Additional information on calculating the conservative emission factor of Costa Rica for the JCM

It is concluded that net emission reductions will be achieved by applying the following emission factors to solar PV projects under the JCM in Costa Rica:

- An emission factor of **0.255 t-CO_2/MWh**, in case the PV system(s) in a proposed project is connected to the national grid including through internal grid which is not connected to a captive power generator.
- An emission factor of **0.255 t-CO_2/MWh**, in case the PV system(s) in a proposed project is connected to internal grid which is connected to both the national grid and a captive power generator.
- An emission factor of **0.533 t-CO_2/MWh**, in case the PV system(s) in a proposed project is connected to an internal grid which is not connected to the national grid.

1. Current status of electric power source mix in Costa Rica

The Costa Rican Institute of Electricity (*Instituto Costarricence de Electricidad*, ICE), a Costa Rican state-owned holding company, administrates the country's electricity and energy including electricity generation, transmission and distribution through the national grid (Figure 1). In some cases, it operates through smaller companies to distribute electricity throughout the country.

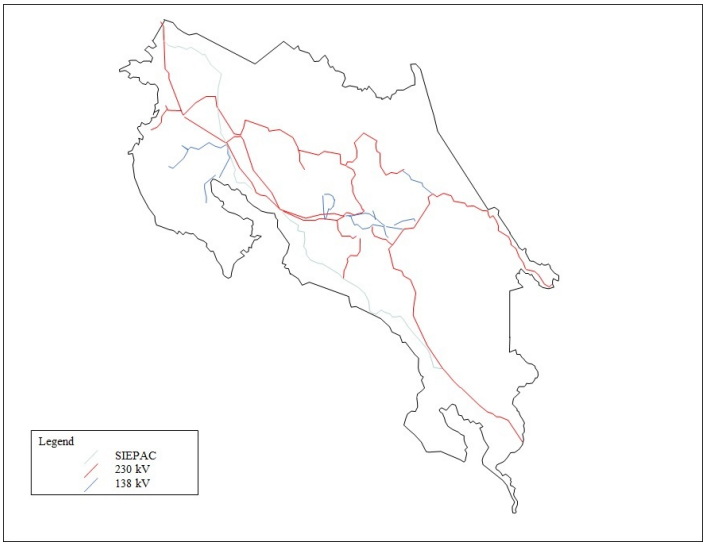

Figure 1. Map of Costa Rican national electricity grid[1]

ICE has a total installed capacity of more than 2,000 MW, which represents 79.3% of the

[1] Approximate figure, based on *Plan de Expansión de la Transmisión 2015 – 2025*, Instituto Costarricense de Electricidad Negocio de Transmisión, Proceso Expansión de la Red, 2015.

total national electricity production. The ICE owns 100% of the country's transmission system and provides energy to 39% of the population. Independent power producers connected to the national grids generate the rest of the electricity.

There are six types of fuel used for national electricity generation, namely diesel, hydro, geothermal, wind, bagasse and Solar[2]. The share of overall electricity generated from 2013 to 2015 by type of fuel used is shown in Table 1. The amount of electricity generated from hydro, geothermal, wind, bagasse and solar power plants, defined as low cost/must run (LCMR) power sources, were 8.928 TWh (87.66% of total electricity generation) in 2013, 9.075 TWh (87.51% of total) in 2014, and 10.607 TWh (97.44% of total) in 2015.

