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Sustainable Energy Planning at Household Sector and Modal Solar Street Light Design: A Case at Chandragiri Municipality

Rojeeb Maharjan [a], Amrit Man Nakarmi [b]

[a] *Department of Architecture & Urban Planning, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[b] *Department of Mechanical Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
Corresponding Email: budhobaje@gmail.com [a], nakarmiamrit@gmail.com [b]

Abstract
Energy planning is a necessary and effective tool which portrays existing pattern of energy use and its impact on environment, economy and society. It is gaining more relevance with time as demand for energy is rising and there is an increasing demand to extract required energy from renewable and clean sources. This study is conducted to understand the current energy consumption pattern of residential sector of Chandragiri Municipality. Primary data required for the research is obtained through household survey and LEAP is used to project three alternatives for future energy use pattern. Business as usual, all electrified and Sustainable development goal along with increasing consumption are the three Scenarios created. At present, in Chandragiri Municipality current energy demand is 225.6 Tera joule and LPG is the highest consumed final fuel and highest energy demand is for cooking. Peak power electricity requirement at present is only 4.4 MW. However, with urbanization and expected increase in use of electrical appliance for cooking, heating, cooling or refrigeration future energy demand will increase to 392.4 TJ by 2030 and 987 TJ by 2050 in BAU scenario. With policy intervention future energy demand can be reduced to 274.5 TJ from 392.4 TJ by 2030 in AEL Scenario. However to meet targets of sustainable development goals of increasing per household electricity consumption by 3000 kWh, current energy consumption has to be increased by 10 % which leads to energy demand of 442.9 TJ in 2030.

Keywords
Residential energy system, ,energy demand, energy security and energy planning

1. Introduction

Energy is the vital element for sustainable development of country. Energy is fundamental to human communities and their sustainable development. The complex relationship of community energy systems and environmental, economic and social aspects of human life highlights the role of planning in future developments [1]. The principles of sustainable development have increasingly been accepted in societies throughout the last decades. Human well-being and improvement of social welfare greatly depend upon affordable access to energy services. Almost all the goods and services that are necessary for communities' development are linked to the provision of commercial energy. Energy is also among the important factors which can affect the environment both by extraction of energy from natural resources and by energy use. Every advanced economy requires secure access to modern sources. Access to reliable and affordable energy services is fundamental in reducing poverty and improving health, increasing productivity, enhancing competitiveness and promoting economic growth [2]. Nepal, being a least developed nation, faces the multitude of challenges related to energy poverty, access to modern energy and energy security [3].

2. Problem statement

In the context of the current rapid urbanization, recent trends indicate that more than a million people will be added to our cities every week until 2050. In this scenario, urbanization could reach over 80% of the global population [4]. In the past few decades, energy consumption has increased in almost every energy sub sector worldwide. Cities are centers of high population density and energy consumption

throughout the world. While occupying just 2% of the land, they account for approximately 75% of the world's energy usage, and contribute to 80% of global greenhouse gas emission. Such a drastic increase in urban population accentuates sustainability challenges, in particular that of climate change In addition, continually increasing GHG emissions from the residential sector makes the sector a large source of GHG emissions globally. Residential sector has been one key sector for reducing its greenhouse gas emissions due to its significant contribution to global warming.

Nepal, being a least developed nation, faces the multitude of challenges related to energy poverty, access to modern energy and energy security. At present, energy share of Nepal is dominated by non-renewable sources and heavy dependence on import of petroleum products. Billions rupees has been spent for importing different kinds of fuel and increasing at the rate of 9% annually. Due to increasing price of petroleum products and a country's growing dependence on it, much of the country's earnings through exports are being used up for importing them. Although there are different clean choices, individuals are as yet working on consuming of fuel-wood emitting more emissions. In this way, replacement of biomass based energy source by clean energy source has turned out to be imperative for natural protection and economic advancement [1].

3. Need and Importance of Research

Energy system is currently based on large fossil fuels dependence. Fossil fuels depletion, environmental damage and territorial unbalance caused by centralized energy model are significant factors to change energy structure, integrating new resources and modifying the way we use them. It is necessary to make compatible socio-economic development with a sustainable energy model, environmental respectful and that could generate local wealth. The key issue is to address current model towards a more balanced system based on the exploitation of renewable resources [5]. Therefore, planning decisions concerning energy system cannot be consider under one specific criterion.

