

Additional information to the Proposed Methodology
“Introduction of High Efficiency Electrolyzer in Caustic Soda Production Plant”

1. Calculation of electricity consumption of the reference electrolyzer

The electricity consumption of the reference electrolyzer is calculated by the electricity consumption of the project electrolyzer (which is monitored) and ratio of specific electricity consumption (SEC) values between reference and project electrolyzer, as follows:

$$EC_{RE,i,p} = EC_{PJ,i,p} \times \frac{SEC_{RE,i}}{SEC_{PJ,i}}$$

where

- $EC_{RE,i,p}$: Electricity consumption of the reference electrolyzer i during the period p [MWh/p]
- $EC_{PJ,i,p}$: Electricity consumption of the project electrolyzer i during the period p [MWh/p]
- $SEC_{RE,i}$: SEC value of the reference electrolyzer i [kWh/t-NaOH]
- $SEC_{PJ,i}$: SEC value of the project electrolyzer i [kWh/t-NaOH]

SEC value of the project electrolyzer ($SEC_{PJ,i}$) is set to be the value of the performance guarantee provided by manufacturer of the project electrolyzer. SEC value of the reference electrolyzer ($SEC_{RE,i}$) is the default value set in the next section.

2. SEC values of the reference electrolyzer

2.1. SEC values of electrolyzers

Japan Soda Industry Association made SEC value of electrolyzers in Japan available on their web site¹. The average SEC value is **2,364 kWh(DC)/t-NaOH** in 2016, which is described with yellow line in Figure.1 below. It is noted that there are 30 plants in Japan and all plants introduced the electrolyzer of Ion-exchange membrane (IEM) technology, and the SEC value is calculated based on the provided result from each plant.

On the other hand, according to a document “Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali” (European Commission, 2014), the average of bipolar ion-exchange membrane electrolyzers is reported as 2,574 kWh(AC)/t-Cl₂, which is almost equal to 2,281 kWh(AC)/t-NaOH. Hence the value is calculated to be within the range of **2,191 kWh(DC)/t-NaOH to 2,236 kWh(DC)/t-NaOH** assuming the general AC/DC efficiency of 96% to 98%, which is described with blue line in in Figure.1

¹ “Trends in electricity consumption, purchased / private electrify, and the power consumption rate” Japan Soda Industry Association, https://www.jsia.gr.jp/en/data/statistics_08.pdf

bellow.

The performance guaranteed values of SECs of possible model of bipolar ion-exchange membrane electrolyzers available in Thailand were collected and averaged within the range of current density (CD) **2.9 kA/m²** to **5.4 kA/m²**, taking the same CD ranges as those documented in the abovementioned document by European Commission. The values are plotted with the gray dot in Figure.1 below. The averaged SEC value is calculated as **1,999 kWh(DC)/t-NaOH**, which is shown in the orange line in the Figure.1 below.

As a result, it is considered that the electrolyzer of the possible model available in Thailand has comparable efficiency advantage as it has the lower SEC value than that of electrolyzers reported in the document published in EU. Hence it is determined to be the reference electrolyzer.

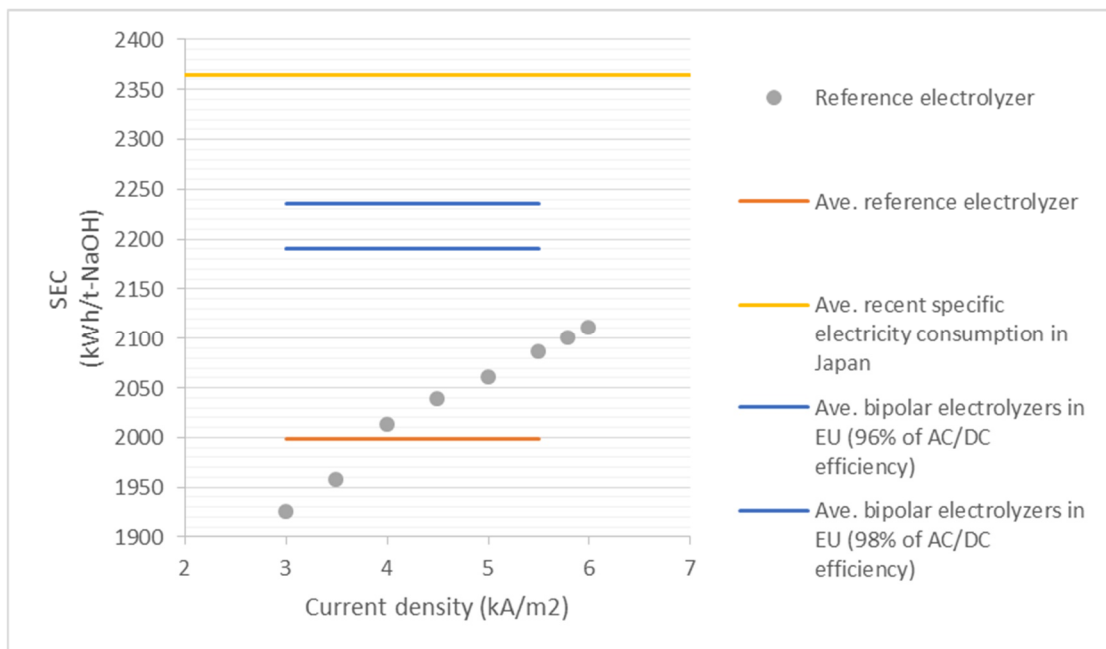


Figure 1: SEC values of electrolyzers

2.2. Determination of SEC values of the reference electrolyzer in Thailand

In order to make it comparable, the SEC values of reference electrolyzer and project electrolyzer are both based on performance guarantee.

Considering the fact that SEC values are positively correlated with CD, the SEC values of reference electrolyzer are set into five range of CDs. Accordingly, the default values of SEC of the reference electrolyzer are as shown in Table 1 below.

Table 1: Default value of SEC of the reference electrolyzer

| CD [kA/m ²] corresponding to SEC performance guarantee of the project electrolyzer | SEC value of the reference electrolyzer [kWh/t-NaOH] |
|------------------------------------------------------------------------------------------------|------------------------------------------------------|
| 4.0 CD < 4.5 | 2,013 |
| 4.5 CD < 5.0 | 2,038 |
| 5.0 CD < 5.5 | 2,061 |
| 5.5 CD < 6.0 | 2,086 |
| 6.0 CD < 6.5 | 2,110 |

3. Aged deterioration of SEC value in electrolyzers

It is known that SEC value worsens with operation time because of deterioration of ion-exchange membranes and electrodes. It is considered that deterioration rate and its effect on SEC values are same on both reference and project electrolyzer from the result of interviews from the manufacturers. Accordingly, deterioration rate is not taken into account in the methodology as the reference emissions are calculated based on the ratio of SEC values between reference and project electrolyzer.