Expansion of electricity access in Kenya thanks to renewable energy sources

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1 Abstract

This paper analyzes the role of renewable energy – such as geothermal, wind, and solar energy – as a key driver in increasing electricity access in Kenya. Traditionally, the push for renewable energy has been motivated by the climate conservation goals of developed nations, which have provided the resources and funding needed to stimulate demand and drive innovation. However, as this paper will demonstrate, renewable energy presents significant opportunities for increasing energy access which in turn stimulates economic development, and social inclusion in emerging markets, especially those in tropical regions like Kenya.

2 Introduction

The tropical rain belt, located around the equator, boasts the greatest solar potential on Earth. This climate zone is home to the Amazonian rainforest and provides a fertile ground for permaculture farms. These farms are able to grow fruits and vegetables year-round at competitive prices, without the need for costly heating systems, unlike farms in temperate regions like Spain, Italy and France which supply over half of Europe's fruits and vegetables [1]. This tropical rain belt is also home to many developing countries which are vulnerable to climate change exacerbated climate events [2], including Kenya, and they historically heavily rely on fossil fuel imports as their main source of energy and economic growth, even though their location gives them prime access to cheap renewable electricity.

Due to investments in renewable energy Kenya's electricity mix has undergone significant transformation over the past two decades, shifting from a fossil-fuel-based system to one that is nearly entirely renewable. This change has been largely driven by public and private investments in geothermal and hydroelectric power plants and public opposition to coal power plants due to obvious environmental problems. Kenya's Scaling-Up Renewable Energy Program (SREP) from 2011 for energy investments rely on geothermal, biomass, biogas and wind generation due to it's cost-effectiveness at the time. This plan has been compiled before the market shift in solar and battery technology which drastically reduced the cost of investment. Solar panels now cost about 95 % less than they did two decades ago (calculated price per watt in 2000 compared to 2024) and 87 % less than at time of compiling the SREP. This indicates that a revision of this plan is much needed, and will be later discussed in the theoretical part. With Kenya joining the Renewable Energy Integration program of the Climate Investment Fund, further revisions in plans of cost-effective energy production and storage will play a key role in shaping the development of Kenya. While the initial capital cost of solar energy systems may still be a barrier, their operational costs are far lower than that of diesel generators, which will always require fossil fuel imports, indefinitely cutting into foreign reserves of Kenya's central bank. And as will be described later in the theoretical part, the cost of installation of a stand-alone solar system is in some cases significantly cheaper than connecting to the grid [3].

The upfront cost of solar technology is increasingly subsidised by government investments such as the Kenya Off-Grid Solar Access Project (KOSAP), which has been funded by a World Bank loan of $150 million USD [4]. This initiative aims to provide and stabilize electricity access to millions of Kenyans. The KOSAP program focuses not only on subsidising solar home systems and clean cooking solutions but also on the creation of "mini-grids" for community facilities, enterprises, and solar-powered water pumps[5].

As described in the theoretical part, impact of renewable energy on economic output is not uniform, however it has been proven to have a positive impact in many countries throughout the development spectrum. [6]

2.1 Hypothesis

The main hypothesis is as such: Share of renewable electricity positively correlates with the access to electricity in Kenya.

- H_0 There is no positive correlation between share of renewable electricity and access to electricity in Kenya.
- H_1 There is correlation between share of renewable electricity and access to electricity in Kenya.

2.2 Verification criteria

- **R-squared** R^2 - $R^2 \geq 0.7$
- **Correlation coefficient** r - $r \geq 0.7$
- **p-value** - p-value ≤ 0.05

2.2.1 Variables

- **Independent variables**
  - Access to electricity (percentage of population with access)
  - Year-on-year GDP growth rate in (%)
- **Dependent variable**
  - Share of electricity production from renewable sources (percentage of total electricity generated from renewable sources)

3 Theoretical part

As described in Kenneth Lee's chapter of Introduction to Development Engineering, electricity is widely seen as a major driver of economic development and electricity consumption nearly perfectly correlates with GDP per capita [7]. As access to electricity rises electric lighting extends workdays, therefore increases labor demand. Developing countries are expected to drive considerable amount of growth in global energy consumption [8]. Thanks to innovations in renewable energy, those countries don't have to rely mainly on fossil fuels in electricity generation, which strongly contributes to climate change and its effects on the planet's fragile ecosystem.

This presents a a developmental challenge. How can electricity access be expanded in countries with high rates of energy poverty while mitigating the consequences of greenhouse gas emissions and therefore climate change?

