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Future Energy Demand Scenarios of Nepal

Kiran Gautam, Amrit Man Nakarmi and Shree Raj Shakya
Department of Mechanical Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal

Key words: Energy scenario, energy intensity, energy planning, MAED model, policy

Corresponding Author:
Kiran Gautam
Department of Mechanical Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal

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Abstract: Energy is vital for the economic prosperity and social development of any country. Future energy demand projection is the basis for sustainable energy planning. The study presents the possible long term energy demand scenarios of Nepal using Model for Analysis of Energy Demand (MAED). The base year for the analysis has been taken as 2017 while the low (BAU), medium and high scenarios have been developed from 2020 through 2040 at different economic growth rates 4.5, 7.2, 9.2%, respectively. Additional policy scenario has been analyzed at 7.2% economic growth rate. Total final energy consumption in the base year was 524.7 PJ while it is found to be 1,162.80, 1,489.65, 1,879.82 and 1,416.07 PJ in low, medium, high and policy scenario, respectively by the year 2040 resulting energy demand growth of 3.5, 4.6, 5.7 and 4.4%, respectively. However, the final electricity demand has been found to increase at the rate of 8.4, 9.9, 11.7 and 10.8% in low, medium, high and policy scenarios, respectively. The share of traditional fuel has been found to decrease in all the scenarios while the share of petroleum is found to increase in all the scenarios. Per capita final energy demand will be 29.42, 37.69 and 47.56 and 35.82 GJ in low, medium, high and policy scenarios whereas the per capita electricity demand will be 789, 1,145, 1,570 and 1,290 kWh, respectively by the year 2040. To fulfill that electricity demand the power plant capacity required would be 12.62, 18.31, 20.64 and 25.12 GW in low, medium, policy and high scenarios, respectively by the year 2040.

INTRODUCTION

Global energy demand is expected to rise by 1.3% each year to 2040 in the current policies scenario. World energy mix as of 2018 is dominated by petroleum (32%), coal (26%), natural gas (22%) and rest by renewable (15%) and nuclear (5%). By 2050, the share of renewable is expected to grow and reach 28% whereas the share of petroleum is expected to reduce to 27%, coal to 20%, natural gas would be the same 22%. In the global context, the industrial sector is consuming the highest amount of energy followed by transportation, residential and commercial sectors and which is expected to continue in the future too.

South Asia comprising of eight countries is home to 1.5 billion people which is 24% of the world's population and all of them are import-dependent for their energy requirement. The energy demand of South Asia is expected to grow at more than double the world over the next several decades predominantly inclined towards fossil fuels in the overall energy mix[1]. Overall energy security improvement is very essential to meet the increasing pressures of growing energy needs.

Nepal is a country with 28.7 million people as of 2017 of which 19.3% live in an urban area while 80.7% live in rural areas[2]. The total final energy consumption in the year 2017 was 524.7 PJ with the per capita final energy consumption of 18.28 GJ. In contrast to the global energy mix, most of the energy demand in Nepal is supplied by traditional fuel which is around 73% followed by imported petroleum products 16%, coal 5% and electricity 4% and the rest by renewable energy, i.e., 2%[3]. The average final energy growth rate in the past 15 years is 3%. While looking at sectoral energy consumption, the highest energy-consuming sector is residential which is 74.57% followed by industrial 10.15%, transport 9.97%, commercial 3.54%, agriculture 1.71% and others 0.06%[3].

The total Gross Domestic Product (GDP) was 22.7 billion USD, the per capita GDP was $791 and the growth rate was 7.5% in the year 2017 which is all-time high compared to the past 10 years. The average growth rate was around 4.1% in the last 10 years. In the total GDP of 22.70 billion USD, the contribution of agriculture, construction, mining, manufacturing, commercial and energy was 28.76, 7.27, 0.59, 5.55, 56.56 and 1.27%, respectively[3].

Energy transitions can be analyzed, planned and managed by the use of energy models. Without knowing future energy demand it is difficult to plan for energy supply that will ensure energy security, availability and economic developments[4]. Different kinds of the model are in use for energy demand projection and scenario development classified as top-down, bottom-up, accounting end-use, e.g., MAED, MARKEL, LEAP, ENPEP, RET Screen, etc.

