



## ESTIMATION OF COST OF COAL POWER GENERATION WITH EXTERNAL COSTS FOR SUSTAINABLE DEVELOPMENT IN INDIA

### Engineering

**Rohit Verma**

Associate Professor, National Power Training Institute, Sector -33, Faridabad , Haryana-121003.

### ABSTRACT

Coal-fired power stations contribute to widespread indirect costs, referred to as externalities. These externalities include the contribution to climate change, the effect of emissions, such as particulate matter (PM), sulphur dioxide (SO<sub>2</sub>) and oxides of nitrogen (NO<sub>x</sub>) on the health of peoples, and the effect of coal mining and power generation on water consumption and available water supplies. Furthermore, coal mining and related activities are associated with many forms of environmental degradation, such as habitat loss. It also has a negative impact on the transportation network, and that further contribute to climate change, as well as transportation network maintenance and other problems. The results of the analysis in this paper provide evidence for the need to invest in alternative (renewable) energy sources, and for government to support those investment initiatives for sustainable development. Cost of coal power with the externalities cost is almost double of what we pay for.

### KEYWORDS:

coal power, external cost, sustainable development, cost of power, externalities

### INTRODUCTION

Coal-fired power stations contribute to widespread indirect costs, referred to as externalities. These externalities include the contribution to climate change, the effect of emissions, such as particulate matter (PM), sulphur dioxide (SO<sub>2</sub>) and oxides of nitrogen (NO<sub>x</sub>) on the health of peoples, and the effect of coal mining and power generation on water consumption and available water supplies. Furthermore, coal mining and related activities are associated with many forms of environmental degradation, such as habitat loss. It also has a negative impact on the transportation network, and that further contribute to climate change, as well as transportation network maintenance and other problems.

The majority of these additional costs are indirectly paid by society at large. Markets generally fail to account these costs, since these costs are borne by individuals within society rather than the decision makers or the entity responsible for the pollution and environmental degradation.

This paper estimates the cost of coal power that includes its external costs in India. Based on these estimates, final cost of coal power has been done. In this paper a relatively conservative estimate of the externality cost of coal-fired power generation is provided, because some impacts are excluded due to data availability, quantization and monetization constraints. Despite its conservativeness, the results of the analysis point to rather large externality costs.

For the electricity generation section, there are a number of researchers focusing on electricity external costs. In summary, the main reasons for studying the external cost of power generation include: (a) to provide and diversify multiple technologies; (b) to propose future policy implication; (c) to emphasize the social and environmental impact of external cost. Lingling et al [1] estimated the external costs of a coal-fired plant as 0.072 US \$/kWh for China. They also estimated the cost component wise in dollar per Mwh for CO<sub>2</sub>- 27.410\$, CH<sub>4</sub>- 931.94\$, SO<sub>2</sub>- 4842.7\$, NO<sub>x</sub>- 4459.4\$, CO- 165.99\$, PM<sub>2.5</sub>- 19,471\$, Fly ash - 23\$, Furnace residue -16.5\$, Gangue- 1.2\$, Contaminated water- 3.32\$ respectively for China. Dimitrijević et al. estimated the external costs from coal-fired thermal plants in Bosnia and Herzegovina, mainly focusing on sulphur dioxide emissions [2]. Mahapatra et al [3] estimated external cost of coal based electricity generation for Ahmedabad.

### EXTERNALITIES IN COAL BASED POWER GENERATION

There are various externalities linked to different stages in the life cycle of electricity generation from coal fired thermal stations. However it is evident and stated earlier that in most cases data related to the externalities is unavailable as well as difficult to obtain, a substantial part of the analysis had to depend on estimates from secondary literature. However, effort has been put in to ensure that such estimates are current and relevant to the Indian context. External cost estimation of coal based power generation through the life cycle approach contain the elements/stages outlined in Table 1.

Environmental	Social
<b>Coal Mining &amp; Processing</b>	
Deforestation	Occupational Injuries/disease/deaths & accidents
Emission	Health Impacts & Mortalities in nearby Communities
Contamination & decline of UG & Surface Water Sources	
Land Degradation	
<b>Coal Transportation</b>	
Emission by Diesel Engines	Death & Injuries in Accidents linked to Coal Transportation
<b>Coal Combustion</b>	
Emission	Health Impacts & Mortalities in nearby Communities
Water Consumption & Degradation	
Waste Disposal (Ash)	

### COSTS OF COAL POWER GENERATION WITH EXTERNAL COSTS

Based on the secondary literature available from [1] – [9], the calculation has been done and results are obtained for each head of external costs in various stages of coal fired power generation and expressed in cost rupees/paise per kWh as summarized in Table 2. The summarized result and its graphical representation in Figure 1 illustrates that external cost are almost equal to the LCOE of coal power generation and increase coal power cost by twice. The result in Table 2 clearly illustrates that coal combustion contributes to majority of external costs.

