Geothermal Power Plant Project Analysis, Greenhouse Gas Emissions Reduction, Economic Evaluation and Financial Profitability , Case Study of the Ranomafana Prospect

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Abstract

The purpose of this study is to conduct the financial and emission analysis of the Ranomafana site as a case study of geothermal power plant in Madagascar. The outputs of energy model using econometric technique are power capacity, electricity generation, annual GHG emission reduction, the Internal Rate Return (IRR), payback period, Net Present Value (NPV) and Profitability Index (Ip). The total initial investment for a 31.5 MW geothermal power plant was 107.9 million USD (at the end of 2022 costs). Economic analysis showed total annual savings and revenue of 11.978 million USD by avoiding fossil fuel electricity generation. About 71,465 tCO2 eq. could be avoided annually. The project is feasible due to positive NPV of 47.186 million USD, an IRR 13.3%, 10 years of payback period and an Ip more than 1.4. Based upon the IRR, positive NPV, short 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 can be useful for other geothermal resources analysis in Madagascar.

***Keywords**: Geothermal energy, project analysis, power plant, GHG emission, techno-economic, financial profitability.*

1. INTRODUCTION

Madagascar is willing to develop geothermal power plant to increase its electrical capacity in order to satisfy the demand especially in rural areas in sound environment.

Volumetric method was used to estimate the heat storage and the electrical potential. (biblio)

This study aims to greenhouse gas emissions reduction, economic evaluation and financial profitability, in the Ranomafana prospect.

2. MATERIALS AND METHODS

The following sections present the materials and the procedure for technical, financial and economic data analyses.

2.1. Materials, software

Econometric technique, RETScreen software and Excel worksheet are the tools used in this study. Note that this software is a clean energy project analysis software. It is a feasibility study tool, for various renewable energy technologies, to evaluate energy production, life-cycle costs and greenhouse gas emissions reduction.

The methodology and the modelling tool focused on the pre-feasibility and feasibility studies [1,2]. The model tool focused on the evaluation of the energy production of different clean and renewable technologies including life-cycle costs and greenhouse gas emissions (GHG) reduction [1–5].

According to some authors, in order to determine the financial viability and risk of the project, it provides standardised and integrated financial analysis, sensitivity and risk analysis [3,5–7].

Figure 1 shows model flow chart showing the five-step standard analysis and design parameters [3]. The modelling includes the energy model, the cost analysis model, the greenhouse gas emission reduction analysis model, the financial analysis model (FAM), and the sensitivity and risk analysis models (SRAM).

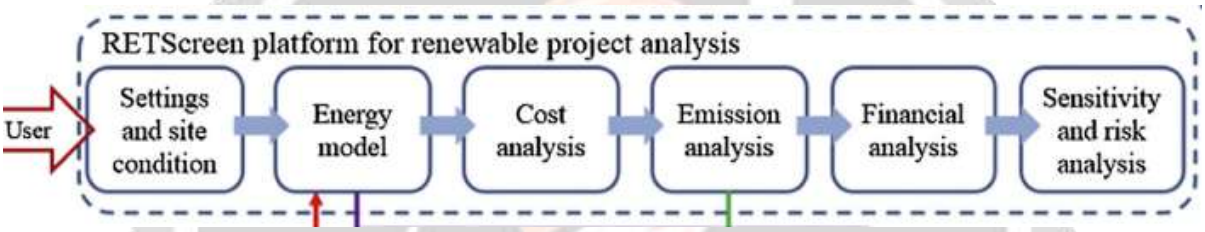


Figure 1: Model flow chart showing the five-step standard analysis and design parameters [3].

2.2. Inputs data

The inputs of energy model are : location/climate data, , energy model, cost analysis, gas emission analysis, financial analysis, sensitivity and risk analysis.
Table 1 presents the data required to proceed with the technical analysis using RETScreen.
Based on the literature, parasitic load of 10% and transmission losses of 2% were assumed
in this study [11,15]. Consequently, the effective full load power capacity for a 31.5 MW geothermal power plant was estimated at 28.786 MW.

