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Comparative Analysis on Environmental and Economic Parameters of Biomass and Coal Fired Thermal Power Plant

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Abstract: ***This paper is trying to focus our attention to fulfil our current energy demands in sustainable way rather than the conventional methodology that was prevalent before independence in our country. One of the finest ways is to advocate and promote their utilizing factors and environmental friendly characteristics to common people but in technical sense one must need to understand the deep drawn mechanism to put forward this change. This process will be initiated effectively only if we know the better available option with all the relevant factors it deals with. So hereby we are presenting the comparative analysis of coal and biomass fired thermal power plants as per their environmental and economic perspectives. It's well known scenario in any market that without profit why should one invest or take risk and as well if others alternatives are available then what's the point of investing in specifically in this direction. Thus to promote and educate general investor and by acknowledging their monetary safety concern our research proved to be one of vital sources of analytical study in this domain.***
Keywords : biomass, coal, analytical techniques , cost estimation

I. INTRODUCTION

The Power sector is a critical infrastructure element for development of an economy. The availability of reliable, quality and affordable Power is proved to be a vital for rapid growth in agriculture, industry and for overall economic development of a state. For this an efficient, resilient and financially healthy power sector is an essential requirement for growth of a state and economic empowerment of the common man. And the most vital driving mechanism behind this sector is the fuel that it consume for power generation purpose and hence it must be needed to evaluate this fuel on the basis of following criteria's:-

A. Easily availability of fuel at source point.
B. Environmental friendliness qualities of fuel.
C. Economic perspectives for utilization purposes.

So our main point of focus on this analytical study lies on this three perspectives as on the ground to provide a comprehensive basis for choice and selection of fuel so that it will be beneficial for the enhancement of power supply in our region with adequate measures that will manifest to secure sustainability and environmental friendliness as well.

Here on this research our main concern from now on is mainly focused on Biomass and coal as fuel sources. As now a days most of the power demand in our country is fulfilling using coal as the main source of energy but it is also well understood the climatic impacts it hampers and which already burdened to finance and take steps towards its mitigating programmes so alternative need of fuel source is as vital as to provide the requisite demand using existing mechanism. In order to carry forward this challenge and taking it as a bigger opportunity our works focuses on the analytical comparison of coal with Biomass as a fuel for power sector which is having its many advantageous features over fossil fuel coal. The most important is the least environmental impacts strategy which we consider as prerequisite and overall study also conclude with its economic perspective as well as because hindrance to that there won't be chances of applying any of such measures.

It's not the case that there isn't available any other optional source of energy then biomass instead of coal but it's the availability of both time and resources that restrict our work on only this domain so that it will provide specialised case study of biomass versus coal contradiction and its better enhancement for humankind basic power requirement specially in our state i.e. Madhya Pradesh.

II. METHODOLOGY

For better comparative analysis it must be need to include all such parameters which are most and critical in relevant to both the

power plant as per environmental and economic criteria.

A. For Coal Fired Thermal Power Plant

Technical speciality of plant, Fuel source availability and quality, Process description and Technology, Baseline environmental status, Geology and Hydrogeology and Meteorology, Ambient Air Quality, Surface and Ground Water Quality, Noise level survey

B. Anticipated Environmental Impacts and Mitigation Measures

Impacts during Construction Phase and Operational phase

Impact on Land use, Impact on Soil, Impact on Air Quality, Impact on Water Quality, Impact on Noise Levels, Impact on Terrestrial Ecology, Impact on Work Zone, Impact on Community Environmental Monitoring and Control.

Infrastructural Requirements for Monitoring, Environmental Cost, Environmental Organizational Setup, Potential risk areas due to power plant •Disaster and hazard management programme

• Resettlement and Rehabilitation Plan • Project benefits • Cost Provisions for Environmental Measures • Economic survey and analysis: Generation cost analysis, Maintain cost analysis,

Tariff plans assessment.

C. For biomass fired thermal power plant:

Technical speciality of plant, Fuel source availability and quality, Process description and Technology, GHG Project Description, Methodology, Validation protocol and conclusions, participation requirements, general description, baseline methodology, emission reductions, monitoring methodology and monitoring plan, duration of the project activity / crediting period, environmental impacts, Economic Perspectives: Generation cost analysis, Maintain cost analysis, Tariff plans assessment.

