Rethinking Access to Clean Energy for Climate Change Mitigation in Tanzania

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Authors' contributions

The sole author designed, analyzed, interpreted, and prepared the manuscript.

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ABSTRACT

The effect of climate change is visibly spread with no boundaries all over the world. With multiple effects of climate change, its mitigation mechanisms vary. However, striving for universal access to affordable, reliable, and sustainable clean energy is arguably one of the significant sought mitigation strategies, especially in the context of Africa. This raises concern about whether the road to clean energy in the work of mitigating the devastating climate change is eloquent or a myth. Using ARIMA, the paper forecasted access to electricity to calibrate the reduction of over-dependence on climate change-inducing energy sources such as firewood and charcoal. The paper used time series data from 1992 to 2022, with a forecast of 10 years. The results show that climate change mitigation through clean energy is far from the reality, the level of future access cannot be used to define progress in mitigating climate change. A large percentage of people will remain unconnected while few will be disconnected due to various reasons such as unaffordability and reliability of electricity supply. Along the energy ladder, consumers are likely to remain at the base where unclean energy sources dominate. People are likely to continue with the course of depending more on unclean energy sources thus, making climate change mitigation through access to electricity a less reality, a myth in such short. An equation of the available potential resources for producing more and more reliable modern energy should be balanced by the utility supplier. Expanding the production and distribution levels should also be on a stage. The energy utility should change the monopoly system in the energy sector and embrace innovation and collaboration at large.

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1. INTRODUCTION

Today, than ever in time, the effect of climate change has increasingly become a global challenge leading to hastened deterioration of people's livelihoods and life in particular [1]. Due to climate change, the practice of agriculture for example which determines the quality of livelihood and life of human beings faces a worrisome standpoint not only in developing countries but at the global scale [2]. Unpredictable weather, dryness, and catastrophic environmental occurrences endanger life on Earth [3]. Mega pollution resulting from heavy industries and all other development activities that increase the emission of greenhouse gases and deforestation that depletes the carbon sinks have been cited as a critical contributor to climate change [4].

The scale of the visible effects resulting from climate change has so far awakened the development planners and government authorities to launch different mitigation approaches. Fostering, access to clean, affordable, and reliable energy is pronounced a key strategy to reduce and mitigate climate change [5,6]. With such phenomena and in the context of Tanzania, where the looming effects seem catastrophe due to fewer mitigation strategies coupled with terrifying poverty rates, the grand question remains, is it the reality or a myth? Does the trend of access to clean energy offer a prime understanding of whether the long-time efforts of cultivating access to clean, affordable, and reliable energy stand a promising reality?

Clean energy is recognized as a quantum driver of not only climate change mitigation but also socio-economic development. The bundles of most renewable energies fall in the class of clean energy [7]. They include wind energy, solar energy, ocean energy, geothermal and bioenergy, liquid fuels, and gaseous fuels including liquefied petroleum gas (LPG) and natural gas [8]. The cleanest forms of energy are always on top of the energy ladder. Electricity is leading when efforts are explained to increase access to clean energy "*Electricity is a superior energy carrier toppling the energy ladder*" [9] and thus, it forms a key focus of this study. Electricity being of multiple use at the domestic and industrial levels is a powerful energy career which when well, can mitigate the risks and effects of climate by preventing or slowing down the increase of atmospheric greenhouse gaseous concentrations by limiting current and future emissions and enhancing potential sinks for polluting gases [10].

In the developing world including Sub-Saharan Africa and Tanzania in particular, the electricity agenda has been on top of development plans and the manifesto of governments [11,12]. Massive investment plans and search for new sources of clean energy have drained fiscal resources. This puts the efforts on a test when information about the level of access to electricity is sought. However, access alone can hardly be used to judge a clear roadmap to clean energy in the work of mitigating climate by reducing overdependence on unclean sources of energy. People do not want access to "clean energy sources" but reliable and affordable clean energy sources [13]. For that, it is crystal clear that the work of ensuring access to clean form of energy sources is wretched if all components of quality energy are not gauged and entangled in the process.

