

Moving beyond energy access – the challenge and impact of unreliable electricity in emerging economies

Energy Insight

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1. Introduction

The United Nations' Sustainable Development Goal (SDG) 7 aims to 'ensure access to affordable, reliable, sustainable and modern energy for all'.¹

The SDGs, born at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012, provide an overarching framework for measuring and reporting against economic and social development indicators. SDG 7 enshrines the principle of universal access to affordable, reliable, sustainable, and modern energy for all by 2030.

Access to electricity is on the rise, although the rate of progress will need to increase to reach universal access by 2030. In 2017, there were some 840 million people without access to electricity, down from 1.2 billion in 2010 (International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank, World Health Organization, 2019). The fastest gains have largely been seen in Asia, with sub-Saharan Africa still seeing relatively slow growth in electricity access. To meet the energy needs of a growing population, progress towards achieving universal access will need to accelerate.

Beyond access, the quality of electricity supply matters – access is not a binary outcome. There are many ways in which a household or a business consumes electricity, and the quality of access can impose constraints on economic and social wellbeing. This is captured in the Energy Sector Management Assistance Program's (ESMAP's) Multi-Tier Framework, which defines five 'tiers' of energy access according to a range of characteristics, including: the capacity of power provided, the maximum level of service provided, availability, reliability, quality, affordability, legality, and health and safety (Bhatia et al, 2015).

There has been relatively less focus on the quality of access – and reliability is lagging behind.² While energy access rates are improving in emerging regions, the majority of households and businesses

that do have a connection to the main grid experience frequent, and often unpredictable and lengthy, outages. While there has been a healthy focus on making sure the rate of access improves, there has been relatively less focus on the importance of a reliable supply of electricity, and the impact of unavailability of electricity supply even where a connection is present. Furthermore, achieving the objective of universal access may present further challenges to reliability, as seeking to connect a growing population with growing energy demands will place a strain on the *availability* and *quality* of power from overstretched grid connections.

Unreliability of electricity supply both increases the cost of running a business and decreases the productivity of businesses, hampering growth and limiting employment opportunities, slowing economic growth, while also affecting education opportunities and socioeconomic equality.

This Energy Insight examines the extent to which poor-quality grid access continues to represent a challenge in emerging economies, and presents evidence on the scale of unreliable grids and their impact on economic development. The focus of this paper is on the extent and impact of electricity outages – that is, the impact of power going off either expectedly or unexpectedly. It should be noted that voltage fluctuations from a poor-quality grid can also cause damage to appliances and affect the functioning of commercial and industrial appliances, and healthcare equipment. The impacts of the *quality* of supply are not discussed in this paper, which focuses more on *availability* of electricity.

The remainder of this Energy Insight is structured as follows:

- **Section 2** sets out the scale of the challenge of unreliable grid connections.
- **Section 3** presents evidence on the impact of unreliable grids.
- **Section 0** describes how issues of unreliability can be addressed.

¹ <https://sustainabledevelopment.un.org/sdg7>

² Energy Institute Blog, 'The Developing World is Connecting to the Power Grid, but Reliability Lags'.

<https://energyathaas.wordpress.com/2017/05/30/the-developing-world-is-connecting-to-the-power-grid-but-reliability-lags/>

2. What is the reliability challenge and who is affected?

2.1 Households in Africa and Asia face frequent disruptions to electricity

Worldwide, over 200 million households use an unreliable grid connection. This represents as many households as the total number of households who lack access to electricity (Dalberg Advisors and Lighting Global, 2018; Graber *et al.*, 2018).