Chandragiri being a newly declared municipality has characteristics of semi-urban area which is rapidly transforming into an urban area. Study of energy consumption pattern for residential sector is not new in case of Nepal. Most past studies in energy consumption have focused on either energy consumption of rural Nepal or Urban Sector. In as early as 1990, rural household energy demand was estimated and projected using 8 variables that included population, household expenditure, agricultural commodity, number of livestock, number of cook stoves, area covered by housing, and topography and forest accessibility consumption [6]. Similar studies have been conducted in various parts of the country like Bhaktapur District, Dhulikhel Municipality, Panauti Municipality, Kathmandu Valley etc. Energy demand of the area is going to be high as compared to past, since different services and infrastructures need to be added to meet the criteria of the municipality. At present only population criteria of a municipality has been fulfilled. With the urbanization, lifestyle of the people will also change. People will definitely try to live more sophisticated and easier life. This may increase energy demand in electricity and imported petroleum products as LPG is substituting as a cooking fuel, living in a modern concrete house which increases energy demand for space heating and cooling. Also people are using inefficient technologies which also increase energy demand. So in order to meet future energy demand, proper energy scenario planning is necessary for which energy projection based on current scenario for future is required. Otherwise we might again face a problem of energy crisis in future which we faced in past decade due to lack of proper energy planning. For proper energy planning of the area, situations and conditions of that area should be taken into account. One cannot generalize all areas by looking into a particular area unless all conditions are similar. So for the proper energy planning, primary data should be considered of that particular case.

4. Research Objective

To analyze the energy consumption pattern of Chandragiri Municipality and investigate how different actions concerning the energy sector will affect the energy system.

Specific Objectives

- To forecast the total energy demand up to 2050 with different scenario development in LEAP model.
- To calculate amount of GHGs and CO2 emission reduction potential of energy consumed in

household sectors and Cost Benefit analysis for different scenarios.
- A comparative analysis of different scenario models.

5. Limitation

- The study will only focus on the energy planning of household sector.
- The intensity and efficiency of end use devices is assumed to be constant throughout the study period.
- Population growth rate is only considered for projection of energy demand.

6. Literature Review

In 1980s, when the term "sustainable development" came into the global consideration, with no doubt, energy became the key element for the community development regarding the three main topics, environment, economy and social equity (Rad, 2008). Adequate and affordable energy supplies have been playing an important role in economic development. Energy is a key element for improving social and economic well-being, and is vital to most industrial and commercial wealth generation. It is necessary for improving human welfare and living standards. Both the energy exploitation from natural resources and energy use can affect our living environment. It is obvious that energy has a strong relationship together with sustainable development. There are several planning theories which have been used as the basis for different planning purposes e.g. energy planning.

Classifies energy planning methods depending on the planning level (local, regional or national) and required time scale (short, medium or long-term) in three categories [7]:

1. Planning by model, including econometric model and optimization model, generally based on mathematical and statistical methods, such as market allocation model (MARKAL) or energy flow optimization model (EFOM)
2. Planning by analogy, which is the process of making a new plan based on the structure of an existing successful plan. This method simulates the quantitative data and checks the outputs with the other methods.
3. Planning by inquiry, which is a method based on the statistical evaluated and optimized answers of selected experts (Delphi method).

Nepal is one of the least energy consuming countries in the world. Energy consumption is the amount of energy that is used for any purpose like domestic, industrial and others purposes. Energy demand for any place is important factor for social, economic and environmental development. It was indicated that the demand for LPG in urban areas increased at the rate of 23% whereas the demand for electricity increased at the rate of 10% (WECS, 2012). Moreover, in Nepal, the largest share of energy is consumed by residential sector (80.36%) in comparison to other economic sectors. Industries and transports consume only 7.89% and 7.12% of energy respectively. Consumption of energy is least in Agriculture (1.17%) followed by commercial sector (3.43%).

