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Distributed power generation in national rural electrification plans: An international and comparative evaluation

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ABSTRACT

As the cost of distributed power generation continues to decrease, technologies such as solar home systems and micro-grids become increasingly attractive in the quest for energy access. Here we show, however, that national rural electrification planning mostly continues to ignore distributed power generation. A detailed review of the national rural electrification plans of the twenty countries with the largest numbers of non-electrified households shows that distributed power generation is usually absent or at best a minor component of the strategy. Our original contribution is thus to show where and how national rural electrification planning lags behind technology and business models, with guidelines for future research on explaining these patterns.

1. Introduction

As the cost of solar panels continues to decrease, countries around the world have an opportunity to solve their energy access problems with distributed power generation. From solar lanterns to home systems and decentralized grids of different sizes, emerging technologies can now be deployed locally without large capital investments in grid infrastructure. These new technologies are increasingly the least-cost approach to providing households, enterprises, and community facilities with basic energy access such as lighting, air circulation, and electric appliances [1,2]. While evidence for their broader socio-economic impact is mixed, recent studies show that they can reduce household energy expenditures, improve the quality of lighting, and enable the use of appliances such as fans and televisions [3,4]. Where electricity demand is too low to justify grid extension or the quality of electricity service from the grid is very poor, distributed power generation can offer immediate relief to energy poverty at an increasingly affordable cost.

What, then, is the role of distributed power generation in national rural electrification plans? To what extent, and how, have governments around the world chosen to seize the opportunity available? Policy support remains crucial for achieving international and national energy access goals, as the energy-poor population tends to be very poor and often cannot afford to pay the full cost of electricity access [5–7]. As the International Energy Agency's 2017 *Energy Access Outlook* shows, rapid progress in electrifying all homes in the world will require aggressive policy support and cannot be left to the private sector alone [8]. Even though the private sector already plays a major role in distributed power generation, the fact remains that without government policy, such as subsidies, poor communities and households that cannot afford to purchase energy technologies at market prices will be left behind. Therefore, investigating the role of distributed power generation in national planning for rural electrification is of direct relevance to the quest for energy access for all.

To answer these questions, here we investigate the national rural electrification plans of the twenty "high-impact" countries with the most serious energy access problems as per the 2017 Global Tracking Framework [9]. For each country, we locate the latest rural electrification plan and examine the role of distributed power generation. We investigate whether a target for distributed power generation exists, whether policy instruments are dedicated to achieving it, and what the target period and budget investment for target achievement are.

Our findings show that, consistent with other research [10,8,11], distributed power generation still remains a secondary consideration. Twelve out of the twenty countries have a national rural electrification plan that includes a distributed power generation target, but even these targets lack ambition and clarity on how they are to be achieved. Governments have yet to make ambitious plans to tap the potential of distributed power generation in their quest for energy access for all.

2. Distributed power generation and rural electrification

Although governments around the world have made rapid progress in rural electrification, over one billion people remain without

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electricity at. In 2014, the global electrification rate increased to 85.3%, though 1.06 billion people still did not enjoy access to electricity [9]. Though governments have made continuous efforts on electrification, it is estimated that there will still be 674 million people living in without electricity in 2030 [8]. The majority of non-electrified people live in remote and sparsely populated rural areas. They also face affordability issues with daily commodities, often making the cost of household electrification prohibitive [12].

In recent years, distributed power generation has emerged as a promising alternative to conventional grid extension [11]. Considering the high cost of extending the grid to remote rural areas, distributed renewable energy generation has proven cost-competitive where population densities are low and projected electricity demand per capita is low [13–16]. Furthermore, renewables have environmental advantages in reducing greenhouse gas emissions and promoting sustainable development [17]. Especially among poor rural areas in Sub-Saharan Africa, distributed renewables are playing an increasingly important role in helping households gain basic electricity access [18]. Given that most urban areas are already electrified and more densely populated regions, such as South Asia, are making rapid progress in rural electrification, the remote and poor rural areas of many Sub-Saharan African countries are the last frontier.

Distributed power generation will play an increasingly important role in the future. The shift from conventional fossil fuel power generation to renewable off-grid and mini-grid generation is accelerating. Although grid extension remains the dominant mode of rural electrification to this date, by the year 2030 only one-half of new electricity connections will be powered by conventional means while the rest will be supported by mini-grids and micro-grids [8]. Densely populated countries in South Asia, including India, are already making progress toward universal electrification through grid extension. In these countries distributed power generation will likely play a minor role in household electrification, though concerns with outages may contribute to a robust market for backup solutions [19].

