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# Emission And Financial Analysis Of Geothermal Energy Resource (The Case Of Lahendong Site In Indonesia)

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## ABSTRACT

**The purpose of this study is to conduct the financial and emission analysis of the Lahendong site as a case study of geothermal powerplant in Indonesia. The outputs of energy model in RETScreen worksheet are power capacity, electricity generation, annual GHG emission reduction, the Internal Rate Return (IRR) and payback period. The sensitivity analyses also were carried out at two scenarios (no grant and with grant) for examining the changes of Feed in Tariff (FiT) and Carbon Credit (CC) impact toward IRR and payback period. Based upon the IRR, payback period and emission $CO_2$ reduction, this study shows the geothermal energy has attractive investment economically and has eco-environmental benefits to be developed. This study is the first analysis about emission and financial analysis using RETScreen software that carried out in Indonesia, therefore this study can be useful for other geothermal resources analysis.**

**Keywords - Geothermal energy, Emission analysis, Financial analysis, $CO_2$ mitigation, Payback period, Internal Rate Return**

## I. INTRODUCTION

Geothermal energy resources are locally available as an energy supply option for many areas in the entire of Indonesia. Indonesia has huge resources for the wide-scale use of geothermal energy as one of the environment-friendly and sustainable renewable energy sources. Straddled along the Pacific Ring of Fire, an arc of seismic activity, Asia's geothermal reservoirs are among the world's largest, Indonesia alone holds 40 percent of the world's total reserves, but less than 4 percent is being developed, leaving the sector wide open for growth [1].

Indonesia's total geothermal energy potential is equivalent to 27,710 MW of electricity- the largest geothermal energy capacity in the world. Of this total 11,369 MW is confirmed as probable reserve, 1050 MW as possible reserve and 2288 MW as proven reserve. The remaining 13,000 MW is still speculative and hypothetical resources. However, progress in this sector has been slow present installed Capacity is only 4.3% of its potential, or around 1200 MW [2]. The status of geothermal energy among Indonesia energy sources for electricity generation is presented in Fig. 1.

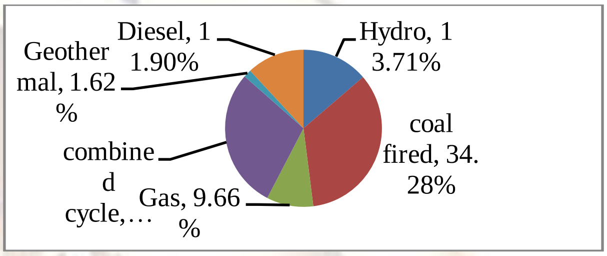


**Figure 1. The share of energy source for electricity generation in Indonesia [3]**

Figure 1 presents that only 1.62% of the geothermal energy use for electricity generation in Indonesia so far. Though Indonesia has a huge potential of geothermal energy resources which is spread over in many areas, the present use of geothermal energy for electricity generation accounts small fraction, among the total energy generation in Indonesia. Therefore, the development studies and investments in geothermal energy analysis should be supported.

The purpose of this study is to conduct the financial and emission analysis of a geothermal site in Lahendong, Indonesia as a case study. In order to calculate both emission analysis and financial analysis, a case study of a geothermal power plant is considered in RETScreen software. For this study, the output of RETScreen performs technical analysis in term of power capacity and electricity generation that can be exported to grid. The emission analysis is presented in term of the nett annual GHG emission reduction. The financial analysis is presented in term of the Internal Rate Return (IRR) and payback period.

Due to availability of the data, geothermal resource potential in Lahendong site is proposed to be analyzed as a case study. The Lahendong geothermal site is located at the coordinates: 1°16'19"N 124°50'7" E in North Sulawesi province, one of the major geothermal resources in Indonesia. The map of the Indonesia with the highlight of North Sulawesi province, which is the location of the case study situated, is presented in Figure 2. It is necessary to conduct the case study analysis for proposed project as a preliminary analysis method for the entire resource in Indonesia.


**Figure 2. Map of the Indonesia with the highlight of North Sulawesi province, the location of the case study.**

## II. Method And Analysis

The method used in this study consists of 4 steps, i.e.: proposed the power project, emission analysis, financial analysis and sensitivity analysis. All the processes were done in RETScreen by putting the input needed. The method used including the input and output of this study were presented in Fig. 2.

The process and the detail inputs are described in the following:

### 2.1 Proposed case power system

An energy model was developed for geothermal powerplant in Lahendong, Indonesia using the RETScreen worksheet. The data needed as the input has been searched and collected from several references. Based on the previous study about characteristic of Lahendong geothermal by [4] the technical data about steam pressure and temperature can be found. The data completed of characteristic to support as the input in the RETScreen worksheet are listed in Table 1.

The characteristics of Lahendong geothermal have high temperature, range in between 300 and 350 C with pressures about 150 bar. It has steam flow 40 kg/s, equal to 144,000 kg/h. It was assumed the plant will be operated as base load in 7884 h (90%), with minimum capacity 40%.

