Multicriteria Decision Making for Low Emission Technologies in Coal-Fired Power Plant

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Abstract. Nitrogen oxides (NO_x), sulfur oxides (SO_2) and particulate matters (PM) are the major pollutants emitted from burning coal in power stations. Clean coal technologies are technologies designed to enhance the environmental performance of coal through use of the technology to an acceptable level. To mitigating this problem, selecting low emission technologies in coal fired power plant is needed. Various criteria and subcriteria is considered through the selection for low emission technologies such as economic, environmental, technical and technology. This paper focus on identfying multicriteria for low emission in pollution control specified in FGD and SCR technologies. Considering LCOE and lifetime of power plant as criteria or subcriteria in selecting technologies in coal fired plant. This research methodology used is literature review and designed to emphasizing more specific criteria and subcriteria relevant to FGD and SCR technologies in coal power plants. Relevant studies have been used as reference to ensure the multicriteria comprehensively represent for selecting low emission technologies.

Keywords: *low emission technologies; multicriteria; clean coal technologies; FGD; SCR; coal power plant.*

1 Introduction

Indonesia's per capita electricity consumption over the four years grew around 26% from 812 kWh in 2014 to 1,021 kWh in 2017. Indonesia relies heavily on fossil fuel power plants to meet its electricity needs. More than 88% of the energy comes from fossil fuels (coal accounts for about 60%, natural gas 22% and oil 6%) and only 12% is renewable energy (Arinaldo & Adiatma, 2019) As of 2020, Indonesia was the 7th largest user of coal power generation in the world contributing 2.2% of global coal consumption (Asmarini, 2021). Coal consist of carbon, sulphur, oxygen, hydrogen, nitrogen and heavy metals are the results of decayed plants and the process is known as coalification (Munawer, 2018). Nitrogen oxides (NOx), sulfur oxides (SO2) and particulate matters (PM) are the major pollutants emitted from burning coal in power stations (Li, et al., 2008). Some of these air pollutants have been confirmed to have serious harmful

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effects such as major environmental challenges, affecting human beings and ecosystems (IESR, 2023).

However, the clean coal technologies is used to reduce pollutant in power generation. Clean coal technologies are technologies designed to enhance the environmental performance of coal through use of the technology to an acceptable level. Clean Coal Technologies encompass a diverse array of technologies pertaining to the production and use of coal. Clean coal technologies consist of coal purification, coal conversion, technologies in pollution control, and carbon capture storage. Pollution control technologies are divided into desulfurization technology, denitration technology, PM control technology and demercuration technology (Chang, 2016).

The most widely method used to reduce SO_2 is Flue Gas Desulfurization (FGD). FGD classified into 3 (three) categories including wet FGD, dry FGD and semi-dry FGD (Hanif, 2020). Meanwhile reducing NO_x through denitrification technology such as Selective Catalytic Reduction (SCR) is significant improvement of exhaust gas emissions (Negri, et al., 2020). This paper focus on identfying multicriteria for pollution control decision making at coal power plant specified in FGD and SCR technologies.

2 Literature Review

The power sector is facing challenges in technological changes to achieve green energy through the using of low emission technologies. By this technological changes, the problem arise is not only in economic perspective but also from another perspective such as environmental, government regulation, the development of the technologies, and others. The complexity and multiciplity problems to achieve this goal is considers as the main problem in the top management of power generation system (Lipka & Szwed, 2021). It considers other perspective such as environmental, government regulation, and others percpective that influence the power generation systems.

Multi criteria decision making (MCDM) can be used for solving the complex problem in power generation system. Many researchers used this method to solve the problems of decisions in using low emission technologies, Liu, et al., (2023) used this methodology for evaluating the sustainability of flue gas desulfurization technologies in the iron and steel industry in China. The criteria used for the evaluation consider environmental, economic and technological dimensions. This research also consider fifteen subcriteria were indentified as global warming potential, ecological impact, toxicity hazard, land occupation, resource depletion, capital cost, operating cost, technical maturity, environmental risk, waste utilization potential, system operation and maintenance (O&M), reliability, flexibility, operational applicability and pollutant removal efficiency (Liu, et al., 2023).

On the other hand, selecting clean coal technologies using several multicriteria have been applied in Brazil's coal fired power plants. The evaluation criteria considers deployment time, combustion efficiency, support operations, cost of investment, cost of maintenance and GHG emission. The results shows that the investment in a coal process is the most applicable technology to reduce the CO_2 emissions. The factors that drive the implementation of clean technologies and the optimization of processes are often linked to continuous process industries, such as thermoelectric plants, where diminishing effluents can lead to significant cost reductions. Nonetheless, the benefit of clean technologies is the potential to transform wasteful expenditures into increased revenue and productivity (Oliveira, et al., 2020).

