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Policy Priorities for Catalyzing DRE Markets: Practical Lessons from the Most Successful Markets

AUTHORS

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ABSTRACT

Despite broad agreement about the importance of power to human development, the critical nature of rural electrification, and the opportunities that distributed renewable energy (DRE) technologies present for energy access, the majority of countries suffering from energy poverty have yet to truly mobilize the power of DRE. Only 40% of low electricity access countries have specific rural energy access targets and fewer have established DRE markets. What are the most critical elements of early stage policy frameworks for low energy access countries seeking to quickly catalyze DRE sector development in-country?

We conduct a two-tiered empirical analysis of the five most active DRE markets in the world (Kenya, Ethiopia, Tanzania, India and Bangladesh) using best available data to provide practical insight into policy priorities for low energy access countries. We survey DRE practitioners operating in these markets to identify the policies and regulations that have most influence on local operations. We then observe the correlation between policy performance and market growth for these countries, finding that statistical relationships corroborate the experiences and perspectives of practitioners.

These two exercises highlight five areas for prioritization: overarching national energy policy that establishes national commitments to electrification; rural electrification plans or programs that integrate DRE as an access solution; technical regulation that streamlines licensing procedures for DRE service providers; adoption of internationally recognized quality standards for DRE products and services; and financial policy that reduces or eliminates import duties and tariffs on DRE products and which supports the availability of local finance. While policy itself is of course not the only factor critical to successful market development, well implemented policy is key to creating enabling environments. Based on the practical experience of peer countries, this study provides applied policy lessons for low energy access countries seeking to catalyze the DRE sector and its benefits for energy access.

1. Introduction: Distributed Renewable Energy Needed to Accelerate Universal Energy Access

Providing universal energy access is one of the greatest development challenges of our time. With almost 16% of the global population lacking access to electricity, the United Nation's Sustainable Development Goal 7 (SDG7) - to ensure affordable and clean energy to all people by 2030 - is a welcome vehicle by which to unlock the underlying benefits of energy access, which include choice, opportunity and freedom. Universal energy access is critical to the achievement of many other SDGs goals, such as ending poverty, achieving food security and promoting sustainable agriculture, ensuring equitable quality education, achieving gender equality, promoting sustainable economies and productive employment for all, reducing inequality and responding with urgency to climate change and its impacts.

However, achieving universal energy access and unlocking its subsequent benefits will require a concerted focus on serving rural communities. In fact 80% of the 1.2 billion without electricity access live in rural areas where connections to the central grid are often economically prohibitive and can take many years to realize [1]. Yet specific focus on solutions for rural electrification are not commonly reflected in national policy. Even in countries with the least electricity access in the world - those where less than 50% of the rural population has access to electricity – we find that while 60% have national energy access targets, only 40% have specific rural energy access targets (see Appendix 1) [2]. Many of the energy poor also live in peri-urban areas where connection to central grid can be difficult [3]. As such, focused attention to faster, cheaper, cleaner electricity solutions in rural and off-grid communities are critical to energy access goals.

Alstone et al. identify persistent and pervasive 'energy isolation barriers' which remote communities continue to experience in the context of centralized, grid-based electrification as a result of the multiple dimensions of geographic, economic and political remoteness [4]. For instance, complex geography and diffuse population inflates the marginal cost of grid extension in many rural areas for poor nations, while the economic limitations of such communities are reflected in low energy consumption and the inability to afford central grid connection fees. The political currency often required for central grid expansion often represents a further social barrier for marginalized or opposition communities. Distributed renewable energy (DRE) systems, which generate and distribute energy services independently of any centralized system, offer an unprecedented opportunity to accelerate the transition to modern energy services in such remote areas by complementing or substituting centralized systems while also offering significant co-benefits such as improved health, positive impacts on income growth, women's empowerment, distributive equity and climate change mitigation [5].

In fact, DRE systems already provide energy services to millions of people, with market penetration increasing annually. GOGLA estimates that pico-solar products alone (defined as products having a PV panel smaller than 10W) currently reach over 89 million people, serving a total of over 19 million households, and thereby improving energy access for 7% of the total off-grid population [2, p. 41]. Kenya, Tanzania and Ethiopia are Africa's leading markets, together accounting for 66% of sales in the region, while India and Bangladesh account for more than 96% of sales in Asia (see Table 1). According to GOGLA, over 20 million quality verified lighting products have been sold in the last ten years by over 100 companies actively

focused on solar lanterns and solar home kits [2, p. 2]. When compared to the largest utilities in the world, the sales from these DRE companies collectively reach the tenth largest number of households worldwide. The magnitude of DRE's global market penetration over such a short period of time highlights its role as a cheap and fast solution to basic energy access (see Table 2).

Well designed and implemented policy is one of the most important factors in enabling energy access, as is well documented in the literature [15]–[18]. Yet low electricity access countries, who stand to benefit the most from DRE market development are often the countries with the least developed DRE policy portfolio. While 40% of these countries had rural electrification targets, only a third have DRE targets (see Appendix 1). What are the most critical elements of early stage policy frameworks for low electricity access countries seeking to quickly catalyze DRE sector development? In this paper we identify success factors for policy best practice that can be adopted in low electricity access countries to catalyze DRE market growth based on policy trends observed in high growth markets. We focus on the five largest DRE markets globally: Ethiopia, Tanzania, Kenya, India and Bangladesh, and provide insight based on practitioner survey and analysis of policy performance indicators. We note however that beyond its establishment, policy is often poorly implemented in country due to limited government capacity, lack of clarity around roles and responsibilities of government ministries, departments and agencies, lack of political will from leaders to implement/enforce policy.

Table 1 Total Sales and Active Companies for Top-Performing DRE Markets

Country	Total Unelectrified Population (Millions)[1]	Estimated Number of Households using SHS/pico-PV as of mid-2015 (Millions)[2]	Number of Active SHS/pico-PV Companies[3]	Number of Active Mini-Grid Companies
Ethiopia	73	2.00	36	15
Tanzania	36	2.50	67	36
Kenya	36	2.70	89	42
Bangladesh	60	3.70	46	19
India	244	8.10	63	84
Rest of SS Africa	632	3.50		
Rest of Asia	512	0.40		

[1] Data from WEO Electricity Access Database [1], data for 2014 or the latest available year

[2] Cumulative sales data for verified pico-PV and SHS products estimated by number of households served was taken the most recent Off-Grid Solar Market Trends Report by BNEF, GOGLA, and Lighting Global [2]. Bangladesh's IDCOL program uses a different quality standard than GOGLA's Lighting Global and sales are not tracked by GOGLA. Cumulative SHS sales for Bangladesh are taken from IDCOL's After Sales Service of Solar Home System (SHS) Program under IDCOL [6]. The Bangladesh estimate is conservative as: IDCOL does not track sales of pico-PV systems; we do not account for additional assumptions on product lifetime or repeat sales as are considered for GOGLA estimates. We assume that IDCOL's SHS sales are one per household.

[3] The lists of companies for pico-PV and mini-grids are compiled from a variety of sources, including the members lists of the Alliance for Rural Electrification [7], GOGLA [8] and Bennu Solar [9] as well as the renewable energy associations of each country [10]–[13].

Table 2 Estimates of Households Served by Largest Global Utilities and DRE Providers (Collectively)

Utility Company	Country	Total Number of Households/ Connections[4,5]	Average National Household Size[6]
State Grid (China)	China	366.70	3.00
ENEL	Italy	61.00	2.60
E.ON	Denmark	46.40	2.60
EDF	France	37.60	2.10
Iberdrola	Spain	30.00	2.80
TEPCO	Japan	29.20	3.00
National Grid (UK)	United Kingdom	22.40	2.10
GDF Suez	France	22.00	2.60
Korea Electric Power	South Korea	22.00	2.80
DRE Providers	Global	19.20	5.00
Power Assets	Hong Kong/China	17.30	2.10
Endesa	Spain	11.11	2.80
Exelon	United States	10.00	2.60
SSE	United Kingdom	8.21	2.10
Duke Energy	United States	7.40	2.60

2. Method: Identifying Priorities for Early Stage Sector Development from Empirical Analysis

In this study we present a two-tiered empirical analysis of the five most active DRE markets in the world (Kenya, Ethiopia, Tanzania, India and Bangladesh) using recent, best available data to provide practical insight into policy prioritization for low energy access countries. We first survey a sample of DRE practitioners operating in these five largest markets to identify the policies and regulations that have most influence on companies operating locally. This real-world insight provides strong messages for policy priority areas. We then observe the correlation between policy performance and market growth for these top performing countries and find that statistically significant relationships corroborate the experiences and perspectives of practitioners. Our study builds on policy best practice theory developed by several institutions (e.g., World Bank, African Development Bank, Asian Development Bank) by identifying practical early stage policy priorities for DRE sector development through empirical data. In the following sections we explain the methodologies and discuss results.

