Joint Crediting Mechanism Approved Methodology TH_AM015
"Introduction of High Efficiency Electrolyzer in Caustic Soda Production Plant"

A. Title of the methodology

Introduction of High Efficiency Electrolyzer in Caustic Soda Production Plant, Version 01.0

B. Terms and definitions

Terms	Definitions
Electrolyzer	An equipment used for the electrolysis of sodium chloride solution, composed of an anode chamber, anode, cathode chamber, cathode, and an ion exchange membrane.
Ion-exchange membrane (IEM) technology	Method for the electrolysis of sodium chloride solution separating 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 power consumption reduction in the caustic soda process. This methodology applies to the project that introduces high efficiency electrolyzer in caustic soda production plant.
Calculation of reference emissions	Reference emissions are GHG emissions from using reference electrolyzer, calculated with power consumption of project electrolyzer, ratio of the performance guaranteed values of

	specific power consumptions (SECs) of reference/project electrolyzers and CO_2 emission factor for consumed electricity.
Calculation of project emissions	Project emissions are GHG emissions from using project electrolyzer, calculated with power consumption of project electrolyzer and CO_2 emission factor for electricity consumed.
Monitoring parameters	● Power consumption of project electrolyzer

D. Eligibility criteria

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

Criterion 1	Bipolar electrolyzer(s), which employs an ion-exchange membrane technology, is installed in the manufacturing process of caustic soda.
Criterion 2	SEC value of project electrolyzer under the standard conditions, 32% NaOH and 90 degrees Celsius is less than threshold SEC value set in the table below under the standard conditions, 32% NaOH and 90 degrees Celsius;

CD (Current density) [kA/m^2]	Threshold SEC value of the electrolyzer [kWh (DC)/t-NaOH]
$4.0 \leq CD < 4.5$	2,013
$4.5 \leq CD < 5.0$	2,038
$5.0 \leq CD < 5.5$	2,061
$5.5 \leq CD < 6.0$	2,086
$6.0 \leq CD < 6.5$	2,110

SEC value of project electrolyzer is derived from performance guaranteed value provided by manufacturer.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Power consumption of reference electrolyzer	CO_2
Project emissions	
Emission sources	GHG types
Power consumption of project electrolyzer	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

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

All electrolyzers in the caustic soda process in Japan employ ion-exchange membrane technology, and the average of SEC values of the electrolyzers is 2,364 kWh (DC)/t-NaOH (Japan Soda Industry Association, 2016).

The range of averaged SEC values of the bipolar 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% (European Commission, 2014).

The performance guaranteed values of SECs of possible model of bipolar electrolyzer available in Thailand were collected and averaged within the same CD ranges as those in the above-mentioned document by European Commission (2.9 kA/m^2 to 5.4 kA/m^2). Accordingly, the averaged SEC value is calculated as 1,999 kWh (DC)/t-NaOH.

As a result, it is considered that the possible model of bipolar electrolyzer which is available in the country 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.

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

Considering the fact that SEC values are positively correlated with CD, the reference SEC values are set into five range of CDs. The SEC values of the reference electrolyzer are determined as 2,013, 2,038, 2,061, 2,086 and 2,110 kWh (DC)/t-NaOH corresponding to the range of CDs of 4.0, 4.5, 5.0, 5.5 and 6.0 kA/m^2 respectively.

F.2. Calculation of reference emissions

$$RE_p = \sum_i EC_{RE,i,p} \times EF_{elec} = \sum_i \left(EC_{PJ,i,p} \times \frac{SEC_{RE,i}}{SEC_{PJ,i}} \right) \times EF_{elec}$$

RE_p : Reference emissions during the period p [tCO_2/p]

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

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

$SEC_{RE,i}$: SEC value of the reference electrolyzer i [kWh(DC)/t-NaOH]

$SEC_{PJ,i}$: SEC value of the project electrolyzer i [kWh(DC)/t-NaOH]

EF_{elec} : CO_2 emission factor for consumed electricity [tCO_2/MWh]

i : Identification number of project electrolyzer [-]

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]

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

EF_{elec} : CO_2 emission factor for consumed electricity [tCO_2/MWh]

i : Identification number of project electrolyzer [-]

H. Calculation of emissions reductions

$$ER_p = RE_p - PE_p$$

ER_p : Emission reductions 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.

Parameter	Description of data	Source
$SEC_{RE,i}$	SEC value of the reference electrolyzer i [kWh (DC)/t-NaOH]. The default value is set by the following table.	Additional information The default values are derived from the performance guaranteed value of possible model electrolyzer available in Thailand. The $SEC_{RE,i}$ should be revised if necessary from survey result which is conducted by the Joint Committee or project participants.
$SEC_{PJ,i}$	SEC value of the project electrolyzer i [kWh(DC)/t-NaOH].	Performance guaranteed value provided by manufacturer of the project electrolyzer.
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]. When the project electrolyzer consumes only 1) grid electricity, 2) captive electricity or 3) electricity directly supplied from other sources (e.g. independent power producer (IPP), small power producer (SPP) and very small power producer (VSPP)) to the project site, the project participant applies the CO_2 emission factor respectively. When the project electrolyzer may consume electricity supplied from more than 1 electric source, the project participant applies the CO_2 emission factor with the lowest value.	**Case 1)** [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 "Grid Emission Factor (GEF) of Thailand", endorsed by Thailand Greenhouse Gas Management Organization (TGO) unless otherwise instructed by the Joint

Default values for $SEC_{RE,i}$:

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

	[CO$_2$ emission factor] **Case 1) Grid electricity** The most recent value available from the source stated in this table at the time of validation **Case 2) Captive electricity including cogeneration system** EF_{elec} 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; $EF_{gen} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$ b) Calculated from measured data 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 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	Committee. **Case 2)** [Captive electricity] For 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 Option b) Generated and supplied electricity by the captive power generation system ($EG_{PJ,p}$ [MWh/p]). Fuel amount consumed by the 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 tables 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is

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<td>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><td>fuel type</td><td>Diesel fuel</td><td>Natural gas</td></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 systems (42%) are applied.

Case 3) Electricity directly supplied from other sources including cogeneration system
EF_{elec} is determined based on the following options:
a) The value provided by the electricity supplier with the evidence;
b) The value calculated in the same manner for the option a) of 2) captive electricity as instructed above;
c) The value calculated in the same manner for the option b) of 2) captive electricity as instructed above;
When the project electrolyzer may consume electricity supplied from more than 1 electric source, the project participant applies the CO_2 emission factor with the lowest value.</td>
<td>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 electric energy generation systems version 02.0" for the default efficiency for off-grid power plants.

Case 3)
[Electricity directly supplied from other sources including cogeneration system]
<u>For Option a)</u>
The evidence stating information relevant to the value of emission factor (e.g. data of power generation, type of power plant, type of fossil fuel, period of time).</td>
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History of the document

Version	Date	Contents revised
01.0	20 September 2021	Electronic decision by the Joint Committee Initial approval.