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Closing the Energy Poverty Gap in Africa Using Landfill Gas

By Baba Freeman

Abstract

Energy poverty is widespread in African countries and power generation capacity has continued to lag population and economic growth. The prospects for adding generation capacity are currently diminished as global financial institutions reduce lending for carbon-based energy developments in response to the adverse effects of climate change. Concurrently, large population centers in Africa continue to generate waste that can be utilized for power generation on competitive terms using landfill gas. Power generation from landfills also has the benefit of reducing greenhouse gas emissions associated with each landfill and displacing gasoline and diesel demand from use in transportation and backup power generation. Despite these attributes, the uptake of landfill gas power across Africa has been negligible. This paper highlights economic feasibility assessments of African landfill power generation projects from literature and develops options for policymakers to boost landfill gas power penetration on the continent. It concludes by proposing guidelines to enable policymakers to recognize political and market constraints and incorporate potential solutions to these constraints into future policies.

Energy poverty in Africa

The continent of Africa is severely energy poor. Mckinsey & Co (2015) estimates that electricity consumption in sub-Saharan Africa (SSA) was about 514kWh/capita, lower than India, Latin America, and Brazil with 626kWh, 1961kWh, and 2381kWh of electricity consumption per capita respectively. The International Energy Agency (IEA, 2019) estimates that only about half of Africa's population, numbering about 600million had access to electricity and about 80 percent of companies in sub-Saharan Africa suffer losses from frequent disruptions to electricity supply. This is in stark contrast to other parts of the world, in which about 90 percent of the population has access to electricity. Table

1 below shows a comparison of per capita electricity consumption across different regions and countries.

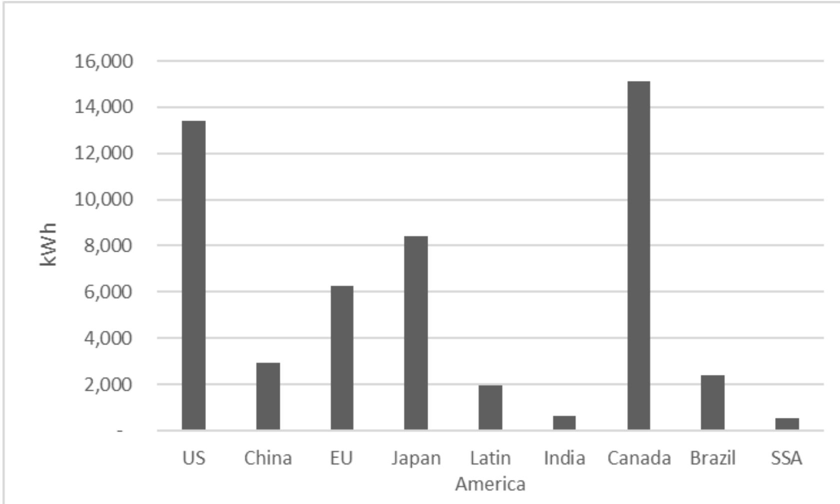

Figure 1: Electric power consumption/capita (kWh) in different regions of the world[1]

The overall picture of African underperformance (using SSA as a proxy) in energy consumption shown in Figure 1 reflects what obtains on the ground in most African countries.

Feasibility of power generation from landfill gas in Africa

Landfill gas can be utilized as fuel for heating or consumed in electrical power generation via internal combustion generators or gas turbines (The World Bank, 2016). It can be also used as a transportation fuel in the form of compressed natural gas (CNG). Hydrogen from landfill methane can also be extracted for fuel cells. Table 1 below shows landfill power projects by region.

Table 1: Landfill gas to power projects by region (2012).[2]

Region	No. of LFG Power Plants	Capacity (MW)
Australia	18	76
Europe	739	1,310
Latin America	8	18
North America	369	2,484
Asia	19	72
Africa	4	4
Total	**1,157**	**3,964**

[1] Castellano et al. *Powering Africa*, McKinsey & Co., 2015.
[2] The World Bank, Urban Development Series, Knowledge Papers, No. 23, *Financing Landfill Gas Projects in Developing Countries*, September 2016. Page 6.

Europe and North America dominate the plant count with 64 percent and 32 percent of global landfill gas power plants respectively. North America and Europe also dominate global installed capacity, accounting for about 63 percent and 33 percent of global totals respectively. Other regions contribute negligible amounts to global plant count and capacity. For example, Africa accounts for less than 1 percent of global landfill gas power capacity despite having 15 percent of global population and producing about 15 percent of global waste. Waste that can be utilized for landfill gas power generation. (Njoku et al., 2018.)

