Energy and Economic Growth
Applied Research Programme

Energy and Poverty

EEG Energy Insight

This note is published as part of a series of Energy Insights, under the auspices of the Applied Research Programme on Energy and Economic Growth (EEG), a UK Department for International Development (DFID) financed initiative to produce cutting-edge research on the links between energy and economic growth. EEG works closely with policy makers in sub-Saharan Africa and South Asia to build more sustainable, efficient, reliable, and equitable energy systems.

The purpose of this Energy Insight is to provide an overview of the links between a lack of access to modern energy services and poverty. The paper is split into three sections. The first section explores the benefits of electrification and the negative consequences of poor reliability and lack of energy access. The second section then looks at the scale and distribution of the energy access problem globally, noting the uneven distribution of access within the developing world, different forms of exclusion, and some of the challenges of achieving UN Sustainable Development Goal 7 (universal access to modern energy services). The final section then explores some caveats around the causal links between energy access and social and economic development, noting that energy access is a necessary, but on its own not sufficient, condition for addressing poverty.

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The importance of modern energy services

Electricity access is generally referred to in terms of the proportion of households with connections to the electricity grid. However, access to modern energy cannot be measured by this statistic alone. For a start, electricity supplies may be provided by other means than national grids, such as solar lanterns, solar home systems, or local mini grids. Moreover, even for households that are connected to the grid, families cannot be considered to truly have access if the electricity supply is intermittent, or if voltage is unstable and damages appliances connected to it, or if the electricity from the supply is too expensive to use for anything except lighting. Finally, achieving universal access to energy services requires looking beyond the home to also consider the vital role access to electricity plays in the delivery of public or community services, and in the underpinning of livelihoods and economic development. In reality, access to energy is a prerequisite for social and economic development and a vital enabler across three domains: community services, work, and the domestic space (Figure 1) – something that is explored further below.

Figure 1: The three domains of energy access

Figure 2: Solar powered vaccine fridge in a rural clinic in Sierra Leone (Credit - Simon Trace)

Community services

A lack of modern energy supplies in the public domain leaves people without access to basic community services. Around the world, about 1 billion people are served by hospitals, clinics, and health posts that are without electricity. For example, 46% of such facilities in India and 40% in sub-Saharan Africa lack electricity (Practical Action, 2013). Without electricity, many basic medical services cannot be provided. Challenges range from the risks associated with having to provide emergency treatment and child birth services in low light or the dark, to an inability to maintain a cold chain for vaccines or to provide basic services that are dependent upon electricity, such as X-rays or diagnosis equipment for HIV/AIDS. Table 1 shows a list of basic energy services that are required for a clinic for both general infrastructure and the delivery of specific medical services.

Table 1: Typical energy services required for a clinic to deliver basic health services (Practical Action, 2013)

Purpose / service	Energy service / equipment
General infrastructure	• Lighting in clinics, wards, offices, and theatres, and public security • Communications: mobile phone charging, VHF radios, internet • Cooking and water heating • Space heating or fans for air circulation and cooling • Sterilisation equipment • Waste autoclave and grinder
Medical services and devices	• Vaccine refrigerator to maintain cold chain for vaccines • Suction apparatus, incubator, and other maternity equipment • ELISA test equipment for HIV diagnosis • Portable X-ray machine • Laboratory equipment, including centrifuge, haematology mixer, microscope, blood storage, blood typing equipment, blood glucose meter, ECG, ultrasound, CT scan etc • Surgical equipment and facilities for tracheostomy, tubal ligation, obstetric fistula repair, appendectomy, neonatal surgery, open treatment of fractures, amputation, cataract surgery etc.

Health is not the only public service that suffers from a lack of access to electricity, though. It is estimated that around 50% of children in primary education in the developing world (291 million children) attend schools with no electricity (ibid.), leading to the absence of basic infrastructure such as lighting, the pumping of water supplies, or the provision of cooking facilities for school feeding programmes. It also prevents the use of equipment such as information and communication technology to support teaching and learning. Beyond health and education facilities, public institutions, such as government offices and police stations, all face limitations to their functionality without adequate levels of electricity, while public services, such as water supply and treatment or street lighting for security, are impacted or totally absent.

