Working Paper: Prospects for Energy Efficiency in Sierra Leone's Power Sector

The Future Demand for Residential Air Conditioning

Sierra Leone is in the early stages of developing its power sector, with only around 20% of the country's population as a whole (and only 13% of its rural population) having access to electricity. The nascency of Sierra Leone's power sector and current low levels of appliance ownership create an opportunity for the country to establish electricity pricing and energy efficiency policies that help meet future demand growth while mitigating carbon emissions.

This paper is based on research commissioned by EEG and carried out by the Energy Institute at HASS, University of California Berkley, into the potential global growth in electricity demand to power air conditioning. It looks at how that demand materialises in the context of planning for the development of Sierra Leone's power sector.

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Prospects for Energy Efficiency in Sierra Leone's Power Sector

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Abstract

This paper summarises Sierra Leone's existing generating and transmission capacity and looks at existing energy efficiency and electricity pricing policies in Sierra Leone. In that context it also reviews the likely growth in energy demand for domestic air conditioning. The paper finds that 'back of the envelope' projections suggest that, despite low adoption rates of adoption, AC could dramatically increase total electricity demand in Sierra Leone in the coming decades. The environmental impact of Sierra Leone's growing demand for cooling depends on the pace of technological change. The energy efficiency of AC has improved dramatically over the past several decades while accelerated investments in low-carbon electricity generation have the potential to decrease emissions from AC. Government policies and market forces that affect these technological innovations will jointly determine the country's ability to keep its households cool without heating up the planet.

Motivation

Sierra Leone is in the early stages of developing its power sector. An estimated 20% of the country's population of 7.8 million has access to electricity. The majority of the country's population lives in rural areas, where the rate of electricity access is around 13%. Roughly 30% of the urban population, which is concentrated in Freetown, has access to electricity, but consumption levels are low and outages are frequent. The nascency of Sierra Leone's power sector and current low levels of appliance ownership create an opportunity for the country to establish electricity pricing and energy efficiency policies that help meet future demand growth while mitigating carbon emissions. Introduction

Overview of Power Supply and Demand

Sierra Leone's state-owned power sector has 100-150 MW of operational capacity and roughly 130,000 grid-connected customers.[1,2] Sierra Leone's generating capacity is about half that of nearby Togo and 1/200th that of Switzerland, countries with similarly- sized populations.[3,4] In addition to capacity constraints, Sierra Leone's grid suffers from significant transmission and distribution losses that represent an estimated 35% of purchases by the Electricity Distribution and Supply Authority (EDSA).[5]

Table 1 lists Sierra Leone's current generating assets. As of 2018, the largest generation source in Sierra Leone is a pair of barge-mounted heavy fuel oil power plants off the coast of Freetown that jointly supply 65 MW of capacity during the dry season and 23 MW during the rainy season. In 2020, EDSA extended its contract with the Turkish operator, Karpowership, for another five years.[6] The other primary generating asset in the country is the state-owned Bumbuna hydroelectric plant, which supplies 5 MW of capacity during the dry season and 50 MW during the rainy season.[7] The transmission system consists of a 161kV line that connects the Bumbuna hydroelectric plant to Freetown and a 33kV line connecting the eastern towns of Bo and Kenema.

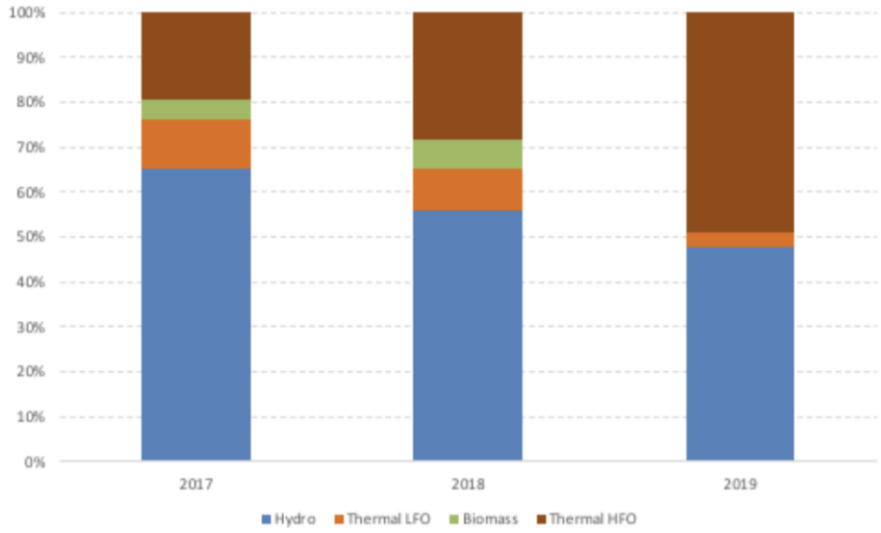
Table 1: Current Generating Assets (Source: AF Mercados EMI. 2020).

