Energy Demand Projection 2030: A MAED Based Approach

FORECASTING ENERGY MIX AND ELECTRICITY DEMAND

Government of Nepal
Investment Board of Nepal
2068

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List of Abbreviations

MAED	Model for Analysis of Electricity Demand
IAEA	International Atomic Energy Agency
GDP	Gross Domestic Product
GWyr	Gigawatt Year
MW	Megawatt
GWh	Gigawatt Hour
GoN	Government of Nepal
Kwh	Kilowatt Hour

Introduction

Nepal has faced an increasing gulf between the demand and supply of energy in the past several years. More than a third of the population does not have access to electricity and is forced to depend on traditional fuels for energy requirements. Furthermore, Nepal's electricity intensity is around 175 KWh per capita, one of the lowest in the world.

A number of energy/electricity forecasts have been undertaken by multilateral as well as government agencies. Although these forecasts have considered consumers' ability and willingness to pay for electricity, they have failed to take into consideration latent demand.

In order to address the issue of latent demand and come up with a more realistic demand for energy, including electricity, The National Planning Commission and the Office of the Investment Board have jointly conducted this study on energy demand. In this study, the MAED (Model for Analysis of Energy Demand), developed by IAEA (International Atomic Energy Agency) has been used. MAED is a scenario based planning tool, where each scenario can be considered a possible long term development pattern of a country. MAED is a policy tool which is useful in forecasting a country's total energy (and electricity) demand given its economic, social and technological evolution pattern. This approach takes into account the evolution of the social needs of the population, such as the demand for transportation, lighting and air conditioning. The advantage of MAED over other models is that it allows for flexibility in switching between energy sources, thus reflecting structural changes in the economy over time.

The demand for energy comes from industry, transportation, household and service sectors. The demand for energy in Industry sector is comprised of demand in the agriculture, construction and mining and manufacturing sub-sectors. Energy demand in transportation encompasses of demand generated for freight transport and passenger transport. The household section is broken down into rural and urban households. Energy demand in the household sector takes into account heating, cooking, and other appliances.

The main output in this context is the energy, and not solely electricity requirements, for Nepal in the year 2030. Although electricity demand can be derived from the output, the readers must realize that the model encompasses all form of energy sources. However, it does not take into account the willingness and ability to pay for the energy/electricity.

The model includes certain scenarios around the base case. These scenarios consist of variability in GDP (Low, Base case, High, Higher), Contribution of the manufacturing and service sub-sectors to the economy, and fuel substitution in household as well as a combination of these.

The MAED model forecasts medium- to long-term energy demand based on the following:

I. Socio-economy
II. Technology
III. Demography

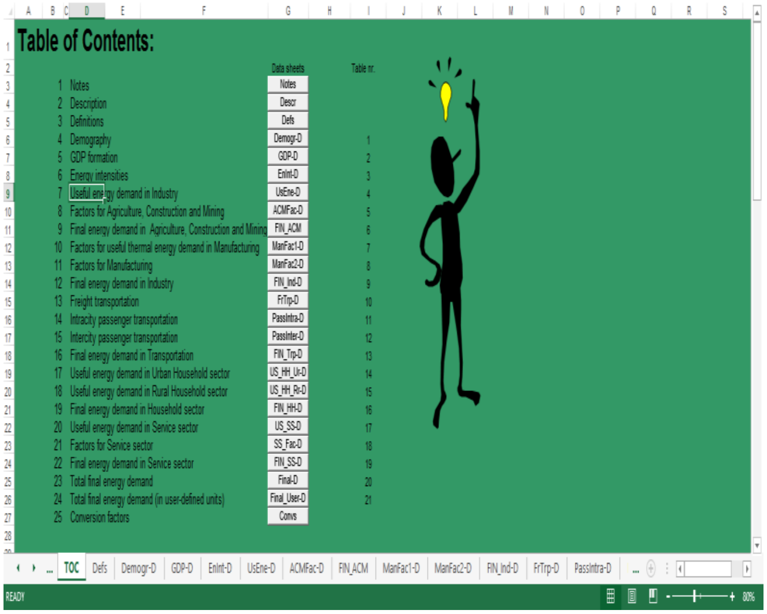


Figure 1: The Variable list and output for the MAED model

The model presents a framework for evaluating the impact on energy demand by certain changes in the overall macroeconomic picture of a nation as well as the standard of living of population. Demand for energy is disaggregate into a various end-use categories. The demand for energy is affected by a number of variables, such as demography (urban/rural population, population growth rate, potential/active labour force), GDP (Total GDP and GDP structure by main economic sectors), Energy intensities for industry (agriculture, construction, and mining), Modes of Freight Transportation and Passenger Transportation, Intra/Inter-city Transportation, and household usages (Heating, Cooling, Kitchen, Water Heating). The total demand for energy is combined into the following energy consumer sectors:

- Industry (includes Agriculture, Construction, Mining, and Manufacturing)
- Transportation
- Service
- Household

Since the model takes into account the macroeconomic as well as household-level picture, the starting point of the model is the base year energy consumption patterns. This requires collection, verification, and in some cases, estimation, of certain data. Since this exercise is extremely dataheavy, a lot of compilation and reconciliation of data is a pre-requisite. Certain derivations and calculation of input parameters should be completed before using the model in order to establish a base year energy balance. The base year energy balance presents the current state of energy in a country and thus contributes to the development of future scenarios, based on its situation, legal framework, and development objectives. Such scenarios can be divided into two groups: scenarios based on socio-economic objectives and scenarios based on technological factors, such as efficiency and penetration of different energy sources, such as biomass, solar, hydro, fuel, and thermal. The model, however, does not take into consideration the affordability of such energy sources.

Proper estimates can be derived from the model if the assumptions, especially for social, economic, and technology are consistent throughout. In order to use the model effectively, the user should have a good understanding of the interplay among various driving forces and determining factors. This is because the model output is a mere reflection of the assumptions-based scenarios. Reasonable estimates are derived by evaluating the output and modifying initial assumptions.

Since the model emphasizes on energy demand, various energy forms compete for a given end-use category. For instance, fossil fuels and electricity compete for freight transportation. Similarly, biomass and electricity compete for cooking purposes. Therefore, the model derives the end-user demand, in terms of useful energy, and then converts the useful energy into final energy. This process takes into consideration penetration and efficiency of all energy sources, including electricity.

Since the demand for different types of fossil fuels depends on technological shifts as well as relative prices, the model does not break down demand for fossil fuels into demand for coal, gas, or oil. However, the model estimates substitution of fossil fuels by other energy forms, including electricity, solar, and biomass. The substitution of fossil fuels largely depends on policy decisions and the stage of formulation of such decisions; hence, this can be covered by scenarios.