Work

Poor levels of access to electricity also severely limit what is possible in terms of economic development. Electricity powers livelihoods and contributes to economic development. In the agricultural value chain it can help increase production by driving an irrigation pump, but also enable food-processing activities that add value to local crops. Energy for mechanical processing is also a common need for small enterprises. Milling of grains is one of the most common non-farm enterprise sectors, alongside pressing of seeds for oil, or the removal of husks or shells (Figure 3). Cooling is used extensively in the food production chain for both storage and transportation: for example, milk chillers allow smallholder farmers to pool their milk production and store it until a tanker from a dairy can collect it. Transforming raw materials into end or intermediate products, such as timber planks or wooden furniture, can be done by hand, but is speeded up and made more efficient with powered tools, while repair of equipment, including vehicles and engines, often requires welding or powered equipment, such as drills

Figure 3: Taking mechanical power off a micro hydro installation in Mozambique to drive a maize mill (credit: S. Trace)

and other workshop machinery. Information and communication technologies often spread quickly when electricity is available and can also have livelihood benefits. Appliances, such as television, radio or internet and mobile phone services, can bring more clients to a shop, bar, or restaurant, for example.

The importance of electricity as a constraint on economic growth (and therefore the creation of jobs and the delivery of revenue to support public services) is confirmed at the macro scale by data from the World Bank's Enterprise Survey, which suggests that it is the most important barrier to firms in South Asia and the second most important barrier for firms in sub-Saharan Africa (Stern, 2017). The costs to business of poor connectivity or the absence of an electricity supply are well illustrated by the case of Sierra Leone, where just 13% of households have access to electricity (World Bank, 2017). Here the national unconstrained demand for electricity (including the mining sector) stands at around 256 megawatts (MW), compared to a national grid-connected generation capacity that peaks at just over 80MW, reduced to around 50MW in the dry season due to a reduction in hydropower availability (Trace, 2018). The problem of low and unreliable supply of power in the economy is such that companies, and households that can afford to, often turn to generating their own power in place of or to supplement grid power. Table 2 shows that over 70% of the current generating capacity in the country is in fact in private hands, with more than two-thirds of that (174MW) owned by non-mining businesses and private households. The total capital costs that have been borne by households and private firms (excluding mining companies) to install generating capacity to address the limitations of grid power supply is estimated at over US$ 100 million to date.

Table 2: Public vs private generation capacity in Sierra Leone (MCC, 2013)

Type of power plant	Installed capacity in MW	Number of plants	State owned, private, mixed	Grid connected or decentralised
Thermal oil plant	37	7	State owned	Grid connected
Large hydropower plant (>10MW)	59	2	State owned	Grid connected
Small hydropower plant (<10 MW)	6.75	4	State owned	Grid connected
Auto-generator (135MW) plus two years' imports (39MW)	135+39=174	33,000	Private	Isolated
Mining company generator	88.5	Unknown	Private	Isolated
Photovoltaic	0.025	Unknown	Mixed	Isolated
Total MW	356.3			

Energy access in the home

Beyond the restrictions on public services and livelihoods, however, the impact of a lack of access to modern energy supplies is felt most heavily in the home. Lack of electricity restricts productive, leisure or study activity in the home after dark. A candle or simple wick kerosene lamp provides just around 11 lumens of light, as compared to around 850 lumens from a basic 15 watt (W) CFL fluorescent bulb (Practical Action, 2014) – a clear illustration of why carrying out productive activities after dark is almost impossible without electricity. Absence of electricity also imposes high costs as a result of household expenditure on alternative, less efficient, and more expensive energy supplies, such as batteries, candles, and kerosene. The cost of recharging mobile phones for households without an electricity supply can also be expensive, both in time (to walk to the nearest source of electricity) and cost. A study in rural

Table 3: Example of average monthly household energy expenditure in 69 rural Kenyan households (Van Acker *et al*, 2014)

	Mean cost Kenyan Shillings / (US$)
Batteries	300.1 (3.50)
Candles	55.8 (0.65)
Kerosene	399.28 (4.65)
Phone charging	177.1 (2.06)
Total	933.14 (10.86)

Kenya, for example (Van Acker *et al*, 2014), found that people walked on average 2.3 km eight to 12 times a month to recharge a mobile phone, at a cost that represented around 20% of the total household expenditure on energy (Table 2).

