Additional information on calculating the emission factors of Chile for the JCM

Summary

To secure net emission reductions in the methodology, the following reference emission factors will be applied depending on the grid to which a proposed project activity will connect in Chile:

- Table 1 summarises the applied reference emission factors for the biomass power plant in a proposed project activity, which is directly connected to a regional grid, or connected to a regional grid via an internal grid *not* connecting to a captive power generator (Case 1).
- Table 1 also summarises the applied reference emission factors for the biomass power plant in a proposed project activity, which is connected to an internal grid connecting to *both* a regional grid and a captive power generator (Case 2).

Table 1. Reference emission factor for Case 1 and Case 2

Regional grid name	Emission factor for Case 1 (tCO_2/MWh)	Emission factor for Case 2 (tCO_2/MWh)
SEN (National System)	0.361	0.361
Aysén System	0.214	0.214
Magallanes System	0.348	0.348

- A reference emission factor of **0.533 t-CO_2/MWh** is applied, in the case that the biomass power plant in a proposed project activity is *only* connected to an internal grid connecting to a captive power generator (Case 3).

1. Status of the electricity system in Chile

The Chilean electric power grid is organised into three independent systems[1] (Figure 1): the National Electricity System (SEN, *Sistema Eléctrico Nacional*), which is the interconnecting system of the Central System (SIC, *Sistema Interconectado Central*) and the Northern System (SING, *Sistema Interconectado Norte Grande*) since November 2017, serving the northern and central part of the country; and two small systems, Aysén and Magallanes serving the south. All electric power generation, transmission and distribution activities are implemented by the private sector under the supervision of the National Energy Commission (CNE, *Comisión Nacional de Energría*).

[1] National Energy Commission (2018) 2018 Energy Statistical Yearbook Chile

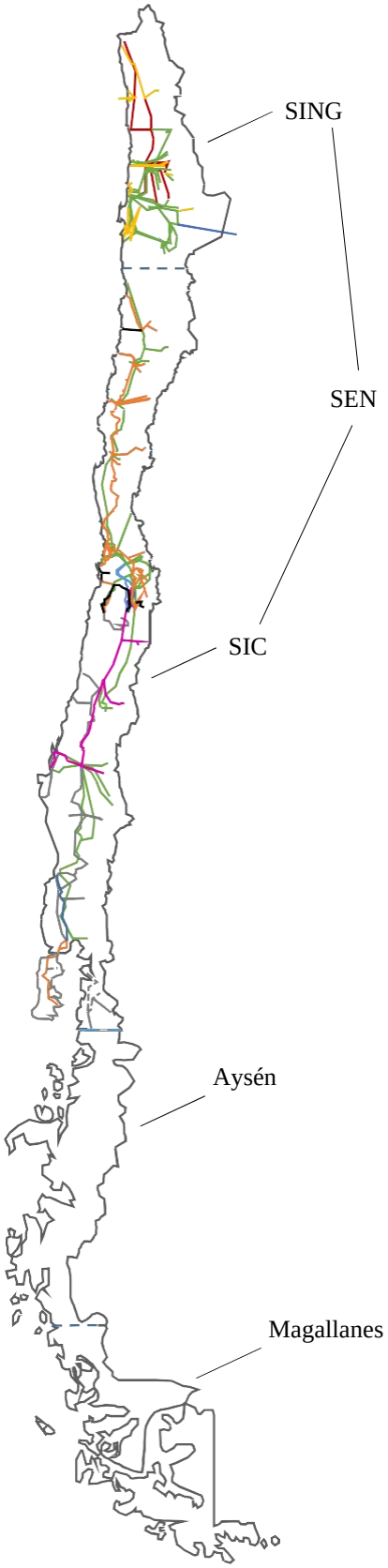

Figure 1. The three independent electricity systems in Chile

Throughout 2019-2021 (Table 2), the SIC and SING (hereafter referred to as SEN) was the main electricity system in Chile, covering more than 99% of the national electricity generation. The rest of electricity is supplied by the Aysén and Magallanes.

Table 2. Annual Power Generation per Electricity System*

Year	Gross Power Generation (TWh)			
	SEN[2]	Aysén[3]	Magallanes[4]	Total**
2019	77.09	0.18	0.35	77.62
2020	77.70	0.18	0.34	78.22
2021	81.44	0.19	0.36	82.00

* Power generation represents the amount of electricity generated by power plants connected in each grid that is transmitted and distributed for consumer use.