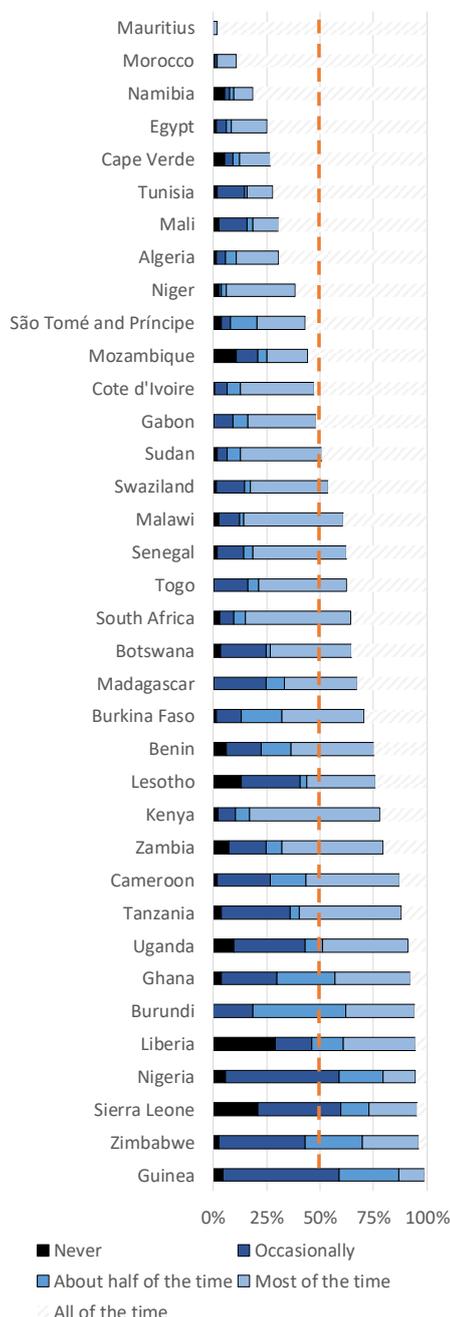
In most African countries, most households that are connected to a grid do not have an available supply of electricity all the time. Of the 36 countries covered by the Afrobarometer household survey, 23 record the majority of households as having at best access to their grid-based electricity ‘most of the time’. The worst affected countries are Guinea, Zimbabwe, Sierra Leone, Nigeria, Liberia, Burundi, Ghana, and Uganda, where over 90% of households report not having electricity all of the time. In fact, for these same eight countries, the majority of households report only receiving power from the grid-based electricity connection ‘about half the time’ or less (Figure 1).

Many households in Africa and Asia do not receive a constant supply of electricity throughout the day. Recent data from household surveys in the ESMAP ‘Beyond Connections’ series shows a similar reliability challenge in Africa and Southeast Asia. In Rwanda, only 50% of households can use their grid-based electricity supply for at least 22 hours a day, while in Ethiopia just 20% of households connected to the grid receive supply for 20 hours a day.

In Myanmar and Cambodia, 40% and 75% of households, respectively, have a grid-based electricity supply for at least 22 hours per day.

See Figure 2.

Figure 1: Most households in Africa do not have electricity all of the time

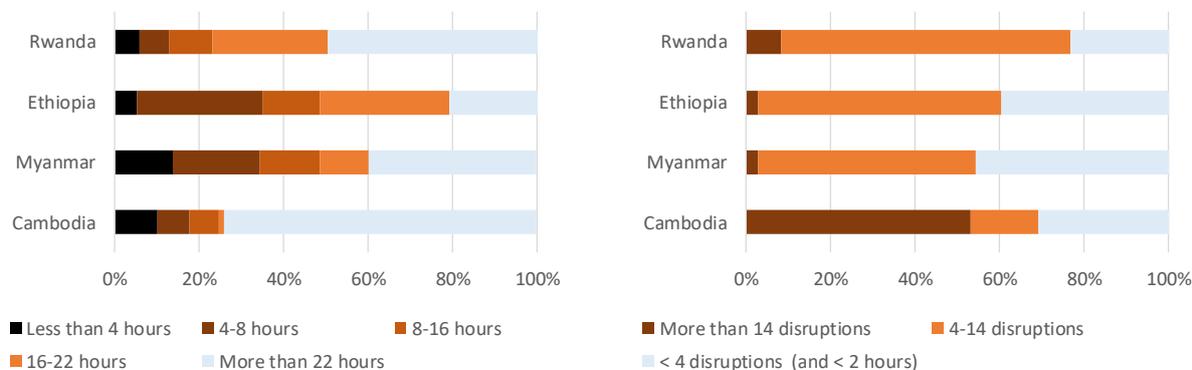


Source: Analysis of Afrobarometer survey data (Afrobarometer, 2016)