Table 1 Data used to calculate the Power capacity and Grid exported electricity of the proposed configuration for the Energy Model by RETScreen software [source: 2-11-16-17-18-19-20-21-22-23].

Technical item	Unit	Quantity
Installed capacity of geothermal power	MW	Up to 31.5
Availability	%	95
Steam flow	kg/h	226 800
Operating pressure	kPa	420
Steam temperature (fluid in reservoir)	°C	154

Saturation temperature	°C	145
Steam turbine (ST) efficiency	%	77
Back pressure	kPa	8
Initial costs	$/kW	3750
O&M costs (savings)	$/kW-year	16.20
Electricity export rate	$/kWh	0,05
Parasitic loads	%	10
Transmission loss	%	2
Life time	years	25

Concerning the Cost Analysis Model required by the software, for the geothermal power plant of 31.5 MW, the input data are presented in Table 2.

Table 2: Input data cost analysis model required by the software

Electricity exported to grid	Capacity kW	Electricity MWh	Initial costs $	Electricity export revenue $	Fuel cost $	O&M costs (savings) $	Simple payback yr
Power							
Geothermal power (1)	28 786	239 555	107 946 662	11 977 762	0	466 198	9,4
Total	**28 786**	**239 555**	**107 946 662**	**11 977 762**	**0**	**466 198**	**9,4**

Table 3 presents the input data on the share of each fuel type in the country's fuel mix, electricity generation efficiency, and the transmission and distribution (T&D) losses [27–29] along with GHG emission factors used for calculating GHG emissions.

Table 3: Input data for calculating the greenhouse gas emissions in the base case electricity scenario [2, 27,29,30,31,32].

Base case electricity system (Baseline)

Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Electricity generation efficiency %	T&D losses %	GHG emission factor $kgCO_2/kWh$
Natural gas	100,0%	49,4	0,0036	0,0009	60,0%	5,0%	0,314
Electricity mix	100,0%	86,6	0,0064	0,0016		5,0%	0,314

Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Fuel consumption kWh	GHG emission factor $kgCO_2/kWh$	GHG emission tCO_2
Electricity	100,0%	86,6	0,0064	0,0016	239 555 232	0,314	75 226,5
Total	100,0%	86,6	0,0064	0,0016	239 555 232	0,314	75 226,5

Proposed case system GHG summary

Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Fuel consumption kWh	GHG emission factor $kgCO_2/kWh$	GHG emission tCO_2
Geothermal	100,0%	0,0	0,0000	0,0000	239 555 232	0,000	0,0
Total	100,0%	0,0	0,0000	0,0000	239 555 232	0,000	0,0
				T&D losses			
Electricity exported to grid	kWh	239 555 232		5,0%	11 977 762	0,314	3 761,3
						Total	3 761,3

3. OUTPUTS AND RESULTS

Outputs and results are presented in the tables 4-5-6-7-8-9 and in figures 2-3-4-5.

The outputs of energy model are : location/climate data, benchmark, Geothermal Power plant of 31.5 MW, summary of the target, gross annual GHG emission reduction (95%), financial parameters, annual revenue, cost saving revenue, summary of financial viability, histogram/distribution and cumulative cash flow, impact and distribution of the risk, financial analysis, sensitivity and risk analysis.

Location

	Unit	Climate data location	Facility location
Name		Madagascar - Itasy	Madagascar
Latitude	°N	-19,9	-19,9
Longitude	°E	47,0	47,0
Climate zone		3C - Warm - Marine	3C - Warm - Marine
Elevation	m	1539	1539