Cooking using firewood, charcoal, or other solid fuels is usually highly inefficient and either expensive (in urban areas where such fuels need to be purchased) or requires huge physical effort to collect and carry firewood in rural areas. Cooking using solid fuels also imposes a huge health risk from the inhalation of indoor air pollution. Over 4 million people (mostly women and children, who have the highest exposure) die prematurely each year from respiratory or cardiovascular diseases and cancer caused by exposure to smoke from cooking (WHO, 2014).

Distribution of the energy access challenge

Energy access in developing countries is highly unequal. While some experience uninterrupted modern energy services, others remain completely without. This section explores how energy access is distributed across three different variables: space, income, and gender

Spatial distribution of challenge

As at 2014 (the latest figures available) 1.06 billion people in the world lacked access to electricity, while 3.04 billion people lacked access to clean cooking facilities (World Bank, 2017). Official statistics portray electricity access as largely a problem for rural populations across sub-Saharan Africa and South Asia (Figure 4), while access to clean cooking facilities is a problem that is more evenly spread across sub-Saharan Africa, and South and East Asia, and is both an urban and rural issue.

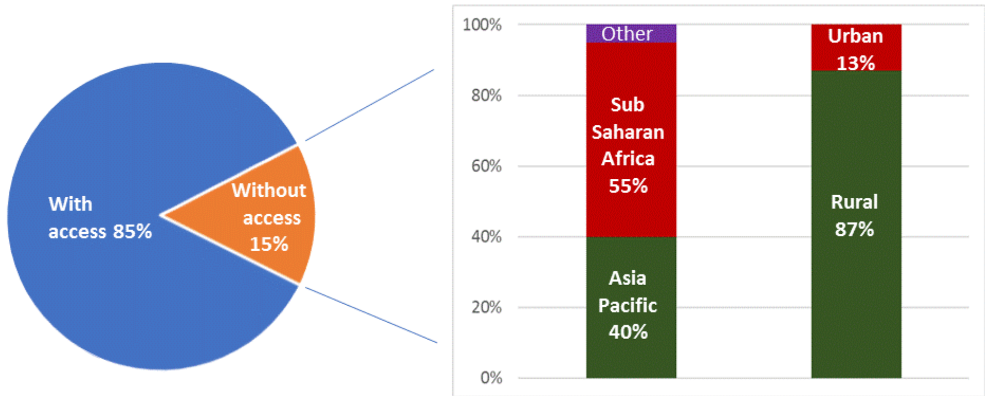

Figure 4: Global energy access figures 2014 (World Bank, 2017)

In reality, levels of access to electricity for urban populations are likely to be overstated in official statistics. The World Bank has developed the Multi-Tier Framework (MTF) to provide a more nuanced view of access to electricity than traditional connection statistics (Table 3).

Table 2: Selection of key characteristics from the MTF (World Bank, 2015)

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power	No service provided[1]	Very low power, minimum 3 watts	Low power, minimum 50 watts	Medium power, minimum 200 watts	High power, minimum 800 watts	Very high power, minimum 2 kilowatts
Daily capacity		Minimum 12 watt-hours	Minimum 200 watt-hours	Minimum 1.0 kilowatt-hours	Minimum 3.4 kilowatt-hours	Minimum 8.2 kilowatt-hours
Types of services possible		Lighting of 1,000 lumen hours /day	Lighting, air circulation, TV, phone charge	Tier 2+ refrigeration, water pumping	Tier 3+ iron, hair dryer, microwave	Tier 4+ air conditioner, cooking etc.
Hours per day		Minimum 4 hours	Minimum 4 hours	Minimum 8 hours	Minimum 16 hours	Minimum 23 hours
Hours per evening		Minimum 1 hour	Minimum 2 hours	Minimum 3 hours	Minimum 4 hours	Minimum 4 hours

Using the MTF to analyse the quality and quantity of supply demonstrates that urban populations' access to energy services may be considerably less than simple connection statistics suggest. Figure 5 shows the results of a pilot study using the MTF in Kinshasa. Official statistics report that ninety percent of the city's households are connected to an electricity supply. But a household survey based on the MTF methodology puts only one percent of households as having what could be described as a tier 4 or tier 5 supply (relatively reliable, more than 16 hours of service including 4 hours at night, able to deliver a broad range of energy services etc). Meanwhile thirty percent of the population were placed at tier zero (meaning that some of the ninety percent that were supposed to be connected to an electricity supply had the wires but not the electricity!). The remaining vast bulk of the population had varying levels of access to intermittent and poor-quality electricity supplies.