Incremental initial costs which is the sum of the design, purchase, construction and installation costs of all the elements of the power system. The incremental capital cost is counted based on the capital cost of geothermal plant of 2500 US$/kW [6, 7]. The electricity export rate based on Feed in Tariff as the regulator by the Indonesia government as 0.01 US$/kWh. The government of Indonesia plans to set tariff of electricity from renewable energy as Rp. 1000/kWh (equal to 0.01 US$/kWh) as a policy to encourage the development of electricity generation from renewable energy sources (Energy Minister Law no. 31/2009).

### 2.2 Emission analysis

RETScreen adjust the annual reduction to account for transmission and distribution losses and GHG credit transaction fee. In this work, GHG emission factor was done based on coal as substitution fuel type with the 10% [4] of transmission and distribution losses into account, the result equal to 0.752 $tCO_2$/MWh. The input value for GHG credit transaction fee is 2 %, GHG reduction credit duration is 20 year, and the GHG reduction credit escalation rate is 3%, GHG emission credit rate vary 10-18 US$/ton $CO_2$ [8].

### 2.3. Financial analysis

The input of the financial analysis in RETScreen worksheet are the inflation rate, project life, debt ratio, debt interest rate, debt term as well as initial cost data. For the financial analysis, it is assumed that the project life for 30 years and the tax burden is ignored. Summary of financial parameters for the proposed geothermal power plant are shown in Table 2.

It is assumed that the geothermal power plant operates on the 90% of base load for 7884 h/year, with maintenance and mechanical cleaning of wells and equipment taking approximately 360 h/year. There are many factors affecting the cost of geothermal power generation, including investment, capital structure, government policy and management capacity and skill. Total initial investment in a geothermal power plant is US$ 2500/kW.

Geothermal power plant operating and maintenance costs range from $0.004 to $ 0.014 per KWh, depending on how often the plant runs. Geothermal plants typically run 90% of the time [9]. If the geothermal proposed power plant can produce 241,065 MWh, then the minimum O&M cost ($0.004) for this study for 3,615,975 US$. By taking the minimum O&M cost (0.004 US$/kWh), the total O&M cost for generating 241,065 MWh would be 964,260 US$. Plant lifetime are typically 30–45 years. Financing is often structured such that the project pays back its capital costs in the first 15-20 years. Costs then fall by 50–70%, to cover just operations and maintenance for the remaining 15–30 years that the facility operates.

### 2.4 Sensitivity analysis

The sensitivity analysis is carried out to know the impact of the changes of FiT and carbon credit changes toward IRR and payback period for 2 scenarios (no grant and with grant). Sensitivity analysis can help in a variety of other circumstances which can be handled by the settings of parameter changes in order to detect important criteria and to identify critical assumptions or compare alternative models structures.

In order to support the implementation of proposed geothermal project, several mechanisms were considered such as carbon credit, FiT and grant (government grant). Sensitivity analyses were examined the changes of FiT and carbon credit for two scenarios, i.e. without grant and with grant (assumed 50% of initial capital cost is subsidized with government grant). The sensitivity analysis is examined by changing of FiT ( at the value of 0.07 US$/kWh, 0.1 US$/kWh, 0.13 US$/kWh) and Carbon credit (at the value of 10 US$/ton$CO_2$, 12 US$/ton$CO_2$, 14 US$/tonCO2, 16 US$/tonCO2 and 18 US$/ton$CO_2$). The impact of parameter changes into payback period and IRR as the economic parameter were analyzed in RETScreen worksheet.

The result of the RETScreen model can be obtained by providing the input to the RETScreen worksheet with the characteristics of geothermal site such as steam flow, operating pressure, steam temperature and back pressure. The initial cost was set to be 75,000,000 US$ and the case of electricity export rate was 100 US$/MWh, obtained from the value of FiT taken at 0.10 US$/kWh.

The output shown that the power capacity of the case study is 30 MW and the total electricity export to the grid is 241,065 MWh. The RETScreen Energy model worksheet with characteristic geothermal plant inputs, power capacity and the electricity exported to grid, and the input parameter of sensitivity analysis (at FiT equal to 0.10 US$/kWh) is presented in Fig. 4.

## III. RESULT AND DISCUSSION

### 3. 1 Emission analysis Result

RETScreen result of the emission analysis of proposed project is presented in Fig. 5.

It was found that the value of GHG emission base case at 181,253 tCO2, while the value of GHG emission proposed case at 18,125 tCO2. By reducing the GHG emission base case to proposed case, the gross annual GHG emission proposed case was found to be 163,128 tCO2. Due to the 2% of GHG credit transaction fee, the net annual GHG emission reduction becomes 159,865 tCO2. This same calculation results for two scenarios, with grant and without grant.

### 3. 2. Financial Analysis Result

To give an idea of the result of financial analysis in RETScreen worksheet with the case with FiT equal to 0.1 US$/kWh and Carbon credit equal to 12 US$/ton CO2 were chosen to represent the result of analysis.