Table 20-1 Final energy demand by energy form

Item	Unit	2015	2020	2025	2030	2035	2040
Traditional fuels	GWyr	10.866	10.440	9.997	9.471	9.177	8.377
Modern biomass	GWyr	0.080	0.274	0.473	0.675	0.913	1.117
Electricity	GWyr	0.257	0.360	0.485	0.637	0.826	1.033
District heat	GWyr	0.000	0.000	0.000	0.000	0.000	0.000
Soft solar	GWyr	0.000	0.002	0.005	0.010	0.016	0.024
Fossil fuels	GWyr	0.509	0.643	0.803	0.991	1.215	1.458
Motor fuels	GWyr	0.760	1.227	1.518	1.867	2.279	2.768
Coke & steam coal	GWyr	0.000	0.000	0.000	0.000	0.000	0.000
Feedstock	GWyr	0.000	0.000	0.000	0.000	0.000	0.000
Total	GWyr	12.473	12.946	13.281	13.652	14.425	14.779

Table 20-2 Final energy demand per capita and per GDP

Item	Unit	2015	2020	2025	2030	2035	2040
FE per capita	[MWh/cap]	4.227	4.093	3.916	3.755	3.702	3.538
FE per GDP	[kWh/US$]	15.657	13.040	10.683	8.687	7.226	5.801

Table 20-3 Final energy demand by sector

Item	Unit	2015	2020	2025	2030	2035	2040
Industry	GWyr	0.553	0.675	0.824	1.011	1.240	1.519
Manufacturing	GWyr	0.416	0.512	0.630	0.778	0.960	1.183
ACM	GWyr	0.137	0.163	0.194	0.233	0.280	0.336
Transportation	GWyr	0.643	1.089	1.356	1.677	2.056	2.507
Freig. transp.	GWyr	0.367	0.618	0.749	0.914	1.121	1.381
Pass. transp.	GWyr	0.276	0.471	0.608	0.763	0.934	1.126
Household	GWyr	11.118	10.990	10.868	10.681	10.782	10.325
Service	GWyr	0.160	0.192	0.232	0.283	0.347	0.428
Total	GWyr	12.473	12.946	13.281	13.652	14.425	14.779

... PassInter-D | FIN_Trp-D | US_HH_Ur-D | US_HH_Rr-D

Figure 2: The Output Sheet for the MAED model

The final energy demand output is given in terms of GWyr. The final output page contains the following sections:

I. Final Energy Demand By Energy Form
II. Final Energy Demand per Capita and per GDP
III. Final Energy Demand By Sector

Base Case Assumptions

Due to the exceptional events of 2015, 2014 is considered as the base year for the demand forecast. Nepal's base year population of 27.6 million grows at 1.35% per year and reaches 39 million by 2030. Projected demographic trends indicate increasing rates of urbanization and lower family sizes. As a result, urban population grows from 40% in 2014 to 49% in 2030 and the number of households increases from 5.4 million in 2014 to 7. 7 million. Both demographic trends indicate to higher per capita electricity usage over time.

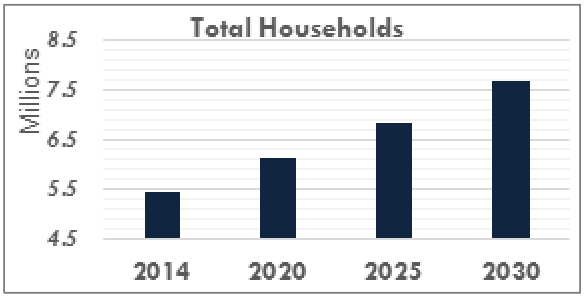


Figure 3: Projections for the number of households

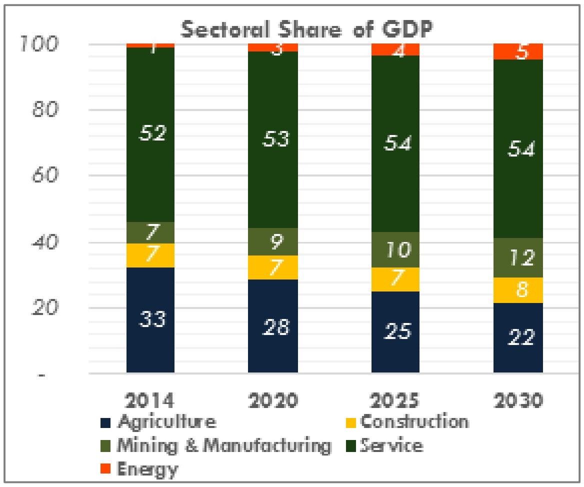


Figure 4: Sectoral Split of GDP Projections

GDP is assumed to grow at a constant real rate of 5%. The current constitution of GDP is heavily dependent on agriculture. The agriculture sector's contribution to the GDP is 33%, and this share is expected to decrease over time to 22% and be replaced by mining and manufacturing. The share of mining and manufacturing in GDP is expected to increase from 7% currently to 12% in 2030. The service sector currently accounts for 52% of GDP and is expected to contribute about the same (54%) in 2030.

The base case assumes that electricity will displace many of the currently used fuels over time. By 2030, in the agriculture sector, irrigation will be powered exclusively by electricity. Electricity will also partially replace fossil fuels (coal, natural gas, etc.) and motor fuels (diesel and petrol) in the construction, mining and manufacturing sector. In the transportation sector, freight transport consumes the most amount of energy (70%) and its share increases to 85% in 2030. Electricity will replace a small fraction of total freight transportation energy requirement due to some usage of electric powered trains and battery powered vehicles. Similarly, electricity will also displace motor fuels in the personal transportation with electric buses, cars and mass transit converting to electricity and battery powered systems.

Electricity will also replace fossil fuels and traditional fuels in urban households. Electricity usage for space and water heating is expected to grow over time. Moreover, electricity is also expected to displace LP gas as the dominant energy source for cooking; electricity will 52% of total cooking energy for urban households in 2030 compared to a little over 3% at present. Similarly, electricity usage for rural households also increases, albeit at a slower rate. Electricity will account for 45% of total household cooking energy for rural households. Collectively, these changes in the energy consumption pattern will decrease the share of traditional sources of energy from 77% to 55%. The share of electricity consumption, meanwhile, will grow from 4% to 19%.

