TITLE: FINANCIAL FEASIBILITY ANALYSIS OF GRID CONNECTED PHOTOVOLTAIC PROJECTS IN RWANDA

(Case study: Gigawatt Global Rwanda)

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Declaration

I, Eustache NDIZEYE, hereby to acknowledge that this thesis is my own work, and that it has not been presented for a degree at the University of Rwanda or any other university. All sources of information used in the thesis have been properly credited.

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This thesis has been submitted for examination with my approval as a University advisor

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Eustache NDIZEYE

Abstract

Developing states are shifting from reliance on hydro-carbon based energy output generation which is intensive polluting energy sources into more diversified and environmentally friendly energy source with special interest in clean energy including sun based energy sources. The study aimed at investigating the financial viability of the sun based energy output plant in Rwanda. RETscreen and Homer Pro software were utilized for analyzing the lattice connected Gigawatt global sun based energy output plant as case study. The results revealed that the net present value is positive US $ 49,490,000, indicating that the project is theoretically feasible. A benefit-to-cost ratio of 1.5 indicates a project that is cost-effective. While the research utilizing Homer Pro software shows that the substantial initial expenditure may be returned in 7.3 years, the net present cost and levelised cost of energy are $120,401,802 and 0.224$/kWh, respectively. The incentives and subsidies are crucial financial parameters to consider for reducing the cost of energy to the end consumer through governmental intervention as well as motivating incumbent investors in the energy sector, especially in the sun based electrical energy market in Rwanda, as full electrical energy access is targeted by the government.

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LIST OF ABBREVIATIONS

EAIF: Emerging Africa Infrastructure Fund

ACEF: Africa Clean Energy Finance

EEP: Energy and Environment Partnership

LCOE: Levelized cost of energy

NPV: net present value

IRR: internal rate of return

NPC: net present cost

DPBP: discounted payback period

DC: Direct Current

AC: Alternating Current

FMO: Netherlands Development Finance Company

GIZ: Gesellschaft fur Internationalwidee Zusammenarbeit **(**German Technical Cooperation Agency**)**

REG: Rwanda Energy Group

PV: Photovoltaic

CHAPTER ONE: OVERALL INTRODUCTION

1.1. Background of the study

Nowadays, many states are shifting from reliance on hydro-carbon based energy output generation into more diversified and environmentally friendly energy source with special interest in clean energy. These energy strategies are mainly motivated by the limitation of fossil fuels and, their adverse impact on the environment. In addition, human population growth has been causing a huge straining on the energy sector, hence now more ever alternative and sustainable energy policy are needed to solve the future energy demand challenges. Even though, there have been noteworthy an achievement in the ground of clean energy improvement, its full possible has not been met yet. Up until now, there have been a few states who prospered to certain degree moving from mainly fossil fuel relied on energy sources into more clean and clean energy sources.

According to Aguilar (2015), in the current period the world has seen reliable growth in sun based energy output, an environmental and clean friendly energy resource, due to its adaptability and developments in sun based cell growth permitting for the technology to develop more readily obtainable in numerous contexts in all over the world. Almmar and Aotabi (2010), declared that PV energy output projects have been built the world over, and magnificently demonstrated as one of the important substitutes of energy.

According to Gordon (2018), few of East Africa's inhabitants there is accessibility to electrical energy, the low electrification rates worldwide. Gordon (2018) clarified that, this, joint with the area's vast natural resources, characterize a main prospect for clean energy stakeholders with sun based radioactivity levels are great in line for to contiguity to equator.

In Rwanda, electrical energy access is still limited, especially in rural areas, which has a important impact on the country's long-term growth according to Uwibambe (2017), despite of the sun based suitability due to available daily universal radioactivity (yearly normal) is amid 4 and 6 kWh/m²/ day according to Safari (2010). According to MININFRA (2019), around 1.2 million families situated far from the nationwide energy output network will be given priority to electrical energy accessibility through sun based panel systems (2019).

As reported by Rwanda energy group (REG) (2015), there are still few sun based parks for the utilization of abundant sun based energy through electrical energy production, with the goal of increasing the contribution of clean energy in full electrical energy access by 2024. Stimulating the use of clean energy, mostly on-lattice and off-lattice sun based PV systems.

Current investigation on the sun based energy potential, such as Okello,Van and Vorster (2016), Bimenyimana, Asemota, and Li (2018), focuses on the technical sun based suitability of sun based energy through electrical energy production without taking into account other factors that limiting the deployment of sun based parks in states with great sun based energy potentiality, such as the cost of energy, associated remunerations , and the net present cost of the project incurred after the life cycle. This study focuses on these financial issues hindering the dissemination of sun based parks in Rwanda, through improving the literature with more other parameters to consider when investigating the financial viability of sun based parks in developing states.

This study contributes to the existing academic literature as mentioned above on the sun based energy in the following ways: first, it focuses on the lattice connected and commercial sun based energy output projects in the region where the sun based energy potential is high. We add to those studies by providing a country context analysis of sun based energy viability. Second, this study methodologically contributes to the analysis of economic viability of sun based energy output projects by combining the RETscreen and Homer pro software for analysing improvement.

1.2. Problem statement

Rwanda's sun based radioactivity and sun based wealth were assessed by the U.S. Nationalwide Air and Space Agency (NASA) in partnership with the MININFRA Department of Meteorology (2019), has shown that Rwanda's Eastern Province has the greatest potential for producing energy from sun based resources a meteorological data set to estimate undertaken used monthly averaged global sun based radioactivity.

Rwanda's daily sun based radioactivity ranges from 4 kWh/m² north of the city of Ruhengeri to 5.4 kWh/m² south, Kigali, in the Southern and Eastern provinces of the capital. However, conditions differ from season to season, with average daily irradioactivity levels in the cloudy reaching about 4.5 kWh/m^2 and the entire annual prospective is expected to be around 66.8 Twh.

According to Bimenyimana, Asemota and Li (2018), the electrification rate, on the other hand, is mostly reflective of lattice-connected consumers in urban areas and remains predominantly concentrated in the top quintile, with essentially no coverage in the bottom 40% of the population according to Manfred (2019).

According to from MININFRA (2019), the entire installed capacity to produce electrical energyin Rwanda is 218 MW, mostly hydro. Hydroenergy output project in Rwanda had a contribution of approximately 101.062 Mw in 2018, or almost 50 percent of Rwanda's energy consumption. An appraisal of the potentiality for sun based energy in Rwanda comprised the potentiality for off-lattice and on-lattice Photovoltaic (PV) and intent sun based energy output (CSP)

Various sun based technologies have been deployed in Rwanda since the 1980s, primarily with donor and non-governmental organization (NGO) funding, and a 1991 revision conducted by World Bank development providing an overview of the marketplace at the time as revealed by Niyonteze, Zou, Asemota, Bimenyimana and Shyirambere (2020).

The two sun based PV projects known as GigaWatt Global Sun based Energy output (with capacity of 8.5 MW) sited in Rwamagana and the other known as Jali Sun based Energy output (with capacity of 0.25 MW) sited in Gasabo districts are associated to the Countrywide network Lattice (RURA, 2020).

The Households that are situated further extended from the intended national wide network lattice coverage are stimulated to utilize the sun based home systems and mini-lattice Sun based Photovoltaic (PVs) for declining the cost associated with the electrical energy access. Currently the Rwanda's entire on-lattice installed sun based energy is approximated to 12.8 MWas revealed by Eustache, Sandoval, Wali and Venant (2019). Apart from the sun based energy potentiality, there are other aspects hindering the deployment of the sun based parks in the country through improving the electrical energy system market in Rwanda.

The current investigation is aimed at considering the financial factors which can drive to the building of integrated PV in Rwanda so as to ensure that there will be no loss faced by PV investors. PV Sun based parks have become the main issues in many of the states with high irradioactivity level like Rwanda and it is described above in the introduction part that it has shown a drastic change every year.

However, due to what financial and economic parameters inducing why these changes are not seen in a huge scale in Rwanda. Since, there are very few investigations on the viability of sun based parks in Rwanda and as there are no many installed sun based parks in the country.

1.3. Objective of study

In this investigation, there are both specific and overall purposes and they are shown below:

1.3.1. Overall objective

The overall objective of this investigation is to investigate the financial viability of the gird connected photovoltaic system project

1.3 2 Objective specific

The following are the Investigation's specific objectives:

- To measure and evaluate the financial benefits associated with grid connected PV system
- To measure and evaluate the costs associated with grid connected PV system
- To examine the solar energy suitability and potentiality in Rwanda
- To identify the factors influencing the feasibility of solar power plant

1.4. Research Questions

Therefore, to attain the goals (purposes) of the investigation it is good to answer some of the investigation questions such as,

- Is the grid connected PV project financially viable in Rwanda?
- Is the benefit cost ratio greater than one for this project?
- Is the solar energy potential and suitable in Rwanda?
- What are the aspects influencing the viability of solar power plant?

1.5. Scope of the study

The scoping in is the area and boundary where the investigation will not go beyond. For the current investigation, the scope in geographical area, the scopes in content and in time were considered:

1.5.1 Geographical scope

This investigation was carried in Rwanda which is one of the states of East Africa near the equator with the entire area of 26,338 km^2 with Capital city of Kigali. This investigation will not go beyond Rwanda.

1.5.2 Content scope

The current investigation insisted on the financial analysis of integrated PV in Rwanda. In this perspective, the variables like NPV, Payback period were considered so as to give clear image of how important is the consideration of these financial tools towards deciding of whether to go through or let investing in integrated PV project in Rwanda.

1.5.3 Time scope

The investigation considered the data from REG in the Department of finance and other data were gathered from Rwamagana Energy output plant in the regards of PV energy, other variables of financial tools consideration were collected after considering the past kept documents from private energy companies in the time spam covering the investigation.

1.6 Expected Outcomes and Significance of the Study

This part contains the expected outcome and the significance of the study to different stakeholders and these are shown in the following arguments:

1.6.1 Expected Outcome of the Study

The overall expected outcome of this study is the efficiency and productive consideration of financial analysis tools towards the decision of building an integrated PV projects in Rwanda so that the loss in investment will be reduced.

This investigation expects to come up with information and strategies about how the investors can decide whether to invest or not in integrated Photovoltaic. Once we found out that the project is feasible, this will be considered as evidence that electrical energygeneration in Rwanda will rise up to 100% in 2024.

1.7. Significance of the study

The implication of the investigation is the role that the investigation insert to a single individual or a group of people as whole. This investigation is important to different people. The details are below-mentioned**:**

1.7.1. Significance to the researcher

This investigation is important to the researcher because it provides deep insight about the investigation topic and how the information from the investigation will enhance the researcher to get more knowledge and skills related to the investigation. Moreover, the completion of the investigation will let the researcher get Masters' Degree in Energy Economics.

1.7.2. Significance to the community

The community will benefit from this investigation in sense of improving their welfare through having access to electricity. This is because many of Rwandan people who live in rural area have inaccessibility to electricity. In this regards, the community will benefit through having the access to electrical energy and compare the investment in building the integrated PV which in one side and another will enhance the development of PV projects.

1.7.3. Significance to the University

The University will benefit from the current investigation because the copy of this thesis will be submitted in Library so that it will be useful by next readers who will be interested in carrying on similar topic. In another word, the copy of this thesis will be used as material for future readers.

CHAPTER TWO: REVIEW OF LITERATURE

Clearly trying to use global sun-based radioactivity to generate electrical energy using PV Systems in various parts of the world, the technology, efficiency of Modules and the environment in which the component would be installed all have a significant impact on the PV System's energy output. This section focuses on common PV Sizes, efficiency in relation to climatic conditions, annual energy yield and cost of energy as well as payback duration on a continental basis, in order to better comprehend the predominant presentations of PV Configurations.

2.1 Sun based Energy Resource

According to Paul (2019), the sun based energy is produced by nuclear-energy outputed responses within the physique of the sun where this energy reaches the ground superficial through the form of electromagnetic radioactivity. The quantity of the sun based energy carried out by the sun based radioactivity is usually articulated in rapports of sun based continual which is 1367W/m2 according to world energy council, 2015.

2.1.1 Solar energy potential and conversion

According to Nikolay (2019), the quantity of the solar vitality reaching the ground and can potentially be captured is important and ranges 4,375 to 13,843PWh per year. The average quantity of sun based energy established on the border of the ground's stratosphere is around $342Wm^{-2}$ and approximately 239 Wm^{-2} available for harvesting ad capture. Inappropriately, this impending is not completely utilizable.

According to Viswanathan (2017), there are two main possibilities of sun based energy use based on the alteration where passive sun based expertise involves the growth of sun based energy without transmuting updraft or well-lit energy into any other form and active sun based technology involves collection of sun based radiant energy and use unusual paraphernalia to convert it into other forms of energy like heat or electrical energy and these are grouped into two categories which are sun based current technology and sun based photovoltaic technology which involve the conversion of sun based energy into electrical energy bestowing to Paul (2014).

According to Deolalkar (2016), photovoltaic cell, in which the sun based light is converted into electricity, sun based cells produce direct current energy output, which alters according to the strength of exposed bright and this require an inverter to produce the energy output at the anticipated power incidence and phase, PV systems linked to lattice, they want successions as backup.

