

Adaptation of Feed-in Tariff for remote mini-grids: Tanzania as an illustrative case



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ABSTRACT

Following the successful Feed-in Tariffs (FiTs) system worldwide, few countries have implemented FiTs explicitly tailored for off-grid or mini-grid systems. This study takes an integrated approach to examine the feasibility of an off-grid Feed-in Tariff (off-FiT) for existing and new remote mini-grids in Tanzania, using a combination of geographical analysis, technical, economic and institutional assessments. Based on detailed modelling of two community off-grid cases, (i) PV-diesel and (ii) mini-hydro, we identify least-cost rural electrification options that make solar and mini-hydro energy competitive with diesel generators and potential effect of the support scheme on rural electrification plans. In the first case, we illustrate where the off-FiT complements diesel generation of an existing mini-grid (PV-diesel). In the second case (mini-hydro), we illustrate conditions where the off-FiT policy brings mini-hydro generation to non-electrified communities and sells renewable electricity directly to new customers.

Currently, Tanzania has Standardized Power Purchase (SPP) rates, which target generators connected to the national grid and distribution systems of mini-grids or isolated grids. We found for the off-FiT tariff the total amount needed to support the same number of customers by solar and hydro-mini grids versus diesel would be of 31.5 million US\$, or a premium of 0.11 US\$/kWh to the present current SPPs tariff of 0.24 US\$/kWh for PV. We also found that a technology specific FiT tariff would be most suitable to attract national and international investors by providing a rate of return that compensates the risk of the investment. The overall support is comparable to the 36 million US\$ that the government currently subsidizes and allocates to diesel mini-grids in country, and this shows the potential for a long-term renewable energy strategy for mini-grid areas.

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1. Introduction: Feed-in Tariffs for renewable energy in Africa

There is a growing interest in promoting renewable energy development in Sub-Saharan African countries as a way of providing a more independent energy pathway that transitions from dependence on external resources. Renewable energy generation in Sub-Saharan Africa can offer off-grid electrification in rural areas where national grids are non-existent [1,2]. Renewable energy can also play a role in decarbonizing national electricity supply and diversifying the energy mix. Renewables can provide revenue for household and community level energy technologies to make a contribution to national generation and expand energy access. In Tanzania only about 14% of the population has access to electricity, with only 3% in the rural areas [3]. There is a wide array of technologies and possible technical solutions that provide electricity services to rural consumers. These solutions range from an individual system to power a single house, to a mini-grid that can electrify a whole village. Effective policy mechanisms for renewable energy promotion are needed to develop and expand renewables in a Sub-Saharan African context [4]. This study focuses on the application of renewable energy to mini-grids limited to systems above 10 kW and up to a few MW [5].

1.1. Generic FiT

Traditional Feed-in Tariffs (FiTs) have been one of the most successful support mechanisms to increase the deployment of renewables in national electricity grids and its application is rapidly spreading [6]. Because renewable energy technologies' costs have reached around grid parity, many developed countries have adjusted their FiT rates. Globally, there are more than 80 countries where such traditional FiTs are in use [7]. Feed-in Tariffs policy encourages the introduction of renewable energy through fixed electricity payments per kWh produced by renewable resources (most commonly solar, wind, geothermal and small hydro), which is "fed into" the grid [6]. A typical Feed-in Tariff often differentiates the rates by technology category. Within the traditional FiT model, payments are usually covered by re-distributing costs amongst all electricity end-users.

1.2. FiT in Africa

In this last decade, traditional FiTs have gained increasing attention as a renewable energy policy mechanism especially for developing countries [8–11]. Competitiveness in developed countries allows for reduced FiTs, however, in developing countries as the users pay lower prices, the FiT mechanism can alleviate the price difference. Several African countries have already introduced the FiT policy (such as Algeria, Kenya, Mauritius, Rwanda, South

Africa, Tanzania, and Uganda) and many proposals are underway, either developing their FiT or planning: Botswana, Egypt, Ethiopia, Ghana, Namibia, and Nigeria [12]. However, the different context of applying FiT programs in African environments demands additional analysis. Power sector reforms have been under way for many years, and the new systems are built on shifting regulatory institutions and goals. Access and affordability are paramount concerns, adding complexity to tariff design. Energy governance and finance are connected to international institutions and development aid, so tariff changes face constraints, but at the same time, some additional potential opportunities for allocating financing [13].

1.3. Feed-in Tariff for promoting rural electrification: a viable option?

In many African countries, the utilization of various renewable energy sources represents the least-cost option for rural electrification [1,14]. Traditionally the promotion of renewable energy technologies in rural areas has been supported by international donations or governments subsidizing the initial capital investment of generation technologies. Unfortunately, this has not been adequate for improving the access to modern energy in Tanzania, or Sub-Saharan Africa in general [15], and the traditional government policies based on the extension of electricity grid have achieved a limited success in increasing access to electricity [16]. Policy makers should not therefore assume that a Feed-in Tariff policy for off-grid areas will incur significant additional costs over conventional technologies [11,17]. To ensure sustainability of systems, a FiT scheme for off-grid areas focuses on the cost of producing electricity, i.e. delivery of the service during the whole project lifetime (15–20 years), rather than just the delivery of the physical components of the project. By this, we can ensure that the funds will be available not only to commence a project, but to maintain its operation.

1.4. Aim

Tanzania is a particularly relevant case for examining the off-FiT scheme in Sub-Saharan Africa because of its broad institutional efforts to support renewable energy. Our study examines the feasibility of an explicitly tailored FiT that can support rural electrification in Tanzania where the existing regulatory and institutional context might need minor modifications. The so-called off-grid Feed-in Tariffs (off-FiT) is a variation of the FiT scheme for isolated areas and mini-grids that are not directly connected to the main national grid. Specifically, Tanzania has Standardized Power Purchase (SPP) rates, which are explicitly aimed at distribution systems in mini-grids or isolated grids. In the Tanzanian context, funds to support rural energy (the Rural Energy FundREF) including

rural electrification, are already collected through a levy on electricity sales, or by the involvement of international donors. It is therefore imperative to consider in the analysis of off-FiT for mini-grids in rural areas the context of legal, regulatory, and service-level changes. In our study we focus on adapting the existing regulatory framework to promote rural electrification using renewable energy mini-grids.

1.5. Research gaps

New approaches in financing energy delivery mechanisms and promoting diversification of energy resources are key areas for research. This study addresses (i) the need for increasing access to modern energy by a critical assessment of FiT for off-grid areas in the Sub-Saharan African context, (ii) the need for renewable energy regulatory/policy frameworks in Sub-Saharan Africa, (iii) the growing interest in climate projects in developing countries particularly enhanced investment in clean energy technology.

It appears that, at the moment, most of projects promoted under the SPP Agreements in Tanzania are grid-connected projects or few 'isolated grids' at the range of MWs. It is not clear how the current framework is strengthening the promotion of rural projects. In particular to what extent an increase in rural electricity access has been achieved at small village scale installations (15–70 kW) equipped with small-scale diesel, hydropower or solar run by cooperatives, municipalities or private NGOs. The identification of the lowest cost renewables and co-generation facilities for rural electrification projects is necessary to determine the energy option that can provide electricity (and optionally earn a commercial rate of return) at the utility's avoided-cost level.

1.6. Methods and structure of the study

This study takes an integrated approach combining geographical analysis, technical, economic and institutional assessments to examine the feasibility of the existing Standardized Power Purchase Agreements that cover remote mini-grids in Tanzania. The results of a spatial-economic analysis identify at country level the least-cost rural electrification options that can make solar and hydro mini-grid competitive versus diesel generator. The results of the spatial-economic analysis identify the potential effect of the off-FiT support scheme on rural electrification planning. For a detailed techno-economic analysis, we examine two cases: one when the SPP Agreements complement diesel generation of existing mini-grids (PV-diesel hybrid grid) and the second case (mini-hydro) when the Standardized Power Purchase policy brings electricity to communities without electricity and sells directly to new customers.