For the clear cuts towards the achievement of the mitigation of climate change, it is palpable to note it is not clear energy sources that can make happenings, rather, "quality clean energy". The prevailing state of access to unreliable, unaffordable electricity can with challenges create a negative milestone toward mitigation of the climate change [14]. Of all the quality issues, reliability and affordability mostly determine the level of access to clean energy [15]. About 1.2 billion people (17% of the world's population) lack access to electricity (WB, 2019). Nearly, about 85% of those who lack access to electricity reside in low economically developing countries (LEDCs) including Sub-Saharan Africa. Forecasting the future trend of access to electricity is vital to regulate the speed of investment towards access to electricity which is a clean energy carrier [16].

Those with access to electricity which is the cleanest form of energy source (83% globally) are troubled by low quality signaled by flickering supply and unaffordability [17]. These problems are more pronounced not only in Tanzania but also in Developing Asia and Latin America. Thus, succinctly, it is important to have access to quality electricity with the expectation to stimulate a wider array of climate change mitigation [18].

While the struggle for electricity remains real in Sub-Saharan Africa, Western America, Europe, and North Africa have achieved nearly universal access to quality electricity by 97- 99% [19], and so development gain and climate mitigation through dependence on clean energy especially in rural areas is discernible [20].

While the current trend of access and future access is important in informing success towards climate change mitigation, the level of consumption needs also be disentangled. This is because of the fact access and consumption are two different parameters [21]. Sub-Saharan Africa (SSA) and Tanzania in that regard have per capita consumption estimated to be 488 kWh per annum [22,23]. Similarly, it was reported that the 488 kWh is pushed up by the inclusion of South Africa with high electricity access rates in the region [24,25]; if excluded, the average annual per capita consumption shrinks to 150 kWh [26]. Can this level of consumption be used to define climate change mitigation? This is important to understand, figure out and calibrate.

Learning from other countries, the situation is worse and not welcoming to gauge mitigation of climate change. For instance, until 2016, Eritrea had 51 kWh, Central African Republic 36 kWh, Liberia 69 kWh, Kenya 162 kWh, Uganda 70 kWh, Chad 16 kWh, Guinea-Bissau 17 kWh, while Tanzania had per capita consumption of electricity of 95 kWh per annum [27]. If the level of consumption is not improved, it only brings to a simple interpretation that over-dependence on greenhouse gases for domestic use will continue to challenge the efforts of climate change mitigation [28]. Investment efforts in reducing electricity poverty have led to the decline of the population without electricity from 1.2 billion people in 2015 to 1.06 billion people [29]. Equally, the world's electrification rate has increased from 77.7% to 85.5%.

The increase in access to electricity is real progress, it has also benefited rural access at the global scale which increased from 63% to 73% while urban centers had 97% [19,30]. Improved access to electricity in urban areas is a milestone because since 2000 world's urban areas have received 1.6 billion people as new entrants, consequently, increasing the number of people with access to clean energy [19]. Sub-Saharan Africa (SSA) has moderate improvement from 26.5% to 37.5%, thus making 609 million (6 out of 10) people remain off-electricity services compared to 620 million people in 2015 [19]. This means that the number of people depending on

climate change-inducing energy sources is decreasing also.

1.1 Mechanism for Increasing Access to Clean Energy in Tanzania

Tanzania, in response to poor production and quality electricity, there are multiple perceptible strategies put forth in the process of picking up. The strategies include the extension of the National Grid, Micro Hydro Power (up to 1MW), Mini Hydro Power (up to 10 MW), Mini-grids (less than 10MW), and Photovoltaic (PV) which produce varying amounts of electricity [31]. The strategies represent the reliable means of ensuring access to electricity by the rural and sections of urban areas that are unlikely to be connected to the grid [31]. Until recently, statistics indicate that in Tanzania, more than 109 mini-grids are registered to supply electricity in rural areas via the national grid and stand-alone mini-grids [32].