2.1.2 Options for sun based energy output plant.

According to Ahteshamul (2016), principally there are numerous selections for sun based energy output installations. Like centralized, distributed, on lattice and off lattice. In the lattice connected option excess energy output can be fed to the lattice, with the lattice serving as storage. To convert DC energy into AC energy, inverters are required. In places of impoverished countries where there is no power, an off-lattice system should be used.

According to Bimenyimana, Asemota and Li (2018), in Rwanda the Sun based radioactivity is high between 4-6 $kWh/m^2/day$ while dissemination is disadvantaged by the high initial cost and restrictions on high load usage indicating higher sun based suitability in Rwanda for being exploited to the electrical energy production. Although the Rwanda energy sector still faces some challenges including high cost of energy according Munyaneza, Wakeeland Chen (2016), the government has set out some motivation for investors interested in the energy sector as reported by EUCL (2018). Moreover, there are business occasions available in the hydro energy output, sun based energy, geothermal, peat to energy output and methane gas to energy output projects, for energy production and exploitation. Occasions are equally available for strengthening transmission lines and links through on and off lattice solutions according to Samuel, Godwin and Lingling (2018).

According to REG (2021), currently, in Rwanda entire on-lattice install sun based energy is 12MW originating from 5 sun based energy output projects namely jail energy output plant producing 0.25MW, Rwamagana Gigawatt Global producing 8.5 MW, Nyamata sun based plant producing 0.03 MW, Ndera Sun based energy output plant producing 0.15MW and Nasho sun based plant producing 3.3 MW.

Clean energy which comprise of sun based energy assures a clean energy provide and it has been well-thought-out to play an animated role of global warming prevention by combat against climate change Ghellai (2015). Sun based Energy is essentially produced dependent on the intensity of the sun rays reaching the sun based panel and their wavelengths according to Narendra, Anjaneyulu and Kuldip (2014).

In the 1980s, Rwanda used a number of solar-based technology electrification, primarily through support from donors and non-governmental organizations (NGOs), and the 1991 ESMAP (Energy Sector Management Assistance Program) / World Bank project survey. By Marktes Disch and Bronckaers (2012). Generating electricity using solar energy is a low consumption use of natural resources and does not consume fuel for continued operation. Clean energy, on the other hand, is a source of clean energy and has the potential to contribute significantly to the more ecologically, socially and economically sustainable future of Abul (2007).

Nevertheless, the biggest challenge for solar-based electrical energy systems is to maximize the use of the sun's rays and reduce the effect of temperature on sun-based cells, Anjaneyulu and Kuldip, (2014). Solar energy can be made more economical by reducing capital and operating costs and improving the performance of PV plants. The biggest cost savings are likely to be due to improvements in solar field design that could reduce LCOE by 15% to 28%. According to Camacho, Samad, Sanz, Hiskens (2011), it depends on the technology.

2.2 Sun based energy in Rwanda

Rwanda's sun-based radioactivity and resources have been identified by the United States. National Aeronautics and Space Administration (NASA) and University of Rwanda. The eastern provinces of Rwanda are most likely to generate energy from solar-based resources. Another academic assessment, conducted in collaboration with the MINI FRA Meteorological Authority in 2007, used meteorological information to estimate global monthly average solar radiation in accordance with the Rwanda Republic's Energy Sector Strategic Plan (2015).

Insolation in Rwanda ranges from 4 kWh / m² north of Kigali, the capital of the northern and eastern states, to 5.4 kWh / m² east. However, conditions vary from season to season, with an average daily radiation activity of approximately 4.5 kWh / m² in a cloudy environment, with a total annual probability of approximately 66.8 TWh, according to Bimenyimana, Asemota, and Li (2018). Will be done.

According to Habyarimana and Beyer (2013), Rwanda's solar energy is likely, and even during the rainy season, there is plenty of sunshine every day, especially in the eastern states, which are known for their high insolation. According to Mudaheranwa, Udoakah and Cipcigan (2019), the average global sun per day was expected to illuminate a slope of 5.2kWh per m2 per day, according to the Photovoltaic Geographical Information Arrangement (PVGIS). .. Long-term average monthly insolation ranges from 4.8 kWh / (m2 days) (Rwamagana, May) to 5.8 kWh / (m2 days) (Ngoma, July), indicating high potential for solar energy. I am. Improvements reported by Eustache, Sandoval, Wali, Venant (2019).

2.3 Financial viability

Financial feasibility is an assessment of a project's feasibility based on costs, income, assets, liabilities, and annual cash flow (inside or outside of cash flow) to determine if the project can be self-sufficient. According to Helther (2017), financial sustainability studies predict the amount of seed capital required, the source of capital, the rate of return on capital, and other financial aspects. It finds out how much money you need, where it comes from and how it is spent. In order for an investor to participate in a new investment project, the project must be financially viable. The invested capital must be able to bring to investors at least the same economic benefits as other equally risky investments, and it also needs the expected income. Therefore, it is very important to assess the financial feasibility of an institution. According to Bennet (2003), to determine the financial viability consists of evaluation of financial condition and operating performance of the investment and forecasting its future condition and performance.

2.3.1 Criteria for Financial Viability

To assess the economic feasibility of an investment project, you need to identify relevant indicators or criteria. Remer and Nieto (1995) classify evaluation methods into five basic types. 1. Net present value method. 2. Returns the method. 3. Relationship method; 4th place Repayment method; 5. Accounting method. According to Remer and Nieto (2004), there are various cash flow-based methods that can be used to assess the net present value (NPV), internal rate of return (IRR), and financial viability of an investment project. Cost-benefit ratio (B. / C). According to Park (2002), payback period is an additional method sometimes used in financial feasibility studies. This method indicates when the project will be at the break-even point. According to Remer and Nieto (2004), the net present value (NPV) is the difference between the present value of all cash inflows and outflows associated with an investment project. The present value determines whether an investment project is an appropriate investment, taking into account the profits that the investor needs from the investment. According to Sullivan (2006), the Benefit Cost method is often used in public projects. This method maps the project allowance to the project cost. For a project to be profitable, the allowance must be greater than the cost.

2.3.2 Empirical studies

This section presents different previous studies related to the financial viability of sun based energy energy output projects.

Author	**Year**	**Location**	**Findings**
Bhuiyan and Mazumder	2010	Bangladesh	Profitability Analysis of Self-Contained Housing Systems & # 40; 47 Wp x 6 PV & # 41; For Bangladesh's rural and remote places. With an initial of US $ 770 and a 20-year projected useful life, the proposed system was able to generate 4,672 kWh of energy. PV systems are more economically viable in rural areas than in distant areas, according to studies.
Yang and Burnett	2009	Hong Kong	The system consisted of 100 crystalline silicon modules with a capacity of 13 installed on the roof and walls of the building. According to Yang

			and Burnett (2009), the results show that the system has a payback period of 20 years and an energy production cost of $ 0.190.26 / kWh.
Yun, Lalchand and Lin	2010	Spain	With an installation cost of 6.57 USD / Wp and a power generation cost of 0.066 USD / kWh, the 1kWp PV system was able to produce 1,100kWh per year with an expected useful life of 30 years. Such PV systems help reduce greenhouse gas emissions by approximately 17.57 tonnes over their useful life.
Erge, Hoffmann and Kiefer	2008	Germany	They investigated various sizes of PV (1, 5, 20, and 1000 kWp) and reported corresponding COEs of 0.87, 0.66, 0.56, and 0.49 USD / kWh based on an energy output of 700 kWh / kWh. bottom. These numbers directly show the effect of scaling on COE. As system capacity increases, so does COE.

Necaibia,A. et al	2018	Algeria	We investigated the external output of Algeria's grid-type 2.5kWp PV system, annual output 4322.65 kWh, efficiency 15.87%.
El-Shimy	2011	Egypt	They researched at 29 areas in Egypt for the installation of a 10-megawatt photovoltaic system. A 17.4 percent efficient module with a purchase price of US $ 103,740,822. As an outcome, with an annual energy yield of 26.35 GWh and a 25-year lifespan, the Wahat Kharga site was the most profitable.
Allouhi, Kousksou and Saidur	2017	Morocco	They analyzed a 2 kWp PV roof system made with single crystal and polycrystalline technology and reported an efficiency of 15.2% and a power generation cost of 0.073 and 0.082 USD / kWh. The amortization period for these systems was given as 11.10 years and 12.69 years. The estimated useful life is 25 years.

Kebede	2016	Ethiopia	Analysis of 35 locations to implement a 5 MW PV system in Ethiopia using the software HOMER and RETScreen. According to the assessment, the system could supply 8,674 MWh of energy yearly in 25 years at a cost of US $ 200 per MWh. Payback period is 14.5 years. The projected system's entire initial cost was $ 19,767,600.
Adaramola	2015	Nigeria	Evaluation of a grid connection system with an output of 80kWp using Nigeria's HOMER software. The system produced 331,536 kWh of energy annually at LCOE at $ 0.103 / kWh, with an initial investment of $ 2,322 and a lifespan of 25 years.
Akpolat, Dursun and Kuzucuoğlu	2018	Turkey	They investigated a grid-connected PV roof system with an output of 84.75 kWp (339 single crystal modules with an output of 15.37%) in Turkey. The system produced 0.0808 USD / kWh of COE and 90,289 kWh of energy

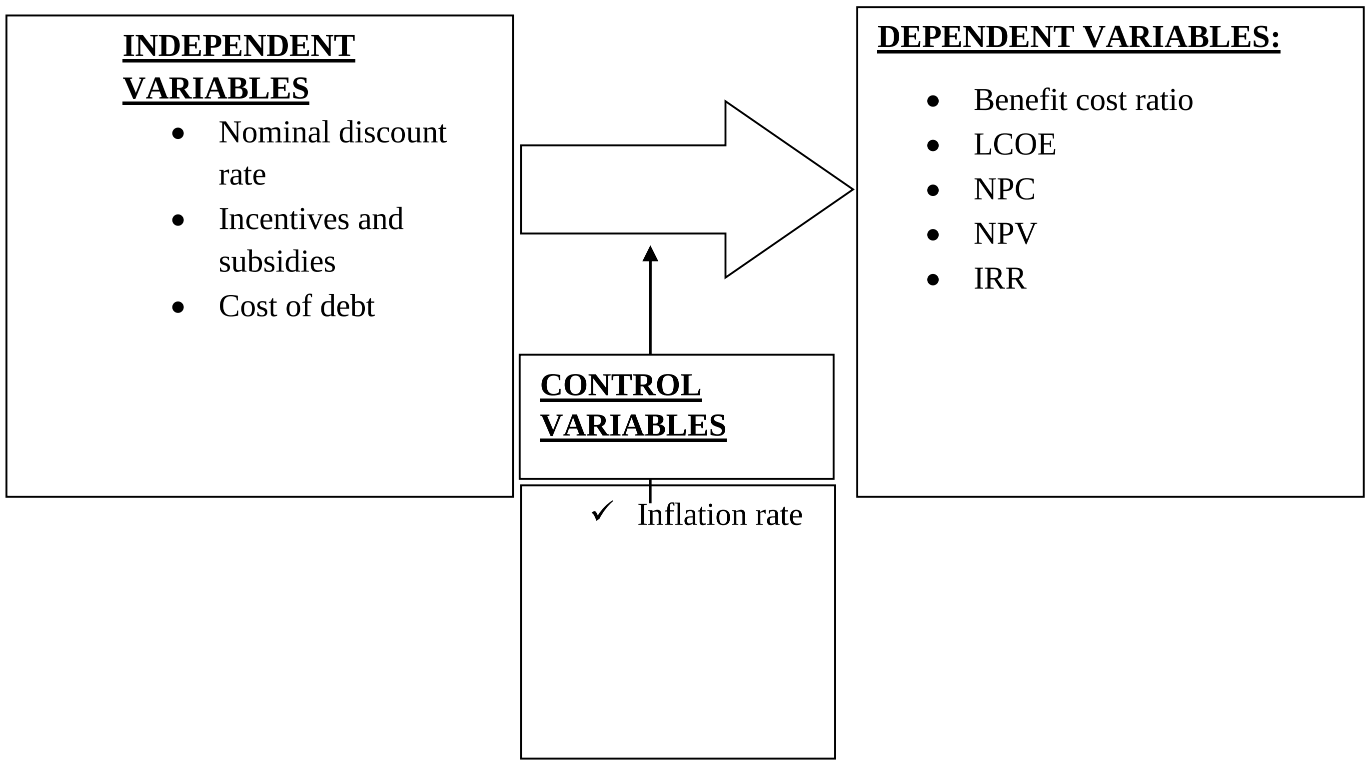
			annually with a payback period of 12.52 years.

