Is a grid connection the best solution? Frequently overlooked arguments assessing centralized electrification pathways

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Abstract

Providing reliable electricity access is still a major challenge in many regions of the Global South. This study discusses indicators characterizing grid power supply and provides various measures next to the electricity access rate to show the linkages between electricity access pathways for doing business. The results of the analysis, done for six selected countries in Sub-Saharan Africa and Asia, indicate that a grid connection, often perceived as cheaper, is characterized by its own challenges. These challenges should also be considered and evaluated when assessing different electrification strategies. The quality of grid supply in terms of length and frequency of power outage, T&D losses, and connection charges are assessed. A trend towards decentralized independent power generation can be observed as one of the consequences.

Keywords: decentralized electricity supply, T&D infrastructure, quality of electricity supply

Introduction

Providing electricity to everyone is still an unsolved challenge from a global perspective. Central electricity generation with transmission and distribution (T&D) is still considered as the most cost-competitive way of providing electricity (Deichmann et al. 2011). Though this might be true for most urban and densely populated areas, the situation in rural areas is different. In absolute numbers, a very large share of humanity is living in rural areas, with rising population growth projected for the future (UN 2012).

This paper presents a framework for understanding the limitations of electricity supply by T&D grids in developing countries with limited or no access to electricity. Combining this with the current state of infrastructure in the most affected regions in the Global South leads to a chicken-egg dilemma:

Does the state of a country's T&D infrastructure influence the sufficiency of its electricity supply and, in particular, will investment in its infrastructure lead to universal access to electricity? Or, should we instead be asking if a decentralized power scheme is in fact the best approach for some rural areas?

Very often the analysis of electrification pathways is carried out using only levelized cost of electricity (Short et al. 1995) for decentralized options in comparison with the cost of grid electricity per kWh. Certainly, more aspects should be included.

Electricity access is a combined measurement of a nation's power sector status, available infrastructure, and economic development. However, today there is much more data available to draw a more comprehensive picture of energy access and infrastructure.

The SE4All Global Tracking Framework (World Bank, IEA 2014) applies a multi-tier approach to describe the current access of electricity, developed by Bhatia et al., 2013. One measure is the amount of energy consumed by a country, and other factors such as the timely availability of power and the possibility of productive use also play a key role.

The frequently cited statistic of 1.3 billion people without access to electricity (IEA 2013) is not very precise nor does it take into account local characteristics, which might offer the key to developing approaches to providing access.

Opportunities for providing access to electricity

Two main options for providing access to electricity can be differentiated (Tenenbaum et al., 2014):

(1) Decentralized options like mini-grid and off-grid systems, where energy technology (renewable or fossil-fueled are installed locally to provide electricity to households or communities connected within a micro-grid) , and
(2) Centralized systems where a national or international T&D system is connected to central electricity generation plants to distribute electricity to the consumers.

As both approaches are based on two different principles the desired path needs to be clearly defined[1]. All available relevant information should be included in a prior assessment. Here it is crucial to take an intensive look at existing infrastructure, as well as the society's perception and reaction to the current state of electricity availability.

Most countries in the Global South have at least a small national electric network installed. This varies greatly in size, capacity, state, and age of the system across countries and regions (Foster & Briceño-Garmendia, 2010). The number of people served by a given infrastructure also varies. A grid is generally divided into transmission and distribution systems whereas the largest share (in relation to length) is made up of distribution lines. The absolute length of transmission lines is generally higher in geographically large countries, where

[1] The differentiation of these two approaches is necessary to define objectives for each possibility, although in the end a combination of both pathways might be the optimal solution in most cases. In this case an integration of both schemes needs to be developed.

the population is more scattered. Certain parameters can be derived depending on the characteristics of the energy infrastructure. The International Energy Agency provides data about both technical and non-technical losses (IEA, 2011). Data is also collected on power outages, their length, their frequency, and their negative economic consequences (Enterprise surveys). Another tracked indicator describes on which level electricity is perceived as a barrier to doing business. Reliable access to electricity is ranked higher in importance than corruption (IEA, 2014), for example.

