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Benchmarking and comparing effectiveness of mini-grid encroachment regulations of 24 African countries ✦ A guide for governments and energy regulators to develop effective grid encroachment regulations

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ABSTRACT

The mini-grid market in Africa is steadily growing and solar PV, wind, hydro or biomass-powered mini-grids are expected to be a major factor in the electrification of rural areas. However, mini-grid markets cannot realize their full potential as most energy regulators do not provide an appropriate answer to the simple question "What happens when the main grid arrives?". The lack of regulatory security of tenure and potentially subsidized tariffs for main grid-sourced electricity risk stranded investments when the main grid arrives and thus threaten private sector participation and investment.

Effective grid encroachment regulations should provide adequate (i) technical requirements, (ii) legal protection, (iii) variety of business models for the post encroachment period, (iv) financial compensation mechanisms for mini-grids, and (v) protection of customer interests upon changes of supplier, should this result from grid encroachment. The research developed a set of objective benchmarks for the above five categories and tests the effectiveness of mini-grid encroachment regulations of 24 African nations against these benchmarks.

The inter-comparison study amongst grid encroachment regulations highlights the gaps in existing regulations of the African countries. It demonstrates that Zambia meets 80% of the developed benchmarks while most other nations lag significantly in offering fair treatment to mini-grid investors in case of grid encroachment. The findings also demonstrate that Zambian regulations have potential usefulness for other countries in and outside Africa to further develop or streamline mini-grid encroachment approaches and regulations towards workable regulatory frameworks that could contribute towards achieving a world-wide goal of 100% renewables.

1. Introduction

Hundreds of millions of people in rural Africa do not have access to sustainable electricity, a key enabler of social and economic development [1]. Providing access to sustainable electricity at household level is a priority for many governments. In order to accelerate prospects for sustainable economic development in communities, it is important to deploy energy technologies that would increase social benefits as well as contribute to the economy of the community [2].

Deployment of mini-grids technologies offer an economical solution to sustainable development and provide the most viable options for rural electrification of clustered communities [3–5]. They can provide access to electricity in a timely, sustainable and cost-effective manner compared to the high cost of extending the main grid distribution network to remote areas that will take many years to reach [6, 23]. Mini-grids can also contribute to other co-benefits such as achievement of the United Nations Sustainable Development Goals (UNSDGs) by providing affordable and clean energy (Goal 7) and effectively helping to mitigate the threat of climate change (Climate Action, Goal 13) by reducing dependence on CO_2 emitting fuels like paraffin, candles and other non-eco-friendly sources of energy, as long as mini-grids use renewable energies (i.e. solar, wind, hydro or biomass power) [7–9].

Recent advancements in renewable energy technologies are resulting in large cost reductions, potentially enabling 100% of the world to be powered by renewable energy. The analysis by the USAID geospatial tool project indicates that off grid technologies, mainly through mini-grid and stand-alone solar PV systems are the least-cost options for most rural areas [10–14]. Mini-grids can improve lighting and encourage new businesses to operate for longer hours. Mini-grids also have potential for local job creation for women and men from productive use of energy

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Fig. 1. Benchmarking group.

(PUE) such as agriculture, agro-processing, small industries, household services and education [15–17].

Despite the benefits of mini-grids, their growth has been constrained by a number of barriers, such as imbalances in subsidy allocation and governments' predilection for tariff parity between off-grid and on-grid power customers [18]. In order to encourage potential private sector participation in mini-grid investments and overcome imbalances, policy makers and energy regulators need to focus more on investor friendly measures such as appropriate technical requirements for grid interconnections and security of tenure. Reducing uncertainty around the arrival of the main grid is critical to the long-term success of mini-grids [19, 20]. In particular, in order to attract mini-grid investors, the investor needs to be able to recover investments in the event of main grid encroachment [21].

In recent years, countries with mini-grids such as Tanzania, Uganda, Nigeria, Ghana, Rwanda and Zambia have taken a big step forward

