# Tariff structures to encourage micro-grid deployment in Sub Saharan Africa: Review and recent findings

Tim Reber* and Samuel Booth
National Renewable Energy Laboratory
*Corresponding author:
tim.reber@nrel.gov
15013 Denver West Parkway
Golden, CO 80201 USA

## Keywords
Mini-grid; Micro-grid; Tariff; Rural electrification; Energy access

## Abstract
*Purpose of review:* This article reviews trends for micro-grid tariffs in Sub-Saharan Africa from two perspectives: guidelines for *setting* tariffs and methods for *structuring* tariffs. Different approaches are briefly described, and general benefits and drawbacks presented based on recent experiences and available literature.
*Recent findings:* The pace of micro-grid deployment has suffered from a lack of private-sector investment, which is often inhibited by unfavorable policies and uncertainty around tariffs. Traditional utility tariffs are too low to allow micro-grid investors to recover their full costs, but a variety of new approaches can be applied to address these challenges.
*Summary:* Broad consensus suggests that cost-reflective tariffs are a critical enabler for micro-grid scale-up. Such tariffs can be coupled with subsidies or with hybridized approaches as well as unique new methods of tapping alternative revenue streams to maintain affordability for low-income customers and financial sustainability for micro-grids. There is no one-size-fits-all approach so long as lifetime costs can be recouped.

## Introduction
The United Nations has challenged the world to achieve universal access to modern energy services by the year 2030 [1]. This undertaking is expected to require investment of roughly US $45 billion annually—more than half of which is expected to be in micro-grids and isolated power systems [2]. Investment of this scale, however, is unlikely to be met by governments and donors alone, making successful mobilization of private investment a paramount criterion for success. Micro-grids must therefore be commercially viable endeavors that can provide a reasonable return for investors to attract the requisite private debt and equity financing to the sector [3]. This ultimately depends on the ability of micro-grid operators to collect tariffs or other payments at sufficient levels to ensure that revenues cover costs and provide an acceptable financial return for the level of risk [4].

Micro-grids are not a new concept and have been operating in emerging countries around the world for decades (e.g. Nepal and Mali have both successfully financed and operated micro-grids since the early

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

2000's) [5]. However, most micro-grids to date have relied heavily on donor support or government subsidies, which is common for electrification programs, but is unlikely to be available at the investment levels required to achieve universal electrification goals. While micro-grids are often the least-cost solution for providing power to remote, rural communities, on a per-kilowatt-hour (kWh) basis they often deliver power that is still more expensive than what existing utility grid-tied customers may be paying [4]. Utility rates in most emerging economies are well below their average cost of service, as large (typically state-owned) utilities are subsidized directly by the government or through donor-funded infrastructure projects [3]. Thus, the tariff that an individual utility customer pays often does not reflect the full cost to the utility of serving that customer but rather the subsidized grid-wide average [5]. This status quo makes it nearly impossible for micro-grids to compete with national utility tariff rates, hindering micro-grid scale-up in markets where micro-grids are asked to charge rates comparable to larger utilities without receiving the same subsidy benefit [6,7].

However, this status quo is beginning to shift, and many developing country governments and power sector actors are now rethinking tariffs and cost-recovery mechanisms to enable micro-grids and broader electrification. While much has been written on the topic of electricity tariffs in general, there remains a relative dearth of literature dedicated specifically to the question of tariffs for micro-grids, though individual experiences and a handful of reviews in the last few years can help shed light on this question. The U.S. Department of Energy's National Renewable Energy Laboratory and Power Africa recently performed a review and assessment of various approaches to micro-grid tariffs and subsidies in Sub-Saharan Africa [4]. That report forms the basis of this article, which draws on that work as well as other resources and experience to succinctly summarize emerging trends and lessons in the tariff space that can be applied to micro-grids to help attract the necessary private capital to enable widespread scale-up. The focus is specifically on tariff and cost-recovery structures that can help the micro-grid sector move beyond government and donor support by enabling financially self-sustaining, privately-financed micro-grids. Unlike government or donor-funded micro-grids, which often aim only to cover operational costs through tariffs, such investor-backed micro-grids must cover both capital investment and operational costs through tariff collection in addition to providing an acceptable return on investment [6,8]. The article is split into two equally important discussions: starting first with how to go about setting and governing tariffs, and then diving into approaches for structuring how tariffs are applied and levied.