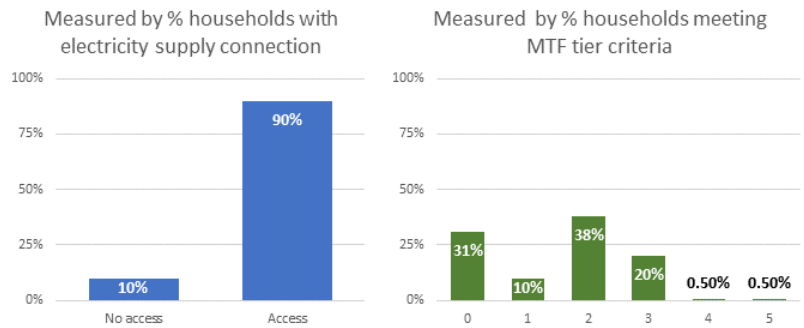

Figure 5: Access to electricity services in Kinshasa, measured using the MTF (World Bank, 2015)

Energy access levels and income

Unsurprisingly, levels of poverty are closely linked to levels of electricity access. This is partly a function of location: the poorest rural populations tend to live in low-density and relatively remote communities, making them very expensive to serve from grid infrastructure because of the length of distribution line required. Off-grid provision technologies are often preferred as a result but, although cheaper than grid extension in such circumstances, can still be more expensive in terms of $ per kilowatt per hour (kwh) than equivalent grid supplies in denser communities located closer to transmission lines (see Figure 6). This often means the poorest

[1] A more detailed version of the multi-tier framework for household electricity considers further tier between tier 0 and tier 1 for basic lighting services that captures the contribution of solar lamps that do not reach the minimum output threshold required for tier 1 access but that are highly affordable and enable households to reduce or eliminate the use (and cost) of kerosene for lighting.

rural communities are faced with higher unit costs for electricity than middle class urban populations, further depressing their ability to access electricity at the volumes necessary to have a significant positive impact on their wellbeing. The fact that grid services are routinely subsidised while other energy access technologies are often not only further serves to widen this affordability gap.

