ECONOMIC ANALYSIS OF CIKASO MINI HYDRO POWER PLANT AS A CDM PROJECT FOR INCREASING IRR

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Abstract
Renewable energy fueled power generations are few developed by private sector in Indonesia. High-cost investment and low electricity selling price to PT PLN as a single buyer is main barriers for private sector to involve in the development of renewable energy fueled power generations. In this project, the economic feasibility of Mini Hydro Power Plant of Cikaso with capacity of 5.3 MW, located at Sukabumi Regency, West Java province was assessed. This project utilized revenue generated from carbon market to increase the economic feasibility. Procedure to register the project to United Nation for Climate Change Convention (UNFCCC) as a Clean Development Mechanism project was explained in detail. Approved Consolidation Methodology (ACM) 0002 Version 12.3.0 was used to calculate grid emission factor in Jawa-Bali-Madura the grid electricity system. It was calculated that the grid emission factor is 0.833 (t-CO$_2$/MWh), and the carbon emission reduction generated for this project is 21,982 ton/year. From the analysis result, it can be proven that the additional revenue from carbon credit could increase the project IRR from 10.28% to 13.52%.

Key words: mini hydro power plant, Clean Development Mechanism, emission factor, IRR.

I. INTRODUCTION

A. Background
Renewable energy potential in Indonesia is quite large. Hydro energy potential in Indonesia is around 75 GW scattered over islands in Indonesia. Until now, only 4000 kW from the potential has been utilized as a power plant [1]. The utilization of mini hydro (over than 1 MW), micro hydro (10 kW – 1 MW) and pico hydro (below 10 kW) is suitable for remote areas and the area where PT Perusahaan Listrihka Listrik Negara (hereinafter referred as to "PLN") Persero’s electric grid is not yet built. PLN is the state-owned electric power company, which has a role as a single buyer in the electricity business in Indonesia [2].

Indonesia government has targeted ratio of renewable energy to be 2.5% from all energy consumption in 2025. Regarding Green House Gas (hereinafter referred as to "GHG") Reduction, Indonesia's government has planned to reduce 26% of GHGs in 2020 [3]. Despite policy and target for supporting renewable energy development have been implemented. Investors of renewable energy power plants still get a constrains on economic problems within the project. Unlike other countries, although the incentive for supporting renewable energy development has been implemented, however, the benefit still not be felt by investors. The incentive for renewable energy regarding electricity tariff for selling to PLN was determined by Regulation of Ministry of Energy and Mineral Resources in the year of 2002, 2006, and 2009 [4, 5, 6].

Despite the electricity tariff determined in 2009 relative closes to the economic price of the renewable energy project. However, it is not applicable to a hydro power plant project. Renewable energy based power plant is not economic. It is one reason why private sector is not interested to involve in it an investment in...
Development of the hydro power plants in remote areas needs high investment cost. Besides that the electricity selling price must compete with the electricity selling price of fossil fuel based power plant that gets a subsidy. This is another reason, why renewable energy based power plant is not a lot of built in Indonesia [7].

Clean Development Mechanism (hereinafter referred as to "CDM") is one of the mechanism of Kyoto Protocol as an attempt to reduce Green House Gasses [8] (hereinafter referred to as "GHG") such gas of CO$_2$, N$_2$O, CH$_4$, and so on. The reduction emission amount refers to the GHG amount generated by every country during a year of 1990. CDM has been implemented throughout the world since 1997, however, the implementation number in Indonesia is less compared to other countries in Asia such as India and China. Ratification of CDM by Indonesian government has been done in 2004, signed by the President of Republic of Indonesia.

Through CDM, developed countries (member of ANNEX I) collaborate with these countries to reduce GHGs emission. The benefit of CDM program for developing countries includes: (1) flow of the foreign fund which could help financial of a domestic project; (2) participation of foreign investors for the project which could minimize the risk to local developers; (3) possibility of transfer technology that could help domestic technology development in domestic; (4) loan rate from a foreign bank usually that has a lower rate compared to domestic bank rate. Among the benefits of CDM project above, lower bank loan rate is the most interesting factor for the local developers. For developed countries, CDM is the mechanism for reducing GHG with low cost compared to develop the project activity in their country.