Figure 2 below shows World Bank (2012) estimates of daily waste production in different regions. Sub-Saharan African daily waste generation ranges from 0.09kg to 3.0kg/capita/day, averaging 0.65kg/capita/day while North African countries produce from 0.16 to 5.7kg/capita/day, averaging about 1.1kg/capita/day. In contrast, OECD countries produce an average of 2.2kg/capita/day of waste, Latin America and the Caribbeans produce 1.1kg/capita/day and South Asian countries produce 0.45kg/capita/day of waste. East Asia has an average of 0.96kg/capita/day. These data suggest that waste production will likely rise as African economies grow.

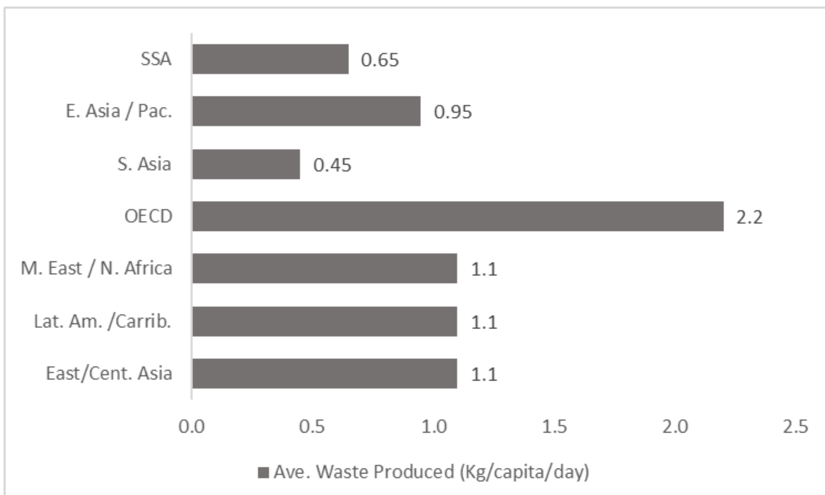

Figure 2: Average waste produced across different regions (Kg/capita/day)[3]

Opportunities to utilize landfill gas or municipal solid waste for power generation are likely to be concentrated in urban centers. At present, Africa has 73 cities with populations above 1 million. Growth in urbanization and the parallel rise in the urban population point to the rising potential for landfill gas power projects to reduce energy poverty on the continent. Furthermore, the difference in waste collection rates between high-income countries and low-income countries highlighted in the World Bank study also suggests that Africa's landfill gas power potential should rise as its economy grows. Low-income countries have a waste collection rate of about 40 percent compared to about 98 percent in high-income countries. (The World Bank, 2012.)

[3] Hoornweg and Bhada-Tata, *What a Waste: A Global Review of Solid Waste Management*, The World Bank, 2012.

Research on landfill gas to power potential suggests that they are economically feasible across many, but not all urban areas in Africa.[4] Ayodele et al. (2018) estimate that landfills in the city of Ibadan, Nigeria can support power generation projects with Net Present Value (NPV) ranging from US$489million to US$830million and payback periods of 5 to 7 years depending on the choice of technology deployed.[5] Ibadan has a population of 3.8million and its inhabitants produce about 232kg of food waste per capita annually.[6] Cudjoe and Su Han (2021) also assessed the economic feasibility of landfill gas to power projects in urban Africa. They estimate NPVs ranging from negative US$87million (Sudan) to as high as US$112million (Morocco). This wide range of NPVs is largely driven by differences in electricity generation potential (e.g., methane content) of landfills and local economic factors such as inflation, interest rates, and tax rates. However, it should be noted that projects in 43 out of 53 African countries have positive NPVs. Figure 3 below shows comparisons between the estimated levelized cost of landfill gas to power projects and contemporaneous electricity prices in African cities with a population greater than 5 million. It supports the conclusion that while economic feasibility is location-specific, African urban centers are largely suitable for landfill gas to power projects.

