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An outlook of Tanzania's Energy Demand, Supply and Cost by 2030

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Abstract

The UN SDGs highlight the importance of energy indicators in achieving sustainable development. The supply side of energy in Tanzania has received a significant boost and there are optimistic targets to suggest further improvements in this area. However, past experiences have shown that the problems of financial constraints and the lack of technical capacities required could either delay or lead to the total abolishment of some projects. In the short- to medium-term, emphasising demand-side management (DSM) could prove crucial in ensuring a sustainable energy system in Tanzania but the evidence is sparse. This study reviews the trends and underlying drivers of energy demand, supply, and cost in Tanzania. Total primary energy and electricity consumption exhibit a rising trend, and challenges on the supply side suggest energy deficit is a looming challenge in the future. Thus, without a significant boost in supply and probably DSM, unserved energy demand could worsen in the future. Key drivers include economic growth, price, electrification rate, population growth, industrialisation, changes in economic structure, and energy efficiency. Forecasted peak demand in the medium (2020-2025) and long term (2025-2030) would average annually 1274.74 MW and 1490.33 MW, respectively. Recent electricity tariffs in Tanzania are ranked among the highest in the sub-region, and the key drivers are own generation and transmission, and power purchase. The current tariff structure favours commercial consumers more than domestic consumers and this might impose significant affordability challenges on women who mostly do not operate in formal businesses. We discuss the implications of the findings.

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An outlook of Energy Demand, Supply and Cost in Tanzania

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1. Introduction

The aim of this study is to review the trends and underlying causal factors in energy demand, supply, and cost in Tanzania using data from 1990 to 2018. Energy indices have been highlighted as key areas in the United Nations Sustainable Development goals. This is because energy resources play a very important role in all economic activities in the world. In Tanzania, the Power Sector Management Plan 2016 update highlights the importance of energy resources to achieving a sustainable industrialisation process in the country. The generation of power has also been identified as key to ensuring the mechanisation of agricultural activities under the new government initiative, the Southern Agricultural Growth Corridor of Tanzania (IRENA, 2017). The provision of other social and economic services also depends critically on energy resources. They include health, education, telecommunication, and water, especially in rural areas. In Tanzania, energy services are required for the growing usage of mobile phones in the country, which has more than 11.7 million registered users as of March 2014 (AfDB, OECD, and UNDP, 2015).

The above suggests the need to achieve a sustainable energy system, which involves a sustainable energy supply and efficient demand-side management. In the case of the former, the Five-Year National Development Plan II, 2016, targets an increase of six-fold in grid expansion from 1.5 GW as of 2015 to 10 GW by 2025/2026 (Mokveld and von Eije, 2018). However, experiences have shown that problems such as financial constraints and the lack of technical capacities required for such infrastructural investments have led to either the delay or total abolishment of some of these future optimistic projects in Tanzania. Therefore, in the short- to medium-term, the pursuit of demand-side management strategies could prove crucial to ensuring a sustainable energy system in Tanzania. At least, the episodes of the global 1970s energy price shock taught us that neglecting the demand side does not provide an efficient way to deal with the energy problem. Unfortunately, demand-side management strategies have not been pursued aggressively even though current and future trends in energy consumption continue to grow astronomically[4]. One important reason could be the lack of in-depth empirical analysis of energy demand trends and the driving factors.

[4] In the electricity sector, consumption is growing at annual average rate of 10-15% in Tanzania.

In this regard, there have been some attempts in the literature to understand energy consumption trends in Tanzania (see Mokveld and von Eije, 2018; IRENA, 2017; Power Africa, 2015; AfDB, 2015). However, these studies are highly descriptive offering no key insights into the underlying causal factors of energy consumption in Tanzania. Other studies such as Winther (2007), Merven, Hughes, and Davis (2010), Mohamed and Yashiro (2014) and Kihonge et al. (2014) rather focused on forecasting energy consumption using the various end-use approaches without estimating the elasticity of energy demand with respect to the various drivers of energy consumption. In terms of estimating causal relationships, notable exceptions are the studies by Adom et al. (2019), Albiman, Suleiman, and Baka (2015), Odhiambo (2009) and Ebohon (1996). While Odhiambo (2009) and Ebohon (1996) examined the causal relationships between energy consumption and economic growth, Albiman, Suleiman, and Baka (2015) examined the causal relationships among energy consumption, economic growth, and carbon dioxide emissions in Tanzania. Albeit these causal studies provide some insight into the possible causes of energy consumption, the bivariate nature of their analysis raises the issue of omitted variable bias, which can affect the outcome of their results. Adom et al. (2019) provided much deeper insight into the underlying causal factors of energy consumption in 27 African countries, which included Tanzania. Their study controlled for the effects of price, income, demographic variables, foreign direct investment, and financial crisis. However, their study was panel-based and did not offer deep insights into the country-specific dynamics. This is very important since the energy structure, consumer behaviour, and economic topography differ from one country to another. As a result, factors that might play an important role in one country may prove less important in explaining energy consumption trends in another country.

The above suggests that the literature on time series analysis of energy consumption in Tanzania is lacking. To the best of our knowledge, this study provides the first comprehensive time series analysis of energy consumption in Tanzania. This article makes the following contributions to the literature. First, we applied the Lasperyers Logarithmic Mean Divisia Index (LMDI) to decompose total energy consumption into structural, scale, and technical effects. Decomposing total energy consumption into different components gives a good understanding of the contribution of economic activities, changes in the production structure, and technological changes to energy consumption trends in various sectors of the economy. To the best of our knowledge, this is novel since we are not aware of any study that has performed such a decomposition analysis for Tanzania. Second, we applied an econometric technique to estimate the long-run elasticity of electricity demand. In this regard, the sources of novelty are derived from dealing with potential endogeneity (due to omitted variable bias) and serial correlation problems. Third, based on the estimated long-run elasticity of electricity demand, we forecast the contribution of economic growth, electrification program, population growth, and industrial growth to future electricity consumption. This is critical as it directs policymakers on how to target demand-side management programs. Finally, we estimate unconstrained electricity demand to capture unmet demand in Tanzania.

The rest of the study is organized as follows: Section 2 reviews the energy demand, supply, and cost in Tanzania. Section 3 discusses the data and method. Section 4 presents and discusses the findings. Section 5 concludes with policy recommendations.

2. Review of Energy Consumption, Supply, and Cost in Tanzania

This section reviews the trends in energy consumption, energy supply, and cost of energy in Tanzania. The section begins with a review of the trends in consumption (i.e. at aggregate and disaggregate levels) and then follows with a review of the trends in energy supply, energy balance, and cost of energy (with gender implications).

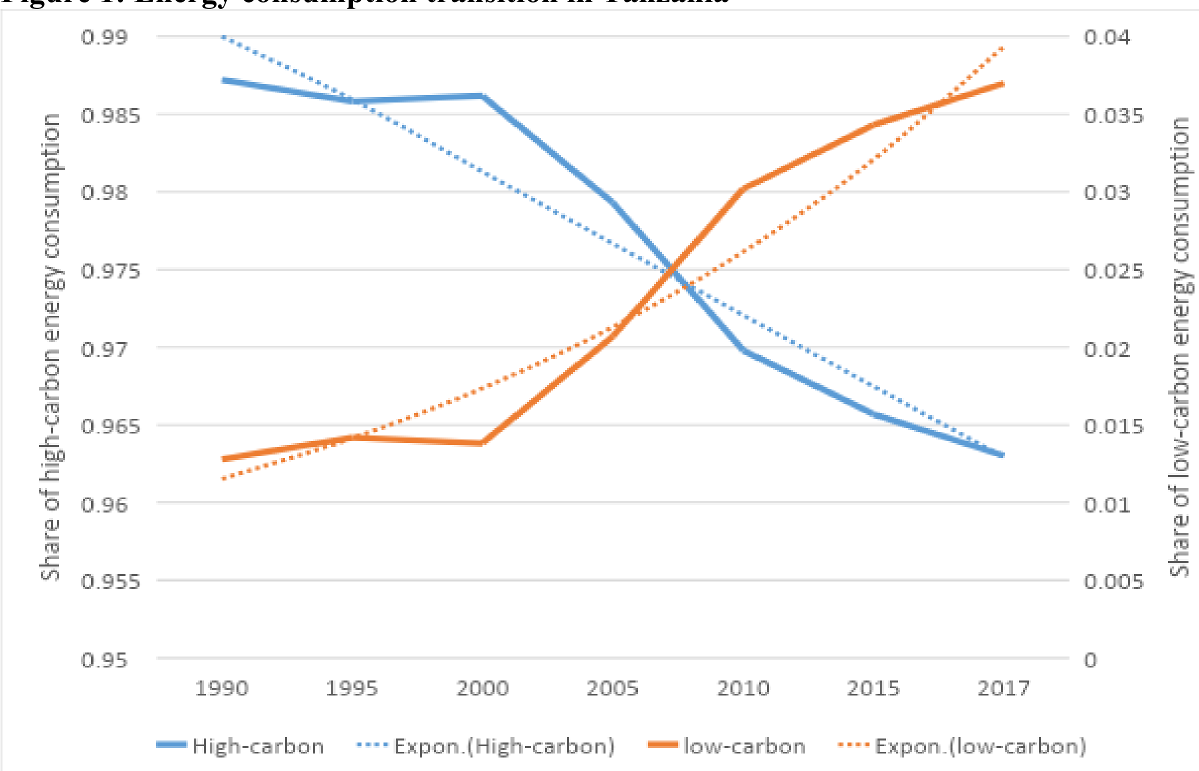
2.1. Review of Energy Consumption Trends

2.1.1. Trends in Total Primary Energy Consumption

Biofuels and waste dominate as the major energy-consuming source in Tanzania, constituting approximately 88% (five-year average) of total primary energy consumption. The next highest consuming source is oil, with a five-year average share of 8.8% followed by electricity, with a five-year average share of 1.94%. Natural gas and coal energy constitute a respective share of 0.38% and 0.54% of total primary energy consumption. Thus, high-carbon energy dominates total primary energy consumption in Tanzania. The current energy source composition implies that, in Tanzania, high-carbon energy consumption (i.e., Biofuel and waste, oil and coal) constitutes about 97.67% of total primary energy consumption, while low-carbon energy consumption (i.e., electricity and natural gas) constitutes 2.33% of total primary energy consumption. Generally, this portrays a picture of high energy-related carbon intensity, slow penetration of renewable and clean energies in the energy mix, and significant scope to improve the transition to low-carbon energy sources.

Despite the high share of high-carbon energy in total consumption, recent trends show a gradual transition towards low-carbon energy types (see *Figure 1*). The signing of the UN sustainable development goal agenda and the government of Tanzania's agenda to de-emphasise high-carbon energy types in favour of low-carbon energy types to save the environment could be potential reasons behind the current transition patterns. Though the current energy mix transition positions Tanzania as a potential green-growth-oriented and environmentally friendly economy, the progress has been very steady.