Additionally, Tanzania's energy utility has installed 29 solar power plants that produce 7MW. The mini-grids will remain to be a key strategy in accelerating access to electricity in rural Tanzania and the rest of Sub-Saharan Africa. This is because of the reason that they are more cost-effective than grid extension [33,33]. However, their cost in terms of operations and business return could have a huge mismatch. On the other hand, IRENA [35] confirmed that mini-grids are believed to have high reliability because they are manageable. In, Tanzania, the electrification impetus increased in the 2000s after the stabilization of institutional and legal frameworks [2]. These include the Rural Energy Board (REB) and Rural Energy Agency (REA) as manifested in the Rural Energy Act of 2005; Energy and Water Utility Regulatory Authority (EWURA), Electricity Act of 2008; National Energy Policy of 2003 (revised in 2015); and Public-Private Partnership Policy (PPP) of 2009 and PPP Act of 2010. The efforts have brought a noticeable increase in rural electricity connection from only 1% in 2003 to 24% in 2020 and from 9% in 2003 to 40.2 in 2022. Further, the efforts have made Tanzania to be among the top ten countries with the highest mini-grid developers in the world. Villages connected to electricity increased from 2,018 in 2015 to 9,112 in 2020 [36].

1.2 The Energy Ladder Model

The energy ladder model came into practice in 1980 because of new rethinking after the notable

wood crisis of the 1970s that extended up to the 1980s [37]. The energy ladder is rooted in an economic view of consumers, basically at the household, but in the context of this paper, it is viewed at the wider national level. It is a prominent model to explain the energy. It also describes the pattern of energy substitution as influenced by economic changes (Elias and Victor, 2005). The ladders consider income as one of the key determinants of energy switch from traditional biomass to clean energy fuels (Heltberg, 2003). In the context of the energy ladder, as income rises individuals consume energy that occupies higher rungs, ascending or climbing the energy ladder. A fuel's rung is dictated primarily by its cost, a reflection of its cleanliness, reliability, efficiency, and even affordability. This paper explored how access to clean energy is influenced by GDP. The model is of the assumption that energy switching is linear [38] and envisions a three-stage energy switch, the first stage is the universal reliance on biomass, followed by transition fuels, and finally advanced fuel [39].