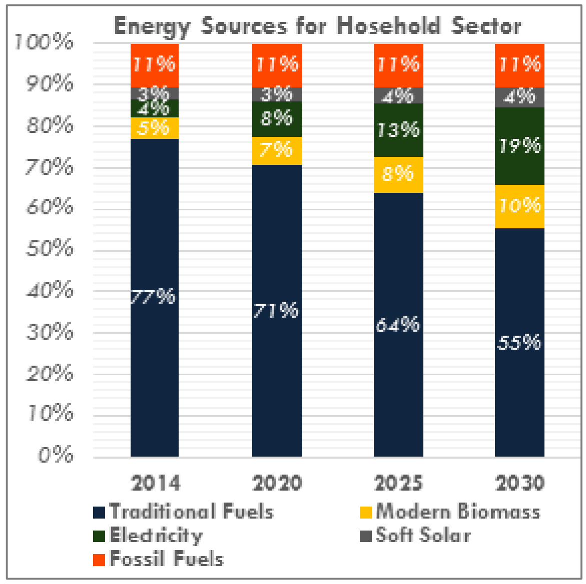


Figure 5: Energy Sources for Household Sector Forecasts

Base Case Results

Table 1 shows Nepal's total energy demand. The share of electricity in total energy gradually increases from 6% at present to 23% of total energy demand in 2030. The share of electricity in the current energy mix is higher than statistics cited by WECS estimates because the base demand for electricity is assumed to constitute energy obtained from the use of diesel generators as well as demand that would otherwise exist in the event of reliable power supply.

Item	Unit	2014	2020	2025	2030
Traditional fuels	GWyr	7.636	7.271	5.635	5.648
Modern biomass	GWyr	0.530	0.707	0.886	1.091
Electricity	GWyr	0.707	1.493	2.462	**3.817**
Soft solar	GWyr	0.281	0.339	0.397	0.464
Fossil fuels	GWyr	1.654	1.884	2.082	2.257
Motor fuels	GWyr	1.012	3.385	3.387	3.263
Total	GWyr	**11.821**	**15.079**	**15.849**	**16.540**

Table 1: Energy Demand Forecast - Base Case Scenario

The demand projection shows that due to increasing urbanization and consumer preferences, the dominance of traditional sources of fuel will decline over time. Traditional sources of fuels will be displaced by electricity, and other sources (solar and modern biomass). The energy share of fossil fuels (primarily coal and LP gas) will remain constant. While demand for energy from fossil fuels will increase due to manufacturing and domestic demand, it will be also decrease as electricity will displace it as the default energy in manufacturing and cooking.

The share of motor fuels will initially increase sharply because increased economic activity will increase the demand for transportation services. Over time, this share is reduced, because by 2030 one half of the total freight transport will be powered by electricity (through vehicles such as trains and cable cars).Electricity powered cars, buses and trains will also replace diesel and gasoline. However, share of motor fuels in the transportation sector will still be very high (90%) compared to electricity (10%) because of the efficiency of electricity powered transport. Put differently, although the same amount of freight and passengers is transported using motor fuels and electricity, a lot more motor fuel is required to do the same work because electricity is by far the more energy efficient source. Therefore the relative share of motor fuels does not decline precipitously from the initial increase. Figure 6 outlines the trend of the share of motor fuels in Nepal's energy mix.

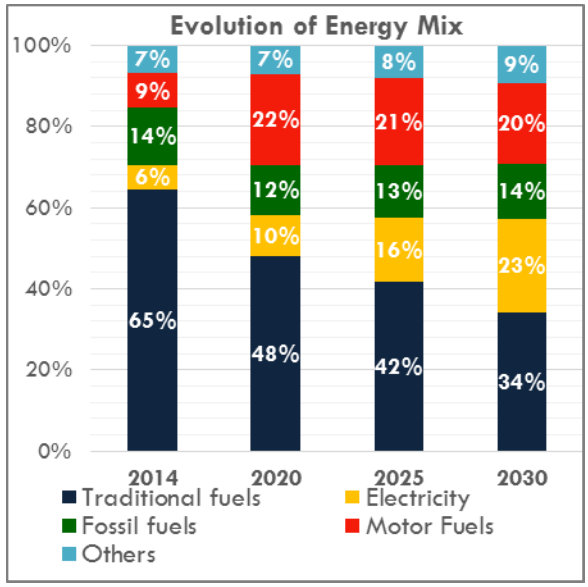


Figure 6: Evolution of Energy Mix

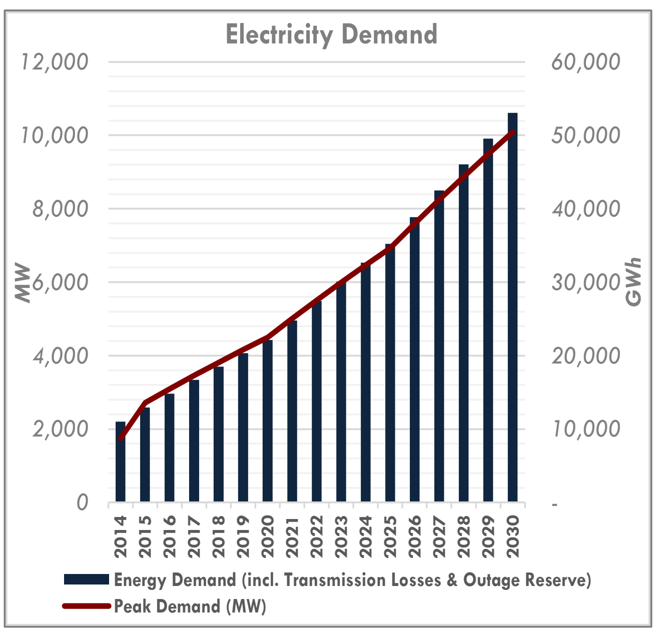


Figure 7: Electricity Demand Forecast

The final electricity demand in 2030 is 3.817 gigawatt years, which is equivalent to 33,433 gigawatt hours (GWh). A final energy demand of 33,433 GWh equates to 6,358 MW at 60% system capacity factor Since the aforementioned installed capacity is for final usage, a reserve capacity is required for transmission losses (1,211 MW) and outages (2,523 MW). Assuming that daily demand load curve remains the same, the required installed capacity to service demand in 2030 is 10,092MW.

The required installed capacity to service demand is sensitive to the system capacity factor. The base case analysis assumes a capacity factor of 60%; this means that a 1MW plant will operate at full capacity for 5,256 hours during any given year (60% of the time). Given the current imperative of building storage plants and anticipated capacity increases in other renewables such as wind and solar, the system capacity will likely be lower than 60%. At a system capacity factor of 50% and 47%, the required installed capacities to service demand in 2030 will be 12,000MW and 12,757MW respectively.

Similarly, in the base case scenario, per capita energy demand for electricity is approximately 980 KWh.