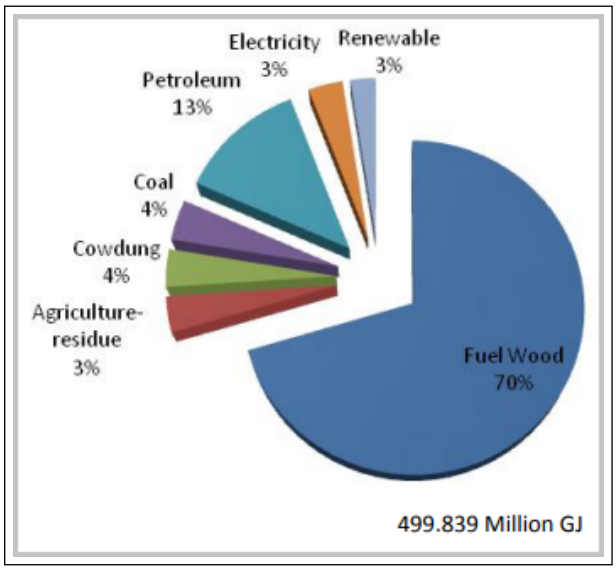

Figure 1: Energy Consumption Pattern of Nepal, Source: WECS)

The energy demand of Nepal was about 500 PJ in the year 2014/15 .which is heavily dependent on biomass energy which accounts about 70% of total energy consumption. Petroleum products, which are imported, accounts for about 13% of the total energy consumed, and electricity represented only 3% of the total energy. Though Nepal has a huge potential for hydropower production, its exploitation has been to a very minimal, and therefore, significant amount of energy supply comes from traditional energy sources such as biomass. Heavy dependence for energy on biomass resources has accelerated the depletion of natural resources and contributed to the degradation of natural environment. It is the biomass sector which dominates the overall energy supply and consumption in the country. The renewable energy services are not

equitably distributed across Nepal. Mainly around the more accessible areas of the Country to install renewable energy schemes. However, people living in the remote and very remote areas and the poor households are mostly deprived of such energy services due to the high initial cost of the renewable energy technologies, low income of households, and low capacity of the institutions involved in the development of renewable energy services at local level. The subsidy policy should encourage private sector to commercialize the renewable energy technologies and focus on better quality and service delivery in rural areas. The current subsidy policy is not smart and addresses the pro-poor. (Ministry of Science, Technology and Environment). Energy is mostly consumed in cooking followed by heating (WECS, 2012). About 61% of energy is consumed in cooking purpose whereas space heating consumes 14% and 13% of energy is consumed by water boiling activities. Less than 1% i.e. 0.72% of energy is consumed for lighting purpose. Electrical appliances contribute 0.41% whereas water pumping contributes only 0.12% of residential energy consumption (Shrestha, Nakarmi, 2015).

7. Research Methodology

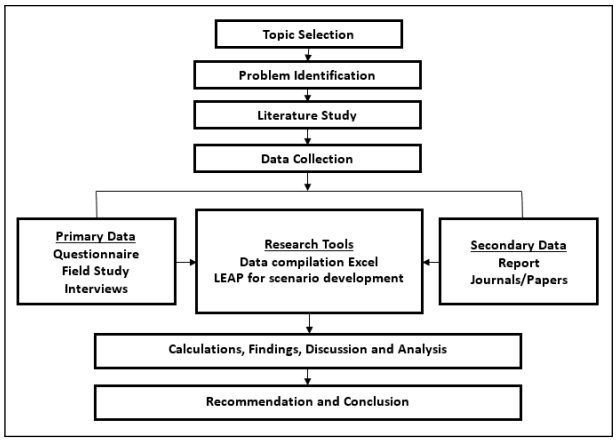

Figure 2: Graph of Research Methodology

In this particular research, the main objective is analyze the energy consumption pattern of Chandragiri Municipality and investigate how different actions concerning the energy sector will affect the energy system in the future and it cannot be approached through qualitative research method. This project requires extensive data from the people that can be useful to find out energy consumption pattern so quantitative research methods based on post-positivist paradigm will be used. Data will be compiled in Excel and the necessary data will be used in LEAP software to get the required outcome. Computer simulation will be done in LEAP which will be verified with data of similar areas for validation.

7.1 Sample size determination

With the confidence level of 95% and error percentage of 10% the sample required was found to be 192 households. The sample size was calculated using the following formula [8]

$$x = \frac{x2NP(1-P)}{[e2(n-1)+x2P(1-P)]} \quad (1)$$

Where,

S = Required sample size

x2= Table value of chi-square for 1 degree of freedom at the desired confidence level

N = population size

P = population proportion

e = Error Percentage

With the confidence level of 95 % and error percentage of 10 % the sample required was found to be 192 households.