1.3 Overview of Tanzania Energy Profile, Demand and Supply

Tanzania is endowed with abundant energy resources of various nature and efficiency. The resources include natural gas, uranium, coal, hydro, biomass, wind, solar, and geothermal [40]. The domestic consumption of energy accounts for 75%, transport 6%, agriculture 4%, and industry 14% while the rest accounted for 1.2%. The current discovery shows that the coal reserve is estimated to be 1.9bn tonnes, with uranium deposits of about 2000 million pounds [41]. Biomass is a dominant source of energy for both urban and rural dwellers 85%, while 9.3% is total energy from petroleum products, 4.5% is accounted by electricity and 1.25% is from coal and renewable energy [42]. Overdependence on biomass creates a state of continued practices of inducing climate change activities. With development efforts in the sector, it is impeccable to gauge whether mitigating climate change can be done by clean energy at large. In terms of electricity, TANESCO is the sole vertical energy utility that dominates distribution through a central national grid and isolated mini-grids in remote areas [39]. Tanzania had electricity fluctuation and erratic supply due to massive dependency on hydropower [38]. The annual demand growth for electricity is between 10-15 %, and the annual electricity consumption per capita was 105 kWh which is below acceptable global average per capita consumption of 500 kWh for urban and 250 for rural areas [43].
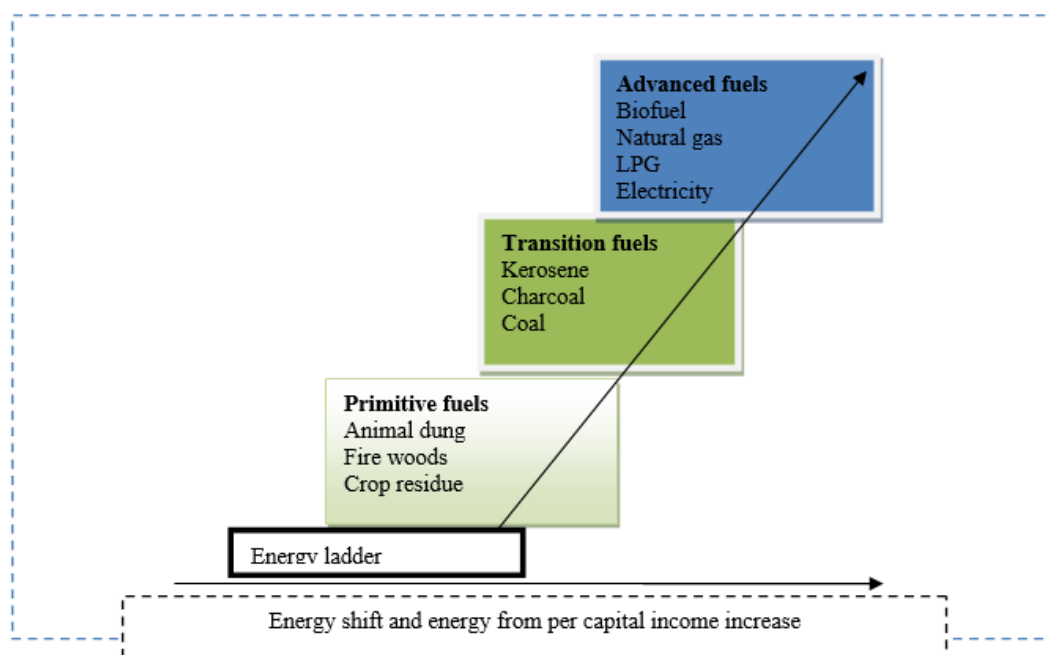

Chart 1. The Energy Ladder for Energy Transition
Source: [37]

2. METHODOLOGY

This paper uses the time series data from Tanzania to analyze the current trend and forecast the future trend of access to electricity which could enlighten the success in mitigating climate change. Data comprised observations from 1992 to 2022 about the percentage of the population with access to electricity. The paper is based on the Box-Jenkins methodology (Box & Jenkins, 1976). The approach is suitable for short-run forecasts. It is an algebraic model that is commonly applied in forecasting and is known as an autoregressive integrated moving average (ARIMA). The Box Jenkins (BJ) methodology [44] is an iterative process (Fig. 1) that follows a systematic flow in the estimation of time series data.

To use the Box-Jenkins methodology, it is important to have either a stationary time series or a time series that is stationary after one or more differencing. ARIMA consists of three parts, first is Autor Regression, AR(p), Moving Averages, MA(q), and Differencing to strip off the Integration (I) of the time series (d), this forms ARIMA (p, d, q).

3. RESULTS

3.1 The Stationarity Tests

This paper aimed to carry out an estimation of clean energy (electricity) access in Tanzania by using time series data from the World Bank. With the ARIMA estimation model, the first quality check includes stationarity checks [44] suggests the check to be done by using graphs, correlogram, and Augmented Dickey-Fuller Test. From the graph of Figs. 2 and 3 the time the variable of interest is non-stationary because it has a trend as opposed to stationary. Its variation along the mean has no constant amplitude and is not consistent.
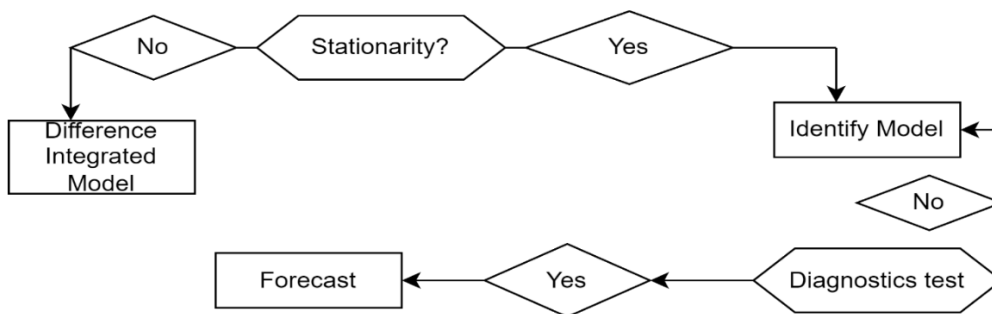