## Setting Tariffs

To be effective and sustainable, any tariff structure typically must balance the needs of three key groups of stakeholders: governments, developers, and customers [4]. The differing priorities between these stakeholders can create a significant challenge for micro-grid tariffs: national rates set by governments in Africa are typically held low—in the $0.05-$0.30 per kWh range—compared to true costs, developers often need to charge between $0.50 and $1.00 per kWh to maintain a viable business model, and customers simply want access to energy at a rate that they can afford and are willing to pay. A variety of approaches to setting and regulating tariff levels may be pursued—ranging from uniform to cost-reflective tariffs as well as a variety of hybrid approaches in between—which are summarized below.

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

**Uniform**

Under a uniform tariff structure, customers are generally charged the same tariff regardless of whether they are connected to an urban utility grid, a rural utility grid, or an isolated micro-grid. The intent of this type of tariff is typically to provide a sense of fairness and equality across all customers—a position that can be highly politically favorable for governments and regulators [9]. These rates are typically cross-subsidized or directly subsidized by the government to keep electricity prices low and affordable—a practice which may not be sustainable in the long run [10].

While often perceived as equitable to customers, uniform tariffs are typically not practical or possible for micro-grid developers [11]. In a recent survey of African power industry stakeholders, two-thirds of respondents indicated that the inability to recover the costs of new power projects under current tariff schemes is the biggest barrier to more rapid power development in sub-Saharan Africa [12].

Ultimately, national tariffs are simply too low to attract investors to develop micro-grids in rural regions, leaving remote customers instead to rely on grid extension by the national utility for electrification. However, given their subsidized nature, many utilities in sub-Saharan Africa are not financially sustainable and thus cannot afford to extend the grid while maintaining existing uniform tariffs without either incurring further losses or requiring additional direct subsidies [10]. For example, in 2016, Tanzania Electric Supply Company Limited (TANESCO) asked the Tanzanian government for a rate hike of 18.9% to cover ongoing losses. In response, the regulator granted TANESCO a rate hike of 8.5%—less than half of what was requested—which the president ultimately blocked the following year, thereby perpetuating the cycle of utility losses that not only inhibits needed grid expansion but also puts at risk the utility's long-term financial solvency [13]. Thus rural customers remain unserved and the electrification problem continues.

**Cost-Reflective**

What are typically referred to as "cost-reflective" tariffs sit at the opposite end of the spectrum. Under such schemes, developers of micro-grids are generally free to set their own tariff and payment structures at levels that are high enough to allow them to recover their costs—both capital and operational. In many cases, these cost-reflective tariffs may also be subject to regulatory approval. Generally, cost-reflective tariffs will be higher than rates charged to existing grid customers, but they are still determined through an ongoing and often implicit negotiation between customers and micro-grid operators to find the price point such that customers are willing and able to pay and operators can still recover costs (otherwise the micro-grid development is likely to fail) [14,15]. Often the cost-reflective rate that would be charged by a micro-grid developer will still be lower than what unconnected customers are ultimately paying for energy services in the form of kerosene, candles, batteries, or other fuels [15,16]. A recent International Finance Corporation analysis suggested that, on average, households in unelectrified communities in East Africa may already be paying "implied tariffs" of US $1.75/kWh for low-quality energy from kerosene and candles—far more than what most cost-reflective micro-grid tariffs would be [17].

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

Cost-reflective tariffs can more effectively attract micro-grid investment by providing a viable means for developers to recoup costs and investors to secure returns, and can thus increase the overall speed of deployment of new micro-grids [7,8,11,16,18]. Notably, this can also reduce the financial burden on already stressed national utilities, as each new utility connection often incurs additional losses for the utility. Many countries, including Tanzania, Rwanda, Kenya and Madagascar have approved versions of cost-reflective tariffs that have resulted in increased deployment of micro-grids [7].

