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Modelling of Future Energy Demand for Tanzania

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Abstract

This paper present modelling of long-term energy demand forecast in the main economic sectors of Tanzania. The forecast of energy demand for all economic sectors is analyzed by using the Model for Analysis of Energy Demand (MAED) for a study period from 2010-2040. In the study three scenarios namely business as usual (BAU), low economic consumption (LEC) and high economic consumption scenario (HEC) were formulated to simulate possible future long-term energy demand based on socio-economic and technological development with the base year of 2010. Results from all scenario suggests an increased energy demand in consuming sectors with biomass being a dominant energy form in service and household sectors in a study period. Predicted energy demand is projected to increase at a growth rate of 4.1% and reach 74 MTOE in 2040 under BAU scenario. The growth rates for LEC and HEC are projected at 3.5% and 5.1% reaching 62 MTOE and 91 MTOE in 2040 respectively. Electricity demand increases at a rate of 8.5% to reach 4236 kTOE in 2040 under BAU scenario while electricity demand under LEC and HEC increases to 3693 kTOE and 5534 kTOE in 2040 respectively. Sectrorial predicted demand results under both scenarios determines high demand of biomass for service and household sectors with decreasing demand of biomass in industry sector. Transport sectors predicted energy demand pattern suggests an increased demand in passenger transport than freight transport in both scenarios. Final energy demand per capita in both scenario show an increased trend with lower growth in LEC scenario while there is a decrease in energy intensity throughout study period.

Key Words: MAED, energy demand, energy demand forecasting, energy demand modelling

1. Introduction

Energy is essential in achieving economic prosperity and advances in social and overall human development. Energy has evolved to match with modern human development and requirements. As countries develop and the economy grows there is always an associated increase in energy use (Reister, 1987). Tanzania being among developing countries, its energy demand subsequently consumption is expected to increase as its economy and population grows (Tiris, 2005). Energy demand in the country has been shown to be spurred by the population growth and economic activities development that has occurred in the past decades (Odhiambo, 2009). A growth in energy consumption has been shown to increase economic diversity which is measured by a number of economic sectors consuming energy (Templet, 1999).

Global energy status is currently steered by fossil fuels which play a crucial role in the world energy market (Goldemberg, 2006; Shafiee and Topal, 2009). Global rate of energy consumption with addition of volatile energy markets and the production challenges faced by many producers has resulted into worries on energy availability, management, security and environmental concerns (Asif and Muneer, 2007; Hughes and Shupe, 2010). Attention to these concerns is serious due to the uneven distribution of the fossil fuel resources on which most countries currently rely on. The growing competition for energy resources, the need for economic development, energy availability at an affordable price and energy supply challenges are making energy security a key issue all over the world (Costantini et al., 2007; Grubb et al., 2006; Hughes, 2009). Without knowing future energy demand it is difficult to plan for energy supply that will ensure energy security, availability and economic developments.

The main motive of this study is to forecast energy demand of Tanzania. The forecast will be focused on simulations of future demand based on social, economic and technological development. The demand forecast is essential to assess and plan for supply through the use of the energy resources for a given set of demand. The study output will present the connection between energy consumption against development while facilitating policy and decision makers to plan for sustainable, reliable and affordable energy.

1.1 Socio-economic Status

1.1.1. Demography

Tanzania had a population of 44.9 million persons in 2012 as compared to 12.3 million persons in 1967 (NBS, 2013). From 2002 to 2012 the population has increased by 30% from 34.4 million to 44.9 million (NBS, 2013). The population growth rate has fallen slightly from an average of 3.3% in the period of 1967-1978 to 2.8%, 2.9% and 2.7% in the periods of 1978-1988, 1988-2002, and 2002-2012 respectively (NBS, 2012; UN, 2013). Figure 1 describes predictions of annual population change for Tanzania in a period from 2010–2100 under high, medium and low variants scenarios (UN, 2013). The trend line equation on annual population change for high variant follows polynomial equation of order 2 given as equation 1. Low and medium variant population change are also following similar polynomial trend line equation of order 2. Country's lifestyle shows a constant household size of 4.9 between 2002 and 2012 censuses whereas an average of 4.8 was reported in 2012 census.

$$\Delta P = -0.008\,(FY)^2 - 0.107(FY) + 3.3462 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where ΔP and FY represents population change and corresponding year.

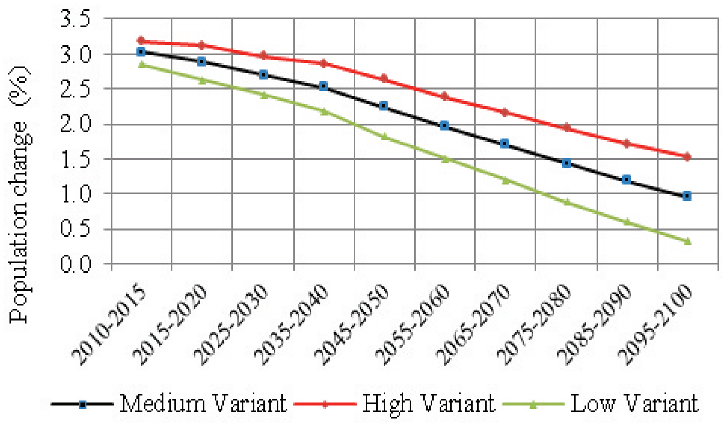

Figure 1: Projected population change (2010 – 2100)

1.1.2. Econom..

Tanzania's gross domestic product (GDP) has been growing steadily since 2000 at a rate of 7% annually. Highest and lowest growth rates of 7.8% and 6% were recorded in 2004 and 2009 respectively (BOT, 2012; NBS, 2012). The GDP per capita at current prices shows an increase trend from US$ 306 in the year 2001 to US$ 608 in 2012 (UN-data, 2014). Figure 2 illustrates GDP growth rate from 2001 to 2012 at 2001 constant prices with projection for 2013 – 2016. GDP growth rates for 2014-2016 are projected figures (NBS, 2012).