Households in Africa and Asia also experience frequent disruptions to their electricity supply. Almost 75% of Rwandan households experience over four interruptions to supply every week, and over 60% of Ethiopian households experience more than four outages each week. For Myanmar and Cambodia, the figures are 55% and 70%, respectively. Households in Bangladesh report daily outages of up to 10 hours (Zhang, 2019), while in Pakistan, scheduled outages frequently hit households, lasting as long as 10 hours a day in towns and cities

and up to 16 hours in rural areas (Shaikh and Tunio, 2017), with load shedding in summertime regularly extending outages to 20 hours per day (Zhang, 2019).

Figure 2: The ‘Beyond Connections’ series of publications show that grid reliability is a major issue in Southeast Asia and in Africa



Source: Analysis of Afrobarometer survey data (Afrobarometer, 2016)

2.2 Businesses also experience important outages – far more than in developed economies

In most high-income countries, it is rare for businesses to experience any electricity outages, and they are short when they do occur. In the UK, France, and the USA respectively, businesses face just 0.1, 0.3, and 0.4 disruptions to electricity supply each week, and these disruptions typically last less than one hour in total.

In emerging economies, businesses face frequent, and often long, electricity outages. Even in countries which appear to have a relatively stable electricity supply, such as India, the Philippines, and Vietnam, the average business experiences at least two outages per week, and those outages last for two to four hours. Rwandan utility customers experience on average 10 interruptions to supply each week, and these interruptions last on average three hours.

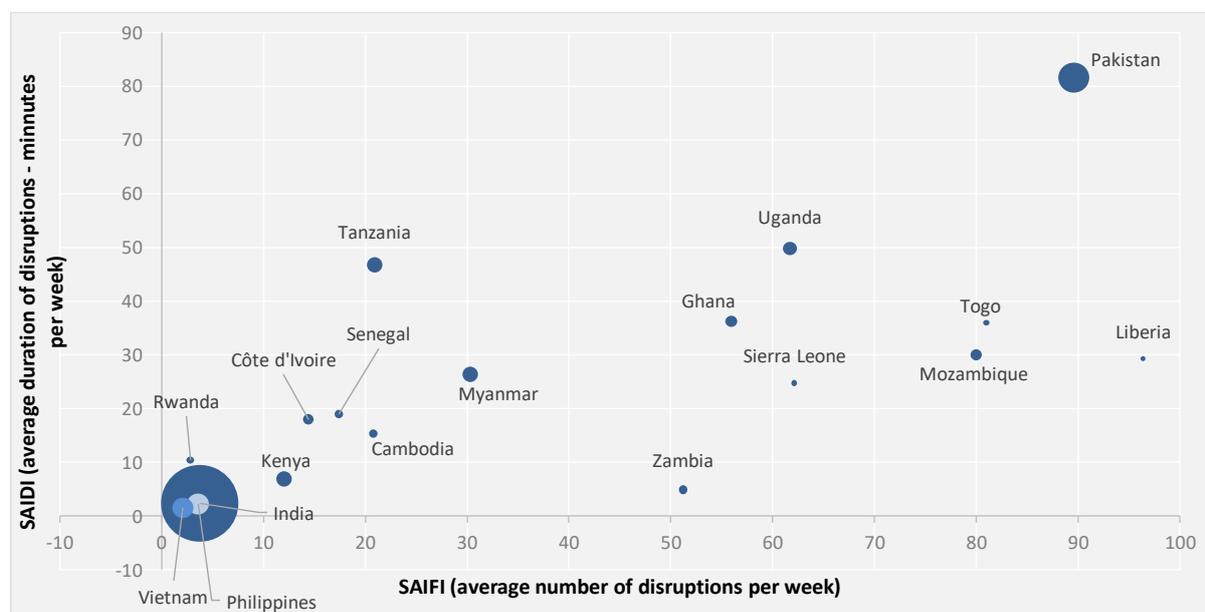
In some countries, utility customers face more than 50 outages each week. At the other end of

the spectrum, businesses in Pakistan have to contend with around 90 interruptions to supply every week, taking out electricity for over 80 hours. Businesses in Zambia, Ghana, Sierra Leone, Uganda, Mozambique, Togo, and Liberia experience more than 50 outages each week.