Figure 1: Energy consumption transition in Tanzania



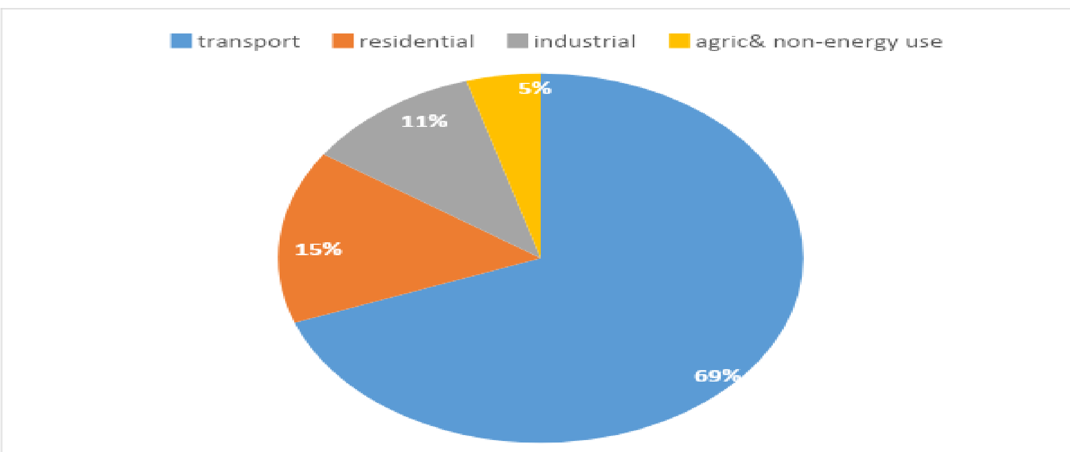
Source: Own compilation with data from IEA

Total primary energy consumption in Tanzania continues to increase. Under the period under review, the average five-year growth rate stands at 12.6%. The residential sector dominates in terms of the share of total primary energy consumption, with a share of about 70%. This is followed by the industrial, transport, and agricultural sectors. These positive trends detected in energy consumption patterns signal the need to invest in supply capacities.

2.1.2. Oil Products

The major consumer of oil products is the transport sector. The transport sector's oil consumption constitutes about 69.45% of total oil consumption. The next major consumers are the residential and industrial sectors, with a respective share of 15.21% and 10.94% of total oil consumption (computed by Authors using data from IEA, 2019). The consumption by the agricultural sector and for non-energy use purposes constitute a combined share of 4.58% of total oil consumption (see *Figure 2*). Among the different consumer groups, transport sector consumption of oil products has been very robust, driven largely by factors, such as economic growth, the influx of fuel-inefficient cars, the proliferation of second-hand vehicles, and population growth. Given the high carbon-intensive nature of oil products, the transport sector could be a major driver of atmospheric greenhouse gas emissions. Legislation to discourage the use of very old cars and encourage fuel-efficient cars is necessary.

Figure 2: Sectoral share of consumption of oil products (1990-2017)

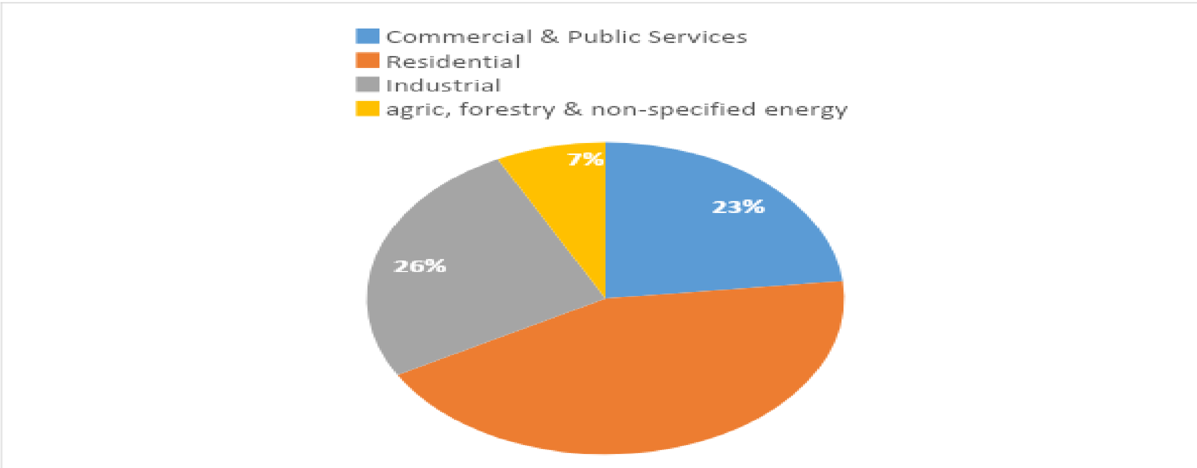


Data source: IEA

2.1.3. Trends in Electricity Consumption

The growth in electricity consumption has been astronomical in Tanzania. The residential sector dominates with a share in total consumption of about 43.6%; followed by the industrial sector, with a share of 25.7%. Commercial and public services consumption of electricity constitutes about 23.2% of the total, while the combined share of agricultural and forestry and non-specified consumption is about 7.44% (see *Figure 3*).

Figure 3: Sectoral share of Electricity Consumption (1990-2017)



Data source: IEA

For the period under review, the residential sector recorded an average (over a five-year period) growth rate in consumption of 39.9%. The next highest consumer categories are the industrial and commercial and public services sectors, with respective five-year average growth rates of 28.7% and 27.7%, respectively. The non-specified and agriculture and forestry classes emerged as the classes with the least average growth rate of 19.54% and 18.33% (per every five-year period), respectively. The major driving factors for electricity consumption are economic growth, population growth, industrialisation and rural electrification programs.

2.2.Energy Supply in Tanzania

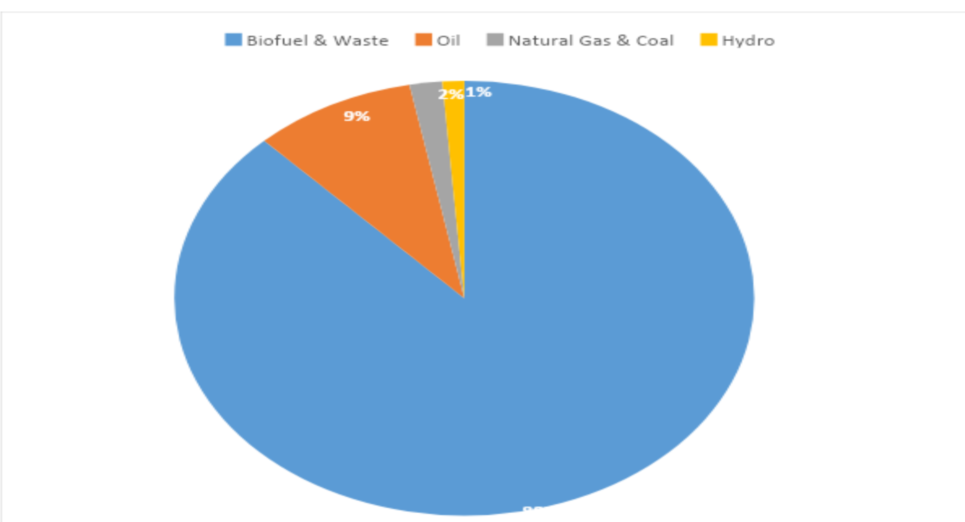
Total primary energy supply has been cyclical in nature, albeit, overall, it has increased consistently in absolute terms. Between 1990 and 1995, the total primary energy supply grew by 13.2% and further to 22.14% for the period 1995-2000. However, the growth in total primary energy supply fell to 14.6% in 2000-2005 and further to 11.85% in 2005-2010. This picked up in 2010-2015 to 14.66% only to fall drastically to 3.21% in the period 2015-2017 (using data from IEA). The cyclical nature of the trend shows that the total energy supply has been variable in Tanzania, and this has created access problems.

In terms of the distribution of energy supply by source, biofuels and waste constitute the major energy supply sources constituting about 88% of the total energy supply in Tanzania. Oil, natural gas, and hydro follow in that order; with respective shares of 9%, 1.8%, and 1.2% (see

Figure 4). The share of renewable energy supply in total energy supply constitutes only approximately 1.2% as against 98% for non-renewable energy supply. This is disturbing as it indicates a very low penetration rate for renewable energy in the total energy supply mix in Tanzania. Notwithstanding, there is a clear transition away from non-renewable energy to renewable energy since 2015 as the share of renewables take an upward trend (increasing by 0.079% from 2015 to 2017) against a downward spiral (by 0.08% from 2015 to 2017) experienced in the share of non-renewable energies. Largely, the transition towards renewables after 2015 can be attributed to the Government of Tanzania's (GoT) efforts through the Five-year development plan and the national energy policy to make renewable energy investment a priority in the energy sector. Unfortunately, the current investment commitments in renewables are on the lower side. This could constrain the country's attempt in terms of achieving the targets set for renewable energy.

On the other hand, the high share of non-renewable energy sources is a signal that energy-related carbon emissions might be on the ascendancy, and this places a moral obligation on GoT to embark on conscious aggressive programs targeted at green energy production. Given the huge potential that already exists in Tanzania, the current energy supply mix speaks volumes about the potential investment opportunities that exist in green energy production and the need to change the energy mix in Tanzania.

Figure 4: Share of Energy Supply by Fuel Type (1990-2017)



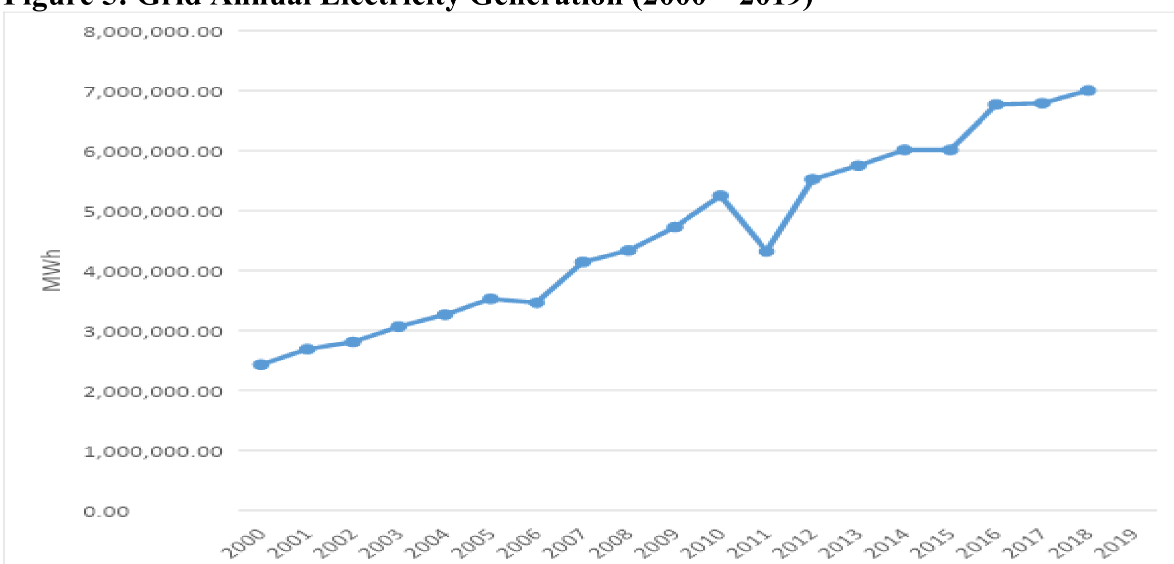
Data source: IEA

2.2.1. Total Electricity Supply

The production of electricity in Tanzania has increased generally but has fallen in some periods. There was a significant drop from 5,246GWh in 2010 to 4,318GWh in 2011, which represents a percentage decrease of 17.69%. The major cause was the hydrological crisis resulting from the lower water levels and a lack of oil supply. However, the grid annual supply has increased from 4.318 GWh in 2011 to 6,017GWh end of 2019 (See *Figure 5*). The load duration curve (see *Figure 6*) shows that there was less constraint on power supply in 2019 compared to 2010 and 2015.