CDM itself has procedures determined by United Frameworks for Convention Climate Change (hereinafter referred as to "UNFCCC"). The procedures should be conducted in order for approved officially by UNFCCC as an entity that provides a certificate for CDM project. Each step conducted in the CDM procedures may need a time more than one year. Basically, all procedures implemented on the project should be clarified whether the project can reduce GHG emission exactly and in line with the determined methodology. One of the conditions that a project can be implemented as CDM project, if the project economic can be increased using additional revenue from selling carbon credit. Project economic is a value of Internal Rate Return (hereinafter referred as to "IRR").
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Report that has been completed in 2009, it can be concluded that this project has IRR value of 10.28%. It is lower than a benchmark that determined based on the lowest rate of Working Capital rate of 12.22% issued by Bank of Indonesia in 2009. The project investment is Rp 122.2 billion funded by 100% owner equity.

In order to increase the feasibility level to the project, it is needed to add additional revenue through CDM mechanism for this project. For this purpose, this project activity would be submitted as CDM project and it was planned to be registered in UNFCCC. Certification of this project activity can be sold, and it can generate additional revenue besides the main revenue from selling electricity to PLN.

B. Purpose

This paper describes the grid emission factors (hereinafter referred to as “EF”) calculation for Jawa-Bali-Madura grid electricity system (hereinafter referred as to "JAMALI system"). Using the EF, the GHG reduction generated from this project activity can be calculated annually. The economy of Cikaso Small scale Hydro Power Plant (hereinafter referred as to "SSHPP") as the CDM project is calculated by considering the additional revenue from selling credit carbon. The economic condition with and without the additional revenue are compared. The economic feasibility of the project is compared using the conservative benchmark at that time.

II. METHODOLOGY

A. Green House Gas Calculation

Grid EF in this project activity is calculated using methodology determined by UNFCCC. Two methodologies are category of I-D: “grid connected renewable electricity generation” [8], ver. 16 and ACM (Approved Consolidation Methodology) 0002 version 12.3.0, “Consolidated methodology for grid-connected electricity generation from renewable sources” [9]. Using both methodologies, the electricity amount exported to the grid is converted to the emission reduction amount, and then based on the carbon market price, the additional revenue is calculated.

Project boundary is determined based on the methodology as illustrated in Figure 2 [8]. This figure indicates that the emission reduction activity is limited to the activities related to the Cikaso SSHPP only. In this project activity, small part of generated electricity is utilized for auxiliary equipments and the remaining is exported to the grid owned by PLN of West Java region. The difference between both electricity amounts is net electricity that used in the in the emission reduction calculation.

The data used during the determination of EF is all electricity generated by all power plants connected by the JAMALI system and all fuel consumption used in the all power plant during 2001-2005 [10-15]. Based on ACM 0002 [9], EF value is calculated by average value of the latest three years of data used during the determination of EF, 2003-2005 [12-15]. JAMALI system is the interconnection electricity system in Jawa, Madura and Bali Island.

Based on AMS-ID [8], Baseline Emission, BE_y, is obtained by multiplying net of electricity, EG_y, by the grid emission factor within the system, EF_y. Equation of BE is indicated in Equation (1).

\[ BE_y = EG_y \times EF_y \]  

where BE_y is baseline emission (tCO_2e) in year y, EG_y is quantity of net electricity generation that is produced and fed through the system as a result of the implementation of the CDM project. 

| Item               | Unit | Value |
|--------------------|------|-------|
| Installed total capacity | MW   | 5.3   |
| Installed capacity each unit | MW   | 2 x 2.25 |
| Average of exported energy to the grid annually | MWh | 26,390 |
| Capacity factor | %   | 58    |
| Head | m   | 40    |
| Water flow | m^3/s | 16.5 |
| Unit number | -   | 3     |
| Turbine type | -   | Horizontal Francis |

Table 1. Cikaso SSHPP specification
activity in the year y, and EF is Emission factor (tCO₂ e). Prior BEp calculation, parameters used in the steps below should be determined [16].

1) Step 1: Determination of Operating Margin Emission Factor

Simple Operating (OM) is selected for the emission factor calculation with the reason as follows.

• Dispatch data analysis emission factor is unable to be implemented, because required data cannot be published

• Number of plants which includes the category of “Low-Cost and Must-Run/LCMR” power generation plan is below of 50% compared to total of power generations connected to JAMALI system during five years (2005-2009).

In this case, numbers of LCMR power plants are five units of power plant in 2005 and 2006, six units of power plant in 2007 and 2008, and seven units of power plant in 2009.

