantum of generation, utilization quantity could be planned and suitable strategies could be formulated and executed to achieve cent-percent utilization. Accordingly, to assist informed decision making and planning, the aim of this study is to forecast generation and utilization of fly ash and to compute the gap between the two.

2. Methodology and Data Analysis

In order to forecast generation and utilization of fly ash data are obtained from secondary source. Generation and utilization of fly ash in the country is monitored and reported by CEA on behalf of Ministry of Power (MOP) (CEA, 2014; MOP, 2013). The latest report of CEA, dated August 2014, on fly ash generation at coal/lignite based thermal power stations and its utilization, presents annual time series data of generation and utilization for 18 years' period, starting from the FY 1996 to FY 2013 as shown in Table 1.

Table 1 Time Series Data of Fly Ash Generation and Utilization

FY	Time Period	Generation (MT)	Utilization (MT)
1996	1	68.66	6.64
1997	2	78.06	8.43
1998	3	78.99	9.22
1999	4	74.03	8.91
2000	5	86.29	13.54
2001	6	82.81	15.57
2002	7	91.65	20.79
2003	8	96.28	28.29
2004	9	98.57	37.49
2005	10	98.97	45.22
2006	11	108.15	55.01
2007	12	116.94	61.98
2008	13	116.69	66.64
2009	14	123.54	77.33
2010	15	131.09	73.13
2011	16	145.41	85.05
2012	17	163.56	100.37
2013	18	172.87	99.62

(Source: CEA, 2014)

A time series is defined as a chronological sequence of observations on a variable of interest (Montgomery et al., 2008). Time series forecasting generally assumes that the same underlying causal relationship that existed in the past will continue to prevail in the future (Shim, 2009). Consequently time series forecasting methods are based on the concept that when an underlying pattern exists in a data series, it can be identified and decomposed, for better understanding the behaviour, which in turn facilitates improved accuracy in forecasting (Makridakis et al., 1998). The four commonly recognized components are trend, seasonal, cyclical, and irregular variation (Shim, 2009). Based on these components an additive decomposed model of time series can be mathematically represented as follows.

$$Y_t = T_t + S_t + C_t + E_t \qquad (1)$$

Where Y_t is the time series value (actual data) at time period t,

T_t is the trend component at time period t,

S_t is the seasonal component at time period t,

C_t is the cyclical component at time period t, and

E_t is the irregular variation component at time period t.

Shim (2009) defines these components as follows. Trend component (Tt) is the general upward or downward movement of the average, over time. The seasonal component (St) is a recurring fluctuation of data points above or below the trend value that repeats with a usual frequency of one year, e.g., Christmas sales. Cyclical components (Ct) is recurrent upward or downward movement that repeats with a frequency that is longer than a year. This movement is attributed to business cycles (such as recession, inflation, unemployment, and prosperity), so the periodicity (recurrent rate) of such cycles does not have to be constant. The irregular variation component (Et) is a series of short, erratic movements that follow no discernible pattern.

A time series covering 18 years of period is not long enough to identify business cycle, because to capture business cycles a long time series is needed (Armstrong, 2002). As available data are annual data, hence they do not include seasonality. The type of data (yearly, quarterly, monthly, weekly, daily, etc.) relates to the characteristics of the time series, in general randomness diminishes as the level of aggregation increases. In daily data randomness dominates while trend is insignificant, contrasting this in yearly data averaging 12 months eliminates most of the randomness, in such a case trend fitting is recommended as it ignores random and seasonal fluctuations and concentrates on the long-term increase or decline instead, thus can correctly identify and extrapolate the trend in the data pattern for long forecasting horizons (Makridakis et al., 1998). Accordingly, for the time series data in consideration the equation 1 can be modified as

$$Y_t = T_t + E_t. \quad (2)$$

Typically, two types of trend fitting are used for business forecasting, namely, linear and nonlinear (Shim, 2009). In order to identify the type of trend in the time series data presented in (Table 1) a sequential chart is prepared with the help of statistical software package SPSS Version 20.0. The sequential chart is illustrated in Figure 1, where for FY 1996 the corresponding time period, t, is equal to 1. The chart reveals that the movements are upward and reasonably linear. Accordingly the trend can be assumed to be linear. Armstrong (2002) recommends a simple representation of trend unless there is strong evidence to the contrary. Supplementing this, in case a nonlinear trend is erroneously attempted to fit into a linear equation, it would not give a good fit and can be identified using t-value and R2 statistics (Shim, 2009). The t-test is extensively used in regression analysis (Makridakis et al., 1998) to statistically test the hypothesis if there is a linear relationship between the response variable and predictor variables (Montgomery et al., 2008). The coefficient of determination R2 measures the proportion of variance in the observed data that can be explained by the estimated regression model (Anderson et al., 2011).

