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## THE BOTTOM LINE

Grid connectivity in rural Lao PDR yields substantial benefits. Household income, spending, and ownership of durable assets improve substantially as a result of it, as does children's education. Policymakers should consider extending grid-connectivity to households still off the grid. For households already connected, reliability and quality of service should be improved. Based primarily on hydropower, grid power in Lao PDR is subject to seasonality. Having households reduce their electricity consumption during the dry season is a temporary solution to avoiding outages. A long-term solution will depend on increasing energy efficiency, adding generation capacity, and extending the grid.

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# Making a Difference in People's Lives: Rural Electrification in the Lao People's Democratic Republic

## Why is electrification important?

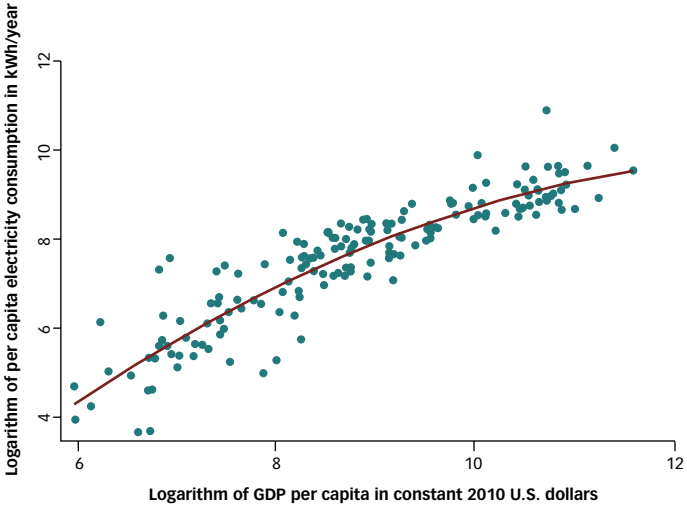
### Electricity advances human welfare and development

The relationship between access to electricity and economic growth is well established, although the existence and direction of causality are debated. Data from 176 countries show a high correlation (0.69) between gross domestic product and electricity consumption (figure 1). Over the past two decades, studies have provided mounting empirical evidence of the various channels through which households and individuals benefit from electrification. In recognition of the beneficial role of electricity in particular, and modern energy in general, the United Nations has declared achieving universal access to modern energy by 2030 as one of the Sustainable Development Goals.

In this study, we investigate the benefits of rural electrification—specifically, the socioeconomic gains of households—using data from a household survey conducted in the Lao People's Democratic Republic (Lao PDR) in 2015–16. The study is an initiative of the Status of Energy Access Report (SEAR), prepared by the World Bank's Energy Sector Management Assistance Program (ESMAP). Documenting the impact of programs that seek to expand energy access has a twofold purpose. First, it allows stakeholders to assess the effects of electrification on a set of outcomes of interest, including poverty, income, health, productive use, education, and the environment. Second, evaluations of the welfare effects of policies and programs can inform future policies and decisions about investments. The evaluations can also be used to compare impacts and share knowledge across countries.

Energy (including electricity) is useful only to the extent that it enables desired services and positive actions. These services and actions, in turn, are critical to the achievement of many development goals. The pathways of electrification's benefits start with the procurement of appliances (figure 2).