3.1 Effects of electricity access in Kenya

Kenneth Lee discussed the problems of microgrids as a potetntial solution to such problem in rural Kenya with pay-as-you-go business model allowing consumers to buy products on credit. However, they identified that the main problem of rural Kenyan electricity access was not the remoteness of villages, but high cost of installation of low-voltage distribution transformer, which cost around $398 USD, while the annual per-capita income was bellow $1000 USD in most rural households. Vast majority of the population without electricity access in Kenya was therefore not off-grid but "under-grid" per se and installing solar microgrids is not a viable long term solution. In their survey of new installation, they did not see significant impacts in the short term with no clear indication as to why. And included an important note from Khandker et al. about rural electrification in India [9], the gains from rural electrification could be much greater for wealthier households which could exacerbate economic inequalities.

3.2 Renewable energy consumption and economic growth accross countries

In Bhattacharya et al. study about the effect of renewable energy consumption on economic growth [6], they studied data of the top 38 countries in the Renewable Energy Country Attractiveness Index developed by Ernst & Young Global Limited from 1991 until 2012. They found that those countries could be separated into three major groups which will be discussed in more detail later.

- **Positive impact:** Austria, Bulgaria, Canada, Chile, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Kenya, Republic of Korea, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Romania, Spain and the United Kingdom
- **Negative impact:** India, Ukraine, the United States and Israel

- **None or limited impact:** Australia, Belgium, Brazil, Ireland, Japan, Mexico, Slovenia, South Africa, Sweden, Thailand and Turkey

3.2.1 Poisitive impact

These countries saw a substantial benefit from the shift to renewable energy in the long run. They found that in most cases, employment elasticities are high compared to capital. The economies in this mix are mostly in the group of economies, which already passed their fossil peak. The ones which have not yet passed this peak are China, Chile, Korea, Morocco and Peru [10].

The most interesting story is of China. The share of electricity produced by renewables has risen from 3 % in 2000 to 11 % in 2021. This is still a marginal share of energy production, given that the rest is produced by coal and oil. However China can be seen as the pickaxe merchant during a gold rush but in renewable energy, as they are the leading force in innovation, production and export of technologies needed for the phase out of fossil fuels. They account for roughly 80 % of solar technology exports in 2022 with around half of that destined to Europe [10].

Korea is similiar to Belgium, in the sense, that they import around 84 % of their energy from China which is mainly produced from fossil fuels. However, their domestic production is nearly all low-carbon with nuclear making up almost 80 %. They however have strong ties to fossil fuel refining, as they are the fifth largest refiner of oil products only behind India, Russia, China and the US. Their electricity generation is also heavily reliant on coal as it makes up around 33 % (199 thousand GWh). Their coal reliance seems to be past it's peak in 2017 (259 thousand GWh) [11].

3.2.2 Negative impact

Their findings suggest that these countries may continue to use non-renewable energy sources for future growth process. Those countries currently rely very heavily on fossil fuel based energy sources and should follow a gradual process for deployment to not jeopardise their economic growth. Indian energy sector is predominantly coal based with 69 % where financing and coordination between renewable resource rich states (Tamil Nadu, Gujarat and Rajasthan) and the rest of the country pose a major challenge for grid integration. Ukraine is the gateway for Russian fossil fuels to Europe and benefits heavily from cheap natural gas, oil and coal as it makes up around 65 % of its total energy mix. They have already passed their fossil peak however. The same can not be said for the US where we can be observe even higher share of fossil fuels (82 %), and whose fossil peak is not expected to come in the near future, given heavy reliance on domestic fracking since 2008 as main source of natural gas and oil. Israel is similiar to the US, except they only produce gas domestically and import fossil energy.[11]

3.2.3 None or limited impact

For majority of those countries, deployment of renewable energy was in an early stage. Those countries were not able to make use of renewable energy effectively in the production process to enhance economic output.

The authors adivise development of new policies or revision of the old ones, to promote the generation and use of renewable energy. Which can be observed for example in Sweden, where wind energy went from 2.75% in 2011 to 14.95% in 2023 with all other sources except solar losing their share. Sweden however already had lower reliance on fossil fuels in the beginning of the studied period compared to other countries in this group [12].

In the case of Mexico, their usage of gas as energy source has seen a major shift since the beginning of the fracking boom (particularly in the US) after the 2008 financial crisis. Share of gas rose from 27.8% in 2008 to 45.4%, while oil dropped from 59.25% to 41.55% during the same period and renewables have not had any significant role in their energy mix. Their imports of natural gas has seen a 4x increase since 2008 and gas imports now accounts for 52.6% of all gas used in the country. Similiar trends, albeit milder, can be observed in oil imports [11].