2.4 Schematic design

The figure below shows the relationship between variables

2.4.1 Figure of Conceptual Framework

The conceptual framework is a diagram that represents all of the researcher's dependent, independent, and controlling variables, as well as their interrelationships. These variables were calculated using inferential statistics, and the variables utilized in the estimation and analysis of the data are presented below, with the dependent variables being the benefit cost ratio, internal rate of return, net present value and levelised cost of energy



CHAPTER THREE: INVESTIGATION METHODOLOGY

3.1. Investigation design

This study used analytical design as it seeks to investigate the financial viability of lattice connected sun based energy output plant. In analytical design, we used two software namely RETscreen and Homer Pro through which the study used different financial parameters suitable for investigation of financial viability of the sun based energy output plant. thevenard (2000), opinioned to use the RETscreen as it assist in the preliminary assessment of the potential clean energy. Samad (2015), opinioned to use the Homer Pro software as simplifies the task of designing of systems both on and off lattice energy output plant for a variety of applications. The econometric modeling of the relationships between the both technical and financial variables described in the above to software used in modeling using the ordinary least square regression analysis.

3.2. Data source

In this investigation, the data were gathered from REG, FMO Entrepreneurial Development Bank and GigaWatt Global Rwanda Ltd have been consulted and the technical data regarding the sun based energy resources were collected from NASA report and the researcher consulted different literature on the case study . Extra climatic factors such as atmospheric pressure, wind speed, air temperature, atmospheric pressure relative humidity and ground temperature within designated locality to numerous months of the year and their yearly averaged values are revealed in the Table 3 from NASA, 2021.

For this study, the global Rwamagana GigaWatt is well suited for solar power, with annual production expected to be 15,293,000 kilowatt hours (kWh). Tax exemptions for solar-based projects in Rwanda were decisive for the project's funding phase. According to the Inside Africa Report (2021), GigaWatt Global's solar facility has a total initial cost of $ 23.7 million and is funded by an international consortium of lenders (75%) and equity investors (25%).

The electrical energy is to be fed into the national wide lattice under a 25 years energy output purchase agreement with the Rwanda Energy, Water and Sanitation Authority (EWSA) (solar farm for Rwanda, n.d.). The development of the project was partially funded by a grant from the Energy and Environment Partnership (EEP). This is a partnership between the Governments of the United Kingdom, Finland, Austria and the United States through the African Clean

Energy Finance Grant of the Foreign Private Investment Corporation (OPIC).). Astrom Technical Advisors, S.L. (ATA) was a technical advisor, SEDI Labs was an important project development partner, and Remote Partners was a local project manager.

3.3. Variable measurement and PV System specification

To compare the economic feasibility of the case study, considering social and environmental factors, the two financial products used in the case study investigated, namely the levelized cost of energy (LCOE), net present value. Value (NPV) was used. ..)) And discount payback period (DPP). This subdivision describes and formulates the net value of PV cost and NPV cost and EG, which are the total power generation of PV.

3.3.1. Independent variables

These are the variables which are influencing the dependent through causal relationship; in this study we considered the following:

- **Nominal discount rate:** this refers to the discount rate which incorporate the expected inflation rate
- **Incentives and grant subsidies:** these refer to the tax exemptions that are effective in encouraging people, investor to save and invest more of their income, this is a contribution that is paid for the initial cost (excluding the credits) of the project.

3.3.2 Dependent variables

These are the variables through which we measure the effect of the independent variables through causal relationship, in this study the dependent variables considered are the following**:**

- **Benefit-to-cost ratio**: this is the proportion of net remunerations to project costs. The present value of annual revenue and savings less annual costs is described as net remunerations, while the cost is defined as project equity.
- **Levelised cost of energy:** this refers to the cost of the energy output kWh produced by the electrical energy system over the life of the system.
- **Net present cost:** this refers to the present value of all the costs the system incurs overs its lifetime minus the present value of all the revenue it earns over its lifetime. Here the cost include capital costs, replacement costs, O$M costs, fuel costs, emissions penalties and the costs of buying energy output from the nation lattice network. The revenues include salvage value and lattice sales revenue and this is being calculated by summing the entire discounted cash flows in each year of the project lifetime**.**
- **Net Present Value:** this is the worth of future cash flows that are discounted at today's currency discount rate and computed at time zero corresponding to the intersection of end year 0 and beginning year 1.

- **Internal rate of return (IRR):** This refers to the discount rate at which the base case and current system have the same net present cost. This is calculated by determining the discount rate that makes the present value of the difference of the two cash flow sequences equal to zero.
- **Equity payback period**: this is the time it takes for the facility owner to recover their initial investment from the project cash flows. It takes into account the project's cash flows from the beginning as well as the project's leverage (debt level), making it a better temporal indication of the project's merits than a simple payback period. The model calculates this value using cumulative after-tax cash flow.

3.3.3 Control variable

A controlling variable is a variable that is used to explain the causal relationships between other variables. The inflation rate was used as a controlling variable between the dependent and independent variables in this study.

Variables to be observed	Formula
Benefit cost ratio	$\mathbf{B_C} = \frac{\mathbf{NPV + (1 - f_d)C}}{\mathbf{(1 - f_d)C}}$ Where **C** is the entire initial cost of the project and $\mathbf{f_d}$ is known as debt ratio The benefit cost ratio is calculated by dividing the present value of remunerations by that of costs and investments
Levelised cost of energy	$LCOE = \frac{NPV_{Costs}}{E_{GT}}$ NPV_{Costs} Representing the net present value of the cost of a system, EGT is the total electrical energy production over its lifetime. Levelised Cost of Energy = {(overnight capital cost * capital recovery factor + fixed O&M cost)/(8760 * capacity factor)} + (fuel cost * heat rate) + variable O&M cost.
Net present cost	Present value of all the costs of installing and operating the Component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime.
Net present value	$\mathbf{NPV} = -I_0 + \sum_{n=1}^{N} \mathbf{C_n} / (\mathbf{1 + r})^{\mathbf{n}}$ the future cash flows, which are discounted at the discount rate in today's currency thus calculated at time 0 corresponding to the junction of the end year 0 and the beginning of year 1

Internal rate of return	$\mathbf{0}=\sum_{n=1}^{N} \mathbf{C_n}/(\mathbf{1}+\mathbf{IRR})^{\mathbf{n}}$ It is Calculated by dividing the difference between the current or expected future value and the original starting value by the original value and multiplying by 100.
payback period	$\mathbf{SP}=\frac{\mathbf{C\_IG}}{(\mathbf{C_{ener}}+\mathbf{C_{capa}}+\mathbf{C_{RE}}+\mathbf{C_{GHG}})\_(\mathbf{C_{O\&M}}+\mathbf{C_{fuel}})}$ Where **C** is the entire initial cost of the project, **IG** is the value of incentives and grants, $\mathbf{C_{ener}}$ is the annual energy savings or income, $\mathbf{C_{capa}}$ is the annual capacity savings or income, $\mathbf{C_{RE}}$ is the annual clean energy(RE) production credit income, $\mathbf{C_{GHG}}$ is the GHG reduction income Payback period = quantity to be invested / discounted annual net cash flow.
Inflation rate	This refers to an increase in the level of prices of the goods and services that households buy. It is measured as the rate of change of those prices. Typically, prices rise over time, but prices can also fall (a situation called deflation). The most well-known indicator of inflation is the Consumer Price Index (CPI), which measures the percentage change in the price of a basket of goods and services consumed by households.

3.4 Econometric estimation technique

In this investigation, the data to be used was related to the technical, economic and financial parameters and infrastructure of the selected energy output plant (Rwamagana Sun based Energy output station). Where the econometric analysis was Ordinary Least square Regression analysis for investigating the causal relationships among the variables of interest used in the study .The data to use was yearly covering the lifetime period of 25 years for the case study sun based. The econometric model of these variables is structured as follow:

$$\boldsymbol{Y_{it}=\alpha_1+\alpha_2 Kd_{it}+\alpha_3 Dr_{it}+\alpha_4 Sub_{it}+\alpha_5 INF_{it}+\varepsilon_{it}} \dots\dots\dots.(\mathbf{1})$$

Where $\mathbf{Y_{it}}$: represent set of dependent variables which are: benefit cost ratio, LCOE, NPC and IRR for the case study plant station,

$\boldsymbol{Kd_{it}}$ **:** represents cost of debt

$\boldsymbol{Dr_{it}}$ **:** Represents the annual discount rate for the initial system investment

$\boldsymbol{Sub_{it}}$**:** representing the incentives and subsidies for clean sun based energy

$\boldsymbol{INF_{it}}$ **:** represent**s** expected inflation rate

ε_{it} **:** Stands for Error terms or disturbance variables which may have an impact to the model but not mentioned. The linear regression analysis is then employed for the investigation of the causal liaison among these variables under study.

3.5. Introduction to Homer Pro and RETscreen 4 Software

RETscreen 4 is a clean energy project research software program based on Excel that assists in examining the technical and financial viability of possible clean energy, energy efficiency, and cogeneration projects. The RETscreen Solar Project Model can be used to evaluate photovoltaic plants' energy production and financial performance. The PV model can be used to evaluate three different applications: Water pumping applications; On-lattice applications, which include both central-lattice and remote-lattice arrangements; Off-lattice applications, which include both stand-alone and hybrid arrangements; and Off-lattice applications, which include both stand-alone and hybrid arrangements.

The HOMER pro stands for Hybrid Optimization Model for Multiple Energy Resource is originally developed at the Nationalwide Clean energyLaboratory (NREL) and in a single run, this considers all available combinations of system types and organizes the systems according to the optimization variables of choice. Enabling the optimization of micro lattice applications in all sectors and this combines three energy outputful tools nested in one software enabling engineering and economics to work side by side and provide informative system insights and the software lets you ask what if questions as you would like to carry out sensitivity analysis for the study where the inputs variables are nominal discount rate, incentives and grant and the output variables are Levelised cost of energy, net present cost, internal rate of return and payback period with inflation rate as controlling variable.

3.5.1. Model of Energy

The user defines the location of the energy project, the type of arrangement used in the base case, the technology for the suggested scenario, the loads, and the clean energy resource in the energy worksheet. In turn, the RETscreen Software calculates annual energy production or savings, and the Homer pro software was used to estimate the dependent variables of interest, such as Levelized cost of energy (LCOE), net present cost (NPC), and Internal rate of return (IRR), while the independent variables were nominal discount rate and incentives and grants.

3.5.2. Cost Analysis

In this worksheet, the user inserts the suggested case arrangement's initial, yearly, and periodical costs, as well as incentives for any base case costs that are avoided in the suggested case.

3.5.3 Analysis of Greenhouse Gases (GHG)

This alternate worksheet can be used to calculate the annual decrease in greenhouse gas emissions by using the suggested technology instead of the base case technology.

3.5.4. Model for Financial Analysis

The user enters a variety of financial parameters in this worksheet, including discount rates, inflation rates, project life, and fuel escalating rates. To determine the project's viability, RETscreen uses a range of financial measures (such as net present value and simple payback). The model assumes that the first year of investment is year 0; expenses and credits are expressed in year 0 terms, thus the inflation rate (or escalation rate) is applied from year 1 onwards, and cash flow scheduling occurs at the end of the year.

CHAPT FOUR: FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter describes the findings of a study that looked into the financial sustainability of solar-powered energy plants in Rwanda. In order to attain the above mentioned objective, the financial analysis was done through RETscreen and Homer pro software and the econometric analysis where the inputs variables are nominal discount rate, incentives and grant and the output variables are benefit cost ratio, Levelised cost of energy, net present cost, net present value and internal rate of return and payback period with inflation rate as controlling variable.

4.2 Descriptive statistics

Table13. Presents the summary statistics of the input, output and controlling variables

Variable	Mean	Std. Dev.	Min	Max
Payback period	6.85	.395	6.2	7.6
Benefit cost ratio	3.7	1.041	2.7	6.1
Net present value	17.912	.332	17.526	18.606
Levelised cost of energy	.075	.069	0	.22
Internal rate of return	10.938	1.574	8.9	14
Net present cost	17.228	.849	15.266	17.85
Inflation rate	3.25	2.137	0	7.5
Incentives and grant	6.98	3.194	2.9	11
Nominal discount rate	7.25	2.155	5.5	11.5

From the Table above reporting the description of data applied in the investigation indicating that the mean value of the payback period is 6.85 years; the mean value of the benefit cost ratio is 3.7; where the NPV of the project has the mean value of $58,456,521; Levelised cost of energy has the average value of $0.075/kWh; the internal rate of return has the mean value of 10.9 percent; the NPC of the project has the mean value of $54,785,652 ;where the inflation rate has the mean value of 3.25 percent; the incentives and grants as percentage proportion of the capital has the mean value of 6.98 percent; and then the nominal discount rate has the mean value of 7.25 percent.

4.3 Financial analysis

Financial analysis was carried out to determine the cost and intended remunerations of the project. This section also looks at the various financing options and their implications on the project. RETscreen Clean Energy Project Analysis and Homer Pro software were used for this simulation because it has strong financial modeling capabilities for some of the economic indicators such as Levelised cost of energy, net present value, internal rate of return and discounted payback period.

RETscreen has also the capability of simulating the technical performance as well as estimating the saving potential from greenhouse gases of renewable/sun based energy project over the entire operational period of the project. The analysis considers the entire investment cost as well as the operation and maintenance cost of the system and matches it against the revenue produced from the electrical energy sales to the utility lattice. The foremost financial indicators essentially used for this financial investigation are Levelised cost of energy (LCOE), net present value (NPV), internal rate of return (IRR), net present cost (NPC) and discounted payback period (DPBP).

Figure 1.RETscreen front view for the financial model.

