REVIEW AND ANALYSIS OF POLICIES AND REGULATIONS WITH SPECIAL REFERENCE TO SOLAR ENERGY (AND ITS DERIVATIVES ASPECTS) IN RWANDA

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by

TUYISHIME Silas (2019ESR2617)

Under the guidance

of

Prof. Ashu Verma

Prof. Sumit K. Chattopadhyay

Dr. Philibert Nsengiyumva

CENTRE FOR ENERGY STUDIES

INDIAN INSTITUTE OF TECHNOLOGY DELHI

HAUZ KHAS, NEW DELHI - 110016, INDIA

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Dedication

This project dedicated to:

Almighty God

My beloved wife

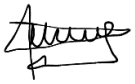
My beloved daughter

My parents

Brothers, Sisters and all my best friends

Undertaking by the Student

I hereby declare that the work presented here in the report has been carried out by me towards the partial fulfilment of the requirement for the award of Master of Technology in Energy Studies in the Centre for Energy Studies, Indian Institute of Technology Delhi. The content of this report, in full or in parts, has not been submitted to any other institute or university for the award of any degree.



Place: Delhi TUYISHIME Silas

Date: December 2, 2020 2019ESR2617

Certificate by Supervisor

This is to certify that the report entitled as, "**Review and analysis of policies and regulations with special reference to solar energy (and its derivatives aspects) in Rwanda**" being submitted by TUYISHIME Silas (2019ESR2617) to the Centre for Energy Studies, Indian Institute of Technology Delhi for the fulfilment of the requirements for the award of the degree of Master of Technology in Energy Studies. This study was carried out by him under my guidance and supervision.

Prof Ashu Verma

Prof. Sumit K. Chattopadhyay

Centre for Energy Studies

Dr. Philibert Nsengiyumva

University of Rwanda

Place: New Delhi

Date: December 2, 2020

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Abstract

Energy is pivotal to the challenges and opportunities the world faces today. Energy consumption shows its impact on evaluating the indicators of socio-economic development all over the world. In Rwanda, energy is a critical productive sector that can catalyse broader economic growth and significantly facilitate socio-economic transformation targets. The country has both conversion and renewable energy sources. The energy regulations and policies give marked attention to the use of clean, modern and energy-efficient technologies.

Energy policies and regulations guide and influence extraction decisions, development, and use of Rwanda's energy resources in a viable manner. The policies and regulations framework outlined comprises a set of governing policies, laws and regulations, guiding principles and strategic directions that Rwandan institutions and partners shall adhere to and adopt during implementation of actions. The energy sector vision is to become one of the most dynamic sectors and investment destinations in Rwanda.

Rwanda has elaborated energy policies and regulations documents to guide national development over different energy resources, including solar energy. This project reviewed policies and regulations of the off-grid solar PV system and its derivatives aspects in Rwanda.

The review and analysis of policies and regulations of Rwanda and referral countries (India and China) show that the policies and regulation of Rwanda has a weakness to be rectified like long time and process of getting a license for the mini-grid project, extension of the national grid in the location of mini-grid and license for auto production when the power produced is more than 50 KW. We also fund the strength and experience of policies and regulations from referral countries to adopt in Rwanda, like financial incentives to support solar energy production and attract investors. The impact of incentives on the solar energy project and the effect of policies and regulations on rural and remote villages' social economy were also assessed.

Table of Contents

List of figures

List of Table

List of Symbols

Mw: The unite of energy

KW: The unite of energy

Km^2: Unite of area

m^2: Unite of area

S: south hemisphere

E: East

List of abbreviation

IIT Delhi: Indian Institute of Technology Delhi

ISA: International Solar Alliance

NGO: Non-Governmental Organisation

PV: Photovoltaic

MINIFRA: Ministry of Infrastructure

MPD: Mini-Grid Project Developer

RURA: Rwanda Utility Regulatory Authority

REG: Rwanda Energy Group

RDB: Rwanda Development Board

FIT: Feed-In Tariff

CUF: Capacity Utilisation Factor

LCOE: Levelized Cost of Electricity

NPV: Net Present Value

Tpb: Payback Period

O & M: Operation and Maintenance

Chapter 1: Introduction

The limitation of conventional energy sources and environmental issues lead Rwanda to promote renewable energy technologies. Energy policies and regulations have an important role in cost reduction and innovation in renewable energy production, where solar energy is on the top. Different countries have implemented various policies and regulations to promote solar energy technologies, which is also the case for Rwanda. Learning from advanced countries' experiences and combination with indigenous factors will help Rwanda to develop solar energy technologies in the energy supply structure.

