SWARM and SMART: Grid Development Dar es Salaam Summary Report

HIVOS

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Reference to part of this report which may lead to misinterpretation is not permissible.

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1 INTRODUCTION

HIVOS advocates a transition towards 100% green and inclusive energy systems that improve the livelihood, support social services and create economic opportunities and growth for all while mitigating climate change. As part of its Energy Change Lab HIVOS tries to develop new approaches to achieve this ambitious goal, with the basic premise that technical solutions exist but are not adequately implemented. Working with different stakeholders and especially with the users - both individuals as companies - is needed.

Looking at the situation in Tanzania HIVOS sees, on the one hand an insufficient load and failing grid system of the state energy company Tanesco and on the other hand a booming small scale solar panel private sector. However, there seems to be no connection between the two. HIVOS is interested in some scoping research on innovative grid options - combining the grid with off grid renewables - for peri urban areas of Dar es Salaam.

HIVOS wants an inventory of possibilities to improve the electrification of new districts of Dar es Salaam by stimulating and gradually integrating small scale PV developments via linking into and extension of the national grid of Tanzania.

This desk study is a first assessment of the possibilities for and issues connected to electrification in the context of Tanzania and Dar es Salaam. After this introduction Chapter 2 gives a brief description of the national context. Chapter 3 describes several issues that are relevant for electrification in Tanzania followed by possible scenarios for electrification in Chapter 4. The conclusions and recommendation are given in the last chapter, Chapter 5.
2 BRIEF DESCRIPTION OF THE NATIONAL CONTEXT

At present, 24% of the Tanzanian population is connected to electricity. Only about 11% of the rural population is connected to electricity services. The government plans to increase the connectivity level to 30% by 2015; 50% by 2025 and at least 75% by 2033. On average, demand for electricity is growing at 10-15% per annum. To foster the desired socio-economic transformation, universal access to modern energy services, in an affordable, reliable, sustainable and environmentally-friendly manner, is inevitable.

The country’s installed electricity generation capacity is 1,564 MW (as of March 2013), of which 1,438 MW is available in the main grid, with the balance of 126 MW accounted for by Small Power Producers (SPPs), mini grids, and imports. About 62% of grid generation capacity is from thermal (32% from natural gas and 29% from oil), whilst 35% is from large hydropower, with the remainder from small renewable-energy power and imports.

Capacity is supplied by the Tanzania Electric Supply Company TANESCO (59%), Independent Power Producers (IPPs) (26%), Emergency Power Producers (EPP) (13%), and SPPs (2%). TANESCO supplies power to the main grid, as well as to isolated grids. The 20 townships in other regions served by TANESCO depend on isolated diesel (18) and natural gas (2) generators and imports.

2.1 Institutional framework

Tanzania’s energy sector comprises various stakeholders, including national institutions, private-sector operators, and NGOs (Figure 2-1).

![Figure 2-1 Institutional Framework and Market Structure of the Electricity Sector](image-url)
The main institutions are:

**Ministry of Energy and Minerals.** The MEM is responsible for the policies to create an enabling environment for stakeholders. Promoting renewable energy is part of its mandate.

**Rural Energy Agency.** The REA is an autonomous body under the MEM that became operational in October 2007. Its principal responsibilities are to (i) promote, stimulate, facilitate, and improve modern energy access in rural areas of mainland Tanzania to support economic and social development; (ii) promote rational and efficient production and use of energy and facilitate the identification and development of improved energy projects and activities in rural areas; (iii) finance eligible rural energy projects through the Rural Energy Fund (REF); (iv) prepare and review application procedures, guidelines, selection criteria, standards, and terms and conditions for the allocation of grants; (v) build capacity and provide technical assistance to project developers and rural communities; and (vi) facilitate the preparation of bid documents for rural energy projects.

The electrification of the urban areas and of the off-grid program is part of REA’s responsibilities. Only the densification of the already electrified urban areas is excluded from REA’s responsibility.

**Tanzania Electric Supply Company.** TANESCO, a public company, is the country’s principal electricity generator, transmitter, and distributor.

The **Energy and Water Utilities Regulatory Authority.** EWURA is an autonomous, multisectoral regulatory authority established by the Energy and Water Utilities Regulatory Authority Act. It is responsible for the technical and economic regulation of Tanzania’s electricity, petroleum, natural gas, and water sectors.

### 2.2 Legislation and regulation

The **Policy Framework** consists of several acts, policy documents and tariff settings. To facilitate implementation of this legislation, EWURA has developed and implemented various rules related to regulation of electricity sector in mainland Tanzania. Information on legislation, rules and regulation can be found on the web site of the Regulatory Authority of Tanzania, EWURA (Electricity and Water Utilities Regulatory Authority - [http://144.76.33.232/](http://144.76.33.232/)).

The Tanzanian regulation is rather light, avoiding burdensome regulations and paperwork. The regulation gives a clear and transparent process for development and interconnection of an energy project. The application for interconnection of systems 10 MW and smaller is a straightforward 3-page document. If the project has a capacity of 1 MW or more, the SPP must obtain a license from EWURA. Smaller projects do not require a license, but EWURA still requires registration of the project for informational purposes.

EWURA regulates electricity sector by reviewing tariff applications from service providers and approving rates and charges for services provided. Since its establishment, EWURA has developed and put into operation various rules related to regulation of electricity sector in mainland Tanzania. Important to mention for grid development are The Electricity (Development of Small Power Projects) Rules, 2014.

All electrical works and goods installed or operated in Tanzania are required to comply with certain standards that EWURA has a responsibility to monitor. A catalogue of standards on electrical works is available on the EWURA website. Also requirements for license application, application forms, model PPAs and Standard PPAs (for SPPs) are available.
Of importance for grid development and RES:

- **Establishment of the Rural Energy Agency and associated Rural Energy Fund.** The REF gets support from the Government of Tanzania and to co-finance rural and renewable energy electrification schemes implemented by TANESCO and the private sector, NGOs and communities.