2. Renewable energy in Tanzania

The total installed power capacity in Tanzania adds up to 1185 MW, which is supplied mainly by hydro followed by gas and oil power sources [18]. Tanzania imports 100% of the petroleum fuels consumed and therefore depends on world market prices. The Energy and Water Utilities Regulatory Authority (EWURA) monitors fuel prices monthly by adding operating costs, tariffs and marginal profits to the world market fuel prices [19–22] (Fig. 1).

Oil prices in Tanzania have been historically volatile but prices have trended upward over the last 20 years reaching 1.48 US\$/l in 2011. If Tanzania relied primarily on diesel for rural electricity, it would have comparatively high generation costs when compared with PV (see Fig. 3).

Private power generation was legally initiated in 1992, when an independent power producer law was first enacted to allow private generators to contribute to the national grid and utility

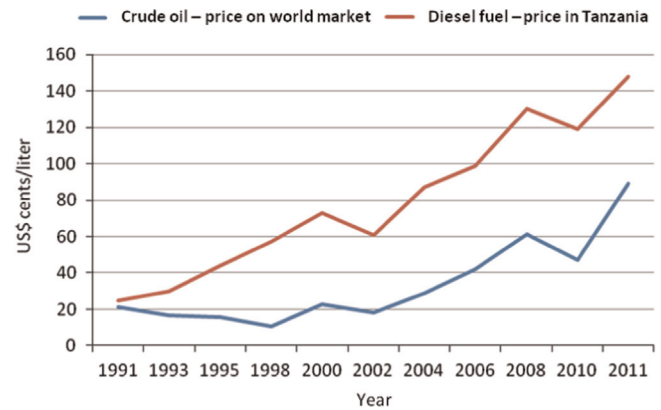


Fig. 1. Pump price for diesel fuel in Tanzania and crude oil price in the global market. Source: own compilation with data from GIZ; IMF, 2011; US EIA, 2012; EWURA, 2012.

supply, thus ending the utility monopoly in generation¹ [23,24]. Two fossil fuel IPPs were developed in the 1990s and early 2000s, with later emergency generation added in the mid-2000s. Since this time, interest has been directed toward renewable energy.

Tanzania is a country with a strong interest in exploring potential benefits of participating in the Clean Development Mechanism, CDM, defined by IPCC in the Kyoto Protocol [46]. In 2005, the CDM Executive Board determined that national policies implemented after 2001 are not considered in the baseline calculations [25]. Therefore, the combination of CDM and Feed-in Tariffs is possible without prejudicing CDM eligibility.

2.1. Establishment of the off-FiT scheme: Institutional and legal framework

Tanzania has been ranked among the top 10 countries in the world for establishing sustainable business models for renewable energy-based mini-grids [26]. To accelerate electricity access and promote the development and operation of small power projects among local and foreign private investors, the Government of Tanzania passed the Rural Energy Act, which established in 2005 a Rural Energy Agency and Rural Energy Fund (REA/REF) [27] to oversee the implementation of rural electrification projects.

Energy pricing is regulated by EWURA, the Tanzanian energy utility regulatory authority [28] that was also formed to oversee tariff issues and policies [29]. When the government established the Rural Energy Board, TANESCO was still a legal monopoly in the generation and supply of electricity. Private sector participation as envisaged by the Rural Energy Act became possible only after the liberalization of the industry through the Electricity Act of 2008. Though even after 2013 TANESCO remained vertically integrated, the Act opened the generation and distribution segments to industry players licensed by the EWURA Regulatory Authority [30].

In 2009 Tanzania introduced a Standardized Power Purchase (SPP) Agreement and in 2010 adopted a standard tariff methodology [28,31]. The SPP Agreement provides the legal basis to interconnect renewable energy generators into both the national grid or into isolated mini-grids, and to export excess power (up to 10 MW) to the national utility [4,32–34]. There are 21 isolated TANESCO-owned mini-grids and five Zanzibar Electricity Corporation (ZECO) owned mini-grids, based on existing diesel generation that SPPs have the potential to replace (either totally or partially) [15,9]. The SPP policy also allows IPPs to construct new

¹ The goal of the initial IPP law, at the time, was to catalyse new private fossil fuel generation to address capacity shortages at a time of state national fiscal crisis and donor movements away from financing public power generation.

isolated mini-grids to service communities without electricity and sell directly to new customers [4,35]. In the case of connection to isolated mini-grid, the Tanzanian SPP Agreements cover higher FiT for SPPs that sell electricity to TANESCO existing mini-grids.

The tasks of the Regulatory Agency, EWURA, include determining the SPP tariff and supervising power-purchase and service agreements, issuing licenses and guaranteeing to preserve the floor prices for 15 years.² To date, EWURA approved 40.1 MW of Small Power Purchase Agreements with biomass (15.6 MW), solar (2 MW) and hydropower plants (22.5 MW); 25.4 MW are already supplying power to the main grid. Six of the 10 approved SPP Agreements are for isolated mini-grids assigned to 1 solar project (2 MW), 3 biomass plants (5.1 MW) and 2 hydropower projects (total 8.5 MW) and 3 more are in the pipeline (2 hydropower of 4.1 MW and 1 solar of 1 MW). In addition, there are 32 other SPP projects under development/preparation.

2.2. The choice of off-FiT values: tariffs based on avoided costs vs. generation costs

Most countries that apply traditional feed-in tariffs use the concept based on electricity generation costs to determine the incentive level according to the expected amount of electricity generated and the estimated lifetime of the power plant. As the electricity generation costs vary according to the renewable energy technology, most Feed-in Tariffs provide technology-specific rate levels [36]. The assumption behind the differentiated FiT values is that different technologies require different support levels to become worthwhile to invest. A flat rate is usually considered instead to be a mechanism that promotes the selection and proliferation of the most competitive (i.e. lowest cost) RE technology.

In the case of Tanzania, the current SPP pays a fixed rate for selling electricity to the national utility TANESCO's grid (at annual average value of 0.10 US\$/kWh) and a higher rate (0.25 US\$/kWh) for selling electricity to isolated mini-grids. It should be highlighted that off-FiT levels are below the cost of diesel for gensets.

We compare two different options to set the off-FiT values. First, under specific circumstances, an off-FiT set by the avoided electricity cost may be sufficient to support new renewable energy projects in off-grid areas. Second, in those cases where the utility's avoided-cost is not sufficient, the incentives are calculated by the electricity generation costs.

2.3. Tariff setting

EWURA uses the Standardized Tariff Methodology [31] to calculate the SPP electricity prices for grid-connected generators and isolated mini-grids. The SPP tariff methodology rests on the concept of avoided costs. By this principle, the methodology determines a tariff that is comparable to the cost of alternative options available to the buyer. More specifically, they are based on the average of the short-run and long-run marginal costs. TANESCO has many isolated grids supplied from fuel-powered plants in different locations of the country. The long-run marginal cost of Tanzania's grid-power (adjusted for losses) is the basis for the calculation of the avoided costs in the long-term as it has been envisioned that all the mini-grids would eventually be integrated

² Avoided cost: many renewable power generators find that they must work with a utility to determine the value of their power to them. There is no universal value. The value of power is location dependent. Avoided costs are the price that the utility would have paid if it had to produce the power itself or bought it. It is the cost it would pay if they did not buy the power from the renewable power provider. It serves as the "floor" price (a price specified in a market-price contract as the lowest purchase price of electricity, even if the market price falls below the specified floor price). If the renewable power generator is willing to sell power to a utility at the avoided cost or lower, it saves the utility from having to build a new generation source. The local rate payers benefit from this. They need not pay for the new plant costs.