7.2 Study Area

Study area of my research is in Chandragiri municipality. Chandragiri is a municipality located in Central development region of Kathmandu District in the Bagmati Zone of Nepal. It is Located in South-west of Kathmandu and largest Municipality in Province 3. The new municipality was formed by merging eleven existing villages.

7.3 Questionnaire development

QQuestionnaires are typically used to collect primary data and to determine the current status or to estimate the distribution of characteristics in a population. Questionnaire was developed to collect primary data on the final household energy consumption of Chandragiri Municipality. Questionnaire was prepared on the basis of the energy consumption by fuel types such as firewood, LPG, kerosene, electricity, solar, agricultural residue etc. and energy

consumption by end use such as cooking, lighting, water heating room heating/ cooling and other electric appliances. The primary data was collected in the hardcopy of questionnaire. The collected data was used as input in the LEAP software.

7.4 Scenario Development

Scenario development is the process of visualizing the future conditions and their consequences that are most likely to happen and ways to respond to get benefit from them.

7.4.1 Business as Usual (BAU)

The Business as usual (BAU) scenario is developed based on historical trends in energy consumption and also existing governmental plans in the residential sector. In this scenario, activities continue as existing pattern. Only the population growth is considered. Energy demand increases in relation to growth in population. Technology advancement during the time frame and market penetration of efficient technologies are not considered.

7.4.2 All electrification scenario (AEL)

In this scenario, it is assumed that by 2030 only electricity will be consumed to meet energy demand for all end use. Cooking, heating, lighting, cooling, water boiling, electrical appliances and other uses are all depended on electrical energy from hydropower or solar sources. This scenario takes into account switching to efficient technology for end use activities like switching of CFL and incandescent bulb to LED bulb. Population growth will be same as BAU scenario

7.4.3 Sustainable development Goal (SDG))

In this scenario, interventions were done to meet the targets of sustainable development goals by National Planning Commission by 2030. The objective of Sustainable development goal is to promote renewable clean energy like electricity and solar. In this scenario, objective is to meet electricity consumption by 3000 KW per household i.e. tier 5 of multi- tier matrix.

8. Findings

Based on primary data collected from household survey it was found that the total energy demand for Chandragiri municipality in the year 2018 was 225 TJ. Out of 225, nearly 60% of energy is used for cooking purpose only (i.e. 134 TJ) followed by electrical appliances nearly 20% (i.e. 47 TJ) and lighting 10% (i.e. 24 TJ). Remaining end-use activities has not significant contribution in energy demand.

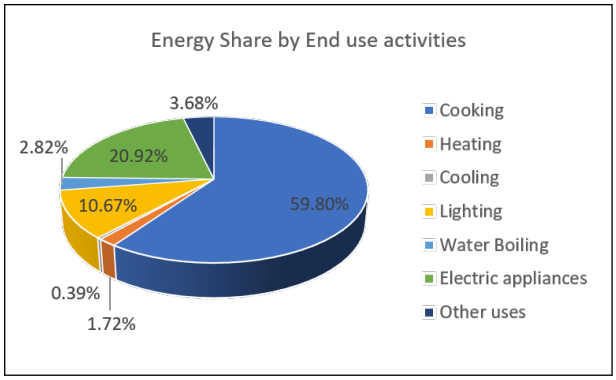

Figure 3: Energy Share by End use activities

Per capita energy consumption was found to be 2.39 GJ which is less than Kathmandu valley 3 GJ and also it was found that 100 % of the household has access to the electricity. The overall per capita electricity consumption Chandragiri municipality was found to be 204.6 Kwh.

	Quantile 1	Quantile 2	Quantile 3	Quantile 4	Quantile 5	Overall
Description	Lower Income	Second	Third	Fourth	Higher income	
% Share	8.69%	42.09%	30.27%	12.79%	6.15%	100%
Yearly Income	Below 157000	157000 to 314400	314400 to 471600	471600 to 628800	628800 and above	265600
Per Capita energy (GJ)	**3.65**	**2.18**	**2.29**	**2.35**	**2.34**	**2.39**
Per Capita Electricity(kWh)	**177.8**	**220.21**	**248.39**	**265.27**	**251.63**	**204.6**

Table 1: per capita electricity consumption Chandragiri municipality

Energy demand for Chandragiri municipality was developed for the year 2018 based on primary data and secondary data.