4.3.1 Energy output Model Result and Analysis

The PV arrangement considered is computer-produced in the RETscreen energy model as revealed in appendix 1. The outcome is revealed in Table8

Table *1*: Energy analysis outcomes Table

Show data		
Photovoltaic		
Type		poly-Si
Power capacity	MW	8.5
Manufacturer		
Model		
Number of units		
Efficiency	%	11.5%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m^2	73,913
Bifacial cell adjustment factor	%	78%
Miscellaneous losses	%	20%
Inverter		
Efficiency	%	75%
Capacity	kW	9,000
Miscellaneous losses	%	0%
Summary		
Capacity factor	%	20.5%
Initial costs	$	23,700,000
O&M costs (savings)	$	474,000
Electricity export rate	$/kWh	Electricity export rate - annual
Electricity exported to grid	MWh	15,293
Electricity export revenue	$	0

Figure 2. RETscreen front view for the energy model.

The GigaWatt Global energy output plant as case study, the entire annual electrical energyexported to the lattice was expected to be 15,293,057 KWh/year through which there will be gross annual greenhouses gases emission reduction of 7,233.6 tons of CO_2 and this emissions reduction is equivalent to the 3,108,083.5 liters of the gasoline which are not consume and also this is equivalent to the 665.3 hectares of the forest planation absorbing carbon.

4.3.2 Entire investments, operation and maintenance costs

The entire investment cost encompasses the subsequent components; module, inverter, mounting structures, and installation. The investment cost used in the study is US$2.84/Wp, which is the typical cost of ground mounted lattice-connected sun based PV installations in Rwanda with the entire installed capacity of 8.5 MWp for the case study. This cost includes that of the modules, inverters, electrical cablings, mountings, lattice connections and labor. the GigaWatt Global Energy output plant were obtained from different reports and websites like FMO Entrepreneurial Development Bank, GigaWatt Global Rwanda Ltd and World Bank the breakdown is presented in Table 4.1. The module cost alone accounts for about 57.6 percent of the entire investment of US$23,700,000.

Table 1.Summary of the financing consortium for GigaWatt Global sun based energy output plant (EAIF, 2018)

Investor	Quantity ($ million)	Instrument
Scatec Sun based, an independent sun based energy output producer headquartered in Norway	≈3.5	Equity (lead equity investor)
Norfund, the Norwegian Investment Fund for Developing States	≈2.61	Equity and mezzanine loan
KLP-Norfund, the largest pension fund in Norway that co-invests together with Norfund	≈1.73	Equity
FMO, the Dutch development bank	≈5.3	Senior debt financing
EAIF (Emerging Africa Infrastructure Fund), a public private partnership	10.6	Senior debt financing
ACEF (Africa Clean Energy Finance Initiative), part of the US government’s Energy output Africa initiative	0.4	Grant
EEP, Energy and Environment Partnership, an EU-funded programme which promotes clean energy, energy efficiency, and clean technology investments	0.3	Grant

For preferring a sun based PV arrangement for the cell locality, a perfect conception for putting into practice the cost is desired. Table 4.2 summarizes the input data factors for the analysis cost estimates within the software RETscreen.

Component	Cost (USD/Wp)
PV module	2.84
Inverter	0.51
Mounting structures	0.42
Accessories	0.24
Installations	0.9
Entire	4.93

Table2.Cost itemization for the Lattice-Connected GigaWatt Global Sun based PV system

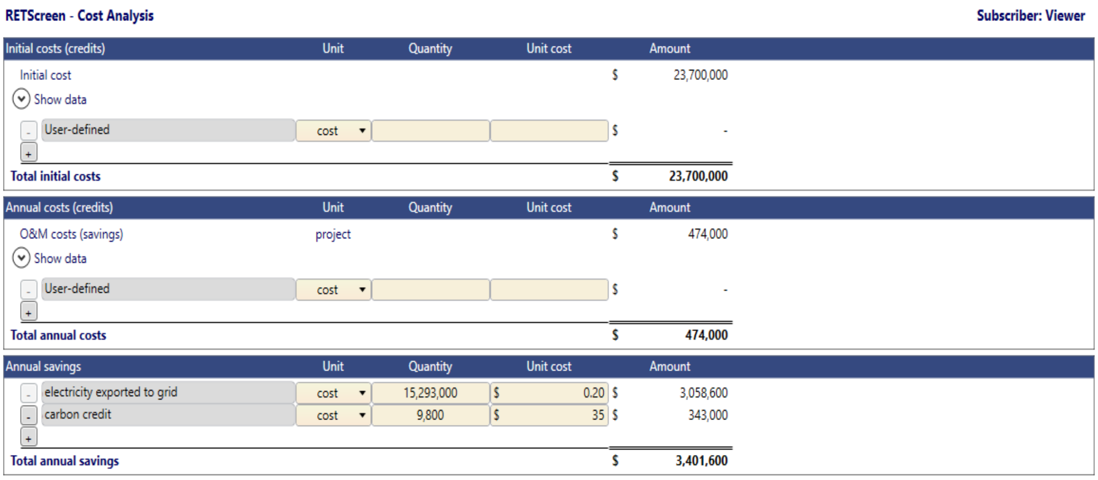
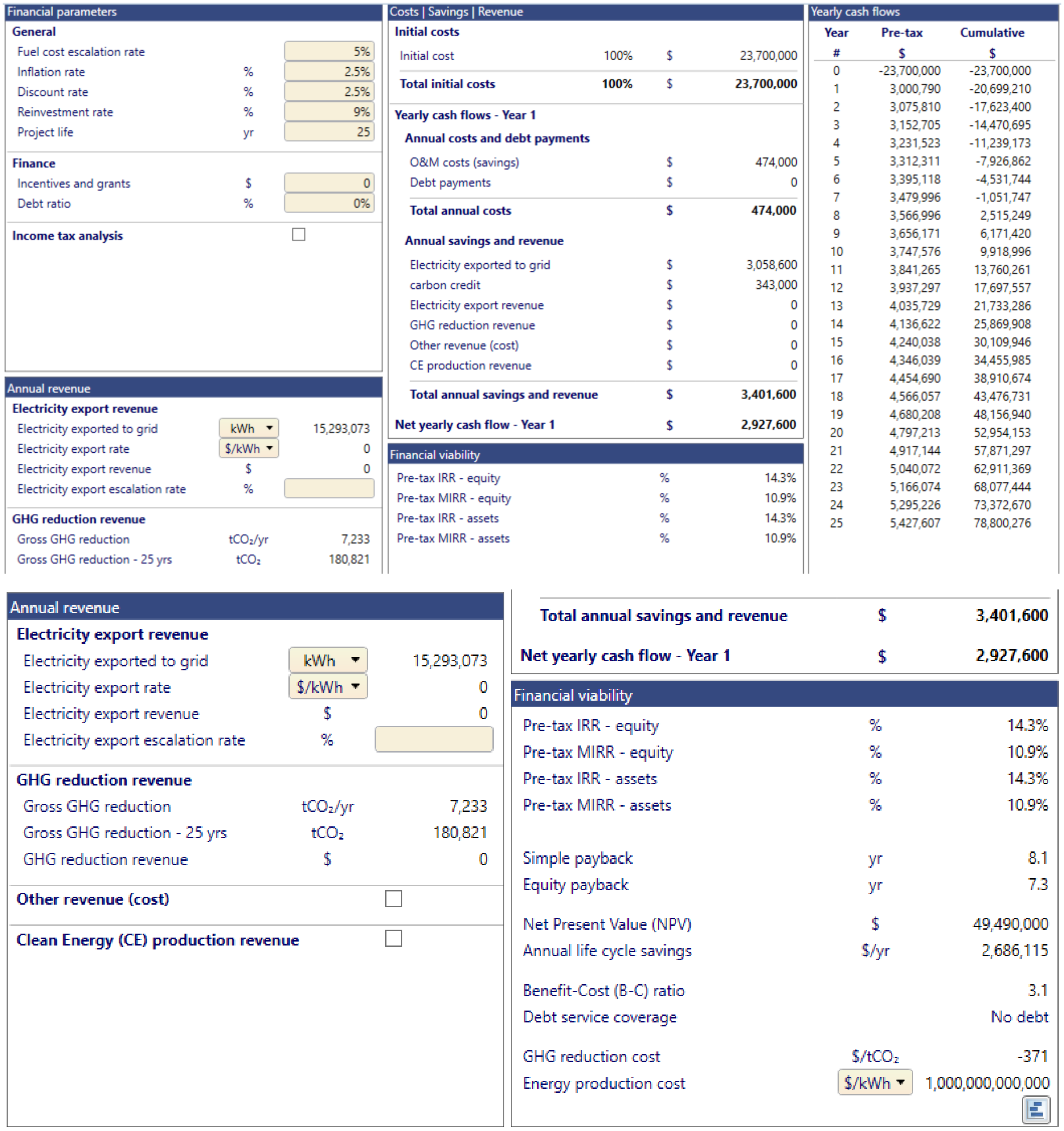


Figure 3. RETscreen front view for the cost analysis.

The PV systems connected to the lattice are overallly deliberated as ‘free of maintenance’ systems, essentially because of the very low level of maintenance carried out on the systems during their operational lifetime paralleled to the other electrical systems. The main maintenance works, conversely carried out on sun based PV systems done on the inverters. For the purpose of this study, the operation and maintenance (O & M) costs for the systems is set at 5% of the capital cost as specified by the REG and RURA draft feed-in-tariff policy and guidelines. The purpose of this section of the study is to look at the different financial parameters obtainable for clean energyproject and in which way they influence the viability of projects. This was carried out by main raising a business as usual (BAU) scenario considering the constraints here below in the RETscreen software package; In Africa, extended-period fuel cost escalation proportions vary anywhere from 0 to 6% with 2.5 to 3.5% being the utmost communal values (RETscreen). For this analysis, a fuel escalation proportion of 5% was applied. Inflation rate within the subsequent 20 years in Africa was presently predicted to vary in the middle of 2 and 6.8% (RETscreen, 2014). An inflation rate of 6% was applied for the study. The present BNR Rwanda dollar discount rate of 6% was applied in this analysis. A projected lifespan of the apparatus likewise had impact on outcomes of the speculation analysis. The anticipated sun based panel lifespan at 20 years is applied for the net present value (NPV) intentions.

Table 3. BAU-Financial analysis constraints

BAU-Financial constraints	
Sun based PV system costs	US$ 4.93/Wp
Operating and maintenance costs	2% of capital cost
Project life	25years
Discount rate	2.65%(BNR)
Inflation rate	2.5 %(BNR)
Grant/ subsidy/Government support	0% of entire investment
GHG credit	US$0/tonne$CO_2$eq
Bulk generation charge	US$0.09/kWh



Financial parameters

General		
Fuel cost escalation rate		5%
Inflation rate	%	2.5%
Discount rate	%	2.5%
Reinvestment rate	%	9%
Project life	yr	25
Finance		
Incentives and grants	$	0
Debt ratio	%	0%
Income tax analysis		☐

Annual revenue

Electricity export revenue		
Electricity exported to grid	kWh	15,293,073
Electricity export rate	$/kWh	0
Electricity export revenue	$	0
Electricity export escalation rate	%	
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	7,233
Gross GHG reduction - 25 yrs	tCO_2	180,821

Costs | Savings | Revenue

Initial costs			
Initial cost	100%	$	23,700,000
Total initial costs	**100%**	**$**	**23,700,000**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	474,000
Debt payments		$	0
Total annual costs		**$**	**474,000**
Annual savings and revenue			
Electricity exported to grid		$	3,058,600
carbon credit		$	343,000
Electricity export revenue		$	0
GHG reduction revenue		$	0
Other revenue (cost)		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**3,401,600**
Net yearly cash flow - Year 1		**$**	**2,927,600**

Financial viability

Pre-tax IRR - equity	%	14.3%
Pre-tax MIRR - equity	%	10.9%
Pre-tax IRR - assets	%	14.3%
Pre-tax MIRR - assets	%	10.9%

Yearly cash flows

Year	Pre-tax	Cumulative
#	$	$
0	-23,700,000	-23,700,000
1	3,000,790	-20,699,210
2	3,075,810	-17,623,400
3	3,152,705	-14,470,695
4	3,231,523	-11,239,173
5	3,312,311	-7,926,862
6	3,395,118	-4,531,744
7	3,479,996	-1,051,747
8	3,566,996	2,515,249
9	3,656,171	6,171,420
10	3,747,576	9,918,996
11	3,841,265	13,760,261
12	3,937,297	17,697,557
13	4,035,729	21,733,286
14	4,136,622	25,869,908
15	4,240,038	30,109,946
16	4,346,039	34,455,985
17	4,454,690	38,910,674
18	4,566,057	43,476,731
19	4,680,208	48,156,940
20	4,797,213	52,954,153
21	4,917,144	57,871,297
22	5,040,072	62,911,369
23	5,166,074	68,077,444
24	5,295,226	73,372,670
25	5,427,607	78,800,276

Annual revenue

Electricity export revenue		
Electricity exported to grid	kWh	15,293,073
Electricity export rate	$/kWh	0
Electricity export revenue	$	0
Electricity export escalation rate	%	
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	7,233
Gross GHG reduction - 25 yrs	tCO_2	180,821
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Total annual savings and revenue	**$**	**3,401,600**
Net yearly cash flow - Year 1	**$**	**2,927,600**

Financial viability

Pre-tax IRR - equity	%	14.3%
Pre-tax MIRR - equity	%	10.9%
Pre-tax IRR - assets	%	14.3%
Pre-tax MIRR - assets	%	10.9%
Simple payback	yr	8.1
Equity payback	yr	7.3
Net Present Value (NPV)	$	49,490,000
Annual life cycle savings	$/yr	2,686,115
Benefit-Cost (B-C) ratio		3.1
Debt service coverage		No debt
GHG reduction cost	$\$/tCO_2$	-371
Energy production cost	$/kWh	1,000,000,000,000

Figure 4. RETscreen front view for the financial viability analysis.

