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CONCEPTUAL AND INSTITUTIONAL PREREQUISITES FOR GUIDING EQUITABLE PROGRESS TOWARDS UNIVERSAL RURAL ELECTRIFICATION

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Abstract

Rural electrification is a means not an end, explicitly or implicitly aimed at improving the socio-economic conditions and living standards of those living in rural areas. Yet, most policies and programs aimed at rural electrification solely target and are evaluated on extending connections, with mixed results. In this article, we argue that next generation electrification policy formulation must consider the following elements: (1) measurement of distinct multi-dimensional supply attributes at higher regional granularity, (2) considerations of local institutional capacity constraints and (3) independent evaluation mechanisms. We draw these arguments from both qualitative and quantitative analyses of longitudinal country-level rural electrification datasets, sub-national cross-sectional datasets and three specific flagship rural electrification schemes. Our results indicate that aggregate connection rates mask inadequate supply quality and geographic disparity in infrastructure provision. Exploring potential mechanism for these differences, we find that rural electrification policy outcomes are modified by the local institutional capacity, which we proxy using an indicator for the quality of government distinct from local economic characteristics. Case studies of flagship rural electrification schemes in brazil, india and morocco provide further insight into potential mechanisms, finding similarities in center-led efforts combined with regulatory controls and the integration of targeted pro-poor subsidies and decentralized electrification technologies.

Keywords: *rural electrification, energy access policy, measurement, evaluation*

Introduction

Global effort to achieve universal access to electricity by 2030 as targeted by the un sdg agenda (sdg7.1) has accelerated in recent years, though with some reversal in 2020 following the pandemic. According to current connection-based indicators some 759 million people remain without access to electricity as of 2019, with rural populations representing the vast majority of the unelectrified (iea, irena, unsd, world bank, who 2021). Aggregate data on connections indicate that asia led this decline as the deficit in this region shrank from 542 million in 2010 to 153 million in 2019, while africa saw an increase in its unelectrified population from 518 million to 592 million during the same period, a trend that needs to be reversed. Literature describing historical rural electrification efforts hints at potential drivers and barriers that may explain some of these differences. Past work has linked the success of rural electrification policies with political systems (trotter 2016), indicators such as corruption and government effectiveness as reported by the world bank (onyeji, bazilian, and nussbaumer 2012) and the institutional environment (falchetta et al. 2021). Nevertheless, despite a long history of rural electrification policies, programs and strategies having been implemented across the globe, evidence on the impacts and evaluation of these in terms of multi-dimensional supply attributes, targeting of specific geographies or marginalized population groups, and requisite institutional capacities remains scarce. Moreover, the notion of connections as the end goal continues to dominate global agenda setting and energy access discourse, although a shift towards recognizing the importance of multi-dimensional supply evaluation is emerging, most notably through the development of the multi-tier framework for measuring energy access (bhatia and angelou 2015). It is increasingly evident that energy access trends measured by connection-based indicators can mask severe differences in affordability and reliability of supply (ayaburi et al. 2020; falchetta et al. 2019; pachauri and rao 2020; pelz, pachauri, and rao 2021). Rural and poorer populations represent the vast majority of

the global unelectrified population and are especially vulnerable to these masked inequities under current indicators (ayaburi et al. 2020; falchetta et al. 2019; pachauri and rao 2020; pelz, pachauri, and rao 2021). As we approach the 2030 mark set under the un sdgs, the risk of missing sdg target 7.1 is quite real, with the iea projecting a severe deficit under the current policy scenario (iea 2020). Other research also suggests that even while new connections maybe provided, household access to essential energy services will still be very unequal even by 2030 without additional efforts (poblete-cazenave et al. 2021). We must therefore take stock of differences in rural electrification progress across and within countries in order derive lessons for much needed policy reform. In this article, we describe evidence drawn from quantitative and qualitative analysis of longitudinal and cross-sectional electrification datasets and country case studies organized under three broad themes; measurement, institutions and evaluation. This is split across three sections that include a discussion of the pertinent literature with respect to each of these key themes. The first section describes the momentum behind multi-dimensional energy access measurement approaches and the need to assess progress at the sub-national level. We then reflect on the institutional and governance barriers and drivers of equitable rural electrification progress. Finally, we conduct a narrative review of three exemplary rural electrification policy country case studies to draw broad transferable lessons for policy development.