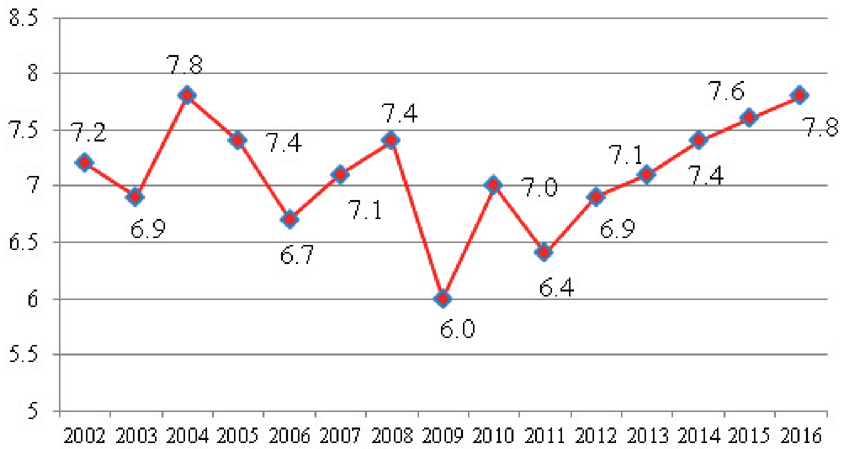

Figure 2: GDP at 2001 constant price

1.2 Country's Energy Status

1.2.1 Primary energy supply

Tanzania has been endowed with numerous energy resources ranging from renewable to non-renewable. The country produces natural gas and coal for domestic consumption mostly in electricity generations and industrial applications and does not produce crude oil. Total primary energy supply of Tanzania is estimated to be more than 22 million tonnes of oil equivalent (MTOE) (Bauner et al., 2012; Wilson, 2010). Primary energy supply is composed of biomass at approximately 90% of the total supply (MEM, 2013c). The rest of primary energy supply is represented by 7– 8% from oil products and 1– 2% from electricity (MEM, 2013b; Mwakapugi et al., 2010). High consumption of biomass is attributed to the low per capita income and limited investment in alternative energy supplies (Monela et al., 1999). Country's dependence on biomass has reached an annual yield of 40 million m^3 while annual sustainable yield is estimated at 24.3 million m^3 (Mwihava, 2010). Biomass in Tanzania is consumed un-sustainably contributing to a deforestation rate which is estimated to be between 130,000 and 500,000 hectares per year (Lema, 2009; Songela, 2009). Population that relied on biomass in the form of woodfuel for the year 2010 was approximated at 79% while that for charcoal was nearly 14% (Mwihava, 2010).

Tanzania imports all its petroleum based products requirements. Imports of petroleum based products was 1,482 thousands of oil equivalent (kTOE) representing 7.14% of total primary energy supplies in 2011 which is 66.8% of total fossil fuel consumption and about 23% of the total imports (IRENA, 2014). Transport sector was estimated to consume 40% of all imported energy in the form of motor oils for the year 2010 followed by industry (25%), household (10%) while the balance were accounted by agriculture and commerce sectors (Wilson, 2010). Total energy use per capita in 2011 was equivalent to 0.45 tons of oil equivalent. The energy self sufficiency of Tanzania was estimated at 92% in 2010 (IRENA, 2014). Historical energy production and imports of Tanzania from 1995 to 2011 is shown in Figure 3 (IEA, 2013). The country has a potential of using municipal solid waste (MSW) as renewable energy source as addressed in (Omari et al., 2014a) and Omari et al. (2014b).

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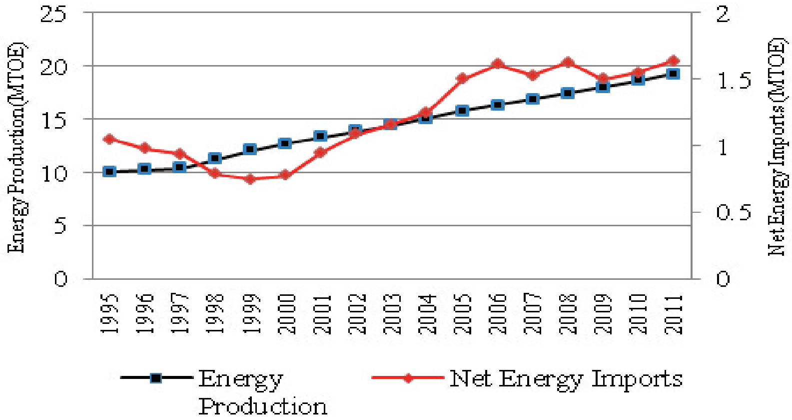

Figure 3: Energy production and energy imports

1.2.2 Electricity

Electricity generation using various energy sources from 2003 to 2013 is illustrated in Figure 4 (MEM, 2013b). The share of hydropower in 2003 was 79% of the total generation whereas the rest were covered by thermal generations using heavy fuel oil (HFO), diesel, JET-A and imports. The share of hydropower decreased to 34% in 2013 followed by natural gas 41% and the rest covered by others thermal generations using HFO, diesel, JET-A and imports (MEM, 2013a). Total installed capacity in 2013 was 1,509.85 MW of which 1,438.24 MW was available in national grid (MEM, 2013c). Out of the total installed capacity available for the grid, 553 MW is hydropower representing 35%. Capacity utilization shows decreasing utilisation of hydro power at 65%, 48% and 43% in 2011, 2012 and 2013 respectively depending on the availability of water (MEM, 2013a).

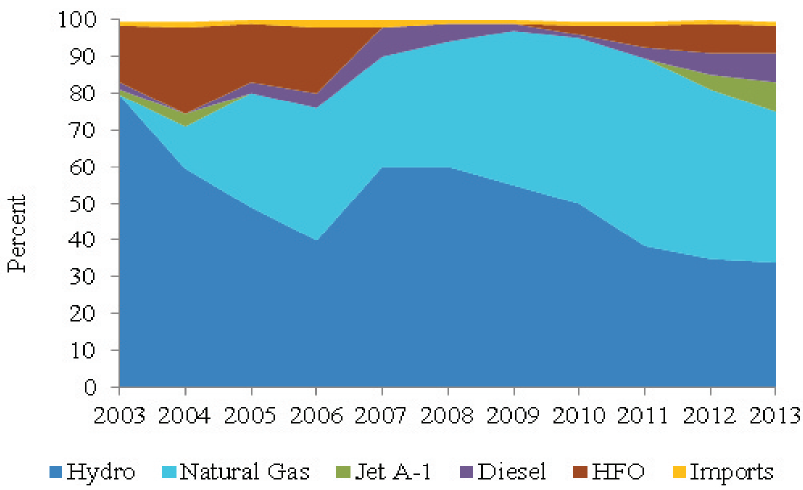

Figure 4: Electricity generations by source

1.3 Energy Models

The following section review in brief factors influencing energy demand and the modelling scheme that has been used in this study.