Climate data

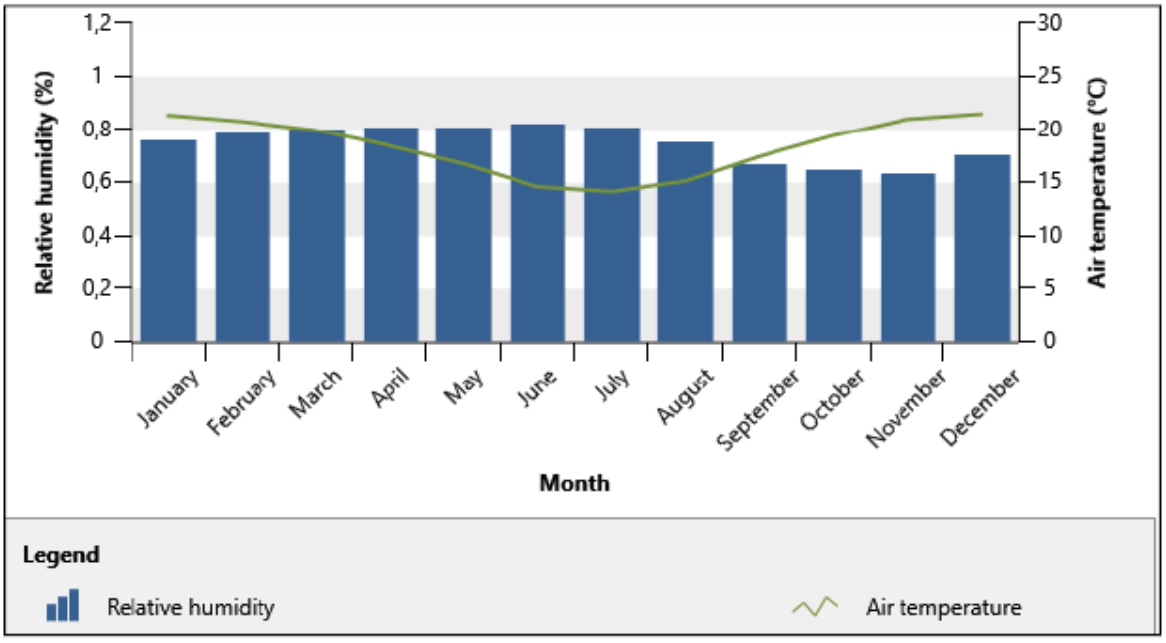


Figure 2 : Location | Climate data

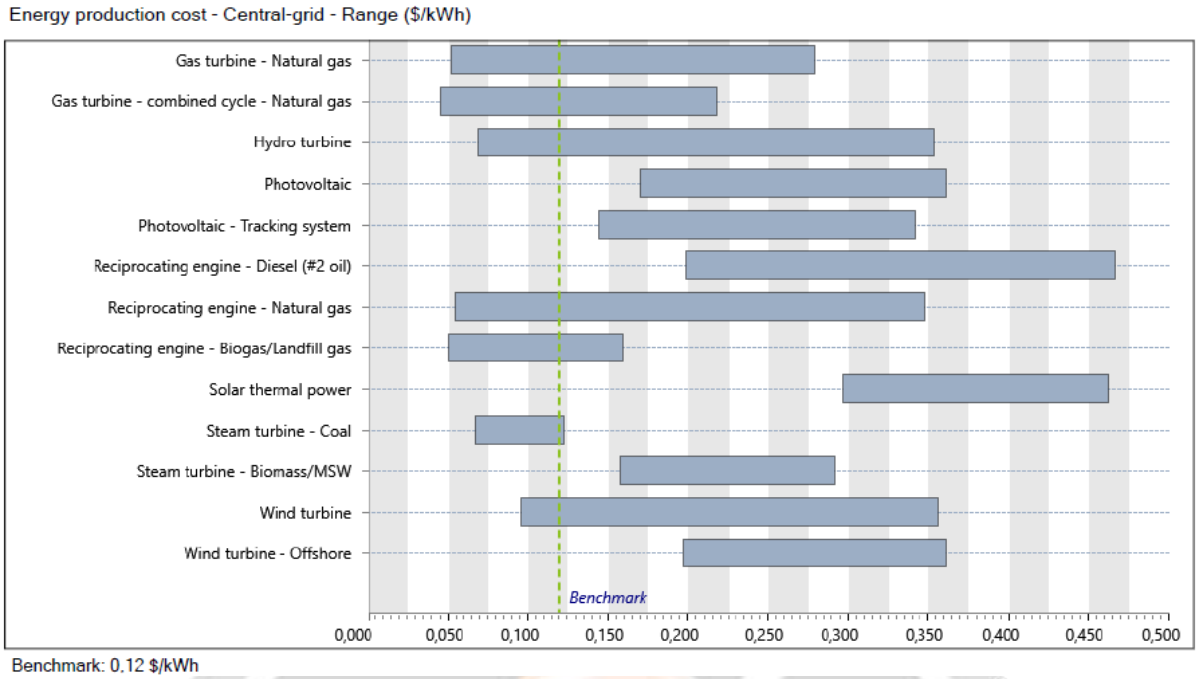


Figure 3 : Benchmark

Table 4 : Outputs - Geothermal Power plant of 31.5 MW

Geothermal power (1)		
Capacity	28 786	kW
Electricity	239 555	MWh

Table 5 : Summary of the Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	239 555	11 977 762	71 465

Table 6 : Outputs - Gross annual GHG emission reduction (95%)

GHG emission		
Base case	75 226,5	tCO_2
Proposed case	3 761,3	tCO_2
Gross annual GHG emission reduction	71 465,2	tCO_2

Table 7 : Outputs - Financial viability parameters, annual revenue, cost savings revenue

Financial parameters

General		
Inflation rate	%	11,5%
Discount rate	%	6,5%
Project life	yr	25
Finance		
Debt ratio	%	60%
Debt	$	64 767 997
Equity	$	43 178 665
Debt interest rate	%	7%
Debt term	yr	12
Debt payments	$/yr	8 154 420

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	239 555
Electricity export rate	$/kWh	0,05
Electricity export revenue	$	11 977 762
Electricity export escalation rate	%	2%

Costs | Savings | Revenue

Initial costs			
Power system	100%	$	107 946 662
Total initial costs	100%	$	107 946 662
Annual costs and debt payments			
O&M		$	466 198
Debt payments - 12 yrs		$	8 154 420
Total annual costs		$	8 620 618
Annual savings and revenue			
Electricity export revenue		$	11 977 762
Total annual savings and revenue		$	11 977 762

Table 8 : Summary - Financial viability

Pre-tax IRR - equity	%	13,3%
Pre-tax IRR - assets	%	5,1%
Simple payback	yr	9,4
Equity payback	yr	10
Net Present Value (NPV)	$	47 186 258
Annual life cycle savings	$/yr	3 868 399
Benefit-Cost (B-C) ratio		2,1
Debt service coverage		1,4
Energy production cost	$/kWh	0,045

