POTENTIAL GREEN HOUSE GAS REDUCTION IN SODA CAUSTIC INDUSTRY

Potensi Pengurangan Gas Rumah Kaca di Industri Soda Kaustik

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Abstrak

Indonesia memiliki kapasitas industri kaustik soda yang besar di Asia Tenggara. Untuk mengetahui potensi pengurangan Gas Rumah kaca (GRK) pada industri kasutik soda di Indonesia. Pada makalah ini dengan menggunakan metodologi SA_AM001 tentang Pengenalan Efisiensi Tinggi Elektrolis di Pabrik Pengolahan Soda kaustik, dihitung potensi pengurangan emisi gas rumah kaca dari konsumsi energi elektrolizer. Metodologi ini telah diterapkan di Kerajaan Arab Saudi, dan dengan menggunakan beberapa asumsi diimplementasikan di Republik Indonesia.

Kata kunci: *pengurangan emisi, kaustik soda industri, skema jcm, metodologi*

Abstract

Indonesia has a large capacity of soda caustic industry in South-East Asia. In order to know a potency of Green House Gas (GHG) reduction amount in soda caustic industry in Indonesia, in this study, using the methodology of SA_AM001 concerning Introduction of High-Efficiency Electrolyzer in Soda caustic Processing Plant. A potency of GHG emission generated from energy consumption of electrolyzers is calculated. The methodology has been implemented in the Kingdom of Saudi Arabia and using several assumptions to be implemented in the Republic of Indonesia.

Keywords: *emission reduction, soda caustic industry, jcm scheme, electricity, methodology*

1. INTRODUCTION

Green House Gas (hereinafter is referred to as GHG) reduction activity for tackling global warming have been starting by a force since 2005 when Clean Development Mechanism started. Through CDM many projects related to the GHG reduction had started by developed countries in the developing countries area. However, since the economic crisis in Europe in 2008, the carbon market price was falling down and finally, reached the lowest price in 2013. In that time, almost all CDM project activities in the world were stopped or postponed. In Indonesia as a developing country, the CDM project activity in that year became fewer and in the following year, the CDM project was none.

In exchange for GHG reduction activity, in 2011, Japanese government through the bilateral cooperation with Asian countries build the new mechanism to reduce GHG emission, which named by Joint Crediting Mechanism (hereinafter referred to as JCM) (Jun, Tae Yong *et al.*, 2016; Sugino, M., *et al.*, 2017; Muhammad Djindan, 2016). In each country which had has the bilateral cooperation with Japanese Government to implement JCM project, Secretariat of the Joint Committee for the Joint

Crediting Mechanism (JCM) between both country was established. The joint committee has a role to organize and to monitor the project implementation including the methodology proposed to calculate GHG emission for each project which proposed to be implemented in that country. A less than half of the investment cost of the JCM project can be subsidized by Japanese Government through Japanese Ministry of Environment or Ministry of Economy, Trade, and Industry. In addition, the technology proposed in the JCM project should be the first implementation in the proposed sector in that country.

In this paper by using a comparison with the JCM project which already implemented in the soda-caustic industry in the Kingdom Arab Saudi, the potential of GHG emission reduction in the soda caustic industry in Indonesia is discussed. In soda caustic industry, the electrolyzers are the main contributor to GHG emission because consumes the highest energy. The GHG reduction is conducted by a replacement of the existing elements of ion exchange membranes bipolar electrolyzers with the latest model of ion exchange membranes.

1.1 Electrolytic Process

Three kinds of electrolysis process by brine electrolysis widely used in soda caustic industry are diaphragm cells, mercury cells, and membrane cells. In recent years, however, there have been fewer plants using the mercury method and the ion-exchange membrane method has become increasingly common. This trend seems to reflect (1) the introduction of an energy-saving process (ion-exchange membrane method/IEM), (2) consideration of the impact of mercury on health and the environment, and (3) reaction to regulations laid down by the Minamata Convention on Mercury in 2013.

In addition, the ion-exchange membrane method has an advantage of power consumption (consumption rate) per production volume of caustic soda or chlorine is generally 24% to 36% less than the mercury and diaphragm methods. This advantage can be utilized to reduce GHG emission from the electricity consumption of the electrolyzers. The basic technology of membrane cell was established in Japan in the 1970s and has been developed and improved to date. Since 1999, all caustic soda production in Japan has been producing by ion-exchange membrane technology.