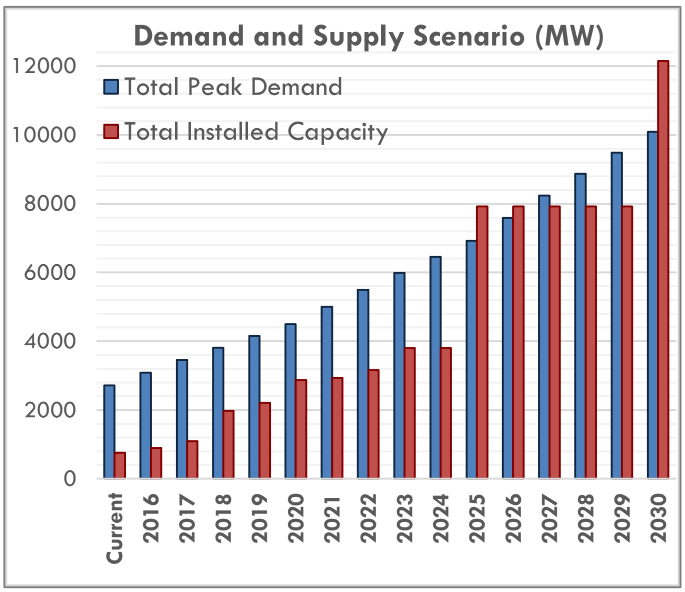


Figure 8: Demand and Supply Forecasts

Energy Supply

The supply of electricity to meet demand is primarily based on run of river hydro power generation with storage projects and renewables as supplementary sources. According to the current supply schedule, there will be sufficient generation capacity to meet the base case demand in 2030 but there will be persistent deficits in the intervening years. This points to the need for careful planning in sequencing of projects in the medium and long term to match supply with demand. Efficient planning is all the more important because hydro power projects have long development cycles and availability (reliable supply of power) is essential to sustained growth in electricity demand.

Table 2 shows major projects (with installed capacities of over 100 MW) that are expected to come into operation within 2030. Timely commissioning of these projects will be critical because of their impact on the electricity supply.

Major Projects

Major Projects	Installed Capacity	CoD
Upper Tamakosi	456	2018
Rasuwagadi	111	2018
Middle Bhotekosi	102	2018
Tamakosi V	227	2022
Upper Karnali/Arun III	305	2023
Upper Arun	335	2023
Dudhkosi	228	2025
Budigandaki	1,200	2025
Nalsing Gad	410	2025
West Seti	750	2025
Tamakosi III	650	2025
Upper Trisuli	216	2025
Pancheshwar	3,360	2030

Table 2: Major Projects in the Pipeline

Scenarios around the GDP

As mentioned in the introductory section, this study includes certain scenarios and sensitivities around the base case. The GDP scenarios are based around the following average GDP growth rates: 7%, and 10%. Table 3 below highlights some of the significant factors that lead to higher demand for electricity when GDP growth rates are higher than the base case of 5%. Different economic sectors grow at dissimilar rates. For example, when the overall economy grows at 7% between 2020 and 2025, the mining sector grows at a rapid rate of 14% but the agriculture sector exhibits a more muted growth rate of 4%. Since the energy intensities of different sectors of the economy are also different from one another, the resulting change in demand is different from the change in overall economic output. Energy intensive activities such as mining, manufacturing and commerce (freight transport) grow at a more rapid rate than less energy intensive sectors such as agriculture, services and household consumption. The net result is that the demand for electricity grows at a faster pace than that of the overall economy.

	Base Case (5% GDP Growth)			7% GDP Growth Rate			10% GDP Growth Rate		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
Population (Millions)	29.89	31.97	34.18	29.89	31.97	34.18	29.89	31.97	34.18
GDP (USB billions)	24.11	30.78	39.28	27.01	37.88	53.12	31.88	51.34	82.69
GDP per Capita (USD per person)	807	963	1,149	904	1,185	1,554	1,067	1,606	2,419
Sectoral GDP Growth Rates									
Agriculture	3%	2%	2%	5%	4%	4%	8%	7%	7%
Construction	6%	6%	6%	8%	8%	8%	11%	11%	11%
Mining	17%	12%	10%	19%	14%	12%	22%	18%	16%
Manufacturing	8%	8%	8%	10%	10%	10%	14%	13%	13%
Service	5%	5%	5%	7%	7%	7%	10%	10%	10%
Energy	19%	13%	11%	21%	15%	13%	25%	18%	16%
Total Electricity Demand (GWhr)	13,079	21,567	33,437	13,666	23,521	38,299	14,664	27,217	48,706
Electricity Usage by Sector									
Agriculture	1%	1%	1%	1%	1%	1%	1%	1%	1%
Construction, Mining and Manufacturing	30%	30%	32%	32%	34%	37%	35%	40%	46%
Service Sector	6%	7%	9%	6%	7%	9%	6%	8%	8%
Freight Transport	4%	6%	6%	4%	6%	7%	5%	7%	9%
Passenger Transport	1%	2%	2%	1%	1%	1%	1%	1%	1%
Household	57%	54%	51%	55%	50%	44%	51%	43%	35%

Table 3: Comparison of Electricity Demand Drivers Across GDP Growth Scenarios

Case 1: High GDP (10% GDP Growth)

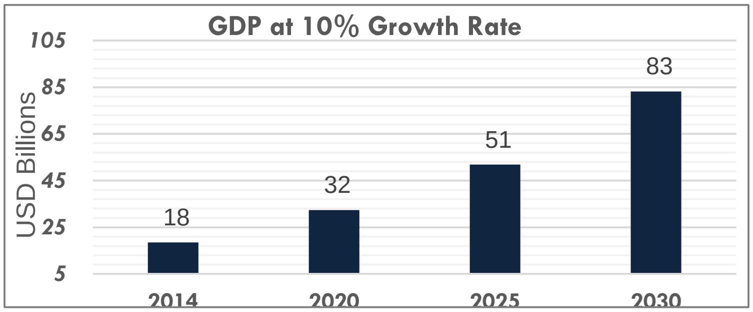


Figure 9: GDP Projections at 10% Growth Rate

The GDP of Nepal at 10% average annual growth rate is estimated to reach USD 83 Billion, which is almost 5 times the GDP in 2014. A higher GDP rate increases energy/electricity requirements. A higher GDP growth rate also alters the target energy mix.