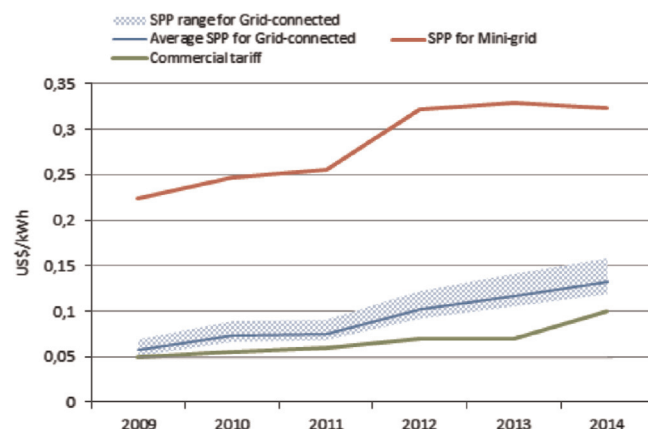


Fig. 2. Evolution of commercial electricity tariffs, standardized SPP tariffs for isolated mini-grids and SPP Tariffs for selling to the national grid (range between dry and wet seasons tariffs) in Tanzania. Sources: own compilation with data from EWURA 2009, 2011, 2012.

with the main-grid. EWURA has begun to revise the tariffs based on a cost of service study (2013) report. The result is that the tariffs for mini-grids are considerably higher than those for main grid generation [28,11]. Looking at the tariff increases (Fig. 2), for an SPP Agreement signed in the year 2011, the price cap will be 1.5 times the 2010 tariff subject to adjustment for inflation reflecting the Tanzania consumer price index [32–34].

3. Mini-grids' techno-economic analysis under off-FiT scheme

In this section, the analysis of the existing SPP framework is explored by calculating the off-FiT rates based on generation cost [36] and comparing the resulting electricity generation costs with the current SPP values. The techno-economic analysis is done for two specific technologies at the country-level (Section 3.1) and under two hypothetical operational frameworks at the community level (Sections 3.2.1 and 3.2.2). This is because the SPP rates may be not sufficient to support the integration of new renewable energy technologies (as PV) into the conventional ones or to bring electricity to new communities through renewables.

3.1. Spatially explicit techno-economic analysis at country-level

3.1.1. Methodology

The off-FiT scheme is only one part of the wider rural electrification planning and to be effective it must be equally integrated with resource planning, operations and transmission, and electrification plans. To illustrate geographically the most economically viable option for off-grid areas in Tanzania, and therefore to analyse the effect of the off-FiT rates, we developed a spatially explicit techno-economic analysis that identifies the least-cost rural electrification options in Tanzania.

The methods include spatial analysis and mapping that use the global and regional databases derived by functions of remote sensing, geographic information systems (GIS) modelling, satellite image processing and processing of long-term meteorological data. Geo-referenced data systematically collected on grid network, travel times to major cities based on transport network model, attributes of populated places and a derived dataset of permanent river courses have formed the boundary conditions of the model [1,16].

The methodology applies a novel approach to assess small hydro energy potential by using elevation and river network data previously employed in flood forecast based on four main physical components: distance to permanent water flows, river or surface gradient along the river, size of the catchment area belonging to each section of the river

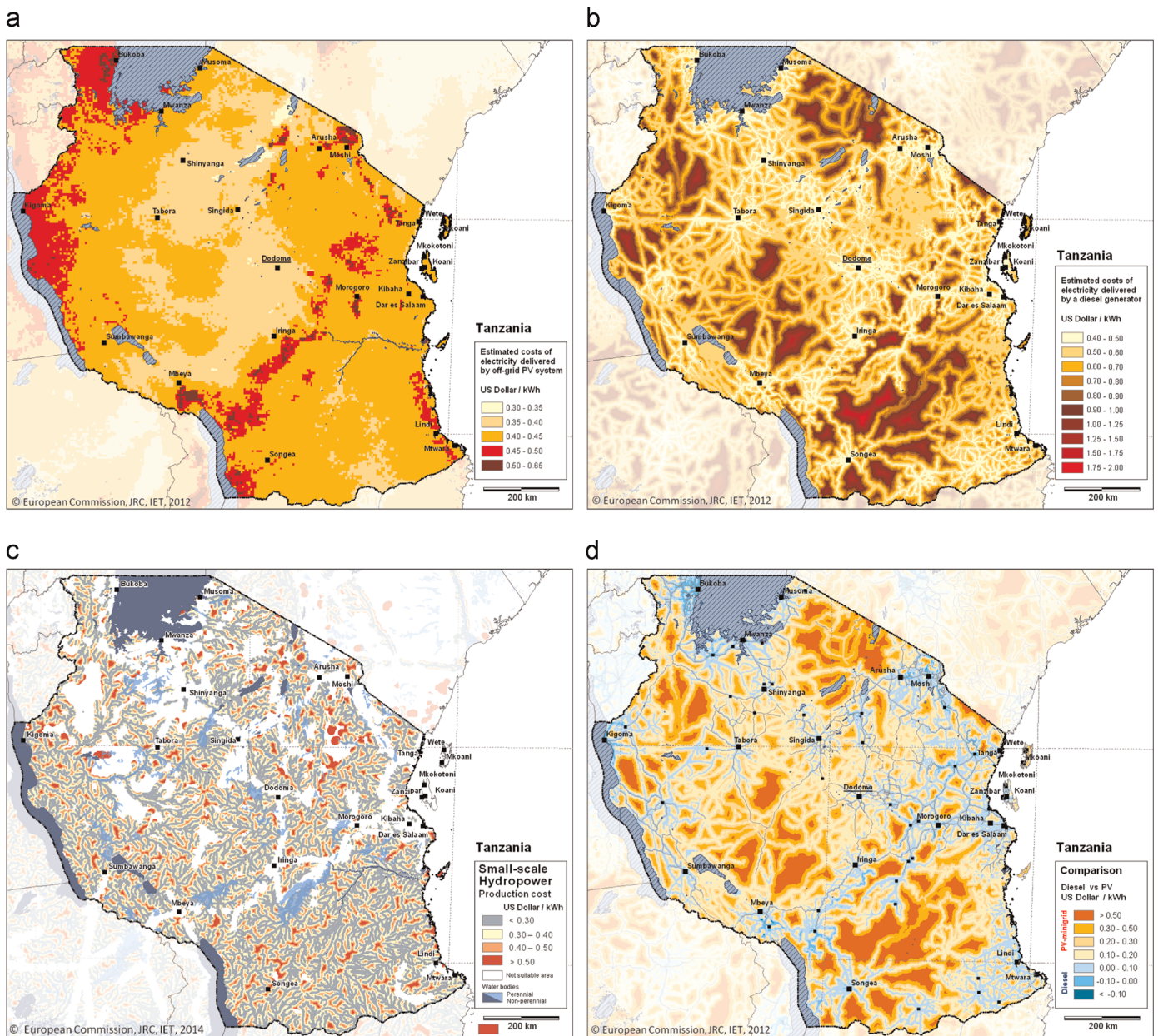


Fig. 3. Electricity production costs for different decentralized systems in Tanzania. The effect of availability of indigenous source on each technology's suitability. (a) Electricity cost: PV mini-grid. (b) Electricity cost: diesel genset. (c) Electricity cost: small hydro. (d) Comparison: Genset vs. solar PV. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

and the mean annual stream flow where it was available. The methodology is a simplified version of one applied in [37].

Solar energy production is modelled using solar radiation data derived from satellite (as solar irradiation field measurements are almost completely lacking in Africa). The algorithm used in the calculations uses hourly solar irradiance data (from 2009 to 2011), an optimized value of the PV array size and the battery size, and the calculation of the system performance ratio [38]. The input parameters for the calculation of the offgrid PV electricity costs are:

- PV module price: 1.4 US\$/Wp (2011); BOS components: 1.3 US\$/Wp.
- Batteries lifetime: 4 years; Battery price: 1.95 US\$/Ah (12 V).
- Operation and Maintenance (O&M) annual costs: 2% of CAPEX.
- PV system lifetime: 20 years (FIT in Tanzania: 15 years).
- Specific daily shape of the electricity load pattern.
- 70% System performance ratio for the PV systems.