Despite this evidence, unreliability and its impacts is poorly understood and poorly measured. Utilities around the world often substantially underestimate the extent of outage (Taneja, working paper). This is in part due to a lack of reliable data from meters, a lack of clear monitoring and reporting frameworks relating to utilities, and a lack of sophisticated instrumentation to accurately measure reliability.

The lack of a reliable electricity connection imposes important constraints on economic output and growth, which are discussed in Section 0 below.

Figure 3: Frequency and duration of disruption are typically correlated – the more often outages occur, the longer they tend to last



Notes: Size of bubble represents population

Source: Analysis of World Bank Doing Business survey data and UN population statistics

3. Unreliable electricity supply imposes important costs on communities, businesses, and utilities

3.1 Adaptation through behavioural change and the socioeconomic costs of unreliability

Households and businesses may be able to adapt by deferring electricity-intensive activities until power returns (Gertier *et al.*, 2017). Alternatively, firms can focus their production processes on activities that are less dependent on having access to a reliable supply of electricity. Households can adapt by increasing home labour hours to undertake tasks that could be accomplished with less labour were a reliable source of electricity available. For example, in Ghana, over half of firms respond to outages by changing production time and 60% operate for fewer hours. Similarly, around 40% switch to less electricity-reliant processes, while 27% switch to less energy-intensive products (Blimpo, 2019).

Such adaptation mechanisms come at a cost in terms of productivity and growth. Across South Asia, almost half of business managers identify a lack of reliable electricity as a major constraint to their firm's operation and growth. Lack of access

to a reliable source of electricity ranks as a more important constraint to businesses in South Asia than regulation and taxes, corruption, and availability of human capital (Zhang, 2019).

Aggregated to national level, the impact of unreliable supply can have a large impact on gross domestic product (GDP). Economic losses due to power interruptions are estimated to cost between 1% and 5% of GDP of countries across sub-Saharan Africa (Ouedraogo, 2017). Similarly, across South Asia, the economic cost of distortions in the power sector is estimated to be between 4% and 7% of GDP (Zhang, 2019). Beyond the immediate short-term loss of output, lack of reliable energy supply also hinders economic growth, entrepreneurship, and job creation. In absolute terms, the cost of lack of reliable access to electricity for households in Pakistan alone amounts to some \$4.5 billion per year (Zhang, 2019).

At a micro level, businesses lose revenue when they are unable to serve their customers. For

example, when the power goes out in Ghana, people are less likely to go to shopping neighbourhoods if they are not sure the power will be on. Chemists are unable to stock life-saving drugs, as they cannot guarantee reliable refrigeration to store them at the required temperature.³

Power outages reduce firm productivity – particularly for smaller firms, who are less able to adapt or bear the cost of an alternative power supply.

In Senegal, the impact of outages is felt most acutely by small and medium-sized enterprises (SMEs): just 1% of large firms report lack of electricity as a major constraint, compared to 59% of SMEs. In terms of impact, over a quarter of SMEs lose more than 10% of their sales due to power outages (Cissokho and Seck, 2013). In Zambia, load shedding results in job losses and economic losses in the manufacturing sector, and voltage fluctuations and unexpected outages cause damage to industrial machinery (Mulenga, 2017). In Ethiopia, power outages increase firms' cost of production by 15% (Abdisa, 2018).