**Hybrid Approaches**

Between uniform tariffs and cost-reflective tariffs, there are a range of hybrid approaches and compromises that blend elements of both. Perhaps most notably is the practice of allowing cost-reflective tariffs but providing grants or subsidies to offset micro-grid costs such that micro-grid tariffs are more consistent with those charged to grid-tied customers. In this case, subsidies can be provided either directly to micro-grid developers or to consumers. However, relying on subsidies from governments that often lack creditworthiness is a risky prospect for investors who require a guarantee that any payments or subsidies will be valid for long enough—ideally at least 7-10 years—to recoup their costs and eventually become profitable [7,8].

There are a range of other hybrid approaches that may include:

- Government-determined tariffs that are based on a full accounting of the costs of building and operating a specific micro-grid. Effectively a "**cost-plus**" methodology this allows governments (rather than developers) to set what they believe a cost-reflective tariff should be but adds work for regulators and requires agreed upon calculations. Such a system has been employed with success in Rwanda [9].
- National utility tariff schemes that account for the higher cost of micro-grids by charging higher rates to all customers (including those tied to the grid) to balance the cost of micro-grids. This amounts to **cross-subsidization** of micro-grids by grid-tied customers and can be an effective though politically challenging approach as it often necessitates rate increases for existing utility customers. This may work best in system in which utilities develop and operate the micro-grids themselves, thereby cross-subsidizing within their own operation. Alternatively, utilities could also pay the cross-subsidies to private developers to offset micro-grid costs, though this may be less attractive to developers given many African utilities' already strained cash-flow.
- Benchmarking micro-grid tariffs to the estimated **avoided cost** of alternative electrification means. Effectively the regulator calculates either (a) the true cost to customers of paying for kerosene or diesel or, in some cases, (2) the theoretical cost to the utility (without subsidies) were it to extend grid services to those customers [19]. The micro-grid tariff is then tied to this calculated avoided cost, which is often higher than the cost of micro-grids. Tanzania has recently had success implementing this approach [20].

## Structuring Tariffs

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

Once an agreeable tariff level has been set, micro-grid operators must then decide on the most effective means to collect tariffs or payments from customers. While tariffs in the most traditional sense are often thought of as a simple cost per unit of energy (e.g. dollars per kilowatt-hour), there are in fact a range of different approaches to tariff and cost-recovery structures at micro-grid operators' disposal.

**Energy Charge**

An energy charge, or consumption-based tariff, is the simplest and most common form of tariff. Operators charge consumers a fixed rate per unit of energy consumed—e.g. X dollars per kilowatt-hour (kWh) consumed. Energy charges are easy to implement and generally widely accepted and can be collected either on a post-paid or pre-paid basis. In the case of micro-grids, where the operator must recoup costs from a much smaller pool of customers than larger utilities, energy charges can expose the mini-utility to higher levels of revenue uncertainty as fluctuations in consumers' consumption levels can have large effects on mini-utility revenue.

**Time-of-use Tariffs**

A time-of-use tariff charges consumers different rates depending on the time at which power is used, with higher rates being charged at times when demand is high or supply is low, and lower rates during times of low demand or high supply. This practice can be employed to try to shift peaks and valleys in demand and have a smoothing effect on the micro-grid's demand profile. This smoothing can simplify system operations and design, increase capacity factors, and reduce overall costs for the mini-utility which can then be passed on to consumers in the form of lower tariffs.[1] Effectively a more complex version of an energy charge, this practice is gaining traction among utilities in many developed countries, but is not yet widely applied to micro-grids.

**Block Tariffs**

Block tariffs split customers into different groups—or "blocks"—which each paying a different rate based on some distinguishing classification. Blocks may be based on level of consumption (e.g. the more energy a consumer uses the higher or lower their marginal tariff rate), power needs (e.g. higher intensity users pay more), customer class (e.g. commercial, residential, public services, etc.). The most common block tariff discerns consumer classes based on consumption—with the biggest consumers typically paying more to cross-subsidize a lower level of subsistence energy consumption for poorer consumers. Bonny Utility Company in Nigeria is one such example that has effectively employed this approach to increase access for low-income consumers [3]. This type of socially-oriented block scheme is effectively a more complex type of energy change and is frequently referred to as an "inverted block tariff" or "lifeline block tariff."