- System is optimized so that energy delivery will fail due to empty batteries on less than 5% of days.

The cost of electricity from diesel gensets used as backup is calculated taking into account:

- Lifetime of the diesel genset: 10,000 h, as an average generators visited would last from 1 to 5 years [39], with most of them ranging in the lower lifetime line. The lifetime varies according to the handling of the generator, i.e. its proper maintenance and adequate operation.
- National retail diesel price: 1.48 US\$/l (2011).
- Fuel consumption.
- Travel time to major cities.

The Levelized Cost of Electricity (LCOE) is viewed as the present value per-unit cost of electricity generated by the mini-grid. As the

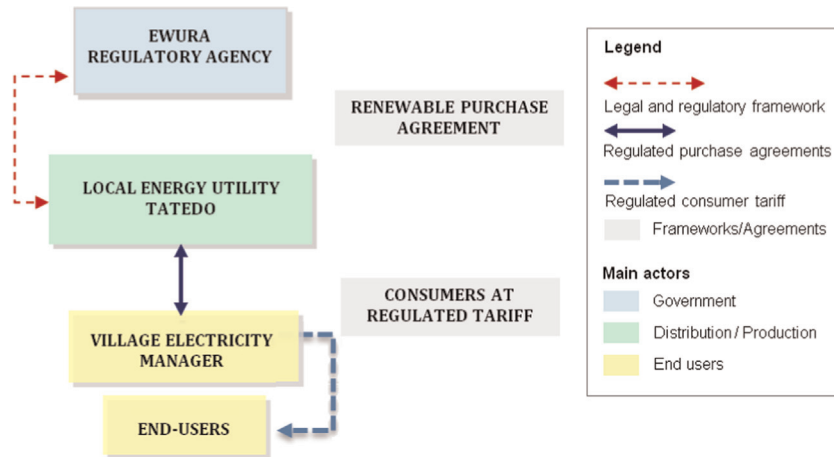


Fig. 4. Cost of electricity generated by diesel genset.

inflation rate varied between 3.4 and 19.8 percent during the last decade therefore we used US\$ in the analysis. By this we could avoid using inflation figures and high nominal discount rate (averaged at 12% peaked 21% in the same period) in the calculations. The application of high national discount rate would have made the comparison of the PV and diesel generation difficult as they are characterized by quite a different lifetime. The LCOE and the off-FiT values by the electricity generation costs are calculated assuming:

- Capital cost of construction of the mini-grid (including replacements of Balance-of-System (BOS)):
 - Lifetime of the hydropower plants taken into account the average lifetime in Africa [16].
- Fuel costs (in the case of hybrid mini-grids with diesel genset as backup).
- Inflation (when FiT rates are in national currency).
- Cost of capital as discount rate: 6%; depreciation: 5%/year,³ and variable profit margins for investors (see Sections 3.2.1 and 3.2.2).

It should be noted that the cost of electricity does not account for the additional distribution grid lines within the minigrid, nor for the cost of electricity meters.

3.1.2. Results

The SPP policy covers new mini-grids that can service communities without electricity. Fig. 3 geographically illustrates the production costs of three technologies for off-grid areas at country level and identifies the least-cost option from two isolated mini-grid alternatives. This geo-referenced analysis allows us to analyse the difference between a country level technology-specific cost-reflective off-FiT tariffs and the current values for SPP avoided costs of electricity.

Fig. 3a shows the geographical distribution of the cost of electricity (US\$/kWh) produced by a 15 kW PV mini-grid in Tanzania. The estimated costs of electricity generated by an off-grid PV mini-grid in Tanzania range from 0.30 US\$/kWh to 0.65 US\$/kWh, nevertheless for 90% of the country it would be less than 0.45 US\$/kWh. Costs related to the specific location project, such as expenses for licensing procedures, shipping, local taxes,⁴ handling, installation, and logistic have not been accounted as are highly dependent on the local conditions.

Fig. 3b illustrates the estimated cost of electricity generated by diesel gensets in Tanzania (ranging from 0.40 to 2 US\$/kWh). The total installed capacity of all isolated diesel mini-grids in Tanzania is 30 MW [40]. At the moment, the majority of settlements rely on TANESCO's

and Zanzibar Electricity Corporation's isolated diesel systems at high cost. According to TANESCO the isolated diesel mini-grids have a cost over 0.40 US\$/kWh (629 TSch/kWh) that accords within the estimated range of electricity costs generated by diesel gensets.

The result map, Fig. 3c, shows the economic differences within the area suitable for electricity production using small-scale hydropower systems.

The bluish areas in Fig. 3d show the location where diesel is more economically advantageous, while the reddish regions indicate where PV options are cheaper [14]. The results of the economic comparison highlight that if Tanzania would rely primarily on diesel generators as the rural electrification option would have comparatively high generation costs when compared with PV. The reddish regions, in Fig. 3d, represent where PV is the favourable mini-grid option with lower costs compared to diesel mini-grid in a range from 0.1 to 1 US\$/kWh. The state-owned utility TANESCO's electricity tariff is subsidized by the government, leading to a loss of 0.42 US\$ per generated kilowatt hour. Therefore, even without taking into account the SPP incentives TANESCO is saving money when investing in PV as an option for the promotion of rural electrification.

The off-FiT rates for isolated mini-grids under the SPP regulatory framework are designed higher than the grid-connected rates to encourage investment that supports electrification in rural areas. Moreover, under the SPP regulatory umbrella, when the SPP Agreement covers the delivery of electricity directly to new customers, the SPP is allowed to propose their own end-user tariff. When applying the current SPPs rates as off-FiT tariff, 0.24 US\$/kWh (380 TSch/kWh), to the isolated mini-grid the range of minimum prices (Eq. (1)) that would be incurred by the final users and high enough to cover costs are in the range of 0.06–0.41 US\$/kWh, with 0.11 US\$/kWh for majority of the population:

$$\text{User Price}_{\min} = \text{Cost}_{\text{tech specific}} - \text{off-FiT}_{\text{tech specific}} \quad (1)$$

3.2. Techno-economic analysis of mini-grids under the off-FiT scheme at community level

In this section, the economic impacts of the off-grid FiT value on the Net Present Value (NPV) (see Appendix), the payback time, and the Internal Rate of Return (IRR) (see Appendix), are analysed at community level under several operational and financial assumptions, to obtain an indication of which off-FiT values make the renewable energy mini-grid financially viable and the involved cash flows. In the NPV analysis, a 6% discount rate has been used to determine today's values of future off-FiT cash flow. When comparing alternative investments in the mini-grid, the project with the highest cumulative NPV is the most attractive from the energy

³ Influences the price of future battery replacements.

⁴ In 2005, the Government adopted the exemption of import duties and taxes on all components for PV modules and balance of system components.

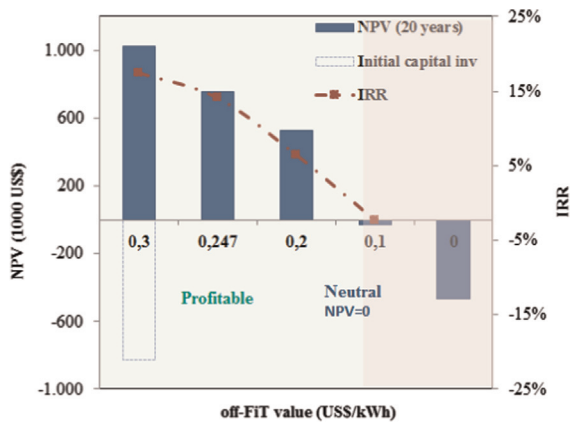


Fig. 5. off-FiT evaluation for isolated mini-grid. The NPV corresponds to each off-FiT value considered with their respective IRR(%). The reddish shadow area represents the non-profitable approach and the greenish shadow area for the profitable approach. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

investor perspective. The IRR approach determines the discount rate at which the cumulative NPV of the mini-grids is equal to zero. This means that the cumulative NPV of the costs of the running mini-grid equals the cumulative NPV of all mini-grid benefits under the off-FiT scheme, if both are discounted at the IRR. The analyses are derived using local data and local documentation so that others can later use the methodology to explore alternative assumptions. The analysis include scenarios for a commercial-profitable and for a non-profit perspective [39], each aiming to increase the use of renewable energy projects through different profitable approaches.