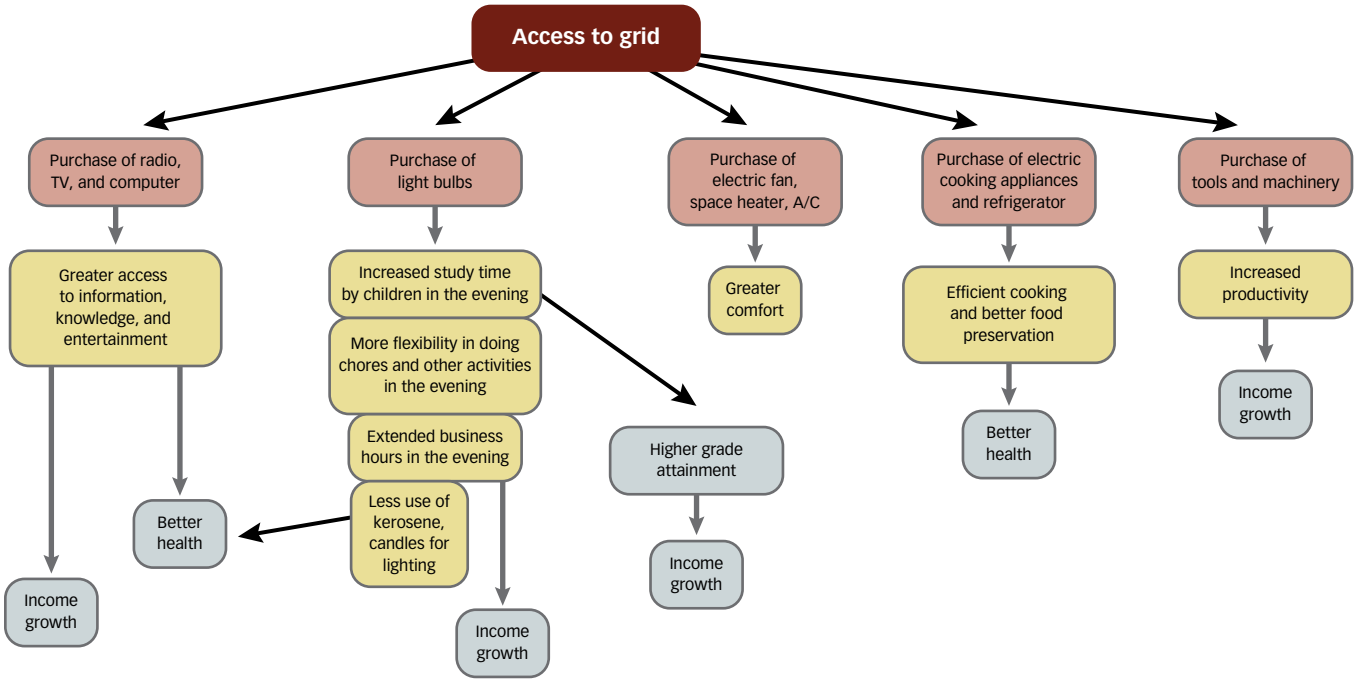
**Figure 1.** Per capita electricity consumption vs. economic development, 2014




*Source:* World Bank Open Data (https://data.worldbank.org).
*Note:* This is a quadratic fitted curve produced using available data from 176 countries in 2014. GDP = gross domestic product; kWh = kilowatt-hour.

Electrification's benefits often materialize through multiple and interrelated pathways; in aggregate, the benefits and their effects can be significant.

**Figure 2.** Benefit pathways of household electrification




*Source:* Authors' illustration based on World Bank (2002).

After gaining access to electricity, households may purchase a variety of appliances, starting with electric lights and followed by radios, televisions, computers, electric fans, air conditioners, cooking equipment, and refrigerators. Electricity access may also lead to increased and more diverse use of mobile phones because members of households with electricity can charge their mobile phones at home rather than traveling to market centers or shops to have their mobile phones charged for a fee.

Electrical appliances yield benefits such as better lighting and the ability to preserve food; these benefits, in turn, have medium-term effects. Thanks to improved lighting, children may spend more time on their studies and adults may engage in productive activities such as handicrafts, or be able to keep a home business open for extended hours in the evening. Radios, televisions, and computers offer information, knowledge, and entertainment. Increased knowledge can lead to better income opportunities and more empowerment, especially for women. Electric fans, air conditioning, and space heaters make life more comfortable. Electric cooking appliances and refrigerators save time and protect against the health hazards of spoiled food and household air pollution. (The latter affects women and children disproportionately, because they spend much of their time indoors.) Finally, electric tools and machinery increase productivity and incomes.

These medium-term benefits have long-term impacts. As children's study hours increase, their school attendance is likely to improve, as is their grade-completion level. Higher education means higher future incomes. As we can see, electrification's benefits often materialize through multiple and interrelated pathways; in aggregate, the benefits and their effects can be significant.

The World Bank has provided long-standing support for the development of Lao PDR's power sector. It is now focusing on improving the domestic market's reliability, efficiency, and financial viability, while also scaling up electricity trade and investments in the regional power market.

