JCM Proposed Methodology

Displacement of Grid and Captive Genset Electricity by a Small-scale Solar PV System

Additional Information

1. Grid emission factor

It is concluded to apply the emission factor of 0.533 t-CO_2/MWh for the displacement of grid electricity which uses diesel fuel as a power source by a solar PV system in Palau to achieve net emission reductions.

1.1. Backgrounds

Although an emission factor of grid electricity is commonly used to calculate emission reductions achieved by implementation of renewable energy projects to displace grid electricity, it is not officially published in Palau.

1.2. Findings and rationales

1.2.1. Estimation for the existing power stations in Palau

The Palau Public Utilities Corporation (PPUC), a public corporation established as the sole energy and water provider for the Republic of Palau, has two power stations, the Malakal Power Plant located in the commercial center and the EPSECO Power Plant located in Aimeliik.

The followings have been found from the information published by the International Renewable Energy Agency (IRENA), Secretariat of the Pacific Community (SPC) and PPUC.

- Engines using only diesel fuel as a power source are installed in both power stations.
- Based on the information by IRENA and SPC, power generation efficiency and the CO_2 emission factor of existing power stations in Palau is estimated to be those shown in Table 1 using constants shown in Table 2.

Table 1 Power generation efficiency and CO2 emission factor

		IRENA (in 2011)		SPC（in2009）
		Malakal Power Station	EPSECO Power Station	Palau total
Electricity	kWh	43,375,400	45,375,400	83,000,000
Diesel fuel	US gal	2,650,504	3,640,389	-
Efficiency	kWh/gal	14.2	12.5	-
Diesel fuel	Litre	10,033,249	13,780,371	23,808,000
Efficiency	kWh/litre	4.20	3.30	3.49
Power generation efficiency of existing power station	%	41%	33%	34%
CO2 emission factor	ton-CO2/MWh	0.631	0.804	0.761

Reference: The International Renewable Energy Agency (IRENA), *Renewable energy opportunities and challenges in the Pacific Islands region "Palau"*, August 2013; SPC, *Palau Country Energy Security Indicator Profile 2009*

Table 2 Constants for calculation of CO_2 emission factor

	values	sources
Net calorific value of diesel oil	43 GJ/t	IPCC 2006[1] Volume 2 Energy
Default emission factors of diesel oil	72.6 kg-CO_2/GJ	IPCC 2006 Volume 2 Energy
Conversion factor of diesel oil	0.85 kg/litre	Petroleum Association of Japan[2]

1.2.2. Power generation efficiency using diesel fuel

Currently, grid electricity is produced solely through diesel generators at two power plants in Palau. Furthermore, considering the following facts, it can be concluded that diesel generation still tends to be the best available option[3] for grid electricity generation in the future in Palau.

- Diesel generator is one of the most energy efficient amongst generators using fossil fuel as a power source
- Lack of infrastructure for the supply of other fossil fuels such as gas pipeline

Existing diesel engines for the grid electricity are expected to be used, but they may be replaced in near future upon reaching the end of its lifetime. Also, new capacity may soon be required to meet increasing electricity demand. The choice of technology for such additional / replacement capacity is likely to be diesel engines due to their proven track record, albeit a highly efficient one.

In a grid where introduction of a single diesel engine may substantially alter the grid emission factor, it is assumed that the project displaces new high-efficiency diesel generators to ensure net emission reductions.

The following information regarding power generation efficiency of new high-efficient diesel generators has been acquired from published information.

"There are two primary types of piston engine for power generation: the diesel engine and the spark-ignition gas engine. Of these the diesel engine is the most efficient, reaching close to 50% energy conversion efficiency."[4]

[1] "IPCC 2006" refers to "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
[2] http://www.paj.gr.jp/statis/kansan/index.html (Japanese language only)
[3] The Secretariat of the Pacific Community, *Towards an energy secure Pacific*, 2011
[4] "POWER GENERATIN TECHNOLOGIES, 2nd Edition", 2014, Paul Breeze

"In general, diesel engines have efficiencies that range from 30 to 45%."[5]

"Power generation efficiency of diesel engines range from 30% to 48%"[6]

"In addition to the SU3 and MARK-30B engines (diesel engines), with output ranges of 2.0 to 4.0 MW and 5.2 to 8.1 MW, respectively, an in-line 2.7-MW six-cylinder engine has recently been developed; both its output and thermal efficiency are better than in conventional engines. The SU3 and MARK-30B engines have attained generation efficiencies of 44.1% and 46.8%, respectively, which are better than any other diesel engine in the world in this class."[7]

It can be said that diesel engines are the most efficient diesel generators, power generation efficiency of diesel engines has not improved dramatically during recent years, and the world's leading power generation efficiency of diesel engines is close to but has not achieved 49%.
Therefore, setting power generation efficiency of new high-efficient diesel generators at 49% is conservative.

A CO_2 emission factor can be estimated from power generation efficiency using the following equation.

CO_2 emission factor of the grid electricity [t-CO_2/MWh]
= (CO_2 emission factor of diesel oil [kg-CO_2/GJ]/1000*3.6) / (power generation efficiency (lower heating value basis) [%]/100)

Applying the default value of the CO_2 emission factor of diesel oil (72.6 kg-CO_2/GJ)[8] and the conservative value of power generation efficiency of new high-efficient diesel generators, the grid emission factor of 0.533 t-CO_2/MWh is derived. This value (0.533 t-CO_2/MWh) is lower than all values obtained from the published information shown in section1.2.1., which also ensures that the power generation efficiency of new high-efficient diesel generators set above is conservative.

[5] " Handbook of Energy Efficiency and Renewable Energy", 2007, Edited by D. Yogi Goswami
[6] "Cogeneration Plan and Design Manual, 6th edition", 2008, The Japan Institute of Energy
[7] "Approach on High Efficiency Diesel and Gas Engine", 2008, Mitsubishi Heavy Industries Technical Review Vol. 45 No. 1
[8] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 3 Power generation efficiency and CO2 emission factor of diesel engine

Power generation efficiency of diesel engine	%	49%
CO2 emission factor	ton-CO2/MWh	0.533

2. Emission factor of captive electricity

The emission factor of 0.8 t-CO_2/MWh, stated in the small-scale CDM methodology AMS-I.F. "Renewable electricity generation for captive use and mini-grid", is commonly used as the emission factor for captive diesel generators. However, as stated in section 1.2.2, the installation of new high-efficiency diesel generators to the grid is possible, which may cause captive generators to be replaced by grid electricity. Therefore, the emission factor of 0.533 t-CO_2/MWh is applied to achieve net emission reductions.

3. Measurement of power generation by solar PV system

Electrical current of the generated electricity by the solar modules is DC, and will be changed to AC by the inverters. The electrical current output (AC) of the inverters is measured using the electricity meter. The inverters are powered by the generated electricity (DC) from the solar modules. Therefore, the measured value of the electricity meter is equal to the sum of amount of electricity supplied to the grid electricity and the amount of electricity supplied to internal power grid. The measured value will be recorded either by manually or by using a data logger.

4. Electricity consumption by monitoring equipment

The electricity consumed by a typical monitoring system ranges from 1 W for a meter to 12 W for a communication and data logger system (see below), and this system will be powered by grid electricity of internal power grid. The electricity consumption is negligible compared to the power generated by the solar PV system.

Item	Power demand	Source
Monitoring equipment	Type 4W Maximum 12W	SMA SUNNY WEBBOX catalog
Electricity meter	Up to 5VA	Osaki Electric A3C-S27VR specification document