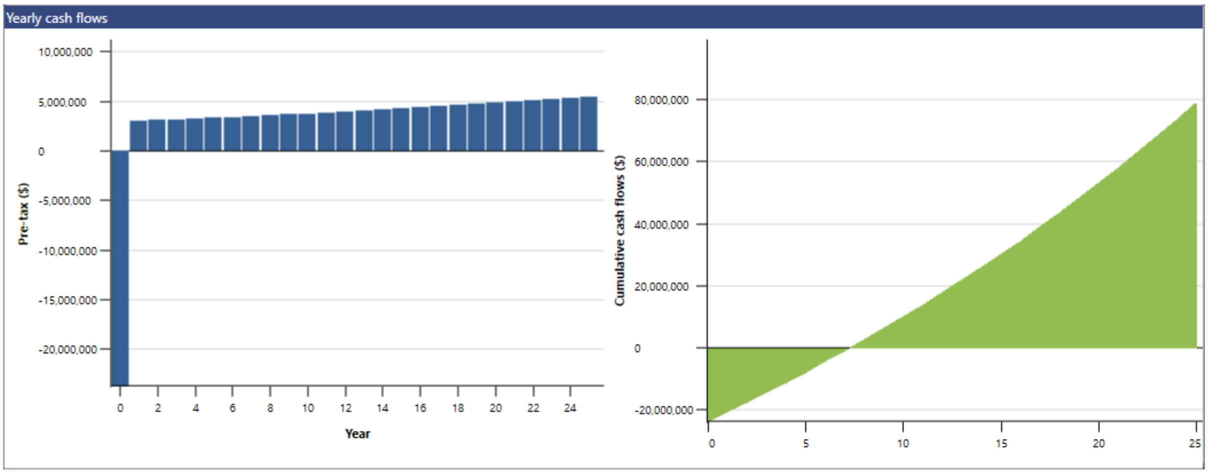


Figure 5.RETscreen front view for the payback period and cumulative cash flows.

4.3.3 Economic and Financial Outcomes Analysis

The end result of the economic and financial model was revealed in Table 11

Table 4. Financial and economic analysis outcomes

Factors	**Value**
Simple payback	8.1 years
Equity payback	7.3 years
net present value (NPV)	US $ 49,490,000
benefit-cost proportion	1.5

Since the equity payback signifies the span of period that it continues for the anticipated venture to recuperate the related perceptible opening investment (equity) out of the venture cash flows prepared. This equity payback thinks through venture cash flows from its opening even the level of debt of the venture. The examination delivers 7.3 years for an equity pay back with 8.1 years as simple payback period. The software as well estimates the NPV of an optional photovoltaic arrangement. The NPV for the arrangement was US $ 49,490,000. Putatively viable project is symbolized by Positive NPV values as an indicator. The net Benefit-Cost (B-C) ratio was the proportion of the net remunerations to costs associated with the venture. The benefit-cost proportion for the project was 1.5, where the proportions superior than unit are suggestive for cost-effective ventures.

4.4 Sensitivity and risk Analysis

The segments on Appendix show the outcome of the thoughtfulness examination computer-produced by software RETscreen and Homer Pro software. The Tables top under displays what come about for the equity payback, Net present value and Benefit Cost ratio when 2 core Factors, inflation rate and Debt interest rate, are wide-ranging by the specified proportions. The thoughtfulness analysis is accomplished at a range of sensitivity of 25%. The Sensitivity analysis under displays what comes about to the equity payback, net present value and benefit cost proportion when the main indicators are wide-ranging. For the sensitivity analysis, more scenarios were developed, by changing the BAU financial constraints, to examine the impression of grants/subsidies, GHG income, Clean energyfeed-in tariffs (RE-FiT), and reducing system cost on the viability of the project.

From the Table 6 on appendix showing the sensitivity analysis of inflation rate on both equity and simple payback periods and other financial parameters .it reports that when the inflation rate increase from 1.5% to 7.5% was lead to the decrease in equity payback period as of 7.6 years up to 6.2 years with an increase in Net present value from 40,892,908 $ to 120,401,802$ as revealed in Table 6 and with an incline in Benefit cost ratio from 2.7 to 6.1with constant simple payback period of 8.1 years as revealed on Table6.

From the Table 8 on appendix showing the sensitivity analysis of incentives or grant as percentage of capital on both simple and equity payback periods and other financial parameters .it reports that when the grants percentage increase from 2.9% to 11% this affect negatively both simple and equity payback from 7.9 to 7.2 years and from 7.1 to 6.6 years respectively while this lead to an increase in net present value from 50,177,300 $ to 52,097,000 $ with a important incline in the lifecycle annual savings from 2,723,419 $ to 2,827,613 $ as revealed in Table8 and with an increase in Benefit cost ratio from 3.1 to 3.4 as revealed on Table 8 And this shows that the grant or incentives for the clean energysources for the electrical energygeneration through lattice connection is a crucial parameter to consider through the development of the clean and clean energy resource contribution on the full electrification program.

With the lower most equity payback period was 6.2 years then it is attained when there is 25% rise in the BAU case cost of fuel and a 25 % discount in the opening cost of the photovoltaic arrangement. The peak equity payback period 7.6 years then it was attained once there is 25% discount in the BAU case cost of fuel with a 25% raise in the opening cost of the photovoltaic arrangement.

The Table 9 reports the sensitivity analysis carried out using Homer Pro software indicating the variation of financial viability parameters when the inflation change from 1.5 % to 6 % while the nominal discount rate is held fixed at 6 %, this is associated to the change in the present cost (NPC) from $43,060,920 to $4,265,393 with the change of Levelized cost of energy (LCOE) from 0.066$/kwh to 0.003 $/kWh while this is associated with change for Internal rate of return(IRR) and simple payback period from 11 % to 8.9 % and from 8.5 years to 9.9 years respectively.

Table 10 revealed the sensitivity analysis conducted using Homer Pro showing the change in nominal discount rate from 5.5 % to 11.5 % when the inflation rate is held fixed at 2 percent in the short run, this is related to the increase in net present cost (NPC) from $37,513,400 to $56,495,680 with an incline in the Levelised cost of energy (LCOE) from 0.049$/kWh to 0.224 $/kWh while this variation is associated with the increase in internal rate of return from 1 % to 14 % and then the decline in simple payback period from 8.7 years to 6.9 years.

Photovoltaic module cost is a crucial element of the photovoltaic arrangement opening cost. In the meantime 1998, fixed photovoltaic arrangement charges had dropped by 6-8% per year on averaged. While for 2011 to 2012, fixed charges drop by $0.88/W (14%) for arrangements with a smaller quantity than 11 kW and by $0.4/W (6%) for arrangements superior than 110 kW (NREL,2014).Those numbers are in line with marketplace analyst downward-trajectory projections for projected market valuing of photovoltaic arrangements. For that reason as photovoltaic charges drop the equity payback is predicTable to drop.
In standings of safekeeping for electric energy, it is greatly probable that there was be ongoing stages of shortage in fuel as deliveries retain declining. For that reason as fuel prices with escalation equity payback decreases and for that reason energy from the sun turn into more remarkable within the extended long period.

4.5 Econometric analysis

4.5.1 Estimation results from Ordinary least square regression analysis model

From the described variables through which the study identified the independent and dependent variables for analyzing both short run and long run causal relationship, here we used the ordinary least square (OLS) regression model analysis for the identified variables for the financial viability analysis.

Table 14. Estimation results from Ordinary least square regression analysis model

VARIABLES	(1) **Payback period**	(2) **Benefit-cost ratio**	(3) **LnNPV**	(4) **LCOE**	(5) **IRR**	(6) **LnNPC**
Incentives on capital		0.035**	0.005***			
		(0.010)	(0.000)			
Discount rate				0.026***	0.511***	0.055
				(0.003)	(0.087)	(0.062)
Inflation rate	-0.156**			0.014**	-0.460**	-0.477***
	(0.045)			(0.004)	(0.119)	(0.085)
Constant	7.486***	2.959***	17.718***	-0.076*	8.557***	18.204***
	(0.205)	(0.072)	(0.000)	(0.031)	(0.840)	(0.598)
Observations	6	5	5	8	8	8
R-squared	0.750	0.812	1.000	0.956	0.938	0.892

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

From Table 14 above reports the causal relationship between the dependent(benefit cost ratio, net present cost(NPC), Levelised cost of energy(LCOE) and internal rate of return(IRR)) and independent variables, Table 14 reports that the rise in proportion of incentives as percentage of the initial capital by 1percent is associated with the incline in the benefit cost ration by 3.5 point percentage and this is important at p<0.01 while the rise in inflation rate by 1 percent this is associated with the decline in the equity payback period by 15.6 point percentage which is important at p<0.05 when other factors are held fixed. The Table 11 above revealed that the rise in expected inflation rate by 1 percent this is associated with the increase in the Levelised cost of energy by 1.4 point percentage which is important at $p<0.05$ while this change in inflation rate is related with decline in the net present cost by 47.7 point percentage which is important at $p<0.01$ and this change in inflation rate is linked to the decrease in the internal rate of return by 46 point percentage and this is important at $p<0.05$ while other factors are kept constant. The Table 11 showed that the rise in nominal discount rate by 1 percentage is associated with the incline in Levelised cost of energy by 2.6 point percentage which is important at $p<0.01$ while this rise of nominal discount rate is linked to the increase of the internal rate of return by 51.1 point percentage which is important at $p<0.01$ when all other factors are kept fixed.

CHAPTER FIVE: MAJOR FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter discusses the results from the study which aim was to investigate the financial viability of the sun based energy output projects in Rwanda.

In Rwanda, the important sun based energy potential of approximately 66.8 TWh is not enough to disseminate and deploy the sun based parks but other financial viability parameters long-term project investment like sun based energy project. The aim of the research was to look at the financial sustainability of spreading sun-based parks.

5.1 Discussion of findings

Findings are discussed according to study objectives as follow:

5.1.1 To measure and evaluate the remunerations associated with lattice connected PV system

The results reported that when the grants percentage increase from 2.9% to 11%, this affect negatively both simple and equity payback from 7.9 to 7.2 years and from 7.1 to 6.6 years respectively while this lead to an increase in Net present value from 50,177,300 $ to 52,097,000 $ with a important incline in the lifecycle annual savings from 2,723,419 $ to 2,827,613 $ as revealed in Table8 and with an increase in Benefit cost ratio from 1.5 to 3.4 as revealed on Table 8 And this shows that the grant or incentives for the clean energy sources for the electrical energy generation through lattice connection is a crucial parameter to consider through the development of the clean and clean energy resource contribution on the full electrification program.

5.1.2 To measure and evaluate the costs associated with lattice connected PV system

The results revealed that as the change in nominal discount rate from 5.5 % to 11.5 % when the inflation rate is held fixed at 2 percent in the short run, this is related to the increase in net present cost (NPC) from $37,513,400 to $56,495,680 with an incline in the Levelised cost of energy (LCOE) from 0.049$/kWh to 0.224 $/kWh while this variation is associated with the increase in internal rate of return from 1 % to 14 % and then the decline in simple payback period from 8.7 years to 6.9 years.

5.1.3 To examine the sun based energy suitability and potentiality in Rwanda

In Rwanda the sun based irradioactivity of 4 to 6 kWh/m^2 shows the sun based energy potentiality where The GigaWatt Global energy output plant as case study, the entire annual electrical energy exported to the lattice was expected to be 15,293,057 KWh/year through which there will be gross annual greenhouses gases emission reduction of 7,233.6 tons of CO_2 and this emissions reduction is equivalent to the 3,108,083.5 liters of the gasoline which are not consumed and also this is equivalent to the 665.3 hectares of the forest planation absorbing carbon.

5.1.4 To identify the factors influencing the viability of sun based energy output plant

The results revealed that the rise in proportion of incentives as percentage of the initial capital by 1percent is associated with the incline in the benefit cost ration by 3.5 point percentage and this is important at $p<0.01$ while the rise in inflation rate by 1 percent this is associated with the decline in the equity payback period by 15.6 point percentage which is important at $p<0.05$ when other factors are held fixed.

The outcomes showed that the rise in nominal discount rate by 1 percentage is associated with the incline in Levelised cost of energy by 2.6 point percentage which is important at $p<0.01$ while this rise of nominal discount rate is linked to the increase of the internal rate of return by 51.1 point percentage which is important at $p<0.01$ when all other factors are kept fixed and this indicates that these variables like benefit cost ratio, payback period , internal rate of return and Levelised cost of energy considered above are influencing the viability of the sun based energy output station in Rwanda.