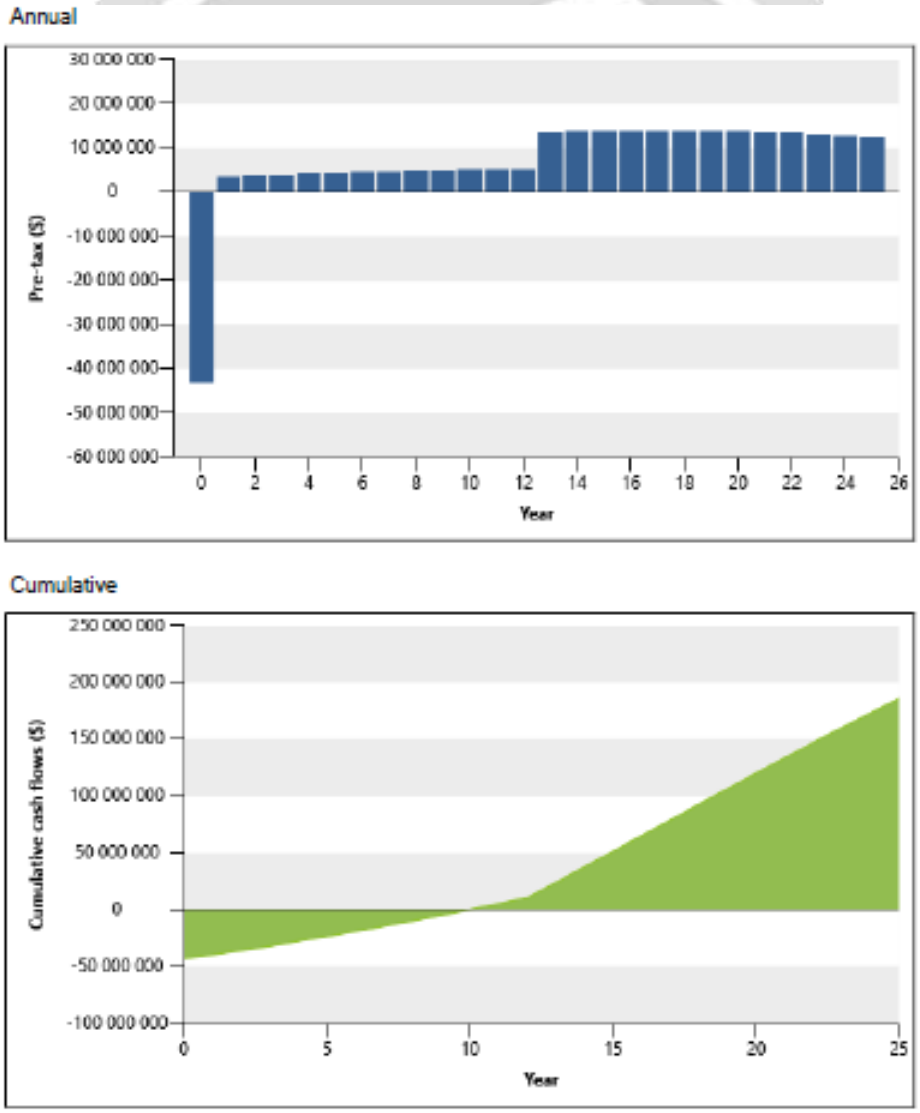
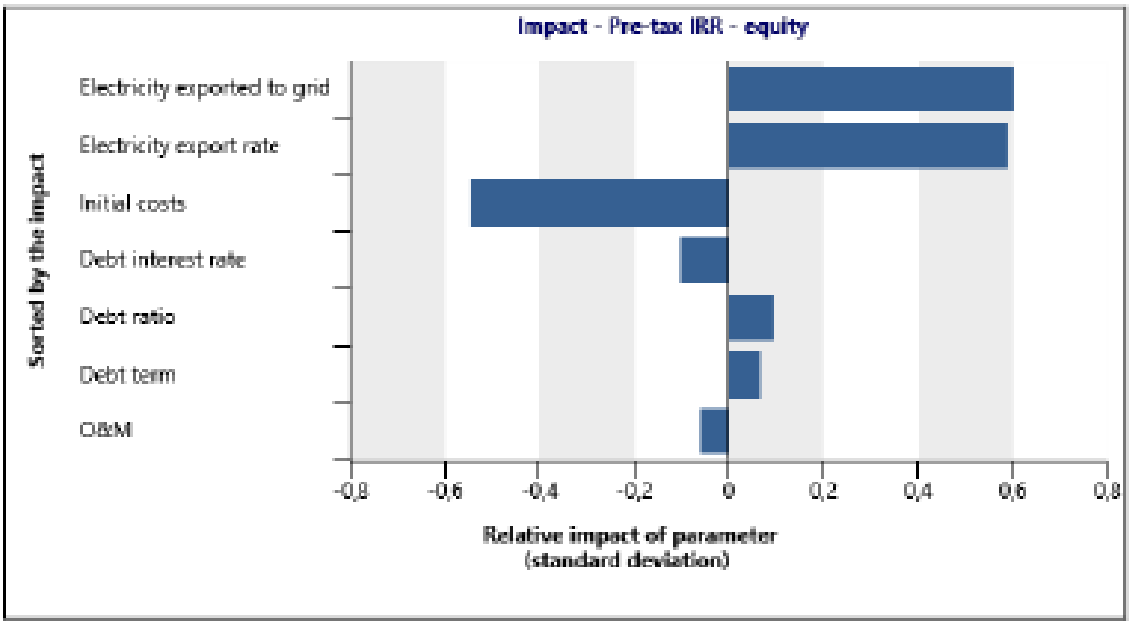


