Environmental Analysis of Coal-Fired Power Plants in Ultra Supercritical Technology Versus Integrated Gasification Combined Cycle

Dwi Ratna Mustafida[1*], Abdul Wahid [2], and Yuli Amalia Husnil[3]

[1*,2] Chemical Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia
[3]Chemical Engineering Department, Institut Teknologi Indonesia, Serpong 15314, Indonesia.
*E-mail: mustafida25@gmail.com

ABSTRACT

This study evaluates and compared the performance of coal-fired power plants in ultra-supercritical (USC) versus integrated gasification combined cycle (IGCC). System performance in terms of environmental analysis. Base on the exhaust emissions than IGCC and USC in terms of SO_2, CO_2, CO, and H_2S. The IGCC system is modeled and simulated with post-combustion capture and both of them used sub-bituminous coal from the Indramayu PLTU. The result display that with the same amount of raw materials (20 ton/h coal) the IGCC produce lower exhaust emissions than USC. IGCC produced 7.80 ton CO_2-eq. / MWh and USC of 27.93 ton CO_2-eq. / MWh. IGCC technology for the long term will be better than USC because it has produced greater electrical power with the amount of material the same coal standard and produces lower exhaust emissions.

Keywords: Clean Coal Technology, USC, IGCC, environmental analysis, sub-bituminous

INTRODUCTION

(Coal contributed the largest share of global electricity generation in 2015 by 39%, followed by 23% for natural gas, 16% for hydro and 11% for nuclear (Figure 1) Until 2050, the share of coal, although declining, will remain the largest, with coal continuing to function as a basic electricity source ((IEEJ), 2017).

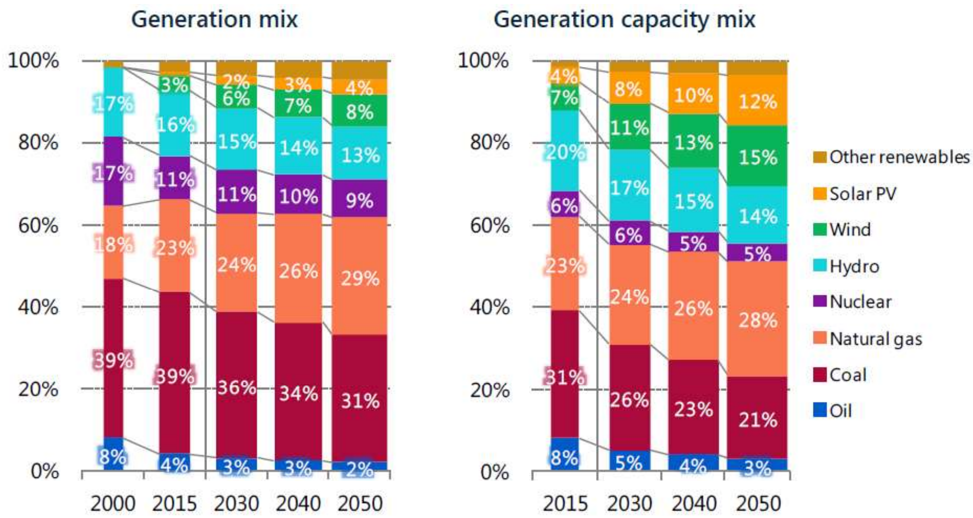

Figure. 1 Global Power Plant Energy Sources [Reference Scenario]((IEEJ), 2017)

Combustion of fuel produced high exhaust emission especially CO_2 gases which increased pollutant concentration in air. Coal contributed 44% of total global CO_2 emissions and became the largest source of GHG (greenhouse gas) emissions, which trigger the acceleration of climate change. In 2017 the composition of Indonesia's electricity production was projected to be 55.6% using coal, and in 2026 coal use would still 50.4% ((persero), 2017).

In addition, Indonesia had signed a Paris Agreement in 2015 where Indonesia should reduce CO_2 emissions by 29% in 2030.

The existing technology in the electricity sector was Ultra Supercritical (USC) and Integrated Gasification Combined Cycle (IGCC). The study of this research is to compare the efficiency of both of these technologies to environmental analysis aspect using Unisim and

Promax Simulation Program. The coal data was obtained from Indramayu PLTU. The data of this research were compared to the *Intergovernmental Panel on Climate Change Guidelines* to obtain the calculation. From report Huaneng Greengen Co the result shows that USC has higher exhaust emissions than IGCC in terms of SO_2, CO_2, NO_x, CO and slag (Co., 2008).