Meanwhile, Liu, et al., (2020) set three layer indicators in evaluation of desulfurization and denitrifications tehcnologies of six typical enterprise in Chengdu, China. The first layer are considers economic aspect, technical aspect, and environmental aspect. The second layer include process maturity, impact on sounding environment; capital cost, operating cost, cost of desulfurization and denitrification, removal rate, dosage and SO_4^{2-} concentration (Liu, et al. 2020).

In terms of technologies use for power plants, the cost of electricity generation or LCOE are determination from capital costs, operating costs, and discount rate. Another study by Lagtah, et al (2019), analyzing the

techno economic of the performance on coal based IGCC power plants, the determination of LCOE consist of capital expenditure, direct capital cost, indirect capital cost and operating and maintenance costs. Also the lifetime of power plant is has to be considered as the determination of LCOE (Lipka & Szwed, 2021). Similarly, reseacrh by Broek, et al (2009) calculated the lifetime of power plant in LCOE determination.

In conclusion, the research in multicrieria decision making for low emission technologies should consider LCOE and lifetime of power plant as criteria or subcriteria in selecting technologies in coal fired plant. LCOE is needed to determine the incremental cost of coal fired power plant production costs while the lifetime of power plant is used in the LCOE calculation as an assumption for each technology used in the power plant. Therefore, these indicators can represent the effect of adding new technologies in power plant.

3 Material and Method

This research methodology used is literature review. Literature review determines how research about multicriteria for decision making in selecting low emission technologies in coal power plant. This approach aims to understand how each criteria and subcriteria consider for decision making in selecting technologies. Previous studies have offered various criteria and subciteria also each study presents different technologies using in clean coal technologies in various object. In this study, the comparison with prior research aims to identify gaps and relevance of criteria and subcriteria. This research is designed to emphasizing more specific criteria and subcriteria relevant to FGD and SCR technologies in coal power plants.

Table 1. Previous Studies in Low Emission Technologies

No	Authors	Technologies	Criteria and Subcriteria	Object
1	Liu, Mengyue, et al (2023)	FGD, Bag Filter, SCR	1. Environmental : a. Global Warming Potential b. Ecological Impact c. Toxicity Hazard d. Land Occupation	Iron and Steel Industry

No	Authors	Technologies	Criteria and Subcriteria	Object
			e. Resource Depletion 2. Economic : a. Capital Cost b. Operating Cost 3. Technological : a. Technical Maturity b. Environmental Risk c. Waste Utilization Potential d. System O&M Difficulty e. Reliability f. Flexibility g. Operational Applicability h. Pollutant Removal Efficiency	
2	Liu, Hezjiun, et al (2020)	Desulfurization and Denitrification Technologies	1. Economic : a. Unit Investment b. Operating Cost c. Desulfurization & Denitifrication Cost 2. Technical : a. Removal Rate b. Dosage c. Process Maturity d. SO Concentration 3. Enviromental : a. By Products Recyclability b. Impact on the Surrounding Environment	Power Generation, Cement Industry, Rubber Industry and Glass Industry
3	Oliviera, et al (2020)	Powdered Mineral Coal, Fluidized Bed Combustion, IGCC, CCS	1. Deployment Time 2. Combustion Efficiency 3. Support Operations 4. Cost of Investment 5. Cost of Maintenance 6. GHG Emissions	Power Generation
4	Lipka & Szwed (2020)	Supercritical coal fired power plant, Supercritical coal fired power plant with CCS, IGCC, IGCC with CCS, IGCC, CCS and Integrated Hydrogen Production	1. Amount of Capital Expenditures 2. Cost Purchasing CO2 emission allowances 3. The unit cost of electricity generation 4. Raw material demand 5. Knowledge of Technology 6. Profitability of the investment project	Power Generation

No	Authors	Technologies	Criteria and Subcriteria	Object
			7. Capacity availability 8. Development perspective	

4 Results and Discussion

This study have been selected 4 (four) criteria and 14 (fourteen) sub criteria for the indicators in selecting low emission technologies. Indicators which using in this study is derived from comprehensive literature review and approved by the practicioner in low emission technologies. The selected criteria and sub criteria are considers as the main aspect that effect the selection of low emission technology in economics perspective, environmental perspective, technology and technical perspective.

Economic perspecive is the main consideration in selecting technologies, the costs incurred by technology selection are calculated based on Life Cycle Costing (LCC). LCC is a method used to calculate the costs arising from an asset over its life cycle and evaluate alternatives that have an impact on ownership costs (Barret in Jati, 2022). The economic indicators based on capital costs and operating costs. In the addition of technology for coal fired power plant, it also takes into account the cost of electricity production or commonly referred to as the unit cost of electricity generation or LCOE. The addition of technology will result in additional capital costs and operating costs so that it will affect the LCOE of the plant. Also, the lifetime of power plants is considers in LCOE determination. In this study, using capital cost, operation cost, LCOE and lifetime of power plant as the sub criteria for the economic indicators.