5.2 Conclusions

In this study we investigated the financial viability of the sun based energy output projects and here we considered the gird connected Photovoltaic system under study, The Benefit-Cost (B-C) ratio of 1.5 is also greater than 1 indicating a cost-effective project. The high initial investment can be retrieved in 7.3 years while the analysis using Homer Pro software, the net present value increase when the expected maximum of $120,401,802 which accord the outcomes of Kim and Hong (2011) and the Levelised cost of energy 0.224$/kWh indicating the higher level of cost associated with electrical energy production through sun based system compared to 0.15$/kWh for hydro energy output system according to RURA, (2020) and this goes in line with the findings of Adaramola (2015) and this is important aspect that terrify the incumbent investors in the energy sector for using sun based energy system for electrical energy production and hence the decline in the dissemination of sun based parks in the country regardless of the sun based potentiality within the country.

5.3 Recommendations

This investigation has both policy and academic implications, as the sensitivity analysis revealed that incentives and subsidies are directly proportionate to the project's benefit cost ratio and lifecycle savings. This study suggests that government assistance is needed to motivate existing and new investors in the energy sector, particularly in sun based energy systems. This study also recommends that central bank of the country should control and govern the nominal discount rate in order to encourage investment in sun based energy systems.

5.4 Future research

This study was limited to the scope through using limited control variables through modeling; the further investigation should focus on the financial viability of on-lattice sun based energy output projects with more controllable elements, as well as the financial viability of off-lattice sun based energy options.

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APPENDICES

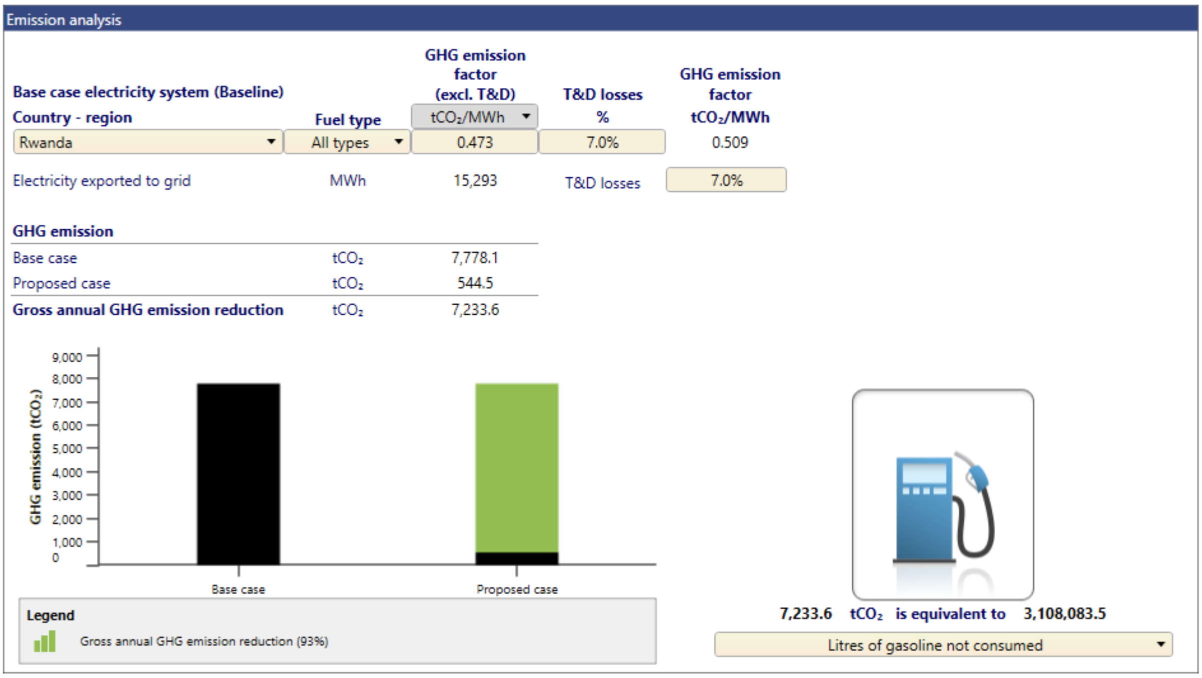
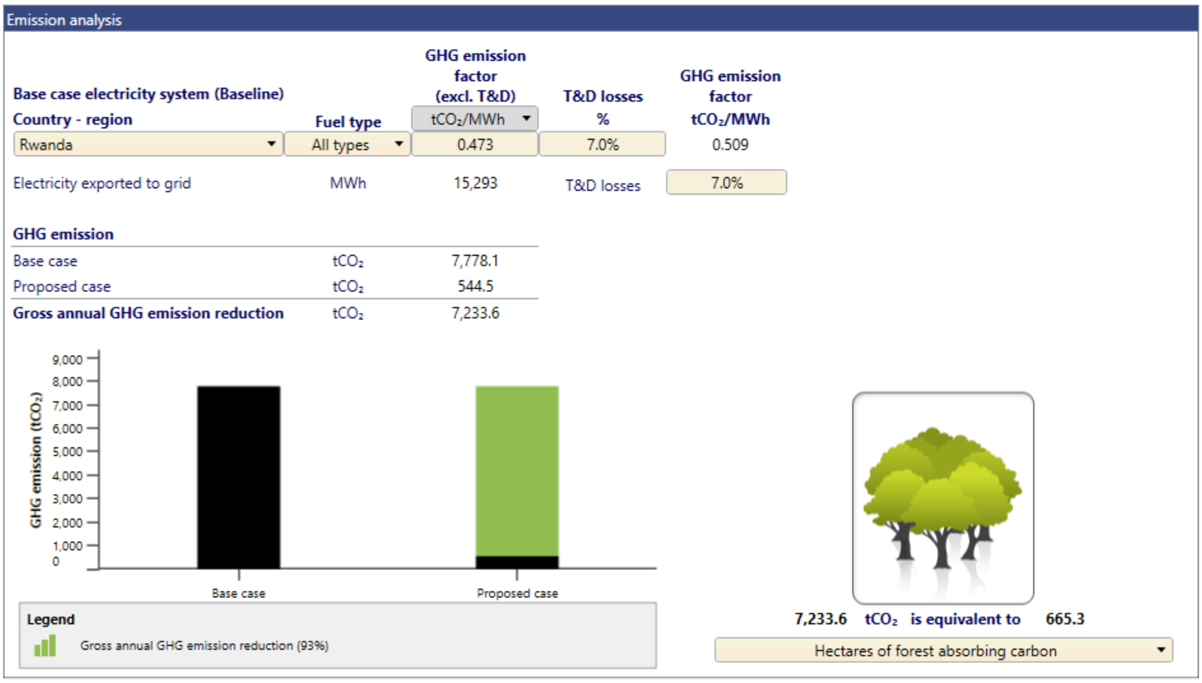


Figure 68: RETscreen view for the GHG emission reduction and equivalence to gasoline.



GHG reduction revenue		
GHG reduction credit rate	$/tCO_2$	35.00
GHG reduction credit duration	yr	25
GHG reduction credit escalation rate	%	2.0%
GHG credits transaction fee	%	0.0%
Net annual GHG emission reduction	tCO_2	7,233.6
GHG reduction revenue	$	253,177

Figure 78: RETscreen view for the GHG emission reduction and equivalence to forest

Economic Metrics

IRR	11%
ROI	7.8%
Simple Payback	8.5 yr

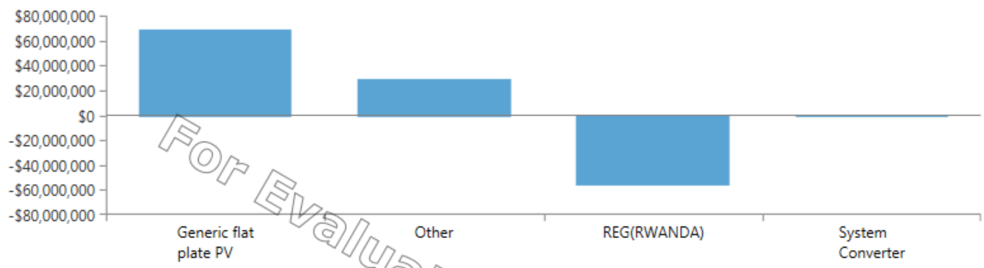
Simulation Results

System Architecture:	REG(RWANDA) (999,999 kW)	ExpectedInflationRate (1.50 %)	Total NPC: $43,060,920.00
Generic flat plate PV (26,405 kW)	HOMER Cycle Charging	NominalDiscountRate (6.00 %)	Levelized COE: $0.06581
System Converter (14,403 kW)			Operating Cost: -$3,151,478.00

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Generic flat plate PV | REG(RWANDA) | System Converter | Emissions

Cost Type: Net Present / Annualized

Categorize: By Component / By Cost Type



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$66,012,747.40	$0.00	$3,942,344.03	$0.00	$0.00	$69,955,091.43
Other	$24,100,000.00	$0.00	$5,595,913.66	$0.00	$0.00	$29,695,913.66
REG(RWANDA)	$0.00	$0.00	-$56,590,767.42	$0.00	$0.00	-$56,590,767.42
System Converter	$480.10	$250.46	$0.00	$0.00	-$54.10	$676.46
System	$90,113,227.50	$250.46	-$47,052,509.73	$0.00	-$54.10	$43,060,914.13

Create Proposal | Time Series Plot | Other...

Economic Metrics

IRR	10%
ROI	7.3%
Simple Payback	8.9 yr

Simulation Results

System Architecture: REG(RWANDA) (999,999 kW)
Generic flat plate PV (29,242 kW) HOMER Cycle Charging
System Converter (14,403 kW)

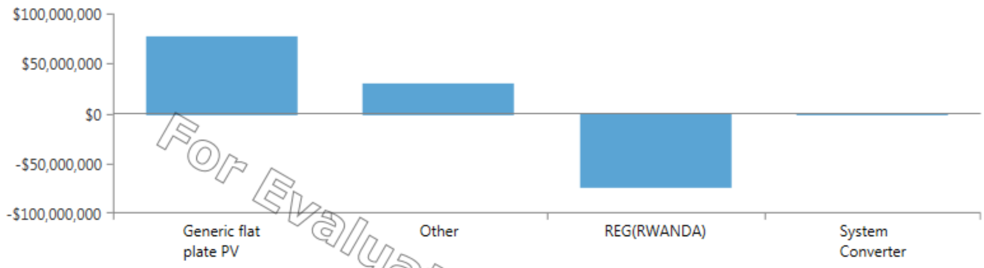
ExpectedInflationRate (3.00 %)
NominalDiscountRate (6.00 %)

Total NPC: $34,081,680.00
Levelized COE: $0.04195
Operating Cost: -$3,589,864.00

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Generic flat plate PV | REG(RWANDA) | System Converter | Emissions

Cost Type
- Net Present
- Annualized

Categorize
- By Component
- By Cost Type

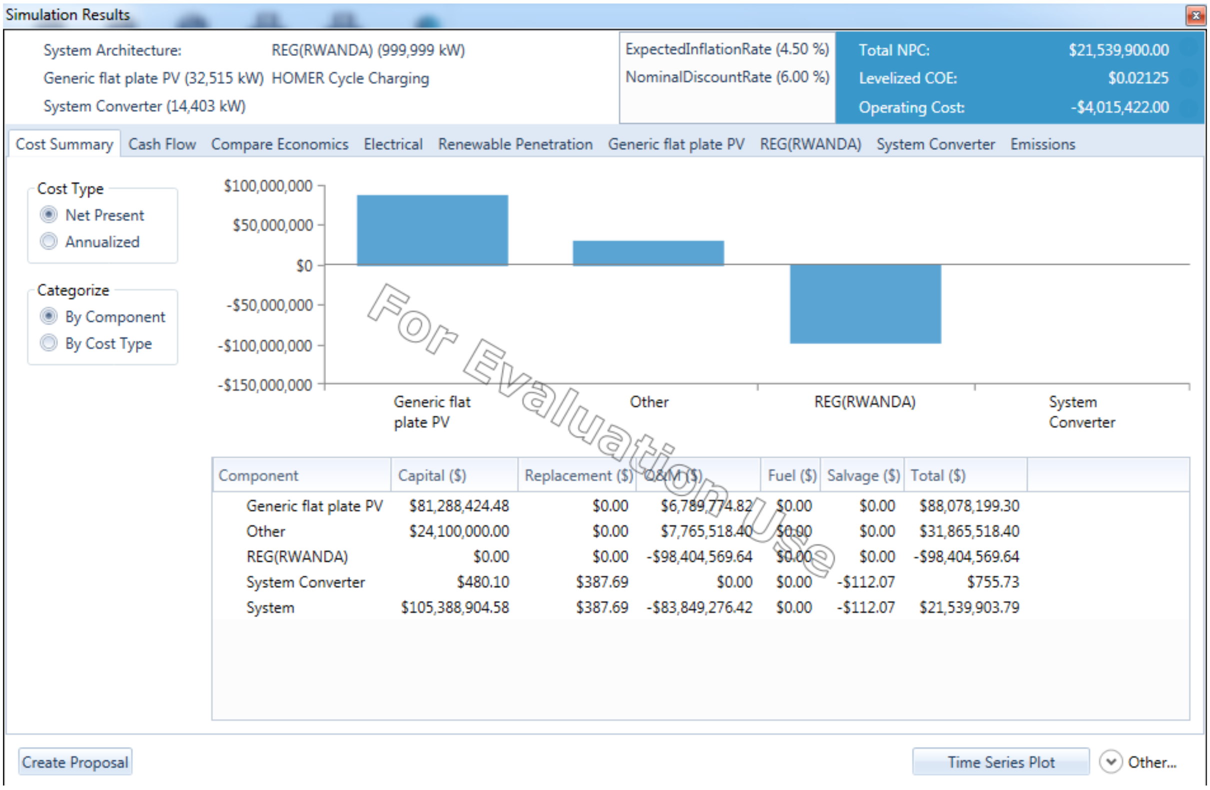


Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$73,105,026.04	$0.00	$5,141,887.70	$0.00	$0.00	$78,246,913.74
Other	$24,100,000.00	$0.00	$6,563,801.55	$0.00	$0.00	$30,663,801.55
REG(RWANDA)	$0.00	$0.00	-$74,829,746.77	$0.00	$0.00	-$74,829,746.77
System Converter	$480.10	$312.11	$0.00	$0.00	-$78.07	$714.13
System	$97,205,506.14	$312.11	-$63,124,057.51	$0.00	-$78.07	$34,081,682.66

Create Proposal | Time Series Plot | Other...

