Viability of the Store-on Grid Scheme Model for Grid-Tied Rooftop Solar Photovoltaic Systems in Selected Sub Saharan African Countries

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Abstract

The viability of the store-on grid (SoG) scheme model across 13 selected Sub-Saharan African (SSA) countries was investigated. The individual country's datasets applicable to the SoG scheme and a typical industrial building as a baseline prosumer were used in the evaluation. Two SoG scheme scenarios (A and B) based on solar photovoltaic (PV) module prices were used in this analysis. The electricity tariffs under the SoG scheme were compared with the time of use rates for the selected SSA countries. The analysis results revealed that the scheme could be viable in only nine and four out of 13 countries under scenario A and scenario B, respectively, with high lending interest rate in some countries being the key hindrance. Under the SoG scheme model, solar PV systems in all the selected countries could feed about 15.65 – 39.25% of the generated energy to the grid. The government tax in the range of 1.95 – 3.38 and 2.48 – 4.31 c$/kWh could be collected from the energy fed to the grid under SoG scheme scenario A and scenario B, respectively. Overall, the SoG scheme exhibits greater potential as an energy business model to foster rooftop solar PV technology adoption in developing countries.

Keywords – Store-on grid scheme; Prosumer annual energy costs; Solar PV energy fed into the grid; Prosumer and utility benefits; Government tax collection

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Nomenclature

BESS	Battery Energy Storage System	F_{profit}^{Grid}	Utility's profits under the SoG scheme
EE	Energy Efficiency	F_{profit}^{SEGI}	Prosumer's profits under the SoG scheme
FiT	Feed in Tariff	I_t	Annuitized investment cost for solar PV system
GDP	Gross Domestic Product	M_t	Annual operation and maintenance cost for the solar PV system
GET-FiT	Global Energy Transfer Feed in Tariff	P_{FiG}^{SEGI}	FiG rate
GST	General and Service Tax	P_{Grid}^{SEGI}	Grid sellback rate
IPP	Independent Power Producer	p_o	Off-peak rate under the ToU scheme
IRR	Internal Rate of Return	p_p	Peak rates under the ToU scheme
LCOE	Levelized Cost of Energy	p_s	Standard rate under the ToU scheme
$LCOE_{PV}$	Levelized cost energy for solar PV system	P_{fee}^{SoG}	Store-on grid rate
LCOS	Levelized Cost of Storage	R_{FiG}	Solar PV system investment cost attributed to the solar energy fed to the grid
PPA	Power Purchase Agreement	T_{Gov}	Government tax revenue
PV	Photovoltaic	n_{Inv}	Inverters' replacement year
RE-FiT	Renewable Energy Feed in Tariff	r_l	Loan interest rate
SDG	Sustainable Development Goal	∂	Depreciation allowance
SoG	Store-on Grid	$CAPEX$	Capital expenditure
SSA	Sub-Saharan Africa	D	Debt share of investment cost
ToU	Time of Use	E	Equity share of investment cost
VAT	Value Added Tax	K	Allowed period for start-up allowance
WACC	Weighted Average Cost of Capital	M	Debt maturity period
$\emptyset_{Inv}$	Percentage of the investment cost that accounts for inverters' replacement	N	SoG contracted period
$\emptyset_{OM}$	Percentage of the investment cost that accounts for the operation and maintenance of the system	R	Solar PV system investment cost
A_t	Annual operating cost of BESS	r	Discount rate
B_{Pro}^{Sec}	Prosumer secondary benefits under the SoG scheme	α	Start-up allowance
CO_2	Carbon dioxide	β	Building use allowance
C_D	Cost of debt	γ	Annual degradation rate of the solar PV system
C_E	Cost of equity	δ	Ratio of standard rate to peak rate of the ToU scheme model
E_{FiG}^{SEGI}	Energy generated by the solar PV system fed to the grid	η	Percentage of the solar energy generated that is fed to the grid
E_{out}^{BESS}	Annual energy output from the BESS	θ	Equity share of the investment cost
$E_{load,p}^{SoG}$	BESS energy supplied to the load during peak period	ρ	Degression rate of the FiG rate
$E_{load,s}^{SoG}$	BESS energy supplied to the load during shoulder period	σ	Initial allowance
$E_{load,o}^{SoG}$	BESS energy supplied to the load during off-peak period	τ	Corporate tax
E_{load}^{PV}	Solar PV energy supplied directly to the load	φ	Non-linearity coefficient
E^{PV}	Annual energy generated by the solar PV system	ψ	Percentage of the solar PV energy stored on the BESS that is charged a fee by the grid based on the SoG scheme PPA

1 Introduction

Access to reliable, clean and affordable energy by all citizens is currently a target for all countries globally. Energy is universally cherished and is addressed in Goal 7 of the 17 United Nations Sustainable Development Goals (SDGs) for 2030. This goal focuses on three main aspects of energy, namely, access to electricity, penetration of renewable energies, and energy efficiency (EE) [1]. Currently, most of the developing countries are devising means of electrifying their communities by using their available distributed renewable energy resources. In 2018, the sub-Saharan Africa (SSA) region had an electrification rate of about 45% with about 600 million people having no access to electricity [2]. Nonetheless, SSA is richly endowed with abundance of a wide range of unexploited renewable energy resources [3]. For developing countries to overcome the challenge of electricity access, concerted efforts are required [4]. Suitable concerted efforts include, among others, policy frameworks that should consistently be updated and support innovations such as off-grid solutions and newer energy business models [4].

Of the existent energy business models, feed in tariff (FiT) and net-metering policies have been widely utilized to foster the implementation of renewable energy technologies globally. The FiT policy implementation recorded success in European countries such as Germany, Portugal and Italy as well as some states in the United States in the past decades [5, 6]. However, the policy has encountered challenges making it struggle and/or fail in most of the developing countries [7-9]. On the other hand, the net-metering policy is widely adopted in the United States and some member countries of the European Union [10], but is still ignored by most governments in the developing countries [9]. Energy business mechanisms such as FiT or net metering policies for solar photovoltaic (PV) technology are currently not available in SSA countries. The absence of such energy business regimes has pushed developers of solar PV systems to design projects in a way that the entire solar PV energy output is consumed by the project host because the excess energy generated cannot be sold [11]. Unlike in many developed countries, rooftop owners in SSA countries cannot earn any money by installing solar PV systems and selling power to the grid [11].

A novel business model referred to as the store-on grid (SoG) scheme model was proposed in [12, 13], and its applicability for the case of rooftop solar PV systems in Uganda was investigated. The SoG scheme model is a novel energy billing scheme for energy businesses, particularly the community-shared energy business initiatives. The SoG scheme's main emphasis is to maximize self-consumption of the generated energy. Thus, the scheme proposes the use of the battery energy storage system (BESS) which is facilitated by the government to maximize energy self-consumption amongst the participating prosumers before feeding into the grid. The SoG scheme constitutes of three key stakeholder categories, namely, government, utility and prosumers. Under the SoG scheme, several prosumers with different solar PV capacities are contracted by a single power purchase agreement (PPA). In study [12], the upper limit for the total solar PV capacity under a single SoG PPA was set at 5 MW, which was evaluated to require 3.9 MWh of BESS. The total solar PV capacity under a single PPA must be less or equal to the set upper limit capacity of the SoG scheme by the regulators. Individual prosumers under the SoG scheme facilitate the acquisition and maintenance of their solar PV systems, while the government facilitates the BESS, and the utility buys the surplus generated energy [12]. To investigate the prosumer costs and benefits under the SoG scheme, a typical prosumer with a 153.6 kW_p solar PV was singled out of all the participating prosumers of a single SoG PPA and analysed in [12, 13].

The SoG scheme proposes a micro-grid system with the BESS that is implemented amongst the participating prosumers under a single PPA to enable energy exchange amongst them and the utility [12]. Fig. 1 shows the schematic layout of the SoG scheme micro-grid implemented amongst the participating prosumers of the scheme under a single PPA, where WB, DB, and IB stand for the warehouse building, distribution building, and industrial building in an industrial park [12]. The number of participating prosumers under a single SoG scheme PPA varies depending on the set upper limit capacity and their available rooftop area suitable for solar PV installation. In Section 3, Fig. 3 shows the SoG scheme model canvas with the high-level strategic details appropriate for the success of an energy business initiative. Further descriptions about the SoG scheme model are detailed in [12, 13].

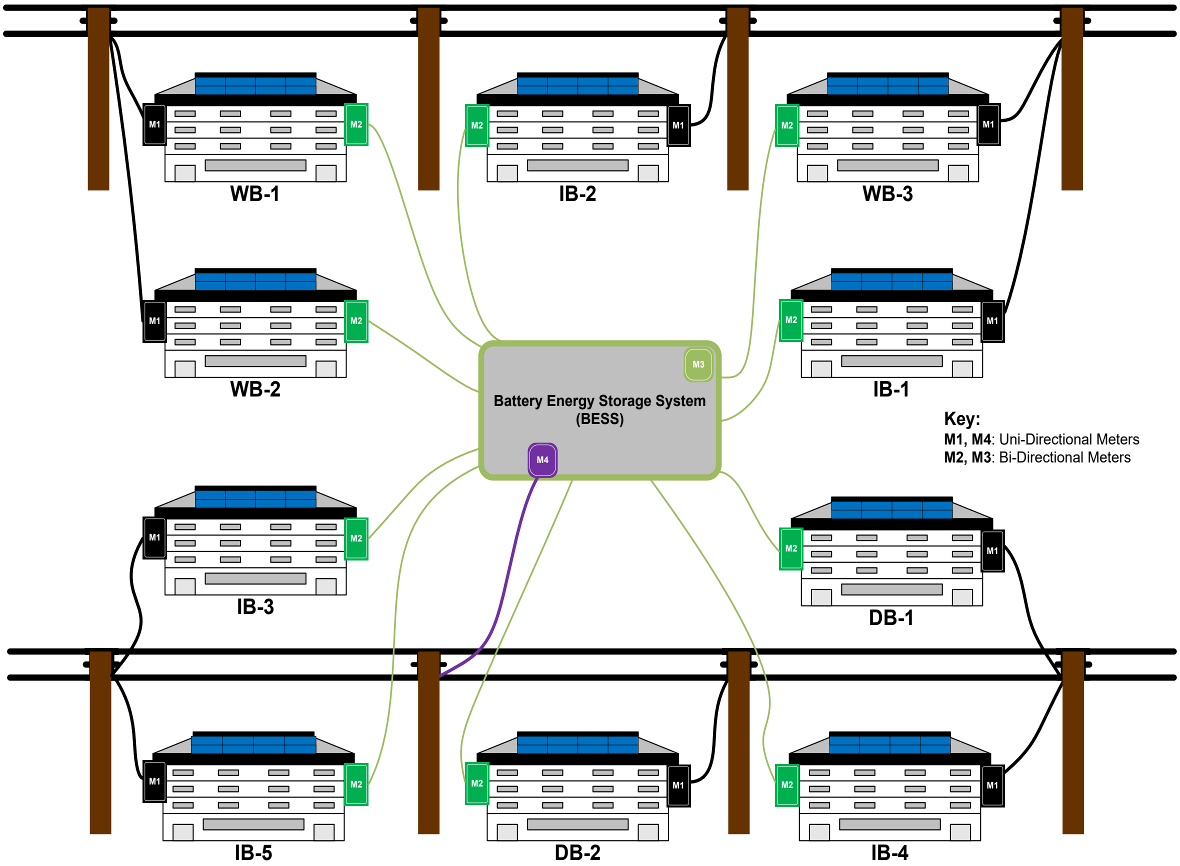


Fig. 1: Schematic Layout of the SoG Scheme Model Micro-Grid System

Considering an individual prosumer under a single the SoG scheme PPA for the case of Uganda, the results revealed that the scheme was cost effective for the prosumer by recording a reduction in the annual electricity purchase costs of about 12.5% as well as feeding about 20% of the generated solar PV energy into the grid [12]. The results of the benefits analysis of the SoG scheme for the solar energy fed into the grid revealed that the prosumer would annually profit $ 389.46, while the utility would annually profit $ 304.27 under the SoG scheme model compared to $ 170.39 under the time of use (ToU) scheme model [13].

The SoG scheme results based on the case of Uganda are promising. However, as recommended by the authors, the scheme should be extended to other developing countries to investigate its suitability [13]. Thus, in this study, the suitability of the SoG scheme model across selected countries in SSA is examined. To investigate the scheme's suitability, scheme parameters of the selected countries, such as solar irradiance, lending interest rate, ToU rates and share of the solar PV energy fed to the grid, were considered. In this study, the SoG scheme model was investigated for suitability in 13 SSA countries, namely, Namibia, Kenya, Madagascar, Mali, Niger, Cote d'Ivoire, Senegal, Togo, Cameroon, Eswatini (formerly known as Swaziland), Zimbabwe, Rwanda and Burkina Faso.

The rest of this paper is organized as follows: Section 2 discusses the literature review, Section 3 explains the study methodology, while Section 4 presents the results and provides the discussions of the results, and Section 5 concludes the study and recommends some future works of the study.