Measuring electrification progress

Conceptual developments in energy access and energy poverty measurement encourage us to look beyond these connection-based indicators towards improvement across distinct multi-dimensional supply attributes linked with distinct energy services (bhatia and angelou 2015). This reflects an alignment with the notion of access to energy services, or end-uses, as the primary goal of energy provision (fell 2017). That is, at the core of energy and fuel poverty lies the "inability to attain a social and materially necessitated level of domestic energy services" (bouzarovski and petrova 2015). This has also been discussed from a justice-theory perspective, describing energy poverty as "an inability to realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services, and taking into account available reasonable alternative means of realising these capabilities" (day, walker, and simcock 2016). These definitions are not limited to academic discourse, rather, the sdg 7.1 target itself speaks to the provision of reliable and affordable access to modern energy services for all. The indicators used to measure progress towards this target remain, however, binary and connection-based.

Recent work examining differences in supply attributes across sub-saharan africa underlines the importance of a transition to multi-dimensional measures, revealing stark inequities in access to reliable supply among the electrified population across the continent (ayaburi et al. 2020; falchetta et al. 2019; pachauri and rao 2020; pelz, pachauri, and rao 2021). Other research using open access earth observation-based data, also reveal wide inequalities in the pace and quality of electrification in sub-saharan africa between 2014-2019, which existing international electricity access tracking statistics mask (falchetta et al. 2020). It is quite likely that looking beyond connections will reveal a more somber state of global access to electrical energy services, which makes this even more important if our goal is to ensure equitable access for all. To illustrate this point, we analyze recent data gathered under the world bank energy sector management assistance program (esmap), mtf household survey effort.1 our analysis compares the rate of urban and rural electrification across ten countries where survey data was collected against the reliability of the supply provided. Figure 1 describes the share of total rural and urban households with access to electricity, against the share of total rural and urban households that are both electrified and receive at least 16 hours of supply per day. That is, both axes represent the same population, with different measures for access. The threshold of 16 hours is selected based on prior work proposing an alternative framework (af) for measuring progress towards sdg 7.1 (pachauri and rao 2020; pelz, pachauri, and rao 2021). Deviations from the diagonal dashed line indicate that fewer households receive reliable supply than those with access to electricity, or in other words, there is a deficit in supply reliability among electrified households. It is evident from this visualization that not only are rural electrification rates much lower than urban electrification rates (this is well known), but that the supply reliability is lower among rural households as well. This clear inequity is entirely masked by aggregate connection rates, hiding a more severe challenge in terms of providing universal access to reliable electricity services

for all. Reflecting on the disparity between access and supply reliability shown here, and in the literature more broadly, we argue that global agenda setting and national electrification policy development must include provisions ensuring decent levels of access across distinct attributes of supply. A conceptual transition to such measures requires broad agreement on how to capture distinct attributes across diverse country contexts and the integration of requisite instruments into routine data collection processes