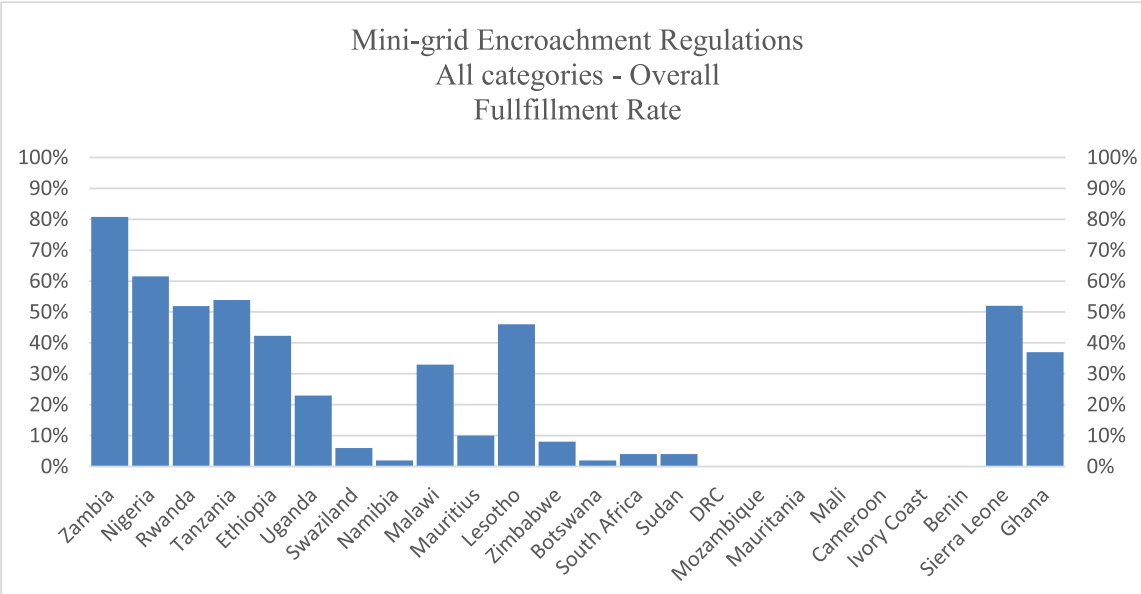

Fig. 2. Overall effectiveness of mini-grid regulations against main grid encroachment.

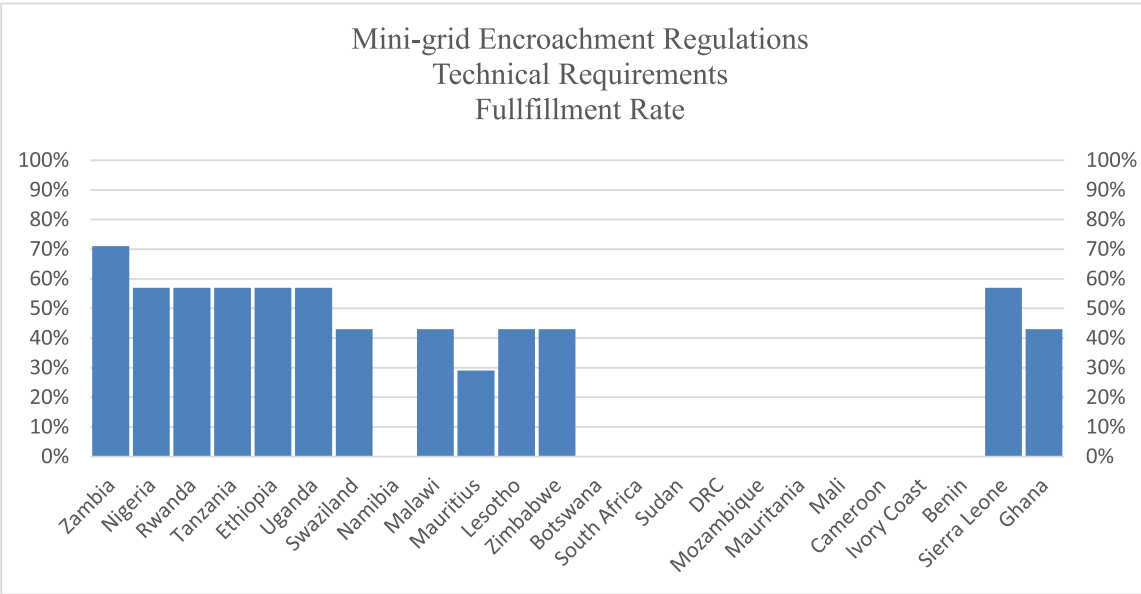

Fig. 3. Mini-grid technical requirements before and after the event of encroachment by the main grid.

in developing dedicated mini-grid policies and regulations. However, there has been little or no research conducted to assess their efficacy as well as the potential impact on mini-grid investors once the main grid arrives in a mini-grid supply area. In the absence of such research, governments and energy policymakers do not have sufficient information and guidance to enable them to put effective grid encroachment policy and regulations in place. International institutions like International Renewable Energy Agency (IRENA), International Finance Corporation (IFC) and the United Nations (UN) recognize the risk from an expected or even unexpected arrival of the main grid in supply areas which are licensed or assigned to mini-grid operators. The arrival of the main grid into these areas may siphon off customers from the mini-grid and cause stranded investments for private investors [22, 23].

This paper endeavours to address this research gap by providing results of the inter-comparison of the effectiveness of grid encroachment regulations in different African jurisdictions, and in this manner assists policy makers and regulators to evaluate the status and continued development of their own mini-grid policies and regulations to attract and retain mini-grid investments.