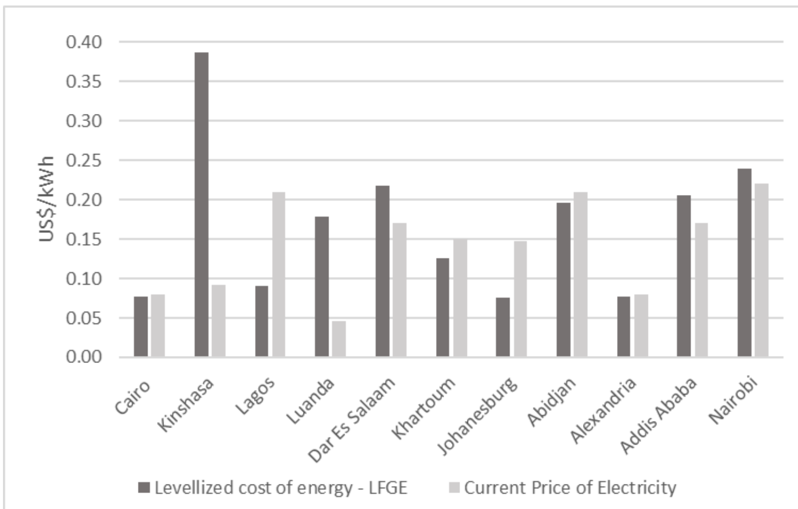

Figure 3: Comparison of levelized cost of landfill gas energy and electricity price in African cities with populations greater than 5 million.[7]

Studies by Aydi et al. (2015) on the Jebel Chakir landfill in Tunisia also suggest that it can produce sufficient gas volumes and greenhouse gas abatement credits to support a 10MW power generation plant with an NPV or about US$5.8million and an IRR of 24 percent (10% percent discount rate).

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[4] Estimating landfill gas to power potential is fraught with uncertainties regarding the amount of gas that can be produced by any landfill, its rate of production, and its duration.

[5] This study analyzes two technology options, anaerobic digestion, and landfill gas recovery technology. Total lifecycle costs range from US$288million to US$413million depending on choice of technology. Midpoint levelized costs of energy were also estimated to between US$0.047/kWh or US$0.05/kWh over the 20-year life of the project depending on choice of technology. A 10 percent discount rate was used to assess project economics.

[6] See Ourworldindata.org, and world population review.com

[7] Levelized cost of energy data is from Cudjoe and Su Han (2021). The only African countries in which economic analysis of landfill gas to power projects do not yield positive NPVs are Uganda, Sudan, Tanzania, DRC, Burundi, Congo, Chad, Ethiopia, Malawi, and Guinea. Price estimates are based on 2012 data. This paper does not account for possible changes since then, nor does it attempt account for changes in foreign currency exchange rates since.

In general, it should be noted that unfavorable cost comparisons may not necessarily disqualify landfill gas power projects from further consideration. In the sanctioning of power projects, some countries may choose to incorporate additional decision criteria related to strategic issues such as energy security and social and political stability. Such criteria can influence the final investment decision in favor of landfill gas power projects. In support of strategic goals, investment in landfill gas power projects may be viewed in the broader context of a country's power generation portfolio. Within each portfolio, opportunities for cross-subsidization may exist across generating assets and market segments. Revenue from the sale of carbon abatement credits can also improve economic returns from otherwise subpar projects.

Environmental considerations in landfill gas to power projects

Landfills contribute significantly to global warming. Biochemical interaction in landfills leads to the production and emission of two major types of greenhouse gases, methane, and carbon dioxide. Cudjoe and Su Han (2021) estimate that methane accounts for 55 to 75 percent of the landfill gas volume while carbon dioxide accounts for 25 to 45 percent. Methane, the more potent of the two in terms of global warming potential, is estimated to cause up to 70 times more warming than an equivalent amount of carbon dioxide (Environmental and Energy Institute [EESI], 2013). Moreover, the International Energy Agency (IEA) estimates that methane makes up about 16 percent of global greenhouse gas emissions globally and municipal solid waste accounts for about 14 percent of global methane emissions (IEA, 2009).

Utilizing landfill gas for power generation reduces greenhouse gas emissions by about 70 percent (Cudjoe and Su Han, 2021). This reduction occurs as landfill methane is burned in internal combustion engines during power generation.[8] Hence, the potential contribution of landfill gas power to mitigating global warming can be quite substantial.