Institutional drivers of global progress in rural g electrification

Measurement of disaggregated multi-dimensional electricity supply is one pre-requisite for equitable progress towards energy access for all. Another important pre-requisite is the institutional and governance backdrop guiding the enactment and proper implementation of electrification policies. Notwithstanding limitations in data availability, much can be learned from reviewing trends at the national level in rural electrification progress and key drivers identified in past literature (aklin, harish, and urpelainen 2018; onyeji, bazilian, and nussbaumer 2012; steckel, rao, and jakob 2017). We begin with an overview of the global electrification policy trends. Based on the database of energy policies from the international energy agency (iea 2021), we can trace the general trends in non-oecd countries in terms of when electrification policies have been enacted and how many. Figure 3 highlights that across all regions the number of electrification policies is generally increasing with many countries enacting electrification policies in the period from 2010-2015 (we count only the first policy in a given country). Importantly, there is a growing number of countries introducing policies in sub-saharan africa, which still lags behind other regions in terms of progress. However, presence of electrification policies does not necessarily imply that electrification goals will be achieved. For example, in countries like tanzania that enacted a number of policies related to electrification over the past 15 years, and where electrification efforts can be traced back to 1970S (van den broek and lemmens 1997), as of 2019, 80% of rural population still does not have access to electricity. While the introduction of electrification policy is intuitively necessary for improvements in rural electrification rates, the institutional capacity to implement these, among other variables, is likely to be important to understanding why certain countries performed better than others.

Assessments of the drivers behind rural electrification success or failure have been generally hampered by lack of reliable data. Nonetheless, there are a few studies that have assessed cross country and within country variation using econometric techniques. Not surprisingly, many detect a strong association between the level of income and electrification (aklin, harish, and urpelainen 2018; foley 1992), and the positive effects of urbanization and increases in population density. While gdp per capita is generally a good predictor of urban and rural electrification, it cannot fully explain the variation in electrification rates of countries that are within the same income group (aklin, harish, and urpelainen 2018). Besides the clear importance of economic development, past research has also highlighted the role of institutions measured either by looking at the type of political system (trotter 2016) or at indicators such as corruption and government effectiveness that are reported by the world bank (onyeji, bazilian, and nussbaumer 2012). A stable institutional environment might be essential for the implementation of long-term electrification policies, and can also help attract domestic and foreign investments (falchetta et al. 2021). In democratic regimes, policy makers are under more pressure to address inequality and provide public services (trotter 2016). Yet the empirical evidence on the role of institutions is not completely conclusive. For example, when looking at the drivers of electrification, aklin et al. (2018) find that more democratic countries do not necessarily perform better in rural electrification efforts. In another paper, where the dependent variable was deployment of renewable off-grid electricity (which might be essential for the electrification of hard-to-reach rural areas), aklin (2021) finds statistically significant positive effects of democratic polity, rule of law and control of corruption.

Lessons from successful policy implementation

We conduct a narrative review of three large flagship national policies in brazil, india and morocco that are considered successful and often cited in the literature as exemplary in achieving their intended targets. While there exists a long history of policy efforts to extend rural electrification across all three countries, we focus here on three specific policies that were all implemented between 1996 and 2010. Detailed references related to each of these case studies can be found in a cross-policy synthesis of these and other energy policies in pahle et al. (2021). Here we focus specifically on generalizable

lessons related to the evaluation of these policies and the institutional and governance specificities that contributed to the actual performance of these. In brazil, the 'luz para todos' (light for all: lpt) program was launched in 2003 aiming to universalize access to electricity initially by 2008, with a special focus on rural and isolated areas. In india the rajiv gandhi grameen vidyutikaran yojana (rggvy) program, launched in 2005 (later subsumed in the deen dayal upadhyaya gram jyoti yojana - ddugjy in 2014) also targeted universal electricity access, specifically in rural areas. Finally, in morocco the global rural electrification program (programme d'electrification rurale globale: perg) came into effect earlier, in 1996 and targeted universal rural electricity access, too. In all three flagship schemes, the focus was specifically on rural and poor populations that had been left behind by previous efforts and programs. Each of these schemes allowed for some combination of three potential means to electrify rural settings: (i) extending the national grid, or decentralized generation systems with (ii) isolated grids, and (iii) individual systems. In the case of brazil and india, these policies followed national legislation stipulating electricity access for all as a requirement that must be met, indicating a strong central push to achieve a basic level of service provision.