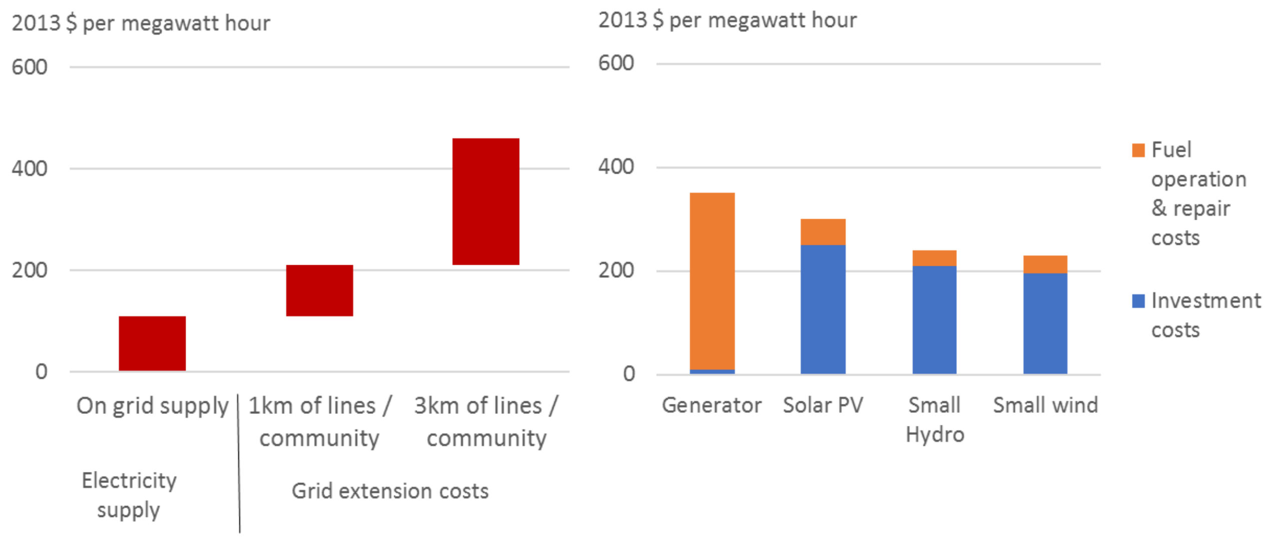

Figure 6: Indicative levelised costs of electricity for on-grid and off-grid technologies in sub-Saharan Africa, 2013 (World Bank, 2015)

Although solar home systems that can provide multiple lights, charge a mobile, and run low power appliances (such as fans and small TVs) are becoming increasingly popular for off-grid communities, particularly in countries such as Kenya and Bangladesh, studies have shown that their cost still limits their affordability to wealthier rural households, with most of the rural poor still only able to afford small solar lanterns or left reliant on kerosene, candles, and torches for light (see for example Samad *et al*, 2013). One additional challenge for consumers who are reliant on off-grid solar for electricity is that, unlike grid connections, the capital cost of off-grid solar (for the user) is a function of the capacity required. For energy services that require little capacity (lighting, fans, TVs, etc.) the capital costs are competitive with a electricity connection for a household that is in relatively close proximity to the grid. The capital cost of solar climbs rapidly however as a user's demanded energy services grow in terms of required capacity (for example, air conditioning, refrigeration, medical equipment, water pumping, irrigation, agro-processing), making energy supplies for productive use much more expensive for communities too remote to be economically connected via the grid. Once again the tendency for governments to subsidise grids in one form or another, but not other energy access technologies, influences further exacerbates this difference in affordability.

In urban areas residents of informal settlements and slums face particular challenges with electricity access. In informal settlements, the lack of land tenure, and the absence therefore of papers such as property tax bills or land ownership documents to establish an 'official' address, often means utilities have no legal basis on which to connect or bill households in the first place. In Thailand this has been addressed to an extent by the issuing of temporary registration numbers or 'quasi household IDs' (GNSED, 2014), while in Ahmedabad in Gujarat, India, the Municipal Corporation issues 'certificate of non-eviction' to facilitate utility connections in such cases (ESMAP, 2011).

Other forms of exclusion also exist for poor urban populations, however. Ironically, despite being densely populated and often lying close to the grid, the relatively low anticipated household electricity consumption rates of informal settlements and slums may mean that they are deemed as uneconomical to serve by, or as low a priority for, some utilities (which are often financially constrained themselves) as their distant and dispersed rural counterparts. High upfront costs for connections are also commonly mentioned as a barrier to urban poor populations getting access to grid electricity (World Bank, 2016). Such costs lead to a high incidence of illegal connections, with some estimates putting these as high as 50% of all slum connections in sub-Saharan Africa (Putti, 2011). Illegal connections are typically made either through direct tapping of low voltage distribution lines or via the illegal sharing of meters between multiple households. Both approaches pose safety risks for users. In the former, in addition, the utility often suffers significant 'administrative losses' through stolen electricity, while in the latter, poor consumers sharing metres may lose out on benefiting from lifeline tariffs aimed at the poor[2]. Where illegal connection rates are high, there is often a high degree of mistrust between communities and utilities. There may also be vested interests, in the form of local cartels making money from the provision of illegal connections. These factors can combine to present security issues for utility staff entering settlements, making the processes of attempting to legalise connections difficult.

The impacts of energy access across gender

Access to modern energy supplies can deliver specific benefits to women. Gender-ascribed roles often mean women perform particularly arduous or dangerous domestic tasks, which improved energy access can help address or ameliorate. Energy for water pumping could reduce or eliminate the need to walk long distances to collect water for domestic supply. Efficient cookstoves could likewise reduce or eliminate the arduous task of firewood collection and remove the threat to women's health from exposure to harmful indoor air pollution. Meanwhile, mechanisation of milling and pressing can eliminate the need for manual de-husking, pounding, or grinding of grain and pressing of oil seeds. Access to electricity in the home may also extend women's economic opportunities where child care responsibilities or cultural norms limit their ability to engage in work outside of the domestic environment. Pumped water might allow for increased irrigation of vegetable crops (often women's responsibility), while simple mechanisation could dramatically speed up the spinning of wool into yarn, for example (Figure 7). There is a risk, however, that the provision of electricity extends the amount of paid work that women undertake, without a concomitant reduction in unpaid domestic work and childcare, leading to a burdensome 'double day' (Wilhite *et al*, 2017).