1.3.1 Factors influencing energy demand

Population, imports, exports, GDP and sectoral changes in the economic profile of a country characterize paths of energy development (Apergis and Payne, 2009; Csereklyei and Humer, 2012). Population is a major driver of energy demand although its most weighty determinant is the level of economic activity and its structure as measured by the total GDP together with a number of sectors and sub-sectors of the economy (Oyedepo, 2012;

Sahu, 2008). Population and economic growths have been discussed in a number of studies as the major factors that influence energy demand (Bhattacharyya, 2012; O'Keefe et al., 1984)

1.3.2 Energy models

A common and accepted classification of energy models is through the use of the distinction between two general groups of energy models namely top-down and bottom-up approach (Fleiter et al., 2011; McFarland et al., 2004). Interactions amongst energy system and the economy are represented by two modeling paradigms known as top-down and bottom-up (Böhringer and Rutherford, 2008). Top-down and bottom-up terms are shorthand for aggregate and disaggregated models. Bottom-up models are characterized as being built on engineering philosophy while top-down models are characterized to represent the view of economists (Böhringer and Rutherford, 2008; Fleiter et al., 2011). Top-down models examines the broader economy but they don't feature technological details of energy production or conversion. Additionally bottom-up models are characterized as those using an engineering approach, reflecting technical potential, and being able to use disaggregated data for exploring purposes (Van Beeck, 1999). Bottom-up models are viewed as being made with detailed considerations of technologies which allow modeling the impact of distinct and well defined technologies on the long term development of energy consumption (Rivers and Jaccard, 2006). Bottom-up models have potentials to model the effects of technology-oriented policies due to technology explicitness.

MAED is a bottom-up approach model widely used for forecasting medium and long term energy demands. MAED inter-relates energy demand with the population, gross domestic product (GDP), technological development, among many other factors (Hainoun et al., 2006; Nakarmi et al., 2013). MAED being bottom-up model is built with detailed considerations of technologies which allow modeling the impact of distinct and well defined technologies on the long term development of energy consumption (Rivers and Jaccard, 2006). MAED relates systematically specific energy demands to the corresponding socio-economic and technological factors that affect the demand (IAEA, 2006, 2009).

Future energy demands are disaggregated into end-use categories as a function of several determining factors including population growth, transportation modes, national priorities for the development of certain industries or economic sectors, energy forms, among others. Key consumption sectors that are considered in MAED comprises of industry, household, transport, and service. The industry is further divided into sub-sectors that comprise of agriculture, construction, mining (ACM) and manufacturing while transport sector is sub-divided into passenger and freight transport. MAED final consumption fuel types and energy forms comprise of fossil fuel for thermal use (mainly industry), motor fuel and electricity (Hainoun et al., 2006). MAED important demographic and economic data are labour force, rural and urban populations, potential labour force, sectoral distribution of GDP (Ediger and Tatlıdil, 2002).

Reconstruction of base year energy consumption pattern is the process that requires compiling and reconciling necessary data to help calibrate the model to the specific situation of the country. The second stage is development of future scenarios that suits country's possible future energy demands. MAED framework of analysis is given by breaking down of the economy by sector through scenario assumptions up to final energy demand. The energy demand is calculated by MAED as a function of a scenario of possible development (IAEA, 2006).

MAED generic equation, in which energy demand in future year is determined, is given in Equation 2.

$$\left(ED\right) = \left(\frac{\mathrm{ED}}{\mathrm{DP}}\right) \times (\mathrm{CH}) \times (\mathrm{DP}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

ED - Represent energy demand in future year;

$\left(\frac{\mathrm{ED}}{\mathrm{DP}}\right)$ - Specific energy demand per unit of driving parameter in base year;

CH - Coefficient to reflect evolution of specific energy demand per unit of driving parameter in future year;

DP - Specific energy demand per unit of driving parameter in future year.

2. Methodology

The following sections details the methodology that was applied in the study. Study period considered in this analysis is from 2010-2040.

2.1 Division of the main economic sectors

The main Tanzanian economic consumption sectors disaggregated were industrial, service, household and transport sectors. The energy consumption in the industrial sector was further subdivided into consumptions by agriculture, construction and mining (ACM) and manufacturing while that for transport was subdivided into freight and passenger transport.

2.2 Elements influencing energy demand

The following are important factors influencing energy demand that were used in the study. These factors are GDP growth rates and their structural changes, population growth and its distribution in the country (urban and rural), changes in life style, population mobility growth, passenger and freight transportation, and market penetration of competing energy forms.

2.3 Modelling Scenarios

Three different scenarios were proposed to represent possible future energy demand for Tanzania as detailed next.

2.3.1 Business as usual scenario (BAU)

The reference economic growth scenario named as Business as usual scenario (BAU) was developed to assume normal economic growth rate and expected development of other factors influencing energy consumption. BAU future economic growth of the country has been assumed to follow trends of the past and no changes in country's policies will be made that affects those trends. BAU was developed to accommodate a moderate population growth rate (medium variant), current level of urbanization (26%), GDP growth rate of 7%.

2.3.2 Low Economic Consumption scenario (LEC)

The slow economic growth scenario named as low economy consumption scenario (LEC) was developed to assume a slower economic growth rate. LEC scenario defines a lower bound for economic development, which could be expected in the number of assumptions. These include high population growth rate (high variant) which aggravates the difficult economic situation (URT, 1992) associated with considerable increase in current level of urbanization. Economic situation and development related to unstable socio-economic and political environments, low level of internal and foreign investment, low GDP at a growth rate of 5% for the entire study period and decrease of growth in income per capita. On international environment the scenario assumed no favourable investment environments due to un- stable political situation in the region, and unexpected climatic, political and economic crises. In life style the scenario assumed no improvement in household size whereas car per family ownership and public transport follows past trends. The scenario does not favour the growth on the use of renewable enegies.

2.3.3 High Economic Consumption scenario (HEC)

The high economic growth scenario (HEC) is developed to assume high economic growth rate and expected development of other factors influencing energy consumption. HEC scenario is presumed from an optimistic perspective based on the assumption that the countrys economy will grow at an higher constant GDP growth rate of 8 % for the entire study period. The growth is linked to no decrease or increase in current population growth rate, no considerable increase in current level of urbanization and negligible net migration value. Economic situation and development under HEC is presumed to be stable with increase in service and industry sectors shares, exploration of more natural gas, minerals and new discoveries in oil resources resulting in positive growth in income per capita.

