# Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa

Tanguy Bernard

*The author reviews trends in rural electrification over the past 30 years in Sub-Saharan Africa. In particular, it is shown that motivations for rural electrification programs have evolved significantly over the years, following changes in development paradigms. The author finds, however, that knowledge of the impact of this has only marginally improved: low connection rates and weak productive utilization identified in the 1980s remain true today, and impacts on such dimensions as health, education, or income, though often used to justify projects, are largely undocumented. Indeed impact evaluations are methodologically challenging in the field of infrastructures and have been limited thus far. Nevertheless examples of recent or ongoing impact evaluations of rural electrification programs offer promising avenues for identifying both the effect of electricity per se and the relative effectiveness of approaches to promoting it.* JEL codes: N77, O18, O20



The last few years have witnessed a renewed interest in infrastructure development in Sub-Saharan Africa. Following years of macroeconomic structural adjustment programs, it is now estimated that the continent's low infrastructure development is responsible for a 2 percent shortfall in economic growth per country. Particularly important are the growing concerns with the continent's low power generation and distribution capacities. In its latest report on infrastructure development in the region, the World Bank (2009) calls for $930 billion to be invested over 10 years in the continent's infrastructure, of which nearly half should be dedicated to the power sector. In fact, despite similar levels in the 1980s, Sub-Saharan Africa's electricity generation capacity per inhabitant is now one-tenth of that in South and East Asia, and electricity coverage is only 40 percent. Within the power sector, rural electrification (RE) remains particularly

The World Bank Research Observer

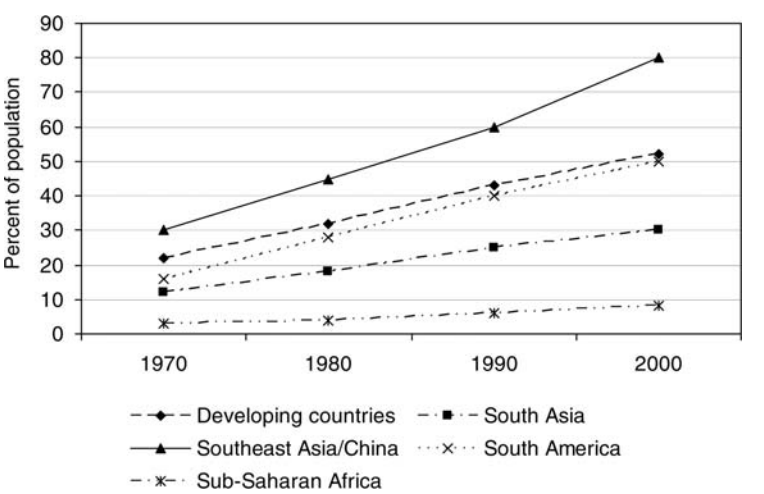
doi:10.1093/wbro/lkq008 Advance Access publication September 1, 2010 27:33–51

low in Sub-Saharan Africa where electrification rates have stagnated over the past 30 years at less than 10 percent, while they reached 50 percent for developing countries as a whole (figure 1). Overall, and despite the important energetic potential of the continent, there are about 226 million Africans living in rural areas without access to electricity.

Thus the World Bank (2009) recommends that 25 percent of investments in the energy sector (about $10 billion per year) be allocated to produce and distribute electricity into rural areas. And while far off the stated objective, African governments and several international donors—including the World Bank, the United Nations Development Program, the African Development Bank, and the European Union, along with many bilateral aid agencies—have increased their focus toward promoting RE.

The support of donors and public sectors to RE rests on three complementary sets of justifications. First, RE is believed to help alleviate poverty. In the short and medium run, local economic growth enabled by access to a reliable source of power can directly and indirectly benefit the poor through higher productivity and enhanced employment opportunities. Further, human capital development (in terms of health and education) facilitated by electricity can help lift constraints to the poor's economic and social well-being. In the longer run, RE can reduce environmental pressures, thereby facilitating the environmental sustainability of the local development process. Overall, while rural electrification is not an explicit target of the Millennium Development Goals (MDGs), many believe that it is a

**Figure 1.** Access to Electricity in Rural Areas of Developing Countries




*Source*: Hannyika (2006).

necessary condition to their attainment in rural areas (including Jeffrey Sachs, director of the MDG project).

Second, the involvement of donors and public sectors in promoting RE is justified by the typically low private sector engagement in the domain—despite potential rents from natural monopoly situations. In fact one major obstacle to RE programs relates to their important costs and limited returns in the short and medium run—in contrast with cellphone development for instance. Indeed investments for grid extension and off-grid schemes to reach remote and scattered communities are often substantial,[1] and the (initially) low electric consumption level of rural populations, along with tariff policies meant to equalize the price of a kilowatt-hour between rural and urban areas (for a given level of service), imply limited returns. Overall if successful electrification programs are often those that have managed to keep costs low and recover part of the investment, it remains that RE usually requires substantial subsidies.[2]

Lastly, RE development, as for most public infrastructure, responds to political incentives for governments. Apart from its potential effects on local growth and poverty reduction, electricity is usually perceived as the key to the modern world. Without it, people and communities are being deprived of many services often considered as basic in rich countries,[3] and governments consider it their duty to promote RE as a means to enhance economic and social cohesion across the territory. It is notable that RE in today's rich countries was often based on temporary political will rather than actual assessment of its socioeconomic returns.[4]

Yet, and despite decades of investments in the sector, little is known about the effective impact of RE on households' well-being (Barnes and Halpern 2000), and most project documents base their expected impact assessments on a priori beliefs. The important level of government and donor subsidies for RE at a time of limited resources and competing investment needs therefore calls for deeper investigations.[5] This is particularly the case in Sub-Saharan Africa where, absent of robust evidence, the dependence of public investment on international aid makes these vulnerable to paradigm shifts that have characterized the past decades. In fact most of what is known today was known sometime ago, particularly in terms of low connection rates and weak productive use of rural electricity. Further, actual impacts of RE on their beneficiaries remain largely unknown due to attribution difficulties, although recent studies provide promising examples of robust evaluations.