The cumulative cash flow analysis result for scenario 1 and scenario 2 were presented in the Fig. 6 and Fig.7 respectively. It is found that the value of IRR for scenario 1 and scenario 2 were 41.3% and 77.5% respectively. The more IRR, the more interesting of the project. The payback period for scenario 1 and scenario 2 are 2.8 years and 1.4 years respectively. It is obvious that if the proposed project with grant subsidized will be more attractive than without grant. However, it is clear that both scenarios have positive IRR as well as short payback period that indicate the proposed projects are attractive.

### 3.3. Sensitivity Analysis Result

he sensitivity analyses are carried out by changing the input parameter in term of FiT and carbon credit. The impact to the IRR and payback as financial parameter are examined.

The result of the sensitivity analysis due to the changes of FiT toward IRR for scenario 1 (no grant) and scenario 2 (with grant) are presented in Fig. 8.

As it becomes obvious from the Fig. 9, for the first scenario (no grant), it is found that payback is sharply decrease by the changes of FiT. The same condition also is applied for the scenario 2 (with grant), that it is found that payback period is sharply decrease by the changes of FiT. However there is no significant difference among carbon credit value, i.e. 10 US$/ton $CO_2$, 12 US$/ton $CO_2$, 14 US$/ton $CO_2$, 16 US$/ton $CO_2$ and 18 US$/ton. This latest finding occurs for both scenarios.

It is found that the IRR range between 30.4% and 53.5% for scenario 1, while the IRR range between 55.9% and 102% for scenario 2 in the case of the FiT value changing as well as the carbon credit changing. The higher IRR, the more interesting project as the economic parameter in this study.

It is found that the payback period between 2.1 years and 3.8 years for scenario 1, while the payback period between 1 years and 1.9 years for scenario 2 in the case of changing FiT value. The less payback period, the more interesting project as the economic parameter in this study.

The result due to the changes of carbon credit toward IRR for scenario 1 (no grant) and scenario 2 (with grant) are presented in Fig.10.

As it becomes obvious from the Fig. 10, for the first scenario (no grant), it is found that IRR is slightly increase by the changes of carbon credit. The same condition also is applied for the scenario 2 (with grant), which is found that IRR is slightly increase by the changes of carbon credit. However there is significant difference among FiT value, i.e. 0.07 US$/kWh, 0.1 US$/kWh and 0.16 US$. This latest finding occurs for both scenarios. It was found that the IRR range between 30.4% and 53.5% for scenario 1, while the IRR range between 55.9% and 102% for scenario 2 in the case of changing carbon credit value. It is shown that the carbon credit influence the IRR insignificantly. If the amount of carbon credit increases, the amount of the IRR will be increase less than 1% gradually.

The result due to the changes of carbon credit toward payback period for scenario 1 (no grant) and scenario 2 (with grant) were presented in Fig. 11.

As it becomes obvious from the Fig. 11, for the first scenario (no grant), it is found that IRR is slightly decrease by the changes of carbon credit. The same condition also is applied for the scenario 2 (with grant), which is found that IRR is slightly decrease by the changes of carbon credit. However there is significant difference among FiT value, i.e. 0.07 US$/kWh, 0.1 US$/kWh and 0.16 US$. This latest finding occurs for both scenarios.

Therefore the FiT plays important role to support the proposed project development. The IRR is most sensitivity to the changes of FiT compare to the changes of CC, also the payback is most sensitivity to the changes of FiT. The changes of CC is insignificant for scenario 1 (without grant) and scenario 2 (with grant).

## IV. CONCLUSION

The case study of geothermal energy in Lahendong site, Indonesia has been carried out in this work. It is found that the proposed project of geothermal power plant with characteristic input given in the RETScreen worksheet, the Lahendong site can produce 30 MW as installed power capacity, and 241,065 MWh per year electrical energy can be produced from this power plant. This project can be considered as a project for CDM, with criteria renewable energy project activities with emission reduction 169 ktCO2 per year.

The sensitivity analysis also has been carried out in order to examine the impact of the changes of FiT and carbon credit toward IRR and payback period as a economic parameter in this study. The results show that FiT is the significant impact to the IRR and payback period for both scenario. The higher IRR indicates the more attractive of the project. In contrast with the payback period, the less payback period indicates the more attractive of the proposed project.

It is found that the IRR range between 30.4% and 53.5% for scenario 1, while the IRR range between 55.9% and 102% for scenario 2 in the case of the FiT value changing as well as the carbon credit changing. Comparison of scenario 1 and 2 result that the IRR for the scenario 2 is higher to scenario 1. It is found that the payback period between 2.1 years and 3.8 years for scenario 1, while the payback period between 1 years and 1.9 years for scenario 2 in the case of changing FiT value.

The emission analysis and financial analysis have been carried out, the results indicate that the project is economically feasible and applicable. Besides that, the proposed project can benefit can benefit locally and globally to the environment due to the GHG mitigation by utilizing geothermal energy to substitute fossil energy. A support mechanism should be established and more financing grant should be assigned for the geothermal development projects in Indonesia. It is clear that beside carbon credit and government grant, a support mechanism such as FiT can be good option to encourage the utilization of geothermal energy in Indonesia. The geothermal energy has the potential to play an important role for the future energy supply in Indonesia. This case study can be a preliminary analysis to explore more potential of geothermal that spread in the islands of Indonesia.