[4] Number of residential connections obtained from company websites and annual reports

[5] DRE Providers represents the more than 100 active companies reported on by BNEF. Estimated number of households served by SHS/pico-PV from BNEF Off-grid Solar Market Trends Report 2016 [2]. This estimate is conservative as: it does not account for sales of SHS/pico-PV products not verified by Lighting Global (and therefore not reported by BNEF); it does not account for mini-grid connections

[6] Average household sizes provided for reference to total number of persons served. Source: OECD [14]

3. "Survey Says": Clear Policy Favorites Identified by DRE Companies in Local Operation

Our first empirical measure of policy priority comes through practitioner perspective. We extended a survey to practitioners in the Power For All partner network currently operating in one or more of the top five performing countries. Twenty-three (23) companies, including eleven (11) companies that sell Solar Home Systems (SHS) and pico-Photovoltaic (pico-PV) products, five (5) companies that operate micro- or mini-grids (collectively referred to here as mini-grids) and seven (7) companies that provide both mini-grid and SHS or pico-PV services participated in the survey. Together these companies provide energy services (either mini-grid connection or lighting products) to over 2.7 million households.

Participants were asked to rank a specific sub-set of policy instruments within three groupings (national energy policy, technical regulation, and financial regulation and policy) according to how important or beneficial the respective instrument has been (or would be) in supporting their local business operation. They were also asked to explain their choice for the number 1 ranked policy measure. The average ranking of each policy instrument in a grouping was calculated as follows, where:

w = weight of ranked instrument
x = response count for ranking choice

$$\frac{x_1w_1 + x_2w_2 + x_3w_3 \ldots x_nw_n}{x_{total}}$$

Weights were applied in reverse, such that a given respondent's most preferred choice (which they ranked as number 1) has the largest weight, and their least preferred choice (which they ranked in last position) has a weight of 1. For readability each instrument's average ranking is expressed as a percentage of the total and its count of number 1 rankings is expressed as a percentage of total responses (see Figure 2). This exercise provides clear insight into policy priority from the DRE practitioner's perspective.

Based on survey results, the most influential national energy policy instrument is the presence of specific off-grid or DRE penetration targets and time frames. This had both the highest average ranking of the sub-group (30%), and also the most number 1 rankings (30%). One respondent explains that DRE penetration targets *"communicate a clear action and commitment from the government and allow for relatively accurate forecasting of future growth potential."* However while 50% of companies that only sell SHS/pico-PV rank specific DRE penetration targets as number 1, 75% of mini-grid only companies ranked national electrification plans that specifically integrate DRE as the number 1 policy. One such mini-grid respondent notes: *"For mini-grids the key policy risk is grid integration. Hence a recognition that mini-grids are part of the national strategy rather than a bet against it is key."* Companies that both operate mini-grids and sell SHS/pico-PV are fairly split between the two.

With respect to technical regulation, clear and low-cost permitting and licensing regimes for DRE owners and operators along with the adoption of internationally recognized product quality standards and

performance reporting requirements were the two most important regulatory measures identified, being almost equal in terms of average ranking (22% each) and number 1 ranking (38%, 33% respectively). Again, when parsed by company type we notice differences in priority. While 60% of companies that only sell SHS/pico-PV ranked adoption of quality standards as the number 1 policy (with one respondent identifying low-quality products as *"one of our biggest perceived market spoilers"*), 75% of mini-grid only companies chose clear, low-cost permitting and licensing regimes as the most important. One mini-grid respondent notes that licensing is *"the first stumbling block when looking to enter a market."* Companies that both operate mini-grids and sell SHS/pico-PV are fairly split between the two.

With respect to financial policy, DRE companies are agreed on the most important measure for the sector. Exemption from import duties/tariffs on DRE products dominates the sub-group, with 50% of the number 1 rankings and the highest average ranking (21%). At least 50% of each company type (mini-grid only companies, SHS/pico-PV only companies and those that both operate mini-grids and sell SHS/pico-PV) chose exemption from imports as the number 1 policy. One SHS/pico-PV respondent explains that *"exemption from import duties allows us to pass along lower costs to customers and make products more affordable."* Financing support (debt financing and loan guarantees) also has a high average weighting (17%) as the other 50% of mini-grid operators all chose it as number 1. One such mini-grid respondent notes that due to the need for *"risk mitigation in emerging markets finance is the most critical element."*

Across each sub-group the standard deviation of the average rankings was small (less than 5% each). This fairly even spread of total assigned weighting suggests that though there are clearly dominant policies, other policy instruments in each grouping are also seen as important by DRE companies. In sum, we draw the following conclusions on policies that best support DRE practitioners in highly successful DRE markets:

- National Energy Policy: It is important for governments to establish specific DRE targets and to integrate DRE into national electrification planning, thereby demonstrating commitment and setting the stage for market entry.
- Technical Regulation: Internationally recognized product quality standards are critical for instilling market confidence for the SHS/pico-PV sector while streamlined licensing and permitting most significantly reduce technical/operational barriers to entry for mini-grid operators.
- Financial Policy: The single most effective financial measure that governments can take to catalyze DRE market growth is to remove import duties and tariffs on DRE products.

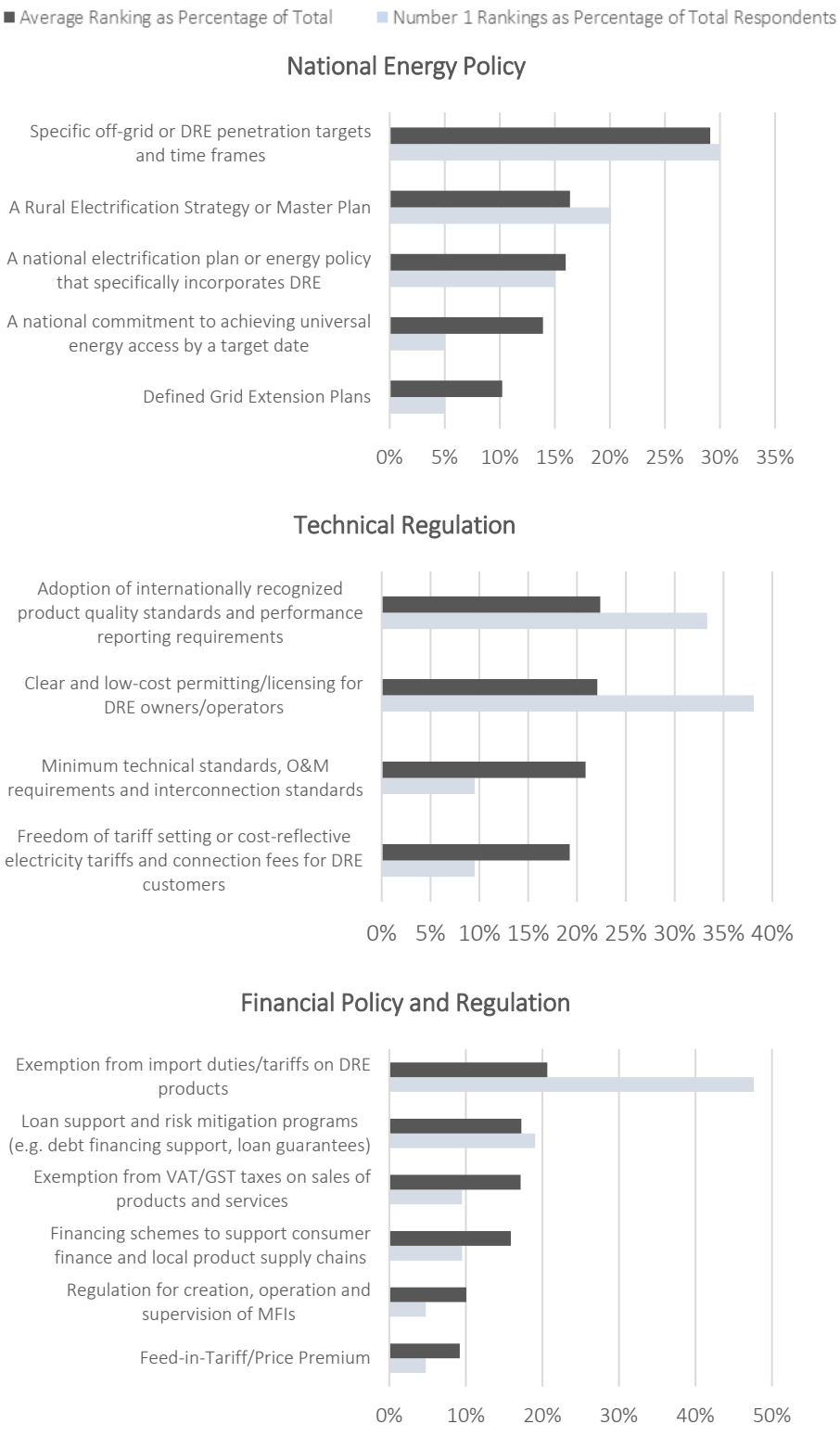

Figure 1 Average rankings for policy and regulatory instruments ranked by DRE Companies operating in case countries