Population growth rate in HEC follows low variant trend to favours economic development. Life style in HEC scenario as a result of low variant growth that favours improvements in household size. HEC scenario is presumed to have increases in car per family ownership, cooking and thermal applications in household shifting to service sector and more population travel within the country and abroad. Furthermore HEC assumes technological improvement in the use of non-comercial energy sources with improved efficiency. Transportation policies in HEC favours upgrading of existing and construction of modern roads with the introduction of railroads in intracity and intercity transport. HEC scenario on international environment favours investment due to stable political situation in the region.

2.4 Base Year Reconstruction

The selection of a base year for the study was from among the recent past years to represent the economic and energy background of the country. The year 2010 was chosen as the base year to present the economic and energy background of Tanzania. The main reason for the choice is the stable energy consumption which represent best pattern for the country. Furthermore the year 2010 is well-matched with Tanzanian Vision 2025 which is to implemented by a series of three five years development plans (FYD) (URT, 1999, 2012). The first series of FYD aims at unleasing the growth potential 2011/12 - 2015/16; the second one nurturing an industrial economy 2016/17 – 2020/21 while the third series aims at realizing competitiveness–export led growth 2021/22 – 2025/26. In 2010 shares of GDP at 2001 prices for service sector was 48.8% of which transport sector constituted 5.1% of the service sector. Agriculture and fishing constituted 24.1% whereas industry and construction was 21.6% (NBS, 2011). Summary of energy balance for a base year in which total energy production was 17,434 MTOE whereas the import was 1,522 MTOE giving total energy supply of 20,078 MTOE. Total population for 2010 was estimated at 43.2 million persons with average household size of 4.8 and share of urban population being 27%.

3. Results and discussions

Modelling results for three scenarios formulated to represent possible developments trends in energy demand of Tanzania based on social, economic and technological development are presented in the following sub-sections.

3.1 Final energy demand forecast

The projected final energy demand for the three scenarios from 2010 – 2040 are presented in Figure 5. The average annual growth rate will amount to 4.08%, 3.45% and 5.07% for BAU, LEC and HEC respectively. The final energy demand will grow from 22 MTOE in 2010 to 74 MTOE in 2040 for BAU scenario. Similar trend is observed for LEC and HEC scenarios in which energy demand will increase to 62 MTOE and 91 MTOE in the year 2040 respectively. The growth in final energy demand for both scenario follows an increasing exponential trend due to exponential growth of population as is the case of global energy demand (Demirbas et al., 2004). The trend line equation representing exponential growth for BAU is given as Equation 3 while the corresponding trend line equations for LEC and HEC are given as equations 4 and 5 respectively.

$$ED = 17.719e^{0.2FY} \quad (3)$$

$$ED = 18.25e^{0.17FY} \quad (4)$$

$$ED = 17.127e^{0.23FY} \quad (5)$$

Where ED and FY denote energy demand and future year forecast respectively.

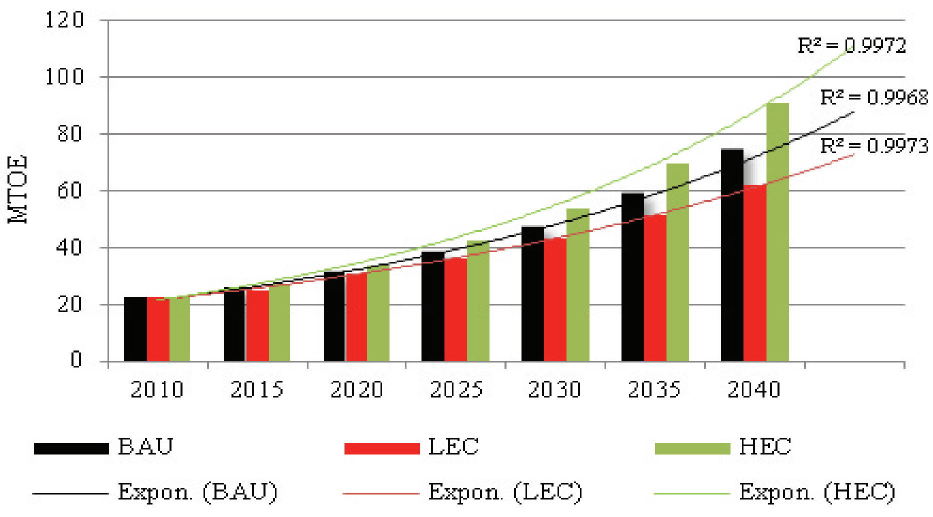

Figure 5: Final energy demand forecast 2010-2040

Table 1. Energy demand by energy form

Energy Form	GROWTH RATE (%)			BASE YEAR (MTOE)	2040 (MTOE)		
	BAU	LEC	HEC	BASE YEAR	BAU	LEC	HEC
Biomass	3.4	2.8	4.1	20.7	57.1	47.5	70.4
Electricity	8.5	8.0	9.5	0.4	4.2	3.7	5.5
Fossil fuels	10.0	9.0	10.9	0.4	6.8	5.1	8.6
Motor fuels	6.4	6.5	7.1	1.0	6.2	5.7	6.8
Solar	11.3	-12.6	12.1	0.000	0.006	0.004	0.008

The energy balances for both scenarios has been dominated by biomass followed by imported energy (fossil and motor fuels) and electricity. Biomass dominate both scenario by having average share of 76.5 % of total final energy demand for BAU, LEC and HEC scenarios in 2040. Moreover, results indicate that imported energy have average share of 17% in 2040 for both scenarios. Electricity will command a share of 5.7%, 5.9% and 6.1 % of final energy demand in BAU, LEC and HEC scenarios respectively in 2040.

3.2 Projected demand by energy form

Table 1 depicts projected demand by energy form for BAU, LEC and HEC scenarios. In comparing the three scenarios, LEC show less projected energy demand growth rate as compared to BAU and HEC. The final energy demand in LEC is less by 12 MTOE as compared to BAU whereas HEC is higher by 17 MTOE as compared to BAU both in 2040. The growth rate of biomass demand is projected to amount at 3.44%, 2.79% and 4.15% for BAU, LEC and HEC scenario respectively. Electricity demand annual growth rate is projected to increase at a rate of 8.51%, 8.01% and 9.48% for for BAU, LEC and HEC scenario respectively. Fossil fuel for thermal applications projected demand is expected to increase at 9.97% for BAU, 8.01% for LEC and 10.39%.