In recent periods, the GoT has pursued aggressive generation of power from natural gas. This, among other things, is to reduce the dependence on hydropower energy sources and ensure a sustainable electricity supply, which is very essential to achieving the SE4-ALL goal in Tanzania. In 2017, out of the total power generation of 7,978 GWh, power generated from natural gas alone constituted a share of approximately 53% as against 29% for hydro and 17.1% for oil.

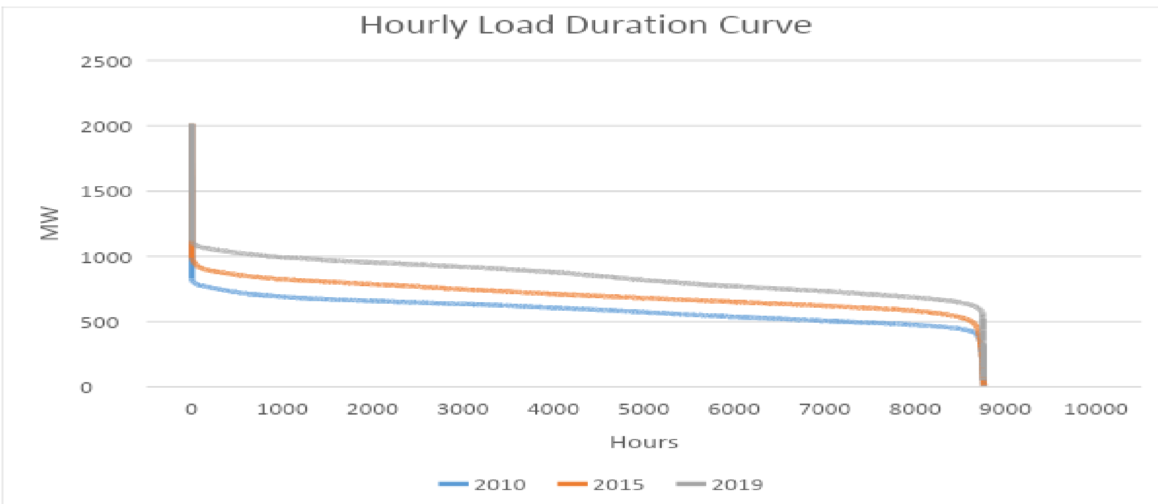
Figure 5: Grid Annual Electricity Generation (2000 – 2019)



Data source: TANESCO

In addition, solar energy is gradually growing in the total electricity mix. Between 2005 and 2017, 104 GWh of electricity was produced from renewable energy sources, with Biofuels constituting approximately 58% and Solar PV constituting 42%. This achievement can be regarded as significant given that it was achieved in less than a decade. Nonetheless, the rate of penetration of renewables is slow in the electricity sector, especially with the current switch to natural gas sources. The current dependence on natural gas, despite being less carbon-intensive, might subject consumers of electricity to higher tariffs in the future, which could negatively influence sustainable access to electricity in Tanzania. This is because the prices in the natural gas and oil markets are highly correlated. Therefore, the development of renewable energy sources in the electricity sector might prove very crucial in ensuring sustainable access to affordable electricity, which is critical for inclusive growth and development in Tanzania. Given the large potential Tanzania has in renewable energies such as hydro, solar, wind, geothermal, and biofuel, there exist significant investment opportunities in developing renewable power supply in the electricity sector.

Figure 6: Load duration curve 2010 - 2019



Data Source: TANESCO Annual reports

In terms of the carbon composition, recent production trends show that there is a gradual transition away from high-carbon electricity sources to low-carbon electricity sources, which is driven largely by the decommissioning of expensive fossil fuel plants by TANESCO and the high generation of electricity from natural gas. The current production structure of electricity in Tanzania is the fruit of some conscious efforts made in the past, such as the National Energy Policy (NEP) of 2015 (operationalised in the second Five-year development Plan [FYDP II, 2016]) and GoT intended action to combat climate change. The NEP sees energy efficiency and conservation as a critical cost-effective way to realize sustainable development in Tanzania. In the FYDP II, the government set the target to increase the share of renewables in the generation mix by 50% and 70% by the close of 2020/2021 and 2025/2026, respectively. In September 2015, the GOT set the

Tanzania 2030 Emissions Reduction Target when the country submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCC). The target is to reduce greenhouse-gas emissions by 10-20% by 2030. *Table 1* shows the intended actions and interventions made so far in the energy sector.

Table 1: Energy Sector Interventions Targeted at Reducing Emissions

Area	**Intended actions**	**Implemented programme**
Generation	Invest in energy diversification system to reduce energy emissions intensity.	
Renewable energy	Increase the share of renewables in power generation and diversify renewable energy sources (i.e., solar, wind, renewable biomass, and geothermal).	Renewable Energy Strategy (2014)
Natural gas	Increase the share of natural gas for power production, cooking, transport and thermal services.	Natural Gas Policy (2013), Natural Gas Act (2015)
Demand-side management	Promote energy efficient technologies for supply, transmission/transportation and demand side as well as behavioural change in energy use.	Energy Efficiency Action Plan, 11th European Development Fund (EDF) National Indicative Programme for Tanzania, EU Technical Assistance Facility (TAF) Assignment, USAID "Partnership for Growth –Energy Efficiency – Tanzania Programme", Energy audit by the Confederation of Tanzanian Industries (CIT) – DANIDA funded, GIZ "Sustainable Energy Programme"

Source: Intended National Determined Contributions (INDCs) report, 2012

2.3.Energy Balance

The balance between energy supply and energy demand is an important criterion used to assess the security of the energy system. In Tanzania, while significant expansions in generation capacity have been made by GOT, current demand requirements are growing rapidly making available supply insufficient to meet the demand requirement. The energy shortage is much prevalent in the electricity sector. With significant unserved demand, industrial activities in important emerging industrial hubs, such as the coastal regions have been significantly affected. The anticipated load for pending customers in these areas has been estimated to be more than 80MW (TANESCO, 2019). At the national level, the expected growth in industries and population is expected to exert significant pressure on the electricity system if significant investment is not made in expanding generation as well as improving the efficiency of generation. Equally critical are investments in energy efficiency and energy conservation and the establishment of cross-border trade in power.

2.4. Costing of Energy in Tanzania

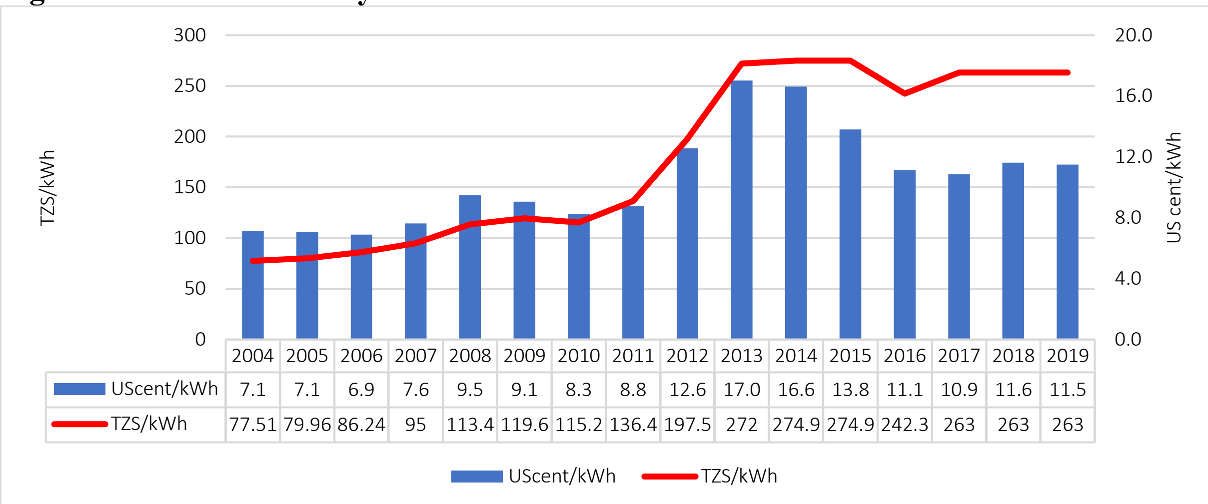
2.4.1. Costing of Electricity

Affordability is a major concern for countries working towards improving access to energy for their population. Estimates have revealed that, for countries working to achieve universal access, affordability issues affect about 57% of the people with access, while in the case of countries with already achieved universal access, issues of affordability affect about 30% of the population (IEA, IRENA, UNSD, WB, WHO, 2018). This makes the cost of energy in Tanzania and in any economy a critical policy and national issue.

The cost of electricity in Tanzania has remained a central issue in the bid to achieve an affordable and efficient supply (i.e., financially viable electricity sub-sector) of energy. The Electricity and Water Utility Regulatory Agency (EWURA) is the regulatory unit that is mandated by the Electricity Act ("Cap. 131") and EWURA Act ("Cap. 414") to review electricity tariffs in Tanzania. In setting the tariffs, the following guidelines are followed: (1) reflect the cost of efficient business operation, (2) recover a fair return on approved investments, (3) ensure price stability, (4) access charges based on comparable charges for comparable use, (5) pay in accordance with the costs imposed, (6) enhance efficiency in consumption and supply, and (7) promote competition and attract investment. However, in setting the tariff, the above guidelines have not been adhered to strictly due to issues of non-competitiveness, energy poverty, and politics. The result is the emergence of a non-cost reflective tariff and huge government expenditure on energy subsidies. The former has been blamed for the financial woes of TANESCO.

Historically, electricity prices have been held administratively low prior to the 2000s. However, recent developments post-2000 period show upward movements in electricity prices (in some part driven by expensive Emergency Power Purchase Agreements). *Figure 7* shows the trend in the average electricity tariffs in USD cents and Tanzania Shillings TZs in kWh. Between 2004 and 2008, the average end-user tariff increased from 77.51 TZS/kWh to 113.37 TZS/kWh, which represents an increase of 46.2%. The percentage increase in 2007/2008 alone was about 20%. This was largely due to the poor electricity supply experienced, which forced the country to depend on expensive Emergency Power Projects (EPP). There was a marginal increase in the price in 2009 but it fell in 2010. Between 2011 and 2014, however, the price of electricity doubled. The recent levels rank Tanzania's electricity price as the second highest among some countries in East and Southern Africa. *Table 2* shows the average electricity tariff for 2018 for selected countries in East and Southern Africa.