2. Methodologies

A benchmarking database with a set of 35 questions – clustered into five categories - was developed to serve as a platform for comparing mini-grid encroachment regulations of 24 African countries. The primary idea in the benchmarking process was to assess the effectiveness of each country's mini-grid regulations by testing "what happens when

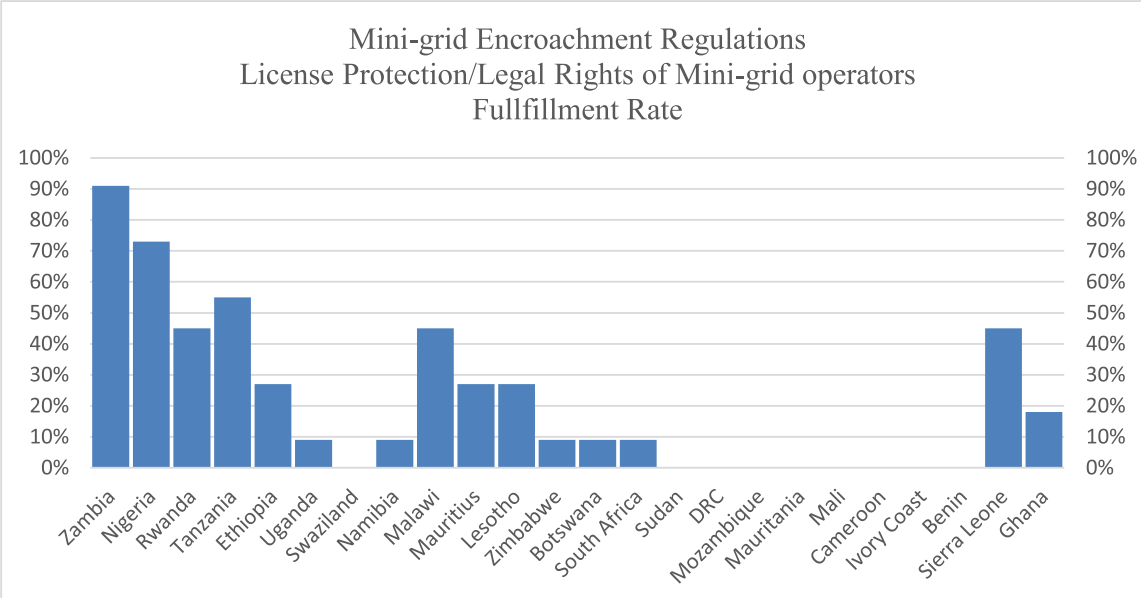

Fig. 4. Licence protection/legal rights of mini-grids against main grid encroachment.

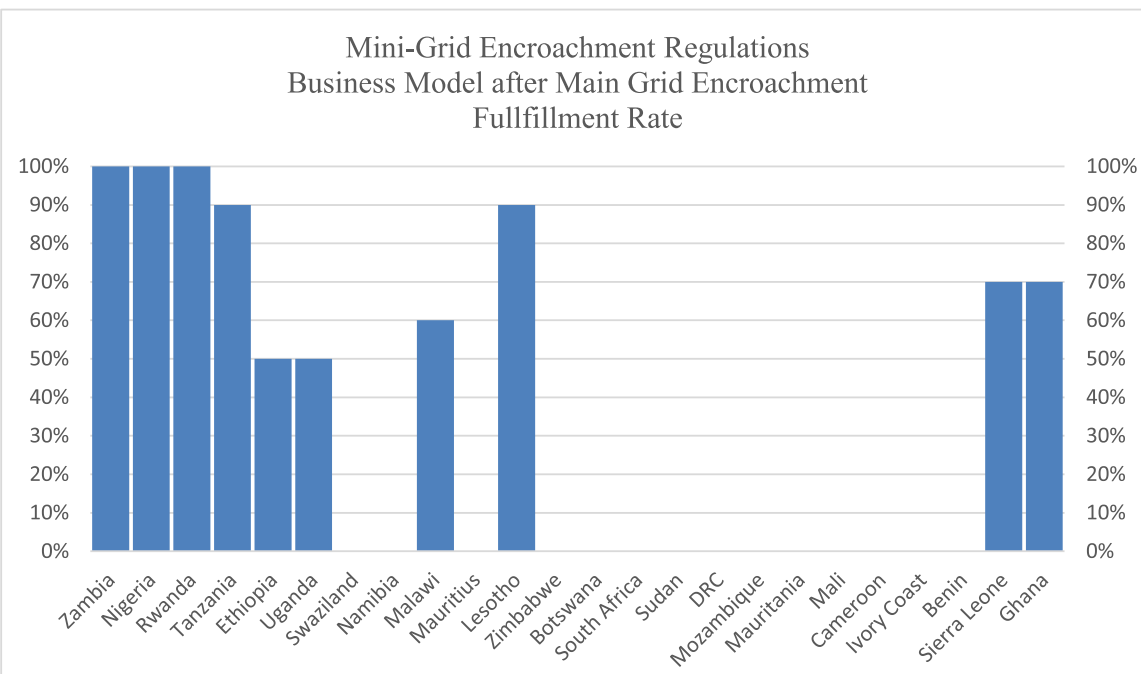

Fig. 5. Business models after main grid encroachment.

the main grid arrives" in areas served by the mini-grid. To this effect, the following approach was adopted in considering the gathering of relevant data for benchmarking:

1 Development of benchmarks
2 Selection of countries
3 Method of data collection
4 Process and analysis of data

2.1. Development of benchmarks

The benchmarks were developed in the five categories: (i) Technical Requirements, (ii) Legal Protection (permits and licences), (iii) Business Models, (iv) Financial Compensation Mechanisms and (v) Customer Interests, to ensure that the grid encroachment regulations provide adequate guidelines for the event that the main grid encroaches into areas served by mini-grid investors.