An ion-exchange membrane is a membrane used for separating anode and cathode chambers, and a fluorine-based cation-exchange membrane is generally used. In brine electrolysis, an oxidation reaction occurs in the anode chamber and reduction reaction occurs in the cathode chamber, which means the mixture and isolation of substances generated in both chambers must be controlled. The ion-exchange membrane used here is the cation-exchange membrane. Na^+ (the sodium ion) in the anode chamber migrates to the cathode chamber through the membrane while Cl^- (chlorine ion) generated in the anode chamber remains, as it cannot pass the membrane. On the other hand, water molecules are reduced to hydrogen and OH^- (hydroxide ion) in the cathode chamber but most of the OH^- cannot pass the membrane, which means NaOH (caustic soda) is generated in the cathode chamber by Na^+ migrating from the anode chamber and OH^- . At this time, the anode chamber becomes strongly oxidized due to chlorine ions while the cathode chamber is strongly alkaline. In addition, liquid temperature increases during the brine electrolysis, both the chemical durability and the separation are required for the ion-exchange membrane. Therefore, a fluoro-based ion-exchange membrane composed of a polymer equipped with a perfluorocarbon backbone and a cation-exchange ability is applied. The latest kind and high efficiency of ion exchange membrane is F-8080 type. This kind o membrane has a higher durability against impurities, high stability of current efficiency and lowest and stable current voltage (Asahi Glass Co. Ltd, 2016). This type of ion exchange membrane is proposed in the JCM project. Figure 1 shows the typical of ion-exchange membrane

Figure 1. Ion-Exchange Membrane Method Electrolyzer (<http://www.eurochlor.org>)

1.2. Soda Caustic Industries in Indonesia

In 2006, about 84% of the total world soda caustic was produced electrolytically using diaphragm and membrane cells, while about 13% was made using mercury cell (Babatope A. Olufemi *et al.*, 2011). In Indonesia the biggest soda- caustic Indonesia, Asahi Chemical which has the same group with the soda-caustic biggest producer in the World.

Table 1 shows the soda caustic industry in Indonesia. Except for Asahi Chemical and PT Sulfindo Adiusaha, the others soda caustic producer uses their soda caustic production to their paper industry. Therefore, the potential GHG reduction is calculated for only two biggest soda caustic producers, which is Asahi Chemical and PT. Sulfindo Adiusaha below. Both companies use ion exchange membrane provided by Asahi Kasei Corporation.

Table 1. Caustic Soda Producer

Company	Capacity (t-NaOH/yr)
Asahi Chemical	700,000
PT Sulfindo Adiusaha	320,000
PT. Indah Kiat Pulp & Paper	165.000
PT. Lontas Papyrus Pulp & Paper	419.950
PT. Pindo Deli Pulp & Paper Mills	80.000
PT. Pabrik Kertas Tjiwi Kimia	112.000
PT. Pabrik Kertas Indonesia	52.800
PT. Riau Pulp Andalan & Paper	260.000
PT. Tanjungenim Lestari Pulp & Paper	9.100
PT. Toba Pulp Lestari	33.000
PT. OKI Pulp & Paper Mills	100.000
PT. Pabrik Kertas Nusantara	13.825
PT. Pabrik Kertas Indonesia	52.800
PT. Riau Pulp Andalan & Paper	260.000

2. MATERIAL AND METHOD

2.1. Calculation Method

The calculation method uses the methodology of Introduction of High Efficiency Electrolyzer in Soda

Caustic Processing Plant which approved by Secretariat of the Joint Committee for the Joint Crediting Mechanism (JCM) between Saudi Arabia and Japan (<https://www.jcm.go.jp>).

$$RE_p = \sum_i EC_{RE,i,p} \times EF_{elec} \dots\dots\dots(1)$$

where,

Rep_p :Reference emissions during the period p [tCO₂/p]

$EC_{RE,i,p}$:Electricity consumption of the reference electrolyzer i, during the period p [MWh/p]

EF_{elec} :CO₂ emission factor for consumed electricity [tCO₂/MWh]

$EC_{RE,i,p}$ is to be calculated by the following equation.

$$EC_{RE,i,p} = EC_{PJ,i,p} \times \frac{SEC_{RE,i}}{SEC_{PJ,i}} \dots\dots\dots(2)$$

where,

$EC_{PJ,i,p}$:Electricity consumption of the project electrolyzer i during the period p [MWh/p]

$SEC_{RE,i}$:Specific electricity consumption of the reference electrolyzer I [kWh(DC)/t-NaOH]

$SEC_{PJ,i}$:Specific electricity consumption of the project electrolyzer I [kWh(DC)/t-NaOH]

$$PE_p = \sum_i EC_{PJ,i,p} \times EF_{elec} \dots\dots\dots(3)$$

where,

Pe_p :Project emissions during the period p [tCO₂/p]

$EC_{PJ,i,p}$:Electricity consumption of the project electrolyzer i during the period p [MWh/p]

EF_{elec} :CO₂ emission factor for consumed electricity [tCO₂/MWh].

