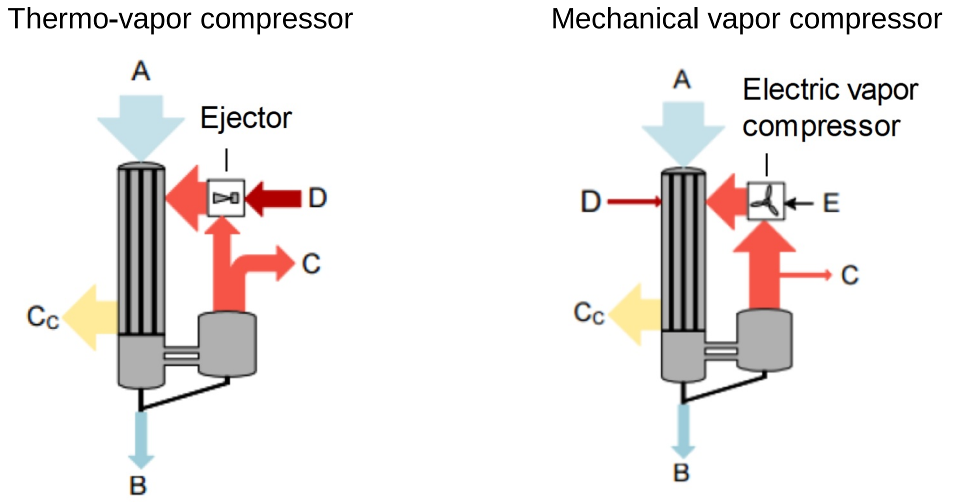
ADDITIONAL INFORMATION

Calculation of reference emission

In case that an evaporator is used to concentrate chemical substances such as amino acid solution, a waste heat recovery system is generally installed to enhance energy efficiency. There are mainly two types of compressors to recover the waste heat which are “thermo-vapor compressor” and “mechanical compressor” as shown in Figure1.



A: Solution before concentration
B: Concentrated solution
C: Non-recovered vapor
Cc: Condensed water
D: Steam
E: Electricity

Figure1: Vapor flows of thermo and mechanical vapor compressors

Source: GEA catalogue

While the thermo-vapor compressor uses steam as driving force for concentrating solution and it enables to recover only a part of the thermal energy from the non-concentrated solution, the mechanical compressor enables to recover the most of thermal energy.

According to the interview with two major manufacturers of evaporators in Japan, the thermo-vapor compressor is still widely used due to the higher initial cost of the mechanical compressor. To calculate reference emissions, this methodology sets the evaporator with thermo-vapor compressor as the reference equipment while calculating reference emissions conservatively as explained below.

Reference emission by evaporator with thermo-vapor compressor is determined by Equation (1)

$$RE_p = \frac{\sum SC_{RE,i,p} \times (h_{steam,i} - SPH \times T_{inlet})}{1000} \times \frac{1}{\eta_{PJh}} \times EF_{fuel} \qquad \text{Equation (1)}$$

RE_p	*: Reference emissions during the period p [tCO_2/p]*
$SC_{RE,i,p}$	*: Reference steam consumption by the reference evaporator i during the period p [t/p]*
$h_{steam,i}$	*: Specific enthalpy of supplied steam to the project evaporator i [MJ/t]*
SPH	*: Specific heat capacity of water [MJ/(t·K)]*
T_{inlet}	*:Inlet watertemperaturefor the steam generation [degree celsius]*
$\eta_{PJ,p}$	*: Efficiency of project boiler for steam supply [-]*
EF_{fuel}	*: CO2 emission factor for the fuel consumed by the project boiler for heating energy generation [tCO2/GJ]*

Among the parameter in Equation (1), Reference steam consumption by evaporator with thermo-vapor compressor is theoretically calculated by Equation (2) based on the thermal dynamics which is commonly used among the engineers to identify the amount of steam input. The specific heat capacity of water may be applied as specific heat capacities of solution in this methodology.