Research Objectives

This paper aims at focusing on important, often neglected aspects regarding the electrification pathway with T&D grids in rural areas. The objective is to

(1) Gain an understanding of challenges related to existing installed T&D infrastructure, and
(2) Provide an overview of the impacts of grid-based electricity supply for productive use in six selected countries.

Methods

The results of this paper are drawn from a comprehensive data analysis. A combination of various sources yields a clear visualization of relations between the given data parameters. Today, a large amount of data is publicly available and helps to narrow the gap between understanding local conditions and the application of appropriate measures for providing electricity (AEEP, 2014). The Results section summarizes findings for the six selected countries Republic of Congo, Ghana, India, Myanmar, Nepal, and Tanzania (Fig. 1). They were chosen to account for a wide geographic variety in South and South-East Asia as well as Central, West and East Africa.

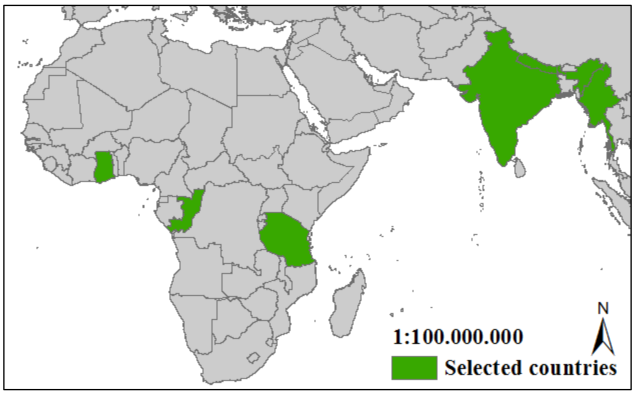

Figure 1: Selected countries for the study.

Table 1 lists the total national electrification rates and the rural electrification access as well as the respective Human Development Index to create a linking to the socio-economic situation of the countries. Here it is important to consider that characteristics vary greatly, which means that a transfer of results to neighboring countries is not advisable because the situation can change dramatically over borders. In the selected countries, electrification rates are generally much lower in rural areas than on a total national level (IEA 2013). Only in the least developed country, Tanzania, is the overall access to electricity almost as low as the access in rural areas. India has the highest values of electrification access. However, looking at absolute numbers of people lacking access to electricity, this country would lead the list.

Table 1: Electrification rate as defined within the World Energy Outlook 2013 (IEA) and HDI 2013 (UNDP).

Country	El. rate total (%)	El. rate rural (%)	HDI[2] Rank
Congo (Rep.)	37	9	140
Ghana	61	38	138
India	75	67	135
Myanmar	49	28	150
Nepal	76	72	145
Tanzania	15	4	159

Results

Poor electricity provision as a barrier to business development

Electricity is recognized as major factor in economic development. Apart from health and educational benefits, it is the major area benefitting from a reliable affordable access to electricity (Kanagawa & Nakata 2008).

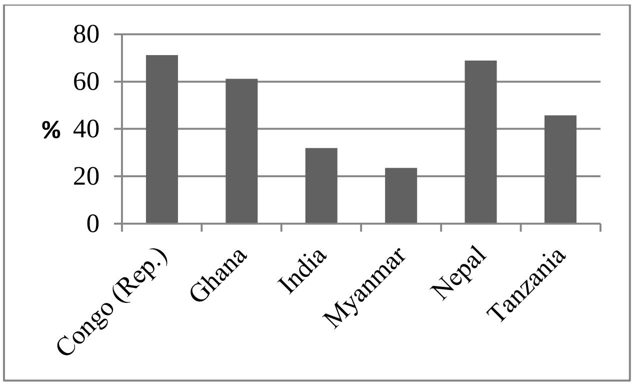

Figure 2: Percent of firms identifying the lack of electricity as a major constraint[3]

Access to electricity is identified as a more important factor in doing business than other hindering aspects, such as access to capital and corruption (IEA, 2014). Figure 2 illustrates the percentage of business enterprises in each country which identify electricity as a crucial factor, starting with about 20% in Myanmar up to more than 70% in the Republic of Congo.