2 Literature Review

2.1 Electricity Status in Sub Saharan Africa

Africa as a continent is endowed with a vast energy generation potential ranging from conventional to renewable energy sources. Overall, the continent has a total solar potential of about 10,000 GW, with a technical potential of solar PV energy estimated at about 6,500 TWh a year and high wind potential of about 109 GW, mostly in the coastal countries of the continent [14-16]. Also, the continent's East Africa Rift Valley offers an estimated geothermal potential of about 15 GW, mainly in Kenya and Ethiopia [15, 16]. Furthermore, the continent has an estimated hydropower potential of about 350 GW, attributed mainly to the Congo and the Nile rivers that are among the world's longest rivers [15]. For the conventional energy resources, Africa has an estimated natural gas and oil potential of about 400 GW as well as an estimated coal potential of about 300 GW [15, 16]. However, the continent's SSA region is characterized by low electricity access, reportedly the least electrified part of the world [17].

Although low electricity access is often used as a proxy for the electricity deficit in SSA, the challenges go far beyond the access shortfall. The current state of the electricity sector in most SSA countries is also characterized by limited consumption, pervasive reliability challenges, prohibitive prices, and financial distress of the utilities [17]. The reliability of electricity supply is a major constraint in SSA [17]. Although their extent varies significantly from one country to another, grid power outages are common across most of the SSA countries [11]. In 2018, countries such as Nigeria and Niger were reported to have had the highest average frequency of interruptions of 304 and 289 interruptions per customer, respectively [18]. Likewise, Nigeria and Guinea recorded the longest average duration of interruptions of 742 and 238 hours of interruption per customer, respectively, of all the West African countries in 2018 [18]. The frequency of power outages in SSA is due to insufficient generation capacities and/or poor transmission and distribution infrastructure [19]. These outages significantly impact the gross domestic product (GDP) and the firms' sales in SSA, especially for the firms without backup power sources [17, 20]. The overall cost of power disruption across SSA is estimated at about 2.1% of the GDP, while the total sales of the African firms is estimated at 4.9% lower than they would be if electricity supply was dependable [20].

During power outage moments, commercial and industrial grid customers have to either incur the high opportunity cost of lost sales and/or manufacturing output, or resort to the costly backup power from diesel generators [11, 19]. Reliance on the backup diesel generators is characterized by increased fossil fuel energy consumption as well as increased air pollution emissions. In most of the SSA countries, the cost of generating power by the backup diesel generators is costlier than the cost of the grid electricity [19]. For the moments of power outage, many facilities in the SSA region usually operate diesel generators at a cost in the range of 28.0 – 32.0 c$/kWh [11]. To curtail the energy costs incurred by relying on diesel generators during the grid power outages, commercial and industrial sectors are transitioning to rooftop solar PV systems that are cheaper. By 2019, about 74 MW of rooftop solar PV capacity had been installed by commercial and industrial sectors across SSA (excluding South Africa) [11, 21]. Although the market is still small, it has a great growth potential backed by the high solar energy resource across SSA countries [21]. If the SSA region aggressively adopts renewable energies to about 35% increment in installed capacity by 2040, it would obtain a 27% reduction in the CO_2 emissions from energy generation. However, this additional installation of renewable energy technologies would necessitate about 31% increment in capital spending or about $153 billion [16].

A world bank investigation on financial viability of the electricity sector in SSA revealed that electricity generation costs differ across the SSA countries. The average unit cost was reported to range from as low as 8 c$/kWh in Zambia to more than 60 c$/kWh in Liberia and Comoros [22]. The weighted average and median unit cost of electricity in SSA were 14 c$/kWh and 21 c$/kWh, respectively [22]. Liberia was reported to have the highest average electricity tariff at 50 c$/kWh, while Ethiopia and Sudan have the lowest average electricity tariff at 4 c$/kWh [22]. By comparing the costs incurred on electricity generation investment and maintenance with the cash collected from electricity sells, only Uganda and Seychelles were able to recover the total cost of service of all the SSA countries [22]. On the other hand, in about 19 countries, the cash collected could only cover operating expenditure [22].

Due to the high upfront investment costs, the solar PV technology uptake in SSA is hindered by financial constrains mainly arising from the absence of the financial sector involvement in the solar PV market [11, 21]. Because of the financial constraints, most of the investment in electricity projects in SSA is financed by foreign sources with minimal involvement of domestic sources. Over three-quarters of private sector investment in electricity projects in SSA is from foreign or mixed domestic and foreign sources [23]. The investment cost requirement for electricity projects usually consists of a mix of debt and equity. In SSA, debt often takes up a sizeable share of the project's investment cost and is commonly issued by banks, while equity constitutes the remainder and is often provided by the private investors or companies [24]. Equity is typically characterized by higher required returns than debt, and the high upfront investment cost of renewable energy projects make them sensitive to the variations in the required returns [24]. The weighted average cost of capital (WACC) is a measure used to express the average financing cost of a project. The levelized cost of energy (LCOE) for renewable energy projects is more sensitive to changes in the WACC than the LCOE for fossil fuel projects [24]. Thus, as the WACC value increases due to the debt and equity costs, the overall LCOE for a renewable energy project increases [24]. For solar PV energy projects across SSA, the WACC values are reported in the range of 8.0 – 32.0 % [24], while the LCOE values are reported in the range of 6.0 – 21.0 c$/kWh [11].

2.2 Electricity Market and End-user Tariff Structures

A variety of electricity market structures exist in SSA ranging from vertically integrated to fully structurally separated models [25]. Over the years, these structures have evolved to permit independent power producers (IPPs) access to the power networks in all cases, that is, generation, transmission and distribution [18, 26]. Although most of the countries still have vertically integrated structural utilities, there is an ongoing restructuring of the utilities towards structural separation [18, 22, 25]. A full wholesale or retail competition does not exist anywhere in SSA, but rather, there are various hybrid models where the public and private investment co-exist. IPPs are found in different market structures, with no clear correlation between the level or sequencing of reform and IPP investment. Majority of IPPs are found in SSA countries with vertically integrated utilities [25]. More details about the electricity market structures in SSA countries are discussed in [22].

Considering the current electrification rate in SSA, the region is in urgent need of more power, and private sector investment remains crucial in foreseeing this accomplishment. IPPs represent the fastest growing sources of power investment in SSA [25]. IPP investment flows show little concern for electricity market structures but are more likely to gravitate to countries with strong planning, procurement and contracting capacity, as well as good regulatory quality [25, 26]. Most of the renewable energy projects developed by IPP in SSA have been backed by power purchase agreements (PPAs) between the developer and off-taker (government or utility operator) [21, 26].

Despite the increase in funding of power projects, only a small number of SSA countries can attract IPPs [25, 26]. To attract private investors in the energy sector as well as to improve the electrification levels, SSA countries offer incentives, with tax exemptions as the most widespread policy instrument in the region [21]. Value Added Tax (VAT)/General and Service Tax (GST) exemption is the most adopted cross-subsidy mechanism by SSA countries for energy projects [18, 21]. The incentive is applicable to either a specific consumption block or a customer category. Likewise, the use of a specific social tariff with a much lower tariff than applied to other small consumers is common [18]. However, it is not clear which tax incentives are applicable to solar PV technology projects, more specifically the rooftop mounted systems in most of the SSA countries. In SSA countries, clean energy policies are limited to tax incentives such as the import duty and VAT rate incentives, which majorly favour utility scale solar and wind plants; while small scale PV systems are often subjected to the normal tax rates [21]. In SSA countries such as Namibia, manufacturers are offered a building allowance of 25% in the first year and 8% per year over 10 years, while in Eswatini, industrial buildings are offered a 50% building allowance in the first year and 4% thereafter [27]. It remains unclear whether such building allowances offered for the use of the buildings for manufacturing purposes would as well apply to the installation of solar systems on their rooftops.

For the developers, the financial viability of energy projects is achievable by securing the revenue flows. However, in the SSA region, revenue flows of energy projects are at the core of the investment difficulties in the power sector [25]. Most of the SSA utilities are characterized by poor credit ratings and inefficient performance. In SSA, power distribution losses average at about 23% compared with the commonly used norm of 10% or less in developed countries [25, 28]. Likewise, the average revenue collection rates are only 88.4% compared with the best practice of 100% [25]. The combined costs of distribution losses and uncollected revenue, expressed as a percentage of the utility turnover, provides a measure of the utilities' inefficiency in the region.

Often, payments made to developers of the utility-scale projects are disbursed by public entities, that is, the utility end-user customers [25]. To recover the unit cost of electricity and the ensure economic viability of the electricity market, utilities use different levy structures for their range of customers. For the electricity end-users of the power grid, different tariff structures and levels exist, varying from one SSA country to another. Tariff structures are the form of charges for electricity consumption, while tariff levels are the actual magnitude of charges that are levied as part of a specific tariff structure [18, 29]. Tariff structures constitute of energy charges, while tariff levels constitute of fixed charges and capacity charges [18]. A fixed charge is a monthly service fee that is billed to the utility customers regardless of their demand and consumption of the month. Capacity charge, also known as demand charge, is a monthly fee that is billed to the clients due to their contracted capacity. Capacity charge is mainly applicable to the high voltage power demand customers. On the other hand, energy charge is a monthly charge that is billed to the utility customers due to the electricity consumption [18].

The energy charges can be classified in three categories, that is, flat tariff, where a single value rating for all the energy units consumed is applicable regardless of the level of consumption; consumption block, where different prices are applied to the energy unit according to the consumption levels; and time of use (ToU), where different prices are applicable depending on the time of the day in which the consumption is made (e.g. peak, off-peak and shoulder/standard) [18]. In SSA, countries such as Mali, Togo, Niger, Burkina Faso and Cote d'Ivoire apply all these categories of end-user tariffs, while Nigeria and Liberia only use the flat tariff category of end-user tariff [18]. Of all the SSA countries, 20 of them utilize the ToU rating schedule for non-residential sectors, that is, industrial and commercial sectors [30].

2.3 Energy Business Schemes in SSA Countries

In many countries and states around the world, the FiT policies were introduced as a means of subsidizing renewable energy projects by providing a fixed tariff for each energy unit fed into the grid by a prosumer. However, the FiT policies struggled and/or failed in SSA, with only a handful of countries having had such a framework by the time energy auctions began to see widespread global uptake around 2016-17 [21]. Although the FiT schemes recorded success in developed countries, they were unsuccessful in developing countries [7, 8, 31-33]. Investigations on the FiT schemes in African countries revealed that the schemes had been poorly working and failed in some countries [8, 31]. The failure of the FiT schemes in African countries were attributed to the unfavourable institutional design, insufficient level of the FiT rates and/or obstacles in the implementation process [31]. Currently, there is no operational FiT scheme for solar PV technology on the African continent [8].

A combination of renewable energy feed in tariff (RE-FIT) and global energy transfer feed in tariff (GET-FiT) programmes that was launched in Uganda and Zambia is among the only programmes in the SSA region to have incentivized any meaningful deployment [12, 21]. In several countries, FiT policies have been abandoned and energy auctions have been adopted [12, 21]. However, energy auctions are more administratively complex and require interest from investors. Moreover, those carried out across the continent are often described as opaque and ill-managed [21]. Nonetheless, if well-run and attractive to bidders, they can spur competition, driving down subsidy costs in the process which would minimize the public purse [21]. Many countries in the SSA region have seen their first large-scale renewable energy projects implemented through competitive auctions at internationally competitive prices [21, 25].

The adoption of the net metering policy has been blithely ignored by most governments in African countries [9, 12]. Although a national net metering scheme has been suspended, South Africa has seen some uptake of the scheme at a municipal level with a number of local authorities overseeing the schemes [21]. Namibia published tariffs for net metering in 2017. However, the scheme has been criticized by municipalities, which are reluctant to see the net metering scheme offset centralized power purchases, a significant source of municipal revenue [21]. Several cases of new net metering regulations failing to encourage uptake exist in SSA. For instance, Ghana introduced a net metering framework around 2015-16, but further progress was hindered by opposition from distribution utilities, and the country was yet to pass a net metering law [21]. Countries considering introducing this legislation include Kenya. Senegal passed a net metering law in October 2018 and a pilot project was launched. Targeting urban areas, the scheme sees a tariff being paid for all excess self-generated energy over a 20-year period and offers tariffs in the range of 8.6 – 12.9 c$/kWh. Notably, the scheme is heavily subsidized that state utility Senelec’s tariffs are higher than the average in SSA which could make the scheme more attractive to consumers [21]. However, implementation of the scheme will add financial pressure on the government of Senegal through its commitment of meeting the scheme’s subsidies.

Overall, lack of well-developed institutional policies such as net-metering and FiT policies in SSA countries remains a hindrance to solar PV development [31, 34]. Also, economic barriers remain the biggest hindrance to solar PV development since the results of the investment are revealed years later due to long payback periods [34-36]. Development of strong policies, financial incentives and supports such as low interest loans, subsidies and lower taxes for implementing solar PV projects are crucial to combat the existent economic barriers to solar PV deployment in SSA [36, 37]. To devise alternative measures of fostering renewable energy technologies in developing countries, other energy business models are being investigated worldwide. As a novel energy business model, the SoG scheme is envisaged as an alternative scheme that could be adopted by developing countries to foster renewable energy uptake, especially rooftop solar PV technology [12, 13]. The scheme’s assessment for the case of Uganda exhibited that its adoption is feasible for all the involved stakeholders [13]. Thus, this study extends the assessment of the SoG scheme viability in other developing countries in SSA. The details of the SoG scheme as proposed in [12, 13] are elaborately discussed in Section 3. Description about the microgrid system and other basic features of the SoG scheme as well as how it compares to other existent energy business models are given in [12].