D. Environmental parameters:

Coal quality parameters are: - COAL CHARACTERISTICS

Total moisture (%)	15-17
Ash (%)	40-43
GCV (kcal/kg)	3000-3500
Sulphur (%)	0.4-0.5

E. Heavy Metal Components in Coal

Sr. No.	Parameter	Conc. (ppm)
1	Lead	4.31
2	Total Chromium	3.59
3	Copper	6.0
4	Zinc	8.27
5	Magnesium	150.5
6	Calcium	7.19

Volume 5 Issue VI, June 2017
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F. Biomass Composition and Properties

Gross Calorific Value (kCal/kg) GCV on as received basis i.e. wet basis)		Energy (MJ/ton) = Calorific (kCal/kg) x 4.184	Biomass requirement % (based on boiler technical specifications)
Bagasse	2344	9807	30%
Soyabean straw	3589	15016	30%
Gram stalk	3239	13552	30%
Wheat	3717	15552	5%
Tuar	4072	17037	5%

G. Analytical Techniques for Soil Analysis

Parameter	Method (ASTM Number)
Grain size distribution	Sieve analysis (D 422 – 63)
Textural classification	Chart developed by Public Roads Administration
Bulk density	Sand replacement, core cutter
Sodium Absorption Ratio	Flame colorimetric (D 1428-82)
pH	pH meter (D 1293-84)
Electrical Conductivity	Conductivity meter (D 1125-82)
Nitrogen	Kjeldahl distillation (D 3590-84)
Phosphorus	Molybdenum blue, colorimetric (D 515-82)
Potassium	Flame photometric (D 1428-82)
Copper	AAS (D 1688-84)
Iron	AAS (D 1068-84)
Zinc	AAS (D 1691-84)
Boron	Surcumin, colorimetric (D 3082-79)
Chlorides	Argentometric (D 512-81 Rev 85)

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

H. Techniques Used for Ambient Air Quality Monitoring

Parameters	Test Method	Low Detection Limit (g/m3)
PM10,(Respirable Particulate Matter)	Respirable Dust Sampling /High Volume Sampling (Gravimetric)	5.0
Particulate Matter, PM2.5	FRM Method/Low Volume sampling (Gravimetric)	5.0
Sulphur dioxide (SO2)	Modified West and Gaeke Method	4.0
Nitrogen dioxide (NOx)	Sodium Arsenite method	9.0
Carbon Monoxide (CO)	Adsorption and extraction followed by GC-MS analysis	50
Ozone (O3)	Spectrophotometric method	2.0
Ammonia, NH3	Indo-phenol Blue Method	20.0
Benzene, C6H6	Adsorption and desorption followed by GCMS analysis	GCMA – 0.001
Benzo(a)pyrene (BaP)	Solvent Extraction followed by GC-MS	GCMS – 0.001
Arsenic (As)	AAS/ICP-MS method after sampling on EPM Filter paper	GFFA/ICP-MS-0.001
Nickel (Ni)	AAS/ICP-MS method after sampling on EPM Filter paper	GFFA/ICP-MS-0.001
Lead (Pb)	AAS/ICP-MS method after sampling on EPM Filter paper	GFFA/ICP-MS-0.001
Mercury (Hg)	AAS/ICP-MS method after sampling on EPM Filter paper	GFFA/ICP-MS-0.001

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

I. Analytical Technique for Water Quality Testing

Parameters	Units	IS:2296
pH	-	6.5-8.5
Colour	Hazen	-
Conductivity	µS/cm	-
DO	mg/l	4
BOD	mg/l	3
COD	mg/l	-
TDS	mg/l	1500
Total Hardness as CaCO3	mg/l	-
Total Alkalinity as CaCO3	mg/l	-
Calcium as Ca	mg/l	-
Magnesium as Mg	mg/l	-
Residual Chlorine	mg/l	-
Boron as B	mg/l	-
Chlorides as Cl	mg/l	600
Phosphate PO4	mg/l	-
Sulphates as SO4	mg/l	400
Fluorides as F	mg/l	-
Nitrates as NO3	mg/l	50
Sodium as Na	mg/l	-
Potassium as K	mg/l	-
Phenolic Compounds	mg/l	-
Cyanides	mg/l	-
Oil & grease	mg/l	0.1
Anionic Detergents as MBAS	mg/l	-
Cadmium as Cd	mg/l	-