Calculation of simple operating margin (EFOM,y) uses Equation (2) as follows.

\[ EF_{OM,average,y} = \left(\frac{tCO_2}{MWh}\right) = \frac{\sum_{m} (EG_{m,y} \times EF_{EL,m,y})}{\sum_{m} EG_{m,y}} \] (2)

where \( EG_{m,y} \) is net quantity of electricity generated and delivered to the grid by power unit \( m \) in the year \( y \) (MWh), \( EF_{EL,m,y} \) is CO₂ emission factor of power unit \( m \) in the year \( y \) (tCO₂/MWh), \( m \) is power unit included in the operated margin, and \( y \) is most recent historical years for which power generation data is available.

2) Step 2: Calculation of Build Margin Emission Factor

Build Margin Emission Factor (EFBM,y) calculation indicates an amount of CO₂ reductions in the absence of fossil fuel based power plant or on the delay to the development.

In the \( EF_{BM,y} \) calculation, the most recently developed a set of power plant having the highest electricity production annually is selected according to the following procedures.

• The set of five power units that have been built most recently, or

• The set of power capacity additions to the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

The set of power units that comprises the larger annual generation is selected, and then Build Margin Emission Factor is calculated using the following Equation (3).

\[ EF_{BM,y} = \left(\frac{tCO_2}{MWh}\right) = \frac{\sum_{m} F_{i,m,y} \cdot COEF_{i,m}}{\sum_{m} GEN_{m,y}} \] (3)

where \( F_{i,m,y} \), \( COEF_{i,m} \) and \( GEN_{m,y} \) can be analogous as the same parameters which are used throughout the operating margin emission factor calculation for a set of power units, \( m \).

3) Step 3: Calculation of Baseline Emission Factor

Combined Margin Emission Factor (EFy) is using Equation (4).

\[ EF_y = w_{OM} \times EF_{OM,y} + w_{BM} \times EF_{BM,y} \] (4)

where the ratio for \( w_{OM} \) and \( w_{BM} \) is 50% respectively (\( w_{OM} = w_{BM} = 0.5 \)).

4) Step 4. Calculation of Baseline Emission

Baseline emission (BEy) is calculated using Equation (5):

\[ BE_y = EG_y \times EF_y \] (5)

Where \( EG_y \) is quantity of net electricity generation and \( EF_y \) is Emission factor.

5) Step 5. Calculation of Emission Reduction

Calculation of Emission Reduction (ERy) is using Equation (6):

\[ ER_y = BE_y - PE_y - L_y \] (6)

This project activity is a renewable energy based power generation. Therefore, there is no leakage, \( L_y = 0 \), and Project Emission, \( PE_y = 0 \).

B. Economic Analysis

The aim to submit the project activity as CDM project is to increase the economic feasibility of the project. The Internal Rate Return (hereinafter referred to as “IRR”) is used as an economic parameter. The value is lower than the selected benchmark. The lowest bank loan rate over the year of 2009 is taken as the benchmark. The feasibility study was completed in 2009. Sensitivity analysis is calculated using ±10% of change of the following parameters,

• Investment cost

• Electricity selling privilege

• General administration and O&M cost

The change of ±10% is considered can be represented the changes due to inflation, increase over the prices, change of water debit and other parameters that able to change parameter of (i) investment cost, (ii) selling electricity price and (iii) generation administration cost and O&M cost.

The IRR project is re-calculated using the additional revenue generated from selling carbon credit and then the economic feasibility of the project is re-analyzed.
III. RESULTS AND DISCUSSIONS

A. Green Houses Gasses Emission

Green houses gasses emitted from power generation plant activity is Carbon Dioxide (hereinafter referred as to "CO\textsubscript{2}"), mainly. The amount of the GHG in JAMALI system rises year by year along with the increase of the coal-fired power plant number as a result of implementation of the Crash Program I.

The increase of CO\textsubscript{2} is shown in Figure 3. Figure 3 indicates that CO\textsubscript{2} rose sharply in 2006. The increase is caused by Cilacap and Tanjung Jati B coal-fired power plants started to operate in that year.

Even, there is no new power plant operated. The consumption of coal increased gradually that resulted CO\textsubscript{2} emissions increased, in the following years. According to the methodology [8], emission factor shall be calculated using the average of the last three years of 2007, 2008 and 2009.