## How is Lao PDR faring in access to electricity?

### The country has experienced a dramatic increase in electrification in the past 25 years

The share of Lao households with access to electricity grew from 15 percent in 1995 to 87 percent in 2016 (World Bank 2018). Electric power generation has also grown rapidly, increasing from 33 megawatts (MW) in 1975 to 200 MW in 1996 to the current level of more than 6,000 MW. This was accomplished through strong government commitment, effective implementation of access programs, a well-structured subsidy and tariff policy, and assistance from international financial institutions.

The objectives of the country's First Power Sector Policy, enacted in 1990, included increasing access to electricity through grid and off-grid connectivity, making tariffs affordable, and promoting economic and social welfare. The body responsible for its implementation is Electricité du Laos. Incorporated in 1997, this vertically integrated power utility accounts for most of the country's generation and 100 percent of its transmission and distribution. The Ministry of Energy and Mines rolled out a Power to the Poor program in 2008, targeting poor households in general, and female-headed ones in particular. This program promotes electrification by providing a credit to enable households to connect to a grid when it becomes available in their community. Where there are no power lines nearby, the program helps communities tap the Rural Electrification Fund and also offers tax breaks for the purchase, construction, and management of imported equipment. In remote areas, the government promotes off-grid solutions, with an emphasis on renewable technologies.

The government of Lao PDR set an ambitious goal of electrifying 90 percent of the nation's households by 2020, and increasing hydropower exports to neighboring countries.

The World Bank has provided long-standing support for the development of Lao PDR's power sector. Over the past decade, Bank support was the cornerstone of the Nam Theun 2 hydropower project, which also benefited from other donors, including the Asian Development Bank, Agence Francaise de Développement, the European Investment Bank, and the Nordic Investment Bank. As the nation's electrification program enters its final stages and the private sector takes the lead in developing power generation, the World Bank is now focusing on the next set of challenges related to the development of the power grid, such as improving the domestic market's reliability, efficiency, and financial viability, while also scaling up electricity trade and investments in the regional power market.

## What is the data source for this study?

### The findings are based on household survey data

The data used in this study come from a household survey carried out by ESMAP in September 2015–January 2016. The survey covers 15 provinces and 3 regions (northern, central, and southern) of rural Lao PDR, as shown in table 1. Households were selected from villages both with and without grid electricity. Overall, 3,500 households (1,500 with grid electricity and 2,000 without) were sampled from 200 villages (100 with electricity and 100 without) in 33 districts. The data were collected by Sengsavang Co. Ltd.

Table 2 shows the degree of electrification in the sample by region, based on the collected data. The grid electrification rate in villages with electricity is 89–94 percent. The overall electrification rate varies quite a bit by region—it is highest in the central region (82.9 percent) and lowest in the northern (63.3 percent). Table 2 also shows the rate of adoption of off-grid sources of electricity. Overall, the grid electrification rate in the sample households is about 76 percent, and the use of off-grid sources of electricity is about 18 percent.

The data used in this study come from a recent household survey covering 15 provinces and 3 regions (northern, central, and southern) of rural Lao PDR. Overall, 3,500 households (1,500 with grid electricity and 2,000 without) were sampled from 200 villages (100 with electricity and 100 without) in 33 districts.

**Table 1.** Distribution of sample households by region and grid connectivity

| Province | No. of districts | No. of villages with grid | No. of villages without grid | In villages with grid | | In villages without grid | Total |
|---|---|---|---|---|---|---|---|
| | | | | HHs with grid | HHs without grid | HHs without grid | |
| **Northern region** | | | | | | | |
| Phongsaly | 3 | 10 | 10 | 150 | 50 | 150 | 350 |
| Luangnamtha | 1 | 5 | 5 | 75 | 25 | 75 | 175 |
| Oudomxay | 3 | 5 | 15 | 75 | 25 | 225 | 325 |
| Luangphabang | 4 | 10 | 15 | 150 | 50 | 225 | 425 |
| Houaphanh | 2 | 5 | 10 | 75 | 25 | 150 | 250 |
| Xaiyabouly | 2 | 10 | 0 | 150 | 50 | 0 | 200 |
| **Central region** | | | | | | | |
| Xiengkhouang | 1 | 5 | 5 | 75 | 25 | 75 | 175 |
| Vientiane | 1 | 5 | 0 | 75 | 25 | 0 | 100 |
| Bolikhamxay | 2 | 5 | 5 | 75 | 25 | 75 | 175 |
| Khammouan | 3 | 10 | 5 | 150 | 50 | 75 | 275 |
| Savannakheth | 3 | 10 | 10 | 150 | 50 | 150 | 350 |
| **Southern region** | | | | | | | |
| Salavan | 3 | 5 | 10 | 75 | 25 | 150 | 250 |
| Sekong | 2 | 0 | 10 | 0 | 0 | 150 | 150 |
| Champasak | 2 | 10 | 0 | 150 | 50 | 0 | 200 |
| Attapeu | 1 | 5 | 0 | 75 | 25 | 0 | 100 |
| **Total** | 33 | 100 | 100 | 1,500 | 500 | 1,500 | 3,500 |