Rwanda has abundant solar energy resources; this form of energy needs policies and regulations for being extracted sustainably and promote solar energy as a business aspect where private companies can invest with expectation of benefit.

1.1. Overview of Rwanda

Rwanda is East African country located at latitudes from 1.050 to 2.840° S and longitudes from 28.860 to 30.900°E. Rwanda republic is a landlocked country, bordered by Uganda to the North, Tanzania to the East, Burundi to the South and DRC to the west. The capital city is Kigali.

Rwanda has 12,756,625 population on total area of 26338 km^2 and has highest density of population on the continent (512/ km^2). Rwanda is divided into five provinces and thirty districts. Figure 1 shows the political map of Rwanda, its provinces and districts[1].

Figure 1: political map of Rwanda shows five provinces and thirty districts [*https://maps-rwanda.com*]

1.2. Project Background

The present project, Review and analysis of policies and regulations with special reference to solar energy and its derivatives aspects in Rwanda, is designed for investigating solar energy policies and regulations and compare them with international standards.

The existing solar energy policies and regulations are reviewed and compared to those of advanced countries like India and China, where solar energy is priority. The present project bases on policies and regulations of off-grid solar photovoltaic system only.

1.3. Problem Statement

Solar energy technology in recent decade has been expanded rapidly ; this expansion has been based on governmental support via policies, regulations and other mechanisms. The governments have to promote solar energy extraction to address environmental issues such as climate change and air pollution mitigation, and energy security. For most African countries, including Rwanda, solar energy policies and regulations are not updated accordingly; this leads to insufficient investment and high solar energy system costs.

1.4. Methodology

To achieve the objective of this study the following methods will be used

- Desk work**: -**Review existing solar energy policies and regulations of Rwanda and find its weakness.

  -Review solar energy policies and regulations of advanced countries and Identify the strength and experiences to adopt.

- Draft a report of findings on solar energy policies and regulations reviewed and give the related recommendations to Rwanda's government.

Chapter 2: Literature Review

2.1. Renewable Energy in Rwanda

Renewable energy technologies produce sustainable and clean energy from different sources. Rwanda's electrical power's total installed capacity was recorded at 226.7MW in 2019; renewable energy accounted more than 60%. Rwanda has many and different renewable energy resources, but most of the potential remains untapped.

- HYDROPOWER is the most technology used to produce electricity in Rwanda. Feasibility studies show that hydropower will increase from 120.6MW produced today to 400MW in 2024.
- SOLAR ENERGY: The solar irradiation is between 4-6 kWh/m2/day. The total grid connected solar energy is 12.08 MW and more than 253,181households are connected to the off-grid solar system. As indicated in Rwanda's national electrification plan, solar photovoltaic will contribute more to rural electrification, where 48% of National electricity access will be the off-grid system.
- WIND ENERGY: Wind energy has not given priority because wind speed in Rwanda is low, around 3m/s. It has only one turbine for water pumping (3m3/h) and one small turbine for electricity generation of 1Kw.
- GEOTHERMAL ENERGY: The reseved potential of geothermal energy in Rwanda ranges from 170- 340 MW and all this amount of energy is unexploited
- BIOMASS: Biomass energy accounts for 85% of primary energy consumed in Rwanda. It is mostly used for cooking with wood in rural and charcoal in town. Rwanda's strategy promotes modern fuel for cooking and efficient biomass technologies [2][3].

2.2. Market and Application of Solar PV Power in Rwanda

There are different markets for the solar PV system, government procurements for health centers, schools, administration centers, street lighting and water pumping, and NGO procurements to support different systems like institutional, irrigation and water pumping, solar home systems and small business systems for rural electrification [4]. The government of Rwanda (MINIFRA) plans to increase the amount of electricity to achieve universal access. This will require new power generation where solar power systems will be installed, both grid-connected and off-grid, to achieve this target.