In this study the EF_{elec} is 0.958 [t-CO₂/MWh] (Irhan Febijanto, 2013).

$$ER_p = PE_p - RE_p \dots\dots\dots(4)$$

where,

Er_p :Emission reduction during the period p [tCO₂/p]

Pe_p :Reference emissions during the period p [tCO₂/p]

Re_p :Project emissions during the period p [tCO₂/p]

2.2. Reference Emission

Based in the fact that the technology provider of ion membrane electrolyzer in the Kingdom of Saudi Arabia and the Republic of Indonesia is mainly provided by Asahi Kasei, thus so the value of RE for Indonesian soda caustic industry can be assumed same with the Saudi Arabian soda caustic industry.

Reference emissions are calculated below

business as usual (BaU) emissions which represent plausible emissions in providing the same outputs or service level of the proposed JCM project in the host country. Reference emissions are the estimated emission that would have occurred under the reference scenario in the same country/the host country. The value can be derived from the current situation and performance, average historical performance, performance of similar product and technologies that compete with the proposed project technology, legal requirement, and best available technology of the host country.

The method to calculate reference emission is determine by JCM secretary in each host country. In this study, the methodology of Introduction of High Efficiency Electrolyzer in Soda Caustic Processing Plant, Version 01.0 (<https://www.jcm.go.jp>) is used. Based on the methodology, the Specific Emission Consumption (hereinafter referred to as SEC) for one-unit electrolyzer is defined under standard condition, 32% NaOH and 90° C, and the value of SEC should be less than the threshold SEC values in each rank of Current Density (hereinafter referred to as CD) as shown in the table below.

Table 2. Rank of SEC for one unit of electrolyzer (<https://www.jcm.go.jp>)⁹

CD (Current Density)	Threshold SEC value of the electrolyzer	
[kA/m ²]	[kWh(DC)/t-NaOH]	
4.0? CD<4.5	2,045	
4.5? CD<5.0	2,088	
5.0? CD<5.5	2,131	
5.5? CD<6.0	2,174	
6.0? CD<6.5	2,217	

3. RESULT AND DISCUSSION

The SEC is assumed to be a same with a SEC value in the Kingdom of Saudi Arabia of 2,088 kWh (DC)/t-NaOH. The total capacity production is 1,020,000 t-NaOH/yr, which consist of 8 units of electrolyzer. For one electrolyzer,

$EC_{RE,i,p}$ is calculated using equaiton (2),
 $EC_{RE,i,p} = 23,755.2$ [MWh/yr]x 2,088.0[kWh(DC) /t-NaOH]/1,990 [kWh(DC)/t-NaOH]
 $= 24,925.0$ [MWh/yr]

PE_p is calculated by using equation (3)
 $PE_p = 23,755.2$ [MWh/yr]x 0.958 [t-CO₂/MWh]
 $= 22,757.5$ [t-CO₂/yr]

RE_p is calculated by using equation (1)
 $RE_p = 24,9250$ [MWh/yr]x 0.958 [t-CO₂/MWh]
 $= 23,878.2$ [t-CO₂/yr]

Total CO₂ reduction one-unit electrolyzer is calculated by equation (4),

$$ER_p = (23,878.2 - 22,757.5) [\text{t-CO}_2/\text{yr}]$$

$$= 1,120.7 [\text{t-CO}_2/\text{yr}]$$

Total CO₂ reduction from 8 unit is

The GHG reduction from 8 units of electrolyzer installed in both factory is calculated as follows,
 $= 8 \times 1,120.7 [\text{t-CO}_2/\text{yr}]$
 $= 8,965.8 [\text{t-CO}_2/\text{yr}]$

The potential reduction from a replacement of the existing IEM bipolar electrolyzers with the latest model gives a potential reduction for each electrolyzer of 1,120.7 [t-CO₂/yr]. The reduction in the soda caustic industry can be more increased by substituting the fuel boilers with hydrogen produced from electrolyzers. The boilers are used for steam production. However, the investment cost and other factors should be considered to determine the feasibility of the implementation.

4. CONCLUSION

This study indicates the potential of GHG reduction by reducing the energy consumption of electrolyzers. The GHG potential amount in Indonesian soda caustic industry is quite higher than the potential at Saudi Arabian soda caustic industry. The higher potential of GHG reduction amount caused by a higher capacity production and a higher value of the emission factor in the regional grid.

By the replacement of the existing elements of ion-exchange membrane bi-polar electrolyzers which has the highest electricity consumption in the soda caustic industry, the replacement of eight units of electrolyzers with the total capacity of 50,000 [t-NaOH/yr] can reduce CO₂ emission amount of 8,965.8 [t-CO₂/r]. The possibility of implementation of this project is higher because a half of the investment cost can be covered by a subsidized by a Japanese government through Joint Crediting Mechanism scheme.

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