*Source:* ESMAP household survey, 2015–16.

*Note:* HH = households.

**Table 2.** Electrification rate in sample households in rural Lao PDR

| Region | Villages with access to grid | | Villages without access to grid | All villages | |
|---|---|---|---|---|---|
| | Households with grid electricity (%) | Households with electricity from nongrid sources (%)† | Households with electricity from nongrid sources (%)† | Households with grid electricity (%) | Households with electricity from nongrid sources (%)† |
| Northern | 89.0 | 11.0 | 67.5 | 63.3 | 27.3 |
| Central | 93.8 | 5.3 | 66.7 | 82.9 | 12.5 |
| Southern | 94.3 | 5.6 | 81.0 | 80.6 | 16.5 |
| All regions | 92.6 | 7.0 | 70.0 | 75.9 | 18.4 |

*Source:* ESMAP household survey, 2015–16.

† Major nongrid sources are mini-grids, solar home systems, and rechargeable batteries.

Children in grid-connected households in Lao PDR study more in the evening—boys by 26–33 minutes and girls by 17–19 minutes—than those from nongrid households. School enrollment also improves: boys' by 4–9 percentage points and girls' by 3–4 points.

## What are the major findings?

### The findings point to widespread benefits of household electrification

We considered a range of outcomes of electrification, both at the household and individual levels, ranging from fossil fuel replacement to children's education. As figure 2 suggests, electrification benefits materialize at different times—some are immediate, others take longer. Our outcome findings are summarized below. For a discussion of how those outcomes were measured, see box 1.

**Reduction in fossil fuel consumption.** Better lighting is one benefit that materializes immediately. Electric lightbulbs soon replace the dim light of kerosene lamps, which are also responsible for indoor air pollution and greenhouse gas emissions in most developing countries. Lightbulbs are most likely the first appliances households acquire. Table 3 reports the reduction in kerosene consumption as a result of grid connection in rural Lao PDR. Households' kerosene consumption drops by 0.33 liter per month because of grid connectivity; the resulting cost savings are 63–68 percent.

**Children's education.** Brighter lighting allows children to study more in the evening. And children who study more are expected to have better school attendance and eventually to perform better than their counterparts from households without electricity. Table 4 shows that children in grid-connected households in Lao PDR do indeed study more in the evening—boys by 26–33 minutes and girls by 17–19 minutes—than those from nongrid households. School enrollment also improves: boys' by 4–9 percentage points and girls' by 3–4 percentage points. Another interesting finding is that children withdraw from household chores and family-run activities after grid electrification. These children probably trade family labor for study. The reduction in labor can be as much as 35 minutes per day for boys and 25 minutes per day for girls.

**Box 1.** Measuring the effects of electrification

In our estimation of the impact of grid electrification in Lao PDR, we used the propensity-score matching (PSM) technique.

The impact of an intervention (such as a grid connection) on outcome variables of interest (such as household income) is the measured change in the outcome that can be attributed to that intervention and to it alone. PSM is a common technique for estimating impact using cross-sectional data. Its use to estimate the effects of electrification in Lao PDR involved the following steps:

- First, grid households are compared with nongrid households. The comparison involves characteristics that are expected to influence household grid connectivity. Many characteristics at the household level (age, sex, and education of household head; amount of agricultural land; and condition of housing structure) and across the village (primary schools, secondary schools, paved roads, health centers, markets, banks, agriculture extension programs; incidence of shocks and natural disasters in preceding 12 months, such as droughts, floods, and crop and livestock diseases; and price of alternate fuels such as kerosene) are used in the comparison process to calculate what is called the *propensity score*, which is the probability of a household's grid connectivity. The propensity score is created for all households—both grid-connected and not.
- Only grid and nongrid households whose propensity scores are the same (called matched households) are retained; others are discarded.
- The difference in mean outcomes between the matched grid and nongrid households is computed. That difference expresses the impact of grid electrification.