3 Methodology

3.1 Selected SSA Countries

This study investigates the viability of the SoG scheme model in selected SSA countries. The country selection was based on the existence of the ToU scheme as the end-user energy charge category for the industrial sector. Fig. 2 shows the location of the selected SSA countries on the African continent.

Table 1 shows the selected SSA countries, considered locations with their coordinates and the ToU rates for the industrial sector. As revealed in literature, only about 20 SSA countries currently use the ToU scheme [30]. Considering 13 out of 20 SSA countries for viability of the SoG scheme could mirror the suitability of the scheme's adoption by individual SSA countries.

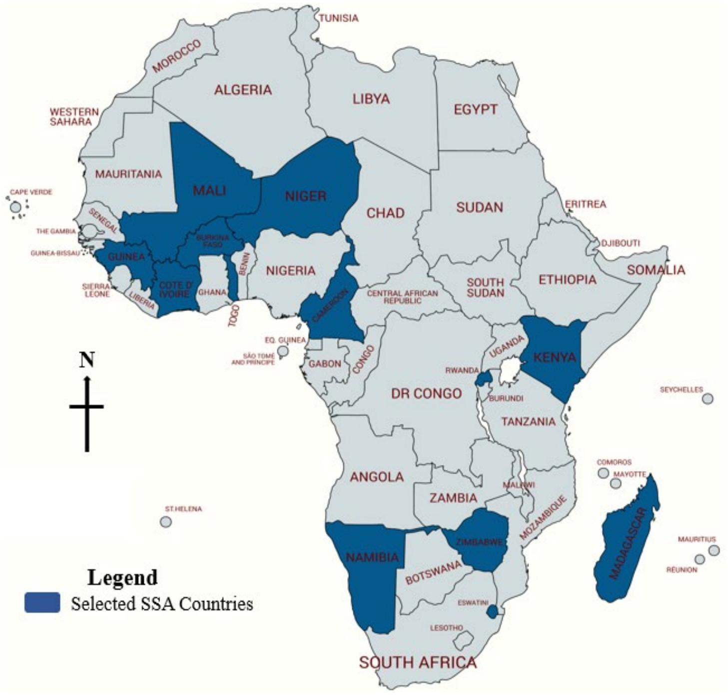


Fig. 2: Map of Africa with Highlighted SSA Countries Considered in this Study

Table 1: Considered Locations in Sub-Saharan African Countries, their Coordinated and Time of Use Rates for Industrial Sector

Country	Location	Coordinates		Time of Use Rate (c$/kWh)			
		Latitude	Longitude	Peak	Standard	Off-peak	Source
Namibia	Windhoek City	22.5609° S	17.0658° E	16.0	13.0	9.2	[38]
Kenya	Nairobi	1.2921° S	36.8219° E	9.5	9.5	4.8	[39]
Madagascar	Antananarivo	18.8792° S	47.5079° E	18.0	4.2	2.3	[40]
Senegal	Dakar	14.7167° N	17.4677° W	22.4	14.7	14.7	[18, 41]
Burkina Faso	Ouagadougou	12.3714° N	1.5197° W	24.4	12.2	12.2	[18]
Cote d'Ivoire	Yamoussoukro	6.8276° N	5.2893° W	14.0	10.2	8.3	[18]
Mali	Bamako	12.6392° N	8.0029° W	19.1	13.0	9.5	[18]
Niger	Niamey	13.5116° N	2.1254° E	13.4	9.3	9.3	[18]
Togo	Lomé	6.1256° N	1.2254° E	16.3	14.4	13.1	[18]
Eswatini	Mbabane	26.3054° S	31.1367° E	27.0	8.5	5.6	[42]
Zimbabwe	Harare	17.8216° S	31.0492° E	13.0	7.0	4.0	[43]
Rwanda	Kigali	1.9441° S	30.0619° E	17.0	13.0	9.9	[43]
Cameroon	Yaoundé	3.8480° N	11.5021° E	15.4	12.7	12.7	[43]

3.2 SoG Scheme Model Application

For any of the selected SSA countries to successfully implement the SoG scheme for an energy business initiative, the SoG scheme model canvas in Fig. 3 should be followed. The SoG scheme model canvas in Fig. 3 shows the building blocks that characterize business models to depict how the energy business initiative could create and deliver value, make money, and visualize its structure under the SoG scheme.

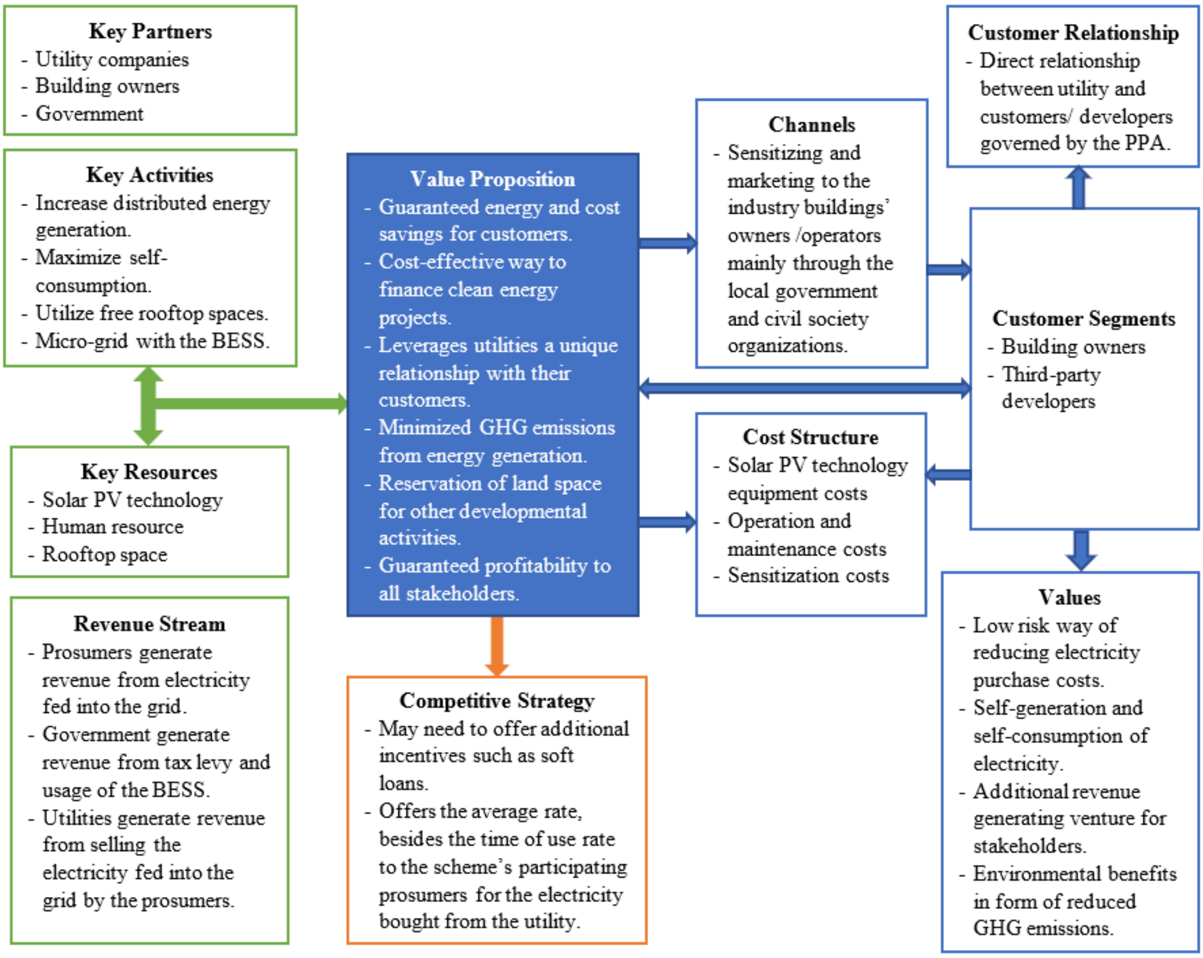


Fig. 3: SoG Scheme Model Canvas for Energy Business Initiatives

a) SoG Scheme PPA Terms and Conditions

To streamline and efficiently implement the SoG scheme in any country or region, the regulatory authority or government develops the PPA as well as the terms and conditions that govern the scheme. The key aspects of the scheme such as guaranteed access to the grid, transacting with the utility for a contracted period, installation of the required BESS for contracted prosumers by the government and the acceptable solar PV capacity under a single contract must be well described in the PPA. In addition, the government specifies the following aspects in the PPA to ensure transparency and awareness about the scheme's operation at any given time to avoid windfall profits as a result of the rates offered by the scheme.

i. Specifies the equity-debt ratio of the investment cost of the solar PV system to be considered in evaluating the WACC and LCOE rate applicable to all prosumers under the SoG PPA.
ii. Specifies the tax incentives applicable to all prosumers under the SoG PPA.
iii. Specifies the percentage of the solar PV energy stored in the BESS that would be charged a fee, referred to as the store-on grid rate, applicable to all prosumers under the SoG PPA.

iv. Specifies the percentage share of the solar PV energy generated that should be self-consumed by the prosumer under the SoG PPA.

v. Specifies the percentage share of the solar PV energy generated that is considered in evaluating the feed-in grid rate applicable to all prosumers under the SoG PPA.

Based on the country's set target for the SoG scheme, the abovementioned specifications might be revised annually in order to achieve the targets as well as to account for market dynamics such as the variation in the ToU rates and solar PV module prices. The potential industrial prosumers are at liberty to adopt the scheme whenever they are ready. It is in the prosumer's powers to determine the solar PV capacity to install on their building, which is mainly dependent on the available rooftop area and their financial capability.

b) Solar PV Systems under a Single SOG Scheme PPA

In this study, a total solar PV upper limit capacity of 5.0 MW evaluated to require a 3.9 MWh BESS capacity was considered for every single SoG scheme PPA based on the description in [12]. To constitute this solar PV capacity, it was assumed that several industrial prosumers are contracted under a single SoG scheme PPA as shown by Fig. 1. For the selected SSA countries, it was also assumed that for every single PPA of the SoG scheme, represented by the micro-grid system in Fig. 1, there is a typical industrial prosumer with a building that has a rooftop area which can accommodate a 153.6 kW solar PV capacity based on the description in [12]. Thus, in each of the selected countries in this study, the prosumer costs and benefits were evaluated based on the typical industrial prosumer, that is, assumed to have a 153.6 kW solar PV capacity system. The required BESS capacity under the SoG scheme is jointly utilized by all the participating prosumers under a single PPA as shown in Fig. 1 and cannot be disintegrated to represent the individual participating prosumers. Thus, the 3.9 MWh BESS capacity that is jointly shared by the participating prosumers under a single SoG PPA was considered in this study's evaluation to determine the levelized cost of storage for each of the selected SSA countries. Furthermore, this typical industrial building was assumed to have a daily energy demand based on its operational and non-operational days of a week. Table 2 shows the energy demands of the typical industrial building during operational and non-operational days for the different ToU periods. For all the selected locations, it was assumed that the ToU periods have the same time ranges. The off-peak period was considered in the range of 00:00 am – 06:00 am; standard peak in the range of 06:00 am – 06:00 pm; and peak period in the range of 06:00 pm – 00:00 am.

Table 2: Typical Industrial Energy Demand Based on the Time of Use Periods

Energy Demand of the Day	**Time of Use Periods' Demand (kWh)**			**Total energy demand (kWh)**
	Peak	**Standard**	**Off-peak**	
Operational	53.04	564.39	53.59	671.02
Non-operational	53.04	105.56	53.59	212.19

Solar PV module prices vary from one country to another. Also, the prices might still vary from one region to another within a country. Thus, because of such disparities in solar PV module prices in SSA, two solar PV module price scenarios (A and B) were considered in this study and their respective details are shown in Table 3. For the SoG scheme model, several industrial prosumers constituting a specified solar PV capacity are contracted under a single SoG PPA with a guarantee to access to the grid as well as the BESS for storage of their energy that can be used during the peak and off-peak periods. Solar PV system design and sizing as well as BESS size description under the SoG scheme model in [12] were adopted in this study. Table 3 shows the system description and costs used in this study.

The weather datafiles for selected locations were generated from Meteonorm database and used in Systems Advisor Model (SAM) tool following the system design details in Table 3 to simulate the performance of a typical industrial solar PV system. In this study, Solton Power's SPI-300P module under CEC Performance Model and ABB's PVI-10.0-I-OUTD-x-US-480-y-z480V [CEC 2011] inverter under inverter CEC Database in SAM tool were selected and used for PV system simulation, while 24 V 100 Ah Li-ion batteries were considered for the BESS under the SoG model. To meet the industrial demand, in this study, solar PV system generation was estimated to supply 75% of the annual demand, the energy stored-on grid (BESS) was estimated to supply 9% of the annual demand, while 16% of the annual demand was to be supplied by the grid. Any surplus generated solar PV energy was assumed to be fed to the grid for each considered location of the study.

