Additional information on calculating the grid emission factor of Lao PDR for the JCM

Summary

It is concluded that net emission reductions are achieved by applying the following emission factors to 3 cases in Lao PDR.

- Table 1 summarizes the applied reference emission factors for the PV system(s) in a proposed project activity, which is directly connected to the Lao Power Grid, or connected to the grid via an internal grid *not* connecting to a captive power generator (PV Case 1).
- Table 1 also summarizes the applied reference emission factors for the PV system(s) in a proposed project activity, which is connected to an internal grid connecting to *both* the Lao Power Grid and a captive power generator (PV Case 2).
- A reference emission factor of **0.533 t-CO_2/MWh** is applied, in the case that the PV system (s) in a proposed project activity is *only* connected to an internal grid connecting to a captive power generator (PV Case 3).

Table 1. Reference emission factor PV Case 1, Case 2 and Case 3

Emission factor for PV Case 1 (t-CO_2/MWh)	Emission factor for PV Case 2 (t-CO_2/MWh)	Emission factor for PV Case 3 (t-CO_2/MWh)
0.319	0.319	0.533

1. Current status of electric power source mix in Lao PDR

The Lao Power Grid, consists of the connected Northern grid, Central 1 grid, Central 2 grid, and Southern grid (Figure 1). The Electricite Du Laos (EDL), a state company, carries out generation, transmission, distribution, supply and commercialization of electric energy.

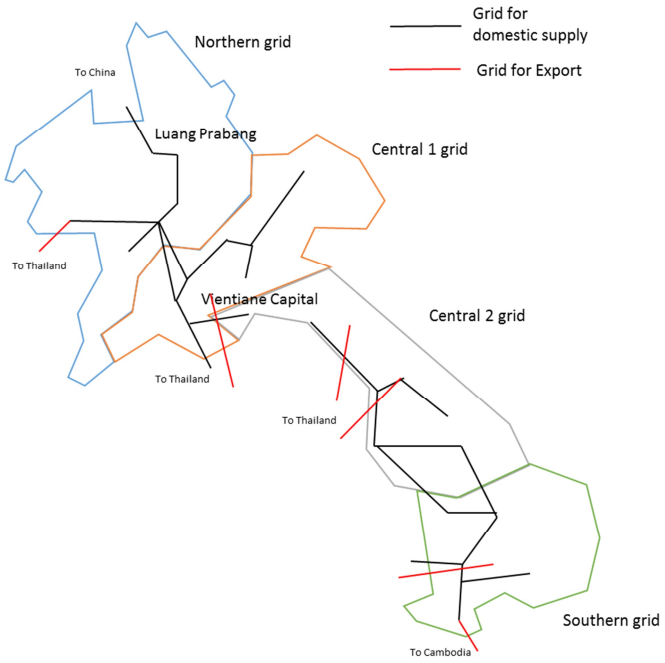


Figure 1. Map of electricity system in Lao PDR[1]

The Lao Power Grid is directly connected with the Thailand, Vietnam, and China Power Grids. According to the document published by Ministry of Natural Resources and Environment (MONRE) Lao PDR[2], the connected Lao Power Grid and Thailand Power Grid (hereafter referred to as "Lao-Thailand Power Grid") is defined as the interconnected electricity system for which Lao grid emission factor was calculated. Electricity generation in the Lao-Thailand Power Grid is provided in Table 1.

Table 1. Electricity generation in Lao-Thailand Power Grid

Electricity source (GWh)		**2012**	**2013**	**2014**	**2015**	**2016**
Coal		32,534	33,387	35,712	32,781	35,303
	Lao grid	0	0	0	0.40	204
	Thailand grid	32,534	33,387	35,712	32,780	35,099
Oil	Thailand grid	2,068	1,787	1,896	1,320	1,075
Gas	Thailand grid	117,063	117,005	118,559	126,985	124,761
Renewable energies		13,747	12,492	13,032	10,174	10,875

[1] Approximate figure based on Electricite du Laos, *Electricity Statistics 2016*