Generator	Technology	Region	Nominal power (MW)
Karpowership	Heavy fuel oil	West	65
Bumbuna	Hydro	North	50
BHR	Heavy fuel oil	West	16
Addax	Biomass	North	15
Kingtom	Heavy fuel oil	West	10
Lungi	Heavy fuel oil	North	6
Kono	Heavy fuel oil	East	6
Koidu/New Sembehun	Diesel	East	6
Bo	Diesel	South	4
Other	-	-	17
Total	-	-	**193**

[1] AF Mercados EMI. 2020.
[2] Ministry of Energy. 2018.
[3] https://www.theglobaleconomy.com/rankings/electricity_production_capacity/
[4] https://www.usaid.gov/powerafrica/togo
[5] Ministry of Energy. 2018.
[6] http://www.karpowership.com/en/sierra-leone
[7] F. Nyama, EDSA, personal communication, September 23, 2021.

Growth in electricity demand has prompted several new investments in generation and transmission capacity. In 2017, Sierra Leone's parliament approved an expansion of the Bumbuna hydroelectric plant that will add 143 MW of capacity.[8] Construction is expected to begin this year after numerous delays.[9] Several thermal plant projects are underway, including an 83 MW combined-cycle gas turbine power plant in Freetown that is expected to be commissioned in 2024.[10] Figure 1 illustrates the rising share of hydrocarbons in Sierra Leone's generation mix, mostly attributable to the Karpowership contract, as the country struggles to meet increasing demand.

Figure 1: Share of Electricity Generation by Source (Source: AF Mercados EMI. 2020).



Sierra Leone's largest transmission project is a 1,300 km, 225-kV ("CLSG") interconnection between Cote D' Ivoire, Liberia, Sierra Leone and Guinea, which is currently in the commissioning phase of construction.[11] The interconnection will enable Sierra Leone to import roughly 45 MW of surplus gas-fired and hydro capacity from Cote D'Ivoire and Liberia, respectively.[12]

Peak urban demand in Sierra Leone is expected to increase from 83 MW in 2017 to 400 MW in 2030. The country's mining operations, which are privately-owned and not connected to the grid, also represent a large share of total electricity consumption. Peak demand from the mining industry was an estimated 123 MW in 2017 and is expected to rise to 180 MW in 2030.[13]

Electricity Pricing

Grid connection fees and electricity tariffs are heavily subsidized by the government. Table 2 summarizes EDSA's current tariff structure.[14] In addition to a monthly service charge of Le 10,500 or roughly one dollar (USD), residential customers pay a per-unit charge of Le 560 or about half a cent per kWh for the first 25 kWh they consume in a month ("Social Band") and Le 1,600 or 15 cents per kWh beyond that threshold ("Normal Band"). The Social Band was recently reduced from 50 kWh to 25 kWh.

The next planned tariff restructuring is to allow only customers who consume less than 25 kWh per month to qualify for the social rate, with customers consuming more than 25 kWh per month paying the normal rate on every kilowatt hour.[15] The

[8] AF Mercados EMI. 2020.
[9] https://www.hydroreview.com/business-finance/pidg-to-invest-us6-million-to-complete-143-mw-bumbuna-ii-hydro-in-sierra-leone/#gref
[10] https://www.dfc.gov/media/press-releases/united-states-signs-217-million-agreement-fund-power-plant
[11] https://www.esi-africa.com/industry-sectors/transmission-and-distribution/transco-clsg-energises-lines-and-accelerates-electricity-access/
[12] Ministry of Energy. 2018.
[13] Ministry of Energy. 2018.

[14] F. Nyama. 2021.