Economic Metrics

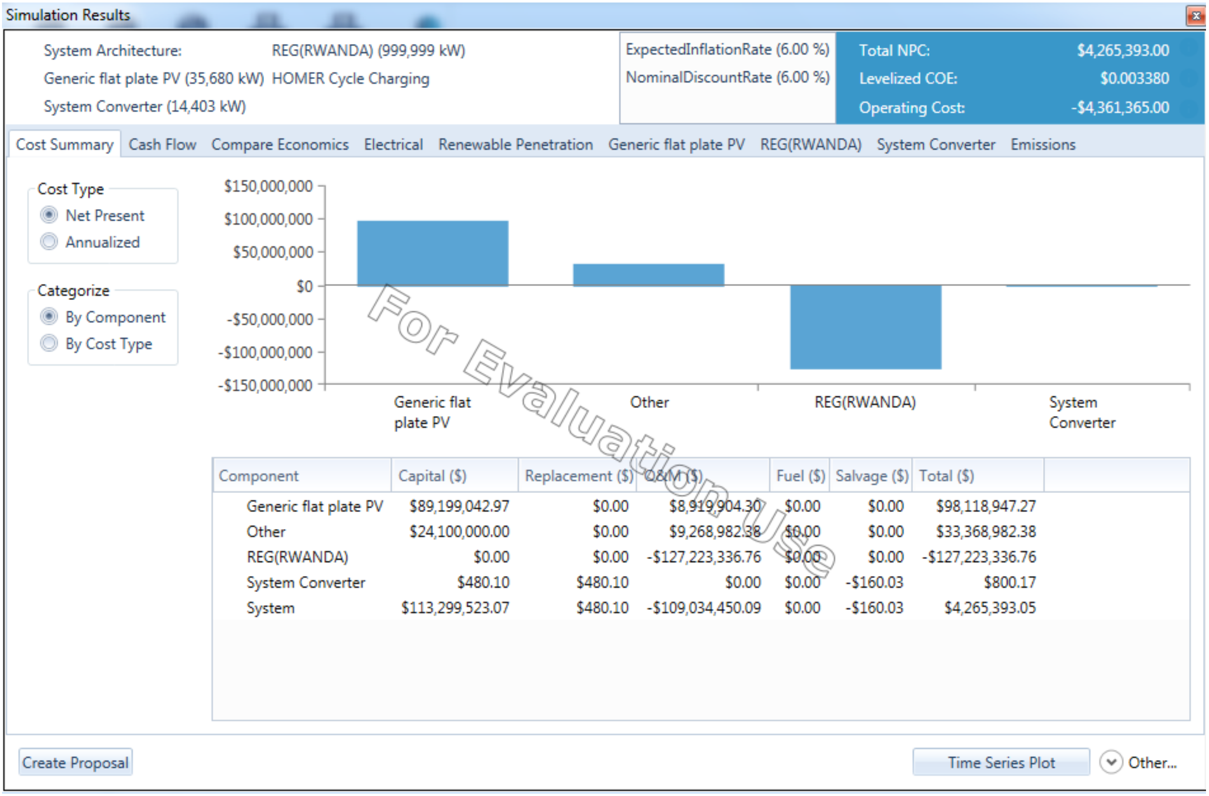
IRR	9.6%
ROI	6.7%
Simple Payback	9.4 yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$81,288,424.48	$0.00	$6,789,774.82	$0.00	$0.00	$88,078,199.30
Other	$24,100,000.00	$0.00	$7,765,518.40	$0.00	$0.00	$31,865,518.40
REG(RWANDA)	$0.00	$0.00	-$98,404,569.64	$0.00	$0.00	-$98,404,569.64
System Converter	$480.10	$387.69	$0.00	$0.00	-$112.07	$755.73
System	$105,388,904.58	$387.69	-$83,849,276.42	$0.00	-$112.07	$21,539,903.79

Economic Metrics

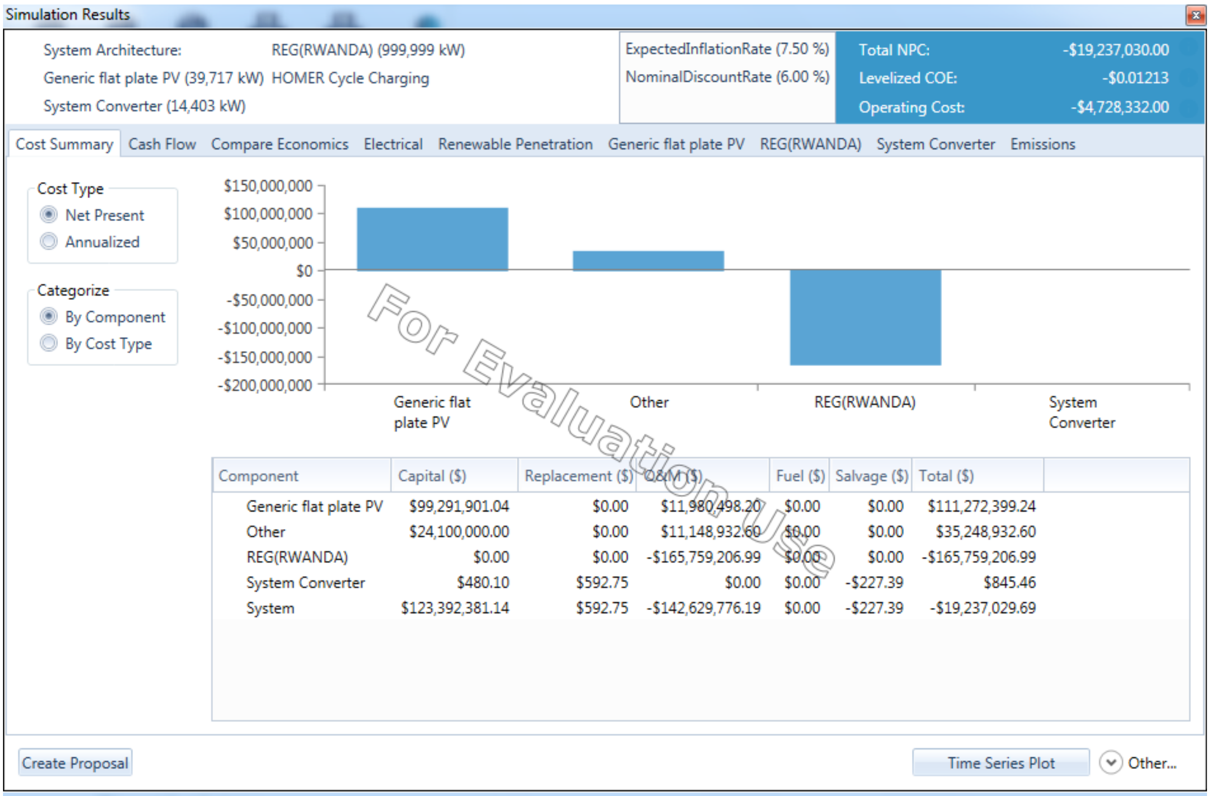
IRR	8.9%
ROI	6.1%
Simple Payback	9.9 yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$89,199,042.97	$0.00	$8,919,904.30	$0.00	$0.00	$98,118,947.27
Other	$24,100,000.00	$0.00	$9,268,982.38	$0.00	$0.00	$33,368,982.38
REG(RWANDA)	$0.00	$0.00	-$127,223,336.76	$0.00	$0.00	-$127,223,336.76
System Converter	$480.10	$480.10	$0.00	$0.00	-$160.03	$800.17
System	$113,299,523.07	$480.10	-$109,034,450.09	$0.00	-$160.03	$4,265,393.05

Economic Metrics

IRR	8.1%
ROI	5.4%
Simple Payback	11 yr

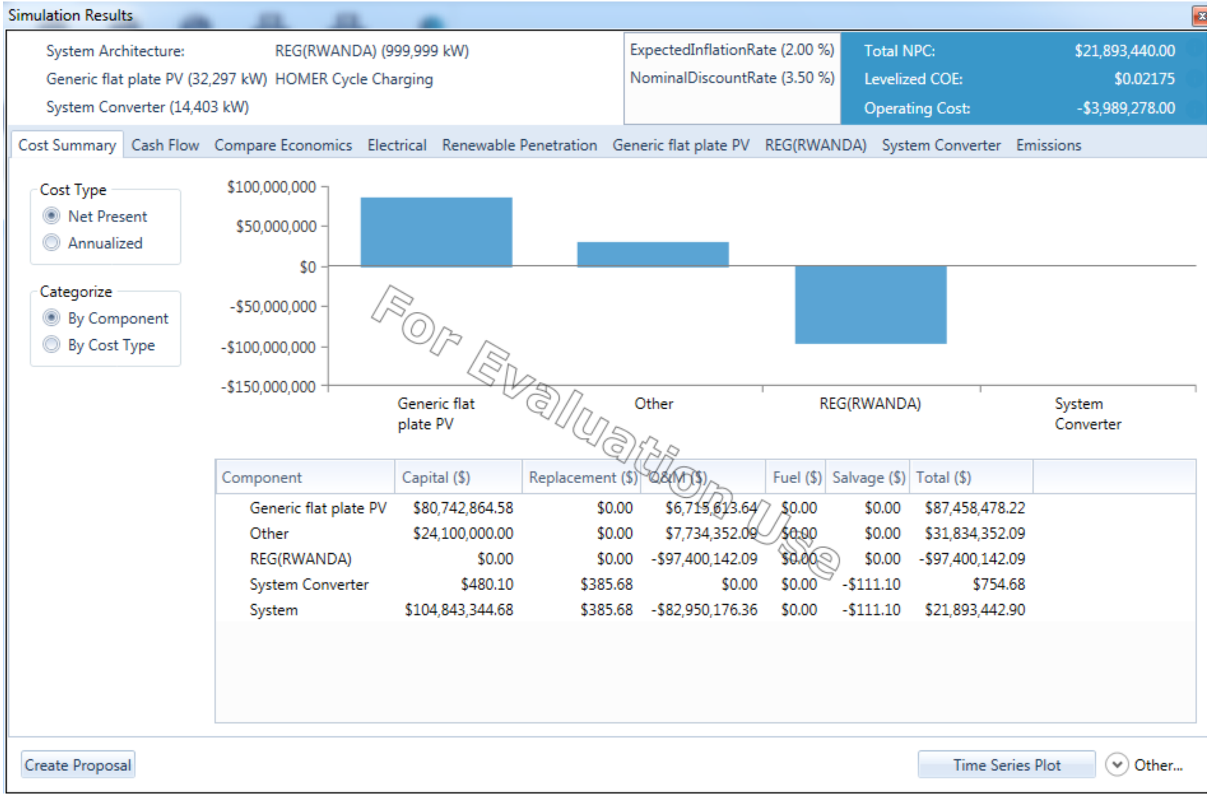


Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$99,291,901.04	$0.00	$11,980,498.20	$0.00	$0.00	$111,272,399.24
Other	$24,100,000.00	$0.00	$11,148,932.60	$0.00	$0.00	$35,248,932.60
REG(RWANDA)	$0.00	$0.00	-$165,759,206.99	$0.00	$0.00	-$165,759,206.99
System Converter	$480.10	$592.75	$0.00	$0.00	-$227.39	$845.46
System	$123,392,381.14	$592.75	-$142,629,776.19	$0.00	-$227.39	-$19,237,029.69