Item	Unit	2014	2020	2025	2030
Traditional fuels	GWyr	7.636	7.272	6.641	5.666
Modern biomass	GWyr	0.53	0.709	0.896	1.121
Electricity	GWyr	0.707	1.674	3.107	5.56
Soft solar	GWyr	0.281	0.34	0.401	0.475
Fossil fuels	GWyr	1.654	2.13	2.709	3.497
Motor fuels	GWyr	1.012	4.181	5.097	6.055
Total	GWyr	11.820	16.306	18.851	22.374

A ... ht (e ... ly b ... n, w ... s. U ... ot d ... %. A ... he tr ... gh that the contribution of motor fuels to the energy mix will not decrease. It can also be observed that the share of the traditional fuels has gone down considerably (from 65% in 2014 to 25% in 2015). In terms of energy mix, the share of traditional fuels is lower in this case than in the base case. High economic growth mandates efficient

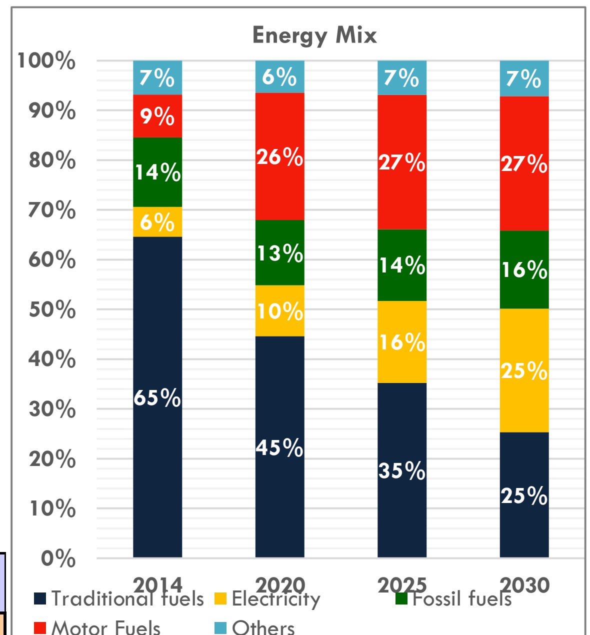


Figure 10: Evolution of Energy Mix: High Growth Scenario

Item	Unit	2014	2020	2025	2030
Traditional fuels	GWyr	7.636	7.272	6.641	5.666
Modern biomass	GWyr	0.53	0.709	0.896	1.121
Electricity	GWyr	0.707	1.674	3.107	**5.56**
Soft solar	GWyr	0.281	0.34	0.401	0.475
Fossil fuels	GWyr	1.654	2.13	2.709	3.497
Motor fuels	GWyr	1.012	4.181	5.097	6.055
Total	GWyr	**11.820**	**16.306**	**18.851**	**22.374**

Table 4: Energy Demand Forecast High Growth Scenario

energy sources; hence the decrease in the traditional fuels' contribution to the energy mix.

The final energy demand for 2030, in this scenario is estimated to be 22.374 GWyr.

The final electricity demand in 2030 is 5.56 gigawatt years, which is equivalent to 77,312 gigawatt hours (GWh). A final energy demand of 77,312 GWh equates to 14,702 MW. As discussed earlier, the aforementioned installed capacity and demand takes into account transmission losses and outages.

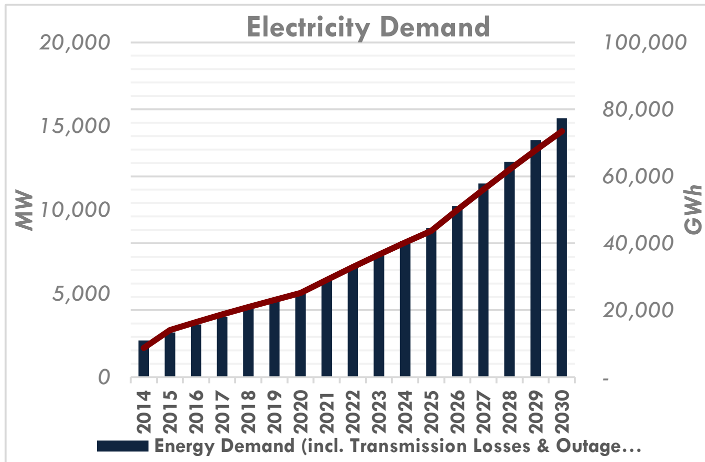


Figure 11: Electricity Demand Forecast: High Growth Scenario

Keeping the supply situation unchanged, the system will be in a state of excess demand in 2030. In this growth scenario, the peak demand is estimated to surpass the installed capacity by about 2000 MW. Under this scenario, it is estimated that the system will have severe power shortages until 2024, when the peak demand is estimated to be more than double the installed capacity. This gap will be reduced in 2025.

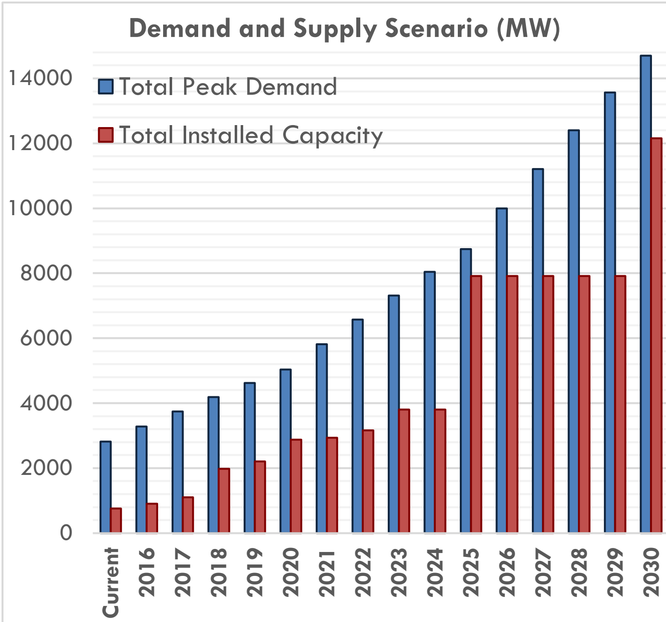


Figure 12: Demand and Supply Forecasts: High Growth Scenario

The required installed capacity to service demand is sensitive to the system capacity factor. If the peak demand were to be addressed, the system would need an installed capacity of 15,000 MW.