This also indicates that in all sectors electricity is needed as a basic service, as the shares of agriculture, service sector and IT vary across the countries. The perception of the lack of power as a barrier mainly results from frequent power outages. Figure 3 shows why the

[2] HDI refers to the Human Development Index 2013. http://hdr.undp.org/en/data

grid electricity supply is inadequate in the six countries. Long power outages occur frequently. Of course, non-electrified regions also perceive the absence of electricity as a barrier to certain business opportunities.

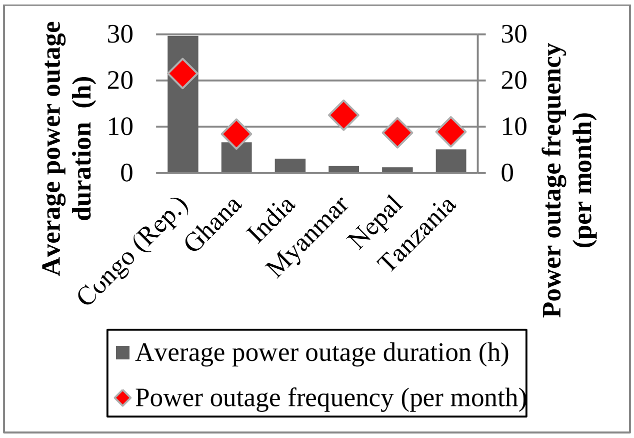

Figure 3: Average power outage duration and frequency.[4]

The Republic of Congo has both the longest and most frequent power outages. Values show the unreliability of the existing grid infrastructure. The discrepancy between duration of outage and frequency is the highest in Myanmar. Here, frequent outages occur for short durations. For India, only data about the average duration of power outages is available from the source. When interpreting these values it is important to bear in mind that the number of people affected by outages changes from country to country depending on the number of connected customers.

Independent self-generation of electricity

With the above presented unreliability of certain infrastructure systems, a rising share of privately generated electricity for business purposes can be observed.

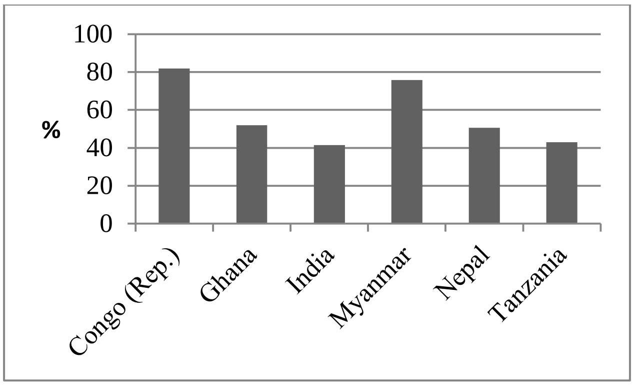

Figure 4: Companies using grid independent electricity generators[6].

[3,4,5,6] Data based on http://www.enterprisesurveys.org/data/exploreTopics/Infrastructure. Depending on the country different base line years are available (Congo (Rep.) 2009, Ghana 2013, India 2014, Myanmar 2014, Nepal 2013, and Tanzania 2013)

The level of ownership or sharing of independent power generation infrastructure is shown in Figure 4. About 40% to 80% of the businesses surveyed in all six countries rely on independent electricity generation with generators.[5] This may lead to varying power supply costs due to different fuel prices. Also, the overall non-availability of access to electricity together with the comparably quick and easy installation of small generators can be the reason for self-generation, which is already a decentralized solution established in many regions.

Transmission and distribution losses

The analysis shows that high losses of up to almost half of the electricity production occur in the six countries (Fig. 5.). Comparing these values to countries with advanced grid systems where losses are usually less than 10%, these levels are very high. T&D losses are a combination of technical and non-technical losses. Technical losses mainly depend on the length of the T&D network lines from power generation to consumer, as well as their respective voltage and currents. Non-technical losses include inadequate or non-existing metering, unrecovered billing and theft.