Ayodele et al. (2018) raise another potential benefit of landfill gas projects, i.e., they can reduce demand for diesel and gasoline used in backup power generators.[9] The International Finance Corporation (IFC) estimates that 9 percent of electric power consumed in Africa comes from backup generators that run on gasoline or diesel. This figure rises to 40 percent in west Africa. It also estimates that about 20 percent of gasoline demand in sub-Saharan Africa is consumed in backup power generation. Hence, landfill gas use can have a substantial impact on environmental degradation over time.

In contrast, power generation from landfill gas could increase acidic gas emissions by about 9 percent as methane is burned in process of power generation and released into the atmosphere (Cudjoe and Su Han, 2021).

Overview of potential policy options

Despite the potential of landfill gas power to alleviate widespread energy poverty in Africa, its rate of penetration on the continent is disappointingly slow. Policy uncertainty and market maturity are two

[8] Internal combustion engines are the predominant technology used in landfill gas power projects. (Ayodele et al., 2018.)
[9] Ben Attia of Wood Mackenzie estimates that diesel generator capacity is higher than grid generation capacity in seventeen African countries. https://twitter.com/solarbenattia/status/1516814403903135752

key factors negating faster adoption, hence, gaining insight into them will be essential to closing the gap.

- **Policy uncertainty**: Electric power sector policies in Africa are predominantly focused on traditional sources of electricity such as hydropower and fossil fuels. Additional focus has also been given to geothermal energy in certain areas, while solar energy has been gaining traction more recently. In contrast, African energy policymakers have given relatively little attention to developing policies to incentivize the use of landfill gas for power generation. Existing energy policy documents are often insufficiently detailed to provide clarity on key aspects of sector governance such as permitting, tariff-setting, and fiscal terms.[10] Hence both investor confidence and growth in the sector are very low.

- **Market maturity**: Bottom-up development can often occur in the absence of overarching policies.[11] However, in many African countries, entrepreneurs may not have the sufficient managerial skill, technical know-how, market awareness, or financial scale to actualize the potential of landfill gas to power opportunities. On the other hand, large-scale commercial and industrial users are also likely to have expectations that are limited to familiar power generation fuels such as diesel and gasoline.

To counteract the above limitations in the policy landscape, existing power sector policies should be expanded to provide the clarity needed to grow landfill gas power supply in each country. Given that lawmaking is generally politically complex and slow, other policy pathways could be explored to quicken the pace of landfill gas utilization. These are discussed below.

- **Government mandates**: African governments can adopt a whole-of-government approach to promoting landfill gas power by committing some government-owned facilities and installations to landfill gas power by a given date. To minimize uncertainty, clear criteria must be set for selecting installations for this scheme. (e.g., proximity to suitable landfills). A possible downside to the effectiveness of this approach is that it may be perceived as another government contracting exercise and may thus be susceptible to capture by well-connected persons and special interest groups seeking above-market rates of return. In response, to facilitate transparency and competition and to lower the risk of interest group capture, the managers of this process can deploy reverse auctions to award landfill gas power supply contracts. Another challenge to this approach is that since most governments are cash-strapped, newbuild landfill gas to power projects may need to be financed, built, and operated by the private sector. However, such investors may not emerge due to fear of not getting paid without the assurance of government guarantees. Rather than provide financial guarantees to prospective landfill gas power providers, an alternative approach could be to assign power purchase agreements with guaranteed offtake clauses to specific, cash-generating public-sector institutions such as the customs service or state-owned commercial entities. These revenue-

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[10] For example, see Nigeria's Electric Power Sector Reform Act of 2005, Kenya's National Energy and Petroleum Policy of 2015, and Mali's National Strategies for the Development of Renewable Energies of 2006.

[11] For example, artisanal mining in many regions was historically self-governing before being integrated into the formal business sector. In addition, the financial technology (Fintech) sector in sub-Saharan Africa has been growing rapidly with regulators sometimes playing catch up.

generating establishments are likely to have access to funds without annual recourse to the government and are better placed to support line-item energy expenditure from year to year.