Much research has been done to improve equipment efficiency and optimization in the (CCT) power plants by analyzing processes from various aspects such as energy (first law of thermodynamics), exergy (second law of thermodynamics), economy and environmental (4-E). The main purpose of this paper is to analyze the previous work done by researchers related to CCT power plant 4-E analysis. If anyone extracts the ideas for the development of the concept of using the article, we will achieve our goal. This review also indicates the scope of future research in the clean coal technology power plants

METHODOLOGY

Process description

The flowsheet of the IGCC process used in the analysis is shown in Figure 2. The process is composed of the following five integrated blocks: coal sizing and slurry preparation, gasification, syngas cooling, and cleaning, acid gas removal (AGR), CO_2 gas Removal and combined cycle power section. However, Figure 2, directly shows the flow diagram of the process of separating H_2S until the process of generating electricity from the syngas of the gasifier reactor output and Figure 3 shown the cryogenic CO_2 separation. Figure 4. Shown the flowsheet of the process of USC. The process is composed of the following two integrated blocks: boiler subsystem and the steam turbine system.

Modeling, simulation, and calculation

An IGCC post-combustion and USC plant integrated with CO_2 capture are modeled and simulated using UniSim Design® R450 and Promax® 4.0 simulation software. The composition of syngas products and IGCC process model based on experimental data (Asif, Bak, Saleem, & Kim, 2015; Wang, 2017). The USC proses model is based on the validated model of Yang, et al. and Zhou, et al. (Yang et al., 2013; Zhao et al., 2017). The Cryogenic is based on a reference model (Air Liquide Indonesia. PT). The model is based on a steady-state operation. In the heat exchanger, there is a pressure drop of 5 psi. Pump efficiency of 65%, Turbine efficiency, and compressor of 75 %. Coal specification was obtained from the Indramayu PLTU and mass was 20000 kg/h shown in Table 1.