Motor fuels demand projected growth rate is above 6% in all scenarios as depicted in Table 1 reaching a maximum of 6.8 MTOE in HEC scenario while that of LEC and BAU scenarios are 5.1 and 6.2 MTOE respectively. Solar energy demand annual growth rate is projected to increase at a rate of 11.3%, -12.6% and 12.1% for for BAU, LEC and HEC scenario respectively. The negative growthrate in LEC scenario is attributed to poor performance in the econmy that hinder its ability to promote renewable energy.

3.3 Energy consumption by sectors

The results of final energy demand by sector are illustrated in Figure 6a, 6b and 6c for BAU, LEC and HEC scenarios respectively. The results of the projected sectorial energy demand show service sector commanding average share of 41% of the final energy demand while household; industry and transport sectors are accounted for 31%, 21% and 7% respectively in all scenarios. Service sector will have total final energy demand of 31.9 MTOE in 2040 for BAU scenario whereas LEC and HEC will have 20.9 MTOE and 42 MTOE respectively. Transport sector depicts higher final energy demand in passenger transport as compared to freight transport in all scenarios. Final energy demand in transport sector in BAU scenarios for 2040 will be 4.64 MTOE for passenger transport as compared to 0.49 MTOE for freight transport. In industry sector manufacturing is the leading sub-sector in consumption of final energy demand as compared to agriculture, construction and mining (ACM) combined together. The same trend is observed for LEC and HEC which depicts higher consumption in manufacturing as compared to ACM. The final energy demand for the three scenarios concludes that the service sector would have the highest shares in the projected final energy demand followed by household sector for BAU and HEC while the highest share holder for LEC would be household sector. This is explained by slow economic growth that does not favours growth in service sector and higher population growth.

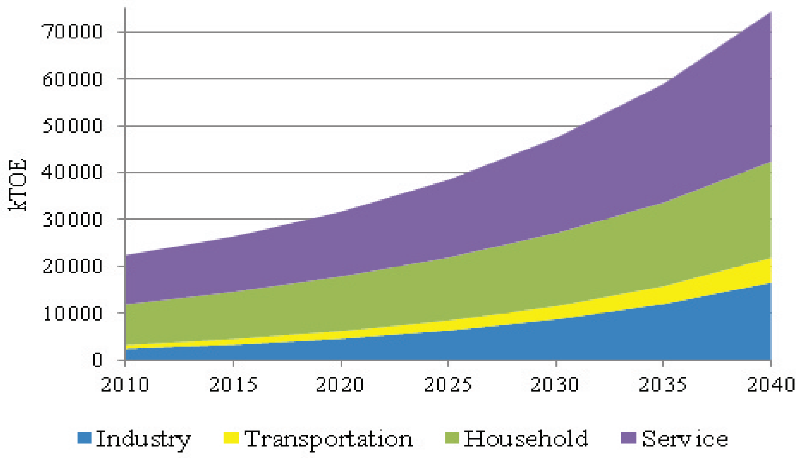

Figure 6a. Final energy demand by sector (BAU)

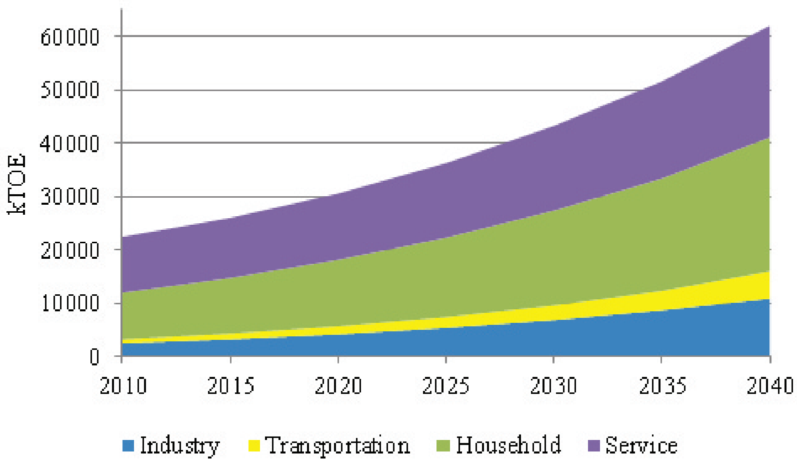

Figure 6b. Final energy demand by sector (LEC)

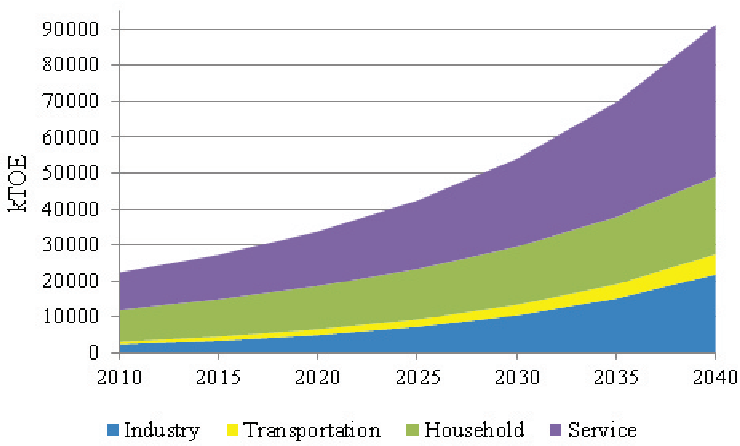

Figure 6c. Final energy demand by sector (LEC)

3.4 Sectorial biomass consumption

Sectorial biomass demand projections for BAU, LEC and HEC scenarios are illustrated in Table 2. The annual growth rate of biomass for BAU, LEC and HEC are projected to be 3.4%, 2.7 % and 4.1 % respectively. The highest consumer of biomass is service sector followed by household and industry sectors respectively. Service and household sectors in BAU scenario are projected to demand 26 MTOE and 17.6 MTOE respectively in 2040. Service sector demand of biomass in HEC scenario is higher by 8.3 MTOE as compared to BAU. In industry sector, biomass projected demand is increasing at a higher rate in manufacturing sub-sector as related to agriculture, construction and mining (ACM). Manufactruing sub-sector biomass demand is projected to increase annually at an average of 6.5% as compared to 4.7% of ACM. The highest growth rate in biomass demand is observed in industry sector at an average value of 6% followed by service sector at 3% and household 2.7%. In LEC scenario the population growth rate has been presumed to be higher as compared to other scenarios resulting into high biomass demand.