** The electricity generation of Los Lagos system is not included due to its limited amount of power generation.

Seven types of primary energy sources are used for electricity generation: coal, diesel and oil, natural gas, hydro, biomass, cogeneration, wind, and solar power. The share of electricity generated in 2019-2021 by each type of primary energy source is shown in Figure 2. The electricity generated from hydro, biomass, cogeneration, wind, solar power plants are considered as low cost/must run (LCMR) power sources.

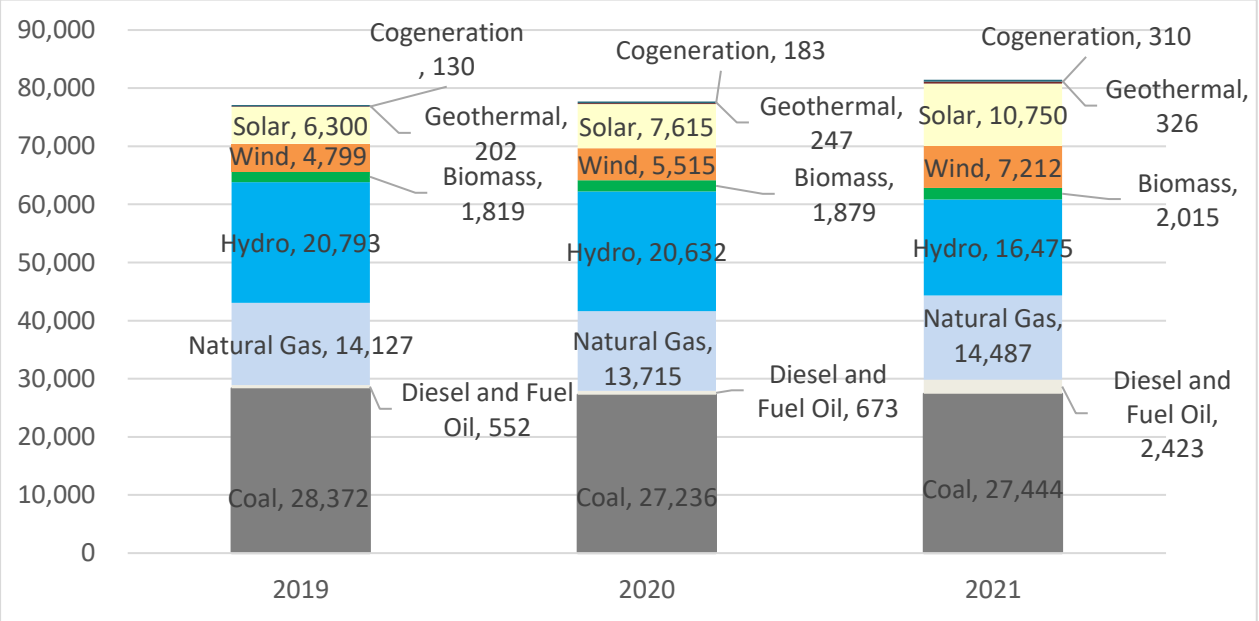

Figure 2. National total power generation by source (GWh, 2019 - 2021)

[2] National Energy Commission (2022) Gross Generation of SEN. (accessed on November 2022) https://www.cne.cl/wp-content/uploads/2022/11/Generacion_Bruta.xlsx

[3] Based on data provided by National Energy Commission

[4] Based on data provided by National Energy Commission

2. Calculation of reference emission factor of electricity systems

Since the three grid systems are independent from each other, reference emission factors are calculated for each system. To identify the reference emission factor of each grid in a conservative and simple manner to secure net emission reductions, the emission factors in this methodology are established by an operating margin that is calculated using emission factors of power plants including LCMR resources.

Conservative emission factor of LCMR power plants is set as zero, and conservative emission factors of fossil fuel power plants are calculated using the following equation:

Emission factor of fossil fuel power plant [tCO_2/MWh]

= (Emission factor of fuel source [$kgCO_2$/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Emission factors of coal, gas and diesel combustion are derived from the "IPCC guideline 2006, Volume 2, Chapter 2, stationary combustion" as 89,500 $kgCO_2$/TJ, 54,300 $kgCO_2$/TJ and 72,600 $kgCO_2$/TJ (Table 3). The heat efficiencies of coal-fired power plants and gas-fired power plants are applied as 39% and 55.6% respectively, taking into consideration the technologies being used in currently operational power plants in Chile (Table 3). Regarding diesel-fired power plants, a heat efficiency of 49%, an efficiency level which has not yet been achieved by the world's leading diesel generator, is applied.