- **EWURA’s promulgation and application of the Small Power Producers Programme.** This is a system of regulations, standardised contracts, and avoided cost–based non-negotiable tariffs pertaining to private small (below 10 MW) renewable-energy power projects to supply the TANESCO grid and enable these entities to supply electricity directly to isolated rural communities. The Standardised Power Purchase Agreements (SPPAs), Small Power Producer (SPP) tariff methodology and tariffs, interconnection guidelines, and SPP implementation rules issued by EWURA enable private entities to invest in renewable power projects for both grid-connected projects and isolated grids.

- **Development of the Medium Term Strategic Plan (2012–16) and Power Sector Master Plan.** These plans reinforce the commitment to collaborate with and encourage the private sector to participate in the development of the energy sector, using various renewable and fossil-fuel sources to ensure national energy security.

### 2.3 Tariffs

An important incentive for direct involvement of suppliers of retail customers is the provision that small power projects selling to retail customers can propose their own tariff. The tariff regulation allows the operator to “... charge a tariff that, at a maximum, shall be limited to the sum of operating costs, depreciation on capital, whether supplied by the operator or others, debt payments, reserves to deal with emergency repairs and replacements, taxes, plus a reasonable return on capital provided by the operator that reflects the risks faced by the operator.” The tariff has to be approved by EWURA.

Incentives for indirect participation as power producer, who sells to the grid operator, are the Standardized Small Power Purchase Agreements (SPPA) for power generation projects with an installed capacity ranging between 100 kW\(^1\) and 10 MW and the Standardized Small Power Producer Tariffs (Feed-in-Tariffs) for the same range of projects. The Feed-in-Tariffs valid in 2015 and 2016 are shown below.

#### Table 2-1 Feed-in tariffs in 2015 and 2016 for main grid and mini grid

<table>
<thead>
<tr>
<th>Description</th>
<th>Prevailing 2015 Tariff TZS/kWh</th>
<th>Proposed 2016 Tariff TZS/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized Small Power Purchase Tariff</td>
<td>190.94</td>
<td>190.46</td>
</tr>
<tr>
<td>Seasonally adjusted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized SPP Tariff Payable in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season</td>
<td>229.13</td>
<td>228.56</td>
</tr>
<tr>
<td>Wet season</td>
<td>171.85</td>
<td>171.42</td>
</tr>
</tbody>
</table>

\(^1\) GIZ is trying to convince EWURA to change this threshold. Example of a smaller project is a SHELL foundation project for water and light of 10kW.
1 USD = 2175 TZS per 5 January 2016 and 1 USD = 2120 TZS on average during November and December 2015. The annual average SPP 2016 tariff for the main grid would then be 0.090 USD/kWh. The mini-grid tariff would be 0.225 USD/kWh. The main grid tariffs are 8% higher in TZS and 10% lower in USD than the 2013 tariffs. The mini-grid tariff is comparable to those in 2013 in TSZ but 25% lower in USD. This shows that there is a risk attached to these tariffs since they are updated annually.

A low social tariff is available to customers using less than 50 kWh a month. The connection fees however prevent lower income citizens to get connected. The one-off fees are now approximately TZS 177,000 (about USD$110) for a rural customer and TZS 320,960 (USD$200), for an urban customer.

2.4 Government driven strategies and plans

The United Nations (UN) Secretary General launched the SE4ALL Initiative in September 2010 to achieve three inter-related goals by 2030. Tanzania has a series of development and sector policies and strategies, which support the country’s progress towards the three SE4ALL goals: universal access, increasing the share of renewable energy (RE) and enhancing energy efficiency (EE).

Renewable Energy Strategy

The Scaling-up Renewable Energy Programme (SREP) – Investment Plan for Tanzania will support the RE development. On the power generation side, the Power Sector Master Plan of 2012 expects Tanzania to require massive capacity additions to meet the electricity demand envisaged for 2035. Although the potential for RE is significant, only 3% is considered to be included in the generation mix by 2035, excluding large hydro.

The SREP Renewable Energy for Rural Electrification Project aims to (i) build an efficient and responsive development infrastructure for renewable energy-based rural electrification, and (ii) demonstrate its effectiveness by supporting a time-slice of private-sector investments in off-grid electricity enterprises. The target is to extend electricity service generated from renewable energy to some 400,000 households or approximately 2 million off-grid rural customers through mini and micro grids and SSMPs.

It is expected that a range of renewable energy technologies will be used to meet electricity needs, depending on the renewable sources available in the particular location and on community characteristics. Micro grids and SSMP stand-alone systems will primarily use solar PV.

REA Prospectus

The Renewable Energy Agency (REA) has been the main driver for off-grid electrification in Tanzania. The REA Prospectus encompasses both grid and off-grid connection projects to provide access to electricity to Tanzania’s population. The on-grid aspects will be based on the development of turnkey

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2 Tanzania’s SE4ALL action agenda, draft of 1 August 2015
3 This might be developments Hivos may want to connect with
solutions following the government strategies and plans, and the off-grid based on mini-grids and
decentralised solutions based on small-scale RE projects and hybrid solutions. The Renewable Energy
Agency (REA) is also responsible for urban development.

**Sustainable Solar Market Packages (SSMPs)**

The Sustainable Solar Market Packages (SSMPs) is a contracting mechanism that bundles supply,
installation and maintenance of solar PV system for public facilities and incentives for commercial sale to
households, business and other non-government customers. It has been providing off-grid solar
electricity for public facilities and households. MEM in collaboration with REA has implemented the first
set of SSMPs (SSMP I) in Rukwa thus benefitting 82 villages and the model has been adopted as SSMP II
for projects in the regions of Kigoma, Geita, Kagera, Tabora and Ruvuma. SSMP II is being prepared for 8 districts within the regions mentioned above to be implemented by REA with TEDAP and Sida funding. The Tanzania SREP project aims to replicate this model.

