Strategizing Demand Side Management on Residential Sector of Nepal and its Impact on Electricity Planning

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Abstract: Approximately 42% of the electrical energy supplied by Nepal Electricity Authority and 80% of the total energy consumption were consumed in residential sector. Demand Side Management programme can lead to sustainable development of the country with appropriate and effective use of the available source and reduce the Green House Gas emission. This paper analyses the residential energy profile and variation in it with inclusion of various national plans and its associated emission based on LEAP framework for five regions with seven end-uses. Intervention of Grid based Electricity in most of the end-use and Solar PV and Micro-Hydro for lighting has been considered. Study shows biomass will still be the dominating fuel in future. Electricity per capita consumption would increase to 369 KWh with generation requirement of 8 times of the present value for sector being more electricity based. In case of solar, 165 MW would be required to meet the 30 % of the lighting load to end of study period. Scenario that can be created and solution for better utilization of energy has been argued in the paper. Country based potential and clean energy that needed to be provided has been observed in the study.

Keywords: DSM; Residential Sector; Strategies; Energy Demand

1. Introduction

There is a trend of having rapid urban growth with increasing use of technology. Domestic energy consumption represents the links between global environmental problems and individual behavior. Climate change is not only accelerating but has been induced by human activity, particularly by the combustion of fossil fuels for energy (IPCC, 2007). Residential energy consumption is the amount of energy that is spent on the various appliances used within housing. Scientists estimate that by 2050, we need to have reduced our greenhouse gas emissions (GHG) by 50% to avoid the worst-case scenarios of climate change. In such context, the building sector appears as the "cornerstone of every national climate change strategy", as it is responsible for up to 30% of global annual GHG emissions, and 40% of all energy consumption (UNEP, 2009). The rising rate of growth of GDP, growth in disposable income, rising purchasing power of people with higher propensity to consume and preference for sophisticated appliances provide constant impetus to growth of energy demand in residential sector. (Economic survey, 2013)

Most of the people live in rural part of Nepal with the urban areas constituting only 17 % of the total population. About two-third of the total households use Firewood as the usual source of fuel for cooking followed by LPG More than two third of the total household's main source of lighting is electricity. Kerosene is still being used by 18.28 percent of the total households for lighting while solar and bio-gas is the source of light for 7.44 and 0.28 percent of the total households respectively. (CBS, 2012) It shows the clean fuel is being used in very less proportion and wood has been the most dominating fuel in present and expected to be in future as well. 80% of the total energy consumption was consumed in residential sector. It can be observed that share of residential sector in the total energy consumption is decreasing in a steady pace, while others sectors have a little shift from the previous years. (WECS, 2010)

The residential energy consumption is highly dependent on the urban and rural population, which was signified by the statistical test criterion shown in relation below, shows the logarithmic model for the residential energy consumption. (Parajuli, 2013)

Keeping in view the growing economies and rising emissions from developing counties, it is imperative that these countries start responding proactively to the climate change mitigation. Any strategy or measure for addressing climate change that stalls the development in these countries will have far reaching impacts in making the future generations even more vulnerable to climate change. (Kumar, 2011)

2. Overview of the Country

Population of Nepal as of the census day (June 22, 2011) stands at 26.5 million with total number of households in the country is 5.427 million with 5.423 million individual households. The average household size has decreased from 5.44 in 2001 to 4.88 in 2011 at the national level. The increment of population during the last decade is recorded as 3,343,081 with an annual

average growth rate of 1.35 percent. Terai constitutes 50.27 percent of the total population while Hill and Mountain constitutes 43 percent and 6.73 percent respectively. (CBS, 2012)

Nepal's energy resources are presently classified into three categories namely the traditional, commercial and alternative. Traditional energy resources include fuel wood from forests and tree resources, agricultural residues coming from agricultural crops and animal dung in the dry form. Traditional energy resources can, of course, be termed as biomass energy resources since it only covers the bio materials for energy purpose. Energy resources coming under the commercial or business practices are grouped into commercial energy resources that particularly include the coal, grid electricity and petroleum products. Biogas, solar power, wind and micro level hydropower are categorised into the alternative energy resources in Nepal. Such resources are considered as the supplement of conventional energy resources. (WECS, 2010)

Table 1: Population and Number of Household in different category (NPHC, 2011)

In Million	Population	No. of Households
Nepal	26.494504	5.423297
Urban/Rural		
Urban	4.523820	1.045575
Rural	21.970684	4.377722
Ecological Belt		
Mountain	1.781792	0.363698
Hill	11.394007	2.532041
Terai	13.318705	2.527558

Table 2: Population and Number of Household in Urban sector of Ecological Belt (NPHC, 2011)

In Million	Population	No of Households
Urban and Ecological Belt		
Mountain	0.049995	0.0012387
Hill	2.468110	0.609897
Terai	2.005715	0.425013

A very least amount of urban population is in Mountain region. Due to this, the urban sector has not considered urban mountain section in the structure. Around 54% of total urban population lives in hilly region where as 45 % are in Terai region. Some is the case for rural population where most are in hilly and Terai region. Rural hill consist of 8.5% of total Rural Population.