## Unstable Support to RE in Sub-Saharan Africa

Over the past 30 years, one can distinguish three phases with respect to RE policies.

### *Period 1: Infrastructures for Development*

Until the early 1980s, under-development was primarily understood as a lack of equipment to support growth, and investments in infrastructures were given a central role in development policies. In rural areas in particular, growth enhancing investments were in part meant to limit migrations to already saturated urban centers. In this context, RE was considered an important part of the solution. By bringing in modernity and a reliable source of energy to support economic activities (agriculture and nonagriculture), it was expected that RE would contribute to limiting rural to urban migration. It was also hoped that households would switch away from fuel woods and thus limit the related deforestation for which forecasts were then catastrophic (Arnold and others 2006). Finally, RE was meant to contribute to long term growth via its effects on human capital development, thereby contributing to enhancing productivity and future revenues (Tendler 1979).[6]

With these predicted benefits, and despite the lack of data to support them, RE programs in the period were given strong support. In addition, if initial investments were high, marginal costs were believed to decrease rapidly as connection and consumption rates increased. Electricity being a synonym for modernity, its "political returns" were also deemed significant.[7]

### *Period 2: Structural Adjustments*

In the 1980s and the early 1990s, infrastructure programs were no longer considered the first priority in Sub-Saharan Africa. Not only did infrastructure development in the previous period contribute to the unsustainable debt burden of most countries, but they did not generate the expected growth in return. The crisis of the 1980s and the structural adjustment plans that followed led to a reassessment of the relative impact of these programs.

This concerned particularly the RE programs, given their high costs[8] and disappointing results—in the rare cases where these were effectively assessed (Rambaud-Measson 1990). Particularly disappointing were the observed low connection rates, despite improved access, and the rare productive use of the electricity provided (De Gromard 1992). In fact one observed that only 25 to 50 percent of households in electrified villages were connected; and for those who were connected, electrical consumption was mostly related to house illumination and radios or televisions. Environmental benefits were also deemed limited, as the impact of wood fuels on deforestation was much lower than initially thought (apart from peri-urban areas), and connected households did not reduce their use of wood as a result of having electricity—in particular for activities such as cooking and heating. Further, benefits in terms of health and education remained

largely unknown, and rural to urban migration did not seem to decrease in villages with electricity. Finally, it was observed that RE concerned essentially wealthier households, for whom the large subsidies involved in RE programs were not justified.[9]

Overall the favorable cost–benefit analyses performed in the previous period appeared overrated, in particular on the side of benefits that remained limited or unknown (Pearce and Webb 1987).[10] At the same time the underlying rationale for RE itself was questioned, with several macro- and microstudies arguing that it is the growth of income that creates the demand for electricity and not the opposite (Foley 1992). At the least RE could thus contribute to an accelerating of growth, but did not constitute a necessary condition to its start (Pearce and Webb 1987).[11]

RE programs were thus judged rather negatively over the period: as noted in a report by the International Labor Organization (Fluitman 1983), "A major impression one retains from a review of the pertinent literature and statistics is that the benefits of rural electrification, including the social benefits, tend to be over-estimated and the costs under-stated. Multi-million dollar schemes, it appears, are repeatedly based on conventional wisdom fuelled by extraneous motives rather than arithmetic. The role of subsidies is therefore debatable, particularly in countries yet unable to satisfy needs more basic than electricity. In our view, the time may have come to substitute the benefit of hindsight for the benefit of the doubt."[12]

### *Period 3: Poverty Reduction*

The late 1990s saw an increased focus of development policies toward fighting poverty in its various dimensions. And with the adoption of the MDGs in 2000, the importance of energy as a necessary condition is now underlined—to fight poverty, enhance health and education, support women empowerment, prevent degradation of natural resources, etc. (see for example DfID 2002; IEA 2002). For Jeffrey Sachs, "Without increased investment in the energy sector, the MDGs will not be achieved in the poorest countries" (Modi and others 2005). As a result, many RE project documents now use the MDGs as their main justification, although with little data to support these claims (World Bank 2008a), and a number of international initiatives have emerged, seeking to catalyze funding for the sector.[13]

To avoid failures observed since the 1980s in terms of low connection rates and limited productive use, options are also considered to promote services without which energy access will not lead to significant progress. Accordingly electrification must be thought as an input among others in integrated projects involving access to productive equipment (via grants, loans, or credit-bail) or

training on the usage of electricity (Peters, Harsdorff, and Ziegler 2009). In addition the problem of low connection rates, particularly among the poor, implies reconsidering the use of targeted subsidies, prepaid meters, or other technologies lowering barriers to connection.[14]

Following the Paris declaration on aid effectiveness, the past few years have also witnessed a growing number of impact studies meant to measure and compare the effects of projects on their beneficiaries, according to different intervention modalities. Such studies are relatively widespread in the field of public health and education, but remain rare in the field of infrastructure in general and quasi-inexistent for rural electrification in particular. The recent increase of RE programs offers the possibility to measure their impact on targeted populations and to study the conditions under which these can eventually be enhanced. In turn these studies may contribute to limiting the type of policy changes described above that can be particularly pervasive in the field of infrastructure, often leading to uncompleted projects and lack of maintenance (Estache and Fay 2007).