Table 2. Sectorial biomass consumption

Energy Form	GROWTH RATE (%)			BASE YEAR (MTOE)	2040 (MTOE)		
	BAU	LEC	HEC	BASE YEAR	BAU	LEC	HEC
Industry	6.1	4.6	7.1	2.1	12.4	8.1	16.4
- Manuf.	6.7	5.2	7.7	1.3	8.9	5.8	11.8
- ACM	4.9	3.4	5.9	0.8	3.5	2.3	4.6
Household	2.6	3.2	2.7	8.4	18.1	22.0	18.9
Service	3.2	1.8	4.2	10.204	26.6	17.4	35.8

3.5 Sectorial electricity demand

The electricity demand under BAU, LEC and HEC scenarios are projected to increase as depicted in Figure 7. Electricity demand for BAU scenario will increase to 4,236.4 kTOE in 2040 which is equivalent to average annual increase of 8.5 % against 365.7 kTOE in the base year. LEC and HEC will observe an increase in electricity demand of 3,693 kTOE and 5,535 kTOE respectively in 2040 which is equivalent to an increase of 8.0% and 9.5% from base year value. As a country's population grows and its economy expands, electricity energy demand multiplies. Projected electricity demand growth follow exponential trend with the trend line equation representing the growth for BAU given as equation 6 whereas the corresponding trend line for LEC and HEC are given by equations 7 and 8 respectively.

$$\mathrm{EED} = 250.44e^{0.407\mathrm{FY}} \quad \text{(6)}$$

$$\mathrm{EED} = 259.6e^{0.384\mathrm{FY}} \quad \text{(7)}$$

$$\mathrm{EED} = 239.84e^{0.451\mathrm{FY}} \quad \text{(8)}$$

Where EED and FY denote electricity demand and future year forecast respectively.

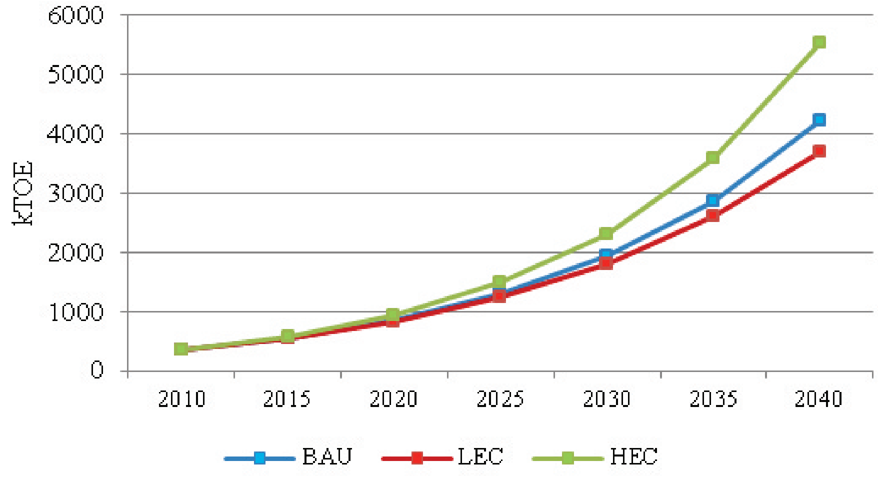

Figure 7. Projected electricity demand

The peak growth rate in electricity demand is observed in the industry sector. Industry sector will command 39.7% share of electricity demand in the period 2035-2040 followed closely by service and household sectors at 35.6 % and 24.7 % respectively in BAU scenario. This is attributed by presumed industrial development in 2040 as compared to the period prior to 2025. The trend before 2025 shows service sector as the highest consumer of electricity. Similar trend is observed for LEC and HEC with different magnitude in the consumption. Table 3 depicts the comparison in electricity demand growth for BAU, LEC and HEC scenarios. Sectorial consumption of electricity show the growth rate of electricity demand for industry to be 9.3 %, 7.8 % and 10.3 % for BAU, LEC and HEC scenarios. Average growth rate for household is 7.6 %, 9 % and 8.5 % respectively for BAU, LEC and HEC scenarios. Household higher electricity demand in LEC scenario as compared to BAU and HEC is due to higher population growth rate as presumed in the scenario. The supply side of the electricity based on intergration of renewable energy has addressed by Kichonge et al. (2014).

Table 3. Sectorial projected electricity demand

CONSUMING SECTOR	GROWTH RATE (%)			BASE YEAR (kTOE)	2040 (kTOE)		
	BAU	LEC	HEC	BASE YEAR	BAU	LEC	HEC
Industry	9.3	7.8	10.3	116.7	1681.7	1100.9	2223.1
- Manuf.	10.1	8.6	11.1	75.3	1350.1	883.8	1784.8
- ACM	7.2	5.7	8.2	41.4	331.6	217.1	438.3
Household	7.6	9.0	8.5	117.5	1046.8	1570.2	1347.8
Service	8.5	7.1	9.4	131.6	1507.8	1022.3	1963.4

3.6 Fossil and motor fuel consumption by sector

Fossil fuel consumption projected trends into 2040 with exclusion of aviation and marine bunkers illustrated in Figure 8. Fossil fuel demand for thermal applications is observed to increase exponentialy in both scenarios with the projected demand in 2040 amounting to 6,754 kTOE. The share of service sector in fossil fuel consumption is 55.9% followed by industry 25 % and household at 19 % in 2040 for BAU scenario. Figure 9 depicts the projected shares in fossil fuel demand by consuming sectros for BAU scenario. There is an observed increase in demand for fossil fuel by service sector while household and industry share decreases. The trend is a result of the presumed economy in BAU scenario that is mainly service oriented. An average of 21.4 %, 30.4 % and 48 % will be commanded by industry, household and service sectors respectively for LEC scenario. However the share for HEC will be 26%, 15.7 % and 58.2 % for industry, household and service sectors respectively. The annual growth rate of fossil fuel for each scenario is projected at 9.8 % for BAU, 9 % for LEC and 10.9 % for HEC.