**Incentives for Small Power Producers**

EWURA provides direct and indirect incentives for the participation of the private sector in rural
electrification:

- Small power plant (SPP) projects can propose their own tariffs when selling to retail customers – this
  incentive has the aim of promoting a direct involvement of SPPs to sell the energy produced in the
  form of a supplier to retail customers. Under this scheme, the operator can charge a tariff that “at a
  minimum, shall be limited to the sum of the operating costs, depreciation on capital, whether
  supplied by the operator or others, debt payments, reserves to deal with emergency repair and
  replacements, taxes, plus a reasonable return on capital provided by the operator that reflects the
  risks faced by the operator”. The tariff needs to be approved by EWURA;

- Exemption from licensing requirements for suppliers who conduct an off-grid and supply activity of
  less than 1 MW;

- Standardised Power Purchase Agreements (SPPAs) for producers of power generation projects with
  installed capacity ranging between 100 kW and 10 MW who sell to the grid and off-grid operator;

- Feed-in-tariff (FiT) systems in place to attract private investors to set up small power plants (SPPs)
  using RE. The FiT applies to small power producers that are connected either to TANESCO’s main
  grid or one of its 20+ existing isolated mini-grids. The FiT’s are specified by EWURA for both cases;

- Obligation or exemption from electrifying customers: depending on the capacity of the SSP, i.e., the
  SPP owner has no obligation to electrify customers in the area where the plant is located where the
  SPP capacities are below 1 MW. However, there are obligations where they have capacities
  exceeding 1MW.

**2.5 Solar energy in Tanzania**

Tanzania has high potential for solar energy, with 2,800 to 3,500 hours of sunshine per year, and a
global radiation of 4–7 kWh per m² per day. To make solar PV more attractive, the government has
removed the value added tax (VAT) and import tax for main solar components (panels, batteries,
inverters, and regulators), which has allowed end-users to get PV systems at a more affordable price.

Solar output is rather constant throughout the year and amounts to an annual output of 1800 kWh/kWp.
This is about twice the annual output realised in the Netherlands. The daily output has a reverse profile
compared to the energy consumption.
2.6 Opportunities

There are several opportunities in Tanzania that may also support the grid development in Dar es Salaam.

The Second Generation Small Power Producer (SPP) Framework is now effective from 1st April 2015. Some of the improvements compared to the First Generation are;

- SPPs will now receive a fixed tariff for the life of the SPPA, instead of a tariff that fluctuates annually based on Distribution Network Operator’s (DNO’s) avoided cost.
- FiTs for selling energy to a DNO will be based on technology-specific costs for hydro and biomass SPPs. Furthermore, for solar and wind SPPs FiTs will be based on bidding prices obtained through a competitive process to provide electricity buyers with the benefits of rapidly decreasing renewable technology costs. For both calculated FiTs and competitively bid FiTs, the cost-reflective tariffs will ensure the investor security by providing a fixed price for the duration of the SPPA, up to 25 years.

There is a number of Power Sector Reforms ongoing with investment in Electricity Generation, Transmission and Distribution. Also there is capacity building on energy conservation and demand side management.

Solar energy as a resource for electricity has good prospects due to a good solar insolation with 4-7 kWh/m²/day and due to decreasing cost for solar installations. These favourable circumstances apply also for small solar installation which may help grid development.

The presence of Sustainable Solar Market Packages (SSMPs) may help to expand the solar development. SSMP is a contracting mechanism that bundles the supply, installation and maintenance of PV systems for public facilities.
3 DESCRIPTION OF ELECTRIFICATION ISSUES

This chapter describes a number of issues regarding electrification starting with the classification. After that demand side management is briefly touched upon in section 3.2. The cost of electricity supply is briefly discussed in section 3.3 and section 3.4 touches upon some technical issues regarding Alternate Current (AC) and Direct Current (DC). Section 3.5 gives some ways of reducing cost in distribution network and section 3.6 is about small power producers. The last section of this chapter, section 3.7 gives an example of a system for Small Power Producers (SPPs) and an example of a grid concept for SPP.

3.1 Classification of electrification

The five states of electrification we distinguish are:
1. First state with individual PV installations used for (predominantly) lighting, charging of small equipment (mobile phones) and maybe refrigeration.
2. Second state where individual houses are linked and PV installations are extended to micro grids to also use electricity for heavier equipment like sewing machines.
3. Third state with micro grids interlinked to form mini grids.
4. Fourth state where mini grids are linked and to grids on city district level
5. Fifth state with full integration with the national network of Tanesco.

These states closely resemble the Tiers defined by The World Bank as shown in Figure 3-1 below.

<table>
<thead>
<tr>
<th>Tier-0</th>
<th>Tier-1</th>
<th>Tier-2</th>
<th>Tier-3</th>
<th>Tier-4</th>
<th>Tier-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak capacity</td>
<td>Power</td>
<td>No Electricity</td>
<td>V. Low Power Min 1 W</td>
<td>Low Power Min 50 W</td>
<td>Medium Power Min 200 W</td>
</tr>
<tr>
<td>Daily capacity</td>
<td></td>
<td>Min 4 Wh</td>
<td>Min 200 Wh</td>
<td>Min 1.6 kWh</td>
<td>Min 4 kWh</td>
</tr>
<tr>
<td>Duration</td>
<td>Hours per day</td>
<td>&lt; 4 hrs</td>
<td>Min 4 hrs</td>
<td>Min 8 hrs</td>
<td>Min 16 hrs</td>
</tr>
<tr>
<td></td>
<td>Hours per evening</td>
<td>&lt; 2 hrs</td>
<td>Min 2 hrs</td>
<td>Max 3 disruptions per day</td>
<td>Max 7 disruptions per week</td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>Voltage problems do not prevent the use of desired appliances</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affordability</td>
<td>Cost of a standard consumption package of 365 kWh per annum is less than 10% of household income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legality</td>
<td>Bill is paid to the utility / pre-paid card seller / authorized representative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health and Safety</td>
<td>Absence of past accidents and perception of high risk in the future</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-1 Access to Household Electricity Supply – World Bank Multi-Tier approach (source WB 2014)

In the following, the different states of electrification; stand-alone systems, micro/mini-grids and the national grid are described at a high level.