## ACKNOWLEDGEMENTS

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**Table. 1 The parameters and characteristics of the proposed project of the geothermal power system**

| Input parameter | Value | Reference |
|---|---|---|
| Project located | Lahendong | - |
| Steam flow | 144,000 kg/h | [5] |
| Operating pressure | 150 bar | [5] |
| Steam temperature | 350 C | [5] |
| Back pressure | 8 kPa | [5] |
| Steam turbine efficiency | 77% | Typical assumption |
| Minimum capacity | 40% | Typical assumption |
| Installed initial cost | US$ 2500/kW | [6],[7] |
| Operating and Maintenance cost | US$ 0.04/KWh | [6] |
| Electricity price sold to grid | US$ 0.10/kWh | Energy Minister Law No. 31/2009 |

**Table 2. Summary of financial parameters for the proposed geothermal power plant**

| Input parameter | Value | Remarks |
|---|---|---|
| Inflation rate | 5% | Data (Indonesia economics) |
| Project life | 30 year | Typically |
| Debt ratio | 20% | Data (Indonesia economics) |
| Debt interest rate | 6.5% | Data (Indonesia economics) |
| Debt term | 20 | Assumed |
| Initial cost | 75,000,000 US$ | Calculated from 2500 USS/kW |

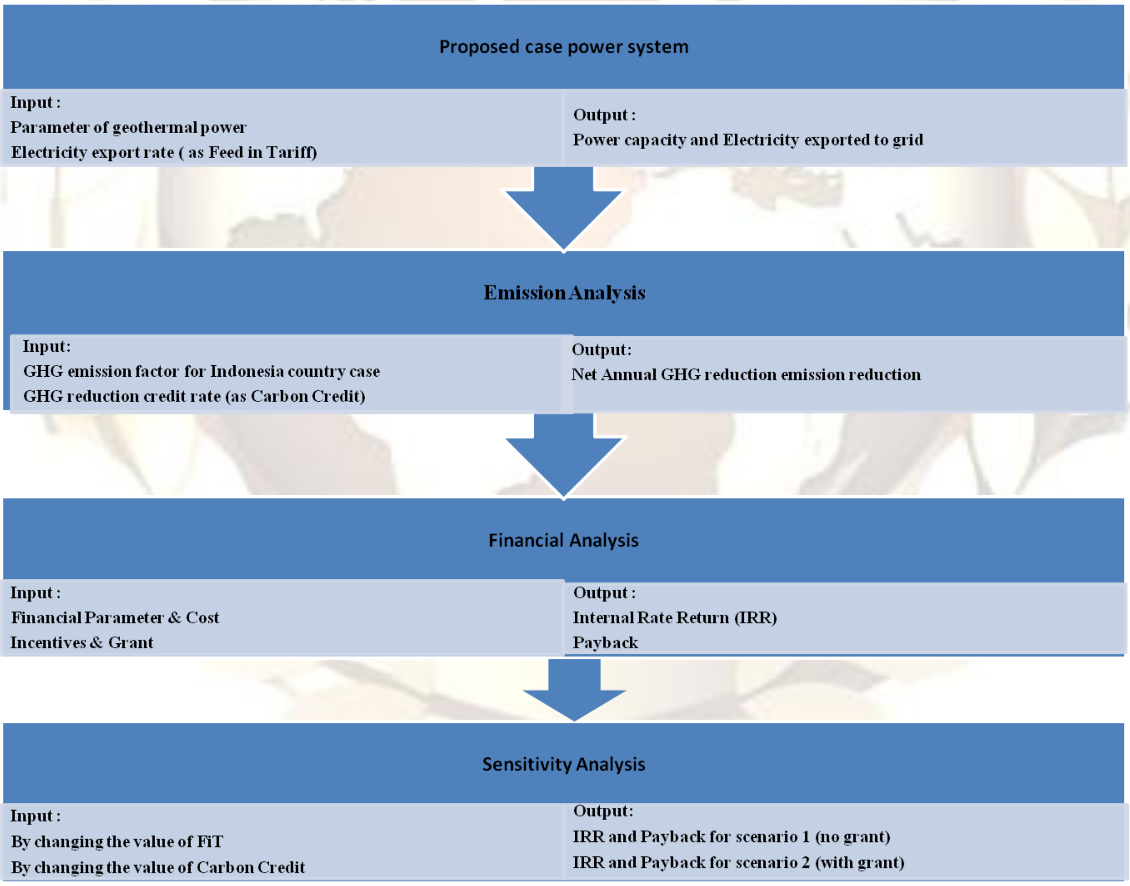


**Figure 3. The method used including the input and output of this study**

RETScreen Energy Model - Power project

Show alternative units

| Proposed case power system | | | | Incremental initial costs | |
|---|---|---|---|---|---|
| Technology | | Geothermal power | | | |
| Availability | % | 90.0% | 7,884 h | | |
| **Geothermal power** | | | | | |
| Steam flow | kg/h | 144,000 | | $ 75,000,000 | |
| Manufacturer | | | | | See product database |
| Model and capacity | | | | | |