## Low Connection Rates

Just as in the 1980s, connection rates by rural African households to electricity, where the provision exists, remain low today. Within grid-electrified villages, studies have for instance documented connection rates of 12 percent in Botswana (Ketlogetswe, Mothudi, and Mothibi 2007), 39 percent in Ethiopia (Bernard and Torero 2009), and 30 percent in Senegal (ESMAP 2007). With off-grid technologies, Jacobson (2007) finds similarly low pick-up rates in Kenya, where 5 percent of households with access to solar kits did purchase one. Without surprise, low connection rates are particularly prevalent among poorer households. For instance Heltberg (2003) shows that less than 5 percent of the households in the lowest income quintile in Ghana and South Africa have access to electricity, while it reaches 25 and 50 percent for the highest quintile. And while such trends also exist in urban areas, connection rates in cities are nevertheless much higher. These low connection rates are not only disappointing from the standpoint of bringing reliable energy to deprived populations, they also pose the problem in terms of cost recovery by significantly raising the average connection costs, further challenging future RE initiatives.

Connection costs are an important part of the explanation. In fact, despite important levels of subsidies, rural households are usually responsible for 10 to 20 percent of the overall cost of connection, which usually amounts to $50 to $250. In Sub-Saharan African countries where a large part of the population lives below $2 a day, these prices naturally tend to exclude the poorer ones. In

order to raise the number of connections, most programs use subsidies, and the past few years have led to a better understanding of the means to enhance their targeting efficiency.[15] However, little if any studies have robustly tested for the effects of subsidy levels on the electricity demand for various social groups. Instead levels are usually based upon a priori estimations of demand levels and an overall amount of subsidies to be allocated.

Even with subsidies specifically dedicated, connection rates remain low, suggesting that price policies may not fully explain the observed levels.[16] In fact low connection rates contrast with the elevated budget shares that households dedicate to their energy consumption, reaching 4 percent of total expenditure by the poorest rural households in Ghana, 7 percent in South Africa, 15 percent in Uganda, and 10 percent in Ethiopia.[17] In an in-depth study by ESMAP (2003) in the Philippines, the authors estimate the total demand for lumens via the budgets allocated to lighting by kerosene, and find very high levels of corresponding willingness to pay.

One explanation may lie in households' low perception of the benefits of electricity. Although most studies find an important demand for electricity, households mainly perceive it as a luxury good rather than a so-called productive investment—actually, Peters, Hardorff, and Ziegler (2009) remind us how industrialized countries have extensively relied on promotional campaigns to explain the potential benefits of electricity in rural areas. In fact in rural areas the lack of demonstration effect, whereby households can learn from others' experiences with electricity use, may further contribute to this perception (Ranganathan 1993). In such a case a critical mass of connected households is necessary to generate a more generalized connection behavior in the communities.[18] Another explanation may relate to the fear of poor households of a weakly understood billing system. In fact it is often the case that connected households consume much less electricity than their flat social rate allows them to (Peters, Hardorff, and Ziegler 2009).

Overall, depending on the hypothesis retained, interventions to enhance connection rates may take very different shapes. They may for instance consist in providing very high subsidies or limit the validity of the subsidy through time in order to generate rapidly the needed critical mass of customers. They may otherwise focus on information campaigns to provide the necessary information on various usages. They could also rely on prepaid meters to overcome fears of weakly understood payment schemes (as is the case with cellphones for instance). The relative performance of these approaches (and eventually their complementarities) must be assessed through reliable comparisons. In Ethiopia for instance, a study by Bernard and Torero (2009) compares connection rates for various levels of subsidies allocated on a lottery basis, allowing an assessment of the impact of subsidies on connection rates among various social groups. In Benin, a study measuring the importance of information on household connections is being

prepared by Leonard Wantchekon. The same study will also assess the effect of prepaid meters and participatory designs of local ground plans.[19]

## Limited Productive Use

As with low connection rates, the low productive use of electricity remains true today as it was in the 1980s. Use of electricity in rural areas is still mainly dedicated to illumination and radio or television, and the rare utilization for agriculture, handicraft, and services are far below the important growth catalyzing effect expected. In a recent study in Kenya for instance, Arne Jacobson (2007) shows that the only "economic" use of off-grid electrical energy is linked to the pursuit at night of certain activities such as accounting and paperwork in small businesses or the preparation of lectures by teachers. Similar observations are also found in villages with access to the centralized grid system (see for instance the ESMAP 2007 study in Senegal). This further limits the argument of RE as an important means for fighting poverty. It also jeopardizes the program's sustainability given the limited use (and hence low profitability) of electric lines.[20]

Use of electricity for domestic activities is also limited. The energy ladder hypothesis, according to which households would rapidly switch to more efficient and clean fuels as these become available and their income increases, has not been verified. In reality most observations suggest that households only *complement* their energy portfolio with electricity, but do not decrease their previous use of fuel for particular usages. For instance Madubansi and Shackleton (2007) find that over an 11-year period after village electrification, fuel wood consumption had not changed in five South African villages, and Hiemstra-van der Horst and Hovorka (2008) report similar results in Botswana.[21] They suggest that this may be due to price and habits-related reasons—such as taste of food—and that providing access to alternative energies will not be sufficient to promote their intensive use.