The benchmarks in these categories represent typical questions which stakeholders, who are involved in the encroachment process, try to address. The Technical Requirements determine the compliance to such technical standards (i.e. the quality of supply) and thus trigger the investment cost. The Legal Protection and the Financial Compensation Mechanisms are central elements to avoid stranded assets of the investor. The Business Models describe options for the market exit of the mini-grid investor. Customer Interests protect the fair pay for electricity by the individual.

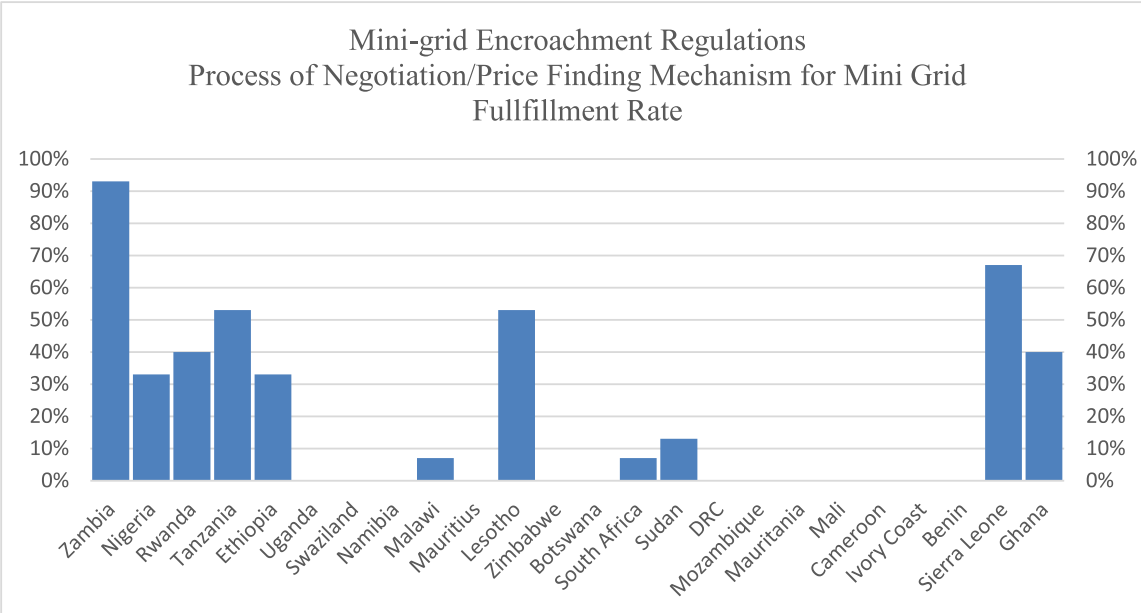

Fig. 6. Process of negotiation/price finding mechanism of mini-grid after main grid encroachment.