Different research works have been carried out in the field of energy planning. Hainoun *et al*.[5] have developed three scenarios of Syrian long term energy and electricity demand and[4] have developed the scenarios of future energy demand upto 2040 for Tanzania using MAED. Balat has analyzed energy demand and supply of Turkey to investigate the contribution of domestic energy sources in energy consumption. Al-Mofleh *et al*.[6] have analyzed the Malaysian energy scenario which outlines the present status of energy utilization and introduces the SCADA system, an energy management tool for the future. Khorasani, etc. has studied the impact of energy conservation policies on the projection of future energy demand of Iran using Long-Range Energy Alternative Planning (LEAP) and developed three scenarios. Khan[7] has forecasted the demand for natural gas which examines the short and long term dynamics of natural gas in Pakistan. Dong *et al*.[8] has reviewed China's energy consumption structure and outlook under three scenarios using LEAP. Malla and Timilsina[9] has developed the end-use energy demand analysis model for Romania to project energy demand by sector and end-use for 2015-50. Specifically in the context of Nepal, Shakya *et al*.[10] have analyzed co-benefits of introducing covariant of Carbon (C) tax scheme in Nepal using the MARKEL framework. Nakarmi *et al*.[11] has used MAED-MARKAL based framework for assessing different pathways for the development of energy systems of Nepal. Bhattarai[18] has analyzed the sectoral energy demand of Nepal using Long-Range Energy Alternative Planning (LEAP) and developed four scenarios with the base year 2005. Shakya *et al*.[10] have studied the Transport sector electrification in a hydropower resource-rich developing country: energy security, environmental and climate change co-benefits. Pokharel[13] have forecasted energy demand till 2012 and 2015 by using the econometric approach. Malla[14] has analyzed the patterns of household energy use and associated air pollutant emissions in Nepal using the LEAP Model upto 2040. Parajuli *et al*.[15] has predicted the energy consumption projection of Nepal using the econometric approach by taking base year as 2010 and projection period of 20 years.

From the literature, it has been found that the overall energy mix of Nepal is dominated by traditional fuels. The residential sector is the highest energy-demanding sector in Nepal. The literature also reveals that unless some policy intervention is done, the consumption pattern still will be dominated by traditional fuels. To switch into cleaner forms of energy and efficient technology some policy measures have to be adopted.

The economic growth rates taken in the previous previous research for the analysis are 3.9, 4.4, 5.6, 6.5, 5.5%[11], 3.31, 6.38, 10%[15]. As Nepal has already achieved the GDP growth rate of 7% and targeted to graduate in developing countries by 2022, it is necessary tomaintain 7-8% of growth rate[3]. Similarly, to maintain the per capita income of at 2,500 USD, the growth rate must be at least 9.2%. In addition to this, as the base year value is very sensitive in predicting future energy demand, a continuous update is necessary for the changing context ofthe energy sector of Nepal. Being a member country of United Nations and part of the Sustainable Development Goal (SDG) initiative, Nepal

has also set the targets for achieving SDG7, universal access to affordable, reliable and modern energy services, increasing substantially the share of renewable energy in the global energy mix and doubling the global rate of improvement in energy efficiency[16, 17]. For which policy scenario analysis is also necessary.

The main objective of this study is to predict the energy demand of different types of fuels in different economic sectors in low (4.5%), medium (7.2%) and high (9.2%) economic growth scenarios by using MAED, an end-use model from 2017 to 2040. Besides, this analysis will provide the best possible path to be adopted to achieve the targets of Sustainable Development Goals.

MATERIALS AND METHODS

Model for Analysis of Energy Demand (MAED) has been used to predict and analyze the medium to longterm future energy and electricity demand of Nepal. The revised version of MAED was developed by the International Atomic Energy Agency (IAEA) which is known as MAED_D[18].

Demand projection by MAED model requires information about demography, economy, energy-consuming technologies, energy consumption, lifestyle, etc.

Data collection: Secondary data at the national level have been collected from different documents published by national and international energy-related organization specially national organization includes Water and Energy Commission Secretariat (WECS), Ministry of Finance (MoF), Ministry of Forest and Soil Conservation (MoFSC), Nepal Electricity Authority (NEA), Alternative Energy Promotion Centre (AEPC), Nepal Oil Corporation (NOC), Department of Mines and Geology, Department of Custom whereas international organizations include International Energy Agency (IEA), World Bank (WB), International Atomic Energy Agency (IAEA), etc.

Selection of the base year: The year 2017 has been selected as the base year and the projection period considered in this study is from 2020-2040 for the analysis.