| Operating pressure | bar | 150 | | | |
| Saturation temperature | °C | 342 | | | |
| Steam temperature | °C | 350 | | | |
| Back pressure | kPa | 8 | | | |
| Steam turbine (ST) efficiency | % | 77.0% | | | |
| Actual steam rate (ASR) | kg/kWh | 4.71 | | | |
| Minimum capacity | % | 40.0% | | | |
| Power capacity | kW | 30,578 | | | |
| Electricity exported to grid | MWh | 241,065 | | | |
| Electricity export rate | $/MWh | 100.00 | | | |

**Figure 4. The result of RETScreen Energy model for geothermal proposed project**

| Emission Analysis | | | | | |
|---|---|---|---|---|---|
| Base case electricity system (Baseline) | | GHG emission factor (excl. T&D) | T&D losses | GHG emission factor | |
| Country - region | Fuel type | tCO2/MWh | % | tCO2/MWh | |
| Indonesia | All types | 0.877 | 10.0% | 0.752 | |
| Electricity exported to grid | MWh | 241,065 | T&D losses | 10.0% | |
| **GHG emission** | | | | | |
| Base case | tCO2 | 181,253.7 | | | |
| Proposed case | tCO2 | 18,125.4 | | | |
| Gross annual GHG emission reduction | tCO2 | 163,128.4 | | | |
| GHG credits transaction fee | % | 2.0% | | | |
| Net annual GHG emission reduction | tCO2 | 159,865.8 | is equivalent to | 159,866 | tCO2 |
| **GHG reduction income** | | | | | |
| GHG reduction credit rate | $/tCO2 | 12.00 | | | |
| GHG reduction credit duration | yr | 20 | | | |
| GHG reduction credit escalation rate | % | 3.0% | | | |

**Figure 5. The RETScreen result of the emission analysis of proposed project**

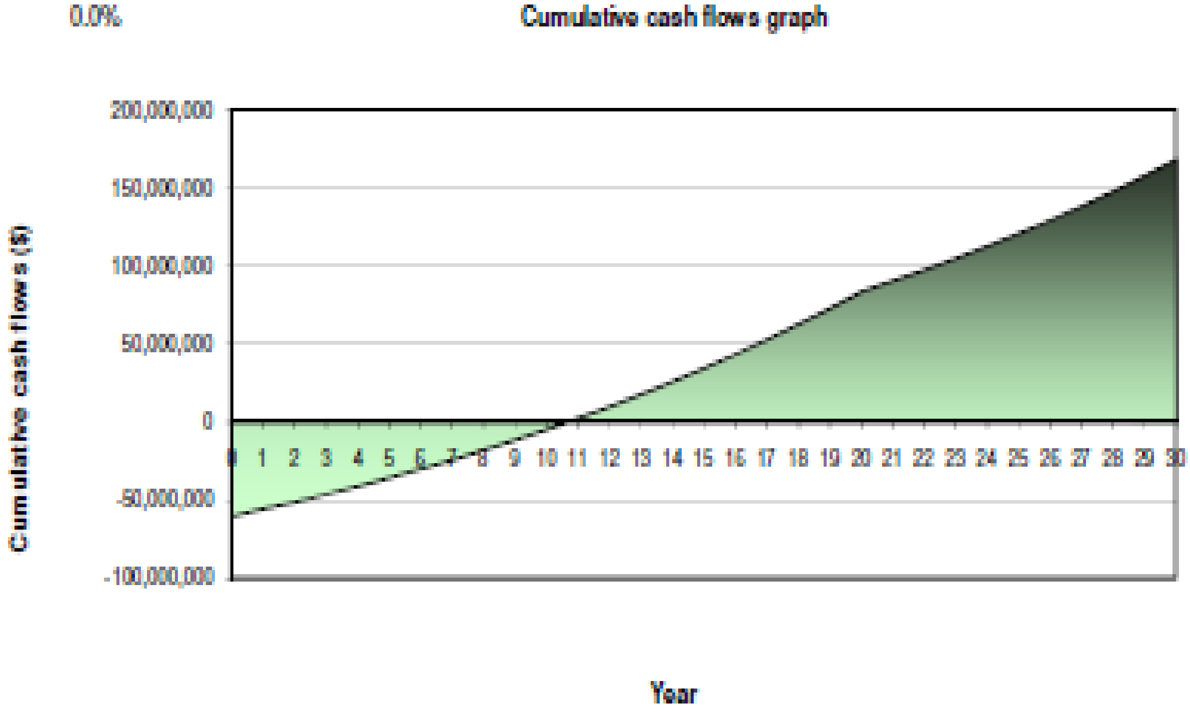


**Figure 6. The cumulative cash flow analysis result for no grant scenario for the case of FiT value at 0.10 US$/kWh and carbon credit at 12 US$/tCO$_2$**