The primary limitation of distributed power generation is that small loads of power may not contribute to rural economic development broadly, though they do reduce energy poverty and reduce household expenditure on conventional alternatives such as kerosene [3,4]. While grid extension and mini-grids are necessary in the long run for 24-h electricity access and different appliances, even smaller system can contribute to better lighting, enable basic appliances, and reduce energy expenditures among populations that cannot afford to pay for grid connections or mini-grid costs.

Our contribution lies in describing and analyzing the role of distributed power generation for national rural electrification plans. These plans play two important roles. First, some but not all of them come with budgets and concrete implementation schedules. In such cases, the plans directly guide investment in rural electrification. Second, even if a national plan does not have resources attached to it, it can facilitate future government policy with clear guidelines and send a signal to private investors on the magnitude of the investment opportunity in rural electrification.

Drawing on and expanding the earlier work of Power for All [11], we investigate whether the growing international interest in distributed power generation translates into concrete targets and policies to support them. Indeed, although the role of distributed power generation has generally drawn lots of attention in recent years, there is little comprehensive research on its role in rural electrification planning. With the exception of Power for All [11], practitioners and researchers have paid little attention to this issue. We contribute a new analysis based on updated, fully transparent (see supplementary Appendix for all our data), and systematically coded data for the twenty countries with the largest numbers of non-electrified households.

Table 1
Basic Sample.

Country	National Electrification Rate %[a]	Non-Electrified Population Millions[b]	DRE Generation Capacity % of Total[c]
Angola	32.00	18.31	0.80
Bangladesh	62.40	59.94	1.64
Burkina Faso	19.20	14.21	2.34
Chad	8.02	12.48	N/A
Congo, DR	13.50	63.77	0.22
Ethiopia	27.20	70.88	0.68
India	79.17	269.51	0.08
Kenya	36.00	29.46	1.00
Korea, DPR	32.37	16.99	0.00
Madagascar	16.82	19.62	2.10
Malawi	11.90	15.04	1.14
Mali	27.29	12.33	1.08
Mozambique	21.22	21.44	0.31
Myanmar	52.00	24.92	0.18
Niger	14.31	16.41	4.29
Nigeria	57.65	74.73	0.20
South Sudan	4.53	11.01	N/A
Sudan	44.90	20.79	0.12
Tanzania	15.50	44.14	3.69
Uganda	20.40	30.91	2.20

[a] Data Source: Global Tracking Framework 2017. Data as of 2014.
[b] Data Source: Based on team calculation, using population data from World Bank and electrification data from Global Tracking Framework 2017. Data as of 2014.
[c] Data Source: Based on team calculation, using generation capacity data from Energy Information Administration's International Energy Statistics and DRE generation capacity data from International Renewable Energy Agency's Renewable Energy Capacity Statistics 2017. Data as of 2014.

3. Data and methods

To understand the role of distributed power generation in national electrification plans, we focused on countries with the largest non-electrified populations based data presented in the 2017 Global Tracking Framework [9]. Specifically, we selected the twenty countries designated as "high-impact" in the report based on the severity of their energy access problem. Our sample is shown in Table 1.

For each of the countries in our sample, we used official government documents and secondary sources to develop an understanding of the role of distributed power generation in national electrification planning. Given that renewables are driving the growth in distributed power generation, we focused on distributed renewable energy (DRE) in particular. We designed a dataset with variables describing four issues: 1) current electrification situation; 2) strategy and plans for improving domestic electrification rate, especially in rural areas, 3) the role of distributed renewable energy today, and 4) the country's plans for using distributed renewable energy as an electrification approach. The fourth issue was the main pillar of this dataset. It relates the importance of distributed power generation in each country's electrification plan to quantitative variables, such as generation target, investment plan, major technologies, and policy instrument. The issues and key variables are demonstrated in Table 2. For the full coding instrument and a codebook, see the supplementary Appendix.

We designed the variables to be measured in advance and modified throughout the data collection process. For comparability, we selected and used data from the year 2014 for variables under issue 1 and issue 3, since 2014 was the most recent year when all available values came from reliable sources. Values for variables under issue 2 and issue 4 were expected to be up-to-date and all data obtained were published or updated no earlier than the year of 2012.

Variables under issue 1 provided a general description of a country's electrification rate and non-electrified population at national, urban and rural level respectively. Most of the countries we focused on had

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