Figure 7: Plot of Electricity Tariffs in Tanzania



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UScent/kWh	7.1	7.1	6.9	7.6	9.5	9.1	8.3	8.8	12.6	17.0	16.6	13.8	11.1	10.9	11.6	11.5
TZS/kWh	77.51	79.96	86.24	95	113.4	119.6	115.2	136.4	197.5	272	274.9	274.9	242.3	263	263	263

Source: EWURA and TANESCO Annual reports

Electricity tariff has three main component charges, which differ among the different consumer classes according to their voltage levels. They are the service charge, energy charge, and demand charge. While the service and energy charges apply to the domestic low usage and general-use consumer categories, all three component charges apply to the other consumer categories[5]. All three-component charges have increased during the period 2005 – 2015, albeit there were periods of no change, for all the consumer classes. However, in 2015, there was a downward adjustment in the energy charge component for all the consumer categories, which ranged from 3TZS/kWh to 8TZs/kWh (EWURA, 2017).

Further reductions in the energy charge occurred in 2016, with the percentage reduction ranging from 1.5% to 2.4%. However, there was an approved tariff increase by EWURA in the

[5] There was a reclassification of consumer groups between 2014 to 2016 and 2017 onwards. Between the period 2014 and 2016, T3-MV (customers connected to medium voltage) was introduced while Zanzibar supply dropped from the category. The 2017 period and onward reclassified the general user category into two (i.e., T1a – residential customers and T1b – light industrial use, communication towers, and billboards. ZECO was also introduced as an additional consumer class to capture sales made to ZECO, connected at high and medium voltage.

energy charge component in 2017 for all categories, with a percentage increase of between 5.7% and 8.8%, but this was declined following the directives of the government.

Table 2: Comparison of electricity tariffs

Member Regulator	Average Electricity Tariff (USD Cents/kWh)	Currency Exchange Rate
CNELEC (Mozambique)	**7.50**	
ECB[6] (Namibia)	**19.00**	US$1 to N$11.84
ERB[7] (Zambia)	**5.32**	US$1 to K10.84
EWURA[8] (Tanzania)	**10.79**	US$1 to TZS 2,245.39
IRSEA[9] (Angola)	**3.17**	US$1 to 166.71 Kwanza
LEWA[10] (Lesotho)	**7.48**	US$1 to M14.53
MERA[11] (Malawi)	**8.00**	US$1 to MK733.50
NERSA[12] (South Africa)	**6.62**	US$1 to R13.47
SERA[13] (Swaziland)	**10.37**	US$1 to SZL13.45
ZERA[14] (Zimbabwe)	**9.86**	

Source: EWURA and TANESCO Annual reports

Several factors affect the cost of electricity service in Tanzania. Important among these factors include staff cost, finance cost, distribution expenses, depreciation, purchased electricity, own generation, and transmission. However, among these factors, own generation and transmission and purchased electricity constitute a significant share of the total cost of service in Tanzania. Own

[6] Functional breakdown in USD Cents/kWh is as follows: Generation – 11.1; Transmission – 2.4 & Distribution – 5.9 for a total amount of 19 USD cents.

[7] Functional breakdown in USD Cents/kWh is as follows: Generation - 1.12; Transmission - 1.99; Distribution 0.83 - & Supply - 1.38.

[8] Customer category breakdown in USD Cents/kWh is as follows: Lifeline – 4.45; Residential and Small Commercial – 13.00; Commercial – 8.68; Medium Voltage – 6.99 & High Voltage and Bulk Supply – 6.77

[9] The average tariff is about 5.29 Kwanza/kWh. Customer category breakdown in Kwanza/kWh is as follows: High Voltage – 4.70; Medium Voltage – 5.13; Low Income Rates – 2.46; Social Domestic – 3; General Domestic – 6.53; Special Domestic – 7.05; Trade Service and Industry – 7.05 & Public Lighting – 4.73.

[10] The average tariff is 7.48 US Cents. Customer category breakdown in USD Cents/kWh is as follows: Residential – 8.94; Commercial not demand metered – 10.11; Street Lights – 5.07; Large Power customers: High voltage – 1.24 and low voltage – 1.37(Large power customers are also charged maximum demand). The tariffs exclude levies and tax.

[11] Customer category breakdown in USD Cents/kWh is as follows: Residential – 7.0, Commercial – 10.0 & Large Power Users – 10.0.

[12] The 6.62 US Cents/kWh is an Eskom average price that also serves as wholesale price to municipalities. On this price municipalities would generally add a mark-up of 60% (different mark-ups by different municipalities). This would then result in an average tariff of 10.59 US cents/kwh. Please note that the 60% mark-up is just a benchmark and would be different from each municipality. Tariffs for municipal distributors could range from 9.0 USD Cents/kWh to 12.0 USD Cents/kWh also depending on the customer class, the consumption and the tariff options.

[13] Customer category breakdown in USD Cents/kWh is as follows: Lifeline – 8.67; Residential – 9.33; General purpose – 12.94; Small Commercial prepayment – 12.94; Small Commercial Credit – 12.94; Small Holder irrigation; 4.91; Large Commercial and Industrial – 5.77; Large irrigation – 5.77.

[14] Customer category breakdown in USD Cents/kWh is as follows: Domestic – 10.0, Commercial – 12.0 & Large Power Users – 8.43.

generation and transmission, on average, account for about 30% of the total cost of service while the purchase of electricity accounts for about 24% of the total cost of service. *Table 3* shows the total cost of service (in TZs billion) for the financial years 2014/15, 2015/16, and 2016/17. Own generation and transmission costs increased between 2014/15 and 2015/16 due to the commencement of Kinyerezi 1 Power generation Plant but decreased in the following period as a result of the reduction in generation from grid-connected Mwanza HFO power plant and other grid liquid fuel power plants[15]. Both distribution expenses and depreciation costs have increased consistently. The reason for the former is that there has been a continuous receipt of a large distribution network that was handed over from the Rural Energy Agency (REA).

Table 3: Total cost of service (electricity)

Item	2014/15	2015/16	2016/17
Other operating costs	113	224	72
Staff costs	73	71	67
Finance costs	193	159	121
Distribution expenses	225	256	260
Depreciation	103	141	340
Purchased electricity	393	484	373
Own generation and transmission	458	565	456

Data source: EWURA reports

2.4.2. Costing of Electricity and Gender

Discrimination against women in social institutions in Tanzania is on the rise (EACREE, 2018). For areas such as health, education, economy, and politics, the Gender Gap Report (World Economic Forum, 2016) shows that Tanzania has successfully closed about 72% of the gender gap. However, in energy, there is still significant gender inequality both in access and affordability. The current tariff structure in Tanzania is not gender-sensitive. The commercial tariffs in Tanzania are currently lower than the domestic tariffs (TANESCO, 216; EWURA, 2017). But between men and women, men are more likely to work in formalised businesses than women. By implication, the current tariff structure might be imposing more electricity charges on women than men in Tanzania. This potential gender inequality has to be thoroughly investigated and dealt with by designing a tariff structure that is gender sensitive. GoT has instituted the Sustainable Energy for All Gender

[15] Mwanza HFO and other grid fuel plants generation were curtailed following commissioning of the Iringa to Shinyanga 400 kV line.

Action Plan (SE4All-GAP). However, awareness about SE4All-GAP among stakeholders in the energy sector is less.

2.4.3. Domestic Prices of Petroleum Products

The Energy and Water Utilities Regulator Authority (Petroleum Products Price Setting) Rules, 2017, authorises EWURA to set monthly petroleum wholesale and retail cap prices for kerosene, petrol, and diesel. Since Tanzania depends largely on imported petroleum products, price developments in the world market are transmitted to the local market. For example, in 2018, the average world market price of crude oil was 71.43 USD/BBL. This represented an increase of 31.7% over the price in 2017. Not surprisingly, the higher world price was transmitted to the domestic market. In that same year, the average domestic price for diesel and kerosene rose by 32%, while the average domestic price of petrol rose by 24%, when compared with the price in 2017 (see *Table 4* for the monthly prices of these products in 2018 for Tanzania).

Table 4: Average retail cap price ex Dar es Salaam 2017-2018 (TZS/Lt)

Month	Petrol	Diesel	Kerosene
Jan-2018	2,167	2,018	2,031
Feb-2018	2,226	2,065	2,055
Mar-2018	2,227	2,134	2,059
Apr-2018	2,315	2,205	2,154
May-2018	2,227	2,145	2,154
Jun-2018	2,282	2,164	2,192
Jul-2018	2,409	2,329	2,192
Aug-2018	2,384	2,292	2,271
Sep-2018	2,373	2,273	2,247
Oct-2018	2,368	2,304	2,247
Nov-2018	2,396	2,385	2,280
Dec-2018	2,436	2,436	2,368
Average – 2018	**2,318**	**2,229**	**2,188**
Average – 2017	**2,004**	**1,873**	**1,832**
Change (%)	**16**	**19**	**19**

Data source: EWURA

Given that the natural gas market and oil market correlate in terms of price developments, the rise in petroleum products drives prices of natural gas to go up. The consultants observe that, with the recent dependence on gas for electricity, there could be possible future affordability issues that electricity consumers in gas-dominated electricity systems might face. More worrying is the issue of the non-discrimination in prices between urban and rural settlements, where access to electricity is a big problem. Though in the interim the government can rely on its subsidy program to provide cost relief to consumers (rural), this might prove very unsustainable given the very tight budget most governments run. To achieve sustainable access to electricity, which is very affordable, the design of effective and efficient power purchase agreements as well as finding an optimal generation mix that is cost-effective would prove very crucial in the future. An equally important approach would be for the government to look for opportunities in pricing designs that discriminate between rural and urban dwellers and possibly between women and men.

3. Data and Method

This section describes the data and variables, and the methods used to decompose energy consumption, estimate long-run electricity demand and constrained and unconstrained electricity demand.

3.1. Data

This study used time series data to analyse the trends in energy consumption. For the decomposition of energy consumption, we used data on total energy consumption, industrial energy consumption, agricultural energy consumption, and energy consumption from the service sector from 1990 to 2017 measured in kilotons of oil equivalent (ktoe). Energy consumption from the service sector included energy consumption from the transport sector, commercial and public services, residential, non-specified, and non-energy use. Real gross domestic product is used to denote the overall economic activity, while the value added in industry, agriculture, and service sectors were used to denote the output in each sector. Data on total energy consumption and sectoral energy consumption come from the International Energy Agency (IEA) Statistics, while data on sectoral output was taken from the World Bank Development Indicator (WDI) database.