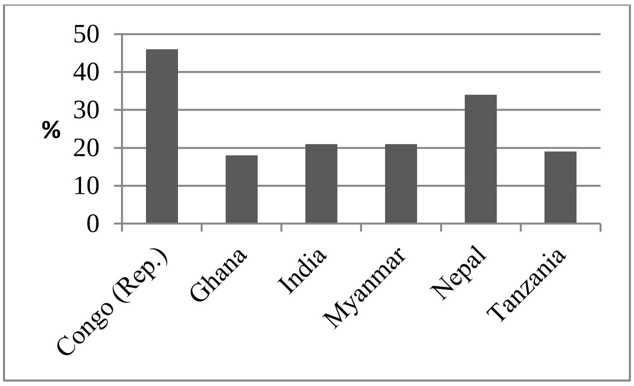

Figure 5: T&D losses of electricity production[7].

High upfront connection fee

Decentralized systems are often characterized by high up-front costs which exclude people who do not possess the requisite financial resources. In these countries, this is a high proportion of the total population (Ahlborg & Hammar, 2011). Yet in many countries, connection to the national grid requires an up-front fee for the cost of connection from the household to the distribution grid, as well as for metering technology. These costs vary across countries but tend to be high in comparison with the populations' ability to pay. For example, the fee can be up to 400 US$ which is higher than an average monthly income (Golumbeanu & Barnes 2013).

As a consequence, many people, especially in rural areas, live near the grid but cannot obtain electricity. In these cases new tariffs or subsidy schemes or micro-

[7] International Energy Agency (IEA) 2011-2014 Energy Statistics and Balances of Non-OECD Countries and Energy.

financing opportunities need to be developed to allow the payment of these fees (Palit & Chaurey 2011).

Tanzania provided a positive example in 2013 when it lowered connection charges significantly, for rural areas in particular (United Republic of Tanzania, 2014). Tenenbaum et al. (2014) state that the connection charges in Asia are generally lower than in Sub-Saharan Africa.

Discussion

The major aspects which are commonly included when looking at electrification pathways are generation costs based on levelized cost of electricity and grid extension cost per kilometer or current costs per kWh. Within this framework a centralized approach for providing access to electricity is often the chosen pathway (Zvoleff et al., 2009).

From the analysis of the provided indicators it can be concluded that access to electricity can have many facets which are not reflected in global data sets (e.g. World Energy Outlook, IEA 2014). This should be taken into consideration when planning the extension of electricity access.

Power outage frequency and length indicate the reliability and quality of the existing electrical infrastructure. Existing infrastructural shortcomings need to be accounted for and the definition of access to electricity should be carefully applied. Having access to an unreliable grid might not in fact count automatically as being electrified. The same applies for populations which theoretically live in the electrified regions but cannot afford the connection charge.

With these aspects in mind in certain regions the choice for the electrification pathway might shift towards decentralized approaches. In all six countries more than 20 % of surveyed firms identify the lack of electricity as a major constraint. The absence or lack of reliability of grid electricity leads to a higher share of private generation (more than 40 % of surveyed firms rely on independent power generation). This occurs even without respective policies in place, which can be interpreted as a clear readiness for decentralized structures.

A more detailed look at T&D losses leads to a better understanding of the state of the electricity systems in the six countries considered in this paper. The upgrade of an already faulty network is a much larger challenge than a total new development of infrastructure. In addition, with reference to the grid connection charges it is shown that electricity is often within physical reach of rural populations but there are no financial means of meeting the costs. Even significant investment in new grid infrastructure cannot solve this problem (Lee et al. 2014).

To account for some limitations of the parameter set discussed here, some complex indicators like the Energy Development Index (EDI) and the Multidimensional Energy Poverty Index (MEPI) have been developed (IEA 2012, Nussbaumer 2012). An inclusion of these can further deepen an understanding of the electricity access situation within different countries in order to establish the most suitable electrification pathway.

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