Case 2: Medium-High GDP (7% GDP Growth)

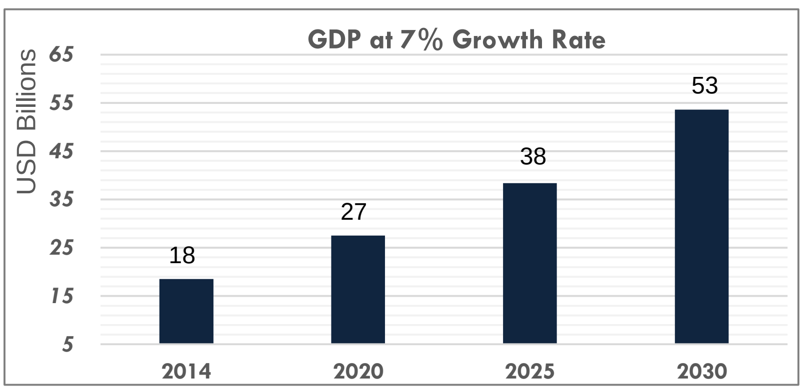


Figure 13: GDP Projections at 7% Growth Rate

The GDP of Nepal at 7% average annual growth rate is estimated to reach USD 53 Billion, which is almost 3 times the GDP in 2014. As the GDP growth rate is higher than that of the base case, energy/electricity requirements will also increase correspondingly. The expected e

Item	Unit	2014	2020	2025	2030
Traditional fuels	GWyr	7.636	7.272	6.641	5.666
Modern biomass	GWyr	0.53	0.709	0.896	1.121
Electricity	GWyr	0.707	1.674	3.107	5.56
Soft solar	GWyr	0.281	0.34	0.401	0.475
Fossil fuels	GWyr	1.654	2.13	2.709	3.497
Motor fuels	GWyr	1.012	4.181	5.097	6.055
Total	GWyr	11.820	16.306	18.851	22.374

A ... age (energy mix), motor fuels will increase sl... which in turn, will increase the demand for tr... e of motor fuels will decrease over time, albeit b...

In addition, in this scenario as compared to the base case scenario, there will be a higher rate of traditional fuel substitution (from 65% of the total energy mix in 2014 to 31% of the total energy mix in 2030). From the graph, we can observe that the proportion of fossil fuels will remain unchanged and that there will be a certain rise in the contribution from alternative energy sources.

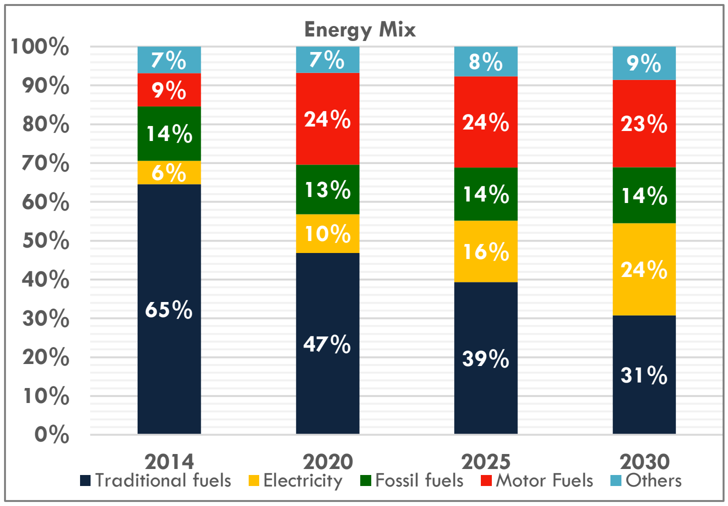


Figure 14: Evolution of Energy Mix: Medium-High Growth Scenario

The final energy demand for 2030, in this scenario is estimated to be 18.399 GWyr, which is about 2 GWyr higher than in the base case and about 3 GWyr less than the energy demand for the high-growth scenario.

Item	Unit	2014	2020	2025	2030
Traditional fuels	GWyr	7.636	7.272	6.637	5.654
Modern biomass	GWyr	0.53	0.708	0.889	1.1
Electricity	GWyr	0.707	1.56	2.685	**4.372**
Soft solar	GWyr	0.281	0.339	0.398	0.467
Fossil fuels	GWyr	1.654	1.975	2.299	2.653
Motor fuels	GWyr	1.012	3.682	3.978	4.153
Total	GWyr	**11.820**	**15.536**	**16.886**	**18.399**

Table 5: Energy Demand Forecast Medium-High Growth Scenario

The final electricity demand in 2030 is 4.372 gigawatt years, which is equivalent to 60,793 gigawatt hours (GWh) after taking into account transmission losses and reserve outages. A final energy demand of 60,793 GWh equates to 11,560 MW.

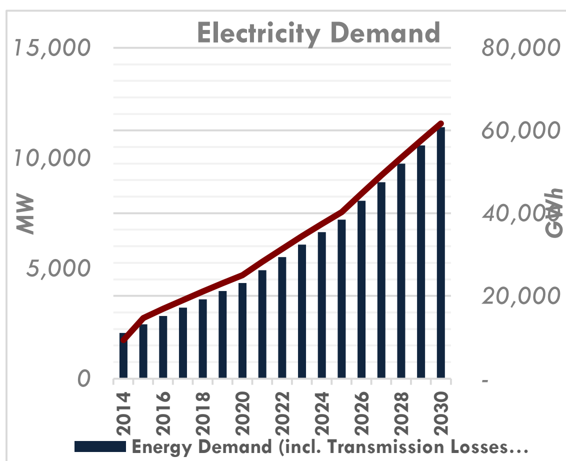


Figure 15: Electricity Demand Forecast: Medium-High Growth Scenario

Keeping the supply situation unchanged from the base case, the system will be able to meet peak demand. Under this high growth scenario, the peak demand is estimated to be almost equal to the installed capacity. Under this scenario, it is estimated that the system will have severe power shortages until 2024, when the peak demand is estimated to be more than double the installed capacity. This gap will end in 2025; however, the system will run deficits after 2025 until 2030. The demand in 2030 will be met since Pancheswar Multipurpose project is expected to commission that year.

