Joint Crediting Mechanism Approved Methodology SA_AM001
"Introduction of High Efficiency Electrolyzer in Chlor-Alkali Processing Plant"

A. Title of the methodology

Introduction of High Efficiency Electrolyzer in Chlor-Alkali Processing Plant, Version 01.0

B. Terms and definitions

Terms	Definitions
Electrolyzer	An equipment used for the electrolysis of alkali chloride solution, composed of an anode chamber, anode, cathode chamber, cathode, and an ion exchange membrane.
Ion-exchange membrane method (IEM)	Method for the electrolysis of alkali chloride solution separates the cathode and anode chambers, in which a cation exchange membrane possesses special properties that permit only transmission of cations (positive ions) not of anions (negative ions).
Bipolar electrolyzer	Electrolyzer in which the elements are connected in series and the power supply is connected only to the end part of the electrolyzer.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	Installing ion-exchange membrane electrolyzer, which reduces electricity resistance of the electrolyzer unit and achieves electricity consumption reduction in the chlor-alkali process. This methodology applies to the project that aims for saving energy by introducing high efficiency electrolyzer for the target factory, commercial facilities etc. in Saudi Arabia.
Calculation of reference emissions	Reference emissions are GHG emissions from using reference electrolyzer, calculated with power consumption of project electrolyzer, ratio of the initial guarantee of specific electricity

	consumptions of reference/project electrolyzers and CO_2 emission factor for electricity consumed. The initial guarantee of the electrolyzer has to be satisfied at the new plant, whose membranes, electrodes and other elements are in the condition that has not used and shows the best performance.
Calculation of project emissions	Project emissions are GHG emissions from using project electrolyzer, calculated with electricity consumption of project electrolyzer and CO_2 emission factor for electricity consumed.
Monitoring parameters	● Electricity consumption of project electrolyzer ● The amount of fuel consumed and/or the amount of electricity generated by captive power, where applicable.

D. Eligibility criteria

This methodology is applicable to projects that satisfy all of the following criteria.

Criterion 1	Project electrolyzer employs an ion-exchange membrane technology in electrolyzers in the manufacturing process of chlor-alkali and the electrolyzer is the bipolar type.
Criterion 2	Specific electricity consumption (SEC) for project electrolyzer *i* under the standard conditions, 32% NaOH and 90 degrees Celsius is less than threshold SEC values set in the table below under the standard conditions, 32% NaOH and 90 degrees Celsius; (see table below) Project specific electricity consumption is derived from specifications based on initial performance test by manufacturer.

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

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption by reference electrolyzer	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumption by project electrolyzer	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions are calculated by multiplying electricity consumption of project electrolyzer and ratio of specific electricity consumption for reference/project electrolyzer, and CO_2 emission factor for consumed electricity. The specific electricity consumption of reference electrolyzer is conservatively set as a default value in the following manner to ensure net emission reductions.

All electrolyzers in the chlor-alkali process in Japan employ ion-exchange membrane technology, and the average of specific electricity consumptions of the electrolyzers is 2,379 kWh (DC)/ton-NaOH (Japan Soda Industry Association, 2014).

The range of averaged specific electricity consumptions of the Bipolar type electrolyzers in EU is from 2,191 kWh (DC)/t-NaOH to 2,236 kWh(DC)/t-NaOH based on the document “Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali, 2014” by assuming general AC/DC efficiency of 96% to 98%.

The operating SECs of the existing bipolar ion-exchange membrane plant in Saudi Arabia were collected and averaged within the range of current density taking the same current density ranges as those in the above mentioned document. Accordingly the averaged SEC is calculated as 2,210 kWh (DC)/t-NaOH.

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. Hence it is determined to be the reference electrolyzer.

In order to calculate reference emissions, SECs of an initial performance test for the reference electrolyzer was collected in order to make it comparable to the SECs of project electrolyzer which are also based on an initial performance test.

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 current density, the reference SECs are set into five range of current densities. The specific electricity consumptions of the initial performance test value of the electrolyzert is determined as 2,045, 2,088, 2,131, 2,174 and 2,217 kWh (DC)/ton-NaOH corresponding to the range of current densities of 4.0, 4.5, 5.0, 5.5 and 6.0 kA/m^2 respectively.

F.2. Calculation of reference emissions

$$RE_p = \sum_i EC_{RE,i,p} \times EF_{elec}$$

RE_p	:	Reference emissions during the period p [tCO_2/p]
$EC_{RE,i,p}$	:	Electricity consumption of the reference electrolyzer i during the period p [MWh/p]
EF_{elec}	:	CO_2 emission factor for consumed electricity [tCO_2/MWh]

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

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

$EC_{PJ,i,p}$	:	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]

G. Calculation of project emissions

$$PE_p = \sum_i EC_{PJ,i,p} \times EF_{elec}$$

PE_p	:	Project emissions during the period p [tCO_2/p]
$EC_{PJ,i,p}$	:	Electricity consumption of the project electrolyzer i during the period p [MWh/p]
EF_{elec}	:	CO_2 emission factor for consumed electricity [tCO_2/MWh]

H. Calculation of emissions reductions

$$ER_p = PE_p - RE_p$$

ER_p	:	Emission reduction during the period p [tCO_2/p]
RE_p	:	Reference emissions during the period p [tCO_2/p]
PE_p	:	Project emissions during the period p [tCO_2/p]

I. Data and parameters fixed *ex ante*

The source of each data and parameter fixed *ex ante* is listed as below.