Key drivers: The key drivers of the energy demand have been taken as GDP growth rates and their structural changes, population growth and its urban and rural share, changes in lifestyle, population mobility, passenger and freight transport and market penetration of competing energy forms[4].

Macroeconomy: The level of economic activity and the structure of the economy are the most important factors for projecting future energy demand. Total GDP and sectoral contribution are the main driving parameters for energy demand projections, their future trajectory is also very important. The contribution of each sector in the future GDP value depicts the future energy demand of that particular sector. The equation for the calculation of GDP[18] is as follows:

$$Y = Y(-1)\times\left(1+\frac{YGR}{100}\right)^{INCR} \quad (1)$$

Where:

Y and Y(-1) = The value of the GDP in the current and the last previous model years, respectively
YGR = Growth rate of GDP between the two model years
INCR = Number of years between the current and last previous model years
GDP (Y) = Formation by economic sector and subsector (10^9 monetary units, MU)

$$YAGR = Y\times\left(\frac{PYAGR}{100}\right) \quad (2)$$

Where, PYAGR is the % shares of GDP contributed by the respective economic sectors. Sample equation for Growth rates of sector/subsector value added is given in Eq. 3:

$$YAGR, GR = Y\times\left\{\left(\frac{YAGR}{YAGR(-1)}\right)^{(1/INCR)}-1\right\}\times 100 \quad (3)$$

Demography: Population growth is one of the important factors determining the future evolution of energy demand.

In MAED the evolution of population as a function of time is defined exogenously as a scenario parameter. In the model, the population figure is used only for the base year and the population size PO for each successive model years is calculated by providing the average annual growth rate of population POGR (1.4% per annum) using Eq. 4:

$$PO = PO(-1)\times\left(1+\frac{POGR}{100}\right)^{INCR} \quad (4)$$

Where:

PO and PO(-1) = The size of the population in the current and the last previous model years, respectively
POGR = Growth rate to the population between the two model years
INCR = Number of years between the current and last previous model years

The total population of the country will reach 40 million by the year 2040 with a 40% share of urban population at 1.4% population growth rate and 3.15% of urbanization growth per annum[2].

Energy demand calculations: Energy consuming sectors have been divided into residential, industry, transport and commercial for the analysis. The residential sector is further divided into urban and rural, the industry is further classified into manufacturing and Agriculture, Mining and Construction (ACM), the transport sector is further classified into passenger and freight. The main elements of energy demand in the model are activity, structure and intensity. Generic equation used in MAED to determine future energy demand is given in Eq. 5[12, 4]:

$$ED = \frac{ED}{DP} \times CH \times DP \quad (5)$$

Where:

ED = Future energy demand
ED/DP = Specific energy demand per unit of the driving parameter in the base year
CH = Coefficient to reflect the evolution of specific energy demand per unit of the driving parameter in the future year
DP = Specific energy demand per unit of the driving parameter in the future year

Details of the calculations methods by sector and enduse are given in the MAED user manual.

Development of scenarios: Energy demand projection and scenario development is the basic prerequisite for the formulation of integrated energy policy, preparing the plan and defining the activities for implementation.

Low, medium and high scenarios have been developed by considering different economic growth rates 4.5, 7.2 and 9.2%, respectively. Finally, an additional policy scenario has been developed by considering different policy intervention options.

Low economic growth scenario: This growth rate has been taken for the analysis since the average growth rate of the past 10 years was around 4.5% which is also a business as usual scenario. This scenario shows what happens if the country continues to follow its current path without any additional policy intervention.

Medium economic growth scenario: It is necessary to achieve higher and sustainable economic growth rate for the country to graduate from its current status of a least developed country to developing country by 2022, for which it requires about 7-8% of growth rate[3]. As Nepal has set a target to move into developing countries by the year 2022, the analysis has been performed at a 7.2% growth rate to identify the future energy needs to maintain this growth rate.

High economic growth scenario: For this scenario development, 9.2% of economic growth has been considered. This is the percentage required to have at least $2500 per capita income.

Policy intervention scenario: This scenario has been developed by doing some policy intervention in the medium growth scenario @ 7.2% to predict changes in energy and electricity demand. It has been assumed that 50% of the urban water heating and cooking will be done by electricity by the year 2030 and 20% of the total passenger-kilometer demand will be fulfilled by electric vehicles.