There are different ways to implement PSM, each with its pros and cons. In this exercise, we use two methods: PSM using nearest neighbor matching (referred to simply as PSM in this Live Wire), and inverse probability weighted estimation (hereafter referred to as IPW). Unmatched households are dropped in the PSM analysis, shrinking the sample. IPW analysis creates a weight based on the propensity score and uses the weight in the estimation, without dropping any observations.

Household incomes grew 32–35 percent because of grid electrification in rural Lao PDR. The corresponding growth in spending for consumption and in the value of durable assets owned was 4–9 percent and 29–46 percent, respectively.

**Table 3.** Effect of electrification on the consumption of kerosene

| Outcome | PSM estimates | IPW estimates |
|---|---|---|
| Change in kerosene consumption (liters/month) | –0.33 | –0.34 |
| Change in expenditure on kerosene | –63.4% | –67.6% |

*Source:* ESMAP household survey, 2015–16.

*Note:* IPW = inverse probability weighted; PSM = propensity score matching. See box 1 for a discussion of the PSM and IPW estimates.

**Table 4.** Effect of electrification on children's outcomes

| Outcome | PSM estimates | IPW estimates |
|---|---|---|
| Change in study time in the evening (boys 5–18 years) (minutes) | 33 | 26 |
| Change in study time in the evening (girls 5–18 years) (minutes) | 19 | 17 |
| Change in current school enrollment (boys 5–18 years) | 9.3% | 4.3% |
| Change in current school enrollment (girls 5–18 years) | 2.6% | 4.0% |
| Change in time spent on household chores and income-generating activities (boys 5–18 years) (minutes) | –35 | –21 |
| Change in time spent on household chores and income-generating activities (girls 5–18 years) (minutes) | –18 | –25 |

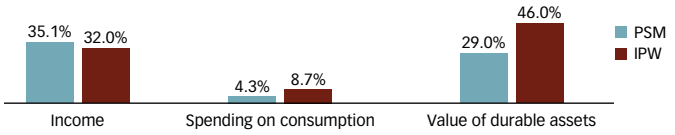
*Source:* ESMAP household survey, 2015–16.

*Note:* IPW = inverse probability weighted; PSM = propensity score matching. See box 1 for a discussion of the PSM and IPW estimates.

**Access to radio and television.** Time spent listening to the radio and watching television in grid-connected households is more than that in nongrid households, the primary reason being that access to electronic media using nongrid sources of electricity is much more expensive.[1] Thus members of grid-connected households have more access to entertainment, news, and information. Because of grid electrification, the time spent listening to the radio increases by about 12 minutes; watching television, by about 2 hours per day.

[1] Dry cell batteries are the main alternate source of electricity for radios, and rechargeable car batteries for televisions in nongrid households.

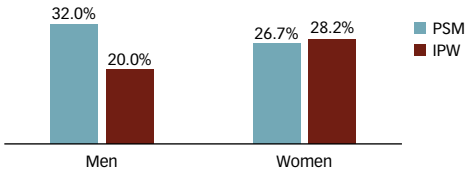
**Figure 3.** Effect of electrification on household income, spending, and assets (increase)




*Source:* ESMAP household survey, 2015–16.

*Note:* IPW = inverse probability weighted; PSM = propensity score matching. See box 1 for a discussion of the PSM and IPW estimates.

**Figure 4.** Effect of electrification on monthly work hours (increase)




*Source:* ESMAP household survey, 2015–16.

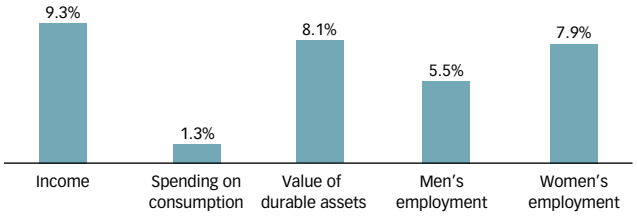
*Note:* IPW = inverse probability weighted; PSM = propensity score matching. See box 1 for a discussion of the PSM and IPW estimates.