2.1 Electricity Consumption by sector

Of the 3157 GWh of the energy sold by the NEA, around 43 % of was consumed in the residential sector. This has always been in the case of Nepal and in other developing countries as well. Industrial is also the electricity consuming sector which has a share of 36% (NEA, 2013).

Table3: Sector wise electricity consumption

Total 11.365 Million GJ	
Sector	**Share**
Residential	42.44%
Industrial	35.60%
Commercial	11.30%
Agriculture	4.14%
Other	6.53%

2.2 Residential Sector Fuel share

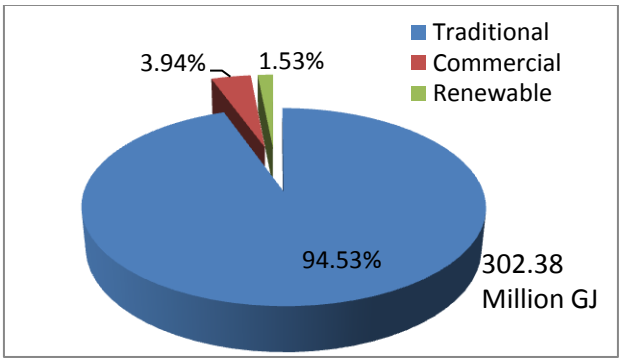

Figure1: Residential Fuel consumption in 2011/12 (WECS, 2012)

Present share of energy consumption has also been dominated by the Traditional Fuel having more than 90 % of total. Historical trend shows a similar division as well. Commercial and renewable is in increasing trend but is at very slow growth rate.

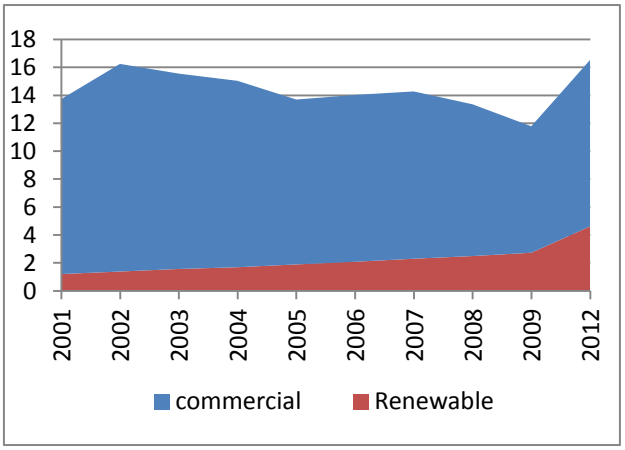

Figure 2: Historical Trend of energy types (WECS, 2010)

Cooking, heating, water boiling has always been the most energy consuming end use in residential sector. It is due to fact that fuel wood is used as the major sources. In case of electricity consumption, its share is divided well showing the potential of electrical energy in all end use (WECS, 2012).

Table 4: Residential Sector Energy consumption

In 000 GJ		
End Use	**Residential Total**	**Residential Electricity**
Cooking	184318.5	878.5
Heating	42872.1	174.2
Cooling	609.4	609.4
Lighting	2317.7	1159.3
Water Boiling	38924.5	326.5
Water pumping	364.9	363.6
Electrical Appliances	1173.6	1114.9
Other Uses	31804.1	197.4
Total	302384.8	4823.0

2.3 Transmission Loss

Table 5: Transmission loss of various countries

Transmission loss (%) by year				
Country	**2008**	**2009**	**2010**	**2013**
Nepal	32	34	34	25.03
India	22	22	22	
Pakistan	21	20	16	
Sri Lanka	16	15	14	
Bangladesh	5	2	2	

The average power loss among 134 countries that are in World Bank's database is 13.67%. (World Bank, 2012)

3. Methodology

There are various methods and software available for the demand projection. This projection and analysis has been done through LEAP. The Long range Energy Alternatives Planning System is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute. Leap can be used to create models of different energy systems, where each requires its own unique data structures. LEAP supports a wide range of different modeling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modeling.

The data's were collected mostly from websites of the different organization. Thesis of student collecting primary data was also taken in reference. The data was filtered and entered into the software as required and analyzed through the software. There are various group and sub group in the structure. The changes in the structure and the data input were done as required.