The techno-economic analysis at community level is performed under two hypothetical operational frameworks. In the first typology, the off-FiT scheme supports bringing energy services to communities without electricity and sell directly to new customers. For this first typology, we have used a micro-hydro mini-grid as a case study (see Section 3.2.1). In the second typology, the off-FiT scheme complements the renewable electricity production from an existing diesel TANESCO mini-grid. For this second topology we use a PV-diesel hybrid mini-grid (see Section 3.2.2). For each typology, we analyse the off-FiT values taking the current SPP policy framework and compare to the existing SPP tariff values in Tanzania.

3.2.1. Bringing RE to non-electrified communities

A micro-hydroelectric case study has been adopted to analyse the SPP framework when bringing energy services to a community without electricity. The hydroelectric option illustrates a case study under a specific institutional and regulatory framework when the power producer is the same entity as the one producing and distributing the electricity directly to mini-grid consumers. For the analysis, a rural site in the Tanga region is selected (the Zege village located in the Usambara Mountains) where there is a proposed new micro-hydropower project. The hydropower project is owned and developed by the Tanzania Traditional Energy Development and Environment Organization (TaTEDO). Zege has 3118 inhabitants – 607 households – and it is surrounded by other six villages with the possibility of connecting to the hydropower plant [41]. According to the national rural electrification master plan there is no plan to extend the grid to Zege in the near future.

The project includes developing a 70 kW capacity micro-hydro power plant and installing a local mini-grid, distribution lines and independent metering to each commercial customer. The hydro-electric's installation and operating costs have been calculated using TaTEDO technical reports [41]. The optimization of the hybrid system configuration and the characterization of the costs

of the electricity generated have been calculated by using several software tools [42,43] and own-design spreadsheets.

The hydropower pilot case is used to analyse how the off-FiT scheme should be customized. The local electricity utility, in this case TaTEDO, would retain the ownership of the mini-grid and would be responsible for the electricity production, installing the electricity measuring devices for controlling the amount of electricity generated by renewable energies (Fig. 4). The regulatory agency, EWURA, would offer the legal and regulatory off-FiT frameworks – including the Standardized Power Purchase Agreement – to the local electricity utility to install the mini hydropower and connect the users to the mini-grid. EWURA would adjust the off-FiT tariffs annually and would guarantee the values for up to 15 years.

For the financial flows we considered the promotion of RE use. Under this hypothetical context, EWURA would provide through the local energy utility the off-FiT incentive per kWh produced by renewable energies. EWURA determines and covers the total amount of incentives generated per year through the local energy utility. Moreover, the local energy operator has the responsibility of installation, operation, and maintenance of the mini-grid. The local energy utility (TANESCO) charges below the production cost to the end-users at the nationally regulated consumer tariffs, ranging from 0.04 to 0.20 US\$/kWh for domestic use (see results in Section 3.2). The potential case of cooperative ownership does not require any specific profit and the revenue accrued would be used for maintenance of the plant and village development activities. Financing the necessary additional sums enables numerous customers to afford access to electricity and allows the hydropower owner a guaranteed value during the entire off-FiT period (the same 15 years period) as that established for power-purchase agreement.

The techno-economic analysis compares the off-FiT rates set by the generation costs with the rates set by the avoided cost. When the project presents the highest cumulative NPV will be the most attractive perspective from the energy investor. The results are presented not as precise predictions, but as an indication of the actors involved in the incentive scheme and the cash flows involved. The NPV and IRR have been calculated for a range of off-FiT values (from 0.1 US\$/kWh to 0.4 US\$/kWh), using the domestic use tariff of 0.07 US\$/kWh, cost and revenue streams over a 15-year period. The analysis determines the minimum off-FiT value that makes the project financially viable ($NPV > 0$) and the off-FiT value to obtain a non-profit outcome ($NPV = 0$).

Fig. 5 shows that the off-FiT scheme for the specific isolated hydropower plant with optimized values from 0.15 to 0.3 US\$/kWh results in positive NPV and with IRR between 5 and 25%, which simply can be considered as a 5–25% positive return. Deutsche Bank reported that equity return expectations for infrastructure investments can be near 8%, but that the return expectations for a comparable project in a developing country may be higher than 20% because of political, counterparty, legal, and currency risks [10]. Under these assumptions, when off-FiT value is higher than 0.25 US\$/kWh,⁵ 20% return or higher can be considered as attractive for the investors. For a non-profit approach, with $NPV = 0$ and interest rate of 6%, the minimum off-FiT value required is at the range of 0.15 US\$/kWh.

The results compare the hydropower mini-grid with (A) and without (B) the off-FiT support mechanism in terms of total costs and the average incentive costs relative to the end-user price for electricity. The results indicate that in the particular case of applying the optimized off-FiT values, the off-FiT mechanism can provide the least costs to the community over a 15-year period.

⁵ When using a diesel-alone system and under the same electricity demand the subsidies needed to cover the difference between end-user prices and real cost ranging from 0.06 to 0.2 US\$/kWh.

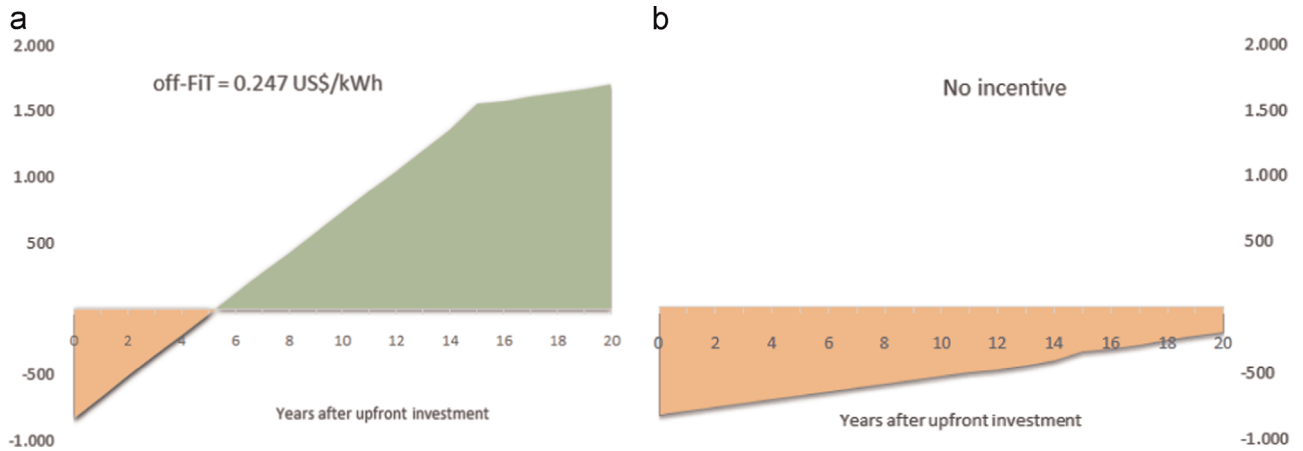


Fig. 6. Cumulative cash flows with and without off-FiT incentives (neutral approach). (a) off-FiT equivalent to SPP value. (b) Projects without incentives.

