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Energy efficiency as a means to expand energy access: A Uganda roadmap

Stephane de la Rue du Can[a,*], David Pudleiner[b], Katrina Pielli[c]

[a] Energy Analysis and Environmental Impacts Division, Energy Technologies Area, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, MS 90R2121, Berkeley, CA 94720, USA
[b] ICF International, USA
[c] US Agency for International Development, Power Africa Initiative, South Africa

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ABSTRACT

While energy efficiency can contribute significantly towards improving access to modern energy services, energy sector investments in many developing countries have largely focused on increasing energy access by increasing supply. This is because the links between energy efficiency and energy access, is often overlooked. This oversight of energy efficiency is frequently a missed opportunity, as efficiency is often a very cost-effective energy resource. In combination with grid expansion and new clean energy generation, efficiency efforts can help to ensure that reliable power is provided to the maximum number of customers at a lower cost than would be required to increase generation alone.

In this paper we describe an analysis method for determining a country's energy efficiency priorities and devising an action plan to integrate energy efficiency as a resource for meeting a nation's energy access goals. We illustrate this method with a detailed case study of Uganda. If the most efficient technologies on the market were adopted in Uganda, 442 MW of generation-level demand could be offset and energy access for an additional 6 M rural customers could be achieved by 2030. Of this technical potential for efficiency, 91% is cost-effective, and 47% is economically achievable under conservative assumptions.

1. Introduction

The benefits of energy efficiency (EE) are numerous and contribute to reducing power plant fuel inputs, thereby saving money, reducing harmful pollution, and enhancing energy security. Even more important for developing economies, EE helps investments in new power generation meet the energy needs of a greater number of citizens by reducing inefficient electricity use. Integration of EE into projects focused on expanding the electricity grid and new clean energy generation will not only reduce electricity demand and help optimize the power supply, but also increase the number of customers that can be served reliably at minimum cost.

Various studies have demonstrated a large, untapped energy efficiency potential, globally (IEA, 2016), in different countries (Meng et al., 2016; Craig and Feng, 2017; Sanstad et al., 2014), and for different sectors (Trianni et al., 2016; Jeong et al., 2017; Li and Tao, 2017). Furthermore, some studies show that the cost of energy savings resulting from EE implementation is far below energy supply costs and retail rates (McNeil et al., 2013; Wachsmuth et al., 2015). Hoffman et al. (2017) show that the savings-weighted average total cost of saved electricity across 20 U.S. states is only $0.046 per kilowatt-hour (kWh). The puzzling discrepancy between what is cost-effective and the current level of investment in EE is often referred to as the *EE gap* (Eto et al., 1996; Backlund et al., 2012). Researchers have investigated the market barriers that hinder EE investments and prevent decsionmakers from reaching rational choices that would help close this gap (Sathaye and Murtishaw, 2004; Sorrell et al., 2004; Jollands et al., 2010; Murphy and Meier, 2011; Bukarica and Tomšić, 2017). Trianni et al. (2014) developed a scheme for classifying EE measures, to provide insight into barriers that hinder their adoption, and Wentemi and Thollander (2013) studied the barriers and drivers of industrial EE in Ghana. A large number of enabling policies and programs have been devised to remedy these market failures and to help narrow the gap.

The existing literature provides important analyses of EE's potential, along with meaningful information on programs that help remove market barriers. However, analyses rarely look at EE's potential in the context of a country's entire economy or offer a method to prioritize the programs and policies needed to tap this potential. Moreover, no economy-wide EE analysis exists for countries in sub-Saharan Africa, and no analysis exists that shows the potential of EE as a resource to increase energy access in developing economies.

Those who evaluate countries with a very low electrification rate

* Corresponding author.
E-mail address: sadelarueducan@lbl.gov (S. de la Rue du Can).

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often conclude that investment should focus mainly on expanding electricity supply by building new capacity and spreading the grid. While such investments are certainly needed, investments that optimize the use of the electricity supplied also contribute to increased energy access. Energy efficient technologies help free capacity, enabling energy services to be provided to more households. Moreover, such freed megawatts (MW) often come at a much lower cost than new capacity additions. For example, in the Uganda case study described herein, a recent compact fluorescent light (CFL) distribution program freed up 32 MW with an investment of only US$0.05 million (M) per MW, while the average investment cost per MW for new capacity is US$2.6 M. In countries like Uganda, with relatively high electricity tariffs ranging from US$0.10 per kilowatt-hour (kWh) for industrial consumers to US $0.18 per kWh for household consumers, EE represents a very competitive energy resource. Energy efficiency can complement capacity-adding efforts by ensuring that the power supply is optimized in the most affordable way.