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

Arsenic as As	mg/l	-
Copper as Cu	mg/l	1.5
Lead as Pb	mg/l	-
Iron as Fe	mg/l	50
Chromium as Cr+6	mg/l	-
Selenium as Se	mg/l	-
Zinc as Zn	mg/l	15
Aluminium as Al	mg/l	-
Mercury as Hg	mg/l	-
SAR	-	-
Insecticides	mg/l	-
Total Coliforms	MPN/100	5000

J. Noise Level Survey

The physical description of sound concerns its loudness as a function of frequency. Noise in general is sound, which is composed of many frequency components of various types of loudness levels distributed over the audible frequency range. The most common and universally accepted scale is the A weighted scale, which is measured as dB (A). This is more suitable for audible range of 20 to 20,000 Hz. The scale has been designed to weigh various components of noise according to the response of human ear. The impact of noise sources on surrounding community depends on:

*Characteristics of noise sources (instantaneous, intermittent or continuous in nature). It can be observed that steady noise is not as annoying as one which is continuously varying in loudness;

*The time of day at which noise occurs, for example high noise levels at night in residential areas are not acceptable because of sleep disturbance; and

*The location of the noise source, with respect to noise sensitive land use, which determines the loudness and period of exposure.

The environmental impact of noise can have several effects varying from Noise Induced Hearing Loss (NIHL) to annoyance depending on loudness of noise.

AREA CODE	CATEGORY OF AREA/ZONE	LIMITS IN Db(A) Leq*	
		DAY TIME	NIGHT TIME
(A)	INDUSTRIAL AREA	75	70
(B)	COMMERCIAL AREA	65	55
(C)	RESIDENTIAL AREA	55	45
(D)	SILENCE ZONE	50	40

K. Impact on Ecology

Combustion of coal produces gaseous and particulate pollutants which remain in air, soil and water and their reactions in atmosphere produces other derivatives. Pollutants affect the normal growth of biota ranging from plankton to higher forms of life. The gaseous pollutants like SO2 and NOx, at a very low dose act as atmospheric fertiliser for the vegetation. However, at higher doses, they are injurious to both vegetation as well as animals. The effects on plants range from loss of productivity, chlorosis of

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

leaf tissue to necrosis of leaf tissue and suppressed growth of sensitive species at higher doses. However, since the predicted ambient ground level concentrate of pollutants are within the prescribed AAQ standard the impact during operation would be minimal. Coal dust particles from coal stockyard are injurious to vegetation. The plant exposed to coal dust shows brown necrotic lesions on the leaves, starting at the tip and progressing down the lamina. Fly ash particles affects vegetation including changes in the circular pattern of leaves, decrease in the number and size of stomata, clogging of stomata leading to physiological changes. However, low levels of fly ash in the soil improve the soil condition. Fugitive dust emission from CHP and ash disposal area will be controlled through dust suppression and dust extraction facilities to minimise these impacts.

L. Economic Perspective

Tariff Plan Determination Techniques For Thermal And Biomass

Tariff determination exercise for a 500 MW Thermal Power Plant

1) Given Data

S.No.	Particulars	Normative Parameters
1	Capacity of Plant	500 MW
2	Capital Cost	4 Cr/MW
3	Debt Equity Ratio	70:30*
4	Return on Equity	15.5%*
5	Interest on Loan	10%
6	Working Capital (10% of Total Capital)	200 Cr
7	Interest on working Capital	10%
8	Depreciation Rate	5.28%*
9	Operation and Maintenance cost	13 Lakh/MW*
10	Plant Load Factor (PLF)	80%*
11	Plant Availability Factor	85%*
12	Specific Oil Consumption	10 ml/MW*
13	Price of Oil	Rs. 10,000/Kl
14	Gross Calorific value of Oil	10,000 Kcal/Lit
15	Station Heat Rate	2,425 Kcal/Lit*
16	Cost of Coal	Rs. 1000 / Tonnes
17	Auxiliary Power Consumption	6.50%*
18	Plant Life (For thermal plant based on Coal)	25 Years
19	Gross Calorific value of coal	4000 Kcal/Kg.