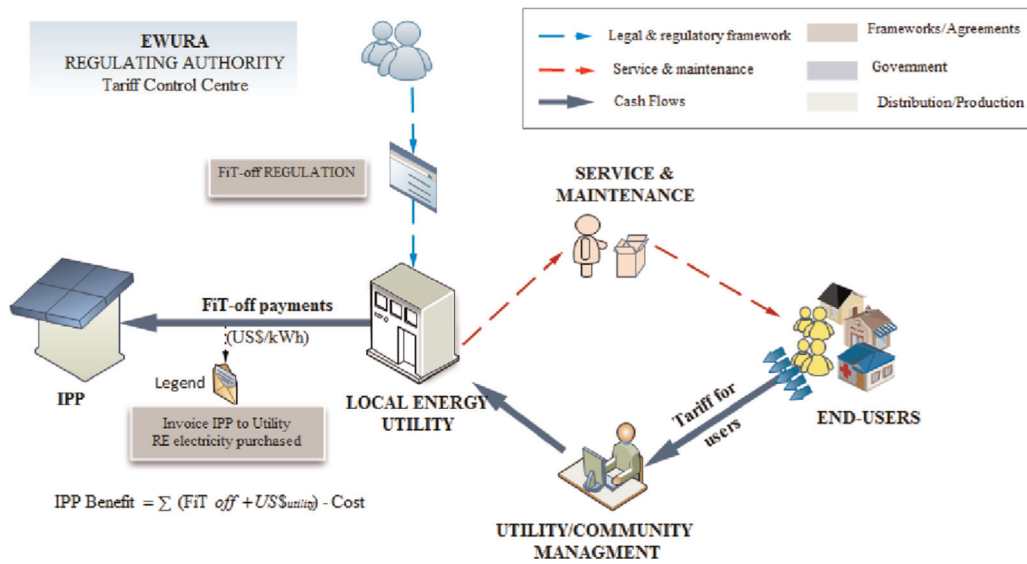


Fig. 7. off-FiT scheme for isolated mini-grids when the renewable electricity producer is a IPP and sells the renewable energy power directly to the local utility.

The overall objective of the Zege project is to contribute to poverty reduction by introducing decentralized electricity generation to the area for productive use for small-scale enterprises and households. The consumer tariffs at national level range from 0.07 to 0.12 US\$/kWh from domestic to commercial use. If off-FiT value was equivalent to the SPP of 2012, the Tanzanian off-FiT would be enough to make affordable the electricity prices when supporting a small hydropower project such as the one in Zege. Without the incentive, the real electricity costs would not be affordable for the majority of remote customers. Therefore, in the case of an existing off-FiT tariff the Local Energy Utility would charge below the production cost to the end-consumer (Tariff user) and at the same time the regulatory agency would assure to the Local Energy Utility the additional incentive per kWh produced by renewable energies for the 15 years.

Fig. 6a and b shows how financing the necessary additional sums enables numerous customers to afford access to electricity and allows the Local Energy Utility to reinvest the benefits in the community.

3.2.2. Bringing RE to an existing diesel mini-grid community

A PV mini-grid with a diesel genset backup has been adopted as a case study to analyse the SPP framework when bringing energy

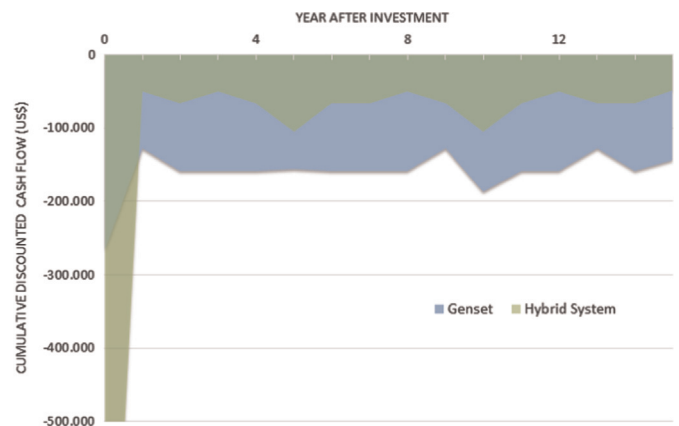


Fig. 8. Cumulative discounted cash flows: PV-hybrid vs. diesel mini-grid.

services to a community already electrified by a diesel mini-grid. This case study illustrates the off-FiT scheme under a specific institutional and regulatory framework, when a producer of renewable electricity sells power to one of the diesel mini-grids

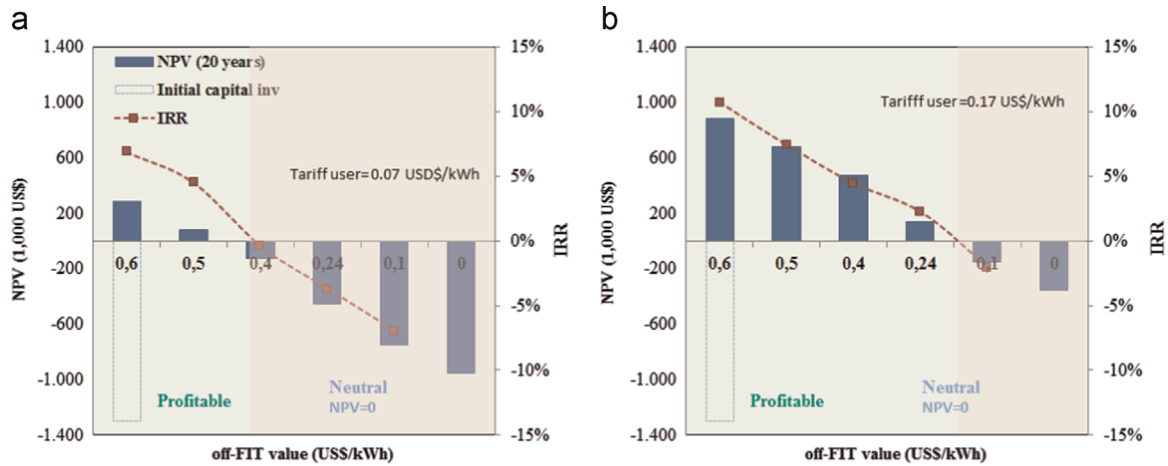


Fig. 9. Economic evaluation of the off-FiT scheme under two different user tariffs. The NPV values correspond to a range of off-FiT values (from 0.6\$/kWh to 0) and their respective IRR. Shading colours distinguish profitable from non-profitable approaches. (a) Tariff user of 0.07\$/kWh. (b) Tariff user of 0.17\$/kWh. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

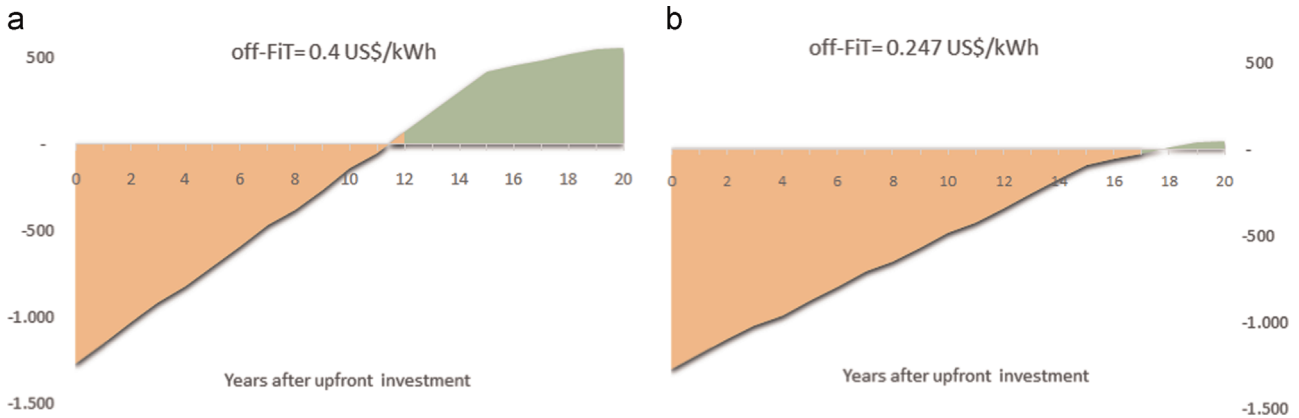


Fig. 10. IPP investor's cash flows in two different approaches (20 years). (a) Neutral: off-FiT = 0.4\$/kWh. (b) off-FiT corresponds to SPP value.

owned by the national state utility (TANESCO). The optimization of the hybrid system configuration and the characterization of the costs of the electricity generated have been calculated by using several software tools [42,43,38] and own-design spreadsheets.