Institutional arrangements and governance of the policies

In each of the three cases, impetus and backing for the new schemes emanated from the center or federal branch of the government, after frustration with inadequate success of previous efforts. This corresponded to a top-down governance structure. In morocco, the central vertically integrated electric utility office national de l'electricity (one), under the oversight of the ministry of energy, mining, water and environment (memee), acted as the de facto regulator. In india, this was a task undertaken by central and state regulatory electricity commissions coordinated by the rural electricity corporation (rec), under the ministry of power. The brazilian electricity regulatory agency (aneel), operating under the central ministry of mines and energy (mme), was the key regulating authority in that case. Overall program execution was thus the responsibility of the central electric power or energy ministries in all three nations. Despite this relatively top-down nature of policy formulation and governance, strong coordination across all levels of government was required for planning and implementation in each case (verdolini et al. 2018). While the central ministries were responsible for monitoring program progress, sanctioning projects and releasing funds for project implementation, they were also responsible for a clear specification of the roles and responsibilities of the executing agents, whether these were utilities, rural cooperatives, or non-governmental or private franchisees and concessionaires. In all three schemes, drawing up operational plans to meet the established targets was the responsibility of the executing agents. This required careful oversight and monitoring of the programs by the central authorities, which was not always successful. In the brazilian case, non-execution of the agreed upon plan resulted in penalties for the implementers which incentivized due completion of agreed tasks (bittencourt 2010). In contrast, in the indian case, poor vertical and horizontal coordination across government levels and branches resulted in slow implementation and unmet targets. Delays with getting required clearances and acquiring land for setting up of the transmission and distribution infrastructure also contributed to the slow implementation of the scheme in certain states. In this case, poor financial viability of the electric distribution companies also resulted in poor repairs and maintenance of the rural electric infrastructure, despite this being clearly allocated as a responsibility they were required to fulfill. In the end, where local capacities were insufficient to undertake the tasks, provision was also made to allow central public sector undertakings (cpsu) to support program implementation in certain states (pib 2013). In the moroccan case, the shs component of perg also encountered challenges. Only half of the 105,000 shs installations targeted through the concessions were eventually implemented, and this was even lower than the 150,000 originally estimated as being required. Furthermore, the regulatory authority subsequently embarked on a program to connect households to the grid in areas already provided with shs, rendering these stranded assets (allali 2011).

Targeted subsidies and the integration of decentralized technologies

A defining feature of each case is that all three countries had a history of electrification interventions and had therefore built significant capacity and gained useful experience from the implementation of earlier (less successful) efforts and schemes. Perhaps related to this earlier experience, a commonality across all three cases was the role of state subsidies and decentralized technologies directed either towards all beneficiaries in remote areas or more

specifically towards low-income households, that helped with mitigating the high costs of grid expansion in remote areas (verdolini et al. 2018). Each of the schemes involved large financial outlays with significant central government backing and funds. In the case of the indian and brazilian programs, these funds were largely from own budgetary sources, whereas in the moroccan case international funding and concessional loans were an additional significant source, backed by central government guarantees. Business models to ensure affordability to end-users were also critical to the success of these schemes. In brazil, cross-subsidization across different segments of residential customers allowed for providing free connections to the scheme beneficiaries and applying social tariffs, i.e., a discount of up to 100% to certain low-income beneficiaries for the first 50 kwh of electricity consumption per month. In morocco, affordability for the end-user was made possible by giving families the option of paying off the charge for their initial connection (they were responsible for only 25% of the total cost) over a period of seven years through low monthly instalments, and the use of a pre-paid card system backed up by a network of recharging points that helped users to monitor and pay for their consumption once connected. In the indian case, poor metering, billing and revenue collection was a major factor in the poor performance of the scheme in certain states. Connections to below poverty line customers were provided for free under the scheme. However, some state electricity distribution companies struggled to manage and maintain financial viability and recover operating costs because of low revenue generation. This lack of economic sustainability also resulted in major challenges with the subsequent effective maintenance and proper upgrading of the rural electricity infrastructure. Sufficient and committed funding for regular repairs and maintenance of electric infrastructure, particularly in the case of distributed generation facilities, was also an issue that impacted the long-term effectiveness of all three programs. All three of the policies were also explicitly technology agnostic. While in each case a primary and substantial focus was on providing connections through grid extension, all three programs recognized that extending the grid to connect very remote communities was uneconomic, and therefore made provisions for decentralized distributed generation to connect isolated communities. This mix of centralized and decentralized approaches to electricity provision was important to achieving the set targets of universalization at reasonable cost.3 nevertheless, there were still issues with the regulations for decentralized systems regarding sizing and capacity of the systems, public acceptance by customers, and lack of appropriate incentives for developers. For this reason, distributed generation remained a last resort only for very remote areas, where grid connections were uneconomic or last mile connectivity could not technically be provided by extending the central grid. Thus, adequate market expansion and regulatory oversight of distributed generation systems remained a challenge in all three cases.