In India, while a grid connection boosts rural incomes, a high-quality grid connection has an even higher impact. Non-agricultural incomes of rural households increase by about 9% as a result of gaining access to a grid connection, but increase by 29% where that grid connection has few outages and a more regular supply of hours per day (Chakravorty, Pelli, and Marchand, 2014). More broadly, India's power shortages reduce the average plant's revenues and producer surplus by 5% to 10%, although productivity losses are smaller than they would otherwise be where inputs can be stored during outages (Allcott, Collard-Wexler, and O'Connell, 2015).

In sub-Saharan Africa, the impact of living in a community with unreliable electricity supply is estimated to reduce the probability of employment by over 35%, with the impact particularly affecting skilled labour (Mensah, 2018).

Lack of reliable electricity is also a major barrier to socioeconomic advancement in a range of

other ways. These can include educational attainment, as electricity is used for lighting and information and communication technologies for studies. By increasing the labour intensity of home chores, lack of reliable electricity can also inhibit the participation of women and youth in the workforce. In India, households with an unreliable grid connection spend 1.8 hours per month more on collecting fuel. Also in India, boys and girls study longer when they have a more reliable electricity supply, and women are able to work more hours per month (Samad and Zhang, 2016).

3.2 The cost of investing in a resilient electricity supply

An alternative to adjusting behaviour to adapt to unreliable electricity supply is to invest in alternative energy sources.

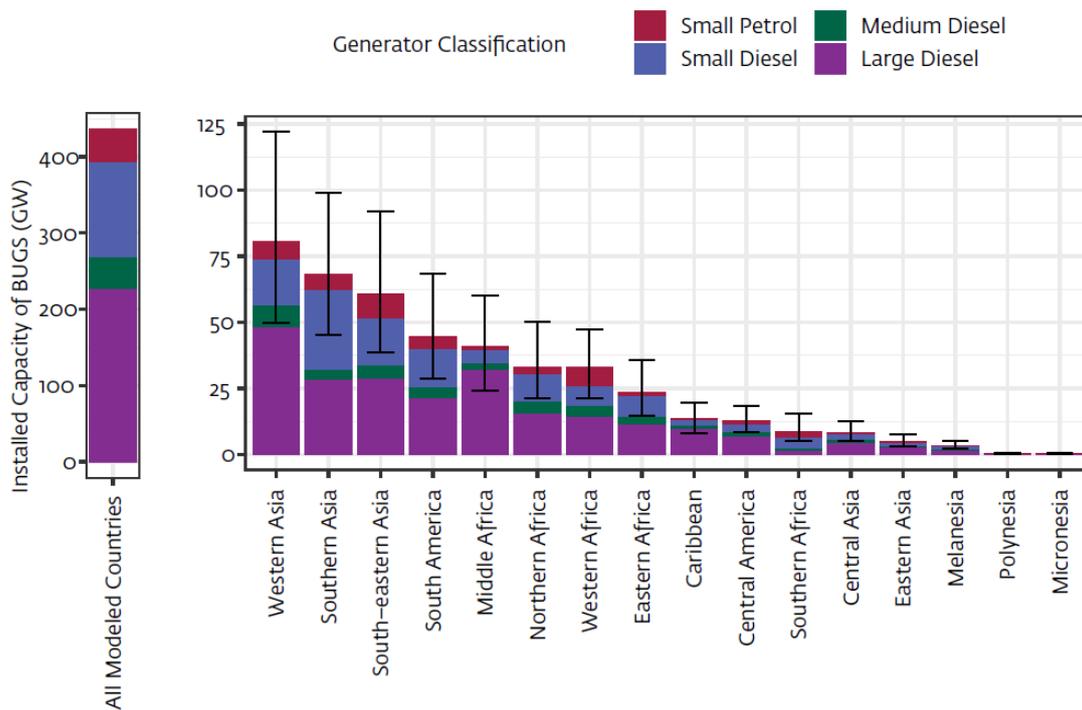
The use of back-up generators is widespread. Indeed, in sub-Saharan Africa (excluding South Africa), installed back-up capacity is twice that of the grid. Across low- and middle-income countries, over 400 megawatts (MW) of fossil-fuel (petrol and diesel) powered back-up generators are installed (Figure 4). Of a global total of around 26 million generators in developing countries, around 75% belong to grid-connected customers, as opposed to serving as the primary source of electricity for households or businesses without a connection to the main electricity grid (International Finance Corporation (IFC), 2019).