For the 12 isolated TANESCO-owned mini-grids, SPPs will replace, in whole or in part, existing diesel generation [15,10]. Under the existing diesel genset mini-grids the national utility is subsidizing every kWh of diesel generation. However, under the new SPP, when renewable energies are incorporated to the diesel mini-grid, the SPP tariffs are set lower than what the utility has to pay for diesel generation, but enough to attract renewable energy developers. In this case, the national regulator, EWURA, could provide the independent power producer (IPP), a FiT scheme including the renewable energy purchase agreement, SPP. At the same time, the regulatory agency offers the legal and regulatory SPP frameworks for IPPs to install the PV system (or wind, biomass, small hydropower, and geothermal power generation technologies) connected to the existing diesel mini-grid (Fig. 7). In this case it is straightforward to adapt the purchase agreement to an off-FiT renewable energy agreement, where the production of renewable electricity gets a supplementary value. Fig. 7 illustrates operational configuration when the independent power producer (IPP) is distinct from the mini-grid operator responsible for the distribution and supply of electricity, the local electricity utility.

Under this regime, when the IPP owns the renewable energy facilities, the local energy utility owns the mini-grid and purchases from the IPPs the electricity produced. The local energy utility operates according to various requirements from the regulator and

the customers, and the regulatory body creates the policy umbrella to support the off-FiT.

The IPPs would receive a payment at the avoided cost rate from the utility, which recover its costs through standard channels. For the financial flows EWURA could provide the incentive tariff to the IPPs per kWh produced by renewable energies. The IPPs sell renewable electricity to the local energy utility under the renewable purchase agreement. EWURA would determine and cover the total amount of off-FiT incentives generated per year through the local energy utility, the IPP has to report to EWURA, and then EWURA makes a technical analysis of the report and determines the amount of off-FiT incentives that will be given to the IPP. Moreover, the IPP has the responsibility of installation, operation, and maintenance of the connected system. In most isolated areas, the real electricity costs are not affordable for the majority of remote customers. Therefore, the local energy utility charges below the production cost to the end-users at the nationally/regionally regulated consumer tariffs. Customers in return expect a certain quality to the delivery, as well as affordable prices. Financing the necessary additional sums enables numerous customers to be able to afford access to electricity and allows the Independent Power Producer owner of the renewable energy technologies a guaranteed value during the whole of the FiT period established. In the case of cooperative ownership (i.e. municipalities), the company is owned by the customers and therefore does not require any specific profit.

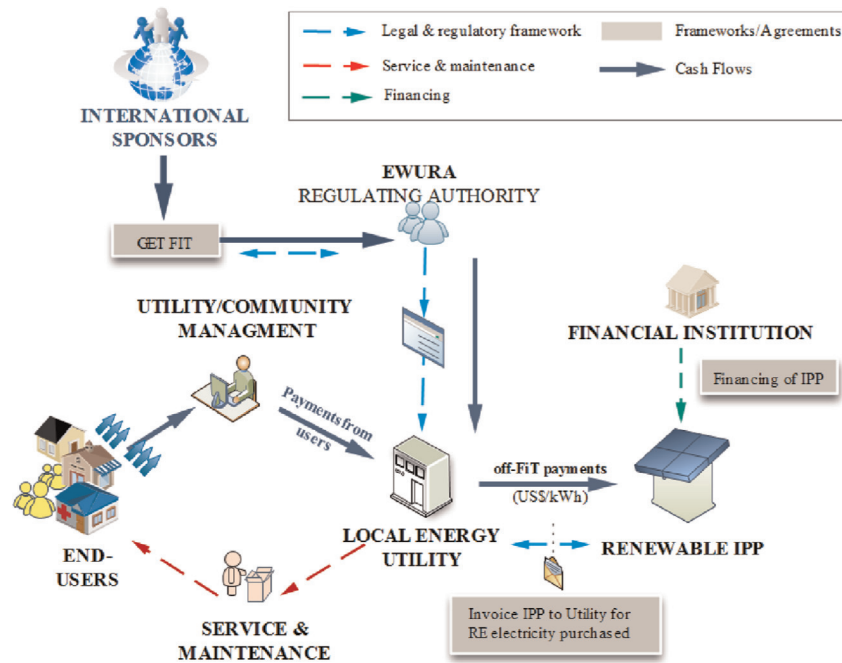


Fig. 11. Village-scale mini-grid under the off-FiT scheme. Premium payments provided by GET FiT to IPP through the governmental regulatory agency and the local utility.

In this case study, the IPP invests in the photovoltaic system and BOS considering that the PV system is being connected to an already existing diesel genset mini-grid. The manual cost and distribution and meters costs are included. Fig. 8 compares the cumulative cash flows corresponding to the initial capital, ray battery replacements every four years, diesel costs, and operating cost for two mini-grids in the case of having a diesel genset versus a PV system with diesel genset as a backup.

In this case the NPV and IRR analyses have been estimated under the IPP perspective therefore it has been assumed that IPP has invested in the photovoltaic system and BOS considering to be connected to an already diesel genset mini-grid. The NPV and IRR have been calculated for a range of off-FiT values (from 0.1 US\$/kWh to 0.6 US\$/kWh), using the user tariff (0.07 US\$/kWh) and revenue streams over a 15-year period (see Fig. 9a). The analysis determines the minimum Off-FiT value that makes the project financially viable and the value of off-FiT to obtain a profit outcome ($NPV > 0$) [39]. The financial analysis under off-FiT values between 0.5 and 0.6 US\$/kWh results in positive NPV and 5–8% return. The minimum off-FiT value required for a non-profit approach with $NPV=0$ and interest rate of 6% is around 0.45 US\$/kWh. When using a diesel-stand-alone system and under the same electricity demand the subsidies needed to cover the difference between end-user prices and real cost range from 0.4 to 0.9 US\$/kWh.

In order to reflect the effect of the user tariff on the NPV we have analysed the same configuration system but increasing the national consumer tariff (0.17 US\$/kWh) (see Fig. 9b). The minimum off-FiT value required for a non-profit approach with $NPV=0$ and interest rate of 6% is around 0.3 US\$/kWh. If the off-FiT rates would be upgraded, the new support scheme could bring electricity at an affordable price to the users from isolated areas (without need of increasing tariff), and at the same time could make renewable energy projects more attractive to implementers by decreasing the financial risk and to guaranteeing the recovery of invested capital.

In this case we can see that the Tanzanian SPP offers more certain revenues for IPPs of renewable electricity wishing to sell power to mini-grids than were available previously, but as the SPP tariff is based on avoided utility costs rather than on technology-specific costs plus profit the current SPP tariff value is not high enough to attract PV investors (Fig. 10). A successful off-FiT

depends on a tariff necessary to attract investors via a reasonable internal rate of return, in this case the value would be between 0.4 US\$/kWh and 0.5 US\$/kWh rather than 0.25 US\$/kWh. That suggests that a specified tariff by technology would be more appropriate to support the appropriate technology in the different off-grid areas depending on the natural resources available. Under these circumstances, when the marginal costs of user tariff and costs are higher than the SPP tariff it is unlikely that the incremental costs could be passed on to electricity consumers. Then grants from external donors or government funds would be needed to pay for the marginal difference. As suggested by Deutsche Bank Climate Change Advisers group [9] a possible way to cover the incremental necessary costs of the premium payment would be by a Global Energy Transfer Feed-in Tariffs (GET FiT). The GET FiT would provide the transfer of payments for FiT premiums from sponsors to developing countries and enabling rates to be based on generation cost rather than avoided cost [34] (see Fig. 11). In the situation of Tanzania a portion of the renewable energy premium payment per kWh of renewable electricity delivered can be recovered from a multilateral donor through the GET FiT. The development partners might enhance their support undertaking the necessary reforms for a coherent, transparent, and attractive investment framework. The GET FiT program would pass a direct incentive, equal to the premium required by generators above avoided cost, through the national government and utility to the IPP. Further research is needed regarding how the GET FiT would be structured and financed in Tanzania.