Table 3. Constants for calculation of reference emission factor

Item	Values	Reference
Best heat efficiency of natural gas power plant (Kelar, 2016)	55.6% (combined cycle)	○ KOSPO website[6], ○ General Electric website[7]
Best heat efficiency of coal power plant (Cochrane and Angamos, 2015)	39% (sub-critical)	○ Environmental Evaluation Services (SEA) Chile[8] ○ UNFCCC, 2015
Best heat efficiency of diesel power plant	49%	JCM Approved Methodologies: PW_AM001, MN_AM003, etc.
CO_2 emission factor of other bituminous coal	89,500 $kgCO_2$/TJ	IPCC guideline for National Greenhouse Gas Inventories 2006, Volume 2, Chapter 2, stationary combustion[9]
CO_2 emission factor of natural gas	54,300 $kgCO_2$/TJ	
CO_2 emission factor of diesel	72,600 $kgCO_2$/TJ	

[6] https://www.kospo.co.kr/kospoeng/573/subview.do (accessed on November 2022)

[7] https://www.ge.com/content/dam/gepower-new/global/en_US/downloads/gas-new-site/products/gas-turbines/gt13e2-fact-sheet-product-specifications.pdf

[8] According to Environmental Impact Assessment of Cochrane Thermoelectric Plant reported to the SEA Chile (accessed November 2022) https://seia.sea.gob.cl/archivos/RCA_COCHRANE.pdf the steam generated is 160 bar and 565°C and is expanded in a steam turbine of the condensation type. According to IEA (2011) Power Generation from Coal, this specification can be classified as sub-critical. The default efficiency factor for sub-critical technology is 39% according to UNFCCC CDM EB (2015) Tool to calculate the emission factor for an electricity system.

[9] IPCC default values at the lower limit of the uncertainty at a 95 per cent confidence interval.

Applying the emission factors and plant efficiencies (Table 3), the conservative emission factors are calculated to be **0.826** tCO_2/MWh for coal-fired power plants, **0.352** tCO_2/MWh for gas-fired power plants and **0.533** tCO_2/MWh for diesel-fired power plants. The conservative emission factors are applied for calculating the reference emission factor of each grid in Chile.

Using the conservative emission factors for each power source data and electricity generation including LCMR resources, operating margins of each grid are obtained using the following equation:

$$EF_{RE,j} = \frac{\sum_i EG_{i,j} \times EF_i}{\sum_i EG_{i,j}} \quad \text{… Equation 1}$$

Where:

$EF_{RE,j}$ = The reference emission factor of regional grid *j* [tCO_2/MWh]

EF_i = Conservative emission factor of power plant type *i* [tCO_2/MWh]

$EG_{i,j}$ = Average electricity generated and delivered to each grid from power plant type *i* including LCMR resources in grid *j* during 2019-2021 [MWh]

There are three possible cases of biomass power plant installation in a project activity in terms of its connectivity to the grid and captive power generator:

- Case 1: the biomass power plant is directly connected to a regional grid, or connected to a regional grid via an internal grid not connecting to a captive power generator.
- Case 2: the biomass power plant is connected to an internal grid connecting to both a regional grid and a captive power generator.
- Case 3: the biomass power plant is only connected to an internal grid connecting to a captive power generator.

a. Reference emission factor of National System (SEN, *Sistema Eléctrico Nacional*)

The SEN system is mainly powered by coal (35%), followed by hydro (25%), natural gas (18%), and solar (10%). Biomass, diesel and fuel oil, wind, and cogeneration power supply the rest of the power generation.