Monitoring and evaluation of the policies

Finally, regular monitoring of achievements against set targets and financial outlays for the programs were important features of each of the cases. In all three cases, this was primarily carried out by central authorities in charge of implementing the programs with the aid of central statistical agencies (national survey and census bodies) and local implementers. Such monitoring also played a role in assuring quality in the implementation of the programs (nygaard and dafrallah 2016; jung and schmitz-borchert 2001; pereira, freitas, and silva 2010). Regular monitoring was an important means to ensure that projects were properly implemented and to ensure efficiency and long-term sustainability of the programs. Web based platforms to display targets achieved, milestones and financial aspects of the programs also increased transparency in the case of the brazilian and indian programs. Independent evaluations of the programs were, however, rarely undertaken in any of the cases. Only in the indian case was an independent study commissioned to evaluate performance in a specific region in one instance (das and sarma 2016). In the brazilian case, a few independent scientific assessments using data that was collected during the implementation, were subsequently carried out (bezerra et al. 2017). For the most part though, all monitoring and reporting was done by the implementers themselves without any independent oversight (government of india 2014; amegroud 2015; mme 2013).

The focus of most of the monitoring efforts in all three of the cases was in assessing financial performance and achievements against set targets with respect to providing new connections. Other elements and broader evaluations covering multi-dimensional aspects related to quality and reliability of electric supply, end-use and consumption, customer

satisfaction etc. Were only partially, if at all, regularly assessed. Furthermore, secondary benefits of the programs in terms of achieving broader social and economic objectives were also not independently evaluated. In all three cases, the central implementing authorities carried out surveys to assess the broader social outcomes of the programs and generally concluded that the secondary benefits were substantial. However, these were never independently verified nor were these systematically quantified in any of the cases. For this reason, the broader social impacts of the programs remain uncertain in all three cases. While there were explicit efforts to target the most rural and remote areas in the case of all three programs, evaluations of the effectiveness of such efforts indicate that the most sparsely populated regions did not always benefit (slough, urpelainen, and yang 2015). Environmental impacts of the policies were not evaluated in any of the cases. Though as part of morocco's perg, off-grid shs, part of its rural electrification strategy for very remote rural regions was proposed for funding under the clean development mechanism and was registered as one of the first programmatic cdm projects (pahle, pachauri, and steinbacher 2016). Overall, despite successes and transferable best practices (with respect to targeted subsidies, technology-agnostic strategy and regulatory controls), implementation challenges were evidently exacerbated by inadequate measures and the lack of independent evaluation of program success with respect to broader societal impacts and measures beyond connections. This critique aligns with recent systematic reviews of literature describing historical rural electrification efforts in the global south, highlighting the severe gap and geographic concentration in independent evaluation and impact assessments (bayer et al. 2020; hamburger et al. 2019).