Table 3: Specifications of Typical Industrial Solar PV System, Costs and Capacities under the SoG Scheme Considered

Entity	**Value**	**Entity**	**Values**	
Typical Industrial Solar PV System			**Scenario A**	**Scenario B**
Modules per string	8	Module price ($/W)	0.40	0.65
Strings in parallel	32	Inverter cost ($/$W_{ac}$)	0.17	0.17
Number of inverters	7	Structural and Electrical BOS ($/$W_{dc}$)	0.36	0.36
Number of modules per roof slant area	256	Evaluated investment cost ($)	143,347	182,515
Inverter replacement time	15	PV system O&M costs ($/year)	2,294	2,920
Solar PV lifetime (years)	25	Inverter replacement ($)	14,335	18,252
Solar PV Systems and BESS under SoG Scheme model				
BESS Capacity under SoG scheme PPA (MWh)	3.9	BESS investment cost ($)	918,179	918,179
Solar PV Capacity under SoG scheme PPA (MW)	5.0	BESS O&M costs ($/year)	3,673	3,673
BESS lifetime (years)	20	BESS annual energy output (kWh)	1,186,196	1,186,196

3.3 SoG Scheme Model Analysis

a) Costs Analysis

Under the SoG scheme model, the LCOE for solar PV system is considered as the cost incurred by the prosumer for the energy supplied directly to their load by the solar PV generated energy. The $\mathrm{LCOE_{PV}}$ rate of the SoG scheme is evaluated by using Eq. (1) [12].

$$LCOE_{PV} = \frac{\sum_{t=1}^{n}\left(\frac{I_t+M_t}{(1+r)^t}\right)}{\sum_{t=1}^{n}\left(\frac{E^{PV}\cdot(1-\gamma)^t}{(1+r)^t}\right)} \tag{1}$$

where, I_t is the annuitized investment cost for solar PV system; M_t is the annual operation and maintenance cost for solar PV system; E^{PV} is the annual energy generated by the solar system; γ is the annual degradation factor of solar PV system; and r is the discount rate, evaluated as the weighted average cost of capital ($WACC$) of the firm expressed by Eq. (2).

$$WACC = \left(\frac{E}{E+D}\right) \cdot C_E + \left(\frac{D}{E+D}\right) \cdot C_D \cdot (1 - \tau) \tag{2}$$

where, E and D are the equity and debt shares of the investment cost, respectively; C_E and C_D are the cost of equity and cost of debt, respectively; and τ is the corporate tax. The cost of equity is the sum product of risk-free rate and equity risk premium multiplied by beta coefficient for the risk premium, while the cost of debt is the ratio of the firm's interest expenses to its debt load. Table 4 shows the equity risk premium, corporate tax, risk-free rate and loan interest rate for the selected SSA countries used to evaluate the discount rate r.

Table 4: Equity risk premium, corporate tax, risk-free rate and loan interest rate for the considered countries

Country	**Equity Risk Premium (%) for 2020** [44]	**Corporate Tax (%) for 2020** [45]	**Risk-free Rate (%)** [44, 46]	**Loan Interest Rate (%)** [47]
Namibia	9.64	32	9.7	8.2
Kenya	13.32	30	11.9	10.4
Madagascar	14.79	20	8.0	41.5
Senegal	10.52	30	12.0	4.5
Burkina Faso	13.32	28	9.3	3.1
Cote d'Ivoire	10.52	25	10.5	7.1
Mali	14.79	35	14.6	3.1
Niger	14.79	30	9.5	3.8
Togo	14.79	28	8.7	4.2
Eswatini	13.32	27.5	13.9	8.2
Zimbabwe	22.86	25	17.4	21.1
Rwanda	13.32	30	12.1	16.1
Cameroon	13.32	33	13.0	3.25

Under the SoG scheme, at any given time, when the prosumer's solar PV system generates more energy than can be consumed, some of the energy is channelled to the battery energy storage system (BESS) and stored for the prosumer to use later. When the prosumer draws energy from the BESS, a store-on grid rate specified in the SoG scheme PPA is levied on that energy. The store-on grid rate P_{fee}^{SoG} is evaluated by using Eq. (3) and the LCOS is evaluated by using Eq. (4) [12].

$$P_{fee}^{SoG} = \psi \cdot \delta \cdot LCOS \tag{3}$$

$$LCOS = \frac{CAPEX + \sum_{t=1}^{N}\left(\frac{A_t}{(1+r)^t}\right)}{\sum_{t=1}^{N}\left(\frac{E_{out}^{BESS}}{(1+r)^t}\right)} \tag{4}$$

where, $LCOS$ is the levelized cost of storage of the BESS for a single SoG scheme PPA; δ is the ratio of standard rate to peak rate of ToU rating model; and ψ is the percentage of solar PV energy stored in the BESS that is charged a fee by the grid based on the SoG scheme PPA. The value of ψ is always specified by the utility (government) for the prosumer's consent before the enactment of the PPA. $CAPEX$ is the BESS capital expenditure; $\mathrm{A_t}$ is the annual operating cost of BESS; N is the SoG contracted period; E_{out}^{BESS} is the annual energy output from the BESS; and r is the discount rate, evaluated by Eq. (2) for the individual selected SSA country.

In case the prosumer's solar PV system generates less than the energy demanded by the industrial building, the prosumer is obliged under the SoG scheme PPA to have the required energy supplied by the grid system. Unlike under the ToU scheme, the grid supplies energy to the prosumer at a grid sellback rate under the SoG scheme that is specified in the PPA. The grid sellback rate P_{Grid}^{SEGI} for the solar energy generating industry (SEGI) is evaluated by using Eq. (5) [12].

$$P_{Grid}^{SEGI} = \frac{(p_o + p_s + p_p)}{3} \tag{5}$$

where, p_o is the off-peak rate under the ToU scheme; p_s is the standard rate under the ToU scheme; and p_p is the peak rate under the ToU scheme. Based on the ToU rates for the selected countries in Table 1, the respective grid sellback rate P_{Grid}^{SEGI} are evaluated.

b) Benefits Analysis

In case the BESS is charged to its full capacity and the prosumer still has surplus energy, the prosumer feeds the surplus energy to the grid at the specified feed-in grid (FiG) rate in the SoG scheme PPA. The FiG rate P_{FiG}^{SEGI} for the SEGI is evaluated by using Eq. (6) [13].

$$P_{FiG}^{SEGI} = [(\gamma\rho - \gamma - r - \rho) \cdot R_{FiG}] \cdot \frac{\begin{bmatrix} \theta + \frac{(1-\theta)}{M} \cdot \left\{ \left(\frac{(1+r)^M - 1}{r \cdot (1+r)^M} \right) + r_l \cdot \left(\frac{(1+r)^{-M} + r \cdot M - 1}{r^2} \right) \cdot (1-\tau) \right\} + \\ \emptyset_{Inv} \cdot \left(\frac{1}{(1+r)^{n_{Inv}}} \right) + \emptyset_{OM} \cdot \left(\frac{(1+r)^N - 1}{r \cdot (1+r)^N} \right) - \\ \frac{\tau}{N} \cdot \left\{ \frac{(\sigma+\beta)}{(r+1)} + \alpha \cdot \left(\frac{(1+r)^K - 1}{r \cdot (1+r)^K} \right) + \partial \cdot \left(\frac{1-(1+r)^{-N}}{r} \right) \right\} \end{bmatrix}}{[E_{FiG}^{SEGI} \cdot (1-\tau) \cdot (\gamma - 1) \cdot (\rho - 1) \cdot (1+r)^{-N} \cdot ((1-\gamma)^N \cdot (1-\rho)^N - (1+r)^N)]} \tag{6}$$

For $$R_{FiG} = (\eta - \varphi) \cdot R \tag{7}$$

where, θ is the equity share of investment cost; $(1-\theta)$ is the debt share of the investment cost; M is the debt maturity period; r_l is the loan interest; $\emptyset_{Inv}$ is the percentage of the investment cost that accounts for inverters replacement; n_{Inv} is the year of inverters' replacement; $\emptyset_{OM}$ is the percentage of the investment cost that accounts for operation and maintenance of the system; R_{FiG} is the solar PV system investment cost attributed to the solar energy fed to the grid, evaluated by using Eq. (7); E_{FiG}^{SEGI} is the energy generated by a solar PV system fed to the grid; P_{FiG}^{SEGI} is the FiG rate; γ is the annual degradation rate; ρ is the degression rate; τ is the corporate income tax rate; r is the discount rate evaluated as weighted average cost of capital (WACC); N is the SoG contracted period; R is the solar PV system investment cost; η is the percentage of the solar energy generated that is fed to the grid; φ is the non-linearity coefficient between the energy generated and the investment cost of the solar PV system under the SoG scheme; σ is the initial allowance; β is the building use allowance; α is the start-up allowance; ∂ is the depreciation allowance; and K is the allowed period for start-up allowance. Since in most of SSA countries there are no clear-cut mentioned tax incentives applicable to rooftop solar PV systems, Table 5 shows the general tax incentives (building, depreciation, initial, and start-up allowances) that were assumed and used in this study to evaluate the FiG rate under the SoG scheme model for the selected countries.

Table 5: General Data Used to Evaluate the Rooftop Solar PV Energy FiG Rate for the Selected Countries

Metric	**Notation**	**Value**
Allowed period of start-up allowance (years)	K	4
Annual degradation rate (%)	γ	0.5
Building use allowance (%)	β	20
Debt maturity period (years)	M	5
Debt share of investment cost (%)	$(1-\theta)$	60
Depreciation allowance (%)	∂	20
Equity share of investment cost (%)	θ	40
SoG contracted period (years)	N	20
Initial allowance (%)	σ	50
Degression rate (%)	ρ	1
Non-linearity coefficient (%)	φ	5
Percentage of investment cost for inverters' replacement (%)	$\emptyset_{Inv}$	10
Percentage of investment cost for O&M cost (%)	$\emptyset_{OM}$	1.6
Start-up allowance (%)	α	25
Year of inverters' replacement (year)	n_{Inv}	15

c) SoG Scheme Model Viability

For the feasibility of the solar PV energy transaction between the industrial solar PV energy prosumer and the utility operator, the FiG rate under the SoG scheme should always lie in the range given by the constraint in Eq. (8) for all parameters of the model. The constraint in Eq. (8) should always hold for the prosumer to attain reasonable returns when feeding the surplus solar PV energy to the grid and likewise for the utility operator when selling the energy to the prosumers under the SoG scheme model.

$$LCOE_{PV} < P_{FiG}^{SEGI} < P_{Grid}^{SEGI} \tag{8}$$

Profits analyses for the solar PV energy fed to the grid by the prosumer and those of the utility operator for the sale of the energy fed to the grid under the SoG scheme were evaluated. To undertake the profits analysis for the prosumer $\mathrm{F}_{\mathrm{profit}}^{\mathrm{SEGI}}$ and utility operator $\mathrm{F}_{\mathrm{profit}}^{\mathrm{Grid}}$ under the SoG scheme, Eqs. (9) and (10) are used, respectively.

$$F_{profit}^{SEGI} = \left(P_{FiG}^{SEGI} - LCOE_{PV}\right) \cdot E_{FiG}^{SEGI} \tag{9}$$

$$F_{profit}^{Grid} = \left(P_{Grid}^{SEGI} - P_{FiG}^{SEGI}\right) \cdot E_{FiG}^{SEGI} \tag{10}$$

Additionally, by adopting the SoG scheme, the prosumer records a reduction in the electricity purchase costs as a result of self-consumption of the solar PV energy generated by the installed system. The reduction in the electricity purchase costs, referred to as prosumer's secondary benefits B_{Pro}^{Sec} are evaluated by using Eq. (11).

$$B_{Pro}^{Sec} = E_{load}^{PV} \cdot (p_s - LCOE_{PV}) + E_{load,p}^{SoG} \cdot \left(p_p - \left(LCOE_{PV} + P_{fee}^{SoG}\right)\right) + E_{load,o}^{SoG} \cdot \left(p_o - \left(LCOE_{PV} + P_{fee}^{SoG}\right)\right) + E_{load,s}^{SoG} \cdot \left(p_s - \left(LCOE_{PV} + P_{fee}^{SoG}\right)\right) \tag{11}$$

where, $E_{load,p}^{SoG}$ is the solar PV energy stored in the BESS and supplied to the load during the peak period; $E_{load,o}^{SoG}$ is the solar PV energy stored in the BESS and supplied to the load during the off-peak period; $E_{load,s}^{SoG}$ is the solar PV energy stored in the BESS and supplied to the load during the shoulder period; P_{fee}^{SoG} is the store-on grid fee levied on the PV energy stored in the BESS; p_p, p_s and p_o are the peak, shoulder and off-peak tariffs, respectively, for the ToU scheme.

d) Government Revenue Analysis

With the government as a key stakeholder in the implementation and success of SoG scheme, it is crucial to assess its revenue collection from the scheme. The government taxes the energy transaction between the prosumer and the utility under SoG scheme. In this analysis, the tax generated per kWh of the solar PV energy fed to the grid under the SoG scheme was evaluated by using Eq. (12). The government tax collection evaluated by using Eq. (12) captures the corporate tax generated from the solar PV energy fed to the grid by deducting the tax allowances offered to rooftop solar PV systems.

$$T_{Gov} = \frac{\sum_{t=1}^{N}\left(\frac{E_{FiG}^{SEGI} \cdot P_{FiG}^{SEGI} \cdot (1-\gamma)^{t} \cdot (1-\rho)^{t} \cdot \tau}{(1+r)^{t}}\right) - \left(\frac{R_{FiG}}{N}\right) \cdot \tau \cdot \left\{\frac{(\sigma+\beta)}{(r+1)} + \alpha \cdot \left(\frac{(1+r)^{K}-1}{r \cdot (1+r)^{K}}\right) + \partial \cdot \left(\frac{1-(1+r)^{-N}}{r}\right)\right\}}{\sum_{t=1}^{N}\left(\frac{E_{FiG}^{SEGI}}{(1+r)^{t}}\right)} \tag{12}$$

4 Results and discussion

4.1 Solar PV System Performance Evaluation

As discussed in subsection 3.2, a prosumer with a typical industrial building was considered for every single SoG scheme PPA in the selected SSA countries. A typical industrial building was assumed to have a pitched roof, that is, having two slant roof areas for installation of solar PV system. For a typical size solar PV system of 153.6 kWp capacity considered in this study, each slant roof area of the building was estimated to accommodate 76.8 kWp array following the system description in Table 3. A tilt angle of 25° was used for the system at all the considered locations, given most rooftops in SSA have an average pitch angle of about 25° [48]. The performance of the solar PV system was simulated for different orientations at every considered location in Table 1. For all the considered countries, a combination of East and West orientations of solar PV arrays yielded the highest annual energy generation. Table 6 shows the solar PV system annual energy generation at the selected locations in SSA.