RESULTS AND DISCUSSION

Gross domestic product: Gross Domestic Product (GDP) prediction from the model at different growth rates shows the economic health of the country.

Figure 1 shows the total GDP in different scenarios. The total GDP will be 62.48 billion USD @ 4.5% economic growth rate, 112.34 billion USD @ 7.2% economic growth rate and 171.85 billion USD @ 9.2% economic growth rate by the year 2040.The total GDP will be 3 times higher in low, 5 times higher in medium and almost 8 times higher in the high scenario by 2040 in comparison to the base year.

Final energy demand: Final energy demand is the aggregate of all energy forms used by all economic sectors. Increasing final energy demand shows the pressure on fuel demand.

The final energy demand in three different scenarios is presented in Fig. 2. In the base year 2017 final energy consumption was 524.7 PJ. In the year 2040, final energy demand has been found 1,162.8, 1,489.65 and 1,879.82 PJ in low, medium and high scenarios, respectively whereas in policy scenario the demand will be slightly less than medium scenario 1,416.07 PJ. The growth rate is 3.5% in low, 4.6% in medium, 5.7% in high scenario and 4.4% in policy scenario.

Final energy demand by economic sectors: The sectoral final energy demand obtained from the MAED Model in three different scenarios also indicates the sectoral growth The final energy demand in industry, transport, residential and commercial sector has been found to reach 281.45, 285.33, 557.8 and 38.22 PJ, respectively by 2040 shown in Fig. 3. In this scenario, the industrial sector energy

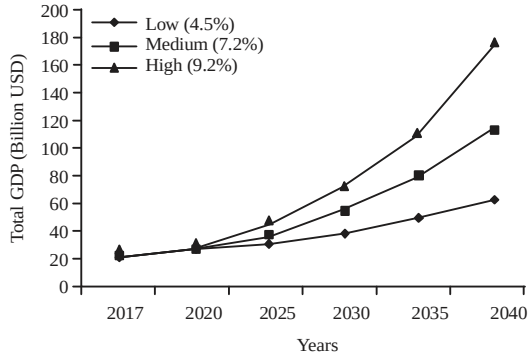

Fig. 1: Total GDP in low, medium and high scenario

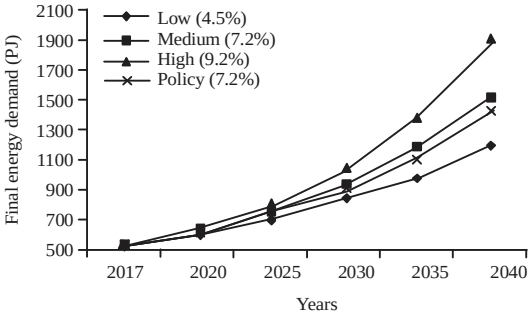

Fig. 2: Final energy demand in low, medium and high scenarios

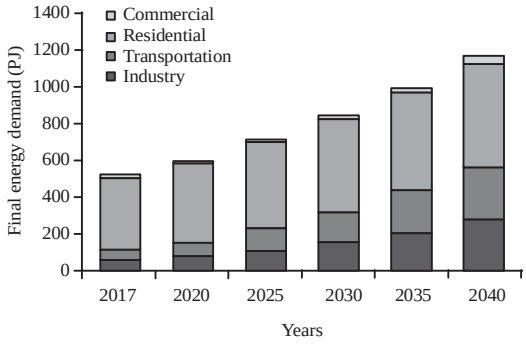

Fig. 3: Sectoral final energy demand in low economic growth scenario

demand will be 4.5 times, transport 5.5 times, residential 1.4 times and commercial will be 2.2 times higher than the base year energy demand. The energy demand of transport sector has been found to increase rapidly.

Figure 4illustrates the sectoral final energy demand in the medium scenario. The energy demand by 2040in industrial, transport, residential and commercial sectors have been found to reach 506.06, 358, 557.8, 66.84, respectively. The demand for industrial, transport, residential and commercial sectors will be 8.1 times, 6.9 times, 1.41 times, 3.9 times the base year. The

