Appendix 1

Additional information to the Proposed Methodology
"Installation of Solar PV System"

It is concluded to apply the emission factor of 0.319 tCO_2/MWh, which is the emission factor of the most efficient natural gas-fired power plant in Thailand, for grid electricity and captive electricity displaced by a solar PV system in Thailand to achieve net emission reductions.

1. Background

Emission reductions are calculated by multiplying the amount of electricity displaced by the emission factor of the grid electricity and/or captive electricity displaced. In order to secure net emission reductions, the emission factors in Thailand were studied.

2. Findings and rationales

2.1. Current status of electricity mix in Thailand

Natural gas-fired power plants has the largest share of the power supply in Thailand. The share has been around 70% of the total. The absolute amount supplied has increased during 2005 to 2013[1]. The share of coal is on the increase and constitute around 20% of the power supply. The share of petroleum is only around 1%. The combined margin (CM) emission factor of the grid for 2012-2014 is calculated to be 0.566 tCO_2/MWh.

2.2. Power generation efficiency and emission factor of natural gas-fired power plants

An attempt was made to obtain a comprehensive dataset on the efficiency of natural gas-fired power plants in Thailand. An enquiry was made to the Energy Regulatory Commission (ERC) regarding the efficiency of natural gas-fired power plants owned by the Electricity Generating Authority of Thailand (EGAT), Independent Power Producers (IPPs) and Small Power Producers (SPPs) which started operation in the period starting from 1 January 2012 to 31 December 2015. However, no data has so far been supplied. Another enquiry was made to an academic with a comprehensive knowledge on energy and emission factors, and found that a dataset on the efficiency of natural gas-fired power plants do not exist.

A web-search was conducted to identify the most efficient natural gas-fired power plants in Thailand. The power plants identified in the web-search are listed in Table 1. The most efficient power plant identified through this exercise is owned by the Khanom Electricity Generating Co., Ltd. (KEGCO). The plant is manufactured by the Mitsubishi Heavy Industry and has an efficiency of 61.2% (Lower Heating Value: LHV).

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

Although it has not been possible to confirm that this KEGCO power plant is the most efficient natural gas-fired power plant in Thailand, the figure 61.2% is close or relatively higher than the most efficient group of natural gas-fired power plants in commercial operation in Japan, which has a LHV efficiency of 56-59%.[2]

As stated in section 1, Emission reductions are calculated by using the emission factor of the grid electricity displaced. But it is difficult to identify which of the natural gas-fired power plants is displaced by solar PV system(s) installed in this project, and even if it is identified, it is difficult to calculate grid emission factor due to the absence of such dataset. Therefore, the grid emission factor for displaced electricity is established by assuming that the most efficient natural gas-fired power plant in Thailand is displaced in conservative manner, which will lead to ensuring net emission reductions. It is assumed that the most efficient natural gas-fired power plant in Thailand has an efficiency of 61.2% (LHV).

Table 1 Efficiency of natural gas-fired power plants in Thailand

Manufacturer	Product	Capacity	Plant efficiency (LHV)
Mitsubishi Heavy Industry[3]	M701F5	488.5MW	61.2%
Siemens[4]	SGT-800	53 MW	56.2%
Siemens[5]	SGT5-4000F	782 MW 769MW	58.7 %
Alstom[6]	GT26	850MW	41.0%

Table 2 Constants for calculation of CO_2 emission factor

Item	Values	Source
Net calorific value of natural gas	1.02 MJ/scf	A study on Thailand grid emission factor 2014
CO_2 emission factor of natural gas	55.39 tCO_2/MMscf	A study on Thailand grid emission factor 2014
Plant efficiency (LHV) of most efficient natural gas-fired power plant	61.2%*	Table 1

* Since auxiliary power consumption is unknown, the plant efficiency of gross electricity generation is

[2] https://www.env.go.jp/press/files/jp/24454.pdf
[3] https://www.mhi-global.com/news/story/1308201706.html
https://www.mhps.com/en/products/thermal_power_plant/gas_turbin/lineup/m701f.html
[4]
http://www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2015/power-gas/pr2015090320pgen.htm&content[]=PG
http://www.energy.siemens.com/co/en/fossil-power-generation/gas-turbines/sgt-800.htm#content=Technical%20data
[5] https://www.marubeni.com/dbps_data/news/2011/110620.html
http://www.energy.siemens.com/hq/en/fossil-power-generation/gas-turbines/sgt5-4000f.htm#content=Technical%20data
[6]
http://www.alstom.com/press-centre/2014/12/alstom-signs-12-year-long-term-service-agreement-for-north-bangkok-combined-cycle-power-plant/
http://alstomenergy.gepower.com/Global/Power/Resources/Documents/Brochures/gas-turbines-technical-performance.pdf

applied. This ensures the calculation of a conservative emission factor.

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

CO_2 emission factor of power generation [t-CO_2/MWh]
= CO_2 emission factor of natural gas [tCO_2/MMscf] / (Plant efficiency (LHV) [%] / 100) * 1,000 * 3.6 / (Net calorific value of natural gas [MJ/scf]*$10^{\wedge 6}$)

Applying the values indicated in Table 2, the emission factor of power generation by the most efficient natural gas-fired power plant of 0.319 t-CO_2/MWh is derived. This value (0.319 t-CO_2/MWh) is lower than the combined margin (CM) emission factor of the grid shown in Section 2.1. From this result, it can be concluded that by applying the emission factor of power generation by the most efficient natural gas-fired power plant for grid electricity displaced by a solar PV system will ensure net emission reductions.

Table 3 Efficiency and CO_2 emission factor of natural gas-fired power plant

Plant efficiency of natural gas-fired power plant	61.2%
CO_2 emission factor ton-CO_2/MWh	0.319

2.3. Emission factor of captive power plants

The emission factor of the most efficient diesel power generation is identified as 0.533 t-CO_2/MWh in the additional information for the approved JCM methodology PW_AM001 "Displacement of Grid and Captive Genset Electricity by a Small-scale Solar PV System." This value is greater than the emission factor of power generation by the most efficient natural gas-fired power plant in Thailand 0.319 t-CO_2/MWh, derived in Section 2.2. In addition, it can be taken for granted that heating values of existing natural gas-fired power plants for captive power generation is lower than the value of the most efficient one. Therefore, the emission factor of the most efficient natural gas-fired power plant will ensure net emission reductions for a project activity that displaces captive electricity by a solar PV system.

From the conclusions in this section and Section 2.2, it can be concluded that by applying the emission factor of 0.319 tCO_2/MWh, which is the emission factor of the most efficient natural gas-fired power plant in Thailand, for grid electricity and captive electricity displaced by a solar PV system, net emission reductions is achieved.