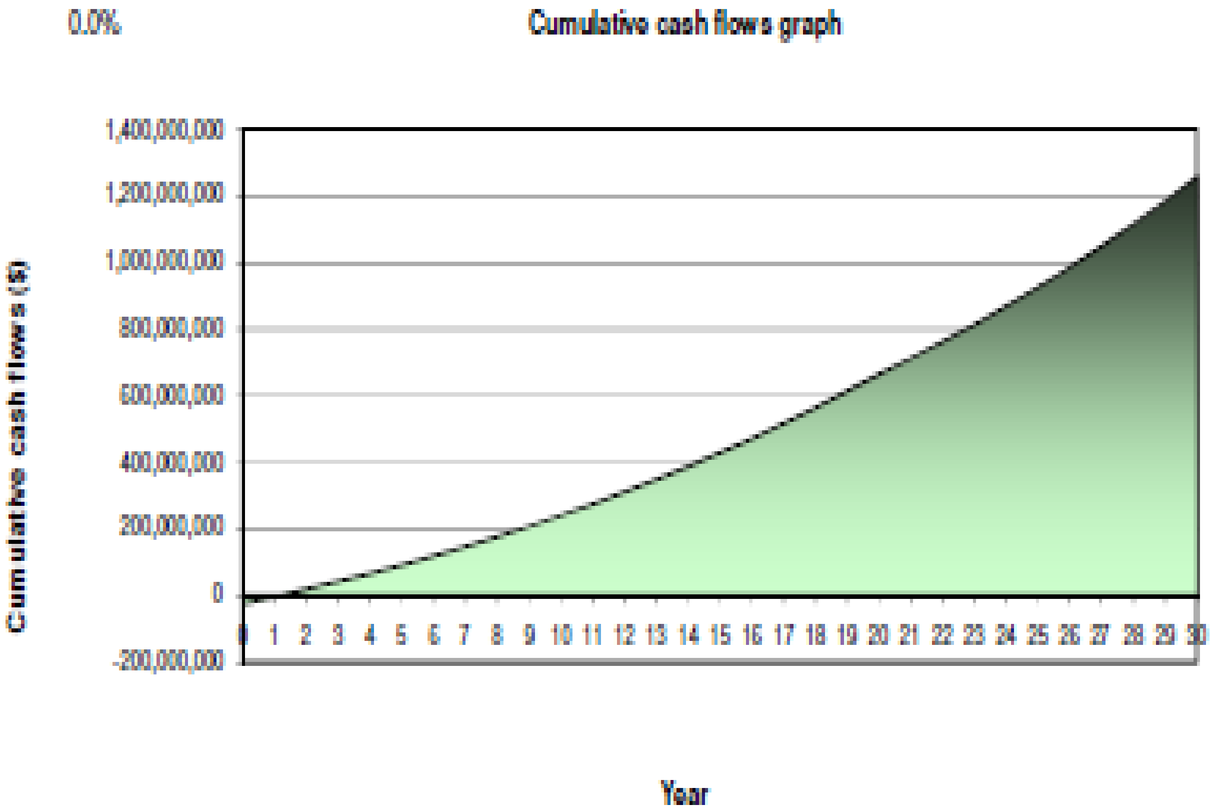


**Figure 7. The cumulative cash flow analysis result for 50% grant scenario for the case of FiT value at 0.10 US$/kWh and carbon credit at 12 US$/tCO$_2$**