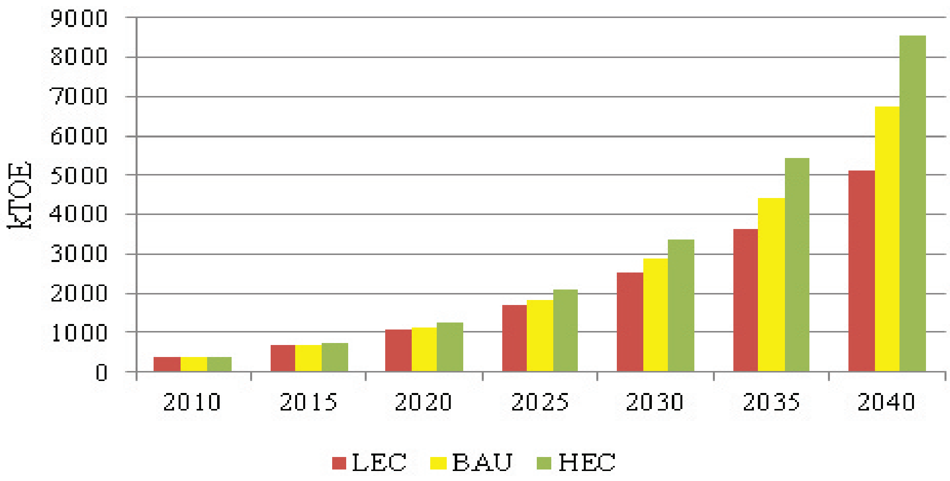

Figure 8: Projected fossil fuel consumptions

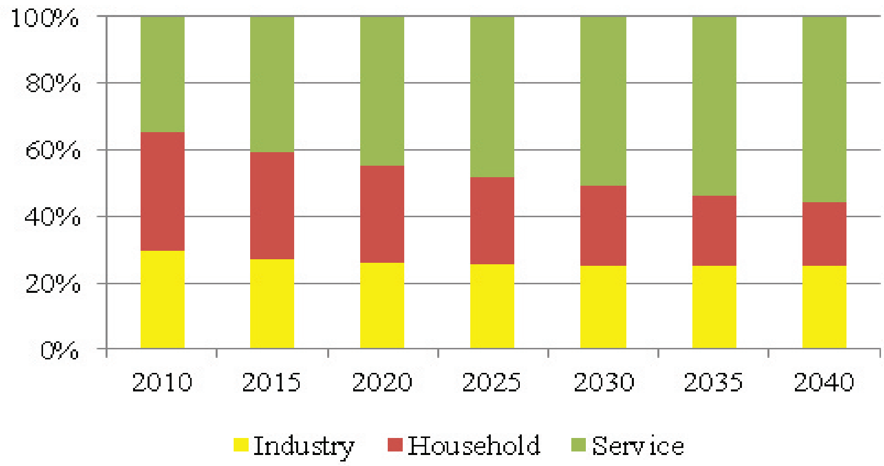

Figure 9: Projected fossil fuel consumptions - BAU

Motor fuel predicted demand in all scenarios is illustrated in Figure 10. BAU, LEC and HEC are projected to consume 6754 kTOE, 5146.7 kTOE and 8570.9 kTOE respectively in 2040 compared to base year demand of 956.2 kTOE. The projected demand is equivalent to an annual growth rate of 6.4%, 6.5% and 7.1% for BAU, LEC and HEC respectively. Motor fuel growth rate in LEC scenario is higher as compared to BAU scenario due to the high population growth presumed in the scenario resulting into the higher demand in passenger transport. Motor fuel shares for a base year were transport 87%, industry 11% and service 1.8%. The distribution of shares in 2040 for the projected motor fuel demand show transport to command a higher share of 85.6% followed by industry at 12.7% and service at 1.7% respectively for BAU scenario. For LEC scenario the share are predicted to be distributed at 89.8% for transport followed by 9% and 1.2% for industry and service sectors respectively. Similar trend is also observed for HEC scenario in which transport sector will command a higher share of 82.6% followed by industry at 15% and service at 2.1%. The share of transport in HEC scenario is much lower as compared to LEC and BAU due to low variant population growth and increased activities in industry and service sectors.

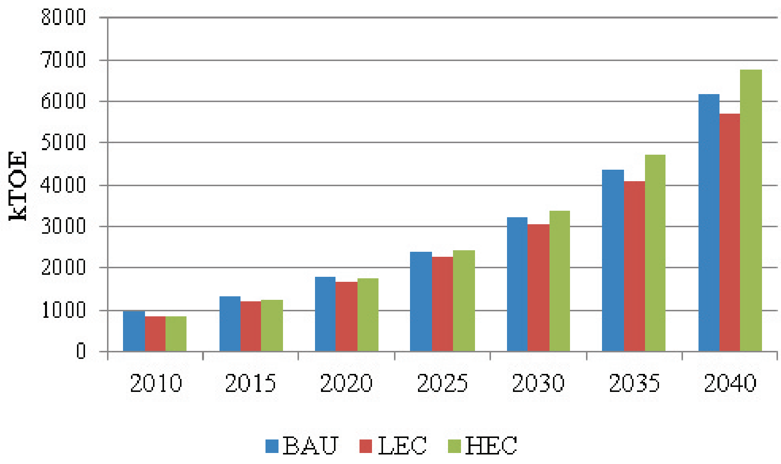

Figure 10: Projected motor fuel consumptions

Table 4 represents fossil and motor fuel demand for sectors and sub-sector growth rates in both scenarios. It is predicted there will be an average fossil fuel growth rate of 9.2%, 11.5% and 8.1% for industry, service sector and household respectively. There is higher growth rate in fossil fuel demand in LEC scenario as compared to BAU and HEC due to presumed high variant population growth rate in the scenario resulting into higher demand. The predicted motor fuel demand growth rate average to 7.1%, 6.6% and 6.5% for industry, transport and service sectors respectively. Higher growth rate in motor fuel is observed in service sector followed by industry and household sectors for BAU, LEC and HEC scenarios.

