Appendix 1

Additional information to the Proposed Methodology

"Introduction of High Efficiency Electrolyzer in Chlor-Alkali Procesing 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) between reference and project electrolyzer, as follows:

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

where

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

SEC of the project electrolyzer ($SEC_{PJ,p}$) is set to be the value of the initial performance test by manufacturer of the project electolyzer. SEC of the reference electrolyzer ($SEC_{RE,p}$) is the default values set in the next section.

2. Specific electricity consumption (SEC) values of the reference electrolyzer

2.1. SEC values of electrolyzers

Japan Soda Industry Association made SEC of electrolyzers in Japan available in their web site[1]. The average SEC is **2379 kWh(DC)/t-NaOH** in 2014, which is described with blue line in in Figure.1 bellow. It is noted that there are 30 plants in Japan and all plants introduced the electrolyzer of Ion-exchange membrane method (IEM), 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 2574kWh(AC)/t-Cl_2. which is almost equal to 2281 kWh(AC)/t-NaOH. Hence the value is calculated to be within the range of **2191kWh(DC)/t-NaOH to 2236 kWh(DC)/t-NaOH** assuming the general AC/DC efficiency of 96% to 98%, which is described with

[1] "Trends in electricity consumption, purchased / private electrify, and the power consumption rate" Japan Soda Industry Association, http://www.jsia.gr.jp/explanation_05.html

yellow line in in Figure.1 bellow. .

In addition, the operating SECs of the existing bipolar ion-exchange membrane plant in Saudi Arabia were collected within the range of current density from **2.9 kA/m2** to **5.4 kA/m2**, taking the same current density ranges as those documented in the above mentioned document by European Commission. The values are plotted with the black dot in Figure.1 bellow. The averaged SEC and current density is calculated as **2210 kWh(DC)/t-NaOH** and 4.14kA/m2 respectively, which are plotted with the orange dot in the Figure.1 bellow.

As a result, it is considered that the electrolyzer at the exiting bipolar ion-exchange membrane plant in Saudi Arabia has comparable efficiency advantage as it has the efficiency level of almost equivalent to the performance of electrolyzers reported in the document published in EU.

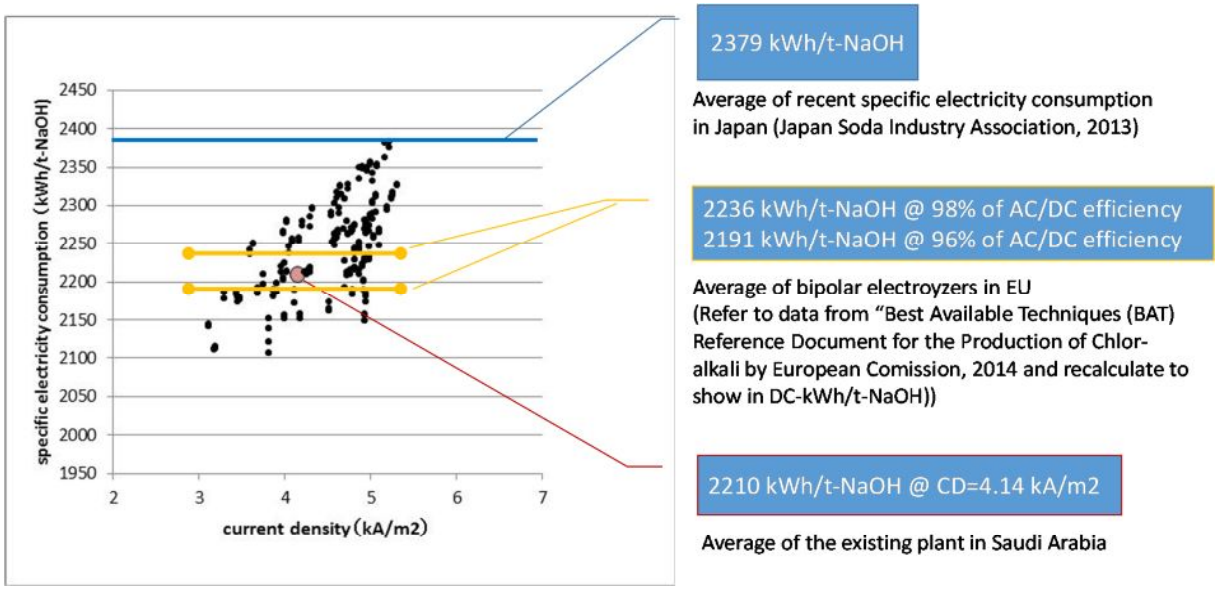

Figure 1: SEC values of electrolyzers

2.3. Determination of SEC values of the reference electrolyzer in Saudi Arabia

In order to calculate reference emissions, SECs of an initial performance test for the electrolyzer at the exiting bipolar ion-exchange membrane plant in Saudi Arabia was collected in order to make it comparable to the SECs of project electrolyzer which are also based on an initial performance test. An initial performance test is conducted at the time of installation by manufactures to check that the installed electrolyzer operates properly. Therefore, the designed SEC value for initial performance value of existing electrolyzer is adopted as the SEC values of the reference electrolyzer.

Considering the fact that the initial performance test is conducted based on production plan of chlor-alkali and it varies for each plant, as well as that SECs are positively correlated with CD, the reference SECs are

set into five range of CDs. Accordingly, the default values of reference SECs are as shown in Table 1 below.

Table 1: The reference SECs values set as default values in this methodology

CD (Current density) [kA/m2] of performance guarantee by manufacturer of the project electrolyzer	Default value of specific electricity consumption of the electrolyzer [kWh/t-NaOH]
$4.0 \leqq CD < 4.5$	2045
$4.5 \leqq CD < 5.0$	2088
$5.0 \leqq CD < 5.5$	2131
$5.5 \leqq CD < 6.0$	2174
$6.0 \leqq CD < 6.5$	2217

3. Aged deterioration of SEC in electrolyzers

It is known that SEC worsens with operation time because of deterioration of ion-exchange membranes and electrodes. It is considered that deterioration rate and its effect on SECs 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 SECs between reference and project electrolyzer.