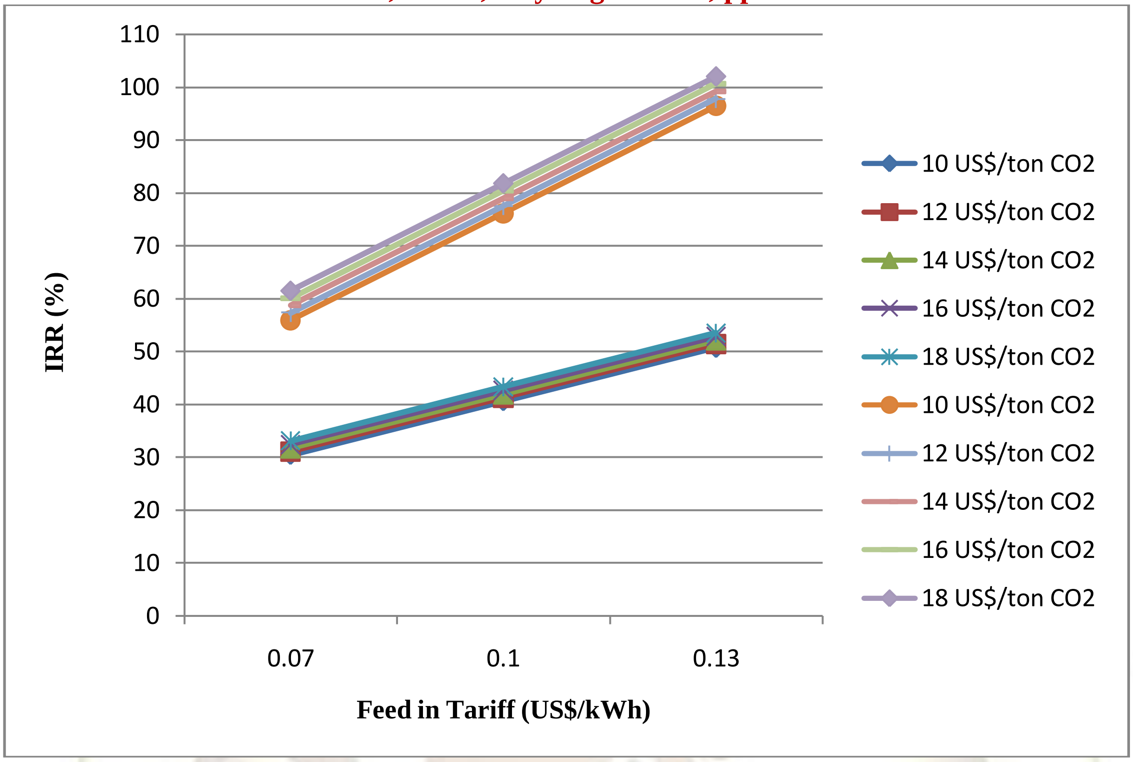


**Figure 8. The changes of FiT vs IRR for scenario 1 (no grant) and scenario 2 (with grant)**

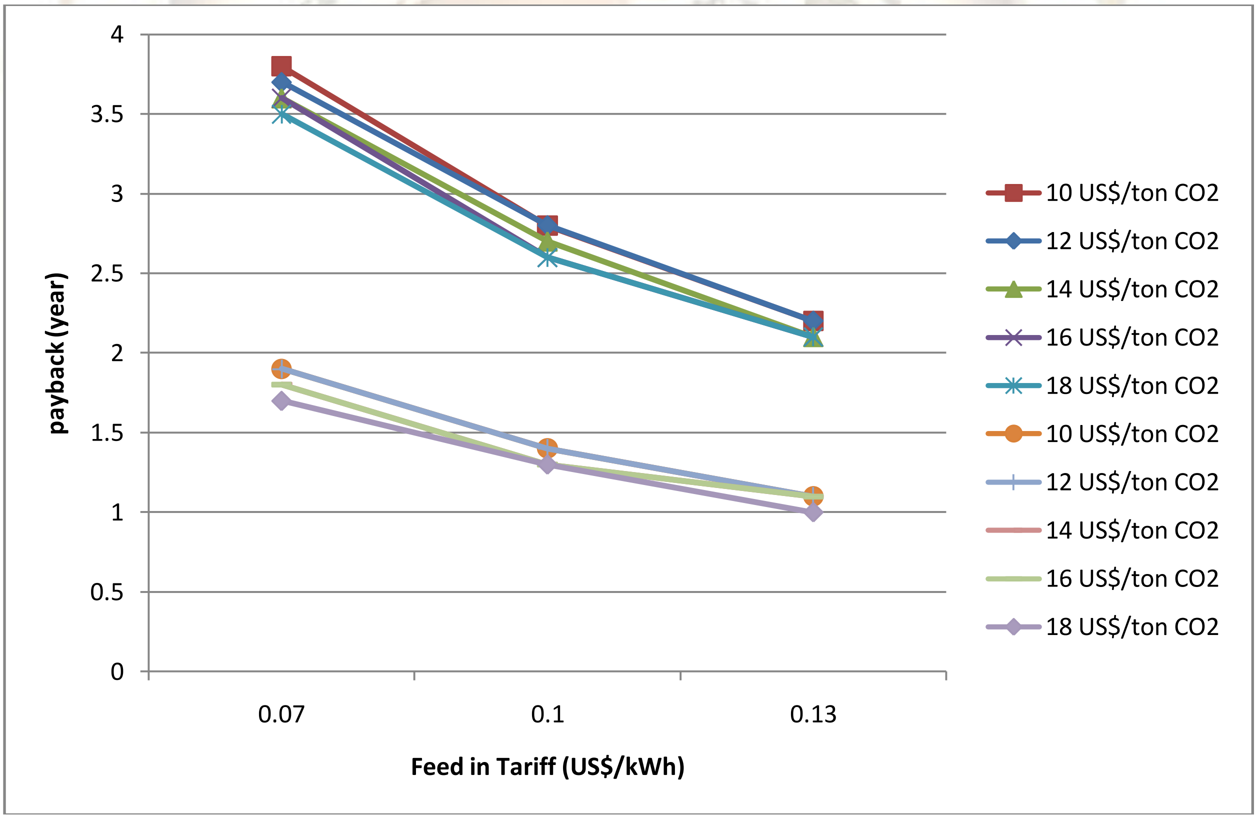


**Figure 9. The changes of FiT vs payback for scenario 1 (no grant) and scenario 2 (with grant)**

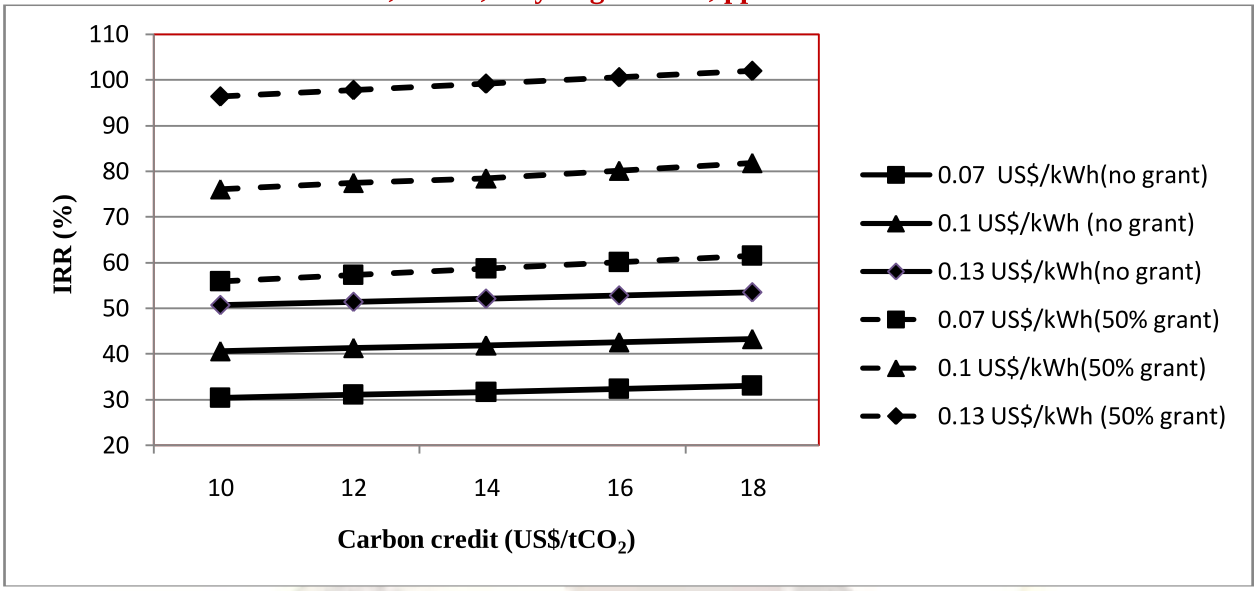