Stand-Alone (SA) systems

SA systems, in particular Solar Home Systems (SHS), have been widely promoted by various international donors, development agencies or local governments to target the most remote and

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scattered population. **Affordability**

reliability and sustainability of individual SHS have been widely criticised after so many programmes failed during the last 2 decades. Recently better and cheaper LED bases systems and innovative financial models (pay as you go) have been more successful. However, the service offered is limited and the SA systems are often considered as pre-electrification. Beside the common SHS usually ranging from 10 to 100Wp, there are other cheaper products as pico-solar.

**Portable pico-PV systems** have now reached much higher quality by incorporating highly efficient end use equipment. Most advanced pico-PV systems include not only LED lamps for lighting but also phone charging, radio and the possibility to gradually add other efficient appliances (some could be called a pico-grid system).

**Micro/Mini-grids (MG)**

Mini-Grids come naturally as an intermediate cost-effective solution for off-grid areas where population density can justify the provision of electricity through a local distribution grid, whatever the production source is.

The electricity service provided by a mini-grid can be limited to 2-6 hours a day usually when the fuel source (mainly fossil fuels & biomass) has a cost to be supported by the customers; Electricity availability can be 12-24 hours if the source is “free” and available 24h/day (hydro) or if a storage solution is available (solar and wind). The MG system offers a pre-electrification service that limits income-generating activities and its economic impacts. Over the last 20 years, many governments, power utilities and private industries have implemented mini-grids, mostly diesel-based MG and some hydro-based MG. Motivation was often more political or social than economic. The greatest MG development was observed in Asia.

**Conventional grid**

Although grid connection or extension in general remains the preferred mode of electrification worldwide, the situation in Tanzania with insufficient grid capacity is such that HIVOS looks for alternatives.

### 3.2 Demand side management

There is a large potential for energy saving through demand side management (DSM). Energy efficient appliances are commercially available and use much less electricity enabling a shift in consumption tier required for the desired services. This means that smaller and cheaper equipment can be used for the same service. An example of such more efficient appliances is super-efficient ceiling fan which uses only one third of the energy of a conventional fan.

On average the use of energy efficient appliances makes a full shift of one tier possible.

### 3.3 Cost of electricity

The existing SPPA is structured in two forms, one is for supplying power to the national main grid (power utility), and the other for supplying mini grids owned and operated by the power utility. This is being reviewed annually. The current SPPA for 2016 for small power producers up to 10MW is:

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5 Recently small firms have been successful in selling and maintaining SA systems especially in Tanzania. Both CSO and SME. e.g. women led organisations such as Solar sisters http://energia.org/2016/02/solar-sister-brings-light-hope-and-opportunity/

- SPPT for main grid: 9.0 US cents /kWh (TZS 190.64/kWh) and
- SPPT for Mini grids: 22.5 US cents /kWh (TZS 477.16/kWh).

The levelized cost of electricity (LCOE) of diesel generation, a PV battery system and a PV battery diesel system based on SREP\textsuperscript{7} are shown in the table below together with the gap between the LCOE and the FiT mentioned above. LCOE for PV are based on investment cost for PV panels and inverter of 2.6 USD/Watt.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Diesel generation</th>
<th>Solar PV battery</th>
<th>PV battery diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCOE in USD/kWh</td>
<td>0.59</td>
<td>0.71</td>
<td>0.53</td>
</tr>
<tr>
<td>Gap in USD/kWh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main grid FiT gap</td>
<td>0.50</td>
<td>0.62</td>
<td>0.42</td>
</tr>
<tr>
<td>Mini grid FiT gap</td>
<td>0.365</td>
<td>0.485</td>
<td>0.305</td>
</tr>
</tbody>
</table>

Prices of this equipment still drop and prices of fuel fluctuate, therefore a sensitivity calculation was made to determine the influence of these prices. The calculation method was not well described in the SREP document so it was decided to make our own calculations to compare the LCOE of the three options. The results will not be fully comparable with the ones found in the SREP document since we may use different assumptions on issues like interest.

**Figure 3-2** shows the results of DNV GL cost calculations for PV installations (PV sec) and PV-battery systems (PV system) with different investment cost compared to diesel generation with different fuel cost for increasing production factors. The production factor is the use of the installation in percentage of the maximum use in one year (maximum use would be 8760 hours at maximum generation capacity).

\textsuperscript{7} Scaling-up renewable energy programme (SREP) Investment plan for Tanzania, May 2013
In Tanzania, PV may reach between 15 and 20% production factor. The figure shows that solar systems may be competitive with diesel generation dependent on fuel prices and cost for PV systems. The gap with the feed in tariffs is large as shown in the table above. Solar energy however is getting cheaper and has the advantage of support systems like REF, SREP and SSMP.

3.4 AC/DC
The following applies for the choice between Alternate Current (AC) and Direct Current (DC):

- AC and DC coupling are common on hybrid mini-grids. However the selection of AC or DC depends on the load profile and the technologies to be coupled in the system.
- The existence of a battery (DC) and its role in the system also affects the decision on current type (AC vs DC).
- Single-phase distribution grids are cheaper than three-phase and can also allow productive uses. However, three-phase grids allow larger uses and the possibility of future connection to the national grid, but only if the mini-grid has the same technical standards.