Solar PV energy in Rwanda can be applied in the following sectors:

- off-grid PV plant in remote and rural areas;
- off-grid PV plant for street lights, chargers and other commercial products;
- large-scale solar PV system (solar PV park)
- grid connected solar Rooftop systems (this is new technology to adopt)

The off-grid PV plant in rural areas provides a sustainable and economic option for satisfy rural households' energy required. It is the biggest market for PV power applications in Rwanda, while grid connected solar PV takes a tiny percentage. However, on-grid rooftop systems, not yet used in Rwanda, can be adopted as a new technology[5].

2.4. Solar Energy Status in Rwanda

Rwanda has a high potential of solar energy. This enormous amount of energy pushes the Rwanda government to plan how solar energy can lead get universal access to electricity, especially in rural and remote areas.

2.4.1. Solar Power Park

Rwanda's total PV park (grid-connected) capacity is 12,23MW from 5 different power plants, namely Jali generating 0.25 MW, Rwamagana generating 8.5 MW, Ndera generating 0.15MW and Nasho generating 3.3 MW. Rwanda's government has an ambition of increasing the solar energy power park and in that respect, an MoU of 30MW solar power plant has been signed[6]. Figure 2 shows the giant solar power plant in Rwanda in Rwamagana.

Figure 2: Rwamagana solar power plant [*Rwanda Energy Group*]

2.4.2. Solar Mini-Grid

The mini-grid is nascent technology in Rwanda due to delays in setting up policies and regulations for conducting the procedures and late on publishing national electrification plan (NEP) so that project developers could not obtain permission to implement mini-grids during this period. Currently, 3,582 households are connected through mini-grid solar systems and produce around 182KW [7]. Figure 3 shows a mini solar Plant for rural village electrification.

Figure 3: Solar mini-grid for rural village electrification [*Rwanda off-grid status report 2018*]

2.4.3. Solar Home System

The electricity access in rural and remote areas is a problem Rwanda facing today. The extension of the national grid is difficult to adopt due to the high cost and transmission losses. The one and best solution to this problem is a solar home system. Today Rwanda has around 253181 households supplied by solar home systems [7]. Figure 4 shows a solar home system application.

Figure 4:Solar home system [*Rwanda off-grid status report 2018*]

2.4.4. Solar Lantern Lamp

The solar lantern lamp is a portable solar photovoltaic lighting system that provides light during the night and charges during the day when the solar is available. The lantern lamp is designed to be similar to kerosene hurricane lamp typically used in the village. Solar lantern enables rural villages to replace dangerous and expensive traditional lighting systems like a candle, oil lamp and hurricane lamp. Besides, solar lanterns can also help for phone charging. Currently, in Rwanda, more than 184,210 solar lantern lamps are used. Figure 5 shows the use of a solar lantern [7].

Figure 5: Solar lantern *[Rwanda off-grid status report 2018]*

2.4.5. Solar Water Pumping

A solar PV water pumping system essentially consists of PV panels directly powering a water pump. During the day, the water pumped can be used directly or stored in the tanks for being used when there is no solar radiation. Water storage tanks replace the battery storage. In Rwanda, usually solar photovoltaic water pumping systems are used for irrigation and a few of them for supplying water to the village households[8]. Figure 6 shows the Nasho center irrigation system in the Eastern Province.

Figure 6:Nasho center irrigation system [*Rwanda irrigation policy and action plan*]

Chapter 3: Objectives

3.1. Main Objectives

The project objectives are manly to review and analyse the policies and regulations with special reference to aspects of solar energy and its derivatives in Rwanda. The solar energy policies and regulations will be reviewed, analysed and compared to those of the advanced country.

3.2. Specific Objectives

1. Review and analysis of existing Policy and regulations of Solar energy in Rwanda
2. Identify the reference countries where solar energy technology is advanced
3. Review and analyze Policies and regulations of Solar energy in advanced countries
4. Find the strength and experiences to adopt and recommend it to the government of Rwanda

Chapter 4: Methodology

4.1. Review of Rwanda Solar energy Policies and Regulations

The total insolation in Rwanda ranges from 4 to 6KWh/m^2/day. This massive potentiality attracts the government to endorse solar PV energy as an alternative option to electrify rural areas, mostly located far away from the national grid. In Rwanda solar energy technology produces electricity through solar PV systems. Investment opportunities exist in solar energy in different application sectors and need better guidance from policies and regulations [3].