Table 6 reveals that a rooftop solar PV system in Windhoek, Namibia would generate the highest energy annually, while a system in Yamoussoukro, Cote d'Ivoire would generate the least energy annually. The difference of 73,446 kWh between the annual energy generated by the system at Windhoek and Yamoussoukro could be attributed to the solar irradiance received at the two sites. Cote d'Ivoire has a reported daily solar PV yield potential in the range of 3.6 – 4.4 $\mathrm{kWh/kW_P}$, while Namibia has a daily solar PV yield potential in the range of 5.0 – 5.8 $\mathrm{kWh/kW_P}$ [49]. Thus, based on the daily solar PV yield potential of the two countries, a solar PV system installed in Namibia would always generate more energy daily than the one installed in Cote d'Ivoire. Fig. 4 shows the monthly solar irradiance received on the plane of array (POA) of solar systems for the East and West orientations at the site in Cote d'Ivoire and Namibia. The POA of solar PV systems in Fig. 4 reveals that the system in Cote d'Ivoire could receive solar irradiance close to that of a system in Namibia only in the months of April to June. For the rest of the months, the solar irradiance on the POA of solar PV system in Namibia could greatly exceeds that of the system in Cote d'Ivoire.

Table 6: Solar PV System Annual Energy Generation at Selected Locations in SSA

Country	Location	Energy Generation based on Azimuth Angle (kWh)		Total Annual Energy Generated (kWh)
		East Orientation	West Orientation	
Namibia	Windhoek City	131,533	130,997	262,530
Kenya	Nairobi	104,819	102,456	207,274
Madagascar	Antananarivo	111,094	110,795	221,889
Senegal	Dakar	120,889	120516	241,405
Burkina Faso	Ouagadougou	119,221	119,950	239,171
Cote d'Ivoire	Yamoussoukro	95,000	94,084	189,084
Mali	Bamako	119,197	119,205	238,402
Niger	Niamey	121,965	121,646	243,611
Togo	Lomé	101,545	101,843	203,388
Eswatini	Mbabane	100,689	99,861	200,550
Zimbabwe	Harare	109,333	106,412	215,745
Rwanda	Kigali	104,864	101,992	206,856
Cameroon	Yaoundé	96,135	95,926	192,061

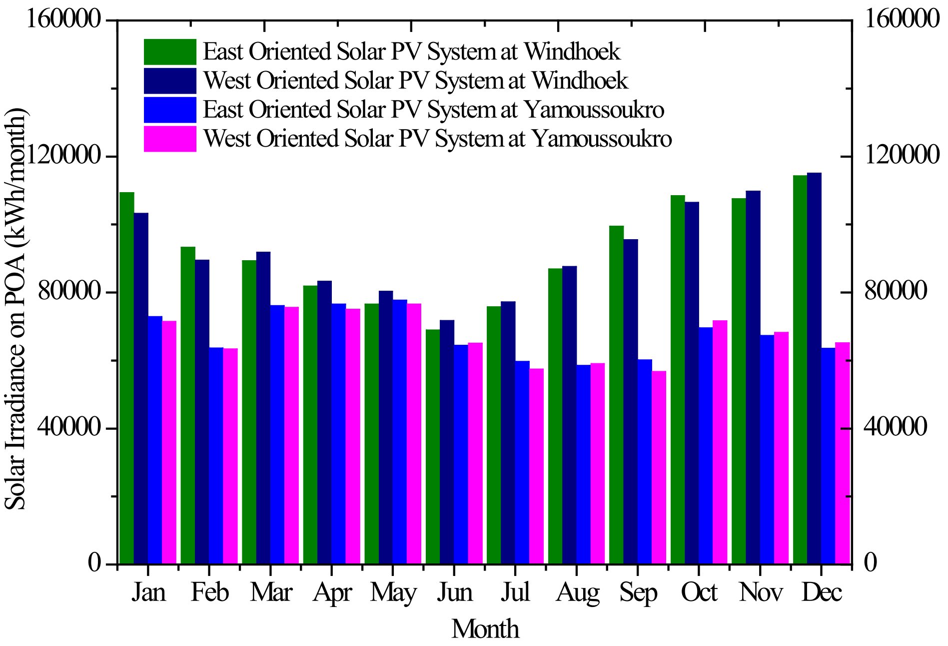


Fig. 4: Solar Irradiance on POA of Solar PV Systems at Windhoek and Yamoussoukro

4.2 Cost Analysis Evaluation

Assuming a beta value of 1 and an industry's cost of debt of 5% as well as using the data in Table 4 in Eq. (2), the WACC of the typical industry was evaluated for the selected countries and is reported in Table 7. The typical solar PV system evaluated for the two scenarios had an investment cost of $ 143,3467 and $ 182,514 for scenario A and scenario B, respectively, based on solar PV module prices shown in Table 3. At a loan maturity period of 5 years and debt share of capital of 60% as well as the respective country's lending interest rate, the industry's annuity in the selected countries was evaluated and is shown in Table 7. For all the selected locations, the applied equity share of capital was 40%, which is an equivalent of $ 57,338.8 and $ 73,005.6 for scenario A and scenario B, respectively. Also, the operation and maintenance costs and the inverters' replacement cost after 15 years for respective scenarios shown in Table 3 were applied to all the selected locations. The solar PV system was assumed to have a degradation rate of 0.5% per annum at all sites. With this information, the LCOE of the solar PV energy at the selected locations was evaluated for a 153.6 kW typical solar PV system for a lifetime of 25 years by using Eq. (1) and is reported in Table 7.

Table 7: Solar PV System Economic Analysis for the selected Locations in SSA

Country	WACC (%)	Annuity ($)		LCOE (c$/kWh)	
		Scenario A	Scenario B	Scenario A	Scenario B
Namibia	9.78	21,654.93	27,571.81	7.08	9.02
Kenya	12.19	22,921.01	29,183.83	10.35	13.18
Madagascar	11.52	43,332.19	55,172.04	13.68	17.42
Senegal	11.11	19,591.91	24,945.10	7.83	9.96
Burkina Faso	11.21	18,833.90	23,979.98	7.79	9.92
Cote d'Ivoire	10.66	21,032.75	26,779.63	10.12	12.88
Mali	13.71	18,833.90	23,979.98	8.73	11.11
Niger	11.82	19,211.32	24460.51	7.94	10.11
Togo	11.56	19,428.41	24,736.93	9.45	12.03
Eswatini	13.06	21,654.93	27,571.81	10.8	13.75
Zimbabwe	18.35	29,458.34	37,507.39	14.43	18.37
Rwanda	12.27	26,328.96	33,522.94	11.21	14.27
Cameroon	12.54	18,914.50	24,082.60	10.33	13.15

The evaluated WACC values in Table 7 of the considered countries are in the range of 9.78 – 18.35%, which agrees with the reported range of WACC values of 8.0 – 32.0% across SSA in [24]. WACC values are high in African countries due to country-specific risks, that is, perceived and actual risks that are higher in SSA than in developed countries. These risks arise from concerns over financial and political stability as well as regulatory and institutional conditions. Thus, investors would require a higher rate of return on the investment to accommodate for such risks. For an investment to be attractive to an investor, its WACC should be greater than the firm's actual internal rate of return (IRR). The IRR for solar PV investment in SSA is reported in the range of 15 – 22 % [11]. Thus, by comparing the evaluated WACC values and the reported IRR range in SSA, an investment in solar PV technology could still be attractive to the investors in most of the selected SSA countries.

Also, the evaluated LCOE for solar PV for both scenarios presented in Table 7 is in the range of 7.08 – 18.37 c$/kWh. In literature, solar PV energy is reported to be delivered at an LCOE between 6.0 – 21.0 c$/kWh in SSA [11]. Thus, the range of the LCOE for solar PV energy evaluated in this study agrees with the range reported in literature for solar PV energy in SSA, an indication that the study results are a good representation of the economic state of solar PV in SSA. It should be noted that the LCOE for solar PV energy is highly sensitive to the WACC and loan interest rates as well as the solar energy resource of the location. Thus, as revealed in Table 7, countries with high WACC and/or high lending interest rate also have high LCOE for solar PV system.

As described in [12], under the SoG scheme model, several prosumers are contracted under a single SoG PPA to install solar PV, while the government through the utility operator facilitates the installation of the battery energy storage system (BESS). Thus, in this study, the

BESS investment cost of $ 918,179 as well as the operation and maintenance cost of $3,673 and the annual BESS energy as reported in Table 5 were used for all systems in the selected countries. The percentage share of the total energy drawn from the storage system that is charged a fee by the grid operator ψ was assumed at 62.02%, and applied to all systems in all the selected countries as was used in [12, 13] to evaluate the store-on grid rate P_{fee}^{SoG} by using Eq. (3). Table 8 shows the values of δ, $LCOS$ evaluated by using Eq. (4), the store-on grid rate P_{fee}^{SoG} evaluated by using Eq. (3), and the grid sellback rate P_{Grid}^{SEGI} evaluated by applying the time of use (ToU) rates for selected countries in Eq. (5).

Table 8: Evaluated Store-on Grid Fee and Grid Sellback Rate for Selected countries in SSA

Country	δ	LCOS (c$/kWh)	P_{fee}^{SoG} (c$/kWh)	P_{Grid}^{SEGI} (c$/kWh)
Namibia	0.8125	9.98	5.03	12.73
Kenya	1.0000	11.57	7.18	6.37
Madagascar	0.2333	11.12	1.61	8.17
Senegal	0.6563	10.85	4.42	17.27
Burkina Faso	0.5000	10.91	3.38	15.60
Cote d'Ivoire	0.7286	10.55	4.77	10.83
Mali	0.6806	12.60	5.32	13.87
Niger	0.6940	11.32	4.87	10.67
Togo	0.8834	11.14	6.10	14.60
Eswatini	0.3148	12.15	2.37	13.70
Zimbabwe	0.5385	15.89	5.31	8.00
Rwanda	0.7647	11.62	5.51	13.30
Cameroon	0.8268	11.8	6.05	13.60

From Table 8, it is revealed that of all the selected SSA countries, it is only in Kenya that the store-on grid rate is higher than the grid sellback rate. This is attributed to the lower ToU rates offered as well as the same rates for peak and standard periods in Kenya as presented in Table 1. Because of the same rates offered during the peak and standard periods, the value of δ is equivalent to 1 for the case of Kenya, which results in a high store-on grid rate based on Eq. (3). On the other hand, due to very low values of δ in Madagascar and Eswatini, the respective store-on grid rate in these countries is very low, while the *LCOS* is very high. This results from the very low standard period rates offered in these countries in comparison to their peak period rate under the ToU scheme as presented in Table 1. Overall, for all the selected SSA countries, the store-on grid rate is in the range of 1.61 – 7.18 c$/kWh and the grid sellback rate is in the range of 6.37 – 17.27 c$/kWh, while the *LCOS* of the BESS varies in the range of 9.98 – 15.89 c$/kWh. The variation in the *LCOS* of the BESS is as a result of the differences in the WACC values in Table 7 of the considered countries that are in the range of 9.78 – 18.35% for the selected SSA countries.

In this study, the industry was considered on average to have at least 10 non-operational days every month to account for the public holidays, maintenances and weekends, while it worked for the rest of the days of the month. The monthly energy demands of the industry were evaluated based on operational and non-operational days for each month as well as the ToU energy demand in Table 2. Table 9 shows the monthly energy demands of the industry in this study.