4. "The Five Habits of Highly Effective Markets": Trends Across High Performing Countries

The second tier of our analysis tests whether the opinions of DRE practitioners on the ground are corroborated by quantitative data on policy performance. In this study we observe the correlation between policy performance indicators and DRE market growth for the same five top performing countries. We use two estimates for DRE market development: (i) cumulative sales of quality-verified solar lighting products, which represents market size; and (ii) the number of DRE companies in operation, which represents market activity. These are both conservative estimators, as solar lighting product sales do not incorporate energy service provision from mini-grids or other DRE systems, and as the number of active companies does not factor in company size. However, due to limitations of data availability we employ these metrics as suitable proxies, noting that greater national and international support for tracking mini-grid and SHS/pico-PV market penetration is clearly needed.

Cumulative number of households using pico-PV products verified through the Lighting Global Quality Assurance Program as of mid-2015 are obtained from BNEF's Off-Grid Solar Trends Report, 2016 [2] for the Sub-Saharan African countries and India. The Bangladesh SHS Program is executed by the Infrastructure Development Corporation Limited (IDCOL). IDCOL uses its own quality assurance standard specific to Bangladesh [19]. Cumulative SHS sales in Bangladesh through the program through mid-2015 are obtained from IDCOL reports [6]. This data does not include sale of pico-PV products in Bangladesh, which are not covered under IDCOL technical standards [19]. The total number of mini-grid and SHS/pico-PV companies actively operating in each country are based on company lists compiled from country renewable energy associations [10]–[13] and member lists from the Alliance for Rural Electrification [7], GOGLA [8] and Bennu Solar [9]. Both of these metrics are normalized through division by total unelectrified population (WEO, 2015) for comparison to each country's respective potential market [1]. We note that while current electricity access estimates rely on binary access definitions, more accurate measurements of electrification will become available with the arrival of SE4ALL's Multi-Tier Framework results [20].

To quantify policy performance we use BNEF's clean energy investment-climate assessment tool, Climatescope. Climatescope is an interactive report and index that evaluates the policy and investment climate for clean energy investment in fifty-five (55) developing countries across the world based on the expert evaluation of over 53 distinct indicators summed to country scores [21]. We select all energy policy related indicators in the Climatescope cache for this assessment, which include: Clean Energy Policies, Power Sector Structure, Distributed Energy Regulatory Framework, Clean Energy Rural Electrification, Energy Access Policies, Policy Barriers (import tariffs), Loans Grants and Grant Programs, Local Investment, and Number of Green Microfinance Institutions (MFIs). See Appendix B for a detailed explanation of how Climatescope defines and measures these indicators.

To illustrate the correlations between our sub-set of Climatescope policy indicators and DRE market development, a least-squares linear regression was performed for each measure of market growth. In each regression plot, the Climatescope indicators are normalized to percent value of the maximum country score awarded for that indicator (see Appendix B). Using this method, the slope of a positive correlation can be

defined as the increase in market growth or development per percent increase in policy performance score. To measure how closely the data points fit the regression line, an r-squared value is provided with each indicator plot.

Due to the small sample size of these regressions, it is important to check the validity of each regression. By plotting residuals against the values for market development, each regression was checked for outliers to determine whether the relationship was valid. See Appendix C for residual plots. Three indicators (Clean Energy Policies, Power Sector Structure, and Local Investment) were shown to contain influential outliers under both market metrics, and therefore their regression models are likely invalid. These were also the indicators with lowest r-squared value in each market metric analysis, rendering them statistically insignificant linear relationships. The five remaining policy indicators correlate strongly and positively to both market development metrics.

The finance related indicators are the strongest correlators to DRE market growth under both metric analyses. The financial mechanism correlated most strongly to sales and active companies is import tariffs and duties, an indicator designed to gauge the cost of bringing clean technology into a country. It is based on World Trade Organization (WTO) data on import duties levied by country on a range of clean energy products (see Appendix B for details). This corresponds to the findings from our practitioner survey, which identified exemption from import duties as the most important financial policy for catalyzing DRE market growth. The Loans, Grants and Grant Programs indicator measures total new in-country investment in distributed projects and is filtered by investor origin, so that the score represents the ratio of commitment to local projects by local investors in the distributed energy space. Together with the Number of Green MFIs, the positive correlation of these indicators highlights the importance of access to local (debt) finance for both companies and customers, also corresponding to the findings of our practitioner survey.

Climatescope's import duties score averages import duty on nine product categories in the clean power supply chain, ranging from inverters to wind turbine blades to PV cells and hydraulic turbine parts. SHS and pico-PV products are commonly imported as photosensitive devices under HS Code 854140, so we isolate this tariff for closer observation. Other than Bangladesh (2.5%) all of the top performing countries have tariff exemptions for solar products (most recent tariff ratings by country from the WTO Tariff Database [22] and from the Ethiopian Revenues and Customs Authority [23] for Ethiopia (who is not a member of the World Trade Organization). However product category descriptions are defined by the respective custom authority and these definitions are subject to amendment. As such, different countries use different HS codes for the same product or interpret the same HS code differently thereby limiting further comparative or causal impact analysis of specific tariff codes over time or across countries.

For each top performing country we also compile data on the number of active MFI companies, their customer base and total outstanding loan balances from local regulatory authorities, Central Banks and local Microfinance Associations (see Table 3). Bangladesh is setting the precedent for microfinance across the world, having almost 700 active MFIs serving 20 million customers (averaging 11.62 MFIs per million

customers). Microfinance in Bangladesh is driven by grassroots organizations, which have become very innovative, offering credit for popular energy products (such as solar charging devices) to distinguish themselves in highly competitive markets. Without Bangladesh the other four top performing countries perform more similarly, averaging 1.05 MFIs per million customers. There is clear room for expansion in the microfinance space, and as the regression results demonstrate, there is positive correlation with continued market expansion.

The other policy indicators strongly correlated to both market metrics relate to distributed energy regulatory frameworks and energy access policy. The Distributed Energy Regulatory Framework indicator specifically gauges regulations and policies for enabling the development of mini-grids and small power projects (<10MW). The energy access policy indicator gauges policies and enablers for increasing energy access with a focus on rural electrification programs. When we unpack the specific policy measures that comprise each of these indicators we find that there are particular policy measures which all top performing countries have undertaken, contributing to high scores and influencing the strength of indicator correlation (see Figure 5). With regard to regulatory frameworks for distributed energy, we find that all top performing countries have established mini-grid licensing requirements and have adopted technical quality standards for products and services, which corresponds directly to the highest ranked technical regulations identified through our practitioner survey.

For instance, with regard to energy access policy, all top performing countries have Energy Access Targets (defined as national level commitments to energy access and electrification in particular) and an active Rural Electrification Program (see Figure 5). Again, this trend corresponds to the highest ranked national energy policies identified by survey respondents. Other high performance areas under Energy Access Policies include tax reductions, mobile money availability and the removal of barriers to operating as a retailer of clean energy products. Unpacking these two indicators also shows which policy areas are still lacking, even in top performing countries, namely: tariff deregulation, the provision of connection grants for customers and clear rules of operation on central grid arrival are all areas of needed improvement even for top performers.

This exercise of observing correlation between quantified policy performance and DRE market size and activity across the most successful DRE markets in the world corroborates the findings of our practitioner survey. Deconstructing the five policy performance indicators with strongest correlation confirms the experience of local operators, and highlights important market accelerators for governments in low energy access countries seeking to catalyze DRE market growth:

- Reduction of import duties and tariffs on DRE related products
- Supporting the availability of local finance through loans and grants and microfinance
- Establishment of energy access targets or national commitments to electrification
- Establishment of rural electrification plans or programs that incorporate DRE

- Technical regulation through established licensing procedures for mini-grid operators and through adoption of quality standards for products and services

See the policy reference guide in Appendix D for quick identification of policy and policy status across these areas for each of our top performing countries.