![Figure 3. CO\textsubscript{2} Emitted from coal fired power plant in JAMALI system during 2004-2010 [17]](image)

Table 2.
Fuel specification

| Fuel Type | Calorie Value | Carbon Content Standard | Oxidized Carbon Factor Standard | Carbon | Emission, CO\textsubscript{2} | Specific Gravity | Emission CO\textsubscript{2} |
|-----------|---------------|-------------------------|--------------------------------|--------|-----------------------------|----------------|---------------------|
| TJ/kt fuel | tC/TJ         | (A)x(B)x(C) x 44/12     | (E) x (F)                      | kl fuel | tCO\textsubscript{2}/kt fuel |
| Sources   | (A)           | (B)                     | (C)                            | (D)    | (E)                         | (F)            | (G)                |
| MFO       | 41.02         | 21.1                    | IPCC                           | 1       | 865.50                      | 3,173.51       | 0.00099            | 3.142              |
| HSD       | 42.73         | 20.2                    | IPCC                           | 1       | 863.12                      | 3,164.77       | 0.000845           | 2.674              |
| Coal      | 24.03         | 26.20                   | IPCC                           | 1       | 629.61                      | 2,308.56       |                    |                    |
| Natural Gas | 48.00       | 15.30                   | IPCC                           | 1       | 734.40                      | 2,692.80       |                    |                    |

Note: HSD: High Diesel Speed, MFO: Marine Fuel Oil, IPCC: Intergovernmental Panel on Climate Change; PERTAMINA: Perusahaan Pertambangan Minyak dan Gas Bumi Negara/State-Owned Oil Company of Indonesia, kt fuel: kilo tonne fuel; tC: tonne carbon, TJ: Terra Joule, kl fuel: kilo litre fuel
electricity generated deducted by the loss generated from own consumption and generated from sub stations.

Fuel consumption of each power plant during five years, 2005-2009 is shown in Table 6. Amount of GHG emitted from each kind of fuel is shown in Table 7. Table 8 shows \( \text{EF}_{\text{simpleOM}} \) derived from the amount of CO\(_2\) emission and total amount of electricity generated during the last three years, 2007, 2008, and 2009. The value of \( \text{EF}_{\text{simpleOM}} \) was calculated using Equation (4), and the result is 0.9583 (tCO\(_2\)/MWh).

### Table 3.
Electricity generated in JAMALI system based on the fuel type (MWh nett)

| Source of plant | Operation year | 2005  | 2006  | 2007  | 2008  | 2009  |
|-----------------|----------------|-------|-------|-------|-------|-------|
| Hydro           |                | 7,023 | 5,309 | 5,930 | 6,251 | 6,635 |
| Diesel Oil      |                | 128   | 101   | 87    | 173   | 121   |
| Gas Turbine Gas |                | 2,603 | 2,038 | 2,126 | 3,073 | 4,688 |
| Gas Turbine Oil |                | 2,547 | 2,087 | 1,958 | 2,191 | 3,275 |
| Geothermal Coal |                | 6,185 | 6,183 | 6,672 | 7,337 | 8,188 |
| Steam Gas       |                | 45,477| 51,826| 57,206| 54,140| 56,965|
| Steam Gas       |                | 646   | 669   | 941   | 690   | 563   |
| Steam Oil       |                | 6,673 | 7,171 | 7,685 | 8,274 | 7,301 |
| Combined Cycle Gas |            | 16,559| 6,193 | 17,929| 18,953| 20,301|
| Combined Cycle Oil |           | 8,980 | 8,444 | 7,192 | 10,505| 7,527 |
| Total Net Production |         | 96,821| 100,021|107,726|111,586|115,564|

### Table 4.
Ratio of low cost and must run power of power plant in the last 5 years (2005 - 2009)

| Item                        | Units | 2005    | 2006    | 2007    | 2008    | 2009    |
|-----------------------------|-------|---------|---------|---------|---------|---------|
| Total Generation Net        | GWh (net) | 83,436  | 88,351  | 95,124  | 97,999  | 100,741 |
| Low Cost and Must-run generation | GWh (net) | 13,385  | 11,670  | 12,603  | 13,588  | 14,823  |
| Low Cost and Must-Run Generation/ Total Generation | % | 16% | 13% | 13% | 14% | 15% |

### Table 5.
Lost ratio

| Year | 2005 | 2006 |
|------|------|------|
| Average losses in Java-Bali system due to own consumption | 3.94% | 4.21% |

### Table 6.
Fuel consumption in the grid during 2005-2009

| Fuel Type | unit | 2005    | 2006    | 2007    | 2008    | 2009    |
|-----------|------|---------|---------|---------|---------|---------|
| HSD       | kilo litre | 4,406,883 | 3,623,332 | 3,498,197 | 4,031,017 | 2,781,649 |
| MFO       | kilo litre | 1,944,142 | 2,054,365 | 2,225,317 | 2,374,577 | 2,150,386 |
| IDO       | kilo litre | 4,074   | 2,343   | 2,306   | 4,401   | -       |
| Gas       | MMBTU | 136,744,924 | 141,147,996 | 145,991,700 | 167,844,288 | 219,008,065 |
| Coal      | ton   | 24,524,261 | 26,860,205 | 29,584,714 | 28,353,988 | 29,409,721 |