Electricity losses in AC hybrid systems are approximately twice as large as the losses in DC systems. Also an AC micro-grid is about twice as expensive as a DC grid total Costs AC Microgrid: 165,595 USD compared to total Costs DC Microgrid: 86,580 USD) 8.

3.5 Low cost network design
In the National Electrification Program Prospectus9 possible low cost network design are studied. The objective was to determine whether there are MV and LV network designs that can be implemented at lower costs compared to those currently used. The reference is the current practice and the price of TANESCO’s standard LV and MV networks. The study used two approaches:

1. Lower costs obtained from technologies different to those currently used. The examined new technologies are:
   - Two-phase MV systems
   - Single-phase MV systems (two wire and single wire earth return – SWER)
   - Shield Wire MV Supply systems, SWS
   - Use of LV single-phase electric motors

2. Lower costs from the optimisation of the presently used technologies (changing mechanical dimensioning criteria and making maximum use of line elements.

The Prospectus has identified low-cost network design technologies which would reduce costs significantly. Low-cost network design should become a priority in project preparation. As resistance from TANESCO must be expected, the use of low-cost technologies will require Government support.

It is recommended that the MEM demands REA and TANESCO to prepare electrification plans which explicitly indicate (i) how standards of existing technologies have been improved or changed to reduce costs and what are the resulting cost savings and (ii) which electrification projects will use new technologies (for example, SWER or 2-phase MV) and what are the resulting cost savings.

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9 United Republic of Tanzania, National Electrification Program Prospectus, July 2014
3.6 Small Power Producers - SPP

Tanzania’s policy allows small power producers to supply electricity from both grid-connected and off-grid power supply systems. The Tanzanian Rural Energy Agency created TEDAP (Tanzania Energy Development and Access Project), which is funded by the World Bank and channels funds into subsidies, special collateral financing, preferential interest rates and technical assistance for grid-tied and off-grid projects. Small Power Producers (SPPs) with generation capacity of less than 1 MW are exempted from obtaining a licence but required to register with the national regulatory authority EWURA and they may be subject to ex post review of their tariffs upon complaint from 15% of their customers.

The Rural Energy Fund was set up to provide grants to support initial project preparation (in the form of a matching grant), as well as connection subsidies of up to 380 EUR per connection or up to 80% of the transmission and distribution costs. By 2010, 17 MW of off-grid projects based on small hydro and biomass were in various stages of development. More information is provided in the MGPT10 Tanzania case study. “The major hurdles in the success of mini-grids are not technology-related.

There are no significant technology barriers that hinder mini-grids whether they are powered by diesel generators, renewable energy or a combination of both (hybrid systems). Rather, since supply to remote villages with low income is not economically viable, financial sustainability is the key challenging factor. Compounding the problem is the fact that there is no “one-size-fits-all” solution.” (SE4ALL Energy Access Committee, OFID 2014).

For the grid development in Dar es Salaam it is important to know the different possibilities of SPP with regards to the location (connected to the isolated mini-grid or to main grid) and nature of the customers (retail to end consumer or wholesale to utility). In the figure below the four possible combinations are shown.

![Figure 3-3 Possible combinations of grid development and SPP.](image)

3.7 Examples of SPP - SOPRA and mini grid - CSGriP

This section briefly discusses an example of a system for Small Power Producers (SOPRA) and an example of a grid concept for SPP (CSGriP).

**SOPRA** stands for Sustainable Off-grid Power Station for Rural Applications and provides for autonomous energy grids at locations where this was not previously feasible. The basic solution comprises a number

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10 MGPT = Mini Grid Policy Toolkit, The Toolkit is a product of the Africa-EU Renewable Energy Cooperation Programme (RECP)
of transformers, a battery pack and an advanced regulating system for the batteries. The solution is mobile and can therefore be used anywhere in the world. The storage technology for approximately 10,000 users fits in a single 20 foot container.

The system works using solar energy, wind energy or hydro energy, but also with conventional energy sources as backup. Due to various management and communication systems being integrated in the SOPRA concept, users can pay in a number of ways, consumption can be regulated and the system can be remotely controlled. The SOPRA concept can be supplied on a turnkey basis, including the sustainable energy generation, energy storage, distribution network, management and service and maintenance.

The aim of the CSGriP (Cellular Smart Grids Platform) is to develop a grid concept at distribution level that will – for parts of it – operate largely self-sufficiently and self-regulating with local generation and local purchase of energy. This involves relatively low energy storage and new Smart Grid technologies. The grid parts are connected to each other by a backbone (the current medium voltage power grid) to temporarily be able to exchange energy when necessary. This innovative concept builds an intrinsically stable grid unit and maintains it without the need for a far-reaching and complex ICT infrastructure. The purpose of the concept is maximum local matching of supply and demand and maximum integration of decentralised sustainable energy such as solar-PV, micro-CHPs and wind turbines.
4 SCENARIOS FOR ELECTRIFICATION

The states of electrification and individual supply technologies described and discussed in chapter 0 are used to draft possible paths for electrification.

Figure 4-1 gives a general picture of a possible grid and off-grid constellation.

![Illustrative View of Grid and Off-Grid Perimeters](image)

**Figure 4-1 Illustrative View of Grid and Off-Grid Perimeters (Source: DFID 2013)**

The figure shows stand-alone systems and micro / mini grids on the one hand as off-grid supply and main grid distribution and transmission. The mini grid is more or less the crucial part of electrification.

If adequate compensation and technical arrangements can be made, there is no reason why the mini-grid cannot be connected to the main grid. There are different ways of structuring this new operating model to optimise power supply, and costs to investors, consumers and the utility.

For the development of the grid constellations conventional scenarios can be followed as discussed in section 4.1 but also innovative scenarios as in discussed in section 4.2.

4.1 **Common electrification tracks**

In general there are two tracks of electrification: centralized and decentralized. The centralized track builds on national or regional grids and centralised generation, while the decentralized track is based on off-grid or micro / mini grid initiatives with locally produced energy (see Figure 4-2 Tracks of electrification).