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
<tr><td>$SEC_{RE,i,p}$</td><td>Specific electricity consumption of the reference electrolyzer i [kWh (DC)/t-NaOH]. The default value is set by the following table.
<table>
<tr><td>CD (Current density) [kA/m^2] of performance guarantee by manufacturer of the project electolyzer</td><td>Default value of SEC of the electrolyzer [kWh(DC)/t-NaOH]</td></tr>
<tr><td>$4.0 \leq CD < 4.5$</td><td>2,045</td></tr>
<tr><td>$4.5 \leq CD < 5.0$</td><td>2,088</td></tr>
<tr><td>$5.0 \leq CD < 5.5$</td><td>2,131</td></tr>
<tr><td>$5.5 \leq CD < 6.0$</td><td>2,174</td></tr>
<tr><td>$6.0 \leq CD < 6.5$</td><td>2,217</td></tr>
</table></td><td>Additional information
The default SEC values are derived from the initial performance test value of existing electrolyzer which is installed in the chlor-alkali processing plant in Saudi Arabia.
The survey should prove the use of clear methodology.
The $SEC_{RE,i}$ should be revised if necessary from survey result which is conducted by the Joint Committee or project participants.</td></tr>
</table>

$SEC_{PJ,i,p}$	Specific electricity consumption of the project electrolyzer *i* [kWh(DC)/t-NaOH].	Specification of the project electrolyzer *i* prepared for the performance test by manufacturer
EF_{elec}	CO_2 emission factor of electricity consumed. When the project equipment consumes only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively. When the project equipment may consume both grid electricity and captive electricity, the project participant applies the CO_2 emission factor with lower value. [CO_2 emission factor] For grid electricity: The most recent value available from the source stated in this table at the time of validation For captive electricity, it is determined based on the following options: a) Calculated from its power generation efficiency (η_{elec} [%]) obtained from manufacturer's specification The power generation efficiency based on lower heating value (LHV) of the captive power generation system from the manufacturer's specification is applied; $$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$ b) Calculated from measured data	[Grid electricity] The most recent value available at the time of validation is applied and fixed for the monitoring period thereafter. The data is sourced from the National Committee for the Clean Development Mechanism (Saudi Arabia DNA for CDM), unless otherwise instructed by the Joint Committee. [Captive electricity] For the option a) Specification of the captive power generation system provided by the manufacturer (η_{elec} [%]). CO_2 emission factor of the fossil fuel type used in the captive power generation system (EF_{fuel} [tCO_2/GJ]) For the option b) Generated and supplied electricity by the captive power generation system ($EG_{PJ,p}$ [MWh/p]). Fuel amount consumed by the

<table>
<tr>
<td></td>
<td>The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{PJ,p}$) and the amount of electricity generated ($EG_{PJ,p}$) during the monitoring period p is applied. The measurement is conducted with the monitoring equipment to which calibration certificate is issued by an entity accredited under national/international standards;
$$EF_{elec} = FC_{PJ,p} \times NCV_{fuel} \times EF_{fuel} \times \frac{1}{EG_{PJ,p}}$$
Where:
NCV_{fuel} : Net calorific value of consumed fuel [GJ/mass or volume]

Note:
In case the captive electricity generation system meets all of the following conditions, the value in the following table may be applied to EF_{elec} depending on the consumed fuel type.
● The system is non-renewable generation system
● Electricity generation capacity of the system is less than or equal to 15 MW
<table>
<tr><th>fuel type</th><th>Diesel fuel</th><th>Natural gas</th></tr>
<tr><td>EF_{elec}</td><td>0.8 *1</td><td>0.46 *2</td></tr>
</table>
*1 The most recent value at the time of validation is applied.
*2 The value is calculated with the equation in the option a) above. The lower value of default effective CO_2 emission factor for natural gas (0.0543tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine</td>
<td>captive power generation system ($FC_{PJ,p}$ [mass or volume/p]).
Net calorific value (NCV_{fuel} [GJ/mass or volume]) and CO_2 emission factor of the fuel (EF_{fuel} [tCO_2/GJ]) in order of preference:

1) values provided by the fuel supplier;
2) measurement by the project participants;
3) regional or national default values;
4) IPCC default values provided in table 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.

[Captive electricity with diesel fuel]
CDM approved small scale methodology: AMS-I.A.

[Captive electricity with natural gas]
2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.
CDM Methodological tool "Determining the baseline efficiency of thermal or</td>
</tr>
</table>

	systems (42%) are applied.	electric energy generation systems version02.0" for the default efficiency for off-grid power plants.

History of the document

Version	Date	Contents revised
01.0	18 October 2017	Decision by the Joint Committee Initial approval.