[15] Ministry of Energy. 2018.

current block pricing scheme is likely preferable to this proposed scheme, which severely penalizes consumption above 25 kWh rather than just increasing the marginal cost of electricity consumed above that threshold. Another pricing proposal under consideration is to enable customers to pay the initial connection fee, which is currently $96 for single-phase and $183 for three-phase, in monthly instalments and raising the monthly service charge from Le 10,500 to Le 13,300.[16]

Table 2: Current EDSA Tariff Structure

Customer Class	Band	Units ii	Tariff charge Excluding GST of 15%	Monthly Service Charge
T1 Social Band	First 0-25kWh per month for All T1 Residential Customers	**SLL/kWh**	**560**	10,500
T1 Normal Band	Consumption Exceeding 25kWh per month for all T1 Residential Customers	**SLL/kWh**	**1,600**	10,500
T2 Commercial	Commercial	**SLL/kWh**	**1,870**	14,115
T3	Institutions	**SLL/kWh**	**1,800**	14,730
T4	T4 Large Customer and Industries	**SLL/kWh**	**1,890**	75,630
T7	Welding	**SLL/kWh**	**1,900**	39,570
T5	Street Lighting	**SLL/kWh**	**1,678**	29,460

Source: F. Nyama, EDSA, personal communication, September 23, 2021.

Energy Efficiency Policies

In 2013, the Economic Community of West African States (ECOWAS) published a regional energy efficiency policy with targets relating to efficient lighting and cooking, distribution losses, standards and labelling, and financing mechanisms.[17] In alignment with that policy, in 2016 the government of Sierra Leone published its own energy efficiency policy highlighting similar goals and mandating the creation of a National Energy Efficiency Action Plan (NEEAP).[18] The document lists numerous policy measures including electricity tariff reform; efficiency standards and labelling for appliances, vehicles, and buildings; certification of energy auditors; utility billing and infrastructure initiatives; and import tariffs on inefficient products. However, the targets set by ECOWAS have not yet been met and Sierra Leone has not yet produced a NEEAP or enacted legislation to fulfil the goals stated in its policy.

Future Energy Demand for Residential Air Conditioning

Annual per capita electricity consumption in Sierra Leone is very low - about 35 kWh per capita.[19] As incomes rise, so will household demand for energy-using assets. In a survey of rural households in Kenya, Lee et al. (2016) find that grid-connected households typically own mobile phones and radios and rank higher-wattage devices such as televisions, DVD players, and irons highly as the appliances they hope to purchase next.[20]

[16] Ministry of Energy. 2018.
[17] Economic Community of West African States (ECOWAS). 2015. ECOWAS Energy Efficiency Policy.
[18] Ministry of Energy. 2016. Energy Efficiency Policy of Sierra Leone.
[19] https://ourworldindata.org/energy/country/sierra-leone
[20] Lee, K., Miguel, E., and Wolfram, C. 2016. Appliance Ownership and Aspirations among Electric Grid and Home Solar Households in Rural Kenya. *American Economic Review: Papers & Proceedings*.

In addition to income growth, hotter temperatures imply increases in air conditioner adoption. Sales of residential air conditioners are soaring worldwide, to more than 135 million units annually.[21] Using data on current air conditioning (AC) ownership from Sierra Leone's Integrated Household Survey and projections about future income and climate, Davis et al. (2021) forecast that residential AC penetration in Sierra Leone will increase from less than 2% of households today to around 3.5% by 2030 and 10% by 2050.[22]

The effect of increased AC uptake on total electricity demand is highly uncertain, but back-of-the-envelope calculations suggest a large role for AC. Combining West African market data on AC energy efficiency and cooling capacity and an assumption of 2,667 operating hours per AC unit per year from the Collaborative Labelling and Appliance Standards Program with AC adoption forecasts from Davis et al. (2021) and population growth forecasts from the United Nations yields the following projections:[23]

Table 3: Back-of-the-Envelope Projections of Energy Consumption from AC (GWh)

	Scenario 1: Low Energy Efficiency	**Scenario 2: Medium Energy Efficiency**	**Scenario 3: High Energy Efficiency**
2030	166	161	155
2050	636	616	595

Source: CLASP (2020); Davis (2021); and author calculations.[24]

For comparison, Sierra Leone's current annual electricity consumption is roughly 270 GWh.[25] As such, these projections suggest that, despite low adoption shares, AC could dramatically increase total electricity demand in Sierra Leone in the coming decades.