Overall, electrical energy is mainly used for illumination as well as for *connecting* rural areas with their urban counterparts (via radio, television, and cellphones). One explanation for this apparent suboptimal use is the lack of economic opportunities. In this case RE may need to be allocated in priority to more economically dynamic areas (Foley 1992). Another related explanation is that electricity cannot alone kick-start local growth and that RE needs to be designed as part of integrated development plans (for instance along with other infrastructures), which was also pointed out in the 1980s. A third explanation links to the lack of access to finance to purchase the necessary productive equipment.

To account for these, several RE programs comprise additional features such as access to credit or direct provision of productive equipment such as mills and

threshers (for example the so called Multifunctional Platforms). At the household level, other approaches propose to sell "electricity services" instead of electricity per se, through the lease of electrical equipment (low voltage refrigerators, compact fluorescent lamps, mills, etc.) as part of their connection plan. The ESMAP (2007) study in Senegal lists a number of potential interventions for the use of electricity to raise agricultural productivity. Overall, while solutions may exist, the weak levels of usage still observed today suggest that these are not systematically exploited. One of the reasons may be the lack of credible evidence with respect to their efficacy. Studies such as experimental ones can help to test alternative approaches (or various levels of a given approach) one against another, at a pilot level.

## Largely Unknown Impacts

While funding for RE programs often rests on their supposed impacts on such outcomes as health, education, or poverty level, there is still very little empirical evidence to substantiate them. For instance, in an extensive literature review, Brenneman (2002) finds a number of contradictory results across studies, partly due to the lack of robust comparisons of populations with and without electricity. Similarly Sebitosi and Pillay (2007) observe that of two reports assessing the impact of the same RE program, one reported the outcome as being "near total success" and the other as "near total failure." Overall one observes little effort to measure the impact of RE (Briceño and Klytchnikova 2006; Estache and Fay 2007; World Bank 2008b). This in turn may have contributed to the inconstant support to the sector over time.

Several difficulties explain this lack of evidence, most of which are common to infrastructure programs in general. First, energy mostly acts as an enabler of development, potentially affecting a large array of outcomes (economic, social, environmental, etc.). In the absence of clearly stated objectives, aggregating all potential benefits toward computation of cost–benefit ratios may be perilous. Second, RE programs affect final outcomes—such as poverty—through long causal chains where the outcome depends heavily on the interaction of other external factors. As a result, impact results from a particular study may lack the type of external validity necessary to inform other potential programs in the field. Third, the progressive realization of RE impacts raises the issue of the appropriate timing for their measure. All three difficulties may be partially overcome by assessing the impact of RE on clearly stated objectives that are to be fulfilled in the relatively short run through rather simple causal chains. Alternatively intermediate indicators of impact that are likely affected in the short run (such as changes in time allocated to reading at night), and assumed to be related to the final outcome in the longer run (such as school performance), may be used.[22]

Lastly, the impact assessment of RE poses a number of attribution problems. That is, the ensuring that observed changes in final outcomes are in effect due to RE and nothing else. In other words, simple "before and after" comparisons will fall short of separating correlation from actual causality running from the provision of electricity to changes in the outcome. In fact, if RE impacts were large and rapid enough, a plausibility judgment could be made to attribute effectively those observed changes to the newly provided electricity. However, with electricity mostly acting as an enabler of changes, the latter may be more diffuse and lengthy to occur, such that judgment calls may wrongly conclude that there are limited impacts. On the contrary, longer term impact assessments based on before and after comparisons are prone to confuse changes in outcomes that result from electrification and changes that are due to all sorts of other changes that naturally occur in a household's environment. Commonly cited examples of successes of RE on poverty levels, such as those in India, Peru, or the Philippines, typically fail to account for such other sources of change in households' income over the period studied.

Further, comparisons of units "with" and units "without" electricity raise the problem of differences in initial conditions, such that impact measures may in part capture these initial differences and not just the effect of electrification. At the village level, it is often the case that electricity is installed in priority, in richer villages where potential gains from it are higher, leading to the so-called "placement bias."[23] At the household level, connection fees being often substantial, better-off households are usually the first to be connected—a regularity observed in most of the literature reviewed here—leading to the so-called "self-selection bias." Failing to account for these differences typically leads to an overestimating of the impact of electrification. One such example is given by Barkat and others (2002) in their study of RE in Bangladesh, who conclude that there is a large impact of RE, based on the finding that average annual income of households in villages with electricity is 64.5 percent higher than that of households in nonelectrified villages, and that within electrified villages connected households have an income 126 percent higher than nonconnected ones. It is, however, likely that households in electrified villages were initially wealthier than their nonelectrified counterparts, such that the observed differences are only partly explained by electrification per se.[24]

Overall, benefits attributed to RE programs rest largely undocumented for lack of impact evaluations. And absent of robust evidence, the current support to the sector may weaken with upcoming changes in development paradigms. Thus the club of Agencies and National Structures in Charge of Rural Electrification in Sub-Saharan Africa notes: "The issue of impact evaluations on development outcomes is central for rural electrification projects, in that the expected indirect effects on income, health, education, agriculture etc. are difficult to measure, and

often more important and more fundamental than the direct effects of electrification. The situation of the sector is all the more difficult that the observed effects are often disappointing: low penetration rates, access rates biased against the poorer categories of the population, weak spillovers on rural economic growth etc. Several analyses have indeed shown that RE is often limited to domestic consumption" (www.club-er.org).