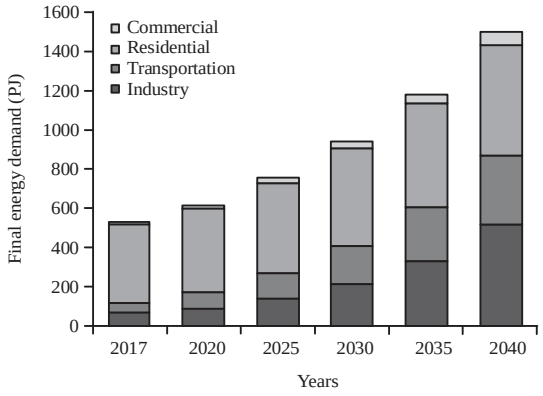

Fig. 4: Sectoral final energy demand in medium scenario

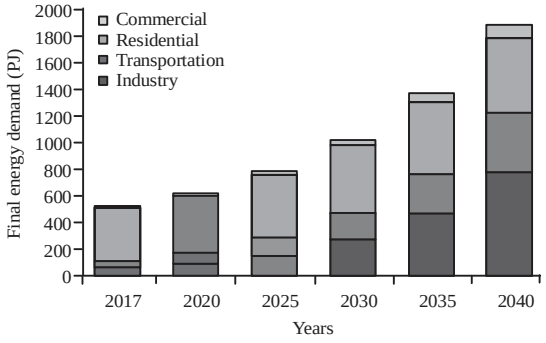

Fig. 5: Sectoral final energy demand in high economic growth scenario

demand for the industrial sector surpasses all other sectors. Figure 5 shows the sectoral energy demand in the high scenario in which the final energy demand of industrial, transport, residential, commercial sector have been found 774.2, 446.81, 557.8 and 101.01 PJ, respectively.

These values are 12.4, 5.4, 1.02 and 5.9 times of base year values in industrial, transport, residential and commercial sector. The highest demanding sector will be industry in 2040 followed by residential, transportation and commercial sector.

Final energy demand in policy scenario in Fig. 6 shows that the final energy demand of industrial and residential sector is almost equal by 2040. The growth rate of energy demand in industry, transport, residential and commercial sectors has been found to be 9.5, 8.8, 1.5 and 6.17%, respectively. Which shows that the highest growth rate will be in industrial sector. The energy demand of residential sector is same in low, medium and high scenario whereas in policy scenario the final energy demand of residential sector differs by 10% because of the intervention of electricity in urban household.

Per capita final energy demand shown in Fig. 7 presents that by 2040,29.42, 37.69 and 47.56 GJ will be