The structure was build under demand which contain residential sector. Residential sub divided into urban and rural which each has a sub group of Mountain, Hill and Terai. The data up to here in kept in the software but still subdivision of urban hill and Terai is needed to be done for further analysis.

As through the collected data from various organizations, their plans have been included in the model. With inclusion of organizations plan, change in patter of energy consumption has been observed with their associated emission.

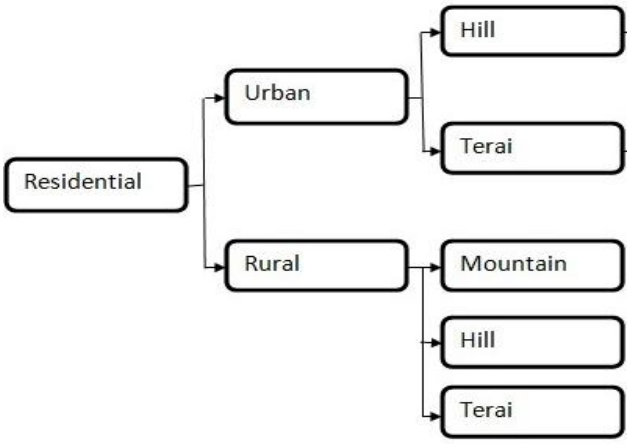

Figure3: Structure of Population Distribution Used in LEAP model

Model used for demand projections is as (Shakya, 2011):

$$ESD_{i,t} = (POP_t / POP_0)^{\alpha 1i} \times (GDP_t / GDP_0)^{\alpha 2i} \times ESD_{i,0}$$

Where POPo: Base year population

POPi: Population in ith year

GDPo : Gross Domestic Product of base year

GDPi : Gross Domestic Product of ith year

α li : eleasticity of Population

α 2i : elasticity of GDP

4. Scenario Description

For the analysis of the residential Sector, various national plans were adopted in the structure. Considering the plan will be implemented as stated, the effect in energy consumption pattern were observed. Two plans were observed in the study; RPP, Renewable Perspective Plan and National Water Plan along with the BAU, Business As Usual. In the entire scenario, growth in the population as estimated in NHPC, 2011 was considered along with the urbanization rate 3.98 as estimated by The World Bank, Nepal.

Table 6: Population Distribution up to 2030

Year	Total (Million)	Urban (Million)	Urban share (%)
2012	26.49	4.5	17
2020	29.49	6.847	23.22
2030	33.72	11.56	34.31

It is seen that by 2030, the national population will be 33.72 million, of which 11.56 million people will be residing in the urban sector of Nepal.

Table 7: Elasticity value of end-uses (Shakya, 2011)

	Elasticity	
Residential End-use	Population	GDP
Space cooling	2.85	0.28
space heating	2.85	0.28
Electrical Appliances	2.85	0.28
Cooking	0.98	0.03
Lighting	0.98	0.03
Water boiling	0.98	0.03
Other	0.98	0.03

Taking the share value of each end-use, overall average elasticity's values were considered for the population and GDP. Elasticity value used for the Population in 1.26 and GDP is 0.067.

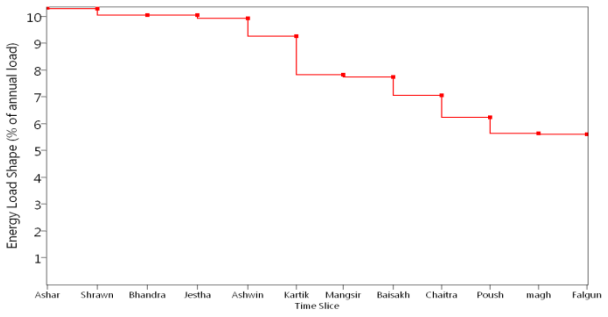

Figure 4: Energy Load Curve 2012/13 (NEA, 2013)

4.1 Business as Usual (BAU)

In BAU scenario, population growth and the urbanization rate was considered along with the present intervention rate in clean fuel and technology. It assumes the intervention rate at as historical trend. Grid Connected electricity in Urban areas and efficient and clean cooking and lighting technology has been considered for the rural areas.