Table 9: Monthly Energy Demand of the Industrial building

Month	Energy Demand based on Time of Use Periods (kWh)			Total Monthly demand (kWh)
	Peak	**Standard**	**Off-peak**	
January	1,644.24	12,907.79	1,661.29	16,213.32
February	1,485.12	11,214.62	1,500.52	14,200.26
March	1,644.24	12,907.79	1,661.29	16,213.32
April	1,591.20	12,343.40	1,607.70	15,542.30
May	1,644.24	12,907.79	1,661.29	16,213.32
June	1,591.20	12,343.40	1,607.70	15,542.30
July	1,644.24	12,907.79	1,661.29	16,213.32
August	1,644.24	12,907.79	1,661.29	16,213.32
September	1,591.20	12,343.40	1,607.70	15,542.30
October	1,644.24	12,907.79	1,661.29	16,213.32
November	1,591.20	12,343.40	1,607.70	15,542.30
December	1,644.24	12,907.79	1,661.29	16,213.32
Total Annual Demand (kWh)	**19,359.6**	**150,942.75**	**19,560.35**	**189,862.7**

From Table 9, comparing the overall total annual energy demand of the industrial building with the simulated annual solar energy generation at all selected sites in SSA in Table 6, it is only the system in Cote d'Ivoire that generates less than the annual demanded energy. It should be noted that with the variation in the considered number of operational days per month, the monthly energy demand of the industry could as well vary. It is possible that in some of the considered countries the industries operate for more or less days of the month than assumed in this study. Such a deviation from the assumption of the study could increase or decrease the annual energy demand of the industry. Likewise, some industries could have some of their operations schedules for the night-time, contrary to the study's assumption of industries operating only during daytime. However, such incidences necessitate real time data on industries' operations in order to have the conclusive evaluation of their annual energy demand and compare it with the possible annual energy generation from the solar PV system.

By using the ToU rates in Table 1 and the energy demand per ToU period in Table 9, the industry's monthly and annual energy costs were evaluated for the selected SSA countries. Also, by using the LCOE in Table 7, store-on grid rate and grid sellback rate in Table 8 with the total monthly energy demand in Table 9, the industry's monthly and annual energy costs were evaluated. Fig. 5 shows the comparison between the annual energy costs of the industry under ToU scheme and SoG scheme for the selected SSA countries.

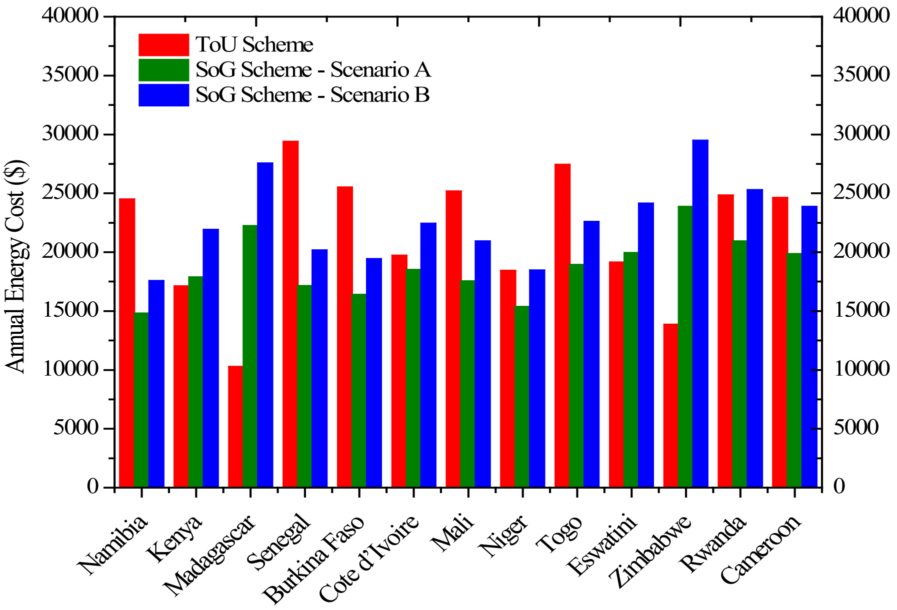


Fig. 5: Comparison of the Evaluated Industry's Annual Energy Cost under the Time of Use and Store-on Grid Schemes for Selected Countries in SSA

A comparison of the annual energy cost under the two schemes in Fig. 5 reveals that in most of the considered countries, the industry would incur lower annual energy costs under the SoG scheme than under the ToU scheme regardless of the scenario considered. For both scenarios of SoG scheme, the industry prosumer in the case of Kenya, Madagascar, Zimbabwe and Eswatini would incur more annual energy costs under the SoG scheme compared to under the ToU scheme. These differences in the annual energy costs could be attributed to the very low energy tariffs offered under the ToU scheme and likewise the high lending interest rates incurred by a borrowing investor in these countries. Most of the industrial energy load is mainly during daytime, that is, during the solar PV energy generating period for the SoG scheme and the standard period for the ToU scheme as shown in Table 9. Fig. 6 shows the comparison between the standard rate under the ToU scheme (from Table 1) and the LCOE rate under the SoG scheme for the two scenarios (from Table 7) for the selected SSA countries.

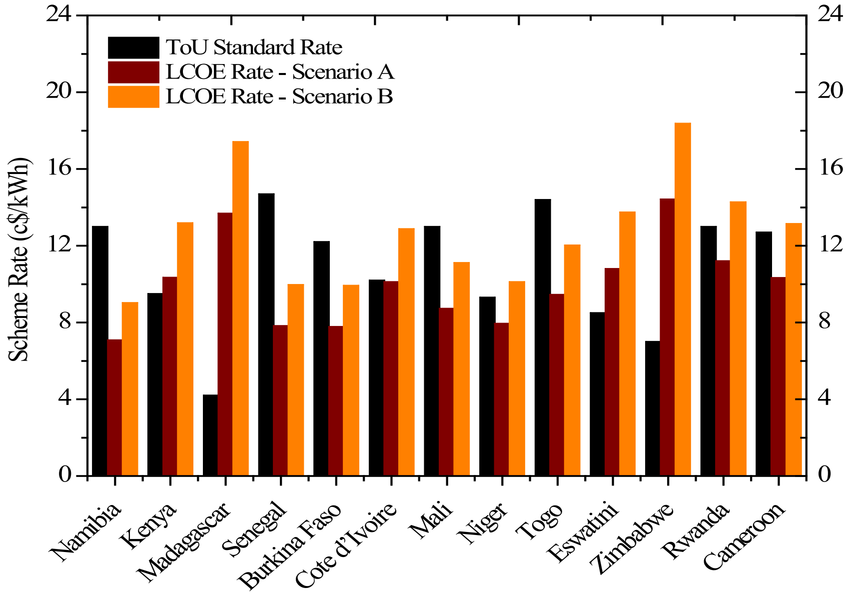


Fig. 6: Comparison between the Schemes' Main Tariffs in Selected Countries in SSA

From Fig. 6, it is evident that the LCOE rate under the SoG scheme is very high in countries such as Madagascar and Zimbabwe compared to the standard rate under the ToU scheme. For instance, the evaluated LCOE rate is about 4.3 times the standard rate in Madagascar, and about 2.6 times the standard rate in Zimbabwe. These high values of the LCOE rate are as a result of the high loan interest rates in these countries as shown in Table 4. Under the SoG scheme scenario A, the LCOE rate is lower than the standard rate of the ToU scheme in most of the selected SSA countries. In this study, the economic analysis of solar PV system was evaluated on the basis that the debt share of the investment cost is 60%. Thus, the lending interest rate on the loan has a significant impact of the solar PV system's LCOE value.

4.3 Benefits Analysis Evaluation

Under the SoG scheme, the prosumers feed their surplus energy generated to the grid at the contracted FiG rate specified in the PPA. Likewise, the grid supplies some of the prosumer's energy demands at the specified sellback rate in the PPA. As an assumed obligation under the SoG scheme model, on an annual basis, the direct solar PV energy to the load should meets 75%, and the energy from the BESS to the load should meet 9% of the industrial energy demand, while 16% of the load is mandatorily supplied by the grid in accordance to the SoG scheme PPA terms. Fig. 7 shows the annual energy fed to the grid by the prosumer and its share of the total annual energy generated by the solar PV systems in the selected countries of SSA.

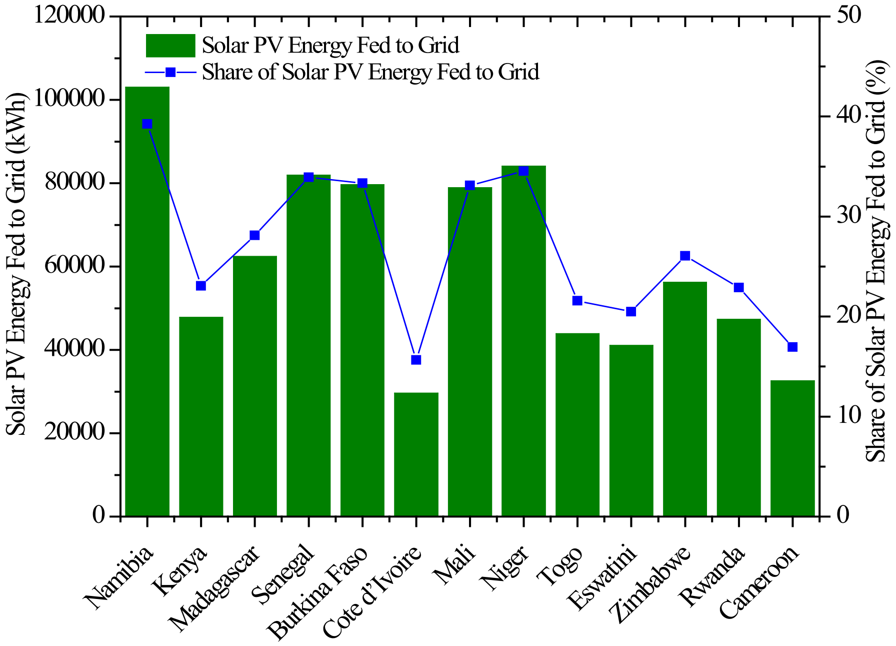


Fig. 7: Annual Solar PV Energy Fed to Grid and Its Share of Energy Generation for Selected Countries in SSA

From Fig. 7, it is revealed that for all the considered countries, more than 15% of the generated solar PV energy is fed to the grid by the prosumer annually. On average, 26.83% of the generated solar PV energy is fed to the grid annually. The least share of the energy fed to the grid annually is 15.65% for the case of a solar PV system in Cote d'Ivoire, while the highest share of the energy fed to the grid annually is 39.25% for the case of a solar PV system in Namibia. The surplus energy generated by the prosumer from the solar PV system is fed to the grid at a contracted FiG rate. At any moment the prosumer's demand is met, as well as the BESS is fully charged, the prosumer would feed the surplus energy to the grid.

The energy fed to the grid varies based on the daily solar irradiance of the location and the prosumer's energy demand. Thus, for some days the prosumer might not feed any units of solar energy to the grid, while on other days the prosumer might feed several units of solar energy to the grid.

Prior to the enactment of the SoG PPA, the regulator evaluates the FiG rates to be offered to any potential prosumers joining the scheme based on Eq. (6). Likewise, in this study, the FiG rates for the two scenarios solar PV modules prices were evaluated by applying the respective data in Tables 3 and 5 in Eq. (6). Table 10 shows the R_{FiG} values evaluated by using Eq. (7) and FiG rates for scenario A and scenario B under the SoG scheme model for the selected countries in SSA.

Table 10: R_{FiG} values and FiG rates for scenario A and scenario B under the SoG scheme model

Country	R_{FiG} ((\$)		**FiG Rate (c\$/kWh)**	
	Scenario A	**Scenario B**	**Scenario A**	**Scenario B**
Namibia	49097.51	62512.99	9.52	12.12
Kenya	25882.85	32955.12	11.9	15.15
Madagascar	33147.67	42204.99	13.58	17.29
Senegal	41477.10	52810.37	10.06	12.81
Burkina Faso	40592.53	51684.09	9.78	12.45
Cote d'Ivoire	15272.25	19445.27	9.76	12.43
Mali	40284.20	51291.52	11.78	15
Niger	42334.67	53902.26	10.24	13
Togo	23775.49	30271.94	10.66	13.58
Eswatini	22184.85	28246.67	11.67	14.86
Zimbabwe	30213.53	38469.12	15.28	19.45
Rwanda	25659.97	32671.34	12.58	16.02
Cameroon	17146.35	21831.44	11.34	14.44

For all the selected SSA countries, the FiG rate varies in the range of 9.52 – 15.28 c\$/kWh and 12.12 – 19.45 c\$/kWh for scenario A and scenario B of the SoG scheme, respectively. It should be noted that the FiG rate is not influenced only by the amount of solar PV energy fed to the grid. By comparing the amount of energy fed to the grid in Fig. 7 and the FiG rate in Table 10 for Namibia and Cote d'Ivoire, it is evident that both countries have almost the same FiG rate under both SoG scheme scenarios yet the prosumer in Namibia feeds in more energy to the grid than in Cote d'Ivoire. The sensitivity analysis in [13] revealed that the FiG rate is most sensitive to the variation in the amount of solar PV energy fed to the grid, followed by the R_{FiG} value and then the discount rate. An increase in any of the parameters R_{FiG} and r increases the FiG rate, while an increase in the amount of solar PV energy fed to the grid decreases the FiG rate. Thus, the FiG rate of the selected SSA countries mainly relies based upon these three parameters, with a slight influence from the lending interest rate and corporate tax rate. Fig. 8 shows the sensitivity analysis of the FiG rate to the variations in the discount rate, r, energy fed to the grid (represented by E), and investment cost attributed to the solar energy fed to the grid R_{FiG} in the range $\pm 50\%$ of the parameter value used to evaluate the FiG rate (baseline) for Namibia in Table 10 for scenario B.