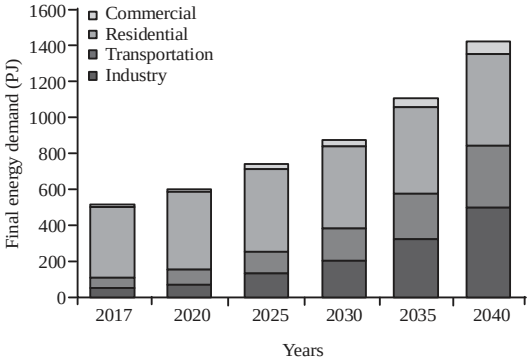

Fig. 6: Sectoral final energy demand in policy scenario

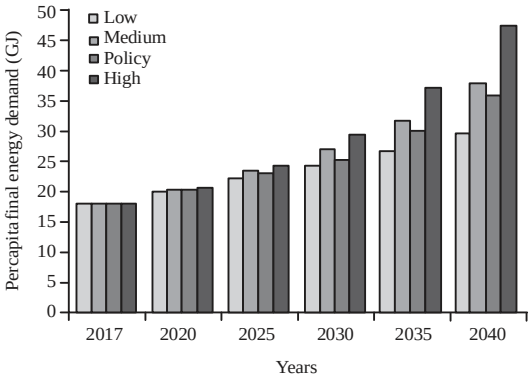

Fig. 7: Per capita final energy demand

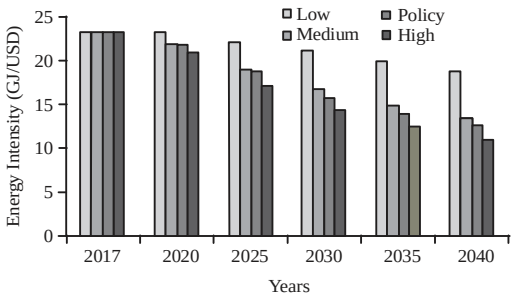

Fig. 8: Final energy intensity

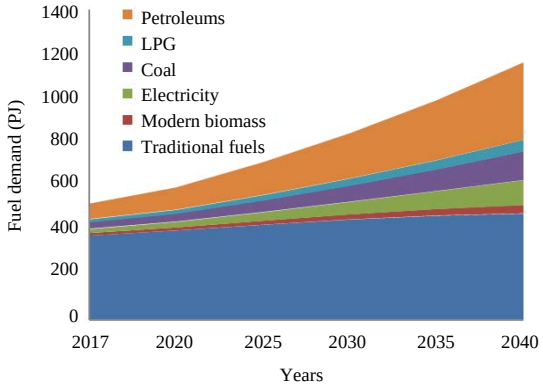

Fig. 9: Final energy demand by fuel types at low economic growth scenario

required in the low, medium and high economic growth scenario, respectively whereas in policy scenario the demand will be 35.82 GJ slightly less than medium scenario.

Energy intensity: The decline in energy intensity of the country in different time period indicates the economy will be more efficient in the future.

Figure 8 shows that the final energy intensity at the base year was 23.11 GJ/USD which is in decreasing trend in all the scenarios. The final energy intensity has been found to decrease to 18.61, 13.26, 10.94 and 12.61 GJ/USD in low, medium, high and policy scenarios, respectively by 2040. The final energy intensity will reduce by 0.9% in low, 2.4% in medium and 3.2% in high scenario whereas in policy scenario it will decrease by 2.6%.

Final energy demand by fuel types: Final energy demand by fuel types gives the overall energy mix of the country in different time horizon.

Traditional energy will increase from 382-481 PJ from base year to final year shown in Fig. 9. Similarly, modern biomass, electricity, coal, LPG and petroleum consumption will increase from 12, 18, 41, 14 PJ to 37, 41, 52.8 and 349.4 PJ by the year 2040.

The growth rate of traditional fuels, modern biomass, electricity, coal, LPG, petroleum has been found to be 1.01, 5.19, 8.41, 6.5, 6.02 and 7.27%, respectively. However, the share of traditional fuel will decrease to 41% from 73%, share of petroleum will increase to 30% from 13% of the base year and electricity will increase to 10% from 3% of the base year. Overall from 2035 onwards there will be domination of commercial energy (petroleum, coal, LPG, electricity) surpassing the traditional fuel.

Traditional energy will increase from 382-516 PJ by the year 2040 as shown in Fig. 10. Similarly, modern biomass, electricity, coal, LPG and petroleum demand will increase from 12, 18, 30.41, 13.73 and 69.48 PJ to 45,163, 234, 59.73 and 472 PJ by the year 2040, respectively.

The growth rate of traditional fuels, modern biomass, electricity, coal, LPG and petroleum will be 1.3, 6.0, 10.2, 9.3, 6.6 and 8.7%, respectively while the share of traditional energy will reduce to 35% and petroleum will increase to 39% and share of electricity will be 11%.

Traditional energy demand will increase from 382-559 PJ by the year 2040 as shown in Fig. 11. Similarly, modern biomass, electricity, coal, LPG, petroleum demand will increase to 54, 223, 357.6, 68 and 618 PJ by the year 2040.