4.1.1. Licenses and Registrative Framework

The regulations number 002/Energy/EL/RURA/2013 of 25th July 2013 [9] indicates the terms, conditions, and licensing process for anyone who wants to invest in the energy sector. Any the The company or individual person holding a trade license may apply for an electricity production license. However, auto production for less than fifty kilowatts (50 kW) shall not be subject to license.

The holder of a license for electricity production shall have the following rights and responsibilities:

1. To construct, operate, maintain and manage his or her electricity production facilities;
2. To contract for sale and delivery of electric power generated in his or her production unit;
3. To connect to public transmission and distribution grid under the conditions determined by this regulation[9].

Regulation No 03/R/EL-EWS/RURA/2019 governing the simplified licensing framework for rural electrification in Rwanda[10] provides the requirement for rural electrification licensing and how to proceed when the national grid arrives in the connecting area of the mini-grid. In the case of the national grid arriving within connecting distance of a mini grid project, the license holder must choose one of the following options to switch to the main grid, negotiate the project's acquisition by utility, and relocate the assets where is possible[10].

4.1.2. Off-Grid Solar PV System

The rural electrification strategy of June 2016[11] states that off-grid electrification through both solar home systems and mini-grid systems will be used to provide electricity in rural villages.

Ministerial guideline of June 2019[12] indicates the minimum standard requirements for a solar home system that whoever wants to invest in this sector must respect. The solar home system must provide at least three lamps of 120 lumens for each one, a phone and radio charging system and one autonomy day. The institution in charge of standard must ensure that the solar system products comply with quality, standards, and warranty requirements. The standard should follow the IEC standard[12].

Ministerial guideline on the mini-grid developer of June 2019[13] gives the guideline to whom who want to invest in a mini-grid solar system. The government can propose a project and made available through a call for application, or mini-grid developer can apply by sending a project proposal to the concerned institution. In both cases, the ministerial guideline gives the requirements and time duration of the process. Mini-grid project developers (MPD) will be required to negotiate the end-user tariff before obtaining a license. The end user's tariff will be negotiated between MPD and technical a committee representing the government and approved by RURA[13].

The off-grid electrification areas are currently marked by the utility (REG) in the national electrification plan [14], which had recently been finalized and published. The Mini-grid project developer who wants to develop a project in a designated area needs to apply for a license from RURA[10]. The project proposal with site proposed, information on technology, standard to be used and environmental impact assessment must be submitted for getting the license[13].

4.1.3. Feed-in Tariff

Regulations N°001/Energy/RURA/2012 OF 09/02/2012 for Rwanda renewable energy feed-in tariff [15] authorize the feed-in tariff (FIT) for renewable energy technologies the most effective government incentive to support extraction of solar energy. FIT is also an instrument designed to attract investors in solar power generation by offering long-term purchase agreements for selling their electricity to the grid. The license holder has the right to connect electricity produced to the public transmission and distribution grid. Renewable energy technologies like solar PV plant is a solution to satisfying Rwanda society's energy demands.

The Feed-in Tariff may only apply to projects within 10 km of the national grid. The Transmission System Operator shall negotiate a discount for the project beyond the 10 km.

Any project developer who denied connection to the grid may complain to the Regulatory Authority[15].

4.2. The Weakness of Rwanda Solar Energy Policies and Regulation

After review and analyse the policies and regulations of solar energy in Rwanda, I find the following weakness that can be a barrier to solar energy development.

- The policies allow only auto production of less than fifty kilowatts (50 kW) without a license, but this may not have any limit. The requirement and process of license application can be a barrier for householders who want to produce their electricity. The license for auto production may not be required because Rwanda still has a low energy generation problem. This can allow the utility to connect new customers as old ones are no longer need electricity from the national grid.
- The license application duration and steps are too long because more institutions must be consulted like RDB, REG and RURA. The time required for the mini-grid project's license is more than 90 days [13]. It will be better if this time is reduced and became less than 30 days.
- The policies provide the second option when the National grid extended to the mini-grid connecting distance; this can reduce the project developer's profit and is better if the main grid is not extended toward the mini-grid when it still has a lifetime.
- Rwanda's policies and regulations do not provide any financial incentive to promote and reduce solar energy system costs. The main problem solar energy facing today is the high cost of essential components of the system. This increases the risk and causes low investment in this sector to provide financial incentives attract the investors and help the country be sufficient for electrical energy and reduce greenhouse gas emissions.