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
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Data as per CERC Tariff Regulations for FY 2009-14

			Select State		Others
Assumption for Biomass Power Project Parameters					
S. No.	Assumption Head	Sub-Head	Sub-Head (2)	Unit	Assumptions
1	Power Generation				
		Capacity			
			Installed Power Generation Cap	MW	1
			Auxillary Consumption during	%	11%
			sta Auxillary Consumption after	%	10%
			stab PLF(Stablization for 6	%	60%
			months) PLF(during first year	%	70%
			after Stabliz PLF(second year	%	80%
			onwards) Useful Life	Years	20
2	Project Cost				
		Capital Cost/MW	Power Plant Cost	Rs Lacs/MW	559.03
3	Financial Assumptions				
		Debt: Equity			
			Debt	%	70%
			Equity	%	30%
			Total Debt Amount	Rs Lacs	391.323
			Total Equity Amout	Rs Lacs	167.710
		Debt Component			
			Loan Amount	Rs Lacs	391.323
			Moratorium Period	years	0
			Repayment Period(incld	years	12
			Morator Interest Rate	%	12.76%
		Equity Component			
			Equity amount	Rs Lacs	167.710
			Return on Equity for first 10 year	% p.a	20.00%
			Return on Equity after 10 years	%	24.00%
			Weighted average of ROE	%	22.00%
			Discount Rate (equiv. to WACC)	%	10.70%
4	Financial Assumptions				
		Fiscal Assumptions			
			Income Tax	%	
		Depreciation			
			Depreciation Rate(power plant)	%	5.830%
			Depreciation Rate 13th year	%	2.505%
5	Working Capital				
		For Fixed Charges			
		O&M Charges		Months	1
		Maintenance Spare	(% of O&M exepenses)		15%
		Receivables for Debtors		Months	2
		For Variable Charges			
		Biomass Stock		Months	4
		Interest On Working Capital		%	13.26%
6	Fuel Related Assumptions				
		Heat Rate			
			After Stabilisation period	Kcal/kwh	4063
			During Stablization Period	Kcal/kwh	4063
		Biomass			
			Base Price	Rs/T	3003.01
			GCV - Biomass	Kcal/kg	3174
			Biomass Price Escalation Factor		5.00%
7	Operation & Maintenance				
		O&M Expenses (2016-17)		Rs Lacs	47.26
		O & M Expenses Escalation		%	5.72%
		O&M Expenses (2013-14)		Rs Lacs	40.00

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

M. Final conclusions from analysis reports after site data verification

Both Environmental and Economic data compiled and obtained following analytical conclusions as:-

1) Biomass is renewable in nature, carbon neutral and has the potential to provide large productive employment in rural areas. It is considered as one of the promising sources for generation of power / energy using commercially available thermal and biological conversion technologies.
2) Biomass is an important renewable source of energy that accounts for nearly 75% of rural energy needs, and the rural population constitutes 70% of the total population of India. Although biomass meets a major part of the total energy requirements, it does not find an appropriate place in the overall energy balance of India, probably due to versatility and diversity of biomass sources, resulting in insufficient availability of documented data about availability, consumption and utilization patterns.

Gross biomass potential in Madhya Pradesh (MW)

Biomass feedstock	Potential (MW)
Biomass potential from crop residue	1,255
Biomass potential from Lantana Mexicana	207
Total	**1,462**

3) Domestic REC Market :India released the National Action Plan on Climate Change (NAPCC) on 30 June 2008 outlining its strategy to meet the challenge of climate change, in keeping with India's domestic goal of sustainable development. NAPCC aims to achieve 15% share of renewable electricity in country's total electricity consumption by 2020.
4) Central Electricity Regulatory Commission (CERC) along with the Forum of Regulators (FOR) created a regulation of Renewable Purchase Obligation (RPO) mandating obligated entities viz. distribution utility, large captive generator and open access consumer to have certain share of RE in their total power requirements as stipulated by respective State Electricity Regulatory 's recently announced enhanced ambitious targets of 170 GW by 2020 there is a likelihood of more aggressive upward revision of RPO target by states and thrust on its compliance through enforcement mechanism, which can help grow REC market in the country.
5) CER Market under CDM of UNFCCC
6) UNFCCC under Kyoto protocol created a compliance market, a legally binding obligation for industrialized countries (called as Annex I countries) to reduce GHG emissions to an average of 5% against 1990 levels during the first commitment period of 2008 to 2012. At Conference of Parties (COP) in 2012 it was agreed to have the on-going second commitment period to further reduce the GHG emissions by at least 18% below 1990 levels by 2020, by when a planned new mechanism is envisaged to be in place for implementation. Various deliberations have been going on for several years now about this new mechanism and a clear guiding agreement is expected in December 2015 during the next planned UNFCCC COP-21 meeting at Paris.