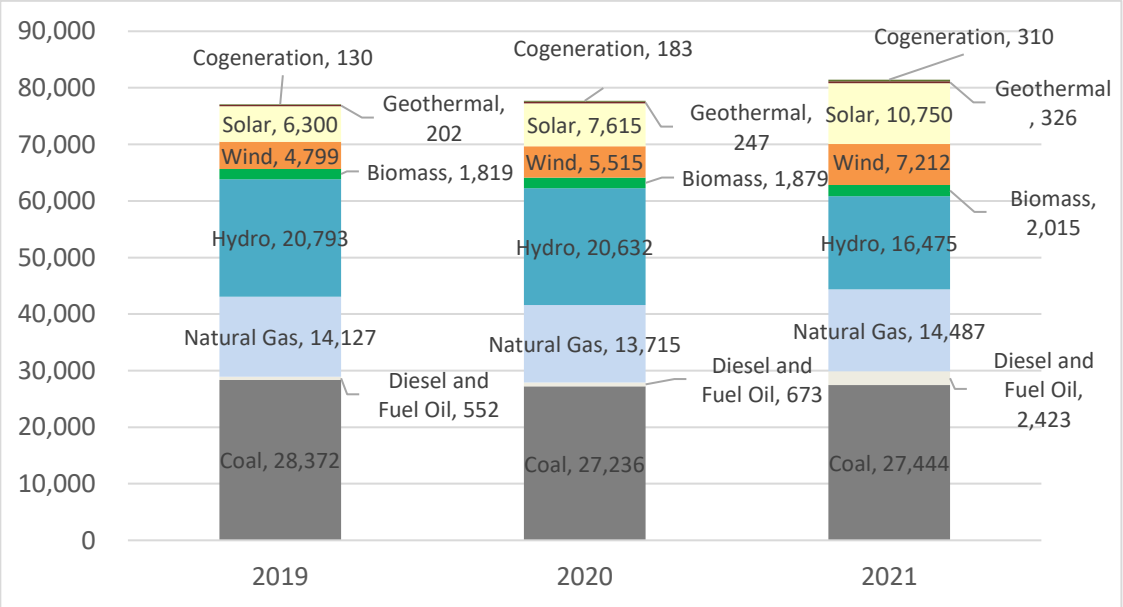

Figure 3. Electric power generated by power plants in SEN grid by source (GWh, 2019-2021)

Applying the conservative emission factors and power generation (Figure 3) to Equation 1, the reference emission factor to be applied for the biomass power plant in a proposed project activity which is directly connected, or connected via an internal grid not connecting to a captive power generator (Case 1), to the **SEN grid is 0.361 tCO_2/MWh,** as shown in Table 1.

b. Reference emission factor of Aysén system

The Aysén system is mainly powered by hydropower (55%) and diesel and fuel (40%). Wind power supply the rest of the power generation.

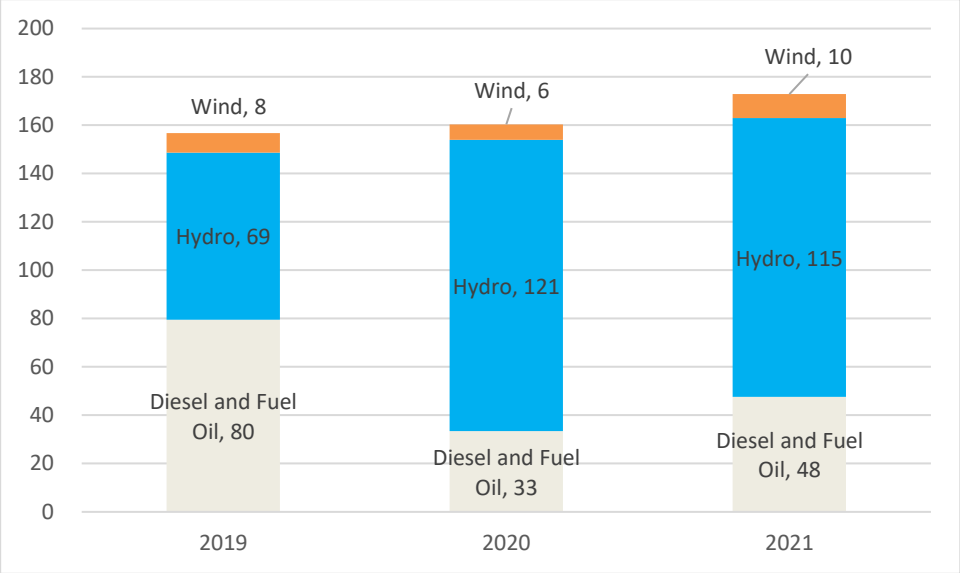

Figure 5. Electric power generated by power plants in Aysén grid by source (GWh, 2019 - 2021)

Applying the conservative emission factors and power generation (Figure 5) to Equation 1, the reference emission factor to be applied for the biomass power plant in a proposed project activity which is directly connected, or connected via an internal grid not connecting to a captive power generator (Case 1), to the **Aysén grid is 0.214tCO_2/MWh,** as shown in Table 1.

c. Reference emission factor of Magallanes system

The Magallanes system is powered mainly by natural gas (94%). Diesel and fuel oil and wind power supply the rest of power generation.