**Power Charge**

[1] Booth, Samuel; Li, Xiangkun; Baring-Gould, Ian; Kollanyi, Diana; Bharadwaj, Abishek and Weston, Peter. *Productive Use of Energy in African Micro-grids: Technical and Business Considerations.* National Renewable Energy Laboratory and Energy 4 Impact. 2018. Forthcoming report.

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

Unlike an energy charge, a power charge instead sets a flat rate for each customer based on their maximum peak power draw. The tariff will be based on a given capacity cap—which must be metered or limited by the operator—and will typically be charged in terms of dollars per peak instantaneous kilowatt provided [21]. Such power charges have been effectively employed in Nepal [19]. While such charges are typically less strictly regulated and may offer more revenue certainty for operators, they also can encourage inefficient and excessive use by consumers who do not pay for consumption [7,19]. Power charges are similar to flat standing tariffs, which may just charge a flat monthly rate to all customers independent of their use.

**Hybrid Charge**

In some instances, power charges may be employed in tandem with energy charges such that consumers are charged according to both their total energy consumption (kWh) and peak power required (kW). This approach can help provide more consistent revenue certainty for developers while maintaining an incentive to encourage efficient use of energy. This approach has been employed with success in Senegal, for example [19].

**Connection Fees**

Connection fees are a one-time fee often used to recoup the investment required to connect a new customer to the micro-grid. While such costs could, in theory, be wrapped up in other billing methods, experience has shown that charging a small connection fee—which must still be modest and affordable—can help build commitment among the community and increase repayment rates [6,8].

**Fee for Service**

The phrase "fee-for-service" can capture a wide array of revenue collection methods, but the general concept remains consistent: rather than charging consumers a tariff for their consumption or power demands, the micro-grid operator instead defines a set of energy-using services and charges customers based on the services that they use. In practice, a customer would be charged a set monthly amount based on the particular set of appliances or energy applications they have—for example, one set monthly charge per lightbulb, another added charge if they have a refrigerator, yet another if they have a TV or radio, etc. [8,21]. This setup can provide simplicity and accessibility for consumers that may be unfamiliar with utility billing models, but also faces implementation challenges as it requires regular inventories of each consumers' appliance makeup [17,19].

**Alternative Revenue**

Building on the emerging trend of fee-for-service, some micro-grid developers are experimenting by tapping alternative revenue sources. For example, some micro-grid developers have turned to selling appliances to new customers, thus increasing revenue not only from the sale of the appliances but also through the increased consumption of electricity by those appliances [17]. Some micro-grid developers may even choose to set up their own energy-consuming businesses within the micro-grid and sell those services directly to the community for additional revenue.[2] Examples of such fee-for-service offerings

[2] Ibid.

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

may include offering centralized phone charging services to unconnected customers or setting up a grain mill and providing milling services on a fee-per-kilogram basis. The International Finance Corporation found that 9 out of 11 micro-grid operators surveyed had included these or other alternative sources of revenue in their business models [17].

## Conclusion

There are a range of structures and mechanisms available to guide setting and collection of tariffs for micro-grids. To attract private sector investment on the scale required to accelerate the pace of micro-grid deployment in Sub-Saharan Africa and around the world, tariff structures must provide avenues for developers to recover both capital and operational costs—and must do so with some degree of long-term certainty and predictability.

When it comes to setting tariffs, options range from maintaining traditional uniform tariffs to allowing cost-reflective tariffs, with a handful of hybrid approaches in between. While there are a handful of tradeoffs that must be considered with each option, the literature and experience are nearly unanimous in their endorsement: cost-reflective tariffs—or at a minimum hybrid approaches that allow developers a means to recoup their expenses—are a key enabler for more rapid and widespread micro-grid scale-up. Whether and how governments choose to reconcile such cost-reflective tariffs with the traditional uniform tariffs that may already be in place depends on the context of each country. However, one thing is clear: simply maintaining uniform tariffs with no consideration of cost recovery requirements will continue to hinder and stifle micro-grid development. Decision-makers should consider that even when charging rates above national tariffs, micro-grids typically still deliver overall cost savings to their customers while bringing the broader-reaching socioeconomic benefits of access to reliable electricity.