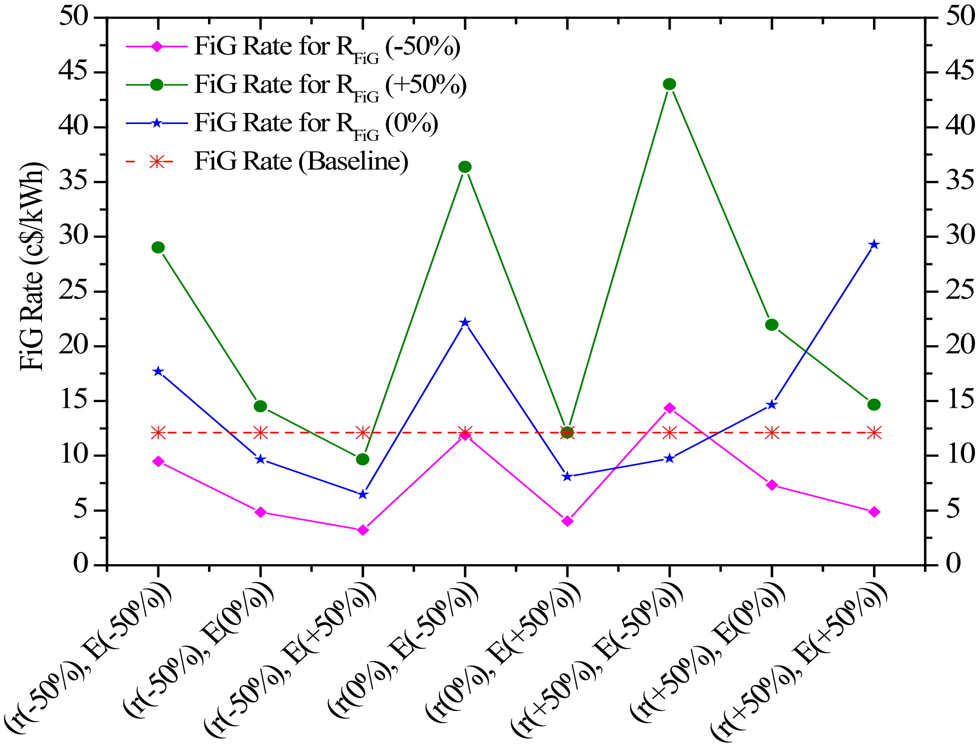


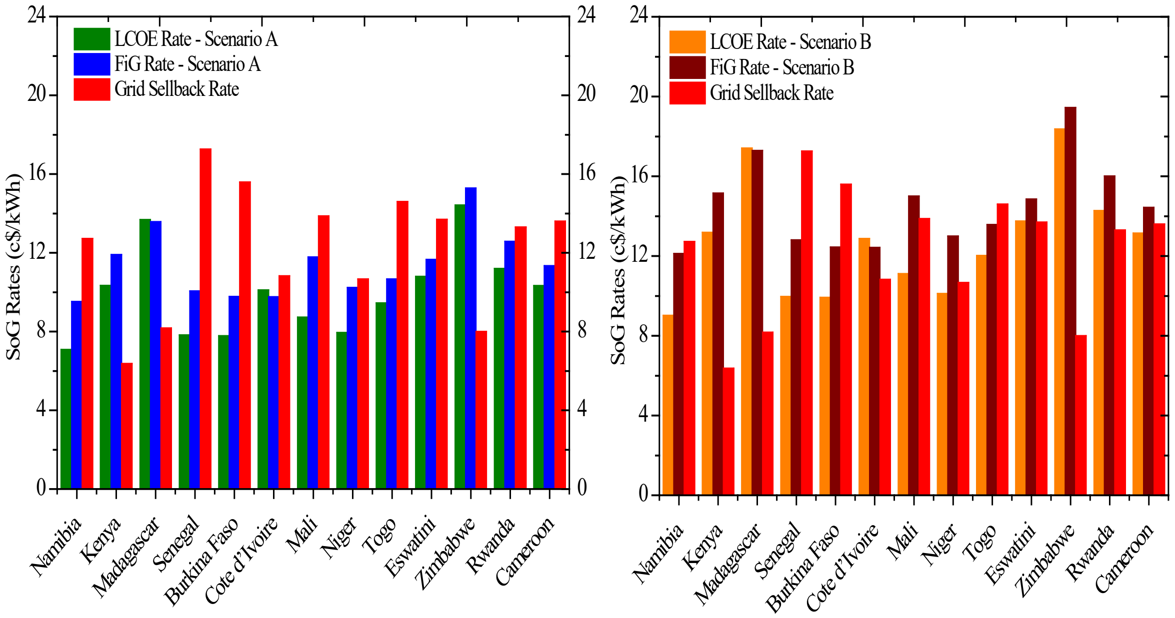
Fig. 8: Sensitivity Analysis of FiG Rate to Variation in R_{FiG}, r and E for the Case of Namibia under SoG Scheme Scenario B

As can be noted from Eq. (7) that the R_{FiG} is directly proportional to the percentage of the solar energy generated that is fed to the grid η. Thus, any change in the amount of the solar energy fed to the grid would directly influence the value of R_{FiG}. From Fig. 8, it is evident that for the variations (r(0%), E(-50%)) and (r(0%), E(+50%)), the FiG rate baseline value is (12.12 c$/kWh) for both R_{FiG}(-50%) and R_{FiG}(+50%). At r(-50%) and r(+50%), all the variations in E and R_{FiG} from (-50%) to (+50%) result in a decrease in the FiG rate.

In case the proportionality in Eq. (7) is emphasized during the FiG rate sensitivity analysis, for the variations (r(-50%), E(-50%)), (r(0%), E(-50%)) and (r(+50%), E(-50%)) for R_{FiG}(+50%), the FiG rate increases in all cases compared to the baseline FiG rate. While for the variations (r(-50%), E(+50%)), (r(0%), E(+50%)) and (r(+50%), E(+50%)) for R_{FiG}(-50%), the FiG rate decreases in all cases compared to the baseline FiG rate. Since under these variations the proportionality in Eq. (7) is violated yet it governs the key parameters used in Eq. (6) to evaluate the FiG rate, then such variations should be omitted in the analysis.

4.4 SoG Scheme Viability Assessment

Under the SoG scheme model, the FiG rate is constrained by Eq. (8) for the scheme to be feasible and profitable to both the prosumer and the utility operator. The FiG rate should always be greater than the LCOE rate but less than the grid sellback rate for the SoG scheme to be feasible in any country. Fig. 9 shows the feasibility of the SoG scheme model in the selected countries based on the two scenarios in accordance to the constraint in Eq. (8).



(a) (b)

Fig. 9: Feasibility of the SoG Scheme Model Based on the Constraint in in Eq. (8) for the Selected SSA Countries: (a) Scenario A; and (b) Scenario B

From Fig. 9 (a), under scenario A of the SoG scheme model, the constraint in Eq. (8) is upheld for industrial prosumers in nine (9) countries, namely, Namibia, Senegal, Burkina Faso, Mali, Niger, Togo, Eswatini, Rwanda and Cameroon and violated for the rest of the countries. From Fig. 9 (b), under scenario A of the SoG scheme model, the constraint in Eq. (8) is upheld for industrial prosumers in only four (4) countries, namely, Namibia, Senegal, Togo and Burkina Faso and violated for the rest of the countries. For both scenarios considered, the SoG scheme model violates the constraint in Eq. (8) for the case of Kenya, Madagascar, Cote d'Ivoire and Zimbabwe. For the case of Cote d'Ivoire, a slight decrease in solar PV module price could guarantee feasibility of the scheme for scenario A. However, for Kenya, Madagascar and Zimbabwe, there is a necessity of improved financial access through soft loans with low lending interest rates in addition to a decrease in solar PV module price for the scheme to be feasible. Generally, most of the SSA countries face a challenge of the banking sector with inadequate capital [26]. Thus, SSA governments should develop local debt capital markets and devise means of strengthening the local banking sector since this sector plays an important role in sustainability and growth of power sector projects.

Considering the solar PV energy fed to the grid, the utility operator's benefits from the sale of this energy were evaluated for both schemes. Under the SoG scheme, the utility is considered to sell the energy at a grid sellback rate, while under the ToU scheme, the utility is considered to sell the energy at the ToU standard rate. The utility benefits were evaluated as the product of the energy selling rate and the amount of energy being sold. Fig. 10 shows the utility benefits recorded from the sale of the solar PV energy fed to the grid by the utility to its customers.

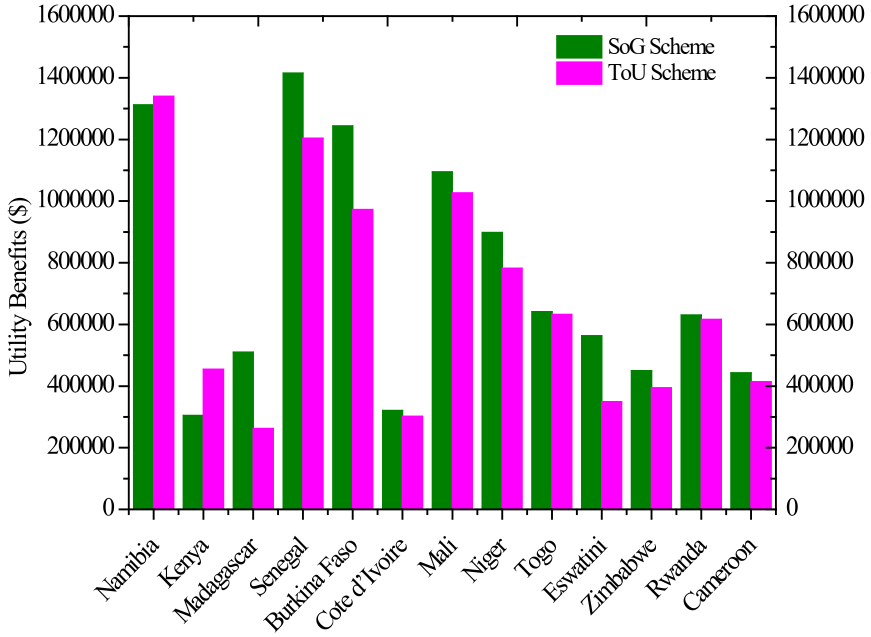
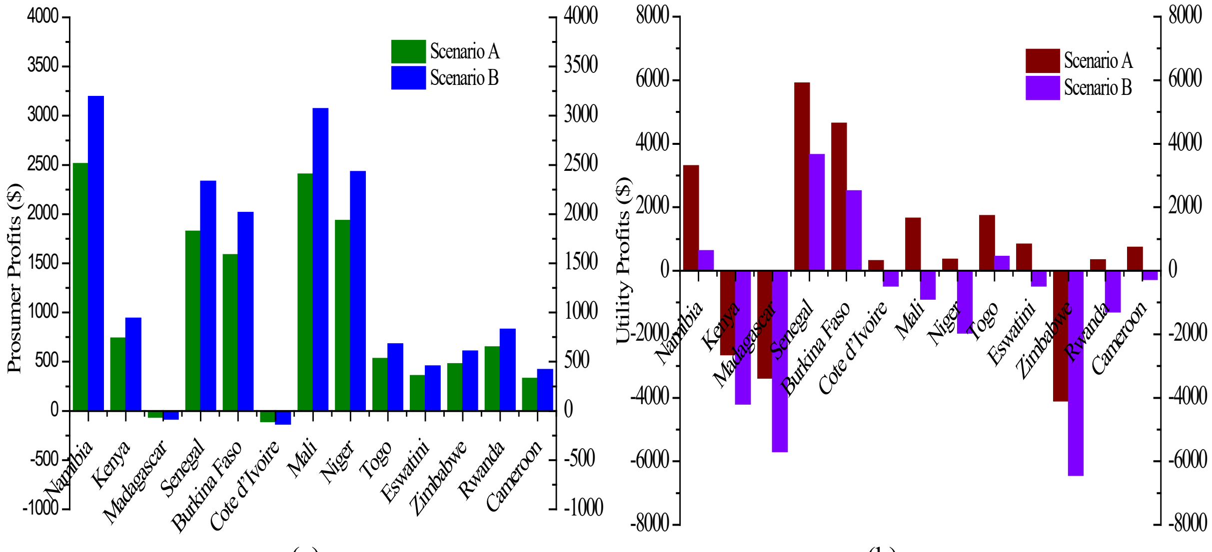


Fig. 10: Utility Benefits from the Sale of the Solar PV Energy Fed to the Grid by the Prosumer to its Customers under the ToU and SoG Schemes

From Fig. 10, except for Kenya and Namibia, the utility operators would record more benefits under the SoG scheme than under the ToU scheme for all the selected countries in this study. Therefore, the adoption of the SoG scheme could guarantee the utility more benefits in 11 out of 13 selected SSA countries in this study. The profits analysis of the prosumer and utility operator under the SoG scheme for the two scenarios was done by using Eqs. (9) and (10). Fig. 11 shows the recorded profits by the prosumer and utility under the SoG scheme for the two scenarios.