Expenditure on back-up systems is often as high as expenditure on the grid. While back-up systems are not used to the same extent as the grid, in regions where grid reliability is low, use of back-up systems, and expenditure on the fuel for those systems, is often comparable to consumption from (and expenditure on) grid-based electricity. For example, in West Africa, back-up generators provide as much as 40% of the power that is consumed from the grid (IFC, 2019). Similarly, in West Africa people spend almost as much on generators as they do on consumption from the grid utility (Figure 5), and in Nigeria people actually spend more on generator fuel than they do on purchasing power from the main grid.

³ MCC blogpost available at www.mcc.gov/blog/entry/blog-101716-mcc-

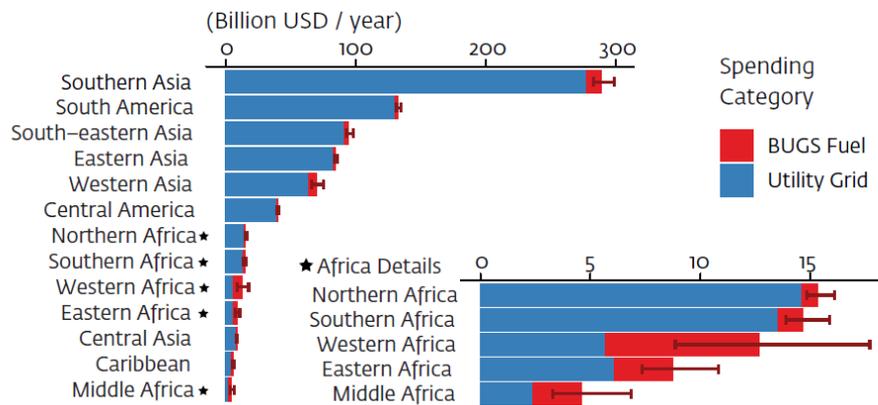
powering-africa-empowering-people-energizing-communities

Figure 4: Over 400 GW of installed capacity in the form of back-up generators in emerging economies



Source: IFC, 2019

Figure 5: Expenditure on back-up generators amounts to billions of US dollars every year – and in some regions is higher than expenditure on consumption from the grid



Notes: [1] BUGS is short for back-up generators. [2] The total spending on utility grid service is shown for comparison to back-up generators. The spending on fuel for generators includes a 90% uncertainty interval error bar [Note added from original source authors]: [3] the 90% confidence interval is presented, as there is substantial variation in expenditure by each back-up generator user, so there can be substantial variation around the central averages presented.

Source: IFC, 2019.

Businesses in Nigeria spend around \$17 billion on the main grid. The Nigerian Labour Congress estimates that manufacturers spend up to 3.5 trillion Naira (\$17 billion) per year on alternative energy sources to adapt to inadequate supply from the national grid (Nigeria Premium Times, 2015).

In Sierra Leone, almost 70% of firms own a generator. Among those firms, the generator is used to power almost half of their electricity, rather than using power from the grid.⁴ A 2013 study found that the installed capacity of privately owned, isolated generators was 174 MW – almost double the installed grid capacity of 94 MW (MCC, 2013).

Typically, the cost of purchasing and running a generator is much higher than grid-based consumption. The extent of the investment in back-up systems, and the cost of operating these systems, represents substantial costs to households and businesses, which are more expensive than a reliable grid connection would be in other parts of the world. For example, in Ghana, the cost of self-generated electricity is on average 322% more than the cost of electricity from the public grid (Abeberese, Ackah, and Asuming, 2017). The use of back-up generators in general is much costlier than the grid, with an average service cost of \$0.30 per kilowatt hour for the fuel alone, which is typically usually much higher than the cost of grid-based electricity (IFC, 2019).