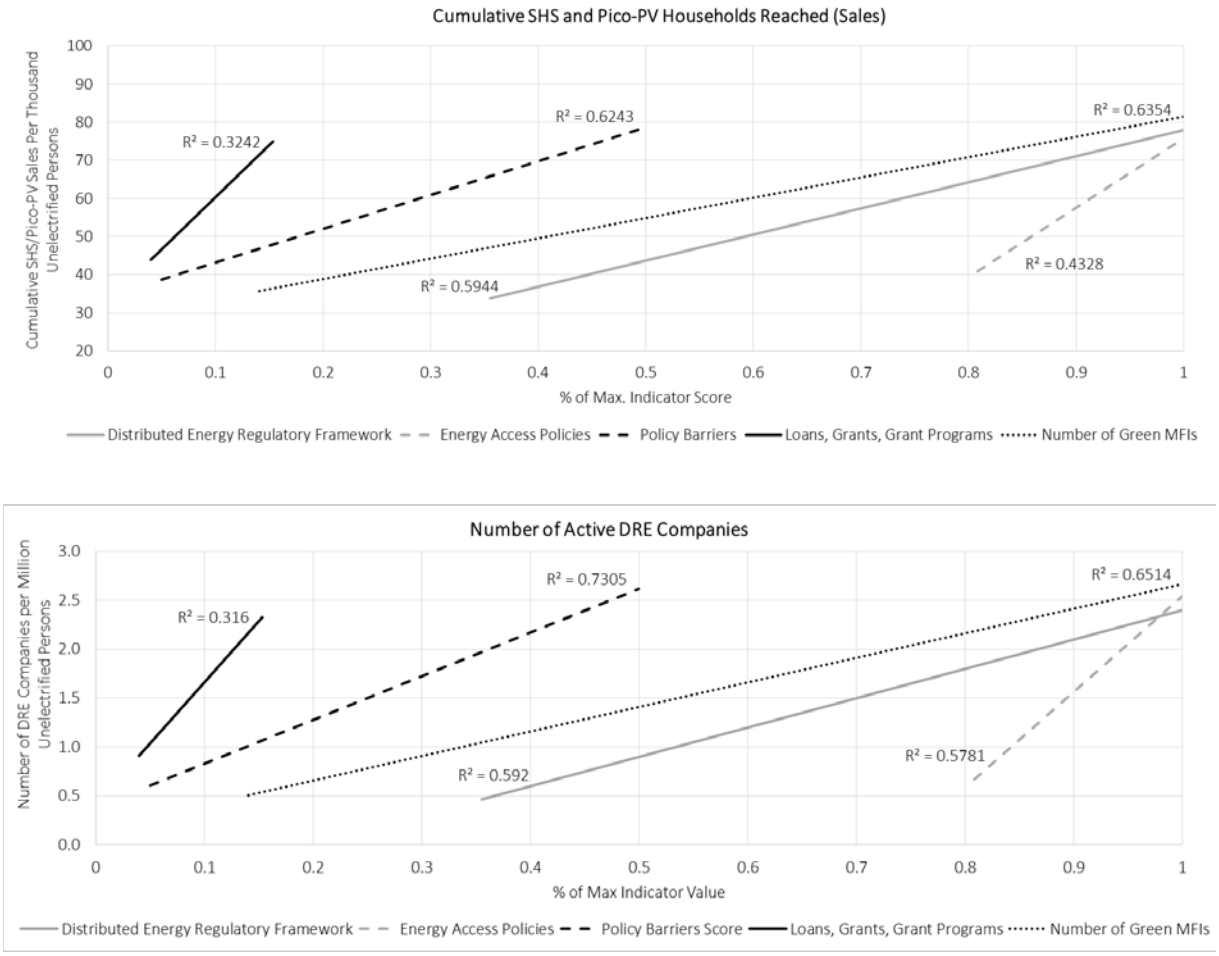

Figure 2 Regression Analyses for DRE Sales and Number of Companies against Policy Performance

Table 3 MFI Activity in Top Performing Countries

Country[7]	Number of Active MFIs	Total Number of Customers (Millions)	Total Outstanding Loans (Million USD)	MFIs per Million Unelectrified Persons	Loans Per Customer (USD/capita)
Bangladesh	697	20.00	3.50	11.62	0.18
Tanzania	82	0.34	0.04	2.28	0.13
India	268	39.90	9.38	1.10	0.24
Ethiopia	35	3.10	0.27	0.48	0.09
Kenya	13	0.81	3.00	0.36	3.70
Average				3.17	0.87

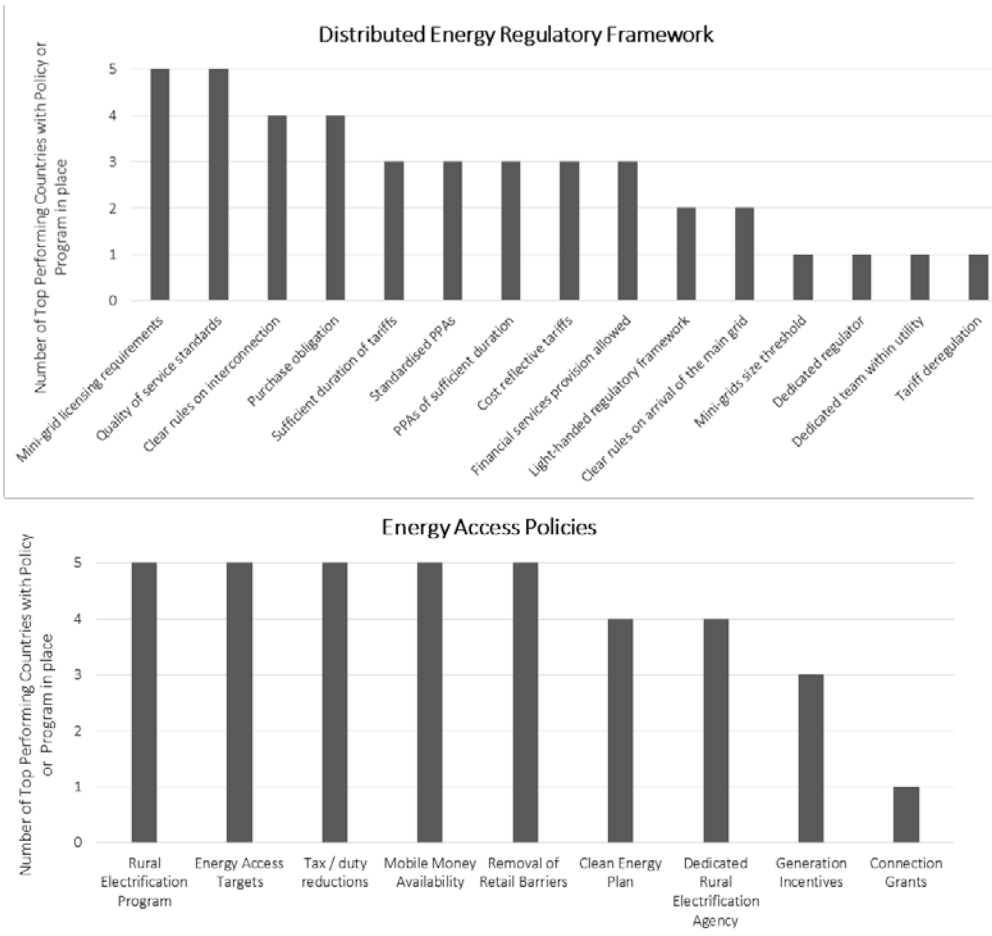

Figure 3 Number of Top Performing Countries that have executed policy/program measures that comprise the respective Climatescope policy indicator

[7] MFI data compiled from local Regulatory Authorities, Central Banks and Microfinance Associations, sources:

5. Limitations and Future Work

Our analysis is limited by a number of data and methodological constraints:

(i) Market Metrics: While we take SHS and pico-PV sales data from best-available sources, the sales data reports from BNEF and GOGLA only report sales from GOGLA members and IFC associates (and not all members and associates participate), meaning that the data does not include any unbranded/generic and unverified products. The data is all self-reported, and is made public only when at least three (3) companies have reported data for any given country. BNEF estimates that the data it reports in its Off-Grid Solar Market Trends study represents about 50% of all sales of off-grid products in the market [2]. Furthermore, the cumulative sales BNEF report includes data for only pico-PV products (less than 10W), while the IDCOL data only accounts for larger system (SHS) sales, both thus being incomplete product sales estimates. As such our cumulative sales (and therefore market size) estimates are also conservative.