The links between EE and energy access, and the multiple economic, environmental, health, and social benefits of EE, have largely been overlooked by many stakeholders in Sub-saharan African countries, including the international donor community. Energy efficiency and energy access are sometimes viewed as competing for funding rather than elements that be addressed together to ensure more widespread energy access (CLASP and World Bank, 2015). Moreover, EE has been perceived as a short-term solution to power outages and load shedding, rather than as a source of energy for future electricity planning. A recent report from the Regulatory Indicators for Sustainable Energy (RISE) database shows that in the least electrified countries policy makers are not paying nearly as much attention to EE as they are to renewable energy (RISE, 2016).

The World Bank and other international organizations recognize EE as one of the three pillars for ending energy poverty and securing access to affordable, reliable, and sustainable energy. However, little has been done to demonstrate the value of energy efficiency in countries with very low electricity access and to help prioritize investment. Some recent analyses have shown the link between energy efficiency and energy access in off-grid settings. For example, Phadke et al. (2015) shows that super-efficient off-grid appliances enable consumers to purchase smaller (and therefore less expensive) solar photovoltaic panels, lowering energy costs to customers by as much as 50%. However, no analysis has been done to show this linkage for on-grid customers at a national level.

This paper attempts to fill this gap and to encourage more research to demonstrate the contribution of energy efficiency to energy access. We present a comprehensive approach to help countries integrate EE as a resource in national energy planning as a means of increasing energy access. The approach links the potential of energy efficient technologies and processes with a set of concrete actions that can be implemented to track progress and narrow the EE gap. First, we present our methodology approach to assessing EE's energy-savings potential and to identifying and prioritizing the programs needed to tap this potential. We then describe a case study in Uganda, where these methodologies have been applied. This paper provides a systematic approach that can be used to better integrate EE as a cost-effective prime resource of choice for energy access development.

2. Methodology

2.1. Technical, economic, and achievable economic potential

Just as transmission lines are the infrastructure for power grids, data and analytic methods are the infrastructure for market deployment of efficiency at scale. Our method uses data and analytics to calculate energy efficiency's technical, economic, and achievable economic potential for a country (Fig. 1) (Rufo and Coito, 2002; EPA, 2007; Swisher et al., 1997). It begins by gathering detailed information on the country's current energy use and then breaking down electricity consumption for each economic sector by end use, based on assumptions of equipment penetration and unit energy consumption. End-use consumption figures are then translated to peak-demand contribution estimates by coincident factors that estimate peak-demand contribution relative to total electricity consumption. Finally, utility growth projections, along with regional and national level planning data, are used to project electricity consumption and demand estimates for future years.

The technical potential for each end use is calculated by examining the impact of different efficiency measures utilizing a top down approach. For instance, the impact of incorporating solar water heaters for the residential water heating end use or efficient motors for the industry motor end use. The impact is estimated using savings percentage estimations, along with scaling factors for the measure's relative applicability to the end use.

The economic and achievable economic potentials are each calculated from the technical potential by removing measures that are not cost-effective for the end user. Cost-effectiveness for the end user is assessed over a measure's lifetime. The only difference between the economic and achievable economic potentials is the discount rate assumed for the time value of money. For the economic potential, a societal discount rate of 7% is assumed; whereas, for the achievable economic potential, a discount rate of 20% is assumed. The social discount rate attempts to reflect the social view of how the future should be valued against the present. Therefore, the cost benefits calculated with a societal discount rate provides an assessment of investment for the benefits of society. We used an estimate of 7%, which is consistent with current guidelines from the Office of Management and Budget (Broughel, 2017; Masiga et al., 2013). In contrast, we applied a financial discount rate that characterizes the private investments to estimate the achievable potential. In this case, the 2010 World Bank estimate lending rate of 20% was used (World Bank, 2017). This reflects the high interest rates available for financing EE in developing countries, as well as the low confidence in EE investments that can be a common barrier in countries that have limited experience with EE technologies and programs.

For the cost data, all measures that can be implemented as either replacements on burnout or retrofits are assumed to be implemented using a replacement-on-burnout methodology. Therefore, an incremental cost of implementing the measures is used rather than the full cost. The cost effectiveness of the measures has been calculated using the metric of Cost of Conserved Energy (CCE). This metric is calculated as the annualized incremental cost divided by the annual energy savings (Meier, 1984). The CCE is an investment metric that allows EE measures to be compared among themselves and against competing energy supplies. Energy efficiency measures with a CCE below the cost of electricity supply are considered cost effective.

For the achievable economic scenario, low, medium, and high cases of the potential are calculated to show the uncertainty of the results associated with the range of potential savings and applicability.

2.2. Energy efficiency policy roadmap

Although a single entity can produce considerable electric power, saving the same amount of power often requires the contribution of multiple entities. Thus, harnessing EE potential requires a comprehensive package of enabling programs and policies to address market barriers in a multitude of sectors and sub-sectors. These packages are based on three basic types of policy instruments: regulations,