## Recent and Upcoming Impact Evaluation Studies

Over the past decade, robust impact evaluation studies based on the comparison of so-called "treatment" and "control" groups have rapidly developed in the fields of health, education, and other development interventions, based on various empirical methodologies (see for example Ravallion 2005, for a review). Yet, despite the important resources allocated and the need for evidence, such studies have rarely been designed to measure the impact of RE. Nevertheless, recent studies have attempted to do so, some of which are described below.

### *Instrumental Variable Estimate*

Since the end of the apartheid regime when two-thirds of the population had no access to electricity, South Africa has engaged in an ambitious Universal Electrification Plan (UEP). Between 1993 and 2001, two million households have thus gained access to electricity throughout the country. In her study of the impact of RE, Taryn Dinkelman (2008) uses the roll-out of the UEP to compare labor market outcomes in rural communities that had received access to electricity before 2001, to those that were yet to be covered. Her argument is that time saved from fuel collection and other chores that can be better provided with electricity can be utilized toward other income generating activities.

The author uses two waves of census data covering rural KwaZulu-Natal, the first wave occurring before electricity was brought to those communities targeted by the UEP. Importantly, however, communities to be electrified early were not randomly chosen, but often politically motivated toward poorer areas. In other words, electrified villages started from a "lower" level than nonelectrified ones, such that simple comparison would tend to underestimate the effect of RE.

To account for these placement biases, Dinkelman relies on a quasi-experimental method, using a community's land gradient as a predictor of electrification—land gradient significantly affecting costs of line construction. Assuming that gradient is not directly related to the employment rate among women, it allows the author to correct her impact estimates from the initial placement biases. She finds that the share of households using electric lighting rises by 23 percent and the share of

those cooking with wood falls by 4 percent within five years, in electrified communities. Further, her results show that thanks to electrification women are 13 percent more likely to participate in the local labor market.

### *Difference-in-difference Estimators on Matched Samples*

In 1997, the recently created Electricity of Vietnam switched its RE focus from agriculture and small-scale industries to providing reliable power to households. From a pre-reform level of 50 percent, connection rates of rural households consequently jumped to 77 percent by 2001 and to 90 percent by 2009.

To document how electricity affected rural lives, Khander and others (2009) rely on surveys collected in 2001 and 2005 in 42 communes electrified over the period. A random sample of 30 households was drawn from each of the communes, among which a significant subset of households had not yet been connected to the grid by 2005. To account for the fact that factors determining households' decisions to connect may well be linked to outcomes of interest, they use difference-in-difference estimators to compare *evolution* of outcomes between so-called "treated" and "control" households. Fixed effects are used to account for community-level and household-level characteristics that could be related to both the decision to connect and to the outcome of electrification, thereby biasing the results (likely upward). Further, to account for eventual different outcome growth trajectories between treatment and control groups, they apply their fixed-effect, difference-in-difference estimator on previously matched samples of treatment and control observations using propensity score matching techniques.

Overall they find that electricity led to an increase in farm income, but not in other sources of income. They attribute this (surprising) result to the use of electric pumps for irrigation, although they cannot directly test for it. They also find improvement in school enrollment for both boys and girls of more than 10 percent. Finally, using triple difference (differences of the previous double-difference estimates, between early connecting and later connecting households), they find that returns are higher for early connectors than for later ones in terms of income, although no such effect is found on schooling outcomes.

### *Randomized Household-level Encouragement*

Starting in 2005, Ethiopia's Universal Electricity Access Program has set out to electrify most rural towns and villages, with a budget of close to a billion dollars for its first five years. In a country where RE rates are close to 1 percent, it is expected that increased access to a reliable source of power will improve households' welfare by improving conditions for education, creating scope for new

income-generating activities, expanding communications and access to information, and other such channels.

Within each selected town or village, households are responsible for paying the costs of connecting their house to the main line, which typically amounts to between $50 and $100. In a country where 80 percent of the population lives on less than two dollars a day, these costs are likely to be prohibitive for a large number of households, limiting the expected impact of RE on growth. To facilitate the connection of poorer households, Ethiopia's power utility has traditionally proposed low interest loans to its clients, thereby smoothing connection costs over three to five years. It appears, however, that take-up of such loans is quite limited, particularly among the poorest households, which are reluctant to engage in long-term financial commitments.

In their study, Bernard and Torero (2009) set out to test the relative efficiency of connection subsidies for various levels of household income. In fact, so-called "smart subsidies" have often been advocated in rural electrification projects, but they have rarely been implemented and—to our knowledge—have never been tested. The study relies on the random allocation of vouchers covering 10 to 20 percent of a household's connection cost, in 10 village communities electrified over the year 2008. A baseline survey conducted before electrification, and a comparison survey conducted a year later, enables comparison of household connection rates over time, between voucher recipients and nonrecipients. The random nature of the voucher distribution further allows their use as instrumental variables for household connection decisions, enabling the identification of the electrification's impact on such outcomes as men, women, and students' time allocation.