There is also generally poor data available on mini- and micro- grid installations and performance. As of 2015 IDCOL reports there were 4 solar based mini-grids in operation in Bangladesh (total 500kWp), with twelve more under construction [24]. GNESD reports that different government agencies have reached over 250,000 households through mini-grid connections [25][8]. Meanwhile, the Tanzania Traditional Energy Development Organization (TaTEDO) reports having installed more than 80 solar, biogas and micro-hydro mini-grids (together 85kWp) serving 13,640 households [26]. These estimates are unofficial, and conservative, tracking mostly mini-grids installed through government programs, often not including private sector estimates, and not reporting on performance or operation of established systems. Authoritative estimates for top performing countries are difficult to source, especially given the lack of specific industry associations and the absence of industry standards for reporting.

(ii) Performance Proxies: BNEF's Climatescope project ranks countries based on past and present ability to attract investment for clean energy based on policy performance and other indicators of enabling environment. The performance is based on quantitative data where possible - for instance, the value of new clean energy investments received per year or the number of operational MFIs. However the source data necessary for such performance ranking is often limited (such as data on MFI operation, size, customer base, or information on outstanding loans for energy services and products specifically) thus affecting the applicability of Climatescope indicators as performance proxies. Likewise, Climatescope's regulatory and policy related indicators are mostly based on expert evaluation of performance using binary (yes, no) or trinary (yes, no, somewhat) scoring. These indicators are thus largely high-level, and future work will involve more rigorous assessments of policy performance and, equally important, policy implementation.

[8] GNESD reports that in India the two most successful models of mini-grids implemented by government agencies were through the West Bengal Renewable Energy Development Agency (WBREDA) and the Chhattisgarh Renewable Energy Development Agency (CREDA). [25] WBREDA is responsible for the installation of more than 20 solar based mini-grids (total 1MWp) serving 10,000 households in West Bengal. CREDA has electrified 35,000 households through low capacity (1-6kWp) solar mini-grids. The private sector has also implemented variants of mini-grids in many states, with local company Husk Power Systems having installed over 3MWp of biogasification capacity across 300 villages serving 200,000 households [25].

(iii) Methodology: The statistical significance of the relationships observed through our correlation analysis is limited by methodology for a number of reasons. First, little to no sales data is available for developing countries with small DRE markets, so the analysis is constrained to a small sample of highly performing countries. Second, we are unable to conduct time series analysis of market growth and policy performance as historical yearly data for policy performance is inconsistent and limited[9]. Furthermore, the number of compounding factors involved in policy implementation and market development can skew temporal relationships between the two. Third (and conversely), snapshots of present policy performance, even where historically informed, cannot not fully explain past market development. Causal relationships thus cannot be inferred through this correlative methodology.

Our stakeholder survey also has a small sample size, so that for both empirical analyses we interpret statistically significant relationships conservatively. Rather that capture causality, our analysis helps identify policy and regulatory trends across the most successful DRE markets. Future work will involve collecting market growth data for a larger sample of countries. We will also explore the effects of individual policy mechanisms through country case study where data is available (for instance, conducting an in depth time series analysis of import duties versus market sales for countries like Kenya, where yearly sales and product cost data are available).

6. Conclusion: Success Factors for Catalyzing DRE Sector Development

Despite broad agreement about the importance of power to human development and the critical nature of rural electrification, progress to date has been slow. Low electricity access countries have the most to gain from DRE penetration yet less than 40% of these countries have specific rural energy access targets and less than a third have explicit DRE targets. In this study we ask, if low energy access countries desire to establish frameworks that quickly catalyze development of the DRE sector in-country, what are the most critical elements of an early stage policy portfolio?

We identify the most important policies for DRE market acceleration through a two-tiered empirical analysis of the five most successful and active DRE markets in the world (Kenya, Ethiopia, Tanzania, India and Bangladesh). We first survey a sample of DRE practitioners operating in these five markets to identify the policies and regulations that have most influence on companies operating locally. This real-world insight provides strong messages for policy priority areas (see Appendix D). We then observe the correlation between policy performance and market growth for these top performing countries and find that statistical relationships corroborate the experiences and perspectives of practitioners.

These two exercises highlight five areas for prioritization:

1. Overarching national energy policy that establishes national commitments to electrification
2. Rural electrification plans or programs that integrate DRE as an energy access solution

[9] Furthermore Climatescope's total suite of indicators, indicator definitions, score methodologies, country scope and source data quality have changed over time (2012-2015), making cross year comparison difficult.

3. Technical regulation that streamlines licensing procedures for DRE service providers, the first barrier to market entry
4. The adoption of internationally recognized quality standards for DRE products and services
5. Financial policy that reduces or eliminates import duties and tariffs on DRE related products and which supports the availability of local finance through loans and grants and microfinance

The establishment of energy access targets and incorporation of DRE into planning are identified as the two principal national policy 'building blocks', critical for laying the foundation of an enabling environment. A detailed review of the policy documents containing energy access targets and the electrification plans which incorporate DRE for top performing countries highlights key components of effective policy language. Universal Energy Access targets are generally established in national energy policies, growth plans and power development plans. We find that successful countries: connect energy to the economy, set explicit targets with accompanying dates, estimate connection rates, place explicit emphasis on DRE, simplify the process for rural electrification through off-grid projects, identify transmission and distribution expansion plans and acknowledge the role of the private sector. DRE is usually integrated into more technical rural electrification programs, plans and rural energy acts. In general, successful DRE integration addresses: payments, ownership, minimum technical standards, collaboration with partners, capacity building and knowledge sharing. Finally, it is important to reiterate that policy design must be matched by implementation. Beyond establishment, policy is often poorly implemented in country due to limited government capacity, lack of clarity around roles and responsibilities of government ministries, departments and agencies, lack of political will from leaders to implement/enforce policy.

The majority of countries suffering from energy poverty have yet to truly mobilize the power of DRE in accelerating universal energy access. This body of work provides applied, practical lessons for low energy access countries seeking to catalyze the DRE sector and unlock the benefits of fast, low-carbon, low-cost solutions to energy access.

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APPENDIX A: ENERGY ACCESS AND DRE TARGETS FOR LOW ENERGY ACCESS COUNTRIES[10]