For the long-run analysis of electricity demand, we used time series data from 1990 to 2018. We measure total electricity consumption as kWh per capita. Real GDP is used to measure the effects of income, while the real average end-user tariff of electricity is used to capture the price effects. We used the consumer price index to deflate the nominal average end-user tariff. The value added in industry is used to capture the level of industrialisation. Population density is measured as the total population per square kilometre of land area. The electrification rate is the total number of the population that has access to electricity. Data on real GDP, industry value added, population density, and electrification rate was taken from WDI, while data on electricity price come from TANESCO and EWURA, and Marandu (2002).

3.2.LMDI for Energy Consumption

To analyse the drivers of total primary energy consumption, we used the Lasperyres Mean Divisia index decomposition to decompose total energy consumption into three effects: activity effect (Q_{effect}), intensity effect ($\mathrm{I_{effect}}$), and structural effect ($\mathrm{S_{effect}}$). The activity effect gives the contribution of changes in overall economic activity (i.e., national gross domestic product) to total energy consumption. The intensity effect captures the contribution of changing energy intensities at the sectoral level. At the sectoral level, intensity changes are driven by technical energy efficiency changes and changes in processes and product mix. The structural effect gives the contribution of shifts in the share of economic activities at the sectoral level.

Equations 1 to 3 show how these effects were computed. Q refers to overall level of economic activity (measured using GDP in constant prices); EI_i is the energy intensity in sector i ($\frac{E_i}{Q_i}$); S_i is the share of sector i's output in total GDP in constant prices; E_i is the total energy consumed by sector i; Q_i is the output of sector i, and T and 0 refer to the current and base periods. The overall explained effect of the changes in energy consumption is the sum of the three effects.

$$Q_{effect} = (Q^T - Q^0)\sum_{i=1}^{N} EI_i^0 * S_i^0 \qquad (1)$$

$$I_{effect} = Q^0 \sum_{i=1}^{N} (EI_i^T - EI_i^0) S_i^0 \qquad (2)$$

$$S_{effect} = (Q^0) \sum_{i=1}^{N} (S_i^T - S_i^0) EI_i^0 \qquad (3)$$

3.3.Estimate of Long-run Electricity Demand Elasticity

Our estimate of the long-run electricity demand is motivated theoretically by the neoclassical demand for inputs and empirically by studies such as Adom et al. (2019), Paramati et al. (2018), Adom (2017), Keho (2016), and Kebede, Kagochi and Jolly (2010). Nonetheless, the current study differs in structure from the other empirical studies. Except for the study by Adom (2017) that analysed electricity demand, the rest estimated total energy demand. Among these studies, only the studies of Adom et al. (2019), Adom (2017), and Kebede, Kagochi, and Jolly (2010) controlled for the effects of price, but only the estimate of price elasticity by Adom (2017) can be compared to the present study's estimate because the author used the price of electricity, albeit their study was on Ghana. Further, compared to the study by Adom (2017), the present study's model is more expanded and less likely to suffer from omitted variable bias. Lastly, all the studies mentioned above, none of them considered the role of electrification rate in their model, which is very critical from a developing economy perspective. Thus, the empirical specification in this study differs from previous studies.

Empirically, we modelled electricity demand per capita as a function of real GDP per capita (y), the square of real GDP per capita (y^2), the real price of electricity (rpe), electrification rate ($elec$), population density (pd), and the level of industrialisation ($indust$)[16]. This is depicted in Equation (4). The square of income was included to test for the existence of energy Kuznets curve in Tanzania[17]. At lower levels of development, limited substitutability options, less-developed technologies, and environmental illiteracy could see consumption levels of electricity rise as development or growth progress. However, with time, the availability of substitutes, improved technological innovation, and the awareness of environmental and resource sustainability could cause further growth or development to lower electricity consumption. The energy kuznets curve exists if $\beta_1 > 0$ and $\beta_2 < 0$ (see Eq. 5). Otherwise, the evidence of energy kuznets curve cannot be substantiated.

[16] All the variables in Equation 1 have been transformed into their natural logs making the interpretation of the coefficient direct elasticity.

[17] Interested readers should check Adom et al. (2019), Ahmed (2017), and Pablo-Romero et al. (2017).

$$elc_t = \alpha + \mu trend + \beta_1 y_t + \beta_2 y_t^2 + \gamma rpe_t + \delta elec_t + \theta indust_t + \vartheta pd_t + \varepsilon_t \qquad (4)$$

$$\frac{\partial elc_t}{\partial y_t} = \beta_1 + 2\beta_2 y_t \qquad (5)$$

The Canonical cointegration regression (CCR) by Park (1992) and the fully modified ordinary least squares (FMOLS) by Phillip and Hansen (1990) were used to estimate Equation 4. The CCR and FMOLS correct for problems of endogeneity (using an instrument approach) and serial correlation (i.e., persistence in the residual error). Albeit these methods use different correction mechanisms for endogeneity and serial correlation, qualitatively, they produce similar results. Two important requirements, which include a test for unit root and a test for a long-run relationship, were performed. The test of unit root based on the Generalised Least Square Augment Dickey-Fuller (ADF_GLS) and Phillip-Perron tests revealed that the series becomes stationary after first differencing, which makes them pass the long-run equilibrium relationship test. The test for long-run equilibrium relationship was based on the residual-based tests by Engle and Granger (1987) and Phillips and Ouliaris (1990). The tests confirmed the existence of a long-run equilibrium relationship, which means that income and its square, the real price of electricity, electrification rate, level of industrialisation, and population density are the true long-run 'forcing' variables that explain the changes in total electricity consumption in Tanzania.

3.4.Estimating constrained and unconstrained electricity demand

Recorded demand does not necessarily represent the true demand due to unmet demand (normally caused by a deficiency in electricity supply). For example, during periods of lower water levels in the hydro sites, temporal or permanent shutdown of thermal plants, and repair works and faults on distribution and transmission networks, there is a restrain on electricity demand. As a result, recorded electricity demand may not depict the true electricity demand. However, during periods of excess supply of electricity, there is no restraint on electricity demand. Consequently, recorded demand depicts the actual demand. This means that for a typical electrical system, restrained and unconstrained demand may occur at different times.

Unconstrained demand (UC_{Dt}) is computed as the sum of restrained demand (RS_{Dt}) and the product of restrained demand (RS_{Dt}) and potential factor (PF_t), where the potential factor is one minus the ratio of actual/recorded demand (AR_{Dt}) divided by the forecasted demand (FC_{Dt}). Mathematically, it is depicted by Equations (6) and (7).

$$UC_{Dt} = RS_{Dt} + RS_{Dt} * PF_t = RS_{Dt}(1 + PF_t) \quad (6)$$

$$PF_t = 1 - \frac{AR_{Dt}}{FC_{Dt}} \quad (7)$$

4. Results and Discussion

4.1.Decomposition of energy consumption

For the periods considered (i.e., 1990-1995, 2000-2005, 2010-2015, and 2015-2017), actual total primary energy consumption increased by 12.05%, 11.6%, 14.7%, and 3.03%, respectively. Figure 8 shows the decomposition results, where AE, SE, IE, and OE denote activity effect, structural effect, intensity effect, and overall explained effect, respectively. For the period 1990-1995, albeit the industrial sector and transport, commercial and residential sectors experienced structural shifts that reduced the energy requirement, overall energy consumption increased primarily due to expanded activities and energy inefficiencies recorded in all sectors. In the industrial sector, the proliferation of outdated equipment and under-utilised capacity in most factories could explain the inefficiency in energy consumption experienced in the sector (IRENA, 2017).

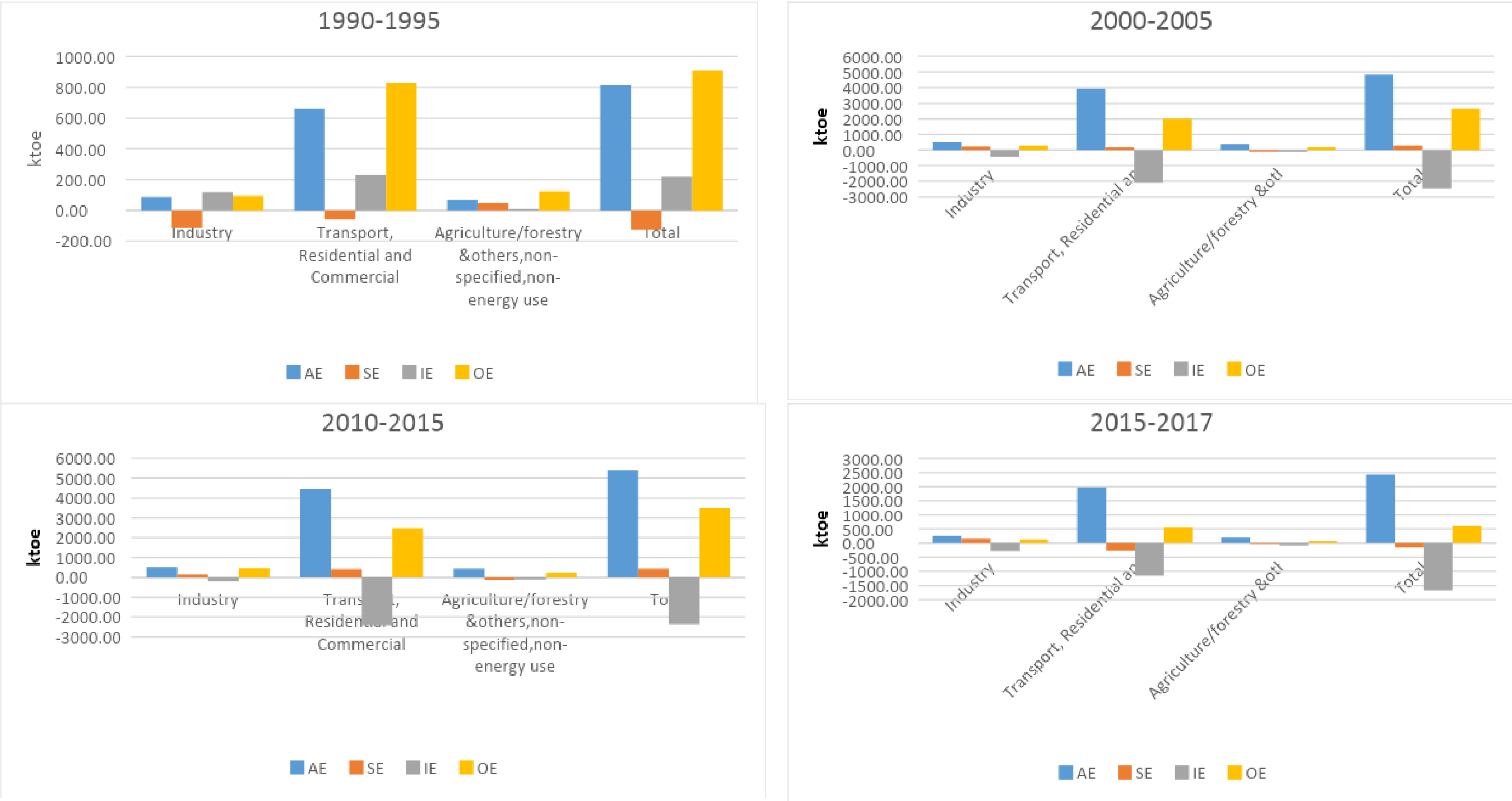
During the period 2000-2005, all the sectors experienced some improvements in energy efficiency and changes in process and product mix as indicated by the negative intensity effects recorded for all sectors. However, this was not enough, as the expanded economic activities in these sectors and structural shifts in favour of energy-intensive products caused energy consumption to increase in this period. In terms of ranking, the activity effect and intensity effect were the two most important drivers of energy consumption in this period, but the former effect was much stronger.