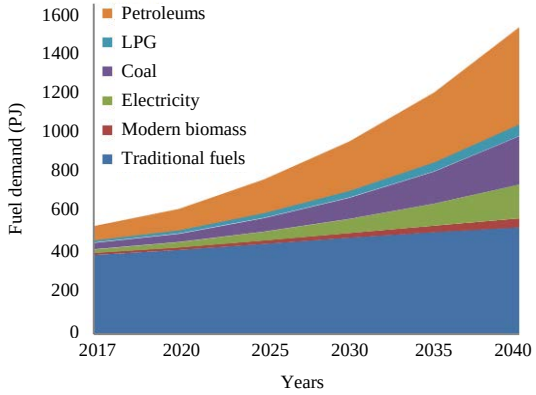

Fig. 10: Final energy demand by fuel types at medium scenario

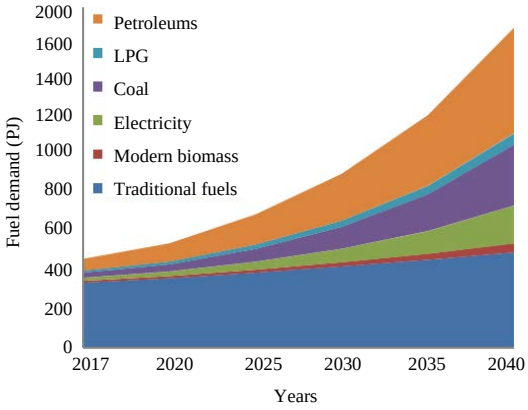

Fig. 11: Final energy demand by fuel type at high economic growth scenario

The growth rate of traditional fuels, modern biomass, electricity, coal, LPG, petroleum has been found to be 1.66, 6.9, 11.7, 11.3, 7.2 and 9.9%, respectively. In high scenario the share of commercial energy will be higher from the year 2030 which is 3% in 2030, 12% in 2035 and 40% in 2040. While the share of traditional fuel will decrease to 31% and petroleum will reach to 31%, coal 17% and electricity will be 13 but there will be mere change in the share of LPG, i.e., 4%.

Final demand in policy scenario for traditional fuel has been found to reach 442.4 PJ, modern biomass 63.99 PJ, electricity 183.6 PJ, coal 233.77 PJ, LPG 59.73 PJ and petroleum 432.56PJ shown in Fig. 12. The growth of traditional fuel is 0.64%, modern biomass is 7.68%, electricity is 10.76%, coal is 9.2%, LPG is 6.6% and petroleum 8.2%. The growth of traditional fuel is lowest and the electricity is the highest among all the fuels. The share of traditional fuel has been found to decrease to 31% from 73% and petroleum share would increase to 31% from 13% in the year 2040 (Fig. 13).

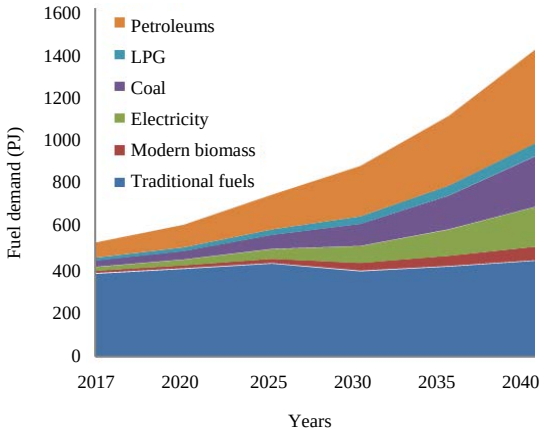

Fig. 12: Final energy demand by fuel types in the policy scenario

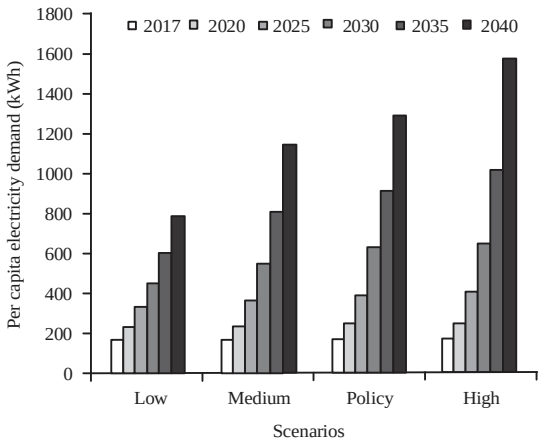

Fig. 13: Per capita electricity demand in the different scenarios

Electricity demand and power plant capacity: Electricity is the clean and indigenous form of energy in the context of Nepal. Use of electricity where ever possible will enhance the energy security of the country. In addition use of electricity will help to reduce the overall final energy consumption.

Electricity demand has been found to reach 31.17, 42.25, 62.06 by the year 2040 in low, medium and high scenario, respectively whereas in the policy scenario demand will reach to 50.99 TWh. Per capita electricity demand will be 789 kWh, 1,145 kWh and 1,570 kWh in the low medium and high scenario, respectively whereas in the policy scenario it will be 1,290 kWh. If all the electricity demand of Nepal is fulfilled by hydroelectricity and assuming plant factor 50%, regular outage and unexpected outage 25%, transmission and distribution loss 20% (NEA, 2017) and additional power requirement to support the peak demand 30%, the total installed capacity requirement would be 12.62, 18.31 and

25.12 GW by the year 2040 in the low, medium and high scenario, respectively while in the policy scenario installed capacity requirement would be 25.12 GW.