Costs Heads	Cost (Paise per kWh)	%
Cost of GHG Emission due to Deforestation	0.137	0.02
Cost of Water Contamination	132.862	16.11
Cost of Land Degradation	0.264	0.03
Damage Cost of Methane Emission by mines	22.489	2.73
Cost of Fatalities, Morbidity & Injuries in Coal Miners	1.054	0.13
Damage Cost by Coal Transportation	5.127	0.62
Total Damage cost by Gaseous emission	581.140	70.48
Cost of water consumption	17.000	2.06
Cost of Mortality and Morbidity	64.457	7.82
External Cost of Coal Power Generation	824.529	100.00

These cost are calculated from secondary literature that give costs in World Context
External Cost of Coal Power Generation for World is Rs. 8.24 per KWh
Levelized Cost of Coal Power Generation is Rs. World average is Rs. 6.70 per KWh
Estimated Total Cost of Coal Power Generation in world context is Rs. 14.94 per KWh
External costs In Indian Context
Estimated External Cost of Coal Power Generation is Rs. 3.73 per KWh
Levelized Cost of Coal Power Generation is Rs. 3.05 per KWh
Estimated Total Cost of Coal Power Generation in Indian context is Rs. 6.78 per KWh

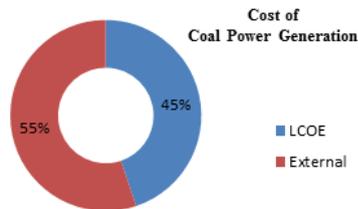


Figure 1: World trend of share of external costs and LCOE in total costs Coal power

**RESULTS & DISCUSSION**

Externalities in Coal Power Generation are Coal Mining & Processing, Coal Transportation, Coal Combustion and are further categorized into two parts i.e. Environmental and Social. The environmental factors taken into account for coal power generation external costing are Deforestation, Emission, Contamination & decline of UG & Surface Water Sources, Land Degradation, Emission by Diesel Engines, Emission. The social factors taken into account for coal power generation external costing are Occupational Injuries/disease/ deaths & accidents, Health Impacts & Mortalities in nearby Communities, Death & Injuries in Accidents linked to Coal Transportation, Health Impacts & Mortalities in nearby Communities. The cost heads for calculating the External Cost of Coal Power Generation are taken as: Cost of GHG Emission due to Deforestation, Cost of Water Contamination, Cost of Land Degradation, Damage Cost of Methane Emission by mines, Cost of Fatalities - Morbidity & Injuries in Coal Miners, Damage Cost by Coal Transportation, Total Damage cost by Gaseous emission, Cost of water consumption and Cost of Mortality and Morbidity. These cost are calculated from secondary literature that give costs in World Context. Finally the External Cost of Coal Power Generation for world average is Rs. 8.24 per KWh. Levelized Cost of Coal Power Generation is Rs. World average is Rs. 6.70 per KWh. Estimated Total Cost of Coal Power Generation in world context is Rs. 14.94 per KWh. Here from the figure1 for world trend of share of external costs and LCOE it is seen that if LCOE is 45% then external costs is 55%. For Indian context Levelized Cost of Coal Power Generation (LCOE) is Rs. 3.05 per KWh (Source: Central Electricity Authority). From the LCOE cost, external Cost of Coal Power Generation has been extrapolated and is Rs. 3.73 per KWh. Estimated Total Cost of Coal Power Generation in Indian context is Rs. 6.78 per KWh.

**CONCLUSIONS**

Coal has been a cheap source of power and electricity since the beginning of the industrial revolution. Cheap and plentiful, coal has problems of environmental and social impacts that were often overlooked because of its very low price. Coal-fired power stations contribute to widespread indirect costs, referred to as externalities. The results of the analysis provide evidence of the need to invest in alternative (renewable) energy sources, and for government to support those investment initiatives for sustainable development. Cost of coal power with the externalities cost is almost double of what we pay for. This study shows that with its external costs coal power is comparable to solar power and other non conventional sources. Over time with technology, environmental awareness for sustainable development, power market advancement and further decrease in costs, nonconventional source of electricity will eventually overtake coal as

our main source of electricity.

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