Table 1. Net electricity generation by fuel type*

Net electricity generation by fuel type (TWh)**	2013	2014	2015	Total 2013-2015
Diesel	1.196	1.043	0.108	2.347
Hydro	6.839	6.717	8.067	21.623
Geothermal	1.517	1.538	1.376	4.431
Wind	0.485	0.735	1.080	2.300
Bagasse	0.086	0.084	0.082	0.252
Solar	0.001	0.001	0.002	0.004
Import	0.061	0.252	0.172	0.485
Total without LCMR and import	1.196	1.043	0.108	2.347
Total (TWh)	10.185	10.370	10.886	31.442

Source: *Generacion y Demanda: Informe Anual*, Centro Nacional de Control de Energia, 2015 (*Generation and Demand: Annual Report*, National Center for Energy Control, 2015)

* There is a difference between the values listed as "Total" and the summation of each value of "Diesel", "Hydro", "Geothermal", "Wind", "Bagasse", "Solar", and "Import" because these values are rounded.

** Electricity generation represents a net amount which is the amount of electricity generated by a power plant that is transmitted and distributed for consumer use.

2. Calculation of emission factor of the national grid

To calculate the emission factor of Costa Rican national grid, the actual dispatch record from diesel power plants for the years 2013-2015 is used. There are eight diesel power plants that supply electricity to the national grid within 2013-2015: Barranca, Garabito, Guápiles, Moín I, Moín II, Moín III, Orotina, and San Antonio. The emission factor is calculated in a conservative way by multiplying the conservative emission factor of diesel power plant and the ratio of total hours of electricity generation by diesel power plants to the total number of hours of electricity generation by all power plants.

[2] Instituto Costarricense de Electricidad. 2015. *Energía Generación y Demanda, Informe Anual, Centro Nacional de Control de Energia.*

The conservative emission factor of diesel power plants is calculated using the following equation:

The conservative emission factor of diesel power plant [t-CO_2/MWh]
=(Emission factor of diesel [kg-CO_2/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Applying the emission factor for diesel combustion of 72,600 kg-CO_2/TJ, derived from "IPCC guideline 2006, Chapter 2, stationary combustion", and the plant heat efficiency (LHV) of **49%**, which has not been achieved yet by the world's leading diesel generator[3], the emission factor of diesel generator is calculated to be **0.533 t-CO_2/MWh.**

Total hours of Costa Rican national electricity generation from 2013 to 2015 are summarized in Table 2. Annual total hours of generation by thermal power plants are aggregated from eight diesel power plants data.

Table 2. Total hours of electricity generation by thermal power plants

	2013	**2014**	**2015**	***Total 2013-2015***
Total hours of electricity generation by thermal (diesel) power plants	6,316	5,060	1,199	*12,575*
Total hours of electricity generation by all power plants	8,760	8,760	8,760	*26,280*

Source: *Generación Real, MWh,* Sistema Eléctrico Nacional - Costa Rica Información Diaria[4]

The emission factor for the national grid per year is calculated using the following equation:

The emission factor for the national grid per year (t-CO_2/MWh)
= the conservative emission factor of diesel power plant [t-CO_2/MWh] * (total hours of electricity generation by diesel power plants [hours] / total hours of electricity generation by all power plants [hours])

As shown in Table 3, the default emission factor for the national grid to be applied is calculated as the weighted average emission factor of 2013-2015, and set to be **0.255** t-CO_2/MWh.

[3] The approved JCM methodologies (PW_AM001, MV_AM001, and MN_AM003) also applied this value.
[4] Available at https://appcenter.grupoice.com/CenceWeb/CencePosdespachoNacional.jsf

Table 3. Calculated emission factor of Costa Rican national grid

	2013	**2014**	**2015**	***2013-2015***
Emission factor ($t\text{-}CO_2/MWh$)	0.384	0.308	0.073	*0.255*

3. Calculation of the emission factor of a captive power generator

To determine the emission factor of a captive power generator which normally uses a diesel generator in a conservative and simple manner, the heat efficiency of 49%, an efficiency level which has not been achieved yet 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 [$t\text{-}CO_2/MWh$]
=(Emission factor of diesel [$kg\text{-}CO_2/TJ$]*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, Chapter 2, stationary combustion", together with the heat efficiency of 49%, the emission factor for a captive power generator is calculated to be **0.533 tCO_2/MWh**.