4.3. The Strength of Solar Energy Policies and Regulation of Referral Country to Adopt

Several different options are used to promote electricity generation from renewable energy resources where solar energy is on the top. Renewable energy becomes an essential issue because conventional energy sources are limited and produce greenhouse gases. The policies and regulations planner around the world are trying to promote solar energy sources to generate electricity by breaking through their barriers. The common barrier that solar energy facing is an expensive technology; financial incentives can overcome this. The Rwanda government

does not provide any financial incentive for solar energy; hence there is low investment in the solar energy sector. The following subsection gives the commonly given incentives in referral countries that can be adopted in Rwanda.

4.3.1. Financial Incentive

4.3.1.1. Capital Investment Subsidies

The government's capital investment subsidies to support solar energy technology investment; can be provided per kW or percentage of total project cost. The capital subsidy is the most popular economic incentives for solar energy. They are attractive due to their simplicity, however they must be monitored against abuse and ensure that project costs are not exaggerated [16].

4.3.1.2. Tax Incentives

Tax incentives are special incentives implemented to support and promote solar energy technologies. Investment tax credits are used to reduce the amount of taxes to be paid. Developing countries like India and China introduce tax incentives to attract investors and support self-sufficiency in electricity production; they can also provide an income tax holiday[16]. Rwanda's taxation policy has not provided sufficient support for the promotion of solar energy technologies.

4.3.1.3. Soft Loans

The soft loan is another type of government incentive to support a solar energy project where a project developer can get a loan at low-interest rates compared to the market rate. The government can offer soft loans in two different ways, by particular government institutions or by sharing the interest of loans taken in the normal bank with the project [17].

4.3.1.4. Green Bond

Green bond is an essential fixed-income market-based financing instrument for raising funds for solar projects that are environmentally beneficial. The green bond is like to other bonds but has also desired credit rating to attract financial institutional, howerver the interest rate must be lower than the market rate. The Indian experience of this type of financial instrument can help Rwanda develop solar energy technology in the Rwanda energy market[17].

4.3.1.5. Effect of Financial Incentives on Solar Energy Project

The effects of financial incentives on solar energy project clarified by calculating the project parameters without and with financial incentives. Let me take an example of a small community of 10 households supplied by solar PV microgrid. Table 1 indicates the loads' profile of the community and Table 2: shows the comparison between the project with and without capital subsidy.

Table 1:Community loads profile

SN	**Appliance**	**Quantity per house**	**Number of House**	**Rating power (KW)**	**Total power (KW)**	**Operation Hour**	**Total Energy per day (KWh)**
1	Indoor Lamps	6	10	0.01	0.6	5	3
2	Outdoor lamp	4	10	0.018	0.72	12	9
3	Radio	1	10	0.02	0.2	8	1.6
4	TV	1	10	0.04	0.4	5	2
5	Phone charger	2	10	0.01	0.2	2	0.4
6	Iron	1	8	1	6	1	6
7	Fridge	1	5	0.15	0.75	24	18
	Total				8.87		**40**
	Peak power				**10**		

Table 2: comparison between project with and without capital subsidy

SN	Parameter	PV Plant without Subsidy	PV Plant with subsidy (25%)
1	Capacity	10 KWp	10 KWp
2	Capital Cost	Rs 1,000,000	Rs 1,000,000
3	Useful life	25 years	25 years
4	Discount rate	0.08	0.08
5	Cost of O & M	1%	1%
6	Auxiliary consumption	1%	1%
7	CUF	0.18	0.18
8	LCOE	Rs 6.6	Rs 5.1
9	NPV	Rs 59,849.22	Rs 309,849.22
10	Tpb	21.3 Years	12 Years

The calculation of different parameters on this example shows that the financial incentive has a more significant effect on solar energy projects' investment. the capital subsudy reduces the Levelized cost of electricity (LCOE) and payback period (Tpb) and increases the net present value (NPV) of the project; these three parameters are essential in project evaluation.

4.4. The Impact of Policies and Regulations in Rural Electrification

Energy is a significant challenge the world faces today; more than 11% of world population lives without electricity access; the electricity access rate in rural areas is lower than in urban areas. The extension of the national grid approach used to electrify rural areas imply intensive capital cost and large investments [18]. In rural electrification, SHS and mini-grids are good strategic alternatives due to the cost and energy losses reduction.