Coal fired Thermal power plant induced environmental loss are summarised briefly as per analysis are:-

Health effects of selected coal-fired power plant pollutants

	Human Toxicity		
Substance	Acute (short-term) effects	Chronic (long-term) effects	Comments
Sulphur	Lung irritant, triggers asthma,	Reduces lung function,	Also contributes to acid rain
dioxide	low birth weight in infants.	associated with premature death.	and poor visibility.
Nitrogen	Changes lung function,	Increases susceptibility to	Forms ozone smog and acid
oxides	increases respiratory illness in	respiratory illnesses and causes	rain. Ozone is associated with

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

	children.	permanent alteration of lung.	asthma, reduced lung function,
			adverse birth outcomes and
			allergen sensitisation.
Particulate	Asthma attacks, heart rate	Cardiovascular disease,	Fine particle pollution from
matter	variability, heart attacks.	pneumonia, chronic obstructive	power plants is estimated to
		pulmonary disease, premature	cut short the lives of 30,000
		death.	Americans each year.
Hydrogen	Inhalation causes coughing,	Chronic occupational exposure is	
chloride	hoarseness, chest pain and	associated with gastritis, chronic	
	inflammation of respiratory	bronchitis, dermatitis and	
	tract.	photosensitisation in workers.	
Hydrogen	Inhalation causes severe	Liver and kidney damage.	Very high exposures through
fluoride	respiratory damage, severe		drinking water or air can cause
	irritation and pulmonary edema		skeletal fluorosis.
	(build up of fluid in the lungs)		
Arsenic	Ingestion and inhalation:	Known human carcinogen of	
	affects the gastrointestinal	high potency. Inhalation causes	
	system and central nervous	lung cancer; ingestion causes	
	system.	lung, skin, bladder and liver	
		cancer.	
Cadmium	Inhalation exposure causes	Probable human carcinogen of	Other effects noted from
	bronchial and pulmonary	medium potency. The kidney is	chronic inhalation exposure
	irritation. A single acute	the major target organ in humans	are bronchiolitis and

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

	exposure to high levels of	following chronic inhalation and	emphysema.
	cadmium can result in long-	oral exposure.	
	lasting impairment of lung		
	function.		
Chromium	High exposure to chromium VI	Known human carcinogen of	Chronic effects from exposure
	may result in renal toxicity and	high potency.	are inflammation of the
	internal haemorrhage.		respiratory tract, effects on the
			kidneys, liver and
			gastrointestinal tract
Mercury	Inhalation exposure to	Methyl mercury ingestion causes	The major effect from long-
	elemental mercury results in	developmental effects. Infants	term exposure to inorganic
	central nervous system effects	born to women who ingested	mercury is kidney damage.
	and effects on gastrointestinal	methyl mercury may perform	
	tract and respiratory system.	poorly in neurobehavioral tests.	

N. Benefits Of Biomass Over Coal Fired Thermal Power Plant

The following local benefits/impact happening in the region due to implementation of biomass based industrial activity like power plant in the region.

Proper utilization of surplus biomass and avoidance of burning or dumping

Generation of additional income for rural farmers due to creation of commercial value for the neglected surplus biomass.

Generation of eco-friendly green power and contribution to the availability of quality power in rural areas (due to the majority projects located in rural area)

Creation of indirect employment for rural unemployed youth due to new supply chain management of biomass.

Creation of direct employment for both skilled and unskilled person during the operation of the plant

Contribution to the sustainable development through generation of renewable energy for a grid system that is predominantly conventional fossil fuel based. By utilizing renewable energy sources the project reduces demand /use of fossil fuels for power generation.

Helping to a bridge the gap of electricity demand and supply at local level

Power plant mobilizes several million rupees investment for setting up the project, quite significant amount in a rural area which is deprived of any development projects.

Power plants act as a nucleus for other economic activities such as setting up of cottage industries, hotels, shops etc. around the area, contributing to the economic development around the project area.