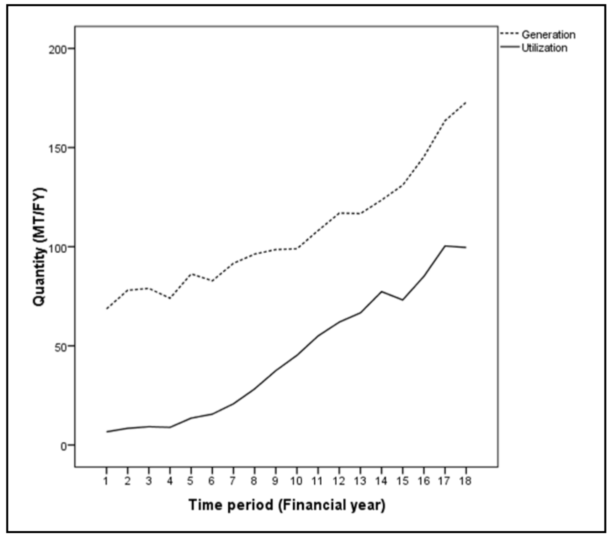


Figure 1 Sequential Chart of Generation and Utilization of Fly Ash

In light of the above rationales, this study hypothesizes existence of linear trend in data of generation and utilization of fly ash with respect to time (financial year). The null hypothesis (H0) is that the slope of the population regression line is zero (there is no linear trend). The alternative hypothesis (H1) is that the slope of the population regression line is different from zero (there is a linear trend). A linear relationship can be modelled using statistical method of simple linear regression analysis. The method has inherent strengths as well as limitations. Strengths of the method are noted here and the limitations of the method are acknowledged in conclusion section. A great advantage of regression method is that it is easy to comprehend and can be represented & understood graphically (Deng and Song, 2013). Simplicity minimises mistakes and also facilitates decision makers' understanding and implementation (Armstrong, 2001). A linear trend can be represented by an equation

$$T_t = a + bt; \quad (3)$$

where the two parameters, a and b, represent the intercept and slope respectively (Makridakis et al., 1998). Parameter values of the regression equation can be estimated using method of least-squares. The method of least square is robust to violations of the underlying assumptions to which other methods are more sensitive, wins for simplicity (Armstrong, 2001) and widely used (Shim, 2009).

Accordingly, the statistical technique of simple linear regression analysis is carried out to identify the underlying trend of the time series data of generation and utilization of fly ash (Table 1). In order to test the hypotheses of existence of linear relationship between dependent variables and independent variable, parametric t-tests are performed to access the statistical significance of the slopes of the regression equations. Analysis is conducted with the help of statistical software package SPSS Version 20.0. The method of least square is used for estimation of parameters. Goodness of fit is assessed using R^2 statistics. Using the estimated parameters regression models of generation and utilization of fly ash are developed. Based on the developed regression models, utilization and generation of fly ash are forecasted separately, and then the gap between the two is computed.

3. Result and Discussion

The result of the data analysis is shown in Table 2. The calculated p-value represents the probability of obtaining a value of t as large as the one calculated for the data. A *p*-value smaller than 0.05, provides the evidence for rejecting the null hypothesis. Accordingly, if a *p*-value is smaller than 0.05 it is concluded that the result is significant (Montgomery et al., 2008). In this study hypotheses of linear trend in generation and utilization of fly ash with respect to time are supported at 0.001 significant levels. Histograms of residue are included in the appendix. The R^2 statistics indicate that about 91% variance in fly ash generation and about 96% variance in fly ash utilization are explained. Thus, regression models for fly ash generation and utilization indicate good fit.

The above estimated parameters of regression models are used in this study for mid range forecast. For this regression models of generation and utilization of fly ash are formulated as follows:

$$Gt = 55.599 + 5.449.t \quad (4)$$

$$Ut = -12.442 + 6.065.t \quad (5)$$

Where Gt is generation of fly ash in MT for time period t

Ut is utilization of fly ash in MT for time period t

t is time period for which forecast is being calculated (for the given regression models, t is determined by subtracting 1995 for financial year being forecasted, e.g. for FY 2014, t = 19)

Using the above regression models, a forecast for generation and utilization of fly ash for 10 years starting from FY 2014 to FY 2023 is determined, and then the gap between the generation and utilization of fly ash is computed and shown in Table 3.