### Table 7.
CO\(_2\) emission in JAMALI grid system during 2005-2009

| Year | Fuel type | 2005 t-CO\(_2\) | 2006 t-CO\(_2\) | 2007 t-CO\(_2\) | 2008 t-CO\(_2\) | 2009 t-CO\(_2\) |
|------|-----------|-----------------|-----------------|-----------------|-----------------|-----------------|
| HSD  |           | 11,785,015      | 9,689,620      | 9,354,980      | 10,779,863      | 7,438,768       |
| MFO  |           | 6,108,049       | 6,454,344      | 6,991,436      | 7,460,377       | 6,756,020       |
| IDO  |           | 11,142          | 6,408          | 6,307          | 12,037          | -               |
| Gas  |           | 8,093,881       | 8,354,497      | 8,641,195      | 9,934,641       | 63,006          |
| Coal |           | 6,615,701       | 62,008,365     | 68,298,053     | 65,456,849      | 67,524,209      |
| TOTAL|           | 82,613,788      | 6,513,234      | 93,291,971     | 93,643,767      | 94,682,002      |
EFBM calculation is conducted after determined the most recently developed a set of power plant having the highest electricity generated annually. Two groups of power plants were determined according to step 2. The first group consisted of five units the most recently developed power plant, and the second group consisted of power plant generating electricity with the amount ratio of 20% from total electricity generated within the system. The highest electricity generated from both groups that consist of power plants producing electricity in amount of 20% from the total in 2009 was selected, as shown in Table 9.

| Item                     | Unit | 2007    | 2008    | 2009    | TOTAL |
|--------------------------|------|---------|---------|---------|-------|
| Total Emissions          | tCO₂ e | 93,291,971 | 93,643,767 | 94,682,002 | 281,617,740 |
| Total Generation         | MWh (net) | 95,123,861 | 97,998,684 | 100,741,000 | 293,863,545 |
| EFOM                    | tCO₂ e/MWh | 0.958 |

Table 9.
Two groups of power plant using to determine build margin emission factor

| Sample group (m) Classification | “The five power plants that have been built recently” (GWh) | “The power plants capacity addition to the electricity system that comprises 20% of system generation (in GWh) and that have been built most recently” | Comments |
|---------------------------------|-------------------------------------------------|-----------------------------------------------------------------|----------|
| Electricity quantity            | 12,578.0                                        | 25,660                                                          |          |
| Proportion (ratio to total generation in JAMALI grid) | 10.88%                                          | 22.20%                                                          | Total generation is 115,564 (GWh) in JAMALI grid |
| Selected group                  | O                                               |                                                                  |          |

C. Emission Reduction, (ERy)
ER in this project activity is calculated using Equation (4) and Equation (5). L_y=P_y=0, and then emission reduction of CO₂ resulted from operation of Cikaso SSHPP is 21,982 tCO₂/yr.

D. Economic Analysis
The calculation results of sensivity analysis are shown in Figure 4. X-axis and Y-axis indicates the amount of parameter change and IRR value. In the Figure, benchmark line of 12.22%, selling electricity price, investment cost, and general administration cost and O&M cost is indicated by symbol of (X), (■), (◆) and (▲), respectively. The selected benchmark used throughout the calculation is the conservative bank loan rate in 2009 when the Feasibility Study completed. Change of three parameters within the amount of ±10% shows IRR is still below than the benchmark value. It can be concluded that the
change of three parameters doesn’t give an effect to the feasibility of the project to be unfeasible.

The assumption of CER (Certified Emission Reduction) is 13 Euro/t-CO$_2$ for 30 years. The calculation results considered the additional revenue from CER shows IRR increased 3.24%, from 10.28% to 13.52% as shown in Table 13. The additional revenue increased the value of IRR of 13.52%. It becomes higher than the benchmark value of 12.22%.

IV. CONCLUSION

According to the calculation result of economic feasibility of the project, it can be proven that the additional revenue generated from carbon credit could increase the project IRR.
from 10.28% to 13.52%. The additional revenue from carbon credit can increase the economic feasibility of a renewable energy.

This mechanism is suitable for Indonesian condition that still doesn’t have incentives to renewable energy power generation development. The other benefit for implementing CDM, the project can be known internationally as the project that contributes in emission reduction of GHG. It can increase the project image as a green project which contributes in GHG emission reduction.

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