Final Energy Demand for Chandragiri Municipality (GJ) 2018								
Fueltype	Cooking	Heating	Cooling	Lighting	Water boiling	Electric appliances	Other uses	G. Total
Fuelwood	2,545	94			2,827		2,921	8,388
Agriresidue							5,372	5,372
Animalwaste								-
Otherbiomass								-
Biogas								-
Biobriquette								-
Gridelectricity	4,901	3,016	886	23,560	226	47,121	-	79,710
Decelectricity								-
Solar				471	377			848
LPG	127,226	754			3,298			131,279
Kerosene								-
Otherpetro								-
Others:battery								-
Total	134,671	3,864	886	24,032	6,729	47,121	8,293	225,596

Table 2: Final Energy demand for Chandragiri municipality

9. Analysis

9.1 Energy Demand

This study shows that if current energy consumption continues by 2050, total energy consumption will increase to 987 TJ (BAU). But in all electrification scenarios, energy consumption will be only 690.5 TJ (AEL) by 2050 while in SDG scenario it will increase to 1114 TJ by 2050. Comparing final energy demand; it is found that energy demand for BAU scenario is higher than in AEL scenario. This is due to highly dependent on traditional fuels and LPG whose efficiency is lower as compared electricity.

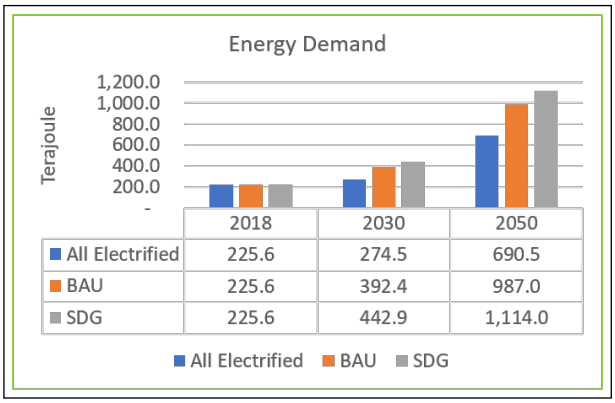

Figure 4: Energy Demand

9.2 Per household Electricity Consumption

The per household electricity consumption which is 816 kWh in 2018, remains constant in BAU scenario whereas with policy intervention of fuel switching to electricity, it increases two times to 1872 kWh by 2030 in all electrification while in SDG scenario, it will increase to 3024 kWh.

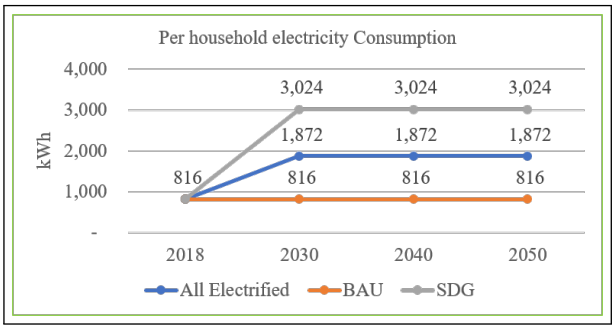

Figure 5: electricity Consumption Per household

9.3 Energy consumption Per Capita

The per capita energy consumption which is 2.4 GJ per person in 2018, remains constant in BAU scenario whereas with policy intervention of fuel switching from dirty fuel of firewood and imported petroleum LPG to electricity, it decreases to 1.7 GJ per person by 2030 in all electrification scenario and will remain constant till 2050. By only fuel switching to electricity, we cannot reach tier 5 of multi-tier energy matrix so energy consumption has been increased, hence per capita energy consumption in SDG scenario is slightly higher than BAU scenario. Per capita energy consumption will be 2.7 GJ by 2030 in SDG scenario.

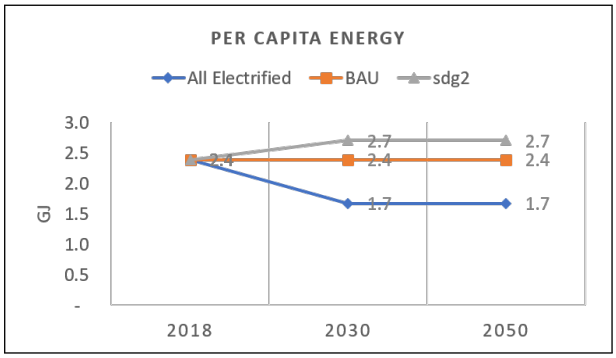

Figure 6: Energy consumption Per Capita

9.4 GHG EMISSION

Emission will continuously increase at the rate of 4.72 % in BAU scenario and increased from 9.5 thousand metric tons of CO2 equivalent in 2018 to 16.4 thousand tons of CO2 equivalent by 2030 and 41.4 thousand metric tons by 2050. But in AEL and SDG scenario it will gradually decrease and by 2030 emission will be reduced to negligible.