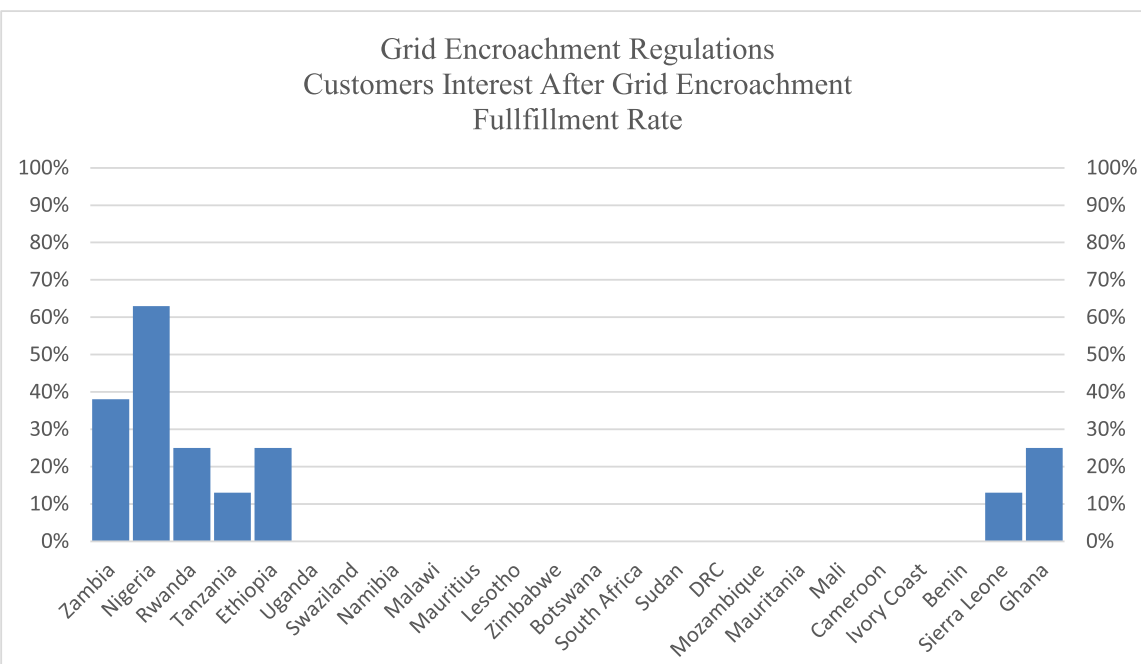

Fig. 7. Mini-grid customer interests after main grid encroachment.

Existence of adequate measures in these essential categories reflects the availability of countries to receive investments in mini-grids from private investors. The 35 benchmarks (Sec. 6) were designed in such a way as to have a short answer of YES / NO / UNKNOWN / UNCLEAR. The answers YES / NO were assigned to a benchmark when the regulation provides clear wording with no room for differing legal interpretation. UNCLEAR was used when the text in regulations is not specific enough and opens room for legal interpretation. UNKNOWN was used in the benchmarking when the regulations do not provide any information on the subject matter.

2.2. Selection of countries

A survey of all African countries which are active in mini-grid developments was undertaken to provide a solid base of countries earmarked for benchmarking. A total of 24 such countries were identified and are highlighted in green in Fig. 1. Seventeen countries already had documentation aimed at regulating mini-grid encroachment to some extent. Seven African countries, including the DRC, Mozambique and Mauritania have no regulations dealing with grid encroachment despite the fact that mini-grid development and mini-grid investments are taking place.

It was already known at the time of this research that some countries, e.g. Mozambique, were developing new regulations for mini-grids, but the drafts were not available for benchmarking. We have included these seven countries in the benchmarking process to highlight the absence of mini-grid and grid encroachment regulations, as the desire was to benchmark as many countries as possible. Nevertheless, the absence of publicly available mini-grid encroachment regulations or the lack of response of the regulators to our direct requests limited the research survey at the end to seventeen sets of regulations, which were thoroughly benchmarked.

2.3. Method of data collection

The research involved reviewing documents such as mini-grid regulations, main grid encroachment regulations, rural electrification acts, energy acts and energy regulation acts for stand-alone mini-grid systems, which were promulgated and publicly available in March 2021 [24–51]. In the absence of national mini-grid regulations covering grid encroachment, various documents of the national libraries – starting with the energy acts or energy regulation acts - were analysed within a structured approach to extract any relevant provisions for the benchmarking process.

2.4. Data analysis

For the data analysis, answers to questions YES/NO/UNCLEAR/UNKNOWN were translated in our data base into 1 and 0. A YES was assigned 1 and a NO or UNKNOWN or UNCLEAR was assigned a 0.

The fulfilment rate – as presented in the figures of Section 3 - is the ratio (in percent) of the number of favourable (YES) answers from the mini-grid encroachment regulations to the maximum number of favourable or wishful answers. In case the actual mini-grid encroachment regulation fully corresponds to the ideal or wishful situation, it attains a fulfilment rate of 100% for the respective country.

3. Results and discussion

The findings of the research are presented based on the overall findings and the individual five categories.

3.1. Overall fulfilment rate of mini-grid regulations

Fig. 2 shows the overall fulfilment rate of mini-grid regulations in the selected five categories [Technical Requirements, Legal Protection (permits and licences), Business Models, Financial Compensation Mechanisms and Customer Interests]. Zambia has an overall fulfilment rate of about 81% which is the highest among the 24 countries and considerably higher than the rest of the countries.

This indicates that the proposed Zambian mini-grid regulations should be significantly more effective to safeguard mini-grid investors' interests against potential main grid encroachment. Most countries have their overall fulfilment rates below 50%, which means that the regulations are incomplete and/or do not effectively protect the mini-grid investor against main grid encroachment. The following sections will provide key information on why most of the countries miss the 50% threshold. Fulfilment rate of 0% for the seven countries describe the actual unavailability of legal regulatory frameworks for protecting mini-grids against grid encroachment. National regulators and governments are urged to approve and publish appropriate regulations.

3.2. Technical requirements of mini-grids

Technical requirements for a mini-grid system describe aspects like the quality of power being supplied to the customers (i.e. quality of power ensures that the electricity generated meets specific frequency and voltage levels which conform to technical specifications) and the readiness of the mini-grid to be connected to the main grid in case of grid encroachment. Other technical requirements include the distribution and transmission cable, energy storage system, metering and energy generation system.