The above forecast is subject to continuity of trend. Forecast shows that in 10 years utilization of fly ash will increase to about 157.38 MT, however the generation of fly ash will also increase significantly. In context of the target schedule set by MoEF for cent-percent utilization of fly ash, i.e. November 2014, interpretation of the forecast is done as follows. It is predicted that the MoEF's target schedule for achieving cent-percent utilization will not be achieved. Further if the existing trend continues, i.e. no new strategy is formulated and no new action is taken, cent-percent utilization is unlikely to be achieved in near future. Likewise, if the existing trend continues, the gap between generation and utilization is predicted to be over 50 MT. As fly ash is a by-product, its generation is difficult to control. Thus, the logical approach to bridge the gap between generation and utilization is to increase utilization of fly ash. The existing strategies and efforts are resulting in an increasing trend of utilization of fly ash; however this increase is not enough in context of ambition of cent-percent utilization. So there is an urgent need to escalate utilization of fly ash. Several public and private funded R&D in last five decades has enabled numerous innovative applications of fly ash (Loya and Rawani, 2013). For example fly ash can be utilized in cement, concrete, brick, tile, mine-filling, land-filling, road-construction, fertilizer, pesticide, paint, synthetic wood, ceramic, glass, geopolimer, catalysts, zeolites, as adsorbents in pollution control applications such as industrial waste waters treatment, recovery of magnetic microspheres, cenospheres, carbon & several precious metals, etc. Large scale utilization of fly ash in such applications can assist in bridging the gap between generation and utilization.

Table 2 Parameter Estimation of Regression Models and t-test Results

Model		Unstandardized Coefficients		Standardized Coefficients	*t*-value	*p*-value	R^2
		B	Std. Error	Beta			
Generation	(Constant)	55.599	4.521		12.297	.000	0.914
	FY	5.449	0.418	0.956	13.045	.000	
Utilization	(Constant)	-12.442	3.231		-3.851	.001	0.963
	FY	6.065	0.298	0.981	20.321	.000	

Table 3 Forecast Using the Regression Models

FY	Time period	Generation (MT)	Utilization (MT)	Gap (MT)
2014	19	159.13	102.79	56.34
2015	20	164.58	108.86	55.72
2016	21	170.03	114.92	55.11
2017	22	175.48	120.99	54.49
2018	23	180.93	127.05	53.87
2019	24	186.38	133.12	53.26
2020	25	191.82	139.18	52.64
2021	26	197.27	145.25	52.03
2022	27	202.72	151.31	51.41
2023	28	208.17	157.38	50.79

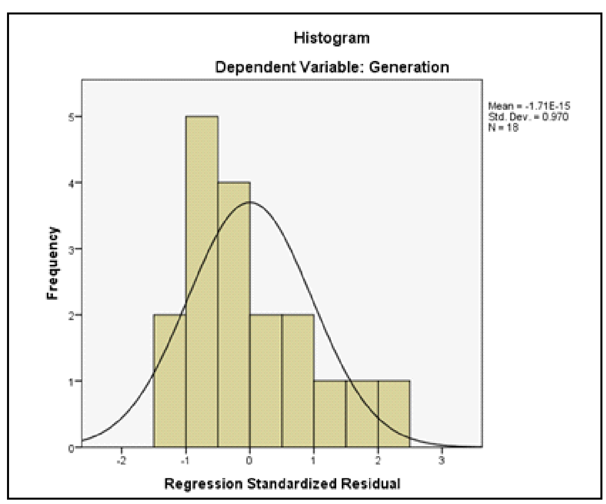
However many of these applications are not yet commercialized utilized to their full potential. In light of this, the study recommends to escalate commercialization of fly ash innovations and technologies, developed by various government and private funded research, for achieving cent percent utilization of fly ash.

