JCM Proposed Methodology

Displacement of Grid and Captive Genset Electricity by 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 the Maldives to achieve net emission reductions.

1.1. Background

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 the Maldives.

1.2. Findings and rationales

1.2.1. Estimation for the existing power stations in the Maldives

In the Maldives, power is provided by STELCO (State Electric Company Limited), FENAKA (FENAKA Corporation Limited), MWSC (Male' Water & Sewerage Company Pvt. Ltd) or the local council in the inhabited islands. Resort islands have their own power supply.

Power source is predominantly diesel with a very small portion coming from solar PV in some islands. For example, according to the data provided by STELCO, the electricity generated by solar PV was less than 0.3% of the total generation in Male in 2013.

The largest power demand is in Male and there is one powerhouse. Diesel is the only source of power at the powerhouse. The data for electricity production, fuel consumption, power generation efficiency and CO_2 emission factor are given in Table 1, using the constants shown in Table 2 for the calculation. The CO_2 emission factor is estimated to be 0.739 t-CO_2/MWh.

Table 1 Power generation efficiency and CO_2 emission factor of powerhouse in Male

Item	Figure 2012	Notes
Electricity production (kWh/yr)	224,562,324	(808,424,366 MJ)
Fuel consumption (liter/yr)	62,492,521	(2,284,101,643 MJ)
Efficiency (kWh/liter)	3.59	
Power generation efficiency of powerhouse (%)	35.4	
CO_2 emission factor (t-CO_2/MWh)	0.739	

Reference: Ministry of Environment and Energy, Republic of Maldives, *Maldives energy Outlook for Inhabited Islands 2013*, nd.

Table 2 Constants for calculation of CO_2 emission factor

Item	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 largely through diesel generators in the Maldives. Furthermore, considering the following facts, it can be concluded that diesel generation still tends to be the best available option for grid electricity generation in the future in the Maldives.

- 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 the near future upon reaching the end of its lifetime. Also, new capacity may soon be required to meet the 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

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)

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."[3]
>
> "In general, diesel engines have efficiencies that range from 30 to 45%."[4]
>
> "Power generation efficiency of diesel engines range from 30% to 48%"[5]
>
> "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."[6]

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)[7] and the conservative value of power generation efficiency of new high-efficient diesel generators, the

3 "POWER GENERATIN TECHNOLOGIES, 2nd Edition", 2014, Paul Breeze
4 " Handbook of Energy Efficiency and Renewable Energy", 2007, Edited by D. Yogi Goswami
5 "Cogeneration Plan and Design Manual, 6th edition", 2008, The Japan Institute of Energy
6 "Approach on High Efficiency Diesel and Gas Engine", 2008, Mitsubishi Heavy Industries Technical Review Vol. 45 No. 1
7 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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 section 1.2.1., which also ensures that the power generation efficiency of new high-efficient diesel generators set above is conservative.

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