Fig. 3 compares mini-grid Technical Requirements before and after the event of a grid encroachment. Zambia reaches the highest fulfilment rate of 71%. Nigeria, Rwanda, Tanzania, Ethiopia, Uganda and Sierra Leone have fulfilment rates of 57%. Malawi, Ghana, Zimbabwe, Lesotho and Swaziland follow with 43% while Mauritius has only 29%. Technical Requirements are often the key in the regulations, which is exemplified by the homogenous level of results of most countries in the range around 50%. Most regulations are still lacking in some of the important aspects, as they fail to address mini-grid Technical Requirement compliance level, the time of compliance or the contribution to the cost for the compliance to technical requirement with the main grid technical requirements. A fulfilment rate of 0% indicates lack of specific mini-grid Technical Requirements for countries such as Namibia, Botswana, South Africa and others.

3.3. License protection / legal rights of mini-grid operators

Providing adequate legal protection (permits and licences) to mini-grid investors against grid encroachment are an integral part of mini-grid regulations. Fig. 4 shows the finding of this category and shows that Zambia has a fulfilment rate of 90%. As Zambian regulations do not provide adequate protection to retain the acquired customer base, the country does not achieve the 100% rate in this category. The analysis further shows that Nigeria has a fulfilment rate of 73% and Tanzania 55%. Rwanda, Malawi and Sierra Leone have fulfilment rates of 45% while Ethiopia, Mauritius and Lesotho have 27%. Uganda, Zimbabwe, Botswana, South Africa and Namibia have fulfilment rates of only 9%. The fulfilment rate picture in this category is very fragmented and documents the wide variety of approaches with regard to investor protection. In most cases the regulations fail to articulate how the licences protect the investor effectively and the loopholes indicate that the licence does not provide protection against unfair competition. The fulfilment rate of 0% in countries indicates a lack of adequate regulatory framework (s) for legal protection (permits and licences) of mini-grid systems.

3.4. Business model after grid encroachment

Mini-grid business models vary by ownership, size and customers. In order to effectively manage mini-grids after grid encroachment, there is a need to adopt an appropriate mini-grid business model that will offer benefits to the three parties, viz., the mini-grid operator, the customers (or the community) and the main grid operator. The findings in Fig. 5 show that Zambia, Nigeria, Rwanda have a 100% fulfilment rate while Tanzania and Lesotho sit at 90%. Sierra Leone and Ghana are at 70%. Malawi is at 60% while Ethiopia and Uganda stand at 50%. Fig. 5 shows that only 10 out of 24 countries offer at least one business model for a potential future collaboration of the mini-grid and the main grid. However, it has to be highlighted that more than 50% of the countries on the other hand have not even considered developing regulations on this important subject matter. Therefore, they achieve only 0% in this category, which documents a significant setback.

3.5. Process of negotiation/price finding mechanism for mini-grids

An appropriate financial compensation mechanism for mini-grids after main grid encroachment is another aspect that reflects the attractiveness of investing in mini-grids by private investors. When main grid encroachment occurs, mini-grid investors want to secure their investments and be compensated for the fair value of their assets / business. It is observed in Fig. 6 that Zambia has a fulfilment rate in terms of negotiation process / price finding mechanism for mini-grids after grid encroachment of above 93%, which is well above the other countries,

with Sierra Leone being the next highest at about 65% fulfilment rate. Zambia fails to achieve 100% of the fulfilment rate as the Zambian regulations can´t demonstrate full effectiveness, which is shown by absence of publicly available pre-determined price finding mechanism for mini-grids after grid encroachment in Zambia.

The majority of the countries fail to achieve even 50% of the fulfilment rate as they simply do not provide any solid process how to arrive at a purchase price for the assets / business of the mini-grids.

3.6. Customer interest after grid encroachment

Community involvement and social aspects are essential for the success of mini-grid projects. According to the benchmarking analysis presented in Fig. 7, Nigeria is leading in this aspect with 63% fulfilment rate, while Zambia has less than 40% fulfilment rate. For example, mini-grid regulation in Nigeria provides a clause for customers to participate in the negotiation processes prior to its finalisation, and the main grid operator is obliged to connect all mini-grid customers to the main grid as opposed to Zambia. This analysis shows that in Zambia, the main grid operator is not obliged to continue offering the existing mini-grid tariff or service in case these are more attractive to customers than the main grid tariffs or services in case they are disadvantageous to the main grid operator. The vast majority of countries – namely 70% – have not even attempted to consider customers' interest in their grid encroachment regulations. As customer protection is supposed to be one of the key domains of energy regulators it is alarming that 70% of the regulations have no clause at all dealing with this important aspect.

4. Conclusions

Benchmarking mini-grid encroachment regulations and comparing their potential effectiveness once the main grid arrives in a mini-grid supply area shows that most African countries are inefficient at attracting and retaining private investment. Existing regulations fail to provide adequate protection for the mini-grid licensee, limit potential business models after grid encroachment, black box the compensation mechanisms for the assets transfer and mostly ignore consumer interests. It is important to underline the fact that regulations are permanently in the process of being reviewed and being adopted. This implies that the benchmarking result has only a temporary validity and should be periodically reviewed.