Prospects for Greener Cooling

Increased AC adoption will confer significant health and quality of life benefits to Sierra Leoneans. Yet, AC units contribute to climate change both through their electricity consumption and emissions from their refrigerant technology. Incentivizing the sale of energy-efficient ACs will promote economic development while mitigating climate change impacts. Potential policy responses include minimum energy performance standards (MEPS), product labelling, bans on especially harmful models, and favourable import tariffs and organized bulk purchases of low-emissions models.[26]

Nearly 55 countries have MEPs or have proposed MEPS for ACs. These include many major cooling markets: 85% of the ACs sold worldwide in 2016 were covered by MEPS.[27] In 2020, China, which supplies the majority of AC units sold in Africa, increased the stringency of its MEPs for new units sold.[28] However, as with other energy-intensive durable goods such as cars, a large share of products sold in low-income countries like Sierra Leone are second-hand units. As such, domestic policy can play a large role in managing emissions. Within Africa, at least six countries have imposed mandatory MEPs for ACs and ratified the

[21] International Energy Agency (IEA). 2018. The Future of Cooling: Opportunities for energy-efficient air conditioning.
[22] Davis, L., Gertler, P., Jarvis, S., and Wolfram, C. 2021. Air conditioning and global inequality. *Global Environmental Change*.
[23] Collaborative Labelling and Appliance Standards Program (CLASP). 2020. Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa.
[24] Based on CLASP, "low-end" reflects units with a cooling capacity of 3.14 kW and an EER of 2.90 W/W and "high-end" reflects units with a cooling capacity of 5.22 kW and an EER of 3.10 W/W.
[25] https://ourworldindata.org/energy/country/sierra-leone
[26] Phadke, A., Young Park, W., and Abhyankar, N. 2019. Providing reliable and financially sustainable electricity access in India using super-efficient appliances. *Energy Policy*.

[27] IEA. 2018.
[28] https://www.nrdc.org/experts/alex-hillbrand/china-top-player-world-ac-market-raises-efficiency-bar

Kigali Amendment to the Montreal Protocol, which aims to phase out hydrofluorocarbons (HFCs), a greenhouse gas category used in many refrigerants.[29]

Private sector innovation is also influencing prospects for the uptake and efficiency of AC in Africa. The Japanese company Daikin - which supplies relatively high-end, high-efficiency AC products - is trialling a subscription business model in Tanzania. Customers pay an initial installation fee of around $77 and roughly $1.40 for a day's use of the cool air.[30] While such prices are unaffordable for most in Sierra Leone, where over half the population lives on less than $1.25 per day, a pay-per-use model that reduces upfront costs could eventually expand diffusion of AC among lower-income households.[31]

In the near term, demand for cooling in Sierra Leone will likely be met primarily by fans, as is true in many other low- and middle-income countries. Evaporative coolers - an alternative technology that cools the air by drawing hot air over wet cooling pads - are highly energy efficient, inexpensive, and require little maintenance relative to air conditioners. However, they are most suitable for hot and dry climates. Sierra Leone has a tropical climate with relative humidity levels ranging in percentage from the low 70s in the dry season to the high 80s in the rainy season. For comparison, Miami's highest average monthly humidity is in the low 70s. At these humidity levels, evaporative coolers deliver only a very small reduction in temperatures (while also exacerbating humidity). As such, fans and air conditioners are more desirable cooling appliances in Sierra Leone.

The environmental impact of Sierra Leone's growing demand for cooling depends on the pace of technological change. The energy efficiency of AC and other cooling technologies has improved dramatically over the past several decades and many industry experts are optimistic about continued improvements. In addition, accelerated investments in low-carbon electricity generation have the potential to decrease emissions from AC. Government policies and market forces that affect these technological innovations will jointly determine the country's ability to keep its households cool without heating up the planet.

About the author

Luca Davis is Jeffrey A. Jacobs Distinguished Professor at Berkeley Haas. His research focuses on energy and environmental markets, and, in particular, on electricity and natural gas regulation, pricing in competitive and non-competitive markets, and the economic and business impacts of environmental policy.

The views expressed in this Working Paper do not necessarily reflect the UK government's official policies.

[29] CLASP. 2020.

[30] https://asia.nikkei.com/Business/Business-trends/As-Tesla-eyes-entry-Daikin-s-pay-per-day-AC-takes-off-in-Africa

[31] https://www.wfp.org/countries/sierra-leone