Figure 7: Spinning alpaca wool in a rural home in the Peruvian Andes (Credit – Simon Trace)

Improved energy supplies may also help meet not just the practical but also some strategic needs of women. Street lighting may improve security for women, allowing more movement outside of the home after dark. Being able to charge a mobile phone at home may increase its availability to women and improve their ability to communicate more widely, opening up new economic and social possibilities, but also allowing for better contact with their maternal home, which, in turn, could also improve their security. Where energy access gives women new opportunities to earn money the possibility of greater economic freedom and independence also emerges.

[2] Lifeline rates enabling the poor to use grid electricity vary in availability. The World Bank reports six countries allowing 30 kwh or less of electricity usage a month at low prices. When meters are shared across households' consumption is pushed over this lifeline amount and the bulk of the electricity supplied is at a higher unit cost than would have been the case if each household had its own meter.

Final caveats

Research trying to establish a direct causal link between energy access and poverty reduction has largely concluded that energy access must be considered as a necessary, but not sufficient, condition for poverty reduction. Although there is a clear body of research demonstrating the link between clean cooking facilities and improvements in health (WHO, 2014), attempts to demonstrate that improved access to electricity directly causes other economic or welfare benefits have proven more difficult. Studies on the impact of access to electricity on educational outcomes have shown mixed results, for example. While a recent study in Kenya (Rom *et al*, 2017) showed access to solar lighting increased students' daily study time by around 10%, other studies (for example (Kudo *et al*, 2017)) have shown no impact on educational outcomes, while at least one study (Squires, 2015) has shown access to electricity as having a negative correlation with educational achievement (as a result of children's time being diverted to productive activity). Likewise, studies in Nepal and India (WRI, 2016) or in Kenya (Miguel and Wolfram, 2018) find no evidence of access to electricity impacting on household income. Finally, as already noted, although energy access has the potential to meet some practical and strategic needs of women it is not guaranteed to do so, and may instead result in an increased burden as women extend their cash earning productive work without a concomitant reduction in their domestic burden.

In the latter case, harmful social norms that regulate unpaid work as solely 'women's work' have to be challenged, alongside the provision of energy services, to ensure net benefits accrue to women. In the broader case, meanwhile it needs to be recognised that while energy access can offer new productive opportunities, other things often have to happen alongside that to convert those opportunities into development dividends. Increased production without parallel improvements to credit availability and better access to markets may not translate into actual improvements in household income for example. Further research is needed to identify and learn from initiatives where improved energy access has been combined with other kinds of subsidy or investment, to boost household income, sustain economic growth, or deliver improvements in government service delivery.

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About the author

Simon Trace has 35 years' experience working in international development, with a focus on access to basic services (energy, water, and sanitation), natural resource management, and technology.

Simon joined Oxford Policy Management in 2017 and is currently the Programme Director for the Facility for Oil Sector Transformation (FOSTER) programme in Nigeria, a £19 million project that aims to achieve more effective use of Nigeria's extractive industries to support national development. He is also leading the work on EEG's Sierra Leone country programme.

Simon has 16 years' experience in senior executive positions in international NGOs, including time as International Director of WaterAid and 10 years as CEO of Practical Action. During his time at Practical Action he provided oversight and technical input for several high-profile energy sector publications, frameworks and strategies, including the UN SE4ALL Global Tracking Framework, the World Bank's Regulatory Indicators for Sustainable Energy (RISE), the World Energy Outlook, and the Poor People's Energy Outlook (PPEO).

A chartered engineer with an MA in the Anthropology of Development, Simon has lived and worked in Africa and Asia. He has served on a number of steering and advisory groups for prominent international initiatives related to energy, including the UN SE4ALL Tracking Framework Steering Group, and is currently a member of the Strategic Advisory Group for the UK Government's £1.5 billion Global Research Challenge Fund.