The Rwanda rural electrification strategy plan of June 2016 [11] gives solar PV priority to electrify rural and remote areas to ensure that households get electricity through the lowest-cost technologies. The policies and regulations of solar energy have a greater role in governing rural and remote area electrification activities and increase investment in that sector. The

policies and regulations set up the mechanism to allow low-income households to get modern energy services through SHS and mini-grid as the basic solar systems[11]. Currently, Rwanda has around 256,763 households connected to solar off-grid systems [19]. Table 3 indicates the off-grid electrification status in Rwanda.

Table 3: Off-grid electrification status in Rwanda

SN	Category	2018	2024 Target
1	Solar Home System (HHs)	253,181	1,274,180
2	Mini Grid System (HHs)	3,582	326,884
3	Total Off Grid (HHs)	256,763	1,601,063

The customers of mini-grids system are mostly households, with a low percentage of small businesses, like shops, bars, restaurants, barbershops, welding, tailoring, carpentry and milling machines and a few social institutions and schools [7]. Figure 7 shows that SHS and mini-grids can power diverse appliances

Figure 7:SHS and mini grids can power diverse appliances [*Rwanda off grid status report 2018*]

Chapter 5: Results and Discussion

The average daily irradiance in Rwanda varies from 4 to 6 kW h/m^2 /day. This enormous amount of energy pushes the government to support solar energy investment extraction by offering policies and regulations. The solar energy policies and regulations of Rwanda are good. However, there is same weakness to be rectified like long time and process of getting license, an extension of the main grid where there is a mini-grid and license for auto production when the production is more than 50 KW.

The solar energy policies and regulations of Rwanda do not give financial incentives priority. The effect of financial incentives is to make solar energy projects profitable by reducing Levelized cost of electricity (LCOE) and payback period (Tpb) and increase the net present value (NPV). In the case above, when capital cost subsidy of 25% given incentive, the consequences are reduction of LCOE from Rs 6.6 to Rs 5.1 and Tpb from 21.3 Years to 12 years and increases of NPV from Rs 59,849.22 to Rs 309,849.22 this make project more profitable.

Solar energy technology has a higher capital cost than conversion technology and needs financial support for being competitive in the energy market. Rwanda's government shall adopt financial incentives policies to reduce the cost of a solar energy project and attract investors; this will help Rwanda achieve universal access as the Rwanda electrification plan's target.

The impact of off grid solar PV system policies and regulations in Rwanda is to catalyse rural electrification activists and improve people's social-economic lives in rural areas where economic activities are introduced by being connected to the electric network.

Chapter 6: Conclusions and Recommendations

6.1. Conclusions

The analysis of Rwanda and referral countries' current policies and regulations show that policies and regulations need to be updated from time to time to make their derivative effects successful. The policies and regulations contribute to the world war of reducing the cost of solar energy technologies; this needs the willingness of government policymakers to adopt and learn from the referral country experience on supporting solar energy technologies. India and China are good references because they are advanced in solar energy technology.

Upon this project, the policies and regulations of solar energy in Rwanda are reviewed and their weaknesses are found and need to be rectified and put on international standards. The policies and regulations of solar energy in India and China as referral countries had also been reviewed. They had the strength and experience to adopt in Rwanda like financial incentives, supporting solar energy production and attracting the investors.

The application of financial incentives helps solar energy projects be profitable by reducing the cost of electricity and payback period and increasing the net present value; this is one way of getting a reduced cost solar PV technology and increase the investment type of energy.

6.2. Recommendations

According to the weakness and strength of policies and regulations listed above and assuming that solar PV off-grid system will be considered an effective solution for rural and remote electrification, the following recommendations suggested for Rwanda's government.

1. Reduce the time and steps required to get a mini-grid project license. The time required for the mini-grid project's licensing is around 90 days; this will be better if it is reduced.
2. Do not extend the national grid in the mini-grid connecting area when it still has a lifetime. When the project developer implements its production project and sells electricity, it is better to allow him to get the expected profit during all project life.
3. Increase financial support for solar energy by providing incentives and demonstration activities to attract the investors as Rwanda's strategic plan for rural electrification is to electrify the remote village via solar mini-grid and solar home system.

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