**Figure 10. The changes of Carbon credit vs IRR for scenario 1 (no grant) and scenario 2 (with grant)**

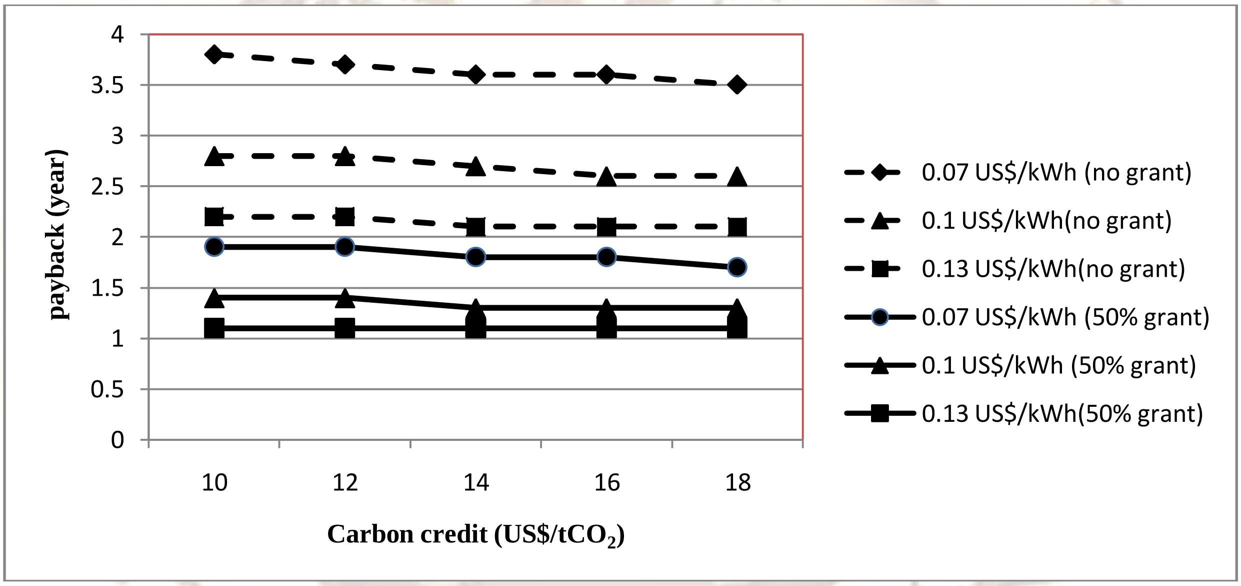


**Figure 11. The changes of Carbon credit vs payback for scenario 1 (no grant) and scenario 2 (with grant)**