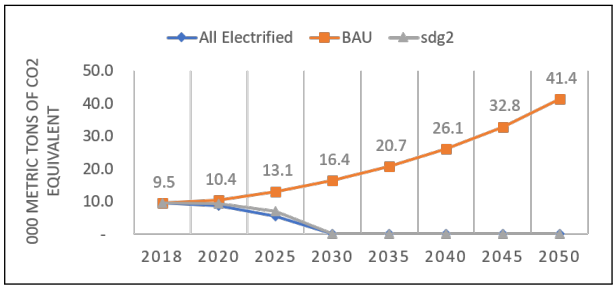

Figure 7: GHG Emission

Per capita GHG emission in the base year was 100.3 kg of CO2 equivalent which will remain constant throughout study period in BAU scenario while in AEL and SDG scenario, it gradually decreased to negligible by 2030.

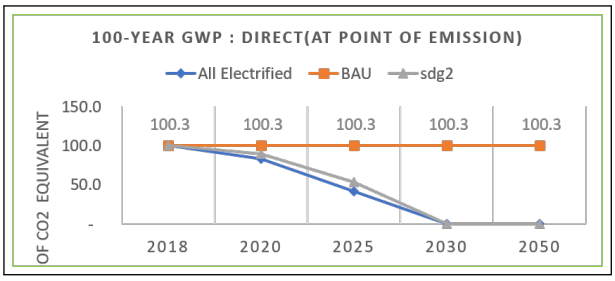

Figure 8: GHG Emission Per Capita

9.5 Peak Power plant requirement

Peak power requirement will increase from 4.4 MW in 2018 to 7.7 MW by 2030 and 19.3 MW by 2050 in BAU scenario. Similarly it will increase to 17.6 MW by 2030 and 44.3 MW by 2050 in AEL scenario. In SDG scenario, Peak power requirement will increase to 28.5 MW by 2030 and 71.6 MW by 2050. If want to achieve SDG goals by 2030 then 28.5 MW of electricity will be required only in Chandragiri Municipality.

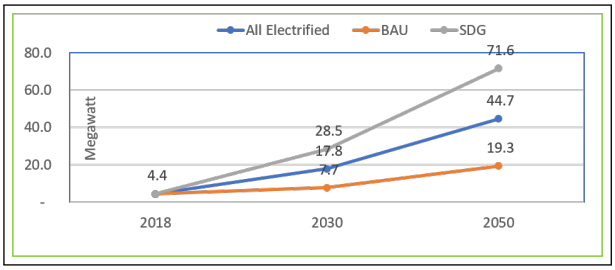

Figure 9: Peak Power plant requirement

10. Conclusion

Current energy consumption pattern in Chandragiri municipality is increasing rapidly in unsustainable way. Continuity of such trend is not desirable as it leads to very high increase in GHG and CO2 emission and increases dependency on non-renewable sources. Such a situation requires policy intervention so that impact on environment, economy and society can be regulated. Development of energy efficient technologies for various household activities have potential to decrease energy demand on one hand, reduce dependency on non-renewable sources and decrease harmful emissions on the other. With relevant policy intervention energy of switching fuel to electricity consumption can be reduce to 689 TJ from 987 TJ by 2050. Also if we are targeting to meet the goals of sustainable development goals by 2030, current energy consumption is not enough to reach the tier 5 of multi-tier energy matrix. We have to increase energy consumption using renewable source of energy either in the form or solar of hydro- power. And in order to meet targets of sustainable development goals which is increasing electricity consumption per house hold by 3000 kWh by 2030. Electricity demand will increase from 2.13 MW in 2018 to 34.5 MW in 2050 with an annual growth rate of 9.1%. During peak hour electricity demand will be 28.5 MW in 2030 and 71.6 MW in 2050.

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