For discount rate vary fixing inflation rate

Economic Metrics

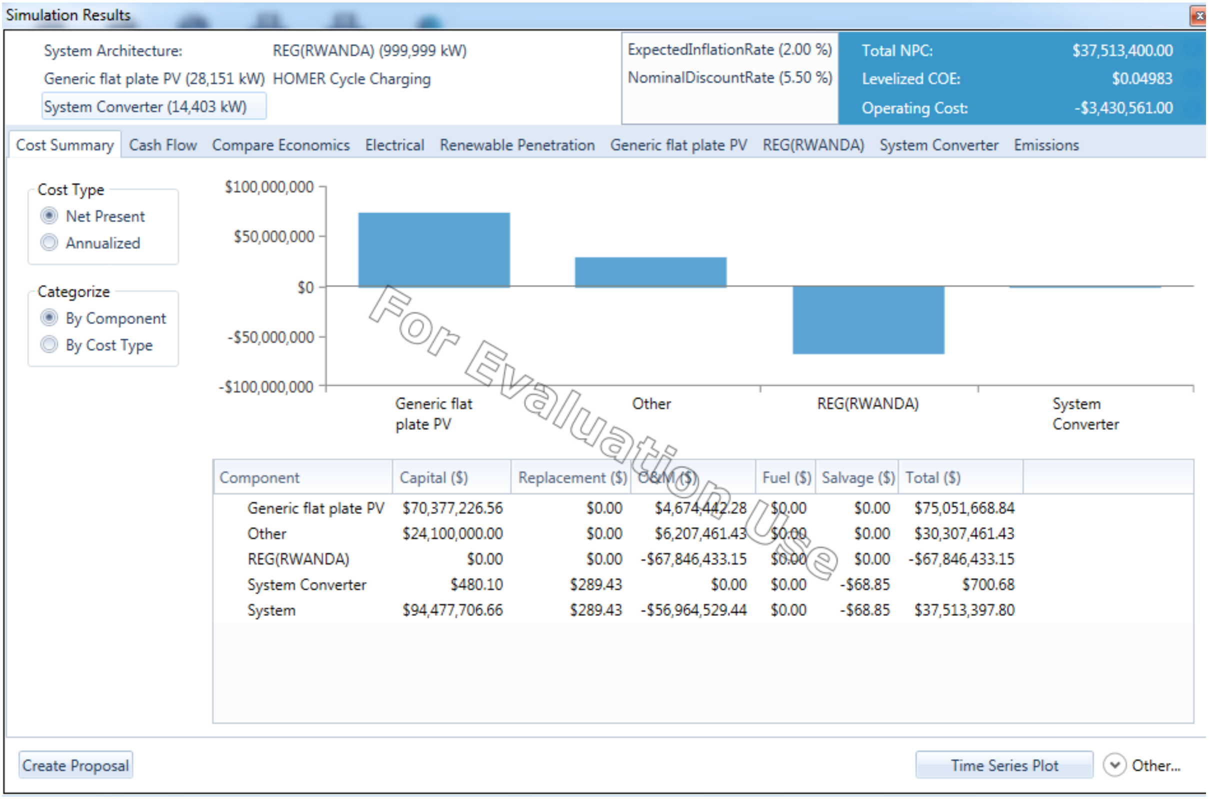
IRR	9.6%
ROI	6.7%
Simple Payback	9.4 yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$80,742,864.58	$0.00	$6,715,613.64	$0.00	$0.00	$87,458,478.22
Other	$24,100,000.00	$0.00	$7,734,352.09	$0.00	$0.00	$31,834,352.09
REG(RWANDA)	$0.00	$0.00	-$97,400,142.09	$0.00	$0.00	-$97,400,142.09
System Converter	$480.10	$385.68	$0.00	$0.00	-$111.10	$754.68
System	$104,843,344.68	$385.68	-$82,950,176.36	$0.00	-$111.10	$21,893,442.90

Economic Metrics

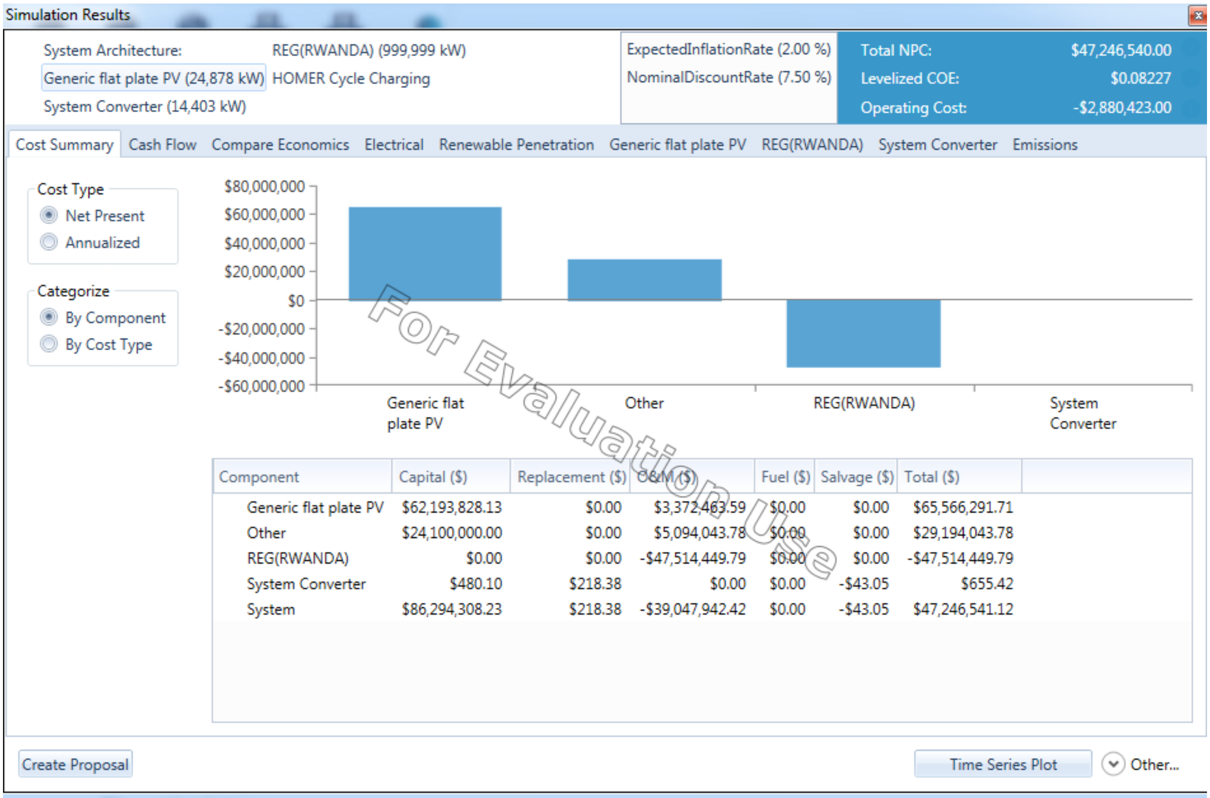
IRR	11%
ROI	7.5%
Simple Payback	8.7 yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$70,377,226.56	$0.00	$4,674,442.28	$0.00	$0.00	$75,051,668.84
Other	$24,100,000.00	$0.00	$6,207,461.43	$0.00	$0.00	$30,307,461.43
REG(RWANDA)	$0.00	$0.00	-$67,846,433.15	$0.00	$0.00	-$67,846,433.15
System Converter	$480.10	$289.43	$0.00	$0.00	-$68.85	$700.68
System	$94,477,706.66	$289.43	-$56,964,529.44	$0.00	-$68.85	$37,513,397.80

Economic Metrics

IRR	11%
ROI	8.1%
Simple Payback	8.3 yr



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$62,193,828.13	$0.00	$3,372,463.59	$0.00	$0.00	$65,566,291.71
Other	$24,100,000.00	$0.00	$5,094,043.78	$0.00	$0.00	$29,194,043.78
REG(RWANDA)	$0.00	$0.00	-$47,514,449.79	$0.00	$0.00	-$47,514,449.79
System Converter	$480.10	$218.38	$0.00	$0.00	-$43.05	$655.42
System	$86,294,308.23	$218.38	-$39,047,942.42	$0.00	-$43.05	$47,246,541.12

Economic Metrics

IRR	12%
ROI	8.6%
Simple Payback	8.0 yr

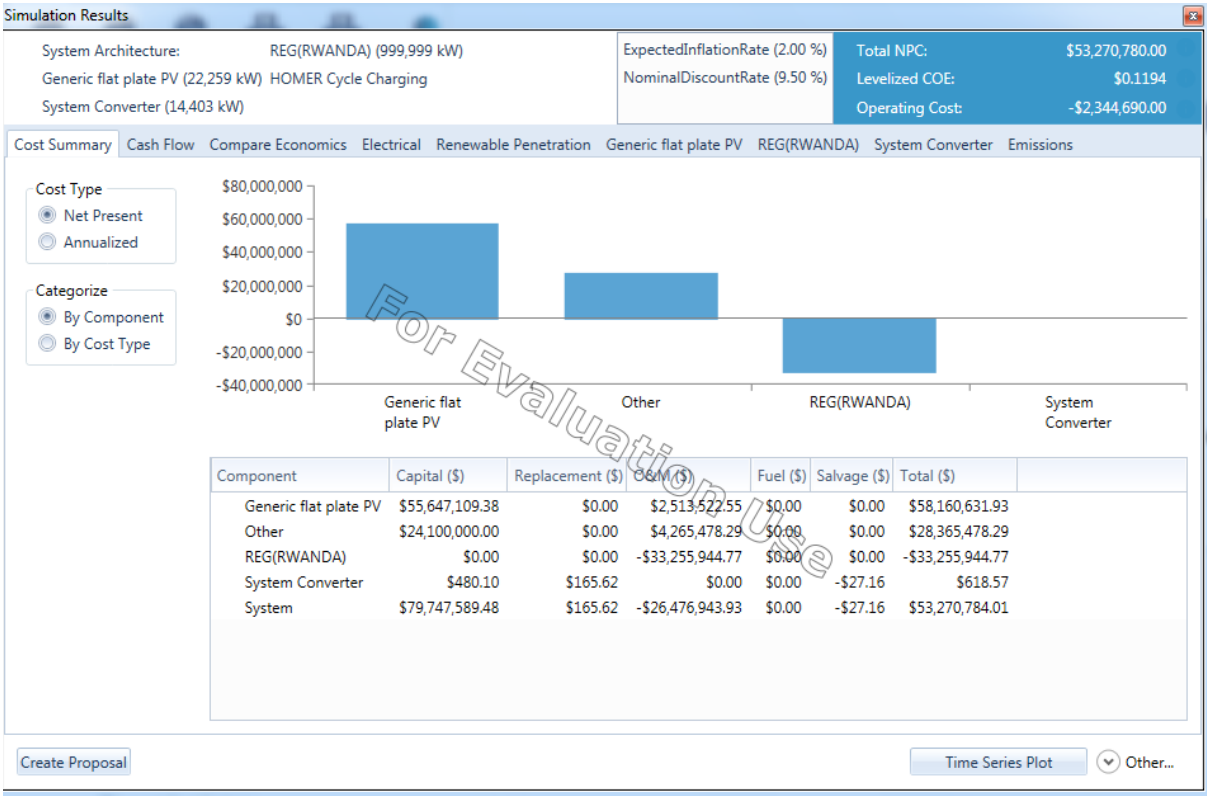


Table 5.Sensitivity analysis Table for inflation rate

Inflation rate	Net Present Value($)	Equity payback period(years)	Simple payback period(years)	Benefit-cost ratio
1.5	40,892,908	7.6	8.1	2.7
3.0	54,317,633	7.2	8.1	3.3
4.5	71,308,334	6.8	8.1	4
6.0	92,893,289	6.5	8.1	4.9
7.5	120,401,802	6.2	8.1	6.1

Table 6.Sensitivity analysis Table for incentives or grants (percentage of capital)

Incentives(% of capital)	Net Present Value($)	Equity payback period(years)	Simple payback period(years)	Annual lifecycle savings(($)	Benefit-Cost ratio
2.9	50,177,300	7.1	7.9	2,723,419	3.1
5	50,675,000	7.0	7.7	2,750,432	3.1

7	51,149,000	6.8	7.5	2,776,159	3.2
9	51,623,000	6.7	7.4	2,801,886	3.2
11	52,097,000	6.6	7.2	2,827,613	3.4

Table 7.Sensitivity analysis Table for inflation from Homer Pro software

inflation(%)	discount rate(%)	NPC($)	LCOE($/kWh)	IRR(%)	ROI(%)	SPBP(years)
1.50	6.00	43060920.00	0.066	11.00	7.80	8.50
3.00	6.00	34081680.00	0.042	10.00	7.30	8.90
4.50	6.00	21539900.00	0.021	9.60	6.70	9.40
6.00	6.00	4265393.00	0.003	8.90	6.10	9.90

Table 8.Sensitivity analysis Table for nominal discount rate from Homer Pro software

inflation(%)	discount rate(%)	NPC($)	LCOE($/kWh)	IRR(%)	ROI(%)	SPBP(years)
2.00	5.50	37,513,400.00	0.0498	11.00	7.50	8.70
2.00	7.50	47,246,540.00	0.0823	11.00	8.10	8.30
2.00	9.50	53,270,780.00	0.1194	12.00	8.60	8.00
2.00	11.50	56,495,680.00	0.2244	14.00	11.00	6.90