**Economic outcomes.** Electricity boosts household incomes through multiple channels (see figure 2), and the cumulative benefits can be quite large over time. As household incomes grow, growth in consumption and assets follows suit. Figure 3 shows the benefits of electrification in terms of growth in income, expenditure, and ownership of durable assets. Household incomes grew 32–35 percent because of grid electrification in rural Lao PDR, and the corresponding growth in spending for consumption and in the value of durable assets owned was 4–9 percent and 29–46 percent, respectively.

**Employment.** Employment growth goes hand in hand with income growth. Figure 4 shows the effects of grid connection on employment: for men, the growth is substantial, at 20–32 percent; for women it is as much as 28 percent. Women spend more time at home than men and thus are more likely to be engaged in

Electrification has substantial environmental benefits, too. Electric lighting, by reducing the consumption of kerosene, lowers the emission of greenhouse gases.

**Figure 5.** Duration effects: Incremental benefits of an additional year of electricity




*Source:* ESMAP household survey, 2015–16.

home-based income-generating activities, which often grow after household electrification.[2]

**Does the duration of access matter?** The electrification impacts reported so far are the average benefits for all grid-connected households. However, benefits may vary by the duration of grid access—that is, early adopters may benefit more than late adopters. When households are connected to the grid, they first attempt to meet their lighting demand by replacing kerosene lamps or candles with electric lightbulbs. Over time, they diversify their electricity consumption by acquiring more appliances and perhaps electric tools and machinery if they are engaged in home-based activities. One could argue that the gradual procurement of appliances may yield incremental benefits for households.

Figure 5 shows that beneficial effects accumulate over time. For each additional year of connectivity, household incomes increase by 9.3 percent, spending on consumption by 1.3 percent, and the value of durable assets owned by 8.1 percent. As expected, the employment of household members also increases incrementally as households continue to be connected to the grid: the hours of employment of men and women increase by 5.5 percent and 7.9 percent, respectively, for each extra year of connectivity.

**Reduction of greenhouse gases.** Thus far, we have estimated the effects of grid access on household- and individual-level outcomes. However, electrification has substantial environmental benefits, too. Electric lighting, by reducing the consumption of kerosene, lowers the emission of greenhouse gases. When households connect to the grid for their own benefit they help lower global emissions of carbon dioxide ($CO_2$).[3]

**Table 5.** Reduction in $CO_2$ emissions due to grid connectivity in rural Lao PDR

| Elements of calculation | Value |
|---|---|
| A. Monthly reduction in kerosene consumption per household (liters) [from table 3] | 0.34 |
| B. Monthly reduction in $CO_2$ emissions per household (kg) [=A*2.5] | 0.85 |
| C. Yearly reduction in $CO_2$ emissions per household (kg) [=B*12] | 10.2 |
| D. Number of grid households in rural areas | 597,609† |
| E. Yearly reduction in $CO_2$ emissions for grid adoption in rural areas (kg) [=C*D] | 6,095,612 |
| F. Yearly reduction in $CO_2$ emissions for grid adoption in rural areas (ton) [=E/1,000] | 6,096 |

*Source:* World Bank/ESMAP Solar Home System Survey, 2015–16.

† National Statistics 2015. $CO_2$ = carbon dioxide.

Based on the reduction in kerosene consumption reported in table 3, a reduction of about 6.1 thousand tons of $CO_2$ emissions per year can be attributed to existing levels of grid connectivity (table 5). Since about 76 percent of rural households in Lao PDR were connected to the grid and 18 percent to off-grid sources at the time of the survey, the total possible reduction of $CO_2$ emissions due to electrification, including those not connected yet to any electricity source, is about 8,000 tons per year.

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[2] While not reported, our findings also show that women in grid-connected households spend more time in income-generating activities than their counterparts in nongrid households.

[3] Other greenhouse gases are also emitted by burning kerosene, but $CO_2$ is considered the largest contributor to global warming.

## MAKE FURTHER CONNECTIONS

Live Wire 2014/20. "Scaling Up Access to Electricity: The Case of Lighting Africa," by Daniel Murphy and Arsh Sharma.

Live Wire 2014/21. "Scaling Up Access to Electricity: The Case of Bangladesh," by Zubair Sadeque, Dana Rysankova, Raihan Elahi, and Ruchi Soni.

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