Country	Unelectrified Population (millions)	Electrification Rate (%)			Energy Access Target (%)						Source (Document, Year)	DRE Target	Source (Document, Year)
		National	Urban	Rural	National Target	Year	Rural Target	Year	Urban Target	Year			
South Sudan	12	1%	4%	0%	No Commitment Found						*South Sudan: Infrastructure Action Plan, 2013 (AfDB) makes projections	No DRE target found	
DR Congo	62	18%	42%	0%	60%	2025					Renewables 2016 Global Status Report, 2016	No DRE target found	
Sierra Leone	5	14%	33%	1%	100%	2030					ECOWAS Renewable Energy and Energy Efficiency Status Report, 2014	27% of population connected to renewable mini-grids, 10% of population powered by stand alone renewable systems	ECOWAS SE4ALL Network - Sierra Leone, 2016
Central African Republic	5	3%	5%	1%	50%	2030	50%	2030	50%	2030	Central African Republic Rapid Assessment Gap Analysis, 2013	Micro- or mini-hydro: 2-5% by 2020, 5-10% by 2030, micro- or mini-solar: 2-5% by 2020, 5-10% by 2030	Central African Republic Rapid Assessment Gap Analysis, 2013
Djibouti	1	42%	54%	1%	100%	2035					Vision Djibouti 2035, 2016	No DRE target found	
Burkina Faso	14	18%	58%	1%	100%	2025	100%	2025	100%	2025	Politique Sectorielle de l'Energie 2014-2025, 2013	12.8% rural population serviced by off-grid renewables by 2020, 26.9% by 2030	ECOWAS SE4ALL Network - Burkina Faso, 2016
Chad	13	4%	13%	1%	No Commitment Found						*Chad has a national development strategy, no specific targets	No DRE target found	
Mauritania	3	29%	47%	2%			40%	2015	80%	2015	Mauritania: Renewables Readiness Assessment, 2015	No DRE target found	
Burundi	10	5%	28%	2%	25%	2025					An Infrastructure Action Plan for Burundi, 2009	No DRE target found	
Somalia	9	15%	33%	4%	No Commitment Found						*Somalia does have a national energy policy, no specific targets	No DRE target found	
Niger	16	15%	62%	4%	65%	2030	30%	2030	100%	2030	ECOWAS SE4All Network - Niger, 2013	100MW off-grid solar; 30% of rural population powered by off-grid DRE	ECOWAS SE4ALL Network - Niger, 2016
Zambia	11	28%	62%	5%	66%	2030	51%	2030	90%	2030	Rural Electrification Master Plan for Zambia 2008-2030, 2009	No DRE target found	
Malawi	15	12%	46%	5%	30%	2020					Malawi Growth and Development Strategy 2006-2011, 2006	No DRE target found	
Angola	16	33%	69%	6%	60%	2025					ANGOLA ENERGY 2025 - Angola Power Sector Long Term Vision, 2008	10MW solar for off-grid systems, 500 (10MW) off-grid solar villages by 2025, 30MW off-grid mini hydro by 2025	ANGOLA ENERGY 2025 - Angola Power Sector Long Term Vision, 2008
Guinea-Bissau	1	21%	37%	6%	80%	2030					ECOWAS SE4All Network - Guinea-Bissau, 2016	No DRE target found	
Kenya	36	20%	60%	7%	100%	2020	100%	2020	100%	2020	Draft National Energy Policy, 2014	Solar PV in 50% of off-grid public systems; SHS: 200,000 by 2022; SWH: 700,000 by 2030; Small hydro: 300MW by 2030	Draft National Energy Policy, 2014
Lesotho	2	17%	43%	8%	40%	2020					Renewables 2016 Global Status Report, 2016	No DRE target found	
Madagascar	21	13%	22%	8%			10%	2020			ADER (Agence de Développement de l'Electrification Rurale)	No DRE target found	
Haiti	7.5	29%	44%	8%	50%	2020					Declaration de politique energetique, 2012	No DRE target found	
Benin	7	29%	57%	9%	100%	2030	100%	2030	100%	2030	ECOWAS SE4All Network - Benin, 2016	2% Rural population served by off-grid DREs by 2020, 5% by 2030	ECOWAS SE4All Network - Benin, 2016
Mali	13	26%	53%	9%			61%	2033			Renewable Energy in Africa: Mali Country Profile, 2015	No DRE target found	
Rwanda	8	27%	72%	9%	100%	2020	100%	2020	100%	2020	Rural Electrification Strategy, 2016	22% population with Tier 1 Energy Access by 2020 facilitated by distribution of SHS	Rural Electrification Strategy, 2016
Ethiopia	73	25%	85%	10%	90%	2020					Growth and Transformation Plan II, 2016	by 2020: 11.45 million improved biogas stoves, 400,000 SHS, 135 mini-hydro stations	Growth and Transformation Plan II, 2016
Guinea	9	26%	53%	11%	100%	2030	65%	2025	80%	2025	ECOWAS SE4All Network - Guinea, 2016	5 mini-hydro sites by 2017, 20 mini-hydro sites by 2025	ECOWAS SE4All Network - Guinea, 2016
DPR Korea	18	26%	36%	11%	No Commitment Found						*No energy access targets found	No DRE target found	
Liberia	4	10%	8%	11%			35%	2030	15%	2030	Rural Energy Strategy and Master Plan for Liberia, 2016	By 2050 11% of population reached by off-grid solutions	Rural Energy Strategy and Master Plan for Liberia Until 2030, 2016
Uganda	31	19%	52%	12%			26%	2022	N/A		Rural Electrification Strategy and Plan: 2013 -2022, 2013	140,000 additional Solar Home System installations	Rural Electrification Strategy and Plan: 2013 -2022, 2013
Gambia	1	45%	66%	13%	No Commitment Found						*No energy access targets found	No DRE target found	ECOWAS SE4ALL Network - Gambia, 2013
Congo	3	42%	56%	16%	No Commitment Found						*No energy access targets found	No DRE target found	
Namibia	2	32%	50%	17%			25%	2010			Energy Policy White Paper, 1998	156 energy shops by 2027 retailing approved energy products/payment centres for national off-grid financing mechanism	Off-Grid Energisation Master Plan for Namibia, 2007.
Eritrea	3	32%	86%	17%	No Commitment Found						*No energy access targets found	No DRE target found	
Tanzania	36	30%	57%	18%			75%	2030			THE DRAFT NATIONAL ENERGY POLICY, 2015	154 (19 small hydro, 61 biomass, 73 diesel PV hybrid) total off-grid projects and 107,635 customers reached by 2020	NATIONAL ELECTRIFICATION PROGRAM PROSPECTUS, 2014
Cambodia	10	34%	97%	18%			70%	2030			Rural Electrification by Renewable Energy in Cambodia, 2007.	No DRE target found	
Myanmar	36	32%	59%	18%	87%	2030					Myanmar Energy Master Plan, 2015	No DRE target found	
Togo	5	27%	35%	21%	82.50%	2030	75%	2030	95%	2030	Seminar on Sustainble Development Objectives Integration, 2016	45% capacity met by renewables (including small-hydro) by 2030. Does not specify DRE	Seminar on Sustainble Development Objectives Integration, 2016
Cameroon	9	62%	96%	23%	No Commitment Found						*Targets cited in AfDB Report 2009, not formal government targets	Of total generation: 11% micro-hydro, 7% biomass, 6% solar PV, 1% wind by 2035	INDC Republic of Cameroon, 2016.
Sudan	24	40%	67%	26%	No Commitment Found						*No energy access targets found	No DRE target found	
Mozambique	16	40%	67%	27%	100%	2025					Strategy for New and Renewable Energy Development 2011-2025	Specific targets eg 50,000 off-grid lighting systems; 5,000 refrigerators; public lighting in all off-grid locations	Strategy for New and Renewable Energy Development 2011-2025
Côte d'Ivoire	8	62%	88%	31%	100%	2025	100%	2025	100%	2025	SEMINAIRE NATIONAL SUR L'ENERGIE 2012, 2012	No DRE target found	
Botswana	1	53%	69%	32%	80%	2016					"State of the Union 2012", Office of the President, 2012.	No DRE target found	
Yemen	14.2	46%	72%	32%	No Commitment Found						*No energy access targets found	No DRE target found	
Nigeria	98	45%	55%	36%	90%	2030	75%	2020	75%	2020	Final Draft Rural Electrification Strategy & Plan, 2015.	No DRE target found	Final Draft Rural Electrification Strategy & Plan, 2015
Gabon	0	89%	97%	38%	100%	2016					PLAN STRATEGIQUE GABON EMERGENT, 2012.	No DRE target found	
Senegal	6	61%	88%	40%	75%	2012	50%	2012	95%	2012	LETTRE DE POLITIQUE DE DEVELOPEMENT DU SECTEUR DE L'ENERGIE, 20	26% rural access met through mini-grid and off-grid renewable energy systems by 2030	SE4ALL - Senegal, 2013
Sao Tome and Principe	0	59%	70%	40%	No Commitment Found						*No energy access targets found	No DRE target found	
Zimbabwe	7	52%	78%	40%			89%	2022	70%	2022	*National Energy Policy 2012 cites goals of SADC Regional Indicative Strat	No DRE target found	National Energy Policy, 2012
Equatorial Guinea	0	66%	93%	48%	100%	2017	100%	2017	100%	2017	The State of Power - Equatorial Guinea, 2015	No DRE target found	With SEGESA CEO Lucas Nguema Mbulito", 2015
Ghana	8	72%	91%	50%	100%	2020	100%	2020	100%	2020	Strategic National Energy Plan, "Main Report" 2006	15% penetration of rural electrification by decentralised renewable energy by 2015 expanding to 30% by 2020	Strategic National Energy Plan, "Main Report" 2006

[10] Energy Access targets taken only from official Government documents (if targets stated in media releases or in other regional strategic planning documents not authored by a local Government agency these plans were noted but not counted. DRE targets taken from official Government documents and from the ECOWAS SE4All documentation for applicable countries

APPENDIX B: EXPLANATION OF CLIMATESCOPE INDICATORS

Climatescope Parameters and Indicators: Climatescope categorizes various clean energy and climate performance metrics as "indicators" under four "parameter" groups, weighted by percentage. The parameter groups and weighting percentages are: Enabling Framework (40%), Clean Energy Investment and Climate Financing (30%), Low-carbon Business and Clean Energy Value Chains (15%), and Greenhouse Gas Management Activities (15%). In this study, we examine DRE-related indicators which fall under the *Enabling Framework* and *Clean Energy Investment and Climate Financing* parameter groups.

Enabling Framework Parameter: This parameter includes 22 indicators in four categories including: Policy and Regulation, Clean Energy Penetration, Price Attractiveness, and Market Size Expectation. According to Climatescope, these indicators encompass "fundamental structures and market conditions typically required for a given country to attract investment and interest from financiers, project developers, or independent power producers looking to develop new low-carbon projects, companies or manufacturing facilities." The following three indicators are part of our analysis.