### *Randomized Phasing-in Across Communities*

With 2 percent of the population having access to electricity in 2007, RE remains dramatically low in Kenya. Further, and as elsewhere on the continent, high costs of grid extension only allow for small incremental increases in household connection rates. In response, various off-grid solutions have emerged over recent years, based on Kenya's natural endowment with sun and water courses. In their ongoing study, Chemin and De Laat (2010) study the impact of one such scheme in the district of Kirinyaga, where Green Power, a Kenya-based NGO, has engaged in promoting access to electrical power to 1,600 households.

The project involves microhydraulic schemes to harness power from the various streams in the Mount Kenya region, from which the electricity is then transmitted to 20 separated microgrids covering each of 80 households. The impact evaluation of electricity is based on household surveys of the 1,600 households set to be connected gradually over the coming four years, along with 600

neighbors. A baseline survey was implemented in late 2007, to be compared with a follow-up survey in 2010. Questionnaires cover diverse aspects of poverty, activities, and time allocation, which are likely to be affected by access to the new energy source.

Impact of electrification will be measured by comparing households from those minigrids that were connected early on to those where power will only come later. In order to account for potential placement biases, Green Power randomly chose which of the 20 minigrids were to be connected first. To further ensure that households within the first 10 minigrids to be electrified were sufficiently similar ex ante to those in the following 10 minigrids, a paired matching was conducted based on observable characteristics collected at the baseline. Accordingly one element of each pair will access electricity early, while the other one will only access it later on. Differences within pairs measured in 2010 will therefore provide reliable estimates of the short-term impact of electricity on households in the community. Lastly Chemin and De Laat have randomized access to a microcredit program across households with and without access to electricity. The purpose is to test the eventual presence of credit constraints, limiting the realization of electricity's impact on household income.

## Conclusion

No one doubts that RE positively affects household well-being. In addition, if RE is not necessarily a sufficient condition to long-term development of rural areas, it is probably a necessary one. Yet the interest for such projects—by nature intensive in resources—has considerably varied over the past 30 years, when RE went from being among the priorities to being considered as expensive and of limited effectiveness. While changes of paradigms in the development community led to these changes, the lack of reliable measures of RE impacts may have also contributed to it.

Measures of success are most often based on intermediary indicators of connection rates and utilization of electric energy. Yet both remain very limited in electrified villages in Sub-Saharan Africa, particularly among the poor. While innovative approaches and complementary interventions are regularly tried, one finds a severe lack of robust studies which compare their performance and bring to light the reasons for failures.

Measures of final impact are mostly nonexistent. While numerous public health and education programs have been the object of robust impact evaluations over the past few years, there are comparatively little studies to assess the role of infrastructure in general and RE in particular on various dimensions of poverty. This is in part due to the specific difficulties of this type of study. Nevertheless a

pragmatic approach of impact measures should allow for the test and measure of the effect of RE programs on their beneficiaries (which are the final impacts), as well the most appropriate means to promote it (how to increase connection rates and the utilization of electrical energy). Similar efforts should be applied to other infrastructure sectors to assess their relative and eventually combined effects.

## Notes

Tanguy Bernard is with the Research Department of the Agence Française de Développement; email address: bernardt@afd.fr. I am grateful to Jocelyne Delarue, Jean-David Naudet, and Maximo Torero for helpful comments. The opinions expressed here are the author's alone and do not implicate the Agence Française de Développement.

1. Total costs to connect a rural household usually vary between $1,000 and $2,000, of which 10 to 20 percent are covered by the household itself.

2. See for instance Barnes (2007) for a historical description of RE programs in Costa Rica, the Philippines, Bangladesh, Thailand, Mexico, Tunisia, Chile, China, the United States, and Ireland.

3. For instance in a recent study by UNICEF in Nigeria, rural households ranked electricity as their second priority after safe water, but before health centers, roads, education, and fertilizers (ESMAP 2005).

4. In the United States for instance, RE essentially developed as part of Roosevelt's New Deal in the 1930s.

5. For sake of brevity, issues regarding the financial sustainability of RE programs are not discussed here, despite their obvious importance.

6. For instance the third Zambian National Development Plan (1978–83) noted: "The direct and indirect benefits of a rural electrification program can be summed up as increasing agricultural production, promoting rural industries, effecting improvements in the fields of health, education, training and the standard of living in general and generating employment opportunities which will reduce migration from the countryside to towns" (Fluitman 1983).

7. At the same time, the 1973 and the 1979–80 oil shocks helped promote investments in solar, microhydraulic, and wind energy, particularly fit for rural areas. This was notably the case for many African countries relying essentially on thermal power stations for which fuels were mostly imported. In fact at the time 70 percent of hydraulic power was then localized in only four countries (Zaïre, Cameroon, Angola, and Tanzania), 70 percent of fossil oil resources were in Nigeria, and 95 percent of coal reserves were in South Africa and Zimbabwe.

8. At the time, RE could represent 10 to 20 percent of public investments in the energy sector, itself representing 25 percent of the total public investment budget (De Gromard 1992).

9. In addition, the collapse of the oil prices weakened the interest for new energy sources, further contributing to the decline of RE programs.

10. For instance the World Bank (1994) ranked energy projects among those infrastructures with the lowest economic returns between 1974 and 1992 (economic rates of return then reached 12 percent for energy, 17 percent for irrigation, 20 percent for telecommunications, 21 percent for transport, and 23 percent for urban development).

11. The debate continues today. For instance, in a recent study, Yemane Wolde-Rufael (2006) uses time series on 17 African countries and tests for a causal relationship between electric consumption and GDP. Results indicate a causality in only 12 countries: running from GDP to electric consumption in six, from electric consumption to GDP in three, and a two-way relationship in three others.