Nevertheless, the conclusions obtained from this study reveal and suggest that the grid encroachment regulation in Zambia is currently the leading regulation for grid encroachment in Africa with an overall fulfilment rate of 81% compared to the second placed Nigeria with 62%, followed by other African countries. Despite the Zambian regulation of not having a publicly available pre-set price or pre-determined price setting mechanism in place, the analysis for Zambia still demonstrates that the country presents various opportunities for mini-grid developers. It provides the opportunity for the main grid operator and mini-grid investor to negotiate in good faith, and – provided that the Zambian Energy Regulation Board (ERB) believes that it is in the best interest of customers in the geographical area of supply concerned (thereby recognising consumer interests) - that the two parties come to an agreement on their own. Another advantage of the Zambian mini-grid encroachment regulation is that it clearly sets out a compulsory compensation settlement approach only where a willing buyer and willing seller cannot reach agreement by means of a carefully designed negotiation, intervention and enforcement process. It is this market driven approach with regulatory oversight and consumer participation (rather than a pre-determined but less flexible price determination approach) that puts Zambian mini-grid encroachment regulations ahead of those of the other countries.

In order to reach the target of the United Nations Sustainable Development Goal (SDG) on energy and power the world with 100% from renewable energy sources, other African countries need to establish or adopt common measures or approaches aimed at fostering mini-grid investment growth. The Zambian mini-grid encroachment regulations can be taken as a reference point to influence mini-grid policy makers and develop suitable mini-grid regulations. The benchmarking outcomes among the 24 African nations clearly show that most nations have not done their homework to address or mitigate the grid encroachment risk inherent in mini-grid investments.

Importantly, we also acknowledge that some countries such as Mozambique and Kenya are in the process of publishing mini-grid or off-grid regulations. Hence, there is a need to review the benchmarking results for these countries after twelve months of publication of this research.

5. Recommendations

The aims and objectives of the mini-grid regulations are typically the electrification of rural areas and provide energy access for all. However, the research highlighted that dedicated regulations dealing with grid encroachment are often the last thing energy regulators think of when designing mini-grid regulations.

Based on the outcomes of this study, we recommend that energy regulators consider the following aspects of a life cycle of a mini-grid in the design of mini-grid-regulations.

I MARKET ENTRY: The mini-grid regulations should allow a simplified entry in to the market.

II MARKET SUPPLY/OPERATION: The chapters and provisions for technical operation, reliable and affordable supply of energy, daily management, customer care and handling of legal affairs should require clear provisions to support the active business phase.

III MARKET EXIT: The terms for the market exit in case of grid encroachment by the main grid or the abandonment of a mini-grid at the end of its useful time require dedicated provisions in the five categories (i) Technical Requirements, (ii) Legal Protection (permits and licences), (iii) Business Models, (iv) Financial Compensation Mechanisms and (v) Customer Interests.

Following these recommendations, mini-grid regulations should be designed to attract private sector participation in mini-grid investments and offer an environment to easily enter the market.

The effective protection of the mini-grid licensee will strengthen the position of the mini-grid investors in the operational phase.

To regulate the eventuality of an unexpected grid encroachment followed by the forced exit from market in a proper manner is as important for the mini-grid investors as the entry. Many more investments in mini-grids will be realised when the regulatory environment offers acceptable terms to avoid stranded assets for the investor.

All three phases in the life cycle of mini-grid require proper provisions to attract investments in mini-grids and thus contribute another piece towards achieving the ambitious goal of net zero carbon emissions by 2050.

6. APPENDICES - Tables of Benchmarks

The analysis for benchmarking the effectiveness of mini-grid regulations against main grid encroachment was based on the five categories with their sets of benchmarks presented in Tables 1–5 below.

Acknowledgements

The research on mini-grid encroachment was inspired by the consultancy work for the implementation of a new set of mini-grid regulations for the Republic of Zambia in 2018. We thank the Energy Regulation Board of Zambia (ERB) and the consulting firm DT Global for allowing the benchmarking of the draft mini-grid Encroachment regulation in this research. We also thank Mr. Jon Exel from ESMAP and Mr. Alexander Filippov (Sustainable Energy Expert) for their comments on our research. Authors Prem Jain and Christopher Mambwe would like

Table 1
Technical requirement before/after main grid encroachment.

Technical requirement benchmarks
1. Are mini-grid operators requested to comply with main grid standards when they connect to the main grid? (Yes/No)
2. Are there mini-grid technical standards detailing the requirements for mini-grids on how to connect to the main grid? (Yes / No)
3. In case where mini-grid does not comply with main grid standards, who pays for the upgrade of the mini-grid to the main grid standards?
a) Seller (Yes/ No)
b) Buyer (Yes/No)
4. Do regulations determine the point in time when mini-grid has to comply with main grid standards:
a) Is there requirement for compliance with main grid standard at the time of initial commissioning of the mini-grid (Yes/No)
b) Is there requirement for compliance with main grid before connection of mini-grid to main grid? (Yes/No)
c) Is there a time limit for compliance after main grid connection of mini-grid? (Yes/No)

Table 2
Legal protection against main grid encroachment.