For the period 2010 – 2015, energy efficiency improved in all sectors as shown by the negative intensity effects, but this was much greater in the services sector. Except for the agricultural sector, where the structural effect was negative (an indication that there was a shift in production towards less energy-intensive products), the structural effect for the rest of the sectors was positive (an indication that production shifted towards high energy-intensive products). The activity effect was positive for all sectors, which means that expansion in economic activities in all sectors contributed positively to energy consumption. Comparatively, the combined positive activity and structural effects dominated the negative intensity effect, and this caused total energy consumption to increase during this period. Among the factors, the activity effect explained much of the variation followed by the intensity effect, with the structural effect producing the least of the effects.

A similar trend was recorded in the period 2015-2017. The activity effect was the dominant driver of energy consumption followed by the intensity effect. Energy efficiency improved in all sectors, but it was greater in the services sector. In large part, the significant improvement in energy consumption efficiency since 2005 could be due to the implementation of the National Energy Policy 2003 and 2015. Moreover, in the services sector, the use of improved cooking stoves in the case of the residential sector and the installation of solar PV for lighting and water pumping for the commercial sector could partly explain the improved use of energy.

In sum, for all the periods considered and for all sectors, activity effect is the main positive contributor to energy consumption followed by intensity effect and structural effect in that order. This confirms the claim that, in Tanzania, economic activity is a major driver of energy consumption. By implication, the predicted growth trend in economic activities in Tanzania suggests equal parallel movements in generation, transmission, and distribution capacities to deal with any potential rise in energy consumption.

Figure 8: Decomposition of Primary Energy Consumption (1990 – 2017)-ktoe



4.2. Drivers of Electricity Consumption

4.2.1. Correlation based analysis

We used the Pearson correlation to examine the association between electricity consumption and key demand factors, viz, electrification rate, the real price of electricity, income per capita, population density, and industrialisation. Table 5 shows the results. Real GDP per capita, level of industrialisation, population density, urban and rural electrification rate, and total electrification rate have a positive and high correlation with total electricity consumption, but the correlation is relatively weaker for rural electrification rate compared to urban electrification rate. This can be explained by the high energy-intensive nature of activities in urban areas visa-vis the less energy-intensive nature of activities in rural areas. On the contrary, the real price of electricity has a negative correlation with total electricity consumption, and the correlation coefficient is 86% approximately. The possible transmission mechanisms might include a deliberate cut down of electricity consumption due to the higher electricity bill and investment in energy-efficient appliances to optimise the use of energy efficiently.

Table 5: Key drivers of electricity consumption (1990 -2018)

	Real GDP per capita	Real price of electricity	Industry value Added (% GDP)	Pop. Density	Rural electr. (% rural pop.)	Urban electr. (% urban pop.)	Total electr. (% total pop.)
Total electricity consumption (net)	0.94438 [14.3586] (0.000)	-0.8642 [-8.5868] (0.000)	0.8458 [7.9257] (0.000)	0.9502 [15.2513] (0.000)	0.63573 [4.1179] (0.0004)	0.9310 [12.750] (0.000)	0.9040 [10.5706] (0.000)

Figures in [] denote t-statistics and figures in () denote the probability values.

4.2.2. Estimate of Long-run Electricity Demand

Correlation-based analysis does not establish a cause and effect relationship. *Table 6* shows the regression-based results. The effect of income on electricity consumption is concave (confirming the results of Adom et al. 2019), and this is statistically significant, which suggests the existence of an energy kuznets curve in Tanzania. In other words, there exists an income threshold, beyond which further increases would result in lower electricity consumption. By implication, economic growth could spur structural reforms in technology and environmental awareness to trigger reductions in electricity. The income elasticity evaluated at the mean is 0.6531, which means that electricity consumption will go up by 6.53% following a 10% increase in real income per capita, all things being equal. The positive effect of income is consistent with the findings of Adom (2017), Kebede et al. (2010), Paramati et al. (2018) and Keho (2016).

Table 6: Regression-Based Results on the Drivers of Electricity Consumption

Variables	CCR	FMOLS
Real GDP per capita: y_t	12.1722*** (3.4943)	11.9931*** (1.9245)
Squared of real GDP per capita: y_t^2	-0.9806*** (0.2748)	-0.8726*** (0.1516)
Real price of electricity: rpe_t	-0.1869*** (0.0315)	-0.1081*** (0.0151)
Electrification rate: $elec_t$	0.1897*** (0.0212)	0.1525*** (0.0128)
Industrialisation level: $indust_t$	0.0816 (0.0585)	0.1958*** (0.0309)
Population density: pd_t	4.5221*** (1.7680)	4.1081*** (1.1709)
Time Trend: $trend$	-0.1042** (0.0491)	-0.1206*** (0.0321)
Constant: α	-49.0991*** (16.5384)	-51.1249*** (9.6436)
Adjusted R-squared	0.7936	0.8065

Figures in () denote the standard errors. ***, ** and * denote 1%, 5% and 10% significance level. The dependent variable is the log of total electricity consumption per capita (net). Canonical cointegration regression (CCR). Fully Modified Ordinary Least Squares (FMOLS).

The price of electricity has a significant negative effect on electricity consumption, and the effect is inelastic. The elasticity suggests that raising the price of electricity in Tanzania by say 10 percent would cause consumers to reduce their consumption of electricity by 1.87%, all things being equal. A tax on electricity price, which is targeted at high-consuming classes could prove useful[18]. However, such a tax policy should be progressive in nature to encourage high-consuming classes to invest in demand management strategies. The price inelasticity of electricity demand means that, as a demand-side management strategy, pricing policies should be effectively combined with other demand-side management policies such as load management to achieve a

[18] A study by ICF international (2014) found that, though there are demand savings opportunities across all consumers, they are much higher in the industrial sector.

significant result in demand management in the electricity sector[19]. The negative price elasticity is consistent with the findings of Adom et al. (2019), Adom (2017), and Kebede et al. (2010).

Increasing the rate of electrification in Tanzania has a significant positive effect on total electricity consumption. According to the estimated elasticity, an increase in the electrification rate by 10 percent will cause total electricity consumption to increase by approximately 2 percent in the long run, all things being equal. Increasing electrification rate implies getting previous unserved communities connected to the grid. However, the positive effect of the rate of electrification on total electricity consumption is strictly conditioned on the availability of electricity supply. Without improved electricity supply, intensifying the rate of electrification would only put pressure on the system and in the end deprive most consumers of electricity supply, thereby defeating the original purpose of improving electricity access. With the current access rate of less than 40% and a target of universal access by 2030, GOT requires significant investment in new generation and demand-side management strategies. On the former, GOT has made progress by encouraging solar home systems and increasing generation capacity with natural gas, but this is still below the expected investment efforts required on the supply side. On the latter, not much has been achieved. However, there are significant gains that Tanzania can benefit from investing in demand-side management programs.

Both the levels of industrialisation and population density have significant positive effects on total electricity consumption, but the effect for the latter is greater. According to the estimated elasticity, increasing the rate of industrialisation and population density by 10 percent could increase total electricity consumption, respectively, by 0.82 – 1.96 percent and 41.1 - 45.2 percent. Again, the positive effects of industrialisation and population density on electricity consumption requires that GOT make a significant investment in the supply and demand side of the electricity sector to ensure the sustainability of the electricity system. The positive effects of industrialisation and population on electricity consumption confirm the findings of Adom et al. (2019), Paramati et al. (2018), and Keho (2016) but contrast the findings of Kebede et al. (2010).

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[19] Demand side management programs can cost-effectively reduce system peak demand by 11.5% after five years in Tanzania (ICF International, 2014).

4.3. Forecasting Electricity Demand

Effective management of the electricity system requires accurate information about future demand trends. This makes forecasting energy demand critical to system planning especially in terms of making the optimal investment, as investment requirements in the sector can be very hefty. This section provides both a trend forecast and a conditional forecast (based on the estimated elasticity in *Table 6*) of future electricity consumption per capita.

4.3.1. Trend forecast

We performed a 10-year trend forecast (2020 to 2030) for net total electricity consumption per capita (kWh). The authors compared the forecasting abilities of different trend models (i.e. linear trend, a polynomial of order 3, and a two-year moving average)[20]. The case for the polynomial trend showed the lowest forecasting error[21]. Therefore, the forecasts are based on the polynomial trend of order 3. Total net electricity consumption is expected to increase ad infinitum. The increase on a per annum basis is expected to be steady, averaging at approximately 3.5 percent. In the medium–term (i.e. 2020 – 2025), the average annual prediction is 169.55 kWh per capita compared to the long-term (i.e. 2026 – 2030) average annual prediction of 170.398 kWh per capita. Compared to the actual value recorded in 2018, the medium-term and long-term forecasted annual averages represent an increase of 39.5% and 39.8% in net electricity consumption per capita, respectively.

4.3.2. Conditional Forecast of Total Net Electricity Consumption

Trend forecast may underestimate the important contribution of other factors to future electricity consumption. As a result, based on the estimated parameters in Table 6, we obtained a ten-year forecast, using the *all else equal* assumption. Specifically, we analysed what it would look like if the rate of electrification, population density, and real GDP per capita changed independently. Thus, the conditional forecast makes it possible to ascertain how much of the predicted future growth in

[20] These trend models seem to depict the electricity consumption well, with an r-square value of between 86% and 91%. The R-square shows the percentage of the total variation in total electricity consumption that is explained by the time trend.

[21] For all the forecast evaluation criteria, the statistics look relatively good for all the trend models. The Mean absolute percent error for all cases is lower than 10 percent, which according to Lewis (1982) signifies high accurate forecast. However, comparatively, the case of the polynomial trend is 3.43 percentage points lower than the two-year moving average and 2.4 percentage points lower than the linear trend model.

total electricity consumption can be attributed to the expansion of electrification rate, economic growth, and population growth. The main assumption here is that the corresponding elasticity for these driving variables is stable during the forecast period. This certainly can pose a problem especially if there is a significant structural break in the data. However, our initial test of parameter instability showed otherwise, which means that the assumption of constant elasticity is a valid claim within the period considered for this study. The reliability of the conditional forecast was ascertained by restricting the estimation sample to 2013 and then used the period 2014 – 2018 to perform an in-sample forecast. The indicators suggest high accurate forecast of the model.[22]

The Government of Tanzania's target for electrification rate is to reach 50% by 2020 (representing an increase of 52.38%, using 2017 figures as the base), 64% by 2025 (representing an increase of 28%, using the 2020 target as the base) and 76% by 2030 (representing 18.75% using the 2025 target as the base)[23]. These targets imply that total net electricity consumption per capita based on the estimated elasticity is expected to increase by 8% by 2020, 4.3% by 2025, and 2.87% by 2030[24]. The average national electrification rate is expected to increase by 56.21% during the period 2020–2030 (forecast values taken from the PSMP 2016 update). Correspondingly, total net electricity consumption per capita is projected to increase by 8.6%, all things being equal. On average, the expansion of electrification program is expected to increase total net electricity consumption per capita by 0.876% per annum (see Table in appendix). In terms of kWh per capita added to total consumption due to electrification, it is predicted to be 12.071 kWh per capita between 2020 and 2030 (see *Table 7*); this represents 12.5% and 20.42% of the total national net electricity consumption per capita recorded in 2010 and 2000, respectively[25]. The possible reason for the predicted slow growth in total net electricity consumption due to electrification programmes is that most of these programmes target the rural population, whose activities are less energy intensive.