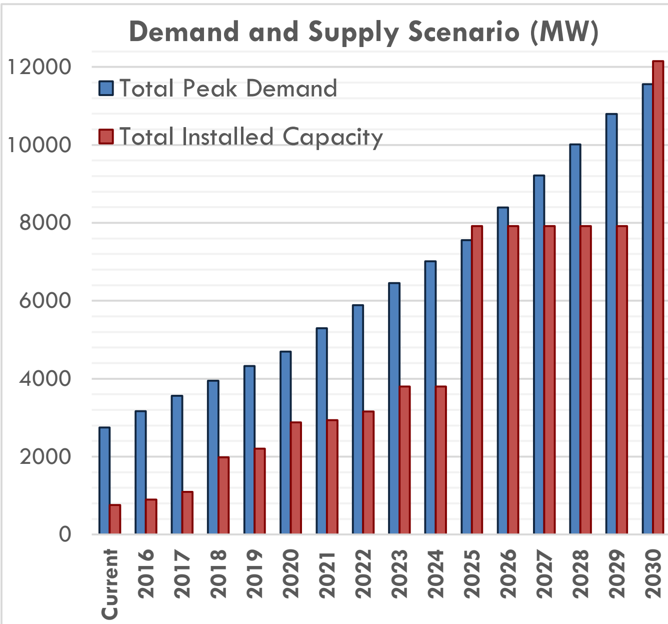


Figure 16: Demand and Supply Forecasts

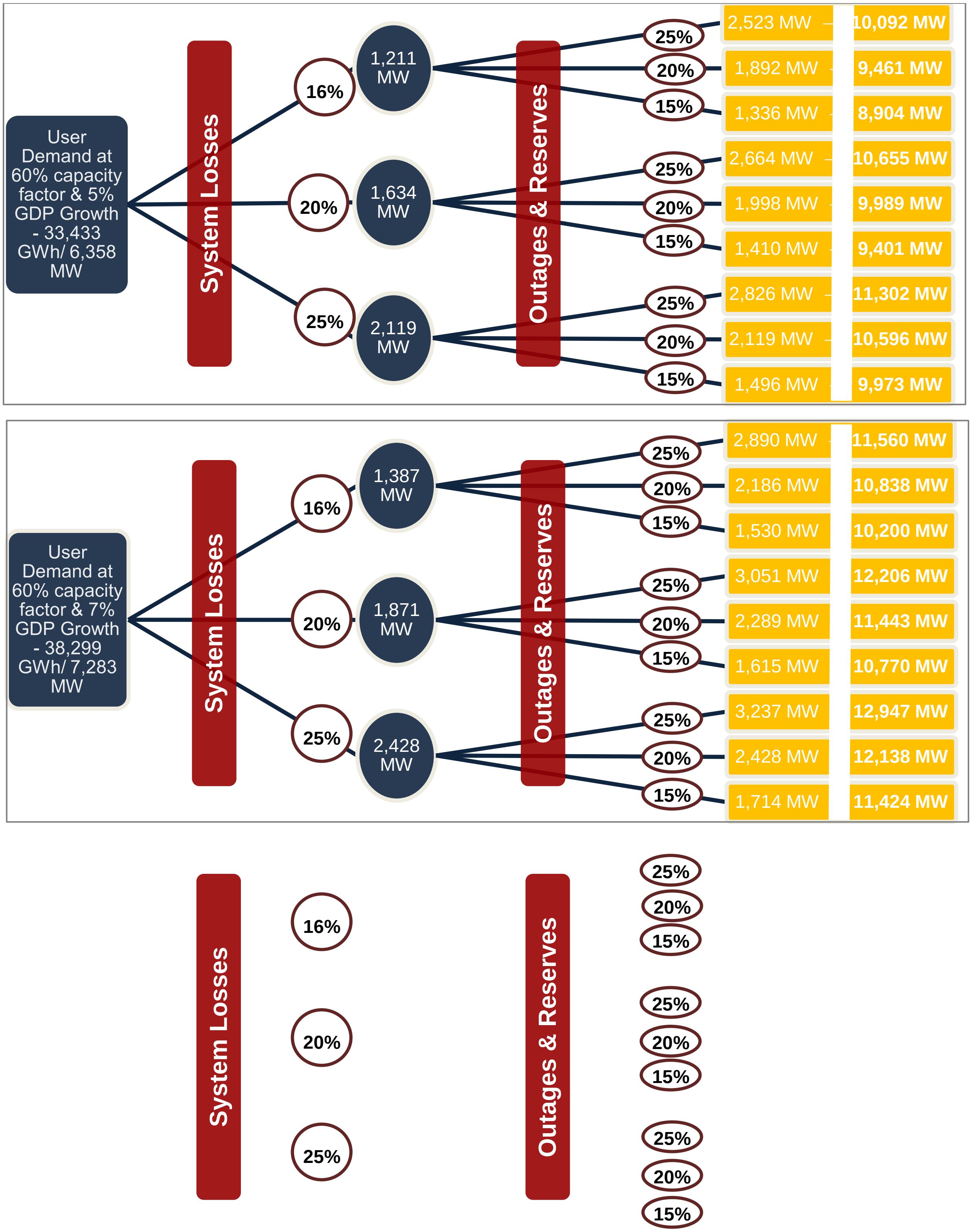
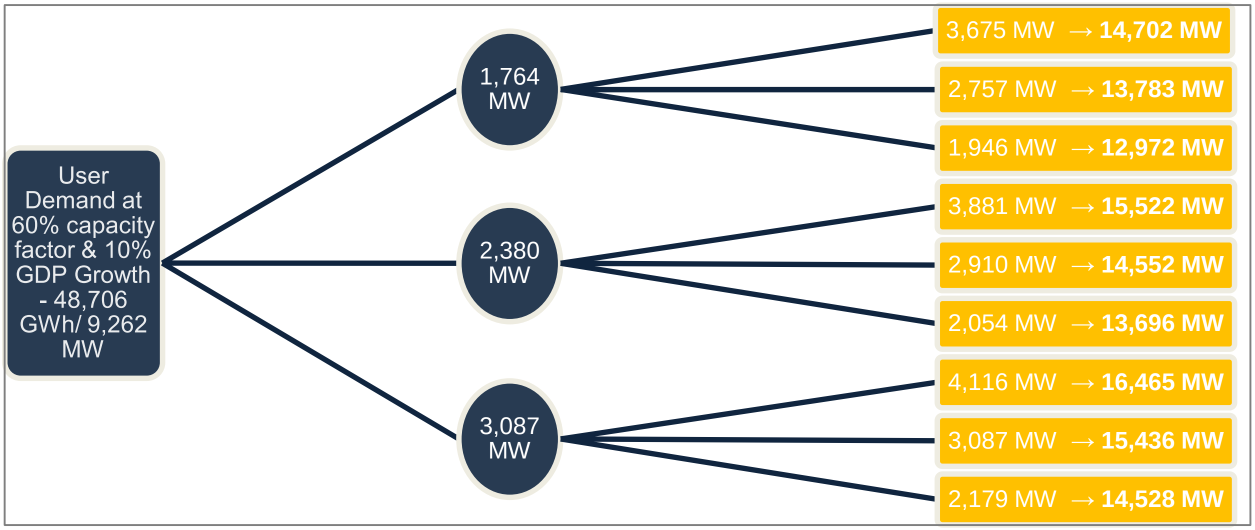


Figure 17: Sensitivity of Final Installed Capacity on GDP, Transmission Losses and Outages


User Demand at 60% capacity factor & 10% GDP Growth - 48,706 GWh/ 9,262 MW
1,764 MW
2,380 MW
3,087 MW
3,675 MW → 14,702 MW
2,757 MW → 13,783 MW
1,946 MW → 12,972 MW
3,881 MW → 15,522 MW
2,910 MW → 14,552 MW
2,054 MW → 13,696 MW
4,116 MW → 16,465 MW
3,087 MW → 15,436 MW
2,179 MW → 14,528 MW

Scenarios and Sensitivities: Sectoral Contribution to the GDP

In the base case we have assumed that the agriculture sector's contribution to the GDP will decrease from the existing 33% to 22%. However, there is a good chance that agriculture might still contribute to a third of the economy. In this case, keeping all other factors constant (as same as the base case), the total energy demanded in 2030 is expected to be 30,012 GWh, which is about 3,000 GWh lower than the energy demand in the base case. Similarly, the total required installed capacity, after taking reserves for transmission losses and outages, is 9,059 MW, which is 10% lower than the required installed capacity of the base case.