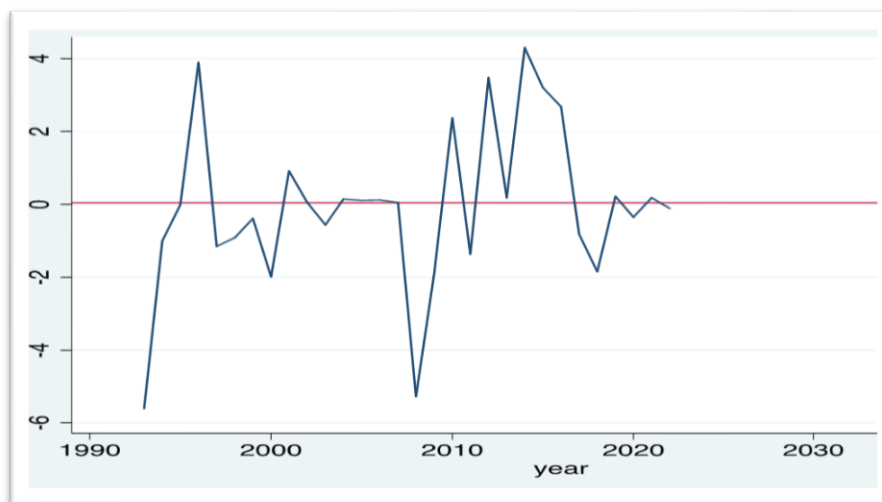**Fig. 1. The Box Jenkins Approach for ARIMA**
Source: [44]

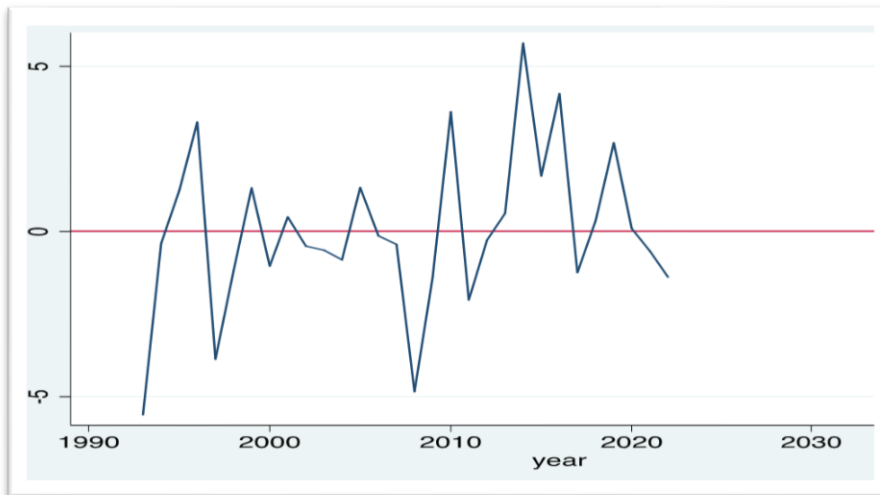**Fig. 2. AR1 (Stationarity test for identification)**

Fig. 3. AR2 (Stationarity test for identification)

3.2 Correlogram Analysis

A correlogram takes on board the parametric correlation of the variables of interest. Time series is commonly and linearly related to its lagged version of itself over successive time intervals. This is one of the analyses suggested by [45] in gauging the existence of the stationarity of the variable of interest. Thus, the analysis in Fig. 4 indicates that the decay is slow and constant along the diagonal path at 25 lags. This confirms that the variable lacks stationarity character.