- **Private power markets**: Promoting business-to-business (B2B) contractual arrangements between private landfill gas power generators and their customers can boost market penetration rates. To achieve this, the permitting requirements should be streamlined, limited to health, safety, and environmental compliance matters, and the process assigned to levels of government closest to the landfill site and end customers. Municipal and state governments should also expedite the granting of access to landfills for power generation on terms that encourage long-term commitment. This approach would likely face substantial resistance from regulatory bodies that currently govern power generation and distribution. In addition, incumbent power providers may construe the emergence of landfill gas power as a threat to market share and may challenge new business-to-business arrangements politically and in the courts of law. Policymakers should consider and evaluate loss of market share concerns by incumbents since it is credible that their investment decisions predate the arrival of landfill gas power projects. Furthermore, it is also possible that the customer segments best positioned to transition to landfill gas power may be those most vital to the commercial success of the incumbent entities. Hence, their loss may lead to going concern risks and to a diminished capacity to serve other market segments. This is because the potential loss of commercially viable customers to new landfill gas power producers can deprive incumbents of the economically stabilizing effect of cross-subsidization. However, these concerns should be weighed against the fact that the loss of commercially viable customers has been underway for years as many turned to off-grid, diesel-powered self-generation. Furthermore, it could be argued that residual customers may stand to benefit as incumbents are left with little choice but to improve their commercial viability by raising their quality of service, reducing the frequency of service interruptions, and improving metering, billing, and collections processes.

- **Compressed Natural Gas (CNG)**: CNG is derived mostly from methane and is commonly used as a transportation fuel. It has a high-octane rating and can be produced from landfill gas. The use of CNG could also have the additional benefit of reducing the per capita demand for gasoline and diesel as transport fuels. This could in turn ease economic burdens on energy-poor, cash-strapped countries that rely on the importation of fossil fuels by reducing their foreign currency requirements and their exposure to adverse energy price volatility. The emergence of financially viable consumers such as CNG-powered bulk transportation companies can help accelerate the adoption of CNG by supporting investments in enabling infrastructure such as specialized filling stations, dedicated supply chains, and technical services. The demand for CNG will likely grow in the future as gas-rich counties in the Middle East and Africa seek further ways to monetize their vast natural gas resources. Therefore, African countries should keenly explore opportunities to utilize landfill gas for CNG as has been done elsewhere (Lee et al., 2011). Having the option to utilize landfill gas for CNG can substantially enhance the commerciality of landfill gas power projects and encourage investment. Thus, policymakers should aim to give regulatory clarity to, and extend investment incentives to potential CNG consumers.

Conclusion and policy guidelines for next steps

The success of specific policy prescriptions largely depends on the extent to which they fit with the political realities within a jurisdiction. Political factors can enable or constrain any given policy recommendation. Therefore, it is prudent for policy design to incorporate and reflect knowledge of key stakeholders and interest groups and their respective preference enforcement power across both national and sub-national scales. Future policies to promote landfill gas power in Africa will likely range from light-touch regulation reflecting private sector-led growth to top-down, government mandate-driven approaches that place greater emphasis on participation and direction by the public sector. Policymakers should consider the following guidelines for integration into their policy design effort.

- **Incumbent resistance to new policies**: Incumbent power generators and distributors would likely resist the emergence of landfill gas to power projects. This will be driven in part by fears about the loss of market share. Therefore, to increase the success of policies to promote landfill gas, policymakers may consider **carving in a role for incumbents to access emerging opportunities** as the marketplace for power supply opens to new sources. Landfill gas power policies may also stand a better chance of success in jurisdictions where there is a clear separation of powers and responsibilities between incumbent operating companies, regulatory agencies, and policy-making bodies.

- **Business maturity and entrepreneurial capacity**: The availability of a dynamic entrepreneurial business community may increase the chances of successful adoption of landfill gas power in a country or province. Supply response to market-creating policies may depend in part, on the business community's ability to capture nascent opportunities in the sector. The availability of technical, financial, and entrepreneurial skills can make a substantial difference in achieving the goals of a policy. **In areas with less business capacity, a successful policy may place greater responsibility on government entities** to build and manage the operations of landfill gas power facilities.

- **Market/demand depth**: Energy markets differ from one geographical area to another depending on the quantity of economically viable consumers in each marketplace. The growth of landfill gas power may be constrained by the availability of customers with adequate demand and the ability to pay for services. Policies to promote landfill gas power should therefore reflect the depth of effective demand in each target market. The uptake of landfill gas power in **markets dominated by economically marginal customers may require higher rates of subsidy** over the life of the project.

In addition to the guidelines above, policymakers should not overlook the need to moderate overall contracting risks that potential investors may face. Landfill gas policies must proactively and explicitly address potential issues relating to the enforceability of contracts, foreign currency exchange rates, capital controls, and the threat of retroactive regulations, to name a few.

Declaration of Competing Interests: No competing interest.

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