Developers and operators of micro-grids have multiple options for how they choose to structure tariffs and approaches to recovering costs. The more traditional energy charge (e.g. $/kWh) is still simple and effective in many cases where cost-reflective or appropriate hybrid tariffs are allowed. To address questions of affordability for lower-income consumers, various forms of cross-subsidization such as block tariffs or time-of-use tariffs can be employed. In situations in which tariff regulations remain strict, mechanisms such as charging fee-for-services or tapping alternative sources of revenue can allow operators a means to collect payment and recoup their costs without charging an explicit per-kWh tariff. In many cases, such schemes can even be used together with traditional tariff structure simply to increase revenue and thus the financial viability of the micro-grid.

Ultimately, it rests on policy- and decision-makers, micro-grid developers and operators and communities to determine the approach that works best within their country's unique context. There is no perfect, one-size solution. However, increased flexibility and new innovations in how micro-grid tariffs are governed and structured may be an important first step to help encourage wider deployment of micro-grids across Sub-Saharan Africa.

**Conflict of Interest**

The authors declares no conflicts of interest.

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

**Human and Animal Rights and Informed Consent**

This article does not contain any studies with human or animal subjects performed by any of the authors.

**Disclaimer**

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-08GO28308 with Alliance for Sustainable Energy, LLC, the Operator of the National Renewable Energy Laboratory, and the United States Agency for International Development. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

## References

1. Angelou N, Elizondo Azuela G, Banerjee SG, Bhatia M, Bushueva I, Inon JG, et al. Global Tracking Framework [Internet]. The World Bank Group; 2013 May. Report No.: 77889. Available from: http://documents.worldbank.org/curated/en/603241469672143906/Global-tracking-framework

2. IEA. Energy for All: Financing access for the poor [Internet]. Paris: International Energy Agency; 2011 Oct. Available from: http://www.worldenergyoutlook.org/media/weowebsite/2011/weo2011_energy_for_all.pdf

3. Bardouille P, Avato P, Levin J, Pantelias A, Engelmann-Pilger H. From Gap to Opportunity: Business Models for Scaling Up Energy Access [Internet]. International Finance Corporation; 2012. Available from: https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Publications/Publications_Report_Gap-Opportunity

4. Reber TJ, Booth SS, Cutler DS, Li X, Salasovich JA. Tariff Considerations for Micro-Grids in Sub-Saharan Africa [Internet]. Golden, CO: National Renewable Energy Laboratory; 2018 Feb. Report No.: NREL/TP--7A40-69044, 1422366. Available from: http://www.osti.gov/servlets/purl/1422366/

5. Walters T, Esterly S, Cox S, Reber T, Rai N. Policies to Spur Energy Access: Volume 1 - Engaging the Private Sector in Expanding Access to Electricity [Internet]. National Renewable Energy Laboratory; 2015 Sep. Available from: https://www.nrel.gov/docs/fy15osti/64460-1.pdf

6. Schnitzer D, Lounsbury DS, Carvallo JP, Deshmukh R, Apt J, Kammen DM. Microgrids for Rural Electrification: A critical review of best practices based on seven case studies. United Nations Foundation; 2014 Feb.

7. Weston P, Verma S, Onyango L, Bharadwaj A, Peterschmidt N, Rohrer M. Green Mini-Grids in Sub-Saharan Africa: Analysis of Barriers to Growth and the Potential Role of the African Development Bank in Supporting the Sector [Internet]. African Development Bank; 2016 Dec. Report No.: 1. Available from: https://www.se4all-africa.org/news-resources/news/article/publication-green-mini-grids-series-1-analysis-of-barriers-to-growth-and-potential-role-of-afdb-150/