Table 4. Fossil and motor fuel consumption growth rate (%)

Consuming Sectors	FOSSIL FUEL				MOTOR FUEL			
	BASE YEAR (kTOE)	BAU Growth Rate (%)	LEC Growth Rate (%)	HEC Growth Rate (%)	BASE YEAR (kTOE)	BAU Growth Rate (%)	LEC Growth Rate (%)	HEC Growth Rate (%)
Industry	**114.6**	**9.4**	**7.8**	**10.4**	**94.8**	**7.3**	**5.8**	**8.3**
- Manuf.	58.0	9.8	8.2	10.8	18.8	8.9	7.4	9.9
- ACM	56.6	8.9	7.4	10.0	76.0	6.8	5.3	7.8
Transport	**-**	**-**	**-**	**-**	**846.2**	**6.3**	**6.6**	**6.9**
-Freight	-	-	-	-	107.7	6.7	5.2	7.7
- Passengers	-	-	-	-	738.5	6.2	6.8	6.8
Household	**139.3**	**7.7**	**8.6**	**8.0**	**-**	**-**	**-**	**-**
Service	**136.3**	**11.7**	**10.1**	**12.8**	**15.1**	**6.7**	**5.2**	**7.7**

3.7 Final energy demand per capita

Modelling results depicts an increasing trend in energy demand per capita. An energy demand per capita of 12.2 MWh for BAU scenario will be realized in 2040 against a base year value of 8.2 MWh. Contrariwise energy demand per capita of 9.3 and 15.9 MWh will be realized under LEC and HEC scenarios in 2040 against 8.2 MWh in the base year. Annual growth rate of energy demand per capita of 1.3%, 0.38% and 2.18% is observed for BAU, LEC and HEC scenarios respectively. Development of final energy demand per capita comparisons for BAU, LEC and HEC scenarios is shown in Figure 11.

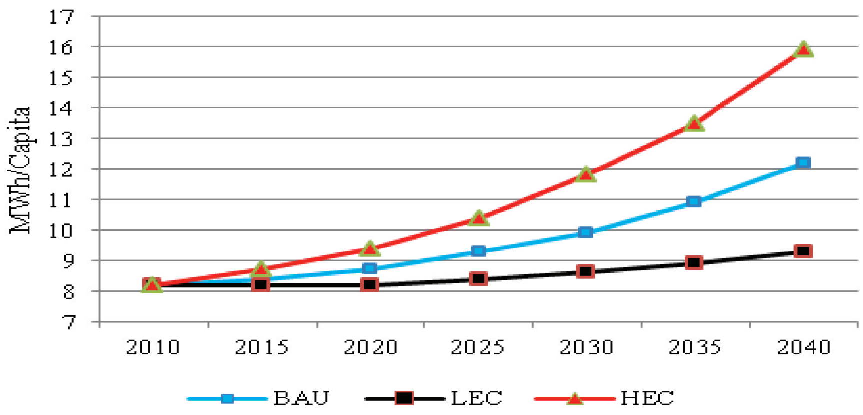

Figure 11: Final energy demand per capita

3.8 Energy intensity

Energy intensity show annual decreasing rate of 2.7% reaching 7.9 kWh/US$ in BAU scenario by 2040 against base year value of 18 kWh /US$. Energy intensity on the other hand will decrease at annual rate of 1.9% and 2.9% under LEC and HEC scenarios respectively in 2040 against base year value. Comparison of final energy demand per GDP in all scenario is shown in Figure 12. Energy intensity in BAU and HEC scenarios is projected to improve by approximately 50% from base year up to 2040 while that for LEC the improvement will be less than that. By these values it means it will take the country approximatelly half the energy to produce a dollar of GDP in 2040 as it was in the base year. The projected decrease in energy intensity is brought about mainly by improvement in technological energy efficiency in industry, service, household and transport. High decrease rate in HEC scenario is due to these changes while low decrease rate in LEC scenario is due to less improvement.

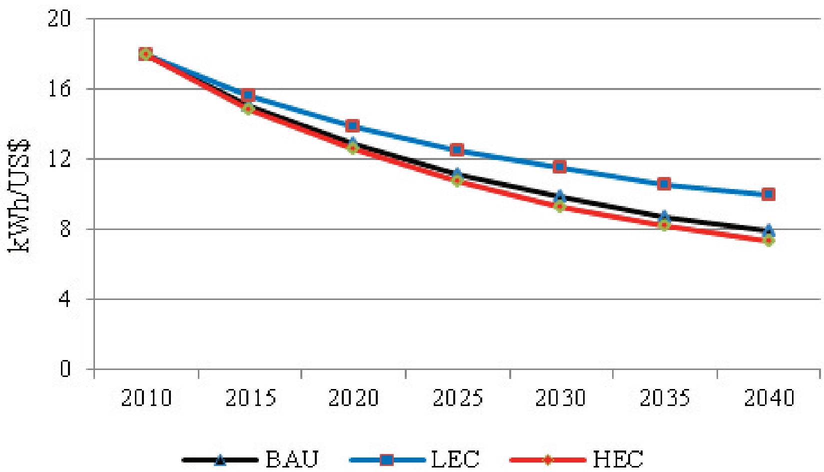

Figure 12: Energy intensity

4. Conclusion

It has been shown from the modelling results that energy demand of Tanzania is increasing exponentially. It has been determined that there is an increase of energy demand in all sectors of the econmy with total demand more than tripled towards the end of study period 2010-2040. Based on the obtained results presented in this study, the following important conclusions are drawn:

- Projected energy demand by energy form show biomass dominate the energy balance in the study period by commanding the highest share followed by fossil and motor fuels combined and electricity. The average share of biomass in both scenario is more than 75 % of total final energy demand.

- Projected sectorial energy demand show service sector to command the highest share of the total final energy demand in the study period. The share of service sector is averaging at 41% of the total energy demand followed by household 31 %, industry 21 % and transport sector 7 %.
- Biomass demand in the study period is projected to grow annually at an average of 3.5 %. Biomass demand will be highly dominated by service sector followed by household and industry sectors.
- The study results show the highest growth rate of electricity demand is in the industry sector followed closely by service and household sectors.
- Fossil fuel demand for thermal applications is increasing exponentialy in both scenario with the highest share being in service sector. Much of the fossil fuel consumption increases is observed in service sector followed by industry and household sectors.
- Modelling results predict motor fuel demand to grow at an average of 6.7% with higher demand being in transport sector followed by industry and service sectors

A further detailed analysis of the supply side is recommended to optimize the use of energy resources available locally to lessen dependence on biomass and imported energy for environmental conservation.

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