CONCLUSION

The final energy demand in the low, medium, high and policy scenarios have been found to reach 1162.8, 1489.65, 1879.82 and 1416.07, respectively by the year 2040 from 524.7 PJ of base year 2017. Final energy demand will decrease by 5% whereas electricity demand will increase by 21% in the policy scenario in comparison to medium growth scenario by the year 2040.

The share of traditional fuel has been found to decrease in all the scenarios but the share of petroleum increases in all the scenarios.

Energy intensity will decrease to 18.61, 13.26, 10.94 and 12.61 from 23.1 GJ/USD by 2040 in low, medium, high and policy scenarios, respectively. In the high scenario, the energy intensity has been found to reduce to almost half of the base year value. The final electricity demand will reach 15.61, 18.91, 22.04 and 21.61 TWh by the year 2030 while the demand will increase to 31.17, 45.25, 62.06 and 50.99 TWh by the year 2040 in low, medium, high and policy scenarios, respectively. The total installed capacity requirement will be 12.62, 18.31 and 25.12 GW by the year 2040 in the low, medium and high scenarios, respectively while in the policy scenario installed capacity requirement will be 20.64. The analysis also shows that unless some policy measures are applied aggressively for using electricity, the import dependency is going to increase rapidly in the future and it will be difficult to achieve SDG target by 2030.

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REFERENCES

01. Singh, B.K., 2013. South Asia energy security: Challenges and opportunities. Energy Policy, 63: 458-468.
02. NPC., 2012. National Population and Housing Census 2011: National Report. Vol. 1, Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Nepal, Pages: 264.
03. MFGI. and MoF., 2018. Economic Survey 2017-18. Vol. 2, Oxford University Press, New York, USA., Pages: 576.
04. Kichonge, B., G.R. John, I.S. Mkilaha and S. Hameer, 2014. Modelling of future energy demand for Tanzania. J. Energy Technol. Policy, 4: 16-32.
05. Hainoun, A., M.K. Seif-Eldin and S. Almoustafa, 2006. Analysis of the Syrian long-term energy and electricity demand projection using the end-use methodology. Energy Policy, 34: 1958-1970.
06. Al-Mofleh, A., A. Quteishat and W. Salah, 2015. The Malaysian energy scenario and the need for a SCADA system. Energy Sour. Part B: Econ. Plann. Policy, 10: 381-387.
07. Khan, M.A., 2015. Modelling and forecasting the demand for natural gas in Pakistan. Renewable Sustainable Energy Rev., 49: 1145-1159.
08. Dong, K.Y., R.J. Sun, H. Li and H.D. Jiang, 2017. A review of China's energy consumption structure and outlook based on a long-range energy alternatives modeling tool. Pet. Sci., 14: 214-227.
09. Malla, S. and G.R. Timilsina, 2019. Assessment of long-term sustainable end-use energy demand in Romania. Int. J. Sustainable Energy, 38: 253-275.
10. Shakya, S.R. and R.M. Shrestha, 2011. Transport sector electrification in a hydropower resource rich developing country: Energy security, environmental and climate change co-benefits. Energy Sustainable Dev., 15: 147-159.
11. Nakarmi, A.M., T. Mishra and R. Banerjee, 2016. Integrated MAED-MARKAL-based analysis of future energy scenarios of Nepal. Int. J. Sustainable Energy, 35: 968-981.
12. Bhattarai, N., 2015. National energy demand projections and analysis of Nepal. P.hD. Thesis, Department of Mechanical Engineering, Institute for Energy System and Thermodynamics, Vienna University of Technology, Austria.
13. Pokharel, S., 2007. An econometric analysis of energy consumption in Nepal. Energy Policy, 35: 350-361.
14. Malla, S., 2013. Household energy consumption patterns and its environmental implications: Assessment of energy access and poverty in Nepal. Energy Policy, 61: 990-1002.
15. Parajuli, R., P.A. Ostergaard, T. Dalgaard and G.R. Pokharel, 2014. Energy consumption projection of Nepal: An econometric approach. Renewable Energy, 63: 432-444.
16. UN., 2016. Sustainable development goals: UN web services section. Department of Public Information, United Nations, New York, USA.
17. NPC., 2015. Sustainable development goals 2016-2030: National (Preliminary) report. National Planning Commission, Kathmandu, Nepal.
18. IAEA., 2005. Model for analysis of energy demand (Maed-2). International Atomic Energy Agency, Vienna, Austria. https://www-pub.iaea.org/MTCD/publications/PDF/CMS-18_web.pdf