Distributed Energy Regulatory Framework Indicator: Climatescope examined some of the core regulatory characteristics related to enabling off-grid, mini-grid and small power project activity. This score is based on 15 questions with "yes-somewhat-no" answers:

Mini-grids: requirements & license
Mini-grids: threshold
Dedicated regulator
Dedicated team within utility
Light-handed regulatory framework
Cost reflective tariffs
Duration of tariffs
Tariff deregulation
Standardized PPAs
PPAs of sufficient duration
Purchase obligation
Clear rules on interconnection
Clear rules on arrival of the main grid
Quality of service standards
SPPs can deliver financial services

These questions were answered by BNEF analysts in concert with in-country officials and industry professionals. The top score awarded in this indicator category was 0.107 to Tanzania.

Energy Access Policies Indicator: The energy access policies indicator was applied only to countries analyzed under the off-grid focus methodology. This methodology applies only to developing countries that are utilizing off-grid energy solutions in order to fairly compare them to developed countries whose electricity sector is dominated by power grids and electric utilities. This score is based on nine "yes-somewhat-no" questions and one (Rural Electrification Budget) numerical question:

[Rural Electrification] Program status
[Rural Electrification] Dedicated agency
[Rural Electrification] Budget
Energy access targets
Clean energy plan
Connection grants
Generation incentives
Tax / duty reductions
Incentives: mobile money
Barriers: licensing

These questions were answered by BNEF analysts in concert with local officials. The top score awarded in this indicator category by Climatescope was 0.073 to Peru.

Policy Barriers (aka Import Duty) Indicator: The policy barrier indicator is designed to gauge the cost of bringing clean technology into a country. It is based on import duty data from the World Trade Organization on the import duties levied by each Climatescope country on a range of clean energy products. These covered nine categories of products including: inverters, solar lanterns, PV cells and modules, wind towers, wind turbine blades, wind gearboxes, wind and hydraulic generators, and hydraulic turbine parts. Lower import duties correspond to lower product costs and thus a better (higher) Climatescope score. The top score awarded in this indicator category by Climatescope was 0.04 to Peru.

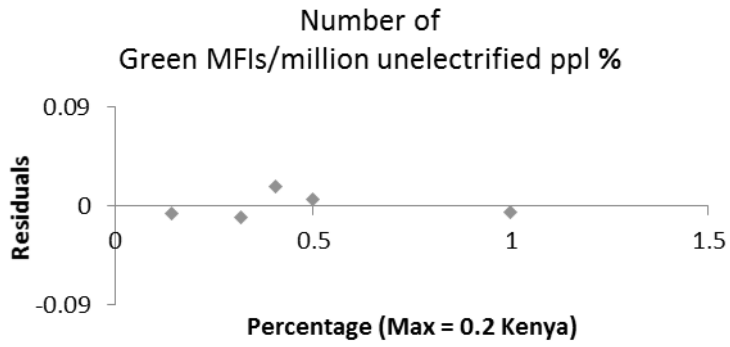
Clean Energy Investment and Climate Financing Parameter: This parameter is composed of 11 indicators in these four categories: Amount Invested, Fund Sources, Green Microfinance, and Cost of Debt. These indicators are designed to gauge a country's historical and current level of investment, and attractiveness to new low carbon investment.

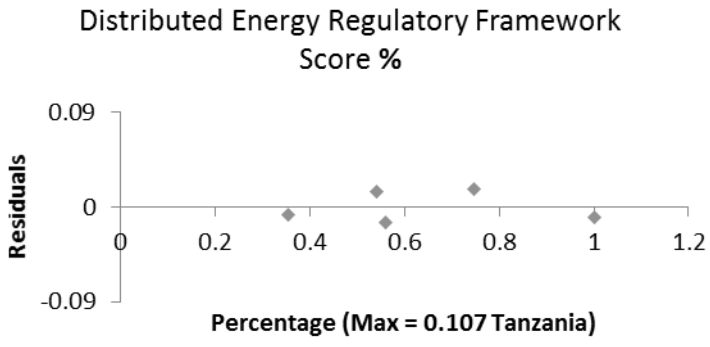
Loans, Grants and Grant Programs Indicator: This indicator measures the total new in-country investment in the clean energy sector of a country for projects less than 1 MW in capacity. Only total new investments were used in the analysis of this indicator. Total investment data was filtered by investor origin and the score represents the ratio of commitment by local investors for local projects over total clean energy investment at a national level. The top score awarded in this indicator category by Climatescope was 0.15 to Nepal.

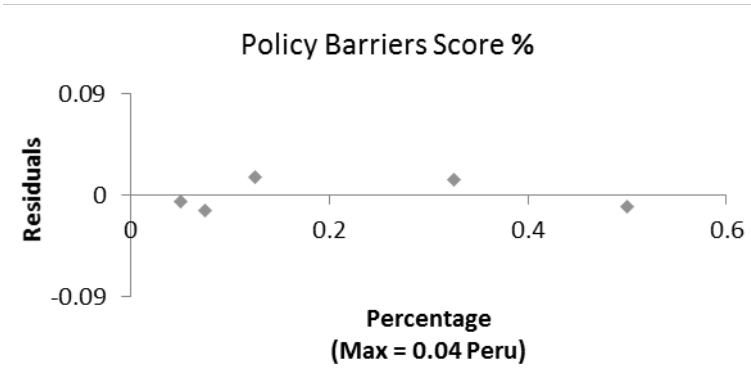
Number of Green MFIs Indicator: This indicator measures the number of microfinance institutions serving the clean technology market. This information was collected from the survey responses of microfinance institutions involved in the clean technology market. According to Climatescope, "Green microfinance is playing an increasingly important role in the deployment of clean energy and energy efficiency technologies in the developing world." Due to this increasing importance, green microfinance indicators collectively make up 5% of the total Climatescope score. The top score awarded in this indicator category by Climatescope was 0.15 to Honduras.