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11 Low carbon mini grids, “Identifying the gaps; building the evidence base” Volume 1 (Chapters 1 and 2) Support Study for DFID Final Report November 2013.
Solar lanterns and solar home systems generally are not linked directly to the main grid. Mini grids ultimately will be connected either fixed or in a loose way. Micro grids may be connected dependent on size and distance to the main grid. The distinction between micro and mini grids is not always clear in literature.

The connection has several aspects like technical, economic, financial, managerial and regulatory aspect. Especially financial aspects are important when planning electrification. Large uncertainties arise in view of demand development, investments and transfer of assets.

The technical, economic / financial and regulatory aspects are further discussed in the next sections.

4.1.1 Technical aspects

This part is mainly based on "A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems Up to 200 kW" (Guidebook 2013). Parts of this guidebook have been copied and this text is displayed in italic.

A grid-connected renewable energy mini-grid includes a locally available energy source (e.g. solar radiation), a device for converting this energy into AC electrical power (which may include a DC-AC inverter), loads, and a point of common coupling where the customer-owned equipment interfaces with the local electric utility’s distribution system. See Figure 4-3 for a schematic illustration.

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In mini-grids, traditionally three types of devices create alternating current (AC). These include synchronous generators, induction (also called asynchronous) generators, and inverters. While generators directly produce AC power, the role of inverters is to convert DC power from devices such as photovoltaic solar modules into AC. As we discuss in detail below, each of these types of devices have distinct interconnection requirements. We include discussion of each of these forms of generation – and in so doing cover the electric generation component of equipment that is applicable to small hydropower, biomass gasification, biogas, solar photovoltaic (PV), wind power, and even diesel generators. The guidebook puts special emphasis on opportunities to save costs wherever possible while maintaining safety and reliability.

The main grid is AC based so eventually micro and mini grids will be connected with AC.

Many mini-grids have not been set-up with the objective of connecting them to the main utility grid. There are micro grids and mini grids already operating for decades before ideas are developed to connect them with the main grid.

When connecting the mini-grid to the main grid in general five options can be distinguished:

1. Interconnect the local electricity generator in parallel with the utility grid, becoming another power plant on the grid, with the utility assuming the responsibility for distributing electricity to customers (small power producer or SPP option);

2. Continue to operate the local distribution mini-grid system, obtaining bulk electricity supply from the main distribution utility (small power distributor or SPD option);

3. A combination of (1) and (2) above (SPP + SPD option);
4. Maintain the local electricity generator for use solely as backup for the local mini-grid when the utility grid goes down (SPD with backup option); or

5. Abandon the local electricity generator and mini-grid distribution system, with customers in the area switching over to the utility grid (no SPP or SPD option).

These five options and a base case where the mini-grid is not connected (yet) to the main grid are illustrated schematically in Figure 4-4.

Figure 4-4 Options for connection of mini-grid with main grid. Source: Guidebook 2013
Under options 1 and 3, where the mini-grid’s existing generating assets are kept in place, provision may be made for islanding operation, where the mini-grid maintains its ability to operate independently when utility grid power is unavailable. Under option 4, such an islanding mode is the only circumstance under which the local generator would operate.

In any of the described cases, whether turning the generator into an SPP, turning the mini-grid into an SPD, or both, all technical requirements set forth by the utility need to be fulfilled. Connection and parallel operation of generation resources of the main grid and the mini grid and also islanding (intentional and unintentional) of the mini grid brings with it a number of technical challenges.

The options in this figure are options for an existing mini grid. In Dar es Salaam the mini-grid does not yet exist. This mini-grid mostly is developed by the electricity company started perhaps as a micro grid and extended to a mini-grid or interconnected to other micro grids.

4.1.2 Economic and financial aspects

The preferred means of electrification mostly is connection with the national or regional network since this is normally the cheapest and the most reliable. However in Tanzania the reliability is doubtful as mentioned already in the introduction.

Alternatives are often more expensive. The price not only depends on the household usage but also on the size of the community and density of population. Each of the states or techniques for electrification like supply from mini grids, national grid and stand-alone systems has its own specific application space with regard to economics. The national grid is favourable close to the grid for large communities with high density of population. Standalone systems are cheapest far from the main grid in small communities. The mini and micro grid have their space in between.

Investors will be reluctant to invest in isolated mini-grids when there is too little clarity on the way forward and the conditions when the mini-grid is connected to the main grid. Often in this case these grids are equipped with inferior component when there is no guarantee for remuneration of the investment.

4.1.3 Rules and regulation

New rules, which were gazetted in April 2014, regulate what happens when the main grid arrives. The rules define a Small Power Project (SPP) as an entity that generates electricity and (1) sells the produced power at wholesale to a Distribution Network Operator (DNO) - which is TANESCO in the present system set up –, or (2) sells the produced power at retail directly to end customers, or (3) carries out some combination of the two. The rules say in Part VII that a SPP which is connected to an isolated grid can, when the main grid arrives, apply for the right:

a. to sell to the Distribution Network Operator that is connected to the main grid and be paid the main-grid FiT,
b. to become a Small Power Distributor who buys in bulk from the main grid and resells to retail customers,
c. to carry out a combination of (a) and (b).

The owner of the SPP is also free to sell the assets when the main grid arrives.

Furthermore, to minimize the risk that the business model becomes obsolete when the main grid arrives, the developer who intends to set up a SPP which feeds into an isolated grid owned by the DNO shall be informed by the DNO of the planned date of interconnection with the main grid.
4.2 Swarm electrification

The common way of electrification has several drawbacks especially in the case of Dar es Salaam. The top down approach needs to be initiated by the owner of the national network which will be a challenge since the present supply is not sufficiently reliable. An alternative way of electrification which represents a bottom up approach is called Swarm electrification. Two major sources that describe Swarm electrification will subsequently be discussed below:

1. An energy network of local energy suppliers in rural India. Improving the Rural Spark energy kit on technical and social-economic aspects, Randjiet Singh, 6 July 2015\textsuperscript{14}.