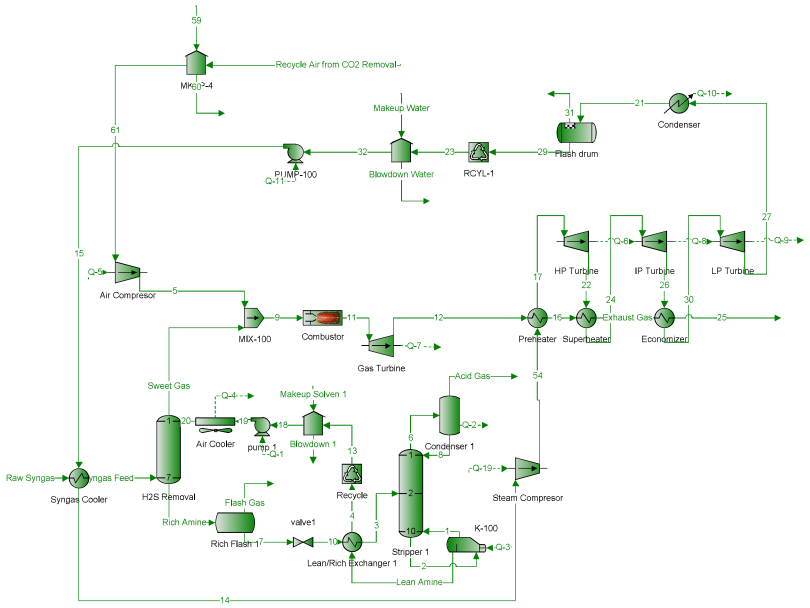

Figure 2. Schematic of the IGCC system with *Promax® 4.0*

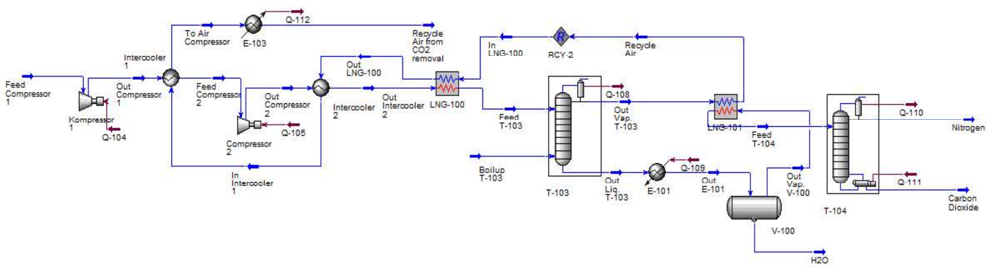

Figure 3. Schematic of the cryogenic CO_2 separation system

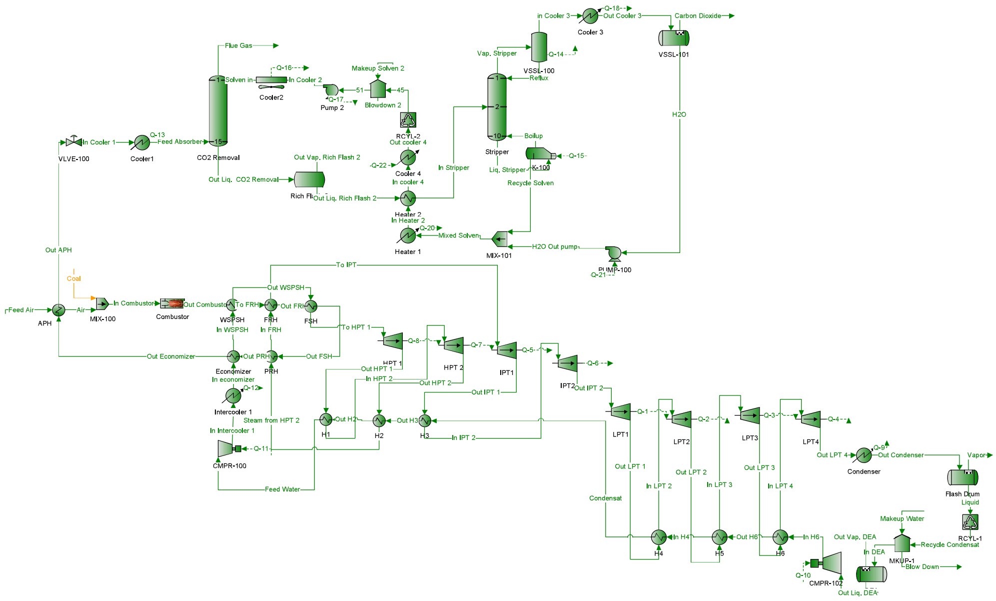

Figure 4. Schematic of the USC system with *Promax® 4.0*

Table 1. Composition analysis of coal

Composition	Value (% wt)
Proximate analysis	
Moisture	14.34
Fixed carbon	37.63
Volatile matter	43.47
Ash	4.56
Ultimate analysis	
C	55.42
H	4.20
N	0.71
S	0.1
O	20.67
Ash	4.56
Calorific value, HHV (kcal/kg)	4236

Environmental analysis is carried out based on the calculation of GHG emissions (CO_2) in the energy sector in the power plant sub-sector. The methodology used in calculating this emission is the method established by the Intergovernmental Panel on Climate Change Guidelines in the

2006 IPCC Guidelines. The application of this method has been stipulated in LHK Ministerial Regulation Number P.73 / Men LHK / Setjen / Kum.1 / 12/2017 dated 29 December 2017 concerning the Implementation and Reporting Guidelines for Greenhouse Gas Inventories. Broadly speaking, the calculation of GHG emissions/ removals is obtained through multiplying data on activities with emission factors, the Global Warming Potential (GWP) index was used to evaluate the climate change impact. The GWP index allows all of the GHG flows during the operation period, $\dot{m}_{GHG}^{op}$, to be expressed on a CO_2_eq basis as shown in the simple equation:

$$\dot{m}_{GHG}^{op} = \sum_{j=1}^{N} \dot{m}_j^{GHG} \times GWP_j \qquad (1)$$

According to the Intergovernmental Panel on Climate Change (IPCC 2007), the GWP index evaluated over 100 years was considered to be 1 for CO_2, 28 for CH_4 and 265 for N_2O (Restrepo, Miyake, Kleveston, & Bazzo, 2012)

RESULTS AND DISCUSSION

Environmental analysis

The environmental model predicted an emission from the process of 7.249 ton CO_2-eq./MWh to IGCC and 25.97 ton CO_2-eq./MWh to USC. The power plant emissions correspond to 87.7%, followed by the pre-burning process (belt conveyors, fans, mills, and others) with 7.3%. The mining and transport stages account for 5% (Restrepo et al., 2012). Figure 5. Shown GHG emissions for IGCC and USC. Table 2 shown the gas emission produce from IGCC and USC.