3.3 Unreliable electricity undermines financial viability of utilities and tax receipts

Finally, unreliable supply hampers the revenue-generating potential of utilities providing electricity. High capacity and reliable electricity are needed to enable productive use that would generate economic and financial gains to users, which would boost ability and willingness to pay for consumption from the utility. A study in Ghana found that firms would be willing to pay 12.6% more for uninterrupted electricity access (Abeberese, Ackah, and Asuming, 2017), while in Nigeria, revenue currently only covers approximately 35% of the costs of the distribution company (Graber *et al.*, 2018). Similarly, resolving reliability issues in Africa could increase tax revenues by more than 4% per year (Blimpo, 2019).

4. Causes of grid unreliability and the way forward

4.1 Causes of grid unreliability

The causes of unreliable electricity supply exist at various points of the electricity system:

- **Insufficient installed generating capacity to meet peak demand.** There must be sufficient supply to meet peak demand at all times of the day and across the year. Installed generation in most sub-Saharan African countries is below the total potential electricity demand of households, businesses, and public institutions. Population increases coupled with economic growth will only increase demand for electricity.
- **Installed generating capacity that is not maintained and operational.** For example, in Bangladesh, less than 80% of available capacity is operational most of the time, with a similar lack of availability recorded in Pakistan (Zhang, 2019).
- **A generating mix that is not capable of ramping up and down to match demand fluctuations.** Installed electricity-generating units need to be able to scale up and down their output to meet fluctuations in demand. This means having the right mix of generating plant installed to provide sufficient system flexibility to meet demand in peak periods, and to be able to slow down production when demand is low. In Bangladesh, one of the causes of low utilisation of installed capacity is over-reliance on natural gas, with domestic reserves not always able to provide adequate supply when most needed.
- **Transmission and distribution (T&D) networks with insufficient capacity, flexibility, or redundancy to convey generated power to end users.** Generated electricity is conveyed from the site at which it is generated to the households and businesses who are the final consumers of power. This means that T&D networks need to be maintained and have sufficient capacity to transport power. This is often not the case, with bottlenecks in some parts of T&D networks, such that even though there is power generated, it cannot reach customers. Similarly, T&D networks need to have alternative routes to convey power to provide flexibility around bottlenecks, and they

⁴ World Enterprise Survey, 2017.

need to have sufficient redundancy built into the system to cope with faults at a particular line or substation without bringing the whole network down.

4.2 What can be done to improve reliability?

To boost reliability and minimise economic losses, a combination of the following solutions should be explored:

- **Investment in generating capacity and reinforcing T&D networks should be prioritised to improve reliability of supply to priority demand centres.**

Where there are shortfalls in the supply to existing customers connected to the main grid, investment should prioritise getting the right capacity, mix of generating technologies, and investment in networks to meet peak demand. Priority should be given to improving the cost and quality of supply to lift households out of energy poverty, and to unlocking productive use from commerce and industry. Losses should be reduced, both to limit outages as a result of electricity losses in the T&D system, and to boost revenues for often financially constrained utilities.

- **Where scheduled outages occur, they should be planned and implemented to minimise economic losses.** Supply to key public institutions, such as hospitals, should be prioritised, and so should supply to businesses that are dependent on a consistent supply of electricity.

A team from the University of California, Berkeley, has identified different feeder lines with differing levels of priority in Accra, Ghana, as part of its EEG-funded GridWatch project. Priority feeders designated as ‘exempted essential feeders’ experienced significantly less load shedding than other feeders⁵.

Energy regulatory authorities and electricity system operators should be politically independent, with the aim of both reducing outages and ensuring that where outages do occur economic losses are minimised.

- **Least-cost electrification planning should form the basis of grid extension plans, and should recognise the role of standalone technologies in providing reliable electricity supply.** In much of sub-Saharan Africa, the rate of connection to the

main grid remains low – for example, reaching just 7% of the population in Burundi. Grid-based generating capacity is often far short of total national demand for electricity, and the grid may not be the most cost-effective way to connect all customers, especially where expanding the grid comes at the cost of providing a reliable quality of service. Alternatives, such as standalone mini-grids and solar home systems, should be included in electrification plans, taking into account not just connecting customers but also the quality of supply received from different sources of energy.