(a) (b)

Fig. 11: Recorded Profits Solar PV Energy Fed to Grid under the SoG Scheme Scenarios: (a) Prosumer; and (b) Utility

Except for Madagascar and Cote d'Ivoire where the prosumer records losses under both SoG scheme scenarios, Fig. 11 (a) shows that the prosumer records profits from the solar PV energy fed to the grid for all the other selected countries under both SoG scheme scenarios. For both SoG scheme scenarios, Fig. 11 (b) shows that the utility records profits for the case of Namibia, Senegal, Burkina Faso and Togo. The utility also records profits for the case of Cote d'Ivoire, Mali, Niger, Eswatini, Rwanda and Cameroon under the SoG scheme scenario A and records losses in the same countries under the SoG scheme scenario B. The profits analysis of both the prosumer and the utility are affected by the WACC value used in the evaluations under the SoG scheme. Since the WACC reflects investment risks, with an improved investment environment in SSA countries, the profits recorded by the stakeholders under the SoG scheme would be positively improved.

In addition to the profits made by selling the surplus generated solar energy to the grid, the prosumer also records to secondary benefits resulting from a reduction in the annual electricity purchase costs as shown in Fig. 5. By using the ToU rates in Table 1, the $LCOE_{PV}$ values in Table 7, the P_{fee}^{SoG} values in Table 8 and the total annual solar PV energy E_{load}^{PV} as well as the total annual BESS energy supplied to the load based on the ToU periods in Eq. (11), the prosumer's secondary benefits were evaluated for each of the selected SSA countries. Fig. 12 shows the prosumer secondary benefits under the SoG scheme scenarios for the selected SSA countries.

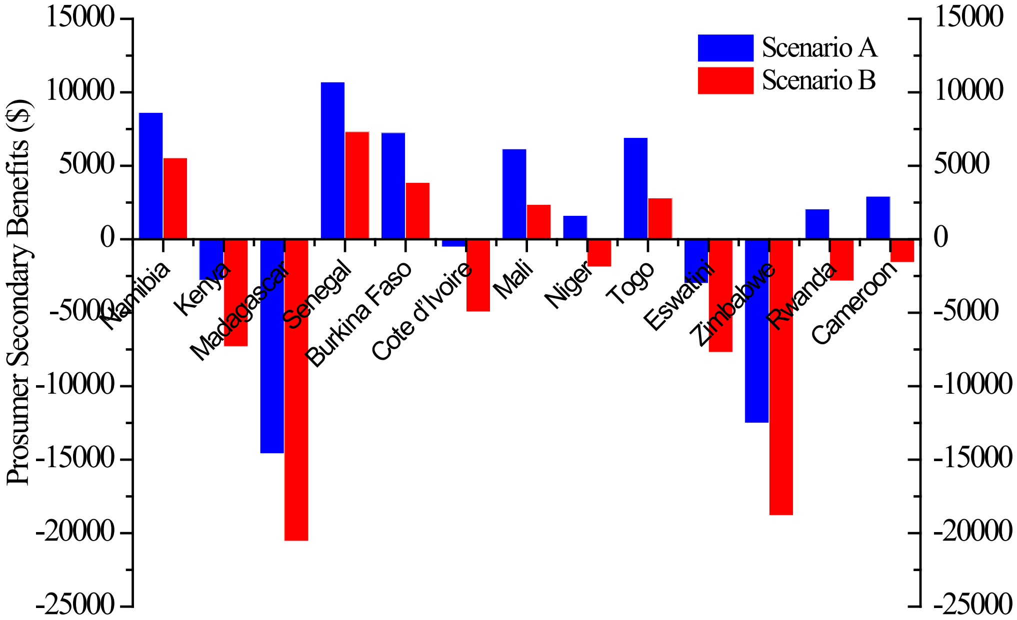


Fig. 12: Prosumer Secondary Benefits under the SoG Scheme for the Selected SSA Countries

Fig. 12 reveals that under the SoG scheme, some prosumers in some countries would record the secondary benefits resulting from a reduction in the annual electricity costs, while in other countries the prosumers would incur more annual electricity costs. Under the SoG scheme scenario A, a prosumer in Namibia, Senegal, Burkina Faso, Mali, Niger, Togo, Rwanda and Cameroon would record the secondary benefits, while a prosumer in Kenya, Madagascar, Cote d'Ivoire, Eswatini and Zimbabwe would incur the secondary costs given that the ToU rate in these countries are very low. Under the SoG scheme scenario B, a prosumer in Namibia, Senegal, Burkina Fano, Mali and Togo would record the secondary benefits, while in the rest of the selected countries the prosumer would incur the secondary costs given that the ToU rate in these countries are very low.

The electricity tariffs in most of the SSA countries do not reflect the cost of electricity services due to under-pricing of the electricity because of government subsidies [22]. For instance, in Madagascar, the government allocated a reasonable share of the discretionary spending to unaffordable and poorly targeted fuel subsidies that were estimated at about 4.1% of GDP in 2017 [50]. Also, Zimbabwe provides low-cost electricity to Zimbabweans compared to the economic cost of electricity service provision because of heavily subsidised rates. This has severe financial consequences on the Zimbabwean utilities given that the government does not compensate the utilities for these subsidised prices [51]. Generally, due to the reliance on imported fossil fuels, most SSA countries provide fossil fuel subsidies and likewise offer subsidies to utilities to cover for the financial losses incurred [52]. Phasing out of the fossil fuel subsidies can reduce the fiscal imbalance and budgetary pressure mounted on the governments in SSA countries. This could result in the creation of the necessary fiscal space to support sustainable clean energy development and eliminate perverse incentives that foster carbon emissions. Therefore, with the phasing out of fossil fuel subsidies, the market electricity tariffs (ToU rates) would reflect the unit cost of electricity generation. In such circumstances the adoption of the SoG scheme would be feasible for all the involved stakeholders in countries where fossil fuel subsidies are currently in place.

4.5 Government Revenue Evaluation

Under the SoG scheme, the government offers tax incentives to the prosumers as a deduction of what would have been collected. After deducting the incentives, the government tax collection from the energy transaction between the prosumer and the utility from the surplus solar energy fed to the grid was evaluated by using Eq. (12) for all the selected countries considering the two SoG scheme scenarios. Fig. 13 shows the recorded government tax collection per unit of the solar PV energy fed to the grid by the prosumer under the SoG scheme scenarios.

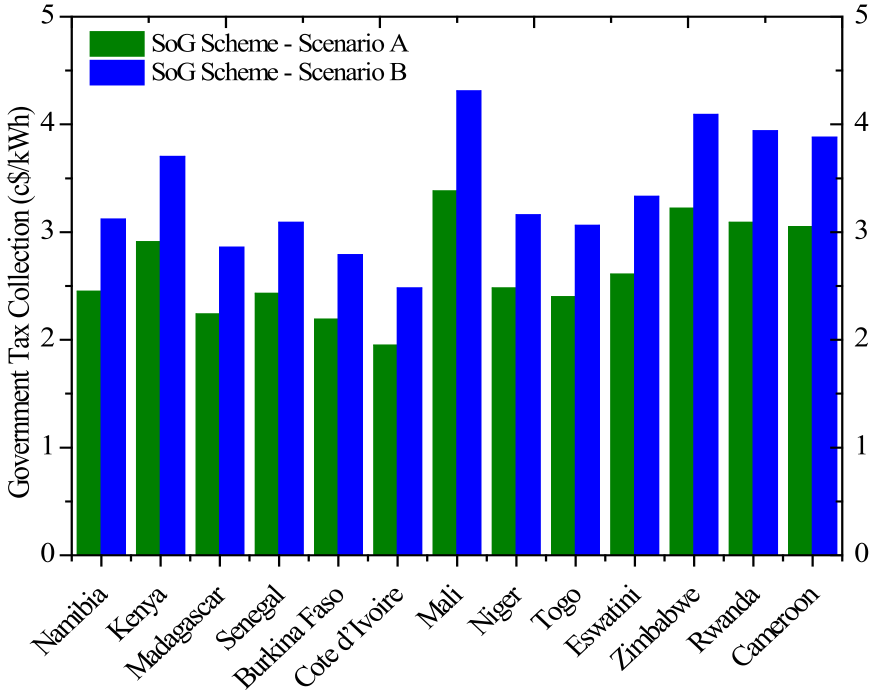


Fig. 13: Government Tax Collection from Solar PV Energy Fed to the Grid by a Prosumer under the SoG Scheme Scenarios

Of all the selected countries, Fig. 13 reveals that the government tax collection would be lowest in Cote d'Ivoire and highest in Mali for both SoG scheme scenarios. The government tax collection is in the range of 1.95 – 3.38 and 2.48 – 4.31 c$/kWh for scenario A and scenario B, respectively, for the selected SSA countries. Considering the government tax collection in Fig. 13 and the store-on grid rate P_{fee}^{SoG} as well as the $LCOS$ of the BESS in Table 8, the sum of government tax collection and store-on grid rate is less than the $LCOS$ of the BESS for all the selected countries. Thus, this indicates that the government might not be able to directly recover its costs incurring in facilitating the installation of the BESS under the SoG scheme. However, it should be noted that because of power outages, SSA countries lose about 2.1% of the GDP, and the total sales of the African firms fall by 4.9% compared to when the electricity supply is dependable [20]. Thus, although the governments might not necessarily recover their expenses on the BESS directly under the SoG scheme, the firms' sales are stabilized which in return generate more revenue for the governments as well as foster the GDP growth.

5 Conclusion and future works

In this study, the SoG scheme model for community-shared energy business initiatives was applied across 13 selected SSA countries to investigate its viability as an energy business model to foster the adoption of rooftop solar PV technology in the industrial sector. The SoG scheme was applied based on two scenarios of solar PV module prices. Using the specific data of the selected SSA countries applicable to the SoG scheme as well as their ToU schemes for the industrial sector end-user tariff structure, the viability of the SoG scheme was assessed. The results of the SoG scheme were compared with the results of the ToU scheme, and the following are the key finding of the study:

- Under scenario A, the SoG scheme is viable in nine out of 13 selected SSA countries, namely, Namibia, Senegal, Burkina Faso, Mali, Niger, Togo, Eswatini, Rwanda and Cameroon, mainly because these countries have a relatively lower LCOE of solar PV systems in comparison to their ToU rates for electricity. On the other hand, under scenario B, the SoG scheme is only viable in four countries, namely, Namibia, Senegal, Togo and Burkina Faso. Given that the LCOE is dependent on the solar PV module prices, thus, under scenario B for which the module price is higher than that of scenario A, the LCOE of solar PV systems becomes relatively higher than the respective country's ToU rates for electricity. Hence, in some countries such as Mali, Niger, Eswatini, Rwanda, and Cameroon, where the SoG scheme was viable under scenario A, the scheme ends up becoming inviable under scenario B.
- For both SoG scheme scenarios considered in this study, the scheme constraint in Eq. (8) is violated for the case of Kenya, Madagascar, Cote d'Ivoire and Zimbabwe. For the case of Cote d'Ivoire, a slight decrease in the solar PV module price could guarantee feasibility of the scheme. However, for Kenya, Madagascar and Zimbabwe, there is a necessity of improved financial access through soft loans with low lending interest rates in addition to a decrease in solar PV module price. As mentioned in the competitive strategy block in Fig. 3, incorporation of soft loan with lower interest rates could make the SoG scheme viable in most of the developing countries. Thus, the policy makers should devise means of establishing soft loans with low lending interest rate dedicated to fostering the deployment of solar PV technology.
- Some of the SSA countries, the ToU rates do not reflect the unit cost of energy generation because of the existent government subsidies. Thus, the comparison of the ToU rates and SoG scheme remains tricky in such circumstances where there are

subsidies on the conventional energy technologies. Therefore, the policy makers in the developing countries could revise the existent government subsidies on the fossil fuel-based electricity generation and direct them toward the deployment of solar PV technology.

- On average, 26.83% of the generated solar PV energy is fed into the grid annually. The least share of the annual energy fed into the grid is 15.65% for the case of a solar PV system in Cote d'Ivoire, while the highest share of the annual energy fed into the grid is 39.25% for the case of a solar PV system in Namibia. Generally, most of the generated solar PV energy is self-consumed by the prosumers under the SoG scheme, guaranteeing some level of energy security to the prosumers. Thus, the deployment of the distributed energy generating systems under the SoG scheme could be crucial in mitigating the persistent power outage challenges in the SSA countries that greatly affect the firms' sales and the countries' GDP.
- Overall, the SoG scheme model exhibits greater potential as a billing scheme for an energy business model to foster rooftop solar PV technology adoption in developing countries. Therefore, developing countries that previously had the FiT scheme struggle and fail to achieve set targets could adopt the SoG scheme. Challenges such as unattractive low rates that were offered under the FiT scheme in the developing countries are addressed under the SoG scheme through the governing constraint of the scheme in Eq. (8). The SoG scheme constraint ensures that the feed-in rate is always slightly higher than the LCOE for solar PV systems, but lower than the utility retail rate under the SoG scheme.

In this study, only the industrial sector electricity customers were considered. In the future, the investigation should be extended to the residential and commercial sectors to examine the viability of the SoG scheme as an energy billing scheme for energy business initiatives for fostering rooftop solar PV technology adoption in developing countries. Also, the study should be extended to other developing countries in other continents to examine the suitability and appropriateness of the SoG scheme model in those places.

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