4. Discussion and conclusions

4.1. Current policy discussions

The lack of clear evidence of new contributions from renewable energy to the demand and supply of energy in Tanzania since the implementation of the SPP regime indicates that there still remains a policy gap. The current tariff regime for mini-grids does not attract enough project developers. For instance, the current SPP tariff seems adequate to attract small hydropower investors, but insufficient to attract photovoltaic developers. The PV and mini-hydro potential have

become an attractive option in rural electrification in Tanzania and together with a properly designed off-FiT scheme they can benefit the rural population. At the same time favourable technology prices and increased support of governments in Africa could assist the African countries to rely more on indigenous renewable resources. In the case of Tanzania, the off-grid Feed-in Tariff under the SPP program can offer a new alternative to expand energy access through the spread of renewable energy technologies in rural areas by covering the incentives for mini-grids.

4.2. Economic analysis

Under the umbrella of the off-FiT scheme, optimally designed mini-grids powered by renewable energy can provide the energy supply for communities at positive net present cost even in the case of high initial investment cost associated with renewable energy technologies. The results of the geographically least-cost option analysis highlight that if Tanzania would rely primarily on diesel generators as the rural electrification option, it would have comparatively high generation costs when compared with PV or hydropower.

The results of the analysis suggest that specified tariffs by technology would be more suitable to support the appropriate technology in the different off-grid areas depending on the natural resources available. An update of the tariff based on technology-specific tariffs and an enhanced capital subsidy scheme could attract national and international investors by providing a rate of return that covers the risk of the investment. This paper has provided insights indicating the range of off-FiT values that make an investment for renewable technology in an isolated mini-grid financially-neutral from a community point of view or profitable under an investor point of view. The economic impacts of the off-grid FiT value on the Net Present Value and the Internal Rate of Return have been analysed under two operational and financial assumptions to obtain an indication of which are the off-FiT values that make renewable energy mini-grids financially viable. As TANESCO consumers pay a uniform tariff (much lower than the cost of the running diesel generators) the higher tariff could be compensated by the newly calculated off-FiT tariff. This could be justified on the basis that the grid connection remains an unlikely prospect for the foreseeable future in many of the regions where mini-grids are most attractive.

When using the off-FiT scheme to promote rural electrification the long-term benefits outweigh the costs, even for the non-profit perspective. Currently the government spends in subsidies approximately 36 million US\$ annually for diesel mini-grids state-owned utilities (with a loss of 0.42 US\$ per generated kilowatt hour). In the case the off-FiT tariff was put in place (additional 0.11 US\$/kWh to the present current SPPs tariff of 0.24 US\$/kWh for PV) to replace the same amount of clients, the total amount needed would be of 31.5 million US\$ approximately leading at the same time to a long-term sustainable energy model. Moreover, the off-FiT as has occurred with grid connected FiTs are expected to be revised and lowered as projects flourish in the short term.

4.3. Decreasing risks

The traditional FiT schemes proved to be a very powerful incentive mechanism in many European countries. In fact, in some cases they triggered so rapid RE deployment that it had to be revised after only a few years. The rates were decreased and the RES technologies started to compete in the retail market offering reasonable alternatives for end users. This policy cycle could be even more attractive in Sub-Saharan Africa. A small producers market can be created based on local resources, and as soon as it reaches a critical level for finance, the off-FiT levels could be decreased. In Sub-Saharan Africa, where investors see very high risks, the global supported off-FiT schemes could alleviate the associated risks and reduce the financial cost of energy investments. We applied 5% discount rate in the analysis that does not

reflect these regional risks. The risk of currency devaluation could outweigh the benefits of the Feed-in Tariff as are usually paid in local currency. However, the application of the US\$ figures filter out the regional specific risks (inflation, devaluation, taxation changes). If these regional policy changes take place their effect will be reflected in the exchange rate changes, so will not affect the US\$ based calculation. In the implementation however the project developers have to take account of the possible exchange rate fluctuations (contractual clause). Moreover, the techno-economic analysis indicates that off-FiT can be a successful support mechanism for promoting investment in RE generation mainly because it can minimize the long-term financial risks surrounding individual projects.

If the off-FiT tariffs would be upgraded, the new support scheme could bring electricity to an affordable price to the users from isolated areas, and at the same time could make renewable energy projects more attractive to implementers, attracting private sector investment by decreasing the financial risk and guaranteeing the recovery of invested capital. To achieve these goals, it may be helpful for Tanzania to conduct a detailed assessment to identify whether international assistance from donor organizations would be appropriate for providing guarantee to the portion of the long-term incentive payments to projects, such as the Deutsche Bank GET FiT concept [9], which is currently looking for an implementing organization, and which has performed specific case studies in Africa and other developing countries [10]. Indeed, the implementation of GET-FiT in Uganda is already taking place, with incremental cost of renewables supported by the EU and implementation support from KfW. In the case of PV systems, the rural electrification program would need to cover the incremental costs of a technology-cost-specific off-FiT [33,34] in order to make the off-FiT policy effective.

4.4. Long-term benefits

It should be noted that renewable energy mini-grid projects often retain income in the local area, and boost the local economy through the provision of jobs. The NPV and IRR calculations consider only the directly quantifiable costs and benefits; consequently, the calculations do not take into account indirect economic benefits such as the employment of local people in installing and maintaining the technologies. Consideration of these benefits may improve the financial viability of small-scale schemes. A continuation of this research will study the social and environmental impacts taking into consideration the user's needs and creating productive uses. In addition, study the implications and the social benefits of mini-grids to reduce rural-to-urban migration by improving rural quality of life and increasing employment in rural areas [44,45].

Stakeholder acceptance can be strengthened by better illustrating real cost of RE mini-grids, possible impact on price levels for rural populations and highlighting the net effect of long-term benefits (minimizing dependence on imported fossil fuels, faster electrification, employment opportunities, etc.).

In a nutshell, the off-FiT scheme offers the opportunity to bring to rural areas a way to reduce the environmental and health external costs of fossil-fuel-based electricity, limit the consumption of fossil fuels bringing much lower operation and maintenance costs, and a higher energy security and energy flexibility through promoting the use of local resources.

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Appendix A

The NPV determines the sum of cash flows for a long-term investment:

$$NPV = \sum_{t=0}^n \frac{C_t}{(1+r)^t} \quad (A.1)$$

where

N	total time of the project
t	time of the cash flow (year)
r	discount rate
C_t	net cash flow at time t

To determine the Internal Rate of Return (IRR), the value of the discount rate is calculated when NPV equals to zero:

$$NPV = \sum_{t=0}^n \frac{C_t}{(1+r)^t} = 0 \quad (A.2)$$

To calculate the off-FiT value required for supporting the renewable electricity produced under a non-profit perspective, $NPV=0$, the following equation will be used in each optimized hybrid system configuration:

$$NPV = I_{inv} - \sum_{t=0}^n ((offFiT)_y + E_{rev}) - O\&M = 0 \quad (A.3)$$

where

I_{inv}	initial investment (US\$)
$off-$	FiT
$ye-$	arly sum of off-FiT Tariff (US\$/year)
E_{rev}	annual revenue from electricity tariff charged to users (US\$/year)
$O\&M$	yearly operation and maintenance costs (USD/year)
n	lifetime of project (in years)

The yearly off-FiT is calculated by

$$offFiT_y = PV_{eg} \times off - FiT \quad (A.4)$$

where

PV_{eg}	annual amount of electricity generated by renewables (kWh/year)
$off-$	FiT
	off-Feed-in Tariff value (US\$/kWh)

$$E_{rev} = E_{tot} \times T \quad (A.5)$$

where

E_{tot}	total electricity generated by the mini-grid
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T

tariff set to users

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