- **Off-grid solutions, such as mini-grids, should be used where they represent a cost-effective way to boost the quality of service to ‘under the grid’ populations.** In locations where the main grid is overstretched, mini-grids may be a more cost-effective solution than boosting supply of power to households that are currently under-served by the grid – of which there are as many globally as there are unconnected households (Graber *et al.*, 2018). Increasingly, mini-grid systems are able to provide 24/7 electricity, by combining hybrid solar-diesel generating systems, or by using storage technologies. Remote monitoring technologies and smart meters can increase the quality of service and reliability: the average uptime of mini-grids owned and operated by members of the Africa Minigrad Developers Association exceeds 97% (ESMAP, 2019).
- **Embedded generating capacity can be used as an alternative to, or alongside, as a supplement to, an unreliable grid connection.** Embedded generation is an increasingly cost-effective alternative to fossil-fuel powered, standalone, back-up generators, or to consumption from the main grid. This can represent a ‘win-win’ situation, by helping reduce the strain on local distribution networks and reducing system costs, while also increasing the quality of supply to end users. Embedded generation options range in size from industrial and commercial consumption to small-scale residential solutions, or even solar home systems and solar lanterns and appliances:
 - Nearly 4,000 MW of rooftop photovoltaic (PV) had been installed in India by the end of 2018, and a further 40 gigawatts (GW) is

⁵ <https://energyeconomicgrowth.org/node/191>

- expected to be achieved through decentralised and rooftop-scale solar projects (Institute for Energy Economics and Financial Analysis (IEEFA), 2019).
- Similarly, the Government of Bangladesh recently approved a nationwide net metering policy (Chowdhury, 2018), which has resulted in 14 MW of rooftop PV installed so far, and the government expects a further 300 MW to be rolled out within four years.⁶
 - Households with an unreliable grid connection often supplement their primary grid-based electricity with a standalone off-grid (or even grid-compatible) solar device.
- **Policy and regulation should provide a level playing field for different types of electricity supply.** Cost-reflective tariffs would provide the right incentives for investment in grid-based electrification compared to alternatives, and would ensure utilities are set up to achieve cost recovery. Where subsidies are used to reach customers with low ability to pay, they should be designed carefully so as not to distort the prices received by electricity distribution companies and generators, to ensure the right incentives are in place to invest in reliable electricity supply.
 - **Electricity users can invest in energy-efficient equipment and processes to reduce reliance and load on the electricity supply.** Firms can invest to increase their resilience to outages, and at the same time reduce the peak load demands on the electricity grid – for example, by taking measures to reduce their demand for electricity, such as through the use of energy-efficient appliances, or by substituting towards inputs that are less dependent on a reliable supply of electricity for processing (Lee *et al.*, 2017).
 - **Working with end users to ‘activate demand’ and support productive use of energy.** Once supply options are available to consumers, a key to ensuring financial viability of utilities and alternative energy sources is ‘activating’ the latent demand of previously under-served customers. This means working with customers to make sure the impact of access to reliable energy is maximised through productive use of energy resulting in productivity and income gains.

⁶ www.pv-magazine.com/2019/09/27/bangladesh-government-pledges-rooftop-pv-on-all-its-buildings/

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About the author

Ed Day is an economic consultant with a decade's experience in economic and financial analysis spanning working with major utilities and policymakers in the UK and Europe, and the role of grid and off-grid energy solutions in Africa and Asia. He began his career as an Overseas Development Institute Fellow supporting the Government of Burundi to develop its Poverty Reduction Strategy Plan, before carrying out research in development policy at the Institute for Fiscal Studies, and consulting for NERA Economic Consulting and Vivid Economics, where he led the Growth and Development practice. He holds an MSc in Economics from University College London.

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