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

8. •Franz M, Peterschmidt N, Rohrer M, Kodev B. Mini-grid Policy Toolkit: Policy and Business Frameworks for Successful Mini-grid Roll-outs [Internet]. Eschborn, Germany: EU Energy Initiative Partnership Dialogue Facility; 2014 Sep. Available from: http://www.euei-pdf.org/en/recp/mini-grid-policy-toolkit **•A comprehensive treatment of the policy and business al considerations that must be addressed in order to scale-up micro-grid deployment.**

9. World Bank. State of Electricity Access Report 2017 [Internet]. The World Bank Group; 2017 May. Available from: http://elibrary.worldbank.org/doi/book/10.1596/26646

10. IEA. Africa Energy Outlook: A Focus on Energy Prospects in Sub Saharan Africa [Internet]. Paris: International Energy Agency; 2014. Available from: https://www.iea.org/publications/freepublications/publication/WEO2014_AfricaEnergyOutlook.pdf

11. IRENA. Accelerating Off-grid Renewable Energy: IOREC 2014 Key Findings and Recommendations [Internet]. Abu Dhabi: International Renewable Energy Agency; 2015. Available from: http://www.irena.org/documentdownloads/publications/iorec/iorec_2014_key_findings.pdf

12. PwC. A new Africa energy world: A more positive power utilities outlook [Internet]. PricewaterhouseCoopers; 2015 Jul. Available from: https://www.pwc.com/gx/en/utilities/publications/assets/pwc-africa-power-utilities-survey.pdf

13. Abdur Rahman Alfa Shaban. Tanzania president reverses utility tariff hike, fires head of power firm. Africanews [Internet]. 2017 Jan 2; Available from: http://www.africanews.com/2017/01/02/tanzania-president-reverses-utility-tariff-hike-fires-head-of-power-firm/

14. Bhattacharyya SC, Palit D. Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? Energy Policy. 2016;94:166–78.

15. IRENA. Accelerating Off-grid Renewable Energy: IOREC 2016 Key Findings and Recommendations [Internet]. Abu Dhabi: International Renewable Energy Agency; 2017 Jan. Available from: http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_Accelerating_off-grid_renewables_2017.pdf

16. IRENA. Policies and Regulations for Private Sector Renewable Energy Mini-grids [Internet]. International Renewable Energy Agency; 2016 Sep. Report No.: ISBN 978-92-95111-46-2. Available from: http://www.irena.org/publications/2016/Sep/Policies-and-regulations-for-private-sector-renewable-energy-mini-grids

17. IFC. Operational and Financial Performance of Mini-grid DESCOs: Findings and Insights from Pioneer Benchmarking of this Emerging Sector [Internet]. Washington, DC: International Finance Corporation; 2017 Jan. Available from: https://cleanenergysolutions.org/resources/operational-financial-performance-mini-grid-descos-findings-insights-pioneer-benchmarking

18. Carlin K, Agenbroad J, Doig S, Henly C, Wanless E. Energy Within Reach: Growing the minigrid market in Sub-Saharan Africa [Internet]. Boulder, CO: Rocky Mountain Institute; 2017 Mar. Available from: https://www.rmi.org/insights/reports/energy-within-reach/

19. Tenenbaum B, Graecen C, Siyambalapitiya T, Knuckles J. From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa [Internet].

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.

Washington, DC: The World Bank Group; 2014. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/16571/9781464800931.pdf?seque%20nce=1&isAllowed=y •**A comprehensive, thorough, multi-chapter volume that addresses the range of policy, financial and business approaches that governments and micro-grid operators may employ.**

20. Sawe E, Katyega M, Odarno L. Mini-grids for Energy Access in Sub-Saharan Africa: Status and Lessons from Tanzania [Internet]. 2016. Available from: https://cleanenergysolutions.org/training/mini-grids-energy-access-tanzania

21. Philipp D. Billing Models for Energy Services in Mini-Grids [Internet]. 2014. Available from: https://www.giz.de/fachexpertise/downloads/2014-en-philipps-pep-fachworkshop-minigrids.pdf

Pursuant to the DOE Public Access Plan, this document represents the authors' peer-reviewed, accepted manuscript. The published version of the article is available from the relevant publisher.