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

Major environmental benefits due to promotion of biomass power plants can be summarized as follows:

Apart from avoidance of GHG CO2 emission due to carbon neutral nature (to the tune of 300tonnes of carbon per GWh) biomass power plant also has much lower emissions of SO2, NOx and particulate emissions compared to coal based power plant .

The biomass power plant project reduces the open-air burning of unutilized biomass resources in fields which otherwise result in high particulate emissions as well as contamination of ground water.

The biomass power project reduces the release of methane through decomposition of biomass residues.

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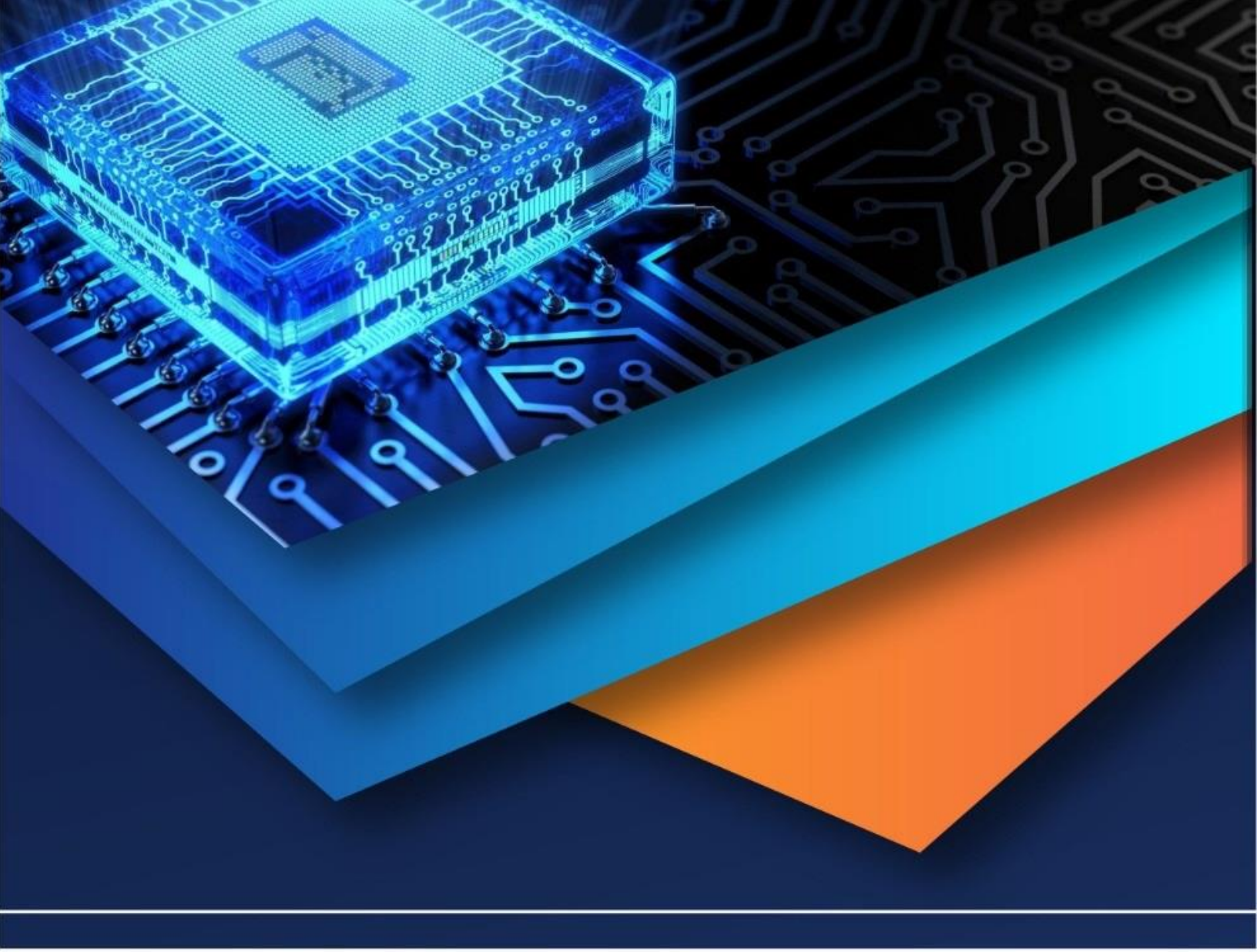

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