12. If RE programs were not totally abandoned, their modalities were reassessed, involving in the early 1990s the entry of private entities to enhance management and services through

competition between power providers. However, if they have sometimes been associated with improved connection rates and services in urban areas, rural zones have mostly remained underserved due to their low profitability (Hanniyika 2006).

13. For instance: the European Union Energy Initiative aims to raise awareness and funding for energy projects in Africa; the World Bank's Lighting Africa initiative supports innovative solutions for energy on the continent; and the AfricaConnect initiative attempted to declare 2010 the year of electrification in Africa.

14. At the same time, to cope with the private sector's failure in providing energy to rural areas in the previous period, new government agencies are now being set up with the objective of promoting RE through better incentives for private sector, through their direct intervention into the financing of projects, or both. For a review of the reforms and the creation of rural electrification agencies in Africa, see Mostert (2008).

15. For a long time subsidies took the shape of lower consumption tariffs. Without targeting mechanisms, however, the largest amount of subsidies were received by the largest consumers—not necessarily the ones for whom the subsidy was designed in the first place. For similar reasons, supply-oriented subsidies often failed to reach the poor. Connection subsidies can, in theory, partially overcome these issues. However, smart subsidies targeted at the most needy households are rarely used (see Barnes and Halpern 2000 and Barnes 2000 for historical descriptions of the evolution of these subsidies).

16. For instance the connection rates observed in Botswana by Ketlogestwe, Mothudi, and Mothibi (2007) are low despite a payment system whereby households only cover 10 percent of the fees at the time of connection, and the 90 percent remaining over a period of 10 years.

17. Note that these costs are probably undervalued as they do not account for opportunity costs linked to the time dedicated to fuel collection or the nonutilization of productive equipment.

18. For instance there are numerous examples of electrified villages where no connection was observed. Even in India where the 1970s' electrification programs were linked to a nearly 100 percent consumption subsidy for electric irrigation, one still found villages without any households connected.

19. On this last point, the study is meant to compare the impact of a participatory approach, on the choice of the line trajectories within the villages, to a more conventional approach where ground plans are defined by external engineers. Participatory planning is a hotly debated issue in other domains of development interventions (such as irrigation or school management). Some argue that local participation leads to better suited and hence more efficient and more sustainable designs. Others oppose that local participation often leads to elite capture and lower performance. The net effect is therefore ambiguous and necessitates empirical answers based on comparisons of *similar* villages with participatory planning to others with more top-down approaches, but where electrification occurs at the same time.

20. Note, however, that RE in northern countries did not lead to instantaneous productive use of it. Rather electricity was long used only to power telegraph, then lights, then radios.

21. In Ethiopia a study actually finds a positive elasticity of fuel wood consumption with respect to income where electricity access is available.

22. One of the mechanisms through which RE is meant to impact on households' revenues is through the relaxing of their time constraint. Time is saved from certain activities (collection of fuel wood or water, time necessary to purchase kerosene or diesel, etc.). Time is gained for certain activities such as the capacity to read at night. Time is reallocated between various part of the day (for instance cooking can be done at night, offering scope for other activities during the day). Theoretically these effects can be most important for children and women (IEA 2002; Barnes 2007). However, they are rarely measured effectively.

23. In fact, as early as 1975, the World Bank established a list of four criteria to select the location of RE projects: (i) good quality of infrastructure; (ii) growth in local incomes; (iii) presence of other development programs in the locality; and (iv) proximity to the national grid.

24. Similarly an on-going study in Benin shows that children from electrified households perform better in school than their nonelectrified peers. It is, however, likely that children from connected households were also more wealthy to start with, which may have influenced their academic performance independently of their access to better lighting (through better nutrition or easier access to books, for instance).

## References


The word *processed* describes informally reproduced works that may not be commonly available through libraries.

Arnold, M., G. Köhlin, R. Persson, and G. Shepherd 2006. "Woodfuels, Livelihood and Policy Interventions: Changing perspectives." *World Development* 34(3): 596–611.

Barkat, A., S.H. Khan, M. Rahman, S. Zaman, A. Poddar, S. Halim, N.N. Ratna, M. Majid, A.K.M. Maksud, and A. Karim, and S. Islam. 2002. *Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh*. Human Development Research Centre, Dhaka, Bangladesh.

Barnes, D.F. 2000. "Subsidies and Sustainable Rural Energy Services: Can we Create Incentives Without Distorting?" ESMAP Discussion Paper 10, The World Bank, Washington, DC.

_____. 2007. "The Challenge of Rural Electrification." In D.F. Barnes, eds., *The Challenge of Rural Electrification: Strategies for Developing Countries*. Washington, DC: Resources for the Future.

Barnes, D.F., and J. Halpern. 2000. "Subsidies and Sustainable Rural Energy Services: Can We Create Incentives without Distorting Markets?" ESMAP Technical Paper 010, World Bank, Washington, DC.

Bernard, T., and M. Torero. 2009. "Impact of Rural Electrification on Poorer Households in Ethiopia." Report for the World Bank, Washington, DC.

Brenneman, A.. 2002. "Infrastructure and Poverty Linkages: A Literature Review". World Bank, Washington, DC.

Briceño, C., and I. Klytchnikova. 2006. "Infrastructure and Poverty: What Data Are Available for Impact Evaluation." World Bank. Processed.