Another interesting case is Belgium, which heavily relies on energy imports. Approximately 89.7 % of Belgium's energy demand is met through imports, and its economy remains deeply intertwined with fossil fuels [11] [13]. Belgium ranks as the 11th highest exporter of refined oil globally, with refined oil being the country's third most exported product, and petroleum gas holding the top export position [13]. These economic realities suggest that transitioning to clean and safe energy will be challenging, given the country's significant long-term investments in fossil fuel infrastructure.

3.3 Impacts of electrification in Sub-Saharan Africa

In Bernards impact analysis of rural electrification in Sub-Saharan Africa [14], the author identifies three major time periods in the development of electrification. The first being around the year 1980 when the electrification of rural locations was seen as a key solution to stop migration from rural to urban areas and a source of economic growth. The second period is the 80s and beginning od 90s, when rural electrification programmes were re-evaluated due to their high costs and disappointing impact. Low connection rates and limited productive use of electricity were observed. In the third period since the 90s until now, rural electrification is seen as a necessary condition for achieving the Millennium Development Goals and fighting poverty. Programs seek to address the problems of low connection rates and limited productive use through integrated projects and targeted subsidies.

Bernard indentifes the key issues when it comes to low connection rates in rural areas as large upfront cost to connect to the grid, low benefit expectation and the fear of not understanding the billing system.

Another identified problem was the lack of productive use. Electricity is still mainly used for lighting, radios, and televisions in rural areas. Productive use for agriculture, crafts and services is much lower than expected. Bernard propses the reasons for this to be lack of economic opportunities, access to finance and lack of integrated development plans with education on potential usage in mind.

Another problem is the lack of known impacts. The funding for rural electrification programmes is often based on their supposed impacts on health, education or poverty, there is very little empirical evidence to support such claims. Bernard claims that this can be due to, among other things, difficulties in measuring the impacts of infrastructure programmes, long causal chains and attribution problems.

3.4 Impacts of electrification in India

In Khandker et al. article about impacts of rural electrification [9] they analyzed the data of a large scale survey of households in India and found several key benefits. They found that rural electrification helps youth lower the time spent finding firewood and increases the time spent studying. Increases the labor supply of both men and women, school enrolment, per capita household income and expenditure and helps reduce poverty. However, most of those benefits accure to wealthier rural households, while poorer households use electricity to a limited extent. They identified that limited electricity supply due to frequent outages negatively effects households' connection and consumption and therefore the possible benefits to rural areas. The study concludes, that while rural electrification brings large benefits, it is necessary to stabilize the supply and ensuring that poorer households also benefit.

3.5 Optimal strategy for electrification in Kenya

The optimal strategy for electrification of Kenya was studied by Moner-Girona et al [3]. They conducted an extensive spatial mapping of the existing energy infrastructure in Kenya and developed a spatial model of rural electrification called RE_RU_KE, taking into account the current state of the energy sector and local resources. The model considers the potential of conventional approaches (diesel generators), clean technologies (solar, wind, hydro, mini-grids), hybrid systems and central grid extension to electrify Kenya at the lowest possible cost.

They conclude, that renewable energy plays a pivotal role in decentralized energy system allowing for energy access in rural areas for competitive prices. Solar power dominates in remote areas which are separated by more than 10km from the grid. According to their modelling, solar generation could make electricity available to 5.98 million people (1284 MW) and hybrid mini-grids could electrify additional 390 thousand people (115 MW). They observe that around 370 thousand people can be covered by diesel generator (33MW). However they conclude that the identified isolated diesel generators are expensive to operate and maintain compared to PV solutions. They also reference findings of Lee [7] about the "under-grid" population that those affected are better off investing €150-200 EUR in a stand-alone solar solution as a first phase of electrification overcoming the challenge of connection fees to mini-grids or grid connections. They stress the need to update the Kenya's National Rural Electrification Plan to reflect the decline in price of renewable energy technologies and their increased competitiveness aginst diesel generators.

4 Practical part

Following table 1 is the result of aggregation of several datasources using a python script. Python and it's libraries Pandas, Statsmodels, Matplotlib and Seaborn were used to perform the data analysis. Source code is available in a public git repository [15].