Excerpt from 1. (Randjiet Singh, 2015)

\textbf{Swarm electrification} is a combination of distributed and decentralized generation. It has the ability to eventually connect to other villages or even the national grid. A big advantage of this system is that the people become owner of a solar home system, or already are. The payback time is only three years. However, it is not clear what price is used but it seems to work. The villagers are not informed about the system, but still use it.

Swarm electrification uses funding as a loan which is paid by the local people.

Swarm electrification focuses on involving the people to maintain the product by themselves. The involvement of the local people is important for the system to succeed as well as the maintenance information. Not only the local people much be involved, also the government should be involved and encourage to cooperate.

Swarm electrification is smart grid or tends to be a smart grid. The most important aspect is the communication between energy suppliers and matching supply and demand.

The swarm electrification concept is applied in Bangladesh. The system consist of a Direct Current Solar Home Systems (SHS), currently consisting of 20 to 85Wp solar panel, battery, and charge controller (Sebastian Groh et al., 2014). The difference between a normal SHS and swarm electrification is that swarm electrification connects groups of house with each other and with other groups (see Figure 4-5).

\textsuperscript{14} http://alexandria.tue.nl/extra2/afstversl/bwk/Randjiet_Singh_2015.pdf
The swarms (groups of SHS) can be connected with other swarms, but also with a national or regional grid. The SHS in a swarm are also connected with each other so they can exchange the energy. Unfortunately, the energy exchange is not yet applied in Bangladesh. This project shows a distributed layout within a swarm, with the option to connect to local electricity grids.

The swarms (groups of SHS) can be connected with other swarms, but also with a national or regional grid. The buildings in a swarm are also connected with each other so they can exchange the energy. Unfortunately, the energy exchange is not yet applied in Bangladesh.

The Solar Home Systems are bought by the local people through micro financing. However, many people can pay for this system, the poorest are still left in electricity poverty. (S Groh et al., 2014) state that it is possible to create a win-win situation for both people with a SHS and for people who cannot afford a SHS by sharing the power and introduce dynamic pricing.

**Excerpt from 2. (Sebastian Groh et al., 2014)**

*Swarm Electrification: Investigating a Paradigm Shift Through the Building of Microgrids Bottom-up.*

**Sebastian Groh, Daniel Philipp, Brian Edlefsen Lasch and Hannes Kirchhoff**

**Abstract**

The study investigates a bottom-up concept for microgrids. A financial analysis is performed through a business model approach to test for viability when replacing a researched energy expenditure baseline in Bangladesh. A case study of Bangladesh illustrates the potential for building on the existing infrastructure base of solar home systems. Opportunities are identified to improve access to reliable energy through a microgrid approach that aims at community-driven economic and infrastructure development. Network effects are generated through the inclusion of localized economies with strong producer-consumer linkages embedded within larger systems of trade and exchange. The analysed approach involves the linkage of individual stand-alone energy systems to form a microgrid that can eventually interconnect with national or regional grids. The approach is linked to the concept of swarm intelligence, where each individual node brings independent input to create a conglomerate of value greater than the sum of its parts.
**Introduction**

The study, however, is often centred on two key players of development: the government and the private sector. This approach fails to take into account “the crucial third agent, in whose name development is carried out: people organised as communities and collectives, people seen not as ‘beneficiaries’ of the state or ‘consumers’ of private services but as drivers of their own destiny, empowered to self-provision basic needs and to govern from below” (Kothari and Shrivastava 2013).

This research investigates a new conceptual approach on rural electrification where the infrastructure of a microgrid is built through the people’s own resources from the bottom-up. Experience has shown that user-centered concepts can contribute to the pursuit of sustainable and effective energy access models (Tenenbaum et al. 2014).

Grid-based solutions, on the other hand, can offer great potential to provide stable and sufficient electricity supply for productive uses, which play a key role in bolstering economic development (Kaygusuz 2011). In the discussions usually there are either centralized (e.g. national grid extension) or decentralized solutions (e.g. stand-alone SHS or isolated microgrids).

Further, discussions are often reduced to on-grid and off-grid population, leaving potential solutions for an estimated one billion people out of scope (AGECC 2010). This group has been referred to as the “temporarily on/off-grid sector” and is further targeted in the step-wise electrification approach presented here (Groh 2014, p. 85).

The authors hypothesize that a paradigm shift could improve existing decentralized methods for rural energy, including stand-alone one-off Solar Home Systems (SHS) and baseline energy fuels such as kerosene. The underlying research question raised here is to what extent a grid can be built bottom-up and in an economically sustainable way thereby meeting the challenges current trends in microgrids for rural electrification face. The authors elaborate on a bottom-up concept drawn from an approach that follows the basic principles of swarm intelligence in distributed information and communications technologies networks and test for its viability. In this scheme, each individual node brings independent input to create a conglomerate of value ostensibly greater than the sum of its parts. In the way that each node in a swarm intelligence network shares information with its neighbours to achieve a compounding network effect, individual stand-alone household energy systems could share electrical power—in that they are linked together to form a microgrid—to achieve a networked grid effect.

Swarm is thus in between stand-alone and mini-grid mitigating the draw-back of both states as shown in the table below.