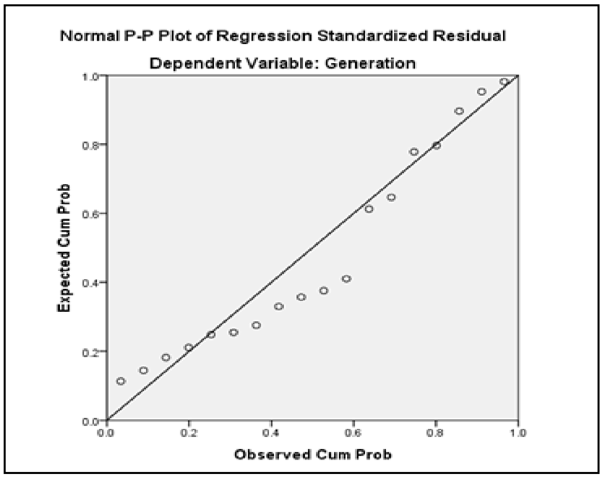
4. Conclusions

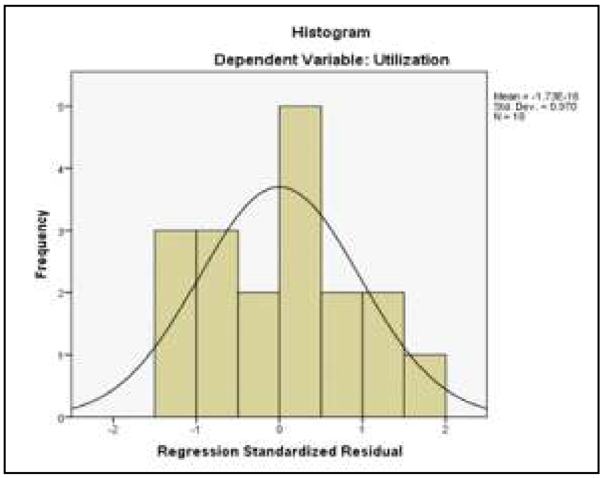
In this paper generation and utilization of fly ash in India is forecasted and then gap between the two is computed. For this annual time series data of generation and utilization starting from the FY 1996 to FY 2013 are analyzed. Regression models for generation and utilization of fly ash are developed and a forecast for 10 years starting from FY 2014 to FY 2023 is obtained. The gap between the generation and utilization is computed. The result shows that if the existing trend continues, cent percent utilization is unlikely to be achieved in near future. Thus, there is an urgent need for more aggressive utilization efforts in order to achieve cent percent utilization of fly ash. Subsequently it is recommended to escalate commercialization of fly ash innovations and technologies developed by various government and private funded research. The findings of the study are expected to assist in informed decision making, planning and managing fly ash utilization.

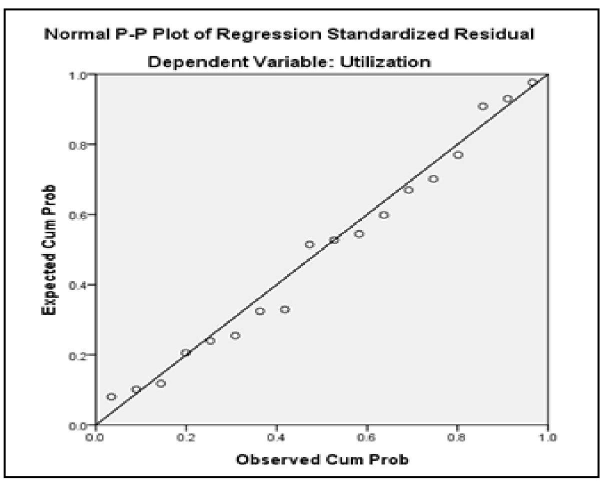
The statistical technique of simple linear regression analysis is used in this study consequently the study possesses all the inherent limitations of the methodology chosen. The limitation includes assumption that the relationship is linear. The prediction of future is based on identification of pattern in the historical data series and assumption that the identified patter will continue to prevail in the future. The result is based on the latest data published by CEA dated August 2014. The data includes 143 coal/lignite based thermal power plants' electricity generation capacity that was operational during 2013-14. Thus the growth trend of past is incorporated; however any aggressive or sluggish growth in production capacity deviating from past trend of growth would require a revision in forecast of generation of fly ash. The methods of forecasting based on identified trend in past treat the system as a black box and make no attempt to discover the factors affecting its behaviour. These limitations can provide directions for further studies. Accordingly future study may use alternative methods such as explanatory models, ARIMA models, qualitative techniques etc. As each forecasting method has its own strengths and limitations, such studies using alternative methods would complement the strength of this study and also serve in overcoming the limitations of this study.

Appendix









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