Year	GDP per capita (USD)	Access to electricity (%)	Share of renewable electricity (%)	GDP growth rate (%)
2000	617.139	15.175	40.371	-4.745
2001	617.047	17.048	59.459	-0.014
2002	611.893	18.912	67.572	-0.835
2003	668.475	16.000	73.357	9.247
2004	692.709	22.642	62.824	3.625
2005	778.323	24.522	59.701	12.359
2006	854.981	26.422	56.591	9.849
2007	1028.226	28.342	67.016	20.263
2008	1118.755	30.280	65.040	8.804
2009	1123.268	23.000	53.435	0.403
2010	1176.311	19.200	67.877	4.722
2011	1178.599	36.157	63.218	0.194
2012	1396.220	38.125	71.725	18.464
2013	1490.422	40.092	72.524	6.746
2014	1613.101	36.000	71.304	8.231
2015	1625.176	41.600	85.015	0.748
2016	1688.852	53.100	83.884	3.918
2017	1805.398	55.831	74.422	6.900
2018	1987.302	61.180	85.093	10.075
2019	2107.735	69.700	86.919	6.060
2020	2067.987	71.492	92.327	-1.885
2021	2208.691	76.542	90.057	6.803

Table 1: Table showing the relationship between electricity access, renewable share, and GDP growth in Kenya. Full data in [15]

Sources: World Bank[16], Ember[17], IMF[18]

The following figure 1 shows significant correlation between Access to electricity and Share of Renewable Electricity in Kenya.

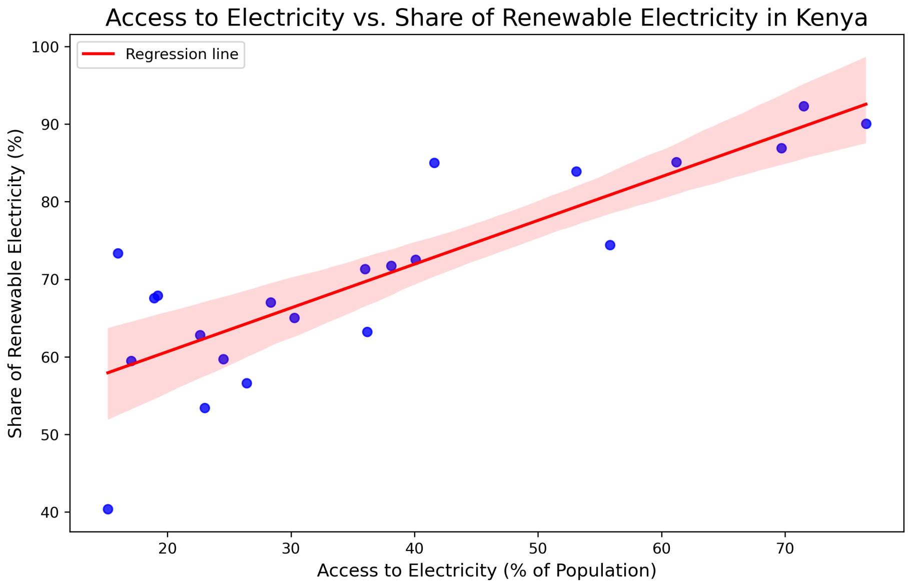

Figure 1: Scatter plot with regression line showing the relationship between electricity access and the share of renewable electricity in Kenya.

- **R-squared:** The coefficient of determination for the regression model is $R^2 = 0.704$, indicating a strong relationship between the variables.
- **Correlation Coefficients:**
  - **Electricity access and share of renewables:** $r = 0.834$, showing a strong positive correlation.
  - **Electricity access and GDP growth:** $r = 0.048$, indicating a weak correlation.
  - **GDP growth and share of renewables:** $r = 0.125$, also a weak correlation.
- **Electricity Access Coefficient:** The regression coefficient is 0.561, statistically significant with p-value < 0.0001.
- **GDP Growth Coefficient:** The regression coefficient is 0.177, not statistically significant with p-value $= 0.505$.

5 Conclusion

The author concludes that there is a strong positive correlation between the share of renewable energy and access to electricity. This finding supports hypothesis H_1 which proposed the existence of such a correlation. Data analysis revealed that the correlation coefficient between access to electricity and renewable energy share is 0.834, indicating a strong positive correlation. The regression coefficient for access to electricity is 0.561 and is statistically significant with a p-value of less than 0.0001.

The paper further indicates that there is a weak correlation between access to electricity and GDP growth (correlation coefficient of 0.048) and also a weak correlation between GDP growth and the share of renewable energy (correlation coefficient of 0.125). The regression coefficient for GDP growth is 0.177 and is not statistically significant with a p-value of 0.505.

Thus, the conclusion of the paper suggests that the share of renewable energy plays a significant role in expanding access to electricity in Kenya.

Thanks to it's current low reliance on fossil fuels, Kenya is expected to benefit from existing and expanding cheap renewable energy as its source of growth.

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