Chemin, M., and J. De Laat. 2010. "The Impact of Rural Electrification on Poverty: Evidence from a Randomized Experiment in Kenya." Processed.

De Gromard, C. 1992. "L'électrification rurale dans les pays en voie de développement : les contraintes financières et la recherche de solutions économiques viables." Paper presented at the conference entitled *Options Techniques pour l'Electrification rurale*, Bingerville, Côte d'Ivoire, September 21–October 2, Institut de l'Energie et de l'Environnement de la Francophonie.

DfID (Department for International Development). 2002. *Energy for the Poor*. London: Department for International Development.

Dinkelman, T. 2008. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." Population Studies Center Research Report 08-653, August.

ESMAP (Energy Sector Management Assistance Program). 2003. "Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits." ESMAP Report 255/03. World Bank, Washington, DC.

_____. 2005. "Nigeria: Expanding Access to Rural Infrastructure: Issues and Options for Rural Electrification, Water Supply and Telecommunication." ESMAP Technical Paper 091. World Bank, Washington, DC.

_____. 2007. "Maximisation des Retombées de l'Electricité en Zones Rurales, Application au Cas du Sénégal." ESMAP Technical Paper 109/07 FR. World Bank, Washington, DC.

Estache, A., and M. Fay. 2007. "Current Debates on Infrastructure Policy." World Bank Policy Research Working Paper 4410. World Bank, Washington, DC.

Fluitman, F. 1983. *The Socio-economic Impact of Rural Electrification in Developing Countries: A Review of the Evidence*. Geneva: International Labor Organization.

Foley, G. 1992. "Rural Electrification in the Developing World." *Energy Policy*, February.

Haanyika, C.M. (2006) "Rural Electrification Policy and Institutional Linkages." *Energy Policy*, 34(17): 2977–93.

Heltberg, R. 2003. "Household Fuel and Energy Use in Developing Countries: A Multicountry Study." Oil and Gas Policy Division, The World Bank, Washington, DC.

Hiemstra-van der Horst, G., and A.J. Hovorka. 2008. "Reassessing the 'Energy Ladder': Household Energy Use in Maun, Botswana." *Energy Policy*, 36(9): 3333–44.

IEA (International Energy Agency). 2002 *World Energy Outlook*. Paris.

Jacobson, A. 2007. "Connective Power: Solar Electrification and Social Change in Kenya." *World Development*, 35(1): 144–62.

Ketlogetswe, C., T.H. Mothudi, and J. Mothibi. 2007. "Effectiveness of Botswana's Policy on Rural Electrification." *Energy Policy*, 35(2): 1330–7.

Khander, S.R., D.F. Barnes, H. Samad, and N. Huu Minh. 2009. "Welfare Impact of Rural Electrification: Evidence from Vietnam." World Bank Policy Research Working Paper 5057. World Bank, Washington, DC.

Madubansi, M., and C.M. Shackleton. 2007. "Changes in Fuelwood Use and Selection Following Electrification in the Bushbuckridge Lowveld, South Africa." *Journal of Environmental Management*, 83(4): 416–26.

Modi, V., S. McDade, D. Lallement, and J. Saghir. 2005. *Energy Services for the Millennium Development Goals*. London/Washington, DC: The World Bank and the United Nations Development Programme.

Mostert, W. (2008) "Comparative Analysis of Experiences with Rural Electrification Funds: Lessons for Africa." Report for the European Union Energy Initiative.

Pearce, D., and M. Webb. 1987. "Rural Electrification in Developing Countries: A Reappraisal." *Energy Policy*, August.

Peters, J., M. Harsdorff, and F. Ziegler. 2009. "Rural Electrification: Accelerating Impacts with Complementary Services." *Energy for Sustainable Development*, 13: 38–42.

Rambaud-Measson, D. 1990. "L'électrification rurale en Afrique Sub-Saharienne: comparaison entre production décentralisée d'électricité et extension du réseau interconnecté dans une situation de crise financière aigüe." *Groupe Energie Développement*, 1.

Ranganathan, V. 1993. "Rural electrification revisited." *Energy Policy*, February.

Ravallion, M. 2005. "Evaluating Anti-poverty Programs." In H. Chenery, and T.N. Srinivasan, eds., *Handbook of Development Economics*. Amsterdam: Elsevier: 3787–846.

Sebitosi, A.B., and P. Pillay. 2007. "Modelling a Sustainability Yardstick in Modern Energisation of Rural Sub-Saharan Africa." *Energy Policy*, 35(1): 548–52.

Shanker, A., and C. De Gromar. 1991. "Electrification rurale dans les pays en développement : blocage ou nouveau départ?." *Groupe Energie et Développement*, 2.Tendler, J. 1979. "Rural Electrification: Linkages and Justifications." Program Evaluation Discussion Paper 3. Agency for International Development, Washington, DC.

Wolde-Rufael, Y. 2006. "Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries." *Energy Policy*, 34(10): 1106–14.

Bank, World. 1994. "Infrastructure for Development." World Development Report, World Bank, Washington, DC.

_____. 2008a. "Maximizing the Productive Uses of Electricity to Increase the Impact of Rural Electrification Programs." ESMAP Formal Report 332/08. World Bank, Washington, DC.

World Bank. 2008b. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. IEG impact evaluation. Washington, DC: World Bank.

_____. 2009. *Africa's Infrastructures: A Time for Transformation*. Washington, DC: The World Bank.