Fig. 4 indicates that the correlation is constant on the positive and negative sides. There is a strong correlation at Lag2. This indicates non-stationarity for the general view of the time series because there are significantly non-zero correlations at the end.

3.3 The Augmented Dickey-Fuller Test (ADF)

Augmented Dickey-Fuller test (ADF Test) is a common statistical test used to test whether a given Time series is stationary or otherwise. The test is mostly and commonly applied in statistical tests when it comes to analyses of the stationarity of a series. The ADF test belongs to a category of tests called the 'Unit Root Test', which is the proper method for testing the stationarity of a time series. This means that a Dickey-Fuller, test null hypothesis that assumes the presence of unit root, thus the p-value obtained should be less than the significance level of 0.05. The results of the ADF are presented in Table 1
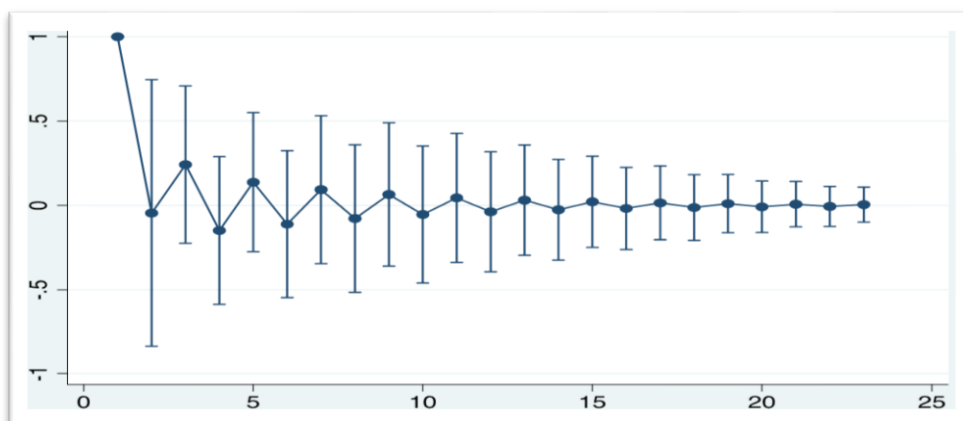

Fig. 4. Parametric autocorrelation at 25 Lag
The x axis is lags in years while y axis is correlation coefficient

Table 1. The ADF for Unit Root

	ADF for Unit Root	Number of observations =30, p value, *z(t)= 0.9916*		
		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.0904	-3.716	-2.986	-2.624
	ADF for Unit Root	**Number of observations =29**		
		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.0904	-3.723	-2.989	-2.625

Mackinnon approximate P-value is z(t)= 0.000

The results show that the time series is stationary at the first difference since the Test statistic in absolute value is greater than the critical values. The null hypothesis of the ADF test is that the variable has a unit root (a causative of non-stationarity). The test statistic −5.905 is an absolute value greater than all the critical values at p<0.05. Hence, the null hypothesis is rejected, signifying the presence of stationarity (unit root).

3.4 Model Identification and Diagnosis

To identify whether ARIMA (111) or ARIMA (211), an estimation was done by identifying the value of *p* and p and *q*. The inspection of the correlogram was done to obtain the q (Fig. 4). Notably, the autocorrelation function determines the value of q, and the partial correlation function is for the p-value. From the correlogram, the partial autocorrelation had 2lags which are significant. Thus, the value of p is 2, leading to a selection of the ARIMA (211) model. ARIMA (111) was estimated but sounded with fewer fits while also suffering from autocorrelation and the residuals were not white noise. Thus, ARIMA (211), autocorrelations, and partial autocorrelations were diagnosed through the Portmanteau white noise test on the residuals, and the model had favorable results as indicated in Table 2. Portmanteau, tests the null hypothesis that the white residual is noise.