$$\sum SS_{RE,i,p} = \sum \frac{(EV_{tot,i,p} \times LH_{EV,i}) - FL_{IN,i,p} \times SPH \times (T_{LS,i} - T_{EV,i})}{LH_{HT,i} \times (SR+1)} \qquad \text{Equation (2)}$$

$SC_{RE,i,p}$	*: Reference steam consumption by the reference evaporator i during the period p [t/p]*
$EV_{tot,i,p}$	*: Total amount of the evaporation from supplied solution by project evaporator during the period p [t/p]*
$LH_{EV,i}$	*: Specific latent heat of the evaporation temperature of solution at the project evaporator i [MJ/t]*
$FL_{IN,i,p}$	*: Total amount of inlet solution to the evaporator i during the period p [t/p]*
SPH	*: Specific heat capacity of solution [MJ/(t·K)]*
$T_{LS,i}$	*: Temperature of the supplied solution to the project evaporator i [degree Celsius]*
$T_{EV,i}$	*: Evaporation temperature of the solution at the project evaporator i [degree Celsius]*
$LH_{HT,i}$	*: Specific latent heat of the heating temperature of the supplied vapor to the project evaporator i[MJ/t]*
SR	*: Suction ratio of ejector in the reference evaporator with thermal vapor recompression [-]*

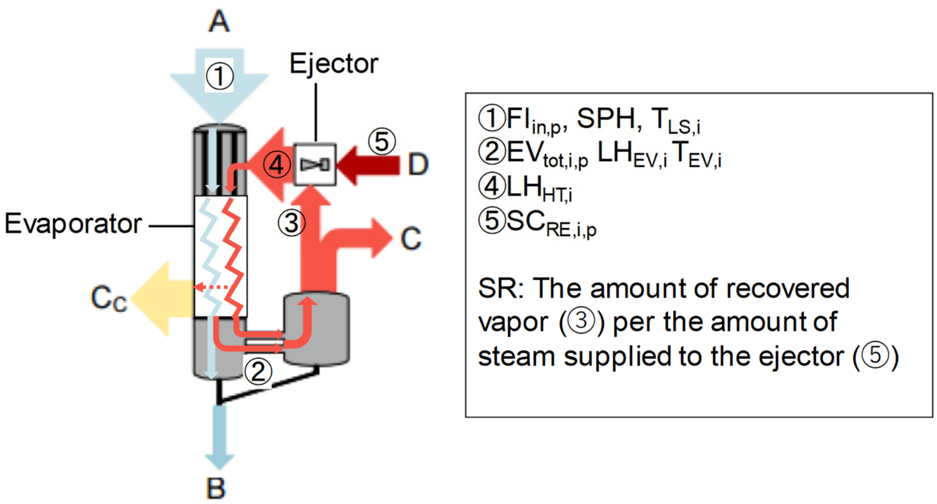


Figure 2: The locations of each parameter described in Equation (2)

Conservative default values

Among the parameters used in this methodology, T_{inlet}, *SR* are set conservatively as explained in the following for securing net emission reductions in the proposed methodology.

・Identification of T_{inlet}

Enthalpy of supplied steam is calculated by multiplying the amount of steam consumption and the difference between the specific enthalpy of supplied steam to the project evaporator and the specific enthalpy of supplied water. The specific enthalpy of supplied water is calculated by multiplying Specific heat capacity of water (SPH) and Inlet water temperature for the steam generation (T_{inlet}) as indicated in Equation (1). In this methodology, the specific enthalpy of supplied water is calculated with the highest atmospheric temperature on monthly average (38.5 degree Celsius) in Thailand[1].

・Identification of SR value

According to the interview with the two major manufacturers aforementioned, SR is set within the range from 0.7 to 1.2 under a vacuum condition[2]. Therefore, the SR value is conservatively set as 1.2 by selecting the highest value to ensure net emission reduction in this methodology.

[1] Thai Meteorological Department (2016) "Climatological Data for the Period 1981–2010". http://climate.tmd.go.th/content/file/75

[2] Suction Ration (SR) is defined as the amount of intake vapor per the amount of new steam. A higher SR shows the better energy efficiency.