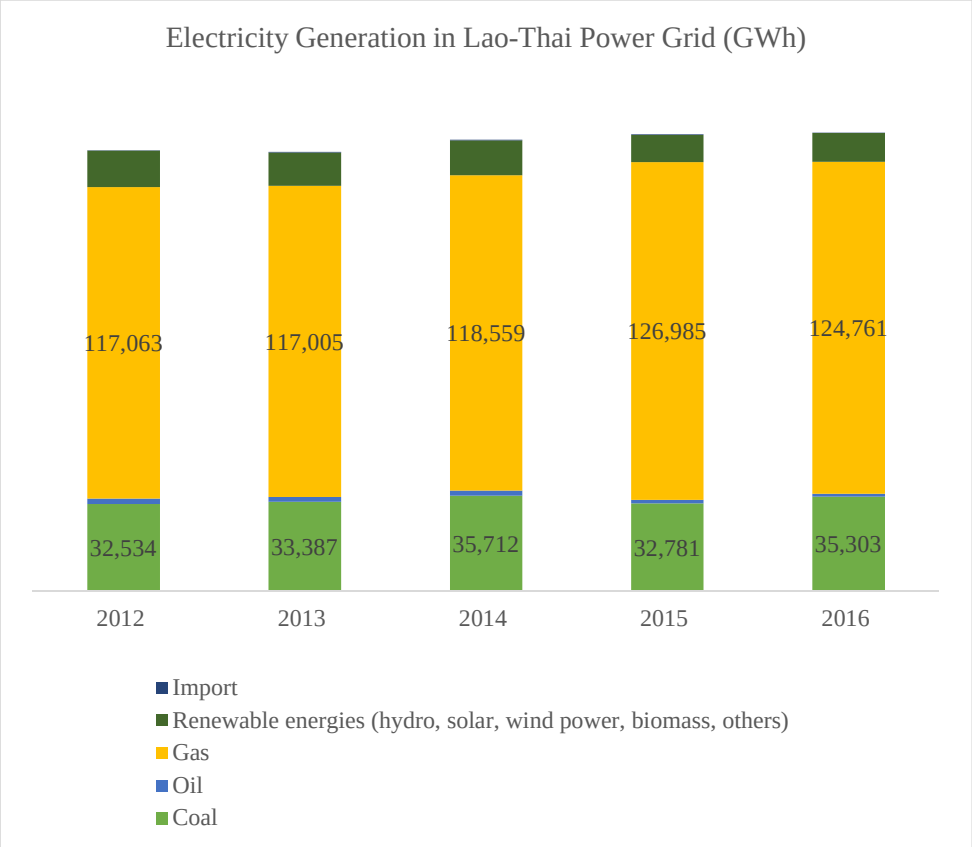
[2] MONRE (2014). Calculation for the emission factor for electricity generation in Lao PDR, 2010 (established for the CDM).

	Lao grid (hydro)	2,642	3,708	3,886	4,210	6,735
	Thailand grid (hydro, solar, wind, biomass, others)	11,105	8,784	9,145	7,955	8,233
Import		149	246	274	302	158
	Viet Nam	36	27	35	48	43
	China	113	219	239	254	115
Total excluding import		**165,413**	**164,671**	**169,199**	**171,259**	**172,014**
% Generation from natural gas		**71%**	**71%**	**70%**	**74%**	**73%**

Sources: Electricite du Laos, *Electricity Statistics 2016;* Electricity Generating Authority of Thailand, *Annual Report 2013; Annual Report 2014; Annual Report 2016.*

2. Calculation of emission factor of the Lao-Thailand Power Grid

Natural gas-fired power plants hold the majority in overall power supply to the Lao-Thailand Power Grid, with an absolute amount increasing during 2005 to 2013[3], and staying at around 70-74% in the last three years (Table 1).



[3] Organization for Economic Co-operation and Development (OECD), Energy Statistics of Non-OECD Countries 2015, August 2015.

Figure 2. Trend of electricity generation sources in Lao-Thailand Power Grid

Therefore, emission from natural gas power plants, which also has the lowest emission factor among fossil fuels, is used to calculate the reference emission factor of the Lao-Thailand Power Grid in a conservative and simple manner to secure net emission reduction.

The CO_2 emission factor of power generation by natural gas-fired power plants is calculated from the plant efficiency using the following equation:

CO_2 emission factor of power generation [tCO_2/MWh] (equation1)

= CO_2 emission factor of natural gas [tCO_2/TJ] *0.0036 [TJ/MWh] / (Thermal efficiency (Lower Heating Value: LHV) [%] / 100)

Applying the CO_2 emission factor of natural gas combustion, which is 54.3 tCO_2/TJ derived from "IPCC guideline 2006, Chapter 2, stationary combustion" together with the thermal efficiency (LHV) of 61.2% to the equation 1, the emission factor of power generation by the most efficient natural gas-fired power plant is calculated to be **0.319 t-CO_2/MWh**.

Table 2. Constants for calculation of reference emission factor

Item	Values	Reference
Best thermal efficiency of natural gas power plant (Khanom Electricity Generating Co., Ltd.)	61.2%[4]	Mitsubishi Heavy Industry[5]
Best thermal efficiency of diesel power plant	49%	JCM Approved Methodologies: PW_AM001, MN_AM003, etc.
CO_2 emission factor of natural gas	54.3 tCO_2/TJ	IPCC guideline for National Greenhouse Gas Inventories 2006, Chapter 2, stationary combustion[6] The lower value is applied.
CO_2 emission factor of diesel	72.6 tCO_2/TJ	

[4] Since auxiliary power consumption is unknown, the plant efficiency of gross electricity generation is applied. This ensures the calculation of a conservative emission factor.

[5] https://www.mhi-global.com/news/story/1308201706.html
https://www.mhps.com/en/products/thermal_power_plant/gas_turbin/lineup/m701f.html

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

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 thermal 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 thermal efficiency using the following equation:

Emission factor of diesel power plant [t-CO_2/MWh] (equation 2)
= (Emission factor of diesel [tCO_2/TJ] *0.0036[TJ/MWh]) / (Thermal efficiency (Lower Heating Value: LHV) [%]/100)

Applying the default value of the emission factor of diesel combustion which is 72.6 tCO_2/TJ derived from "IPCC guideline 2006, Chapter 2, stationary combustion", together with the thermal efficiency of 49% to the equation 2, the emission factor for a captive power generator ($EF_{RE,cap}$) is calculated to be **0.533 tCO_2/MWh**.