Table 2. The Portmanteau test for white noise

Portmanteau test for white noise	25 Lags
Portmanteau (Q) statistic	12.2480
Prob > chi2 (13)	0.5074

The Portmanteau test for the white noise suggests that the model does not suffer from autocorrelation because the Portmanteau statistic is not significant (p>0.05). The plot for the autocorrelations and partial autocorrelations

thus can show the same results. This is a good sign for the analysis, indicating that the model is performing well. Further diagnostic observation was done by inspecting the inverse roots of the ARMA polynomials in Fig. 5. The estimated ARMA process was checked for covariance (stationarity) and it was found that the AR roots lie inside the circle. Further, the MA root lies within the unit circle, all assured that the model met the conditions.

3.5 Forecasting

The purpose of the paper is to forecast the percentage of people with access to electricity in Tanzania for a period of 10 years from 2023-2032 to shed light on whether dependency on climate change-induced energy is mitigated. The forecast uses access data from 1992 to 2022 using the ARIMA (211) Model. Therefore, after model identification and diagnostic evaluation, the forecast results are presented in Fig. 6.

The results show that for the next ten (10) years from 2023 through to 2032, there will be variations in the percentage of access to electricity. The highest percentage of access is revealed in 2023 with 40.44 percent. In the rest of the years do not show a high profile and remain low. For example, the year 2032 shows that the access rate is expected to shrink to 36.58%, this means that it will decline from the current rate of 40.2% (for the year 2022). The key question is how it is possible to have such a decline in access. The reality is, due to the unaffordability of consumption some people connected to electricity might disconnect, especially in the rural areas.

4. DISCUSSION

Access to clean forms of energy such as electricity is one of the most visible strategies for climate change mitigation. It reduces over-dependence on climate change inducing sources
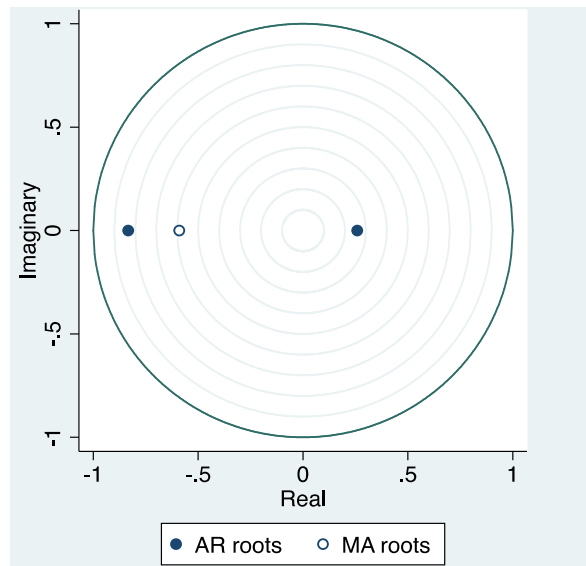
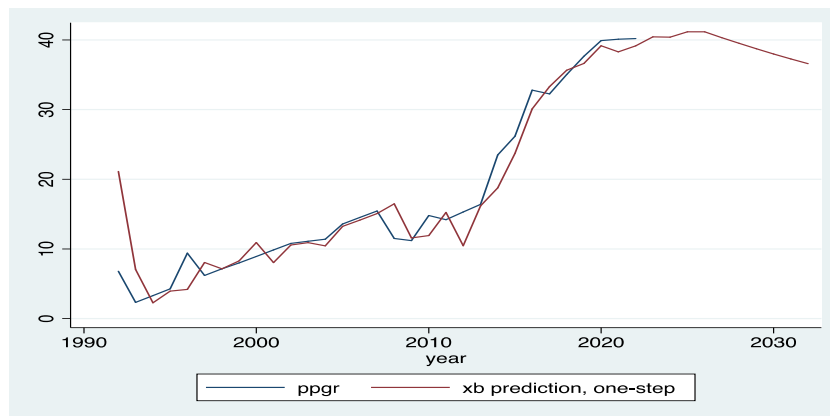**Fig. 5. Inverse roots of ARMA Polynomials**