	Agriculture Contribution to the GDP Percentage Unchanged
Electricity Demand (GWh)	30,012
Required Installed Capacity (MW)	9,059

Table 6: Electricity Demand and Required Installed Capacity (Agriculture Contribution to the GDP Percentage Unchanged)

The second scenario around sectoral contribution to the GDP is the shift in manufacturing sector's contribution to the GDP. In this scenario, we have assumed that the manufacturing sector will account for a fourth of the economy in 2030, from its current state of a mere 2.4%. The contribution of certain other sectors, including agriculture, mining, and services have been reduced to accommodate for the growth in manufacturing's contribution to the GDP. The final energy demanded in this scenario is 40,874 GWh and the installed capacity required to meet this demand, including reserve for transmission losses and outages, is 12,338 MW. The electricity demanded in this scenario is about 7,000 GWh greater than the energy demanded in the base case scenario. Similarly, the installed capacity required to meet the demand in this scenario is 22% greater than that of the base case scenario.

	Manufacturing Contribution to the GDP Percentage Changed to 25%
Electricity Demand (GWh)	40,874
Required Installed Capacity (MW)	12,338

Table 7: Electricity Demand and Required Installed Capacity (Manufacturing Contribution to the GDP Percentage Changed to 25%)

Scenarios around Fuel Substitution

In the base case scenario, in terms of fuel replacement at the household level, we have assumed the following:

In urban households, electricity ***will replace fossil fuels and traditional sources of fuels***

- Electricity will provide 63% of space heating requirements in 2030 compared to 20% in 2014
- Electricity will provide 8% of water heating requirements in 2030 compared to 3% in 2014
- Electricity will provide 52% of cooking requirements in 2030 compared to 3% in 2014

Similarly, ***electricity usage in rural households also increases over time***, albeit at a slower intensity

  - Penetration of electricity for space heating, water heating, and cooking in 2030 is 25%, 4%, 45% respectively

	No Fuel Replacement at the Household Level
Electricity Demand (GWh)	24,239
Required Installed Capacity (MW)	7,316

Table 8: Electricity Demand and Required Installed Capacity (No Fuel Replacement at the Household Level)

In this scenario, we will assume that there will be no fuel substitution at the household level. We will assume that electricity will provide only 20% of the space heating requirements, only 3% of the water heating requirements, and only 3% of cooking requirements at the urban household level. Similarly, it is assumed that penetration of electricity for space and water heating and cooking is zero. In this scenario, the final electricity demand is estimated to be 24,239 GWh and the total required installed capacity to meet this demand is 7,316 MW (28% less than the base case scenario).

In the base case, certain assumptions on fuel replacement in the transport sector are made. The following assumptions were made:

- ***Freight transport*** consumes the most amount of energy (70% in 2014) in the transportation sector and its share increases to 85% in 2030)

- Electricity will ***displace some amount of motor fuel based transport*** (6.5% of total energy in required for freight)

- Electricity will also be ***displace motor fuels in the personal transportation*** sector (with electric buses, cars and mass transit)

	No Fuel Replacement
Electricity Demand (GWh)	21,357
Required Installed Capacity (MW)	6,447

Table 9: Electricity Demand and Required Installed Capacity (No Fuel Replacement)

In this scenario, it is assumed that there is no fuel substitution in the transport industry, combined with no fuel substitution at the household level (zero fuel substitution in aggregate). The final electricity demand in this scenario is 21,357 GWh, which is about 37% less than the base case. Similarly, the installed capacity required to meet this demand is 6,447 MW, which is about 4,000 MW less than the base case. Although the energy demand and required installed capacity are significantly low in this scenario, the country will be forced to import fossil fuels, and hence widen the trade deficit, in order to meet energy demand.

Low Growth and No Fuel Substitution

Under this scenario, we assume that there will be no fuel substitution (same as the case above) combined with a low economic growth. For the low economic growth part, an average growth rate of 4% is assumed. In this scenario, the final electricity demand is estimated to be 19,692 GWh. Similarly, the total required installed capacity to meet this demand, including reserve for transmission losses and outages, is 5,944 MW (41% less than the total required installed capacity from the base case). The total installed capacity, excluding reserve for transmission losses and outages, in this scenario is 3,745 MW. This figure is similar to the figure derived by Nepal Electricity Authority in their electricity demand forecast.

	Low Economic Growth and No Fuel Replacement
Electricity Demand (GWh)	19,692
Required Installed Capacity (MW)	5,944

Table 10: Electricity Demand and Required Installed Capacity (Low Economic Growth and No Fuel Replacement)

Conclusion

Nepal's energy problems are severe: there is an increasing gap between demand and supply of electricity and more than a third of the population does not have access to electricity. In the absence of a proper supply mechanism, many believe that the demand for electricity has been suppressed. Although many studies have been undertaken to come up with a realistic demand of energy/electricity, these studies have failed to consider latent demand.

This energy demand forecast, jointly conducted by The National Planning Commission and the Office of the Investment Board, tackles the latent demand issue, and has come up with a more realistic demand for energy, including electricity. The study uses the MAED model, which is a scenario-based planning tool. The energy demand, according to MAED, is derived from different sectors of the economy, transport/freight preferences and household usages.

In the base case scenario, the energy demand in the year 2030, based on certain assumptions related to socio-economy, technology, and demography is estimated to be 16.54 GWyr, out of which the demand for electricity is 3.817 GWyr. The required installed capacity to meet this demand, at 60% capacity factor, after considering reserve for transmission losses and outages, is 10,092 MW. There are certain scenarios based on variable GDP growth rates, fuel substitution, and composition of the GDP. The outputs from these scenarios hover around the base case results.