License protection / legal rights benchmarks
1. Are mini-grids protected by an exclusive licence from the regulator which can allow them to defend against arrival of main grids? (Yes/No)
2. Are mini-grids protected by an exclusive licence from the regulator which can allow to defend against arrival of other mini-grids in the licensed area? (Yes/No)
3. In case mini-grids are protected by an exclusive licence, indicate the type of protection:
a) Exclusive geographical area, no double subsidies? (Yes/No)
b) Double subsidy/grants? (Yes/No)
c) Exclusive customers? (Yes/No)
d) Others? (Yes/No) If Yes, state protection type.
4. For how long will mini-grid rights be protected after the arrival of main grid? (Indicate period of time)
5. Is main grid entitled to approach existing mini-grid clients? (Yes/No)
6. Is main grid entitled to approach new mini-grid clients? (Yes/No)
7. Can mini-grid operators be legally forced to charge a different tariff (e.g. the National/ main grid tariff)? (Yes/No)
8. Can the regulator terminate the mini-grid licence for other reasons than breach of licence conditions to enable any kind of grid encroachment? (Yes/No)

Table 3
Business model after main grid encroachment.

Business model benchmarks
1. Do the regulators predetermine business models after any grid encroachment? (Yes/No)
2. Which business model does regulator allow after grid encroachment:
a) Co-existence of mini-grid and main grid? (Yes/No)
b) Mini-grid will be completely abandoned and main grid rebuilds a distribution grid and connects all customers newly. (Yes/No).
c) Main grid only buys the distribution of the mini-grid and mini-grid generation assets are abandoned? (Yes/No)
d) Main grid buys complete mini-grid and operates all assets (generation & distribution)? (Yes/No)
e) Mini-grid stops energy generation and becomes a reseller of main grid energy (Small Power Distributor)? (Yes/No)
f) Mini-grid operator becomes integrated Small Power Producer (SPP) for main grid. Main grid becomes only the distributor and supplier for mini-grid customer? (Yes/No)
g) Mini-grid operator signs sales purchase agreement after connection to the main grid? (Yes/No)
3. Can the mini-grid and main grid freely agree on the business model? (Yes/No)
4. Do regulations allow willing buyer/willing seller negotiations? (Yes/No)

Table 4
Price finding mechanism/process of negotiation.

Price mechanism/process of negotiations benchmarks
1. Are willing buyer / willing seller free to determine:
a) The process of negotiation? (Yes/No)
b) The price finding mechanism? (Yes/No)
c) The structure of the deal (e.g. assets or share deal)? (Yes/No)
2. Do the regulations foresee a mechanism to determine the financial transaction value (purchase price/compensation) of the mini-grid? (Yes/No)
3. Can the regulator disagree to a negotiated price under willing buyer/willing seller situation? (Yes/No)
4. Do the regulations foresee a process in case regulator does not accept an agreement based on willing buyer/seller result? (Yes/No)
5. Do the regulations foresee a forced process in case willing buyer/seller cannot mutually agree on a purchase price? (Yes/No)
6. Do the regulations foresee a process in case forced negotiation fail? (Yes/No)
7. Who will determine the final purchase price in case of failed negotiation:
a) the regulator? (Yes/No)
b) the independent auditor? (Yes/No)
8. Do the regulations foresee a process how parties have to come to an agreement? (Yes/No)
9. Do the regulations foresee that the regulator determines the purchase price? (Yes/No)
10. Do the regulations foresee that the parties have to accept the determined purchase price by the regulator? (Yes/No)
11. In case the regulator determines the purchase price, is the price finding mechanism pre-determined and publicly available? (Yes/No)
12. In case parties fail to agree on suitable upgrades costs (technical standards), can the matter be referred to the regulator for determination? (Yes/No)

Table 5
Customer interest after grid encroachment.

Customer interest benchmarks
1. Does the regulation provide a clause for customers to have a say / involvement in the negotiations process? (Yes/No)
2. In case the regulation provides the "say clause" for customers in the negotiations process, to what extent?
a) throughout the negotiation process? (Yes/No)
b) prior to the finalisation of negotiations? (Yes/No)
3. Does the regulation provide a time period in which mini-grid customers have to accept the new tariffs from main grid after encroachment? (Yes/No)
4. How long is the time period in which mini-grid customers have to accept the new tariffs from main grid after encroachment? (Yes/No) and state the duration
5. Are main grids obliged after encroachment to continue offering the existing mini-grid tariff/service in case mini-grid tariffs / services are more attractive than main grid tariffs/services? (Yes/No)
6. Does the regulation provide legal restrictions limiting the prices main grid operator can charge after encroachment? (Yes/No)
7. Is the main grid obliged to connect all the customers to the main grid after grid encroachment? (Yes/No)

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