Fig. 6. Forecast for electricity access (x-axis is % of the population with access, the y-axis is years)

of energy. From the forecast results, it is viable that the rate and trend of access to electricity by most of the population is negatively alarming not to be better in the work of climate change mitigation. The results show that the trend will continue to shrink, this means that the population in Tanzania will continue to rely on wood, charcoal, and other solid biomass for cooking energy. Concerning the energy ladder, although climbing it is associated with the best economic status of energy consumers, the certainty is that energy itself must be available and accessible in the first place. The population cannot climb the energy ladder such that from charcoal to electricity while the latter is not available inadequacy.

To increase the rate of access to electricity, the economy of the state needs to grow first to allow investment in the energy sector to expand production, transmission, and distribution of electricity to consumers whose economy needs to change status to better also to climb and afford electricity along the ladder. Failure to increase production would mean that the population that keeps growing, and the industries that need to be fed with electricity will likely suffer and thus affect income and employees in the end. This felt effect has direct repercussions on access to electricity through reduced purchase power.

The forecast results for the next ten (10) years raise a worrisome trend of less improvement in electricity access. The decline from 40.2 to 36.58 in 2032 offers new insight to investigate. There is a possibility of many connected customers to shy away from electricity due to such issues related

to the unaffordability of its consumption which again stand as one of the most compelling reasons for poor consumption of electricity in Sub-Saharan Africa and Tanzania in particular. This means that, attaining a level of good access to electricity as a means of climate change mitigation is still far and it is really a myth. Moreover, the decline and failure to increase access to electricity is looked at in the name of reliability of supply. The incidence of electricity outages gives no attraction for most consumers to delve into connection [46]. This creates a negative booming loss of interest in state utility, hence leading to reliance on greenhouse-inducing sources of energy especially for domestic use.

While mitigating climate change is based on reducing an increasing flow of heat-trapping greenhouse gases into the atmosphere. This involves cutting and or reducing greenhouse gases from main sources such as power plants, factories, cars, and farms. While these measures are invisibly practical especially due to the high level of industrial development in the world. It is important to venture into the reduction of forest depletion by exploiting the available sources of energy in the country [47]. With such forecast results in Figure 6, the efforts of reducing greenhouse gaseous which are constituents of the atmosphere, both natural or anthropogenic, that absorb and re-emit infrared radiation become a myth towards climate change mitigation. To eradicate the myth of mitigating the effect of climate change in Tanzania and to increase access along the forecast line as in Fig. 6. Tanzania should intensively extract energy from the vast and readily available potentials such as hydropower, natural gas, coal, uranium, wind, geothermal, solar, tidal, and waves.

5. CONCLUSION AND RECOMMEND-ATION

The paper aimed at forecasting the percentage of the population with access to electricity for ten years from 2023-2032 in the work of mitigating climate change. The supposition is that Tanzania is still far from reaching the reality of mitigating climate change through access to clean forms of energy. This is because, the forecast results showed that the rate of increase of people with access to electricity is less encouraging, stagnating, and does not prove the reality. There is a danger of continued dependence on unclean sources of energy due to poor access, this will negatively affect the actions based on mitigating

climate change. This is to say that attaining climate change mitigation through access to clean energy like electricity is still a myth. It is the responsibility of energy utility and development partners and planners to extract the available resources to increase the rate of access to electricity. This, in the end, will move a large population from depending on unclean energy sources which induce climate change. The poor forecast results are happening amid the potential of clean energy sources in the country. There is also a need to increase the use of energy-efficient technologies, especially at the domestic level where up to 85% of energy produced is consumed.

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COMPETING INTERESTS

The author has declared that no competing interests exist.

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