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[22] The mean absolute error is 0.1457. The root mean squared error is 0.1635. The mean absolute percent error is 3.1475, which is less than 10%. Lastly, the Theil Inequality coefficient is 0.0174.

[23] The electrification targets are based on Power Sector Management Plan (PSMP, 2016 update).

[24] Forecasted percentage increase in net electricity consumption per $capita_t$=elasticity of electrification $rate_t$*Percentage change in forecasted national electrification $rate_t$

[25] kWh per capita consumption $added_t$=total net consumption per $capita_{t}$-1*growth rate in consumption due to $electrification_t$

Primarily, electricity in these areas is used only for lighting and to a smaller extent cooking and heating.

Table 7: Forecasted Change in Net Electricity Consumption

Year	kWh per capita added due to electrification	kWh per capita added due to population	kWh per capita added due to economic growth
2020	3.066	12.219	3.036
2021	0.460	13.540	2.610
2022	1.603	15.019	2.767
2023	0.156	16.649	3.121
2024	1.667	18.413	3.330
2025	1.461	20.349	3.637
2026	0.677	22.450	3.767
2027	0.858	24.770	4.121
2028	0.700	27.302	4.439
2029	0.705	30.022	4.579
2030	0.718	32.948	5.142

Source: Computed by Authors

The forecasted change in population density was obtained using a polynomial order of 2 approximation.[26] On average, growth in population density is expected to cause total net electricity consumption to increase by 11.2% per annum during the period 2020 – 2030[27]. In terms of added additional kWh per capita, it is projected that during the period, 233.681 kWh per capita electricity would be added to the national total due to growth in population density between 2020 and 2030 (see *Table 7*). This represents 2.4 and 3.95 times more than the national totals achieved in 2010 and 2000, respectively.

A polynomial trend of order 4 was used to predict real income per capita because it fits the real income per capita data very well[28]. Future electricity consumption will, on average, increase by 2.83% per annum because of expanding economic activities. In terms of added kWh per capita, economic growth is expected to add additional 40.549 kWh per capita between 2020 and 2030 to

[26] The population density is highly trended, with a polynomial order 2 approximation explaining the data very well (99.9% r-square value). The mean absolute percent error is 0.6%, which suggests a very high accurate forecast.

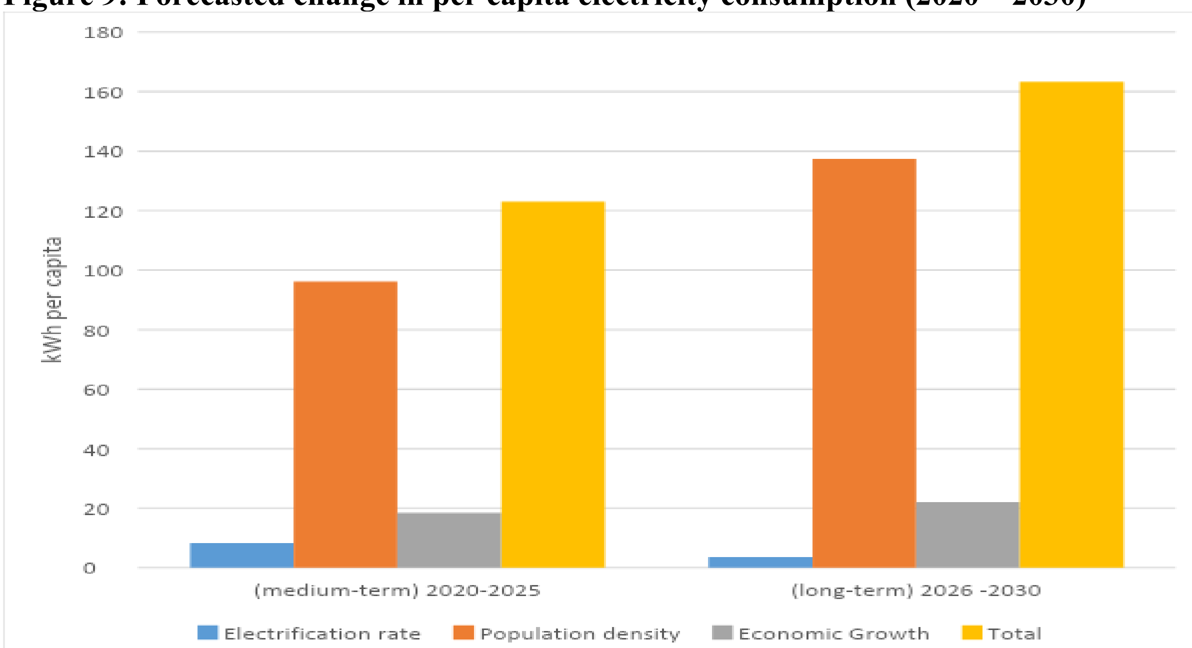
[27] Forecasted percentage increase in net electricity consumption per capitat=elasticity of population densityt*Percentage change in forecasted population densityt

[28] The mean absolute percent error is 1.01%, which according to Lewis signifies a high forecast accuracy

the already existing total net electricity consumption per capita (see *Table 7*). This represents an increase of 41.97% and 68.6% over the levels achieved in 2010 and 2000.

The above forecast values show that the expected changes in electricity consumption are likely to be driven more by population growth followed by economic growth and the expansion of national electrification. The simultaneous increase in all three indicators suggest additional 286.301 kWh per capita of electricity consumption, which is about 1.84 times higher than the level achieved in 2018[29]. Figure 9 shows the distribution of the expected additions in terms of electricity consumption (kWh per capita) across time and the key drivers. In the medium term, we forecast that there would be an additional 123.103 kWh per capita electricity consumption, with population dynamics constituting 78% share and economic growth and electrification rate contributing 15% and 7% shares, respectively. In the long term, there would be an additional 163.198 kWh per capita electricity consumption. Population dynamics would constitute 84% share, and economic growth and electrification rate would contribute 14% and 2% shares, respectively.

Figure 9: Forecasted change in per capita electricity consumption (2020 – 2030)



Source: Computation by Authors

[29] Forecast of power demand according to the PSMP (2016 update) predicts that the net change in power demand between 2020 and 2030 would be 2.187 times higher than consumption levels achieved in 2018.

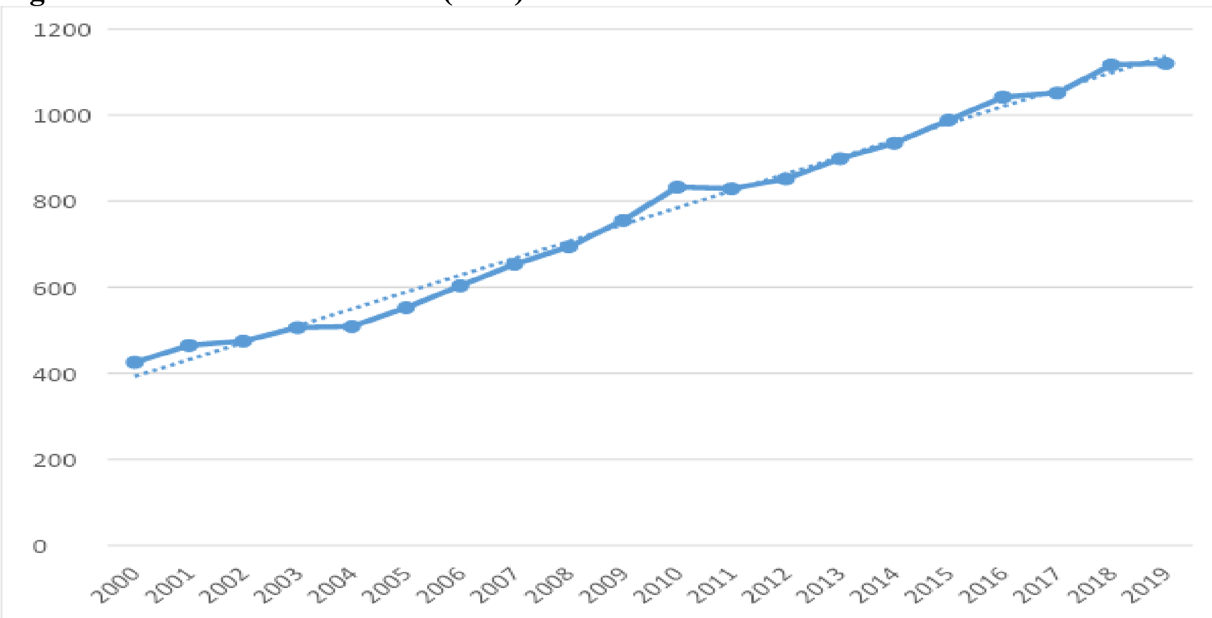
These forecasted values vary significantly from the forecast values obtained based on the trend projections, which means that population growth, economic growth, and the expansion of national electrification programs are likely to be the key driving factors of electricity consumption in the future (see Joint Energy Sector Review [JESR], 2012-2013). The authors do not wish to claim a perfect forecast here despite paying attention to all necessary details. Nonetheless, these forecasts seem to support other similar studies performed for Tanzania that have predicted a rapid increase in total electricity consumption (PSMP 2016 update; JESR, 2012-2013). The predicted rapid increase in electricity consumption suggests that the GOT needs to invest massively in generation, distribution, and transmission infrastructures as well as demand-side management programs. This is very essential to ensure the security of the electricity system, the sustainability of electricity supply, and the achievement of sustainable inclusive development.

4.4.Forecasting Peak Demand

Peak electricity demand refers to the highest electricity demand recorded in the system during a specified period. Figure 10 shows the plot of peak demand from 2000 to 2019. Generally, peak demand is highly trended, rising from 425.65 MW in 2000 to 832.55MW in 2010 and further to 1137.53MW in 2019. This represents an increase of 96% between 2000 and 2010, which represents an annual average increase of about 9% per annum. However, between 2010 and 2019, the increase was approximately 37%, which represents an annual average increase of about 4% per annum. Thus, in the last decade, the increase in peak demand has been modest compared to the previous decade. The rise in peak demand confirms the earlier claim that electricity demand has been increasing in Tanzania at a significant rate. Consequently, authorities need to plan for generation expansions to meet future electricity demand.