<table>
<thead>
<tr>
<th>Solar House System</th>
<th>Minigrid</th>
</tr>
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<tbody>
<tr>
<td>Serves only basic needs</td>
<td>Unable to recover capital cost</td>
</tr>
<tr>
<td>Productive use is limited</td>
<td>Capacity quite inflexible</td>
</tr>
<tr>
<td>Excess generation dumped</td>
<td>High risk for investors</td>
</tr>
</tbody>
</table>

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15 In case of Dar es Salaam this is however not the case due to lack of reliability of the national supply.
5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions are drawn from this first assessment:

- Tanzania has several support programmes and relatively advanced regulation for renewable energy development and electrification:
  - The Scaling-up Renewable Energy Programme (SREP) – Investment Plan for Tanzania will support the RE development
  - The Rural Energy Fund (REF) gets support from the Government of Tanzania and international donors to co-finance rural and renewable energy electrification schemes implemented by TANESCO and the private sector, NGOs and communities.
  - REF and SREP are also applicable for urban development.

- The Sustainable Solar Market Packages (SSMPs) are an important contracting mechanism that bundles supply, installation and maintenance of solar PV systems

- Demand Side Management (DSM) and Energy Efficiency offer good opportunities to lower electricity demand in a cost effective manner. More services can be fulfilled with the same supply.

- Cheaper network are a promising way to reduce cost of electrification

- The prospect of the common way of electrification is not good in Tanzania. The national supply is not sufficiently reliable and the financial condition of Tanesco is weak

- Relevant literature and toolkits are available to support the planning of electrification

- Swarm electrification is considered as a very promising concept with several advantages:
  - It is a bottom up approach which offers more chances that the home systems but doesn”t need the involvement of Tanesco for the first developments
  - It involves the end consumers in a favourable way which frees finance and increases the success rate of DSM and energy efficiency
  - It offers good possibilities for renewable energy (PV)

- Swarm development leads to a mini grid. It is most important to know how this mini-grid will look like in the end and what the possibilities are of connecting with the national grid. This involves the following:
  - Choice of stages - options for connection of mini-grid with main grid (SPP, SPD, etc., see Figure 4-4)
  - How to keep the self-sufficiency after connection?
  - How smart is desirable / sensible?
  - How far to go with DSM and cheaper distribution?
  - Value of technical system plan
5.2 Recommendations

The following next steps are recommended:

- Further investigate the Swarm concept until the stage of mini grid in the context of Dar es Salaam with:
  - Local circumstances (customers, demand, possibilities of PV)
  - Legislation, regulation, practical issues. What can REF, SREP and SSMP offer for this development
  - Possible support Tanesco
  - Practical elaboration of the concept (AC versus DC, DSM, cheaper distribution, need for storage, need for additional generation)
  - Smart (possibilities, benefits, requirements)

- Investigate possibilities of and precondition for PV and electrification with:
  - Technical design (modular development, scale, storage, etc.)
  - Possible support from REF and SREP
  - Possibilities SSMP

- Investigate the preferred way of connection to the main grid with:
  - SPP, SPD or combination (see Figure 4-4)
  - Requirements for island operation and islanding (intentional and unintentional)

The expertise required for next steps concern:

- How societies work in connection with this type of development (Swarm)
- Planning of electricity supply especially in island situations
- Integration of renewable energy and especially solar PV
- Storage
- Network development and possibilities
- Smart development
- Finance
# APPENDIX A. ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
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<tr>
<td>CSGriP</td>
<td>Cellular Smart Grids Platform</td>
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<td>DC</td>
<td>Direct Current</td>
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<tr>
<td>DNO</td>
<td>Distribution Network Operator</td>
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<td>DSM</td>
<td>Demand Side Management</td>
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<tr>
<td>EE</td>
<td>Energy Efficiency</td>
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<tr>
<td>FIT</td>
<td>Feed-in-Tariff</td>
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<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH</td>
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<tr>
<td>IPPs</td>
<td>Independent Power Producers</td>
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<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
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<tr>
<td>LCOE</td>
<td>Levelized Cost Of Electricity</td>
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<td>LV</td>
<td>Low Voltage</td>
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<tr>
<td>MV</td>
<td>Medium Voltage</td>
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<tr>
<td>MW</td>
<td>Megawatt</td>
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<tr>
<td>MWh</td>
<td>Megawatt hour</td>
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<tr>
<td>NGOs</td>
<td>Non-Government Organisations</td>
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<td>PPAs</td>
<td>Power Purchase Agreements</td>
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<td>PSMP</td>
<td>Power Systems Master Plan</td>
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<tr>
<td>PV</td>
<td>Photovoltaic</td>
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<td>RE</td>
<td>Renewable Energy</td>
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<tr>
<td>REA</td>
<td>Rural Energy Agency</td>
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<td>REF</td>
<td>Rural Energy Fund</td>
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<tr>
<td>SOPRA</td>
<td>Sustainable Off-grid Power Station for Rural Applications</td>
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<td>SE4ALL</td>
<td>Sustainable Energy for All</td>
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<td>SHS</td>
<td>Solar Home Systems</td>
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<tr>
<td>SPD</td>
<td>Small Power Distributer</td>
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<tr>
<td>SPPAs</td>
<td>Standardized Power Purchase Agreements</td>
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<td>SPPs</td>
<td>Small Power Producers</td>
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<tr>
<td>SPPT</td>
<td>Small Power Purchase Tariff</td>
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<tr>
<td>SREP</td>
<td>Scaling-up Renewable Energy Programme</td>
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<tr>
<td>SMMPS</td>
<td>Sustainable Solar Market Packages</td>
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<tr>
<td>SWER</td>
<td>Single Wire Earth Return</td>
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<td>SWS</td>
<td>Shield Wire Supply</td>
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<tr>
<td>TANESCO</td>
<td>Tanzania Electric Supply Company Limited</td>
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<tr>
<td>TAREA</td>
<td>Tanzania Renewable Energy Association</td>
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<tr>
<td>TZS</td>
<td>Tanzania Shillings</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>USD</td>
<td>United States Dollar</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<td>WB</td>
<td>World Bank</td>
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<tr>
<td>WWF</td>
<td>World Wide Fund for Nature</td>
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