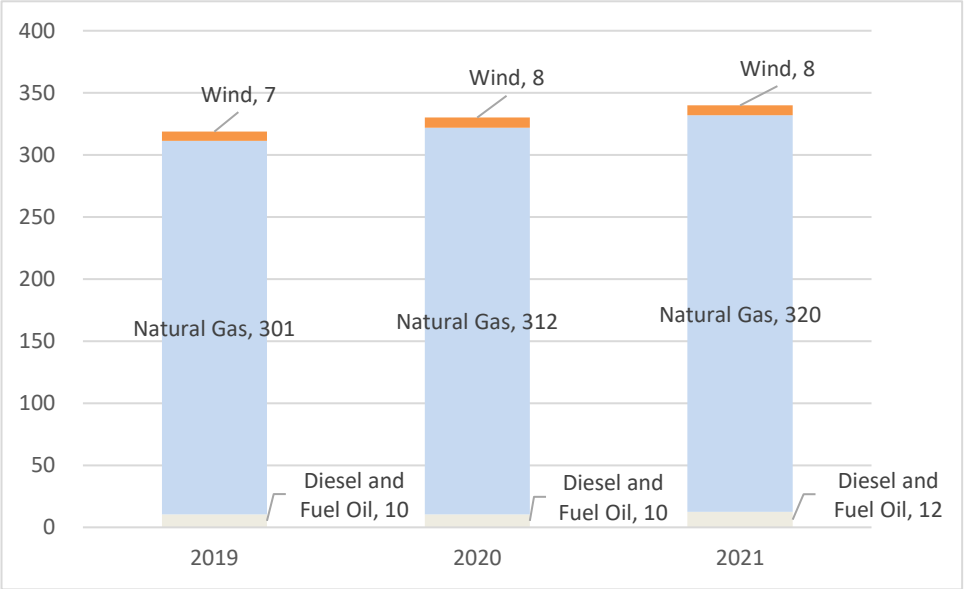

Figure 6. Electric power generated by power plants in Magallanes grid by fuel type (GWh, 2019 - 2021)

Applying the conservative emission factors and power generation (Figure 6) to Equation 1, the reference emission factor to be applied for the biomass power plant in a proposed project activity which is directly connected, or connected via an internal grid not connecting to a captive power generator (Case 1), to the **Magallanes grid is 0.348 tCO_2/MWh,** as shown in Table 1.

3. Calculation of reference emission factor of a captive power generator (Case 3)

To determine the emission factor of a captive power generator which normally uses a diesel generator in a conservative and simple manner, a heat efficiency of 49%, an efficiency level which has not yet been achieved by the world's leading diesel generator, is applied.

The emission factor of diesel power generation is calculated from the heat efficiency using the following equation:

Emission factor of diesel power plant [tCO_2/MWh]

= (CO_2 emission factor of diesel oil [$kgCO_2$/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Applying the default value of the emission factor of diesel combustion which is 72,600 $kgCO_2$/TJ derived from "IPCC guideline 2006, Volume 2, Chapter 2, stationary combustion", together with the heat efficiency of 49%, the emission factor of a captive power generator and the reference emission factor to be applied for the biomass power plant which is directly connected, or connected via an internal grid connecting to *only* a captive power generator (Case 3), is calculated to be **0.533 tCO_2/MWh**.

4. Selection of the reference emission factors in the case a biomass power plant is connected to

both grid and captive power generator (Case 2)

In the case the biomass power plant in a proposed project activity is connected to an internal grid connecting to *both* a regional grid and a captive power generator (Case 2), a comparison was made for each regional grid, between the emission factor for Case 1 (as shown in Table 1) and the emission factor for Case 3 (conservative emission factor of diesel-fired power plants of 0.533 tCO_2/MWh). The lower value resulting from this comparison was then applied as Case 2, as shown in Table 1.