The authors also performed a trend forecast of peak electricity demand. As shown in the figure above, the data is highly trended with an r-square of 99%. The mean absolute percent error is 2.8%. Therefore, we extrapolated the data from 2020 to 2030. Data from 2000 to 2019 represent the actual reported peak electricity demand in Tanzania. The forecast shows a consistent increase in peak electricity demand from 2020 to 2030 (see *Table 8*). In the medium-term (2020-2025), the forecasted annual average peak demand is 1274.73MW, while the long-term (2026 – 2030) forecasted annual average peak demand is 1490.33MW. The Tanzanian government targets to expand generation capacity to 4,195MW by 2020.

Figure 10: Plot of Peak demand (MW)



Source data: TANESCO and EWURA Annual Reports

Table 8: Forecast of Peak Electricity Demand

year	Actual Peak demand	Year	Forecasted Peak demand
2000	425.65	2020	1176.73
2001	464.83	2021	1215.93
2002	474.9	2022	1255.13
2003	506.25	2023	1294.33
2004	508.65	2024	1333.53
2005	552.39	2025	1372.73
2006	603.35	2026	1411.93
2007	653.32	2027	1451.13
2008	693.83	2028	1490.33
2009	755.41	2029	1529.53
2010	832.55	2030	1568.73
2011	828.99		
2012	851.35		
2013	898.72		
2014	934.62		
2015	988.27		
2016	1041.63		
2017	1051.27		
2018	1116.58		
2019	1120.12		

Medium term average is 1274.73MW (2020–2025)

Long-term average is 1490.33MW (2026–2030)

Source: Computed by Authors

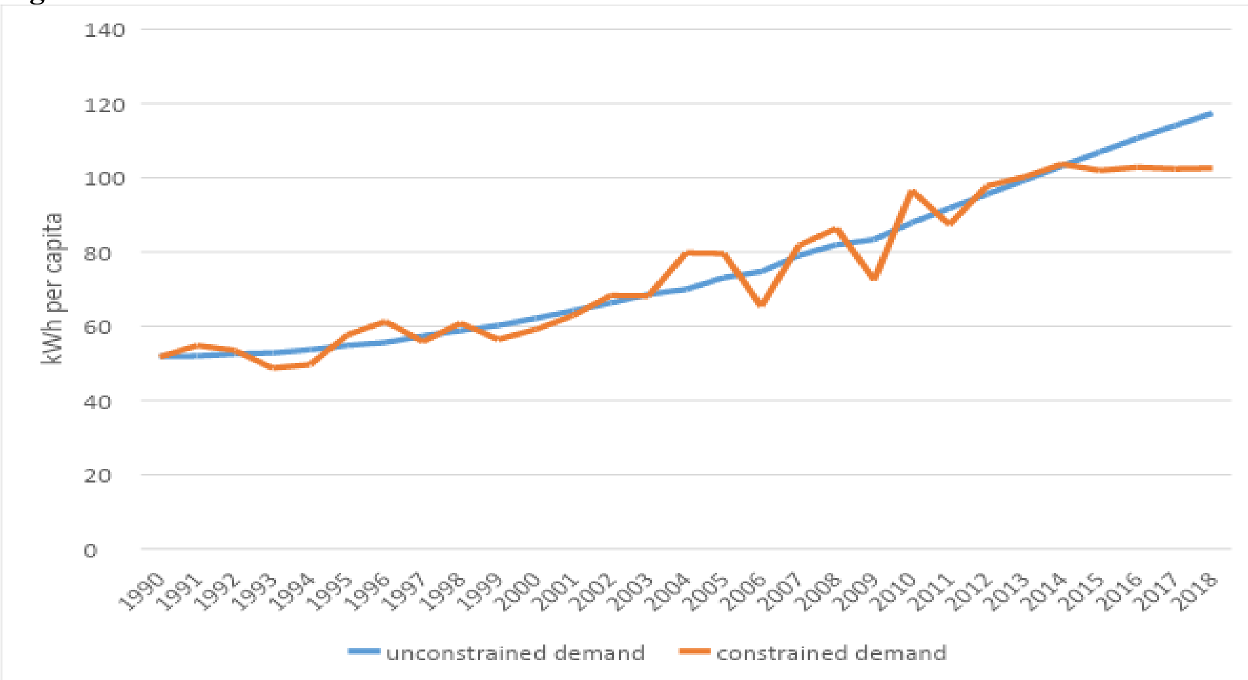
Assuming all these capacities are available for use, the forecasted peak demand value for 2020 falls short of the targeted generation capacity significantly. To make up for this difference, other additional demand such as power export, backup of captive generators for large-scale industries, and industrial innovation should complement the econometric model presented here.

Compared to the forecasted peak demand values in PSMP 2016 update, the forecasts provided here are much lower. For example, in 2019, forecast based on PSMP 2016 update was between 1800MW and 1,960MW. However, the actual recorded peak demand for 2019 (i.e., 1120.12MW) fell outside of the forecast range. Similarly, the actual peak demands for 2015 to 2018 fell outside the forecasted range in the PSMP 2016 update. This raises questions about the forecasting approach used in the PSMP 2016 update, such as the assumptions made about power infrastructure expansions in transmission and distribution (Mkuranga, Kibaha, Bagamoyo, Kisarawe, Chalinze and Dar es) and rural electrification. A review of the PSMP 2016 forecasting model is imminent.

4.5.Estimate of Constrained versus Unconstrained Electricity Demand

Figure 11 shows the plot of the restrained demand (recorded) and unconstrained demand (restrain + unmet demand). Clearly, beginning from 2015, there is a complete dispatch of constrained demand from unconstrained demand and the gap has widened over time. This means that consumers preferred electricity usage pattern has not been satisfied due to the constraints imposed by the electrical system. For example, on the transmission side alone, recorded outages in 2018 were 1.68 times higher than what was recorded in 2016 and more than twice bigger than the recorded figure for 2017. A similar pattern was observed on the distribution side, where most of the outages occur. In 2017, total outages recorded on the distribution lines were 28,224.29hrs. By the end of 2018, this increased to 33,925.68hrs. The growing unmet demand provides opportunities for expansions and upgrades in generation, distribution, and transmission infrastructure in Tanzania.

Figure 11: Plot of Restrained and Unconstrained Power Demand in Tanzania



Source: Computed by Authors

5. Conclusion

This study reviews the trends in energy consumption, supply and cost and the underlying drivers using data from 1990 to 2018. The following results emerged from the study. Total primary energy consumption continues to increase significantly in Tanzania, and there are signs that without significant investment in generation capacity, the problem of energy deficit might persist in the future. Key to this growth has been identified in this study to include expansion in economic activities, energy efficiency improvements, and changes in production mix and processes.

For environmental sustainability, we note that the current energy mix in Tanzania is far from that objective. The share of high-carbon energy sources dominates low-carbon energy sources. That notwithstanding, there are signs of a gradual transition towards to low-carbon energy sources but this is still at the infant stage.

Total net electricity consumption also remains high, and the key driving factors have been identified in this study to include the price of electricity (with a negative effect), income, electrification rate, industrialisation rate, and population density (all with positive effects). Future prediction reveals that the trend is not likely to change, all things being equal. For peak electricity demand, the forecast shows the average peak demand for the medium term (2020-2025) to be 1,274.73MW, while the predicted average for the long term (2026 -2030) is 1,490.33MW. Compared to the 2019 figure, these forecasts suggest an increase of 13.8% for the medium term and a 33.05% increase for the long term. Population growth, economic growth, and electrification rate would be key in determining future patterns in electricity consumption. However, the forecasted peak demand is less than the targeted installed capacity as captured in PSMP 2016 update.

Despite the progress made by the government in expanding the generation capacities in the electricity sector (now depending more on natural gas), existing inefficiencies in the power sector suggest that energy deficit might be a challenge in the future and this might further worsen unserved electricity demand in Tanzania. As found in this study, beginning in 2015, unconstrained electricity demand exceeded constrained electricity demand, suggesting that the preferred consumption patterns of consumers have been restrained.

Recent levels of electricity tariff in Tanzanian make it one of the highest in the sub-region. We further note that one of the key drivers is the purchase of emergency power plants. Interestingly, there are no clear roadmaps for contingency plans within the power sector. We also note with concern that the current electricity tariff structure, which seems to favour commercial consumers, might be deepening the gender energy affordability gap as most women do not end up in formal businesses.

6. Policy recommendations

The predicted growth in energy/electricity consumption is an indication that Capacity expansion in generation, transmission, and distribution is imminent. Specific interventions could include direct investment in *infrastructure* and capacity development. Moreover, most of the existing plants do not operate at full capacity, which raises legitimate concerns about adhering to the scheduled maintenance of the plants. As such, they need close monitoring and maintenance.

Exploit suppressed demand or create new demand to improve infrastructural utilisation in the future. Matching the predicted peak demand to the targeted installed generation capacity in PSMP 2016 update reveals a situation where the generation plant risks underutilisation in the future. Therefore, the government should create additional demand through power export, backup of captive generators for large-scale industries, and industrial innovation.

The government should invest in demand-side management projects. In terms of promoting energy efficiency, the government should target changing long term behaviour. On this score, priority should be given to establishing a national energy efficiency policy and regulation with action plans. Also, because the knowledge and level of awareness of customers on energy efficiency is limited, a strategic action plan to have TANESCO, MEM, REA, and EWURA engage customers by building capacity in energy efficiency is crucial in the short term. In the long term, designing an educational curriculum at the basic level that incorporates courses on environmental and resource management can go a long way to enhance environmental awareness and energy consciousness among the citizenry.

Still, on promoting demand-side management, the government can resort to using market tools such as prices. As shown in this study, the elasticity of price is negative. This naturally suggests a tax on electricity commodity to promote conservation. However, such a tax policy should be progressive in nature to encourage high-consuming end-users to invest in energy conservation.

Invest in renewable energy penetration to achieve environmental sustainability. Also, this may be critical to breaking the dependence on natural gas, as such fuel could impose future high affordability problems. For strategic intervention, future financiers of renewable energy projects can take advantage of the huge potential that exists for climate-smart energy technologies. Private Public Partnership would be required to scale-up investments in this area. Moreover, supporting soft infrastructures such as capacity building in renewable energy in Tanzania is equally critical.

Design and implement a clear roadmap for contingencies: Contingency plans can help save costs in times of distress and hence lower energy costs. Also, building capacity in power contract negotiation might be useful in future power arrangements with the ultimate benefit of helping to save the country from rising energy costs due to contractual negligence.

This study also suggests other potential areas for future research. First, all hydro plants except for New Pangani Falls Plant are currently manually operated. To enhance operational efficiency, it is important to investigate the merits of retrofitting them with automated digital systems to improve their operation. Second, firm- and household-level data are required to do a proper estimate of energy efficiency trends and their impact, and this should be an agenda for future research. Lastly, the current tariff structure has the potential to increase gender inequality, in terms of electricity affordability. The potential extent of this inequality needs an investigation and if found, the necessary adjustments to the tariff structure to make it more gender equitable should be made.

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