Figure 3 : Histogram/Distribution and cumulative Cash flow

Impact



Distribution

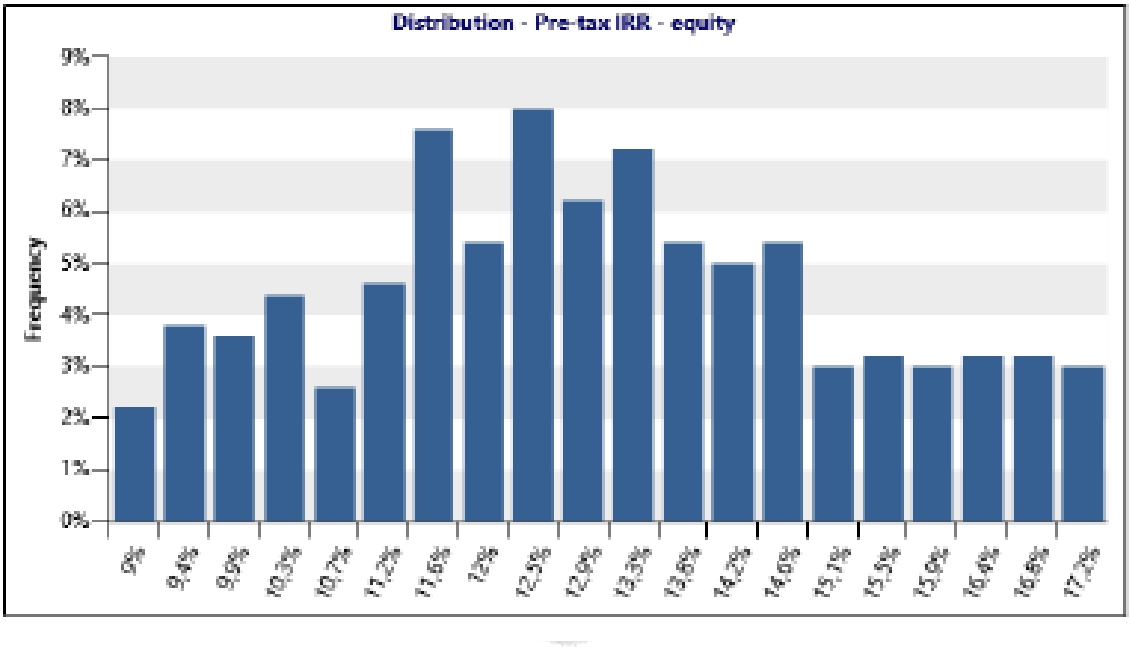


Figure 4 : Impact and distribution of the Risk

Table 9 : Outputs - Risk analysis

Perform analysis on		Pre-tax IRR - equity			
Number of combinations		500			
Random seed		No			
Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	$	107 946 662	20%	86 357 329	129 535 994
O&M	$	466 198	20%	372 958	559 438
Electricity exported to grid	MWh	239 555,23	20%	191 644,19	287 466,28
Electricity export rate	$/MWh	50,00	20%	40,00	60,00
Debt ratio	%	60,0%	20%	48,0%	72,0%
Debt interest rate	%	7,00%	20%	5,60%	8,40%
Debt term	yr	12	20%	10	14
Median				%	13,2%
Level of risk				%	10%
Minimum within level of confidence				%	9,1%
Maximum within level of confidence				%	17,7%

CONCLUSION - EXECUTIVE SUMMARY

This report was prepared using Clean Energy Project Management Software. The main conclusions and recommendations of this analysis are presented below:

For the principal target, the proposed case is summarized as follow:

- Electricity exported to grid : 239 555 MWh
- Electricity export revenue : 11 977 762 USD
- GHG emission reduction : 71 465 tCO_2

With positive NPV of 47.186 million USD, an IRR of 13.3%, 10 years of payback period and an Ip more than 1.4, we conclude that the project is feasible.

This study is the first analysis about emission and financial analysis using RETScreen software that carried out in Madagascar.

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