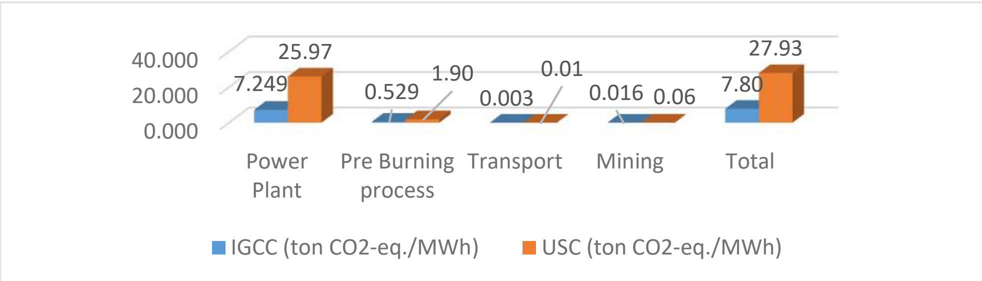

Figure 5. GHG emissions for IGCC and USC

Table 2. Gas emission produce from IGCC and USC

Emission	IGCC (kg/h)	USC (kg/h)
CO	0.005	12.493
CO_2	37351.860	43936.008
Methane	165.744	-
H_2S	23.293	-
SO_2	0.088	39.959
Ammonia	0.457	-

Gas emission produces on IGCC technology shown in Table. 2 in kg/h and then convert to tons/year and N_2O emission obtained from CO_2 emissions produced are multiplied by the mass of coal and the emission factor N_2O. CO_2 emissions produced amounted to 295826.73 tons/year, of CH_4 emissions 1312.70 tons/year and N_2O emissions of 7864.594 tons/year and then multiplying with Global Warming Potential (GWP) index to obtain CH_4 emissions of 36755.49 tons of CO_2-eq/year and emissions of N_2O 2084117.36 tons of CO_2-eq/year and total GHG emissions of 2416699.58 tons of CO_2-eq/year.

These emissions are the emissions generated in the power plant process and it is assumed that the pre-burning process (belt conveyors, fans, mills, and others) emissions are 7.3% and the mining and transport stages account for 5%. The total GHG emissions produced are divided by the total net power produced which is 42 MWh or 333373.91 MWh/year. after being divided by total electricity production, the following emissions were obtained: 7.249 tons of CO_2-eq./MWh in the power plant process, 0.529 tons of CO_2-eq./MWh on the Pre Burning process, 0.003 tons of CO_2-eq./MWh in Transport and 0.016 tons of CO_2 -eq./MWh on Mining so that total GHG emissions amounted to 7.80 tons of CO_2-eq./MWh

In USC technology the emissions calculation would equal with IGCC, The CO_2 produced is 347973.18 tons/year, of CH_4 emissions 61672.762 tons/year and N_2O emissions are 9250.914 tons/year and then after multiplying with Global Warming Potential (GWP) index to obtain emissions of CH_4 1726837.34 tons CO_2-eq/year and N_2O emissions 2451492.295 tons CO_2-eq/year and total GHG emissions of 5083038.062 tons CO_2-eq/year. The total GHG emissions produced are divided by the total net power produced which is 22 MWh or 174266.70 MWh/year. After being divided by the total electricity production, the following emissions are obtained 25.97 tons CO_2-eq./MWh in the power plant process, 1.90 tons CO_2-eq./MWh on the Pre Burning process, 0.01 tons CO_2-eq./MWh at Transport and 0.06 tons CO_2-eq./MWh on Mining so that the total GHG emissions are 27.93 tons of CO_2-eq./MWh.

Another gas emission produced is IGCC, producing CO emission of 0.005 kg/h, H_2S 23.293 kg/h, SO_2 0.088 Kg/h and Ammonia 0.457 kg/h while USC produces CO emissions of 12.493 kg/h and SO_2 of 39.959 kg/h.

CONCLUSIONS

This paper conducted a comprehensive study to evaluate and compare the performance of coal fire power plants between ultra-supercritical (USC) and integrated gasification combined cycle (IGCC). Both processes are modeled and simulated, and environmental analysis is used to evaluate the results. The following conclusions can be derivate:

- Total GHG emissions for IGCC was 7.80 tons of CO_2-eq./MWh and USC of 27.93 tons of CO_2-eq./MWh.
- Another gas emission produced is IGCC, producing CO emission of 0.005 kg/h, H_2S 23.293 kg/h, SO_2 0.088 kg/h and Ammonia 0.457 kg/h while USC produces CO

emissions of 12.493 kg/h and SO_2 of 39.959 kg/h.

IGCC technology requires a greater investment because there are several additional tools such as gasifiers gas turbines and H_2S removal, but when compared to USC, this technology for the long term will be better because it has produced greater electrical power with the amount of material the same coal standard and produces lower exhaust emissions.

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