Ensuring the implementation of low emission technologies in coal fired power plant accordance with environmental regulations set by the government is an important consideration. The environmental impact of technology use is the significant factor used in selecting technologies in power plant. The environmental impact referred to in these studies is how the use of low emission control technology can reduce the potential for environmental damage due to the use of coal as a combustion fuel, including how it can reduce pollution released into the air including SO_2, NO_x, PM, ozone depletion, soil acidification through acid rain and heavy

metal pollution in water. In addition to environmental impacts, there are other sub-criteria used such as toxicity hazard and depletion in natural resources. In the use of FGD technology, a hazardous waste is produce. The waste produce gypsum which is a substance category of hazardous waste so it is necessary to manage the waste so as not to pollute the environment. Meanwhile the use of FGD technology, especially for the cooling process, the use of large amounts of water is required and will have an impact on the availability of water in the area around the coal fired power plant.

Technology that is developed in such a way as to reach a point where the technology is at the maturity stage, then the technology can be used commercially. Developing low emission technology, it is necessary to defined the condition of technology that can be used commercially so that the effectiveness of technology use has reached the theoretical efficiency limit of technology development. In this study, the application of FGD and SCR technology is expected to reduce SO_2 and NO_x emissions optimally because these two technologies have been used widely in various industry. Another concern of the technology indicator is the efficiency of pollutant reduction and the potential for waste reduction from the application of low emission technologies. The efficiency of pollutant reduction in these studies is how effective the technology used is in reducing SO_2 and NO_x while the potential for waste management is used in other forms that generate added value such as building materials.

The low emission technologies such as FGD and SCR in coal fired power plant is expected that will not have an impact on the reliability and flexibility of the existing generating system. The application of this technology is also expected to be able to adjust to the existing conditions both from the specifications of the main components, spare parts and also the operating system. In this study, it is defined that system reliability is a criterion in evaluating the technology used does not cause potential incidents in system operations while operational applicability is defined as an evaluation factor for installing technology to existing systems or called retrofits. The application of technology is expected to be able to adjust to the existing conditions of the system as well as to the main components of the generating machine and spare parts. The flexibility of technology must

be able to adjust to the complexity of the existing system installation. Table 2 present the complete criteria and subcriteria in this study.

Table 2. Criteria and Subcriteria for Selecting Low Emission Technologies

No	Criteria	Literature	Subcriteria	Literature	Defenition
1	Economics	Liu, Mengyue, et al (2023); Liu, Hezijun, et al (2020	Capital Expenditure (CAPEX)	Liu, Mengyue, et al (2023); Liu, Hezijun, et al (2020); Oliviera, et al (2020); Lipka & Szwed (2021)	Cost of investment such as equipments, installation costs, and land.
			Operating Expenditure (OPEX)	Liu, Mengyue, et al (2023); Liu, Hezijun, et al (2020);	Cost of operational such as material cost and other overhead cost.
			Unit Cost of Electricity Generation (LCOE)	Lipka & Szwed (2021)	Considers capital expenditures, operating and discount rate.
			Lifetime of Power Plant	Broek, Machteld van den, et al (2009)	Lifetime power plant considers in determination of LCOE
2	Environmentals	Liu, Mengyue, et al (2023); Liu, Hezijun, et al (2020)	Impact on the Surrounding Environment	Liu, Mengyue, et al (2023); Liu, Hezijun, et al (2020);	The impact of damage to the environment such as atmospheric pollution and ozone depletion.
			Toxicity Hazard	Liu, Mengyue, et al (2023)	Toxic substances in chemicals as the effect from the technologies.
			Resource Depletion	Liu, Mengyue, et al (2023)	Resources consumption such as water, metal and fossil.
3	Technology	Liu, Mengyue, et al (2023)	Technology Maturity	Liu, Mengyue, et al (2023);	The development sttage of technology to reach the theoretical efficiency limit

No	Criteria	Literature	Subcriteria	Literature	Defenition
			Waste Utilization Potential	Liu, Mengyue, et al (2023)	The potential waste resources generated by the technologies.
			Efficiency Removal Pollutant	Liu, Mengyue, et al (2023)	The efficiency of technologies to removes PM, SO_2, Nox
4	Technical	Liu, Hezijun, et al (2020)	Operation & Maintenance System	Liu, Mengyue, et al (2023)	Operation and maintenance system to the retrofits
			Reliability	Liu, Mengyue, et al (2023)	The possibility of an incidenct occuring in the actual operation.
			Flexibility	Liu, Mengyue, et al (2023)	The ability to recover from the failure of the system.
			Operational Applicability	Liu, Mengyue, et al (2023)	The applicability of the technologies in the existing system.

5 Conclusion

This research highlight the criteria and subcriteria using for selecting low emission technologies in coal power plant. The unique subcriteria was added due to characteristic in power generation such as LCOE and lifetime of power plant. The criteria and subcriteria present at Table 2 provides more detailed and systematic for decision makers in selecting low emissions technologies in coal fired power plants.

Future research should focus on further developing on criteria and subcriteria for clean technologies due to energy demand for reducing emissions and green energy.

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