Conclusion and policy relevance

In this article we describe drivers and barriers to equitable rural electrification progress around the world. We apply both quantitative analysis methods to longitudinal data describing national and sub-national electrification rates around the world as well as qualitative analysis methods to three exemplary rural electrification policy country case studies. Our work shows that even today, the tracking of progress towards universal rural electricity access is imperfect and that national aggregates can mask severe sub-national disparity. In fact, national connection rates that describe rapid progress may indeed mask inadequate supply quality and geographic disparity in infrastructure provision. Similarly, while policy implementation has objectively increased following the inclusion of energy access under the sdgs, effectiveness of these in driving equitable progress in rural electrification is uncertain. Our analysis shows that this is modified by institutional capacity, aligning with prior work describing the effects of government quality and corruption on electrification outcomes. Reflecting on the three exemplary case studies in brazil, india and morocco, we find similarities in center-led efforts combined with regulatory controls and the integration of targeted pro-poor subsidies and decentralized electrification technologies. Nevertheless, even among 'successful' policies, evaluation remained weak beyond merely counting connections and financial oversight. Our findings point to several paths for future work relevant to electrification policy reform in countries with rural energy infrastructure deficits. First, inadequate measurement can lead to inefficient implementation of national electrification policies, preserving existing socio-cultural and geographic inequities in modern energy infrastructure provision. Functioning as a control for these inefficiencies and informing more equitable policy targeting, the measurement of distinct supply attributes disaggregated at the sub-national level is a necessary aspirational goal requiring the mainstreaming of multi-dimensional energy access data collection efforts. A better, more detailed national electrification policy data would also substantially improve efforts of understanding under which conditions certain measures are successful. Secondly, strong institutions have historically fostered faster and more effective rural electrification policy implementation. In lieu of such established institutions, we speculate that regulatory controls can function as important mechanisms mitigating institutional limitations. Though limited to imperfect financial controls and connection-based measures across the three schemes we study, these represent hard-won lessons following several less successful efforts in each of the countries. Thirdly, the integration of targeted pro-poor subsidies and decentralized electrification technologies has an important place in equitable policy design given the size of the deficit in many countries alongside the time-cost of centralized infrastructure extension. In reflecting on these findings, we must recognize that rural electrification policies have been and continue to be deployed with limited data availability. A lack of data is evidently not a

binding constraint in the development of rural electrification policy. Rather, we argue that disaggregate data collection across distinct attributes of supply is necessary for independent evaluation and effective regulatory control of these policies, as well as improving their design and targeting. Improved multi-dimensional measures are necessary to define what equitable access to modern energy services entails. Disaggregate data collection is necessary to reveal whether this is provided to all in an equal manner. Combining a standardized set of survey questions together with utility reported data and recent advances in earth observation data processing is a promising pathway to improve the quality and frequency of data updates. This can reveal and thereby help mitigate sub-national differences in institutional capacity that have been shown to modify the success of central electrification policies. There remains immense scope for improving the monitoring and evaluation of rural electrification policy implementation. Notwithstanding the objective goal of reliable, affordable supply provision, which remains imperfectly captured by current indicators, there is very little precedent for linking these efforts with wider socio-economic and environmental impacts that ultimately justify the implementation of these policies. Moreover, as a clear limitation of our work and the literature more broadly, the requisite data for adequately evaluating sub-national multi-dimensional supply quality and related societal impacts is simply not available. Despite some successes as we have shown, the gap in access to affordable, reliable and modern energy services persists in rural areas of the global south. We must learn what we can from past successes and carefully monitor progress in deficit countries in order to continually inform and improve equitable electrification policy formulation. Broadly, our work underlines the importance of independent disaggregated multi-dimensional measurement, regulatory controls and a pro-poor technology agnostic strategy to mitigate heterogenous sub-national institutional capacities that modify the effectiveness of rural electrification policy.

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