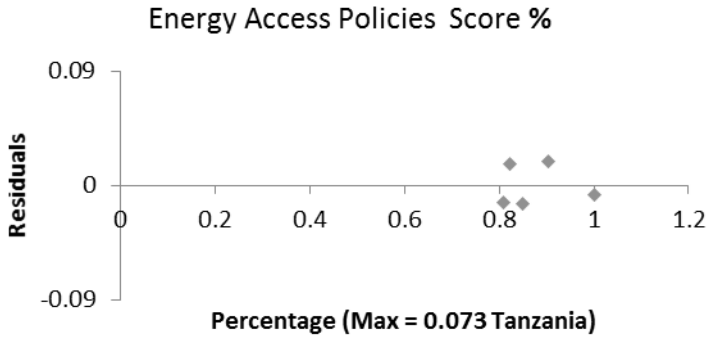
APPENDIX C: RESIDUAL PLOTS

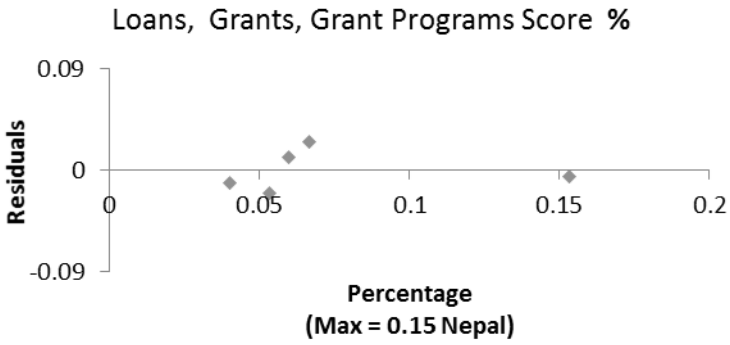
SHS/pico-PV Residuals Plots



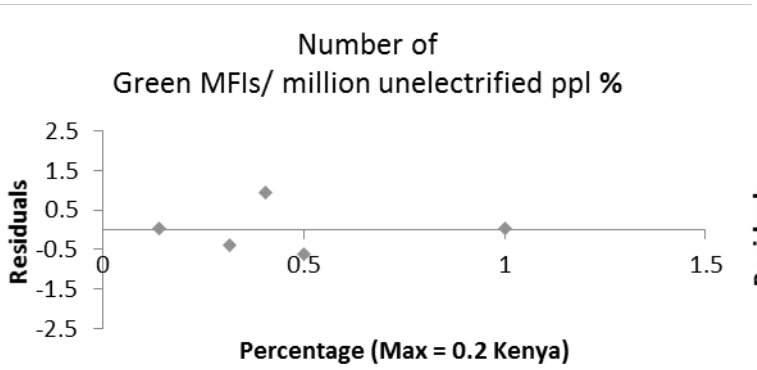


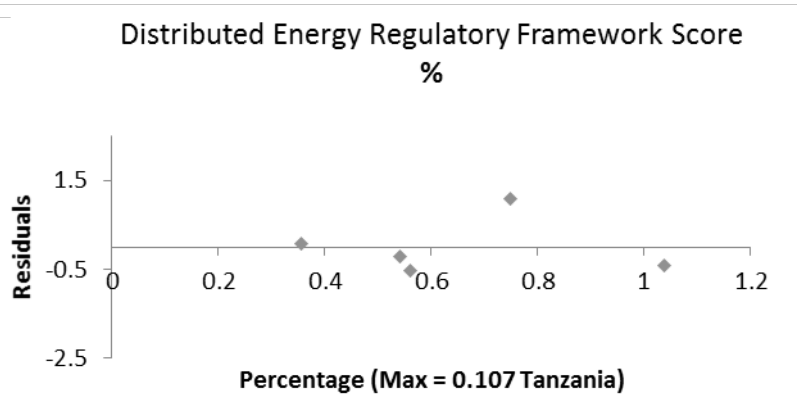


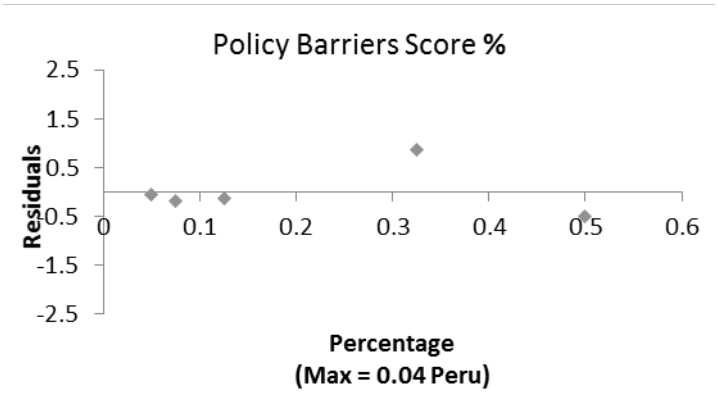


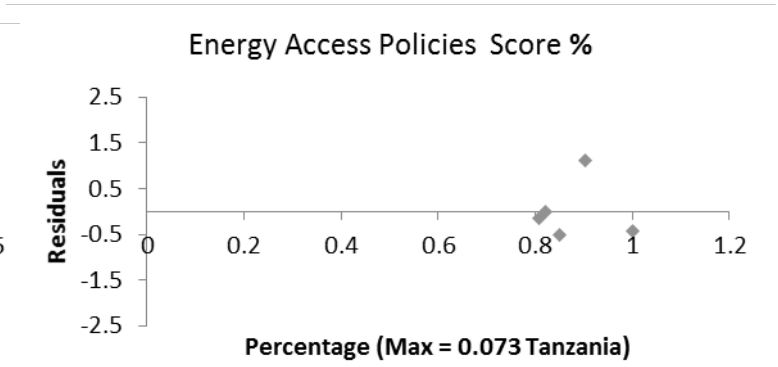


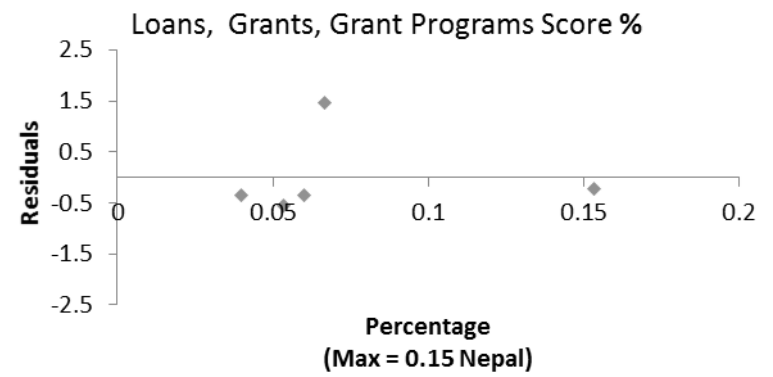
Number of SHS/pico-PV and Mini-Grid Companies Residuals Plots











APPENDIX D: POLICY INSTRUMENT REFERENCE FOR TOP PERFORMING COUNTRIES

Country	National Energy Policy or Strategy	Universal/Rural Electrification Targets	DRE Specific Targets	Rural Electrification Plan or Program	Technical Quality Product/Service Standards	Mini-grid Permitting/Licensing Procedures	Current Import Duty and VAT/GST Rating	MFI Activity (Number of MFIs, Customer Base, Credit Availability)
Kenya	National Energy Policy (NEP) of 2013 [i]	National: 100% by 2020 goal [i]	NEP DRE specific targets, including 100,000 SHS by 2017 [i]	Rural Electrification Authority (REA) through the Energy Act of 2006 [ii]	NEP commissioned minimum standards for solar energy technologies.	Currently being updated; previous regulations for public and private mini-grids were evaluated under contract by ECA [iii]	16% VAT on solar products removed in 2014; now exempt from import duties [iv] Lantern tariff: 5% PV module tariff: 0% [v]	13 Companies 800 Thousand customers 3.03 Billion USD in loans [vi] [vii]
Ethiopia	Growth and Transformation Plan I (2010) and II (2015) [viii] [ix]	National: 90% by 2020 goal [**Error! Bookmark not defined.**]	Plans to produce 3,600,000 solar lanterns, 400,000 household solar PVs, 3600 institutional solar PVs, 135 Mini hydropower Stations [x]	Rural Energy Development & Promotion Centre (REDPC); *waredas* or "regional energy bureaus via Ministry of Water Irrigation & Energy (MOWIE) [xi]	Rural Electrification Fund (REF) gives the Executive Secretariat authority to select equipment to meet acceptable safety and economic standards [xii]	REF offers loans for 95% of mini-grid project costs at 7.5% interest [xiii]	Removal of 100% of taxes levied including those that are related to energy. [xiv] Lantern tariff: 2.25% PV module tariff: 2.25% [xv]	35 Companies 3.12 Million customers 268 Million USD in loans [xvi]
Tanzania	Rural Energy Master Plan (REMP) part of Sustainable Energy Access Agenda[xvii] with "special focus" on < 1 MW systems	National: 75% electrification by 2030 goal [xviii]	REA Long Term Strategy: 6000 settlements will be electrified through off-grid electrification and 5500 through grid connections by 2022 [xix]	Rural electrification agency (REA) Works with Ministry of Energy and Minerals [xx]	National Energy Policy draft specifies upcoming technical standards for solar energy technologies [xviii]	Regulatory framework for mini-grids up to 10 MW including small power purchase agreements [xxi]	0% import duties Value Added Tax Act of 2014 (solar-focused) Lantern tariff: 5% PV module tariff: 0% [v]	82 Companies 343 Thousand customers 44.2 Million USD in loans [xxii] [xxiii]
Bangladesh	Renewable Energy Policy of 2008; 500 MW Solar Program [xxiv] [xxv]	National: 100% electrification by 2021 goal [xxv]	500 MW Solar Program of 2013, committed to 25MW of solar micro-grids [xxv]	Rural Electrification And Renewable Energy Development (RERED) Project II [xxvi]	Government subsidies apply only to solar home systems that meet IDCOL's technical specifications [xxvii]	Modified Rural Area Power Supply System (RAPSS) guidelines for mini-grid implementation [xxv]	5% VAT exemption for RE equipment and raw materials (REP 2008)[11] Lantern tariff: 11.7% PV module tariff: 2.5% [v]	676 Companies 19.98 Million customers 3.5 Billion USD in loans [xxviii] [xxix]
India	National Energy Policy of 2005 [xxx]	National: 100% electrification by March 2017 goal example: Andhra Pradesh [xxxi]	Target of 2000 MW of off-grid solar systems by 2022 under National Solar Mission xxxii	Remote Village Electrification Program (2009)[xxxiii]; The Rural Electrification Corporation (REC) provides support, subsidy	Technical specifications of solar systems, batteries, light bulbs, and other components [xxxiv]	Mini-grid policies by state; example: Uttar Pradesh includes capital subsidy, regulatory framework [xxxv]	Removed excise duties on DRE solar (2014); Lantern tariff: 8% ; PV module tariff: 0% [v]	268 Companies 39.9 Million customers 9.38 Billion USD in loans [xxxvi] [xxxvii]

[11] Repatriation of foreign companies' profit and equity and allowing for a 10-year corporate income tax exemption

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