4.2 Renewable Perspective Plan (RPP)

There is a 20 years plan for renewable energy technology. It is stated as Nepal's 20 years Perspective plan (2011-2030). The target stated by the plan has been observed in the structure. The population growth and urbanization rate is considered same as in Reference scenario. The target of RPP is as follows:

Year	Solar HS	Micro Hydro	ICS	Biogas P
2015	400000	600000	600,000	300,000
2020	1000000		1,000,000	500,000
2025	1500000		1,500,000	900,000
2030	2000000		2,000,000	1,500,000

Table 8: Nepal's Perspective Plan Target (AEPC, 2014)

4.3 Electricity Based Scenario (ELE)

This scenario is based on the National Water plan, 2005. The estimated power generation in future year and share of electricity access through different energy technology has been used to forecast the energy consumption. Following points were considered in the scenario for year 2027:

Urban Sector

100% intervention of Electricity on lighting and 75% on cooking, space heating and water boiling. (WECS, 2005)

Rural Sector

Seventy-five per cent of the households are supplied with INPS electricity, 20% by isolated (micro and small) hydro systems and 5% by alternative energy for lighting (WECS, 2005).

Based on present urban scenario, 20 % of electricity will be used in cooking, space heating and water boiling (WECS, 2012).

Power system loss is used with a value of 25.03% (NEA, 2013). World Average of 13.67% has also been analyzed (World bank, 2012).

4.4 Urban Solar Scenario (URB)

This scenario is focuses on solar power to be used in urban areas of the country. In urban areas, solar power can be used in lighting and for electrical appliances most commonly TV, Radio etc. AEPC has started Urban Solar PV-home system with a short term plan. In similar pattern, installation to be done to have the following share of this end use has been calculated.

Assumption made:

Table 9: Urban Solar Assumption

End Use	Lighting	Electrical Appliances
share	10%	5%

4.5 Scaling-up Renewable Energy Program (SRET)

This scenario is based on Scaling up renewable energy program. Renewable energy development continues to be a high priority program of government as it provides a least cost solution to remote, sparsely populated areas unviable for grid extension, while being clean, safe and environmentally friendly13. GoN's goal for the next 20 years is to increase the share of renewable energy from less than 1% to 10% of the total energy supply, and to increase the access to electricity from alternative energy sources from 10% to 30%. (GoN, 2011)

This scenario tries to find the intervention rate to meet up to the plan provided. It try to analyses the region in which the various possible endues where Renewable and alternative energy source has possible intervention is observed.

5. Result and Discussion

Energy demand of the residential sector seem to be increasing with the increasing years but there is variation with different scenario adopted.

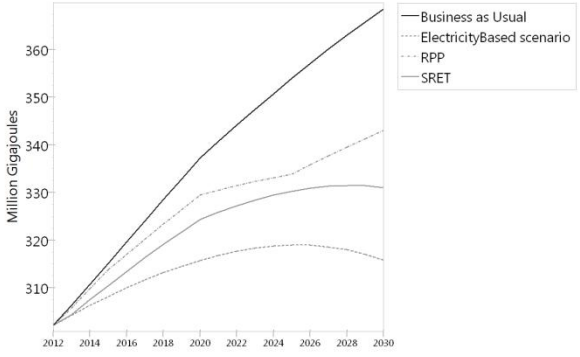

Figure 5: Energy Demand Projection in various scenarios

In BAU scenario, energy consumption will increase with annual growth rate of 1.39% to 2020 and only 0.9% to 2030. As seen in the graph, slope of increment decrease from 2020. This is due to increasing rate of urbanization which in turn is decreasing the demand of rural part.

Similar transition has also been observed in the RPP scenario as well. But with higher intervention of solar PV and micro Hydro with increasing use of Energy Technology such as ICS and Biogas Plan, RPP scenarios shows relatively less increment in the energy. Only, 1.1% of annual growth rate of energy demand has been observed till 2030 and 0.4% till 2030. Intervention was done in mainly rural part of the Nepal which has decreased a huge amount of energy from fuel wood in cooking end-use.

Table 10: Projected Residential Sector Demand in different years of various scenarios

In Million GJ					
Year	2012	2030	2030	2030	2030
Fuels	Base Year	BAU	ELE	RPP	SRET
Electricity	5.2	15.8	44.9	15.8	29.16
LPG	5.2	13.4	8.8	13.4	12.7
Solar	0.006	0.015	0.033	0.03	0.89
Wood	252.8	292.1	219.9	248.8	241.4
Other	39.0	47.6	42.3	64.8	46.8
Total	302.1	368	315.7	342.9	331

But in case of Electricity based scenario (ELE), fuel switching was done using electricity as main source which has increase the energy demand but at very slow rate. Annual Growth rate of just 0.56% upto 2030 and 0.01% till 2030 has been observed.

Similarly in Scaling-Up renewable Energy Program (SRET), priority was given to grid based electricity for most of end use and solar for lighting, it showed a growth rate of .32% till 2020 and 0.1% till the end of study period.

5.1 Residential Electricity Consumption

According to the demand projection of various fuels, Electricity shows an increasing trend with 6.4% every year in BAU and RPP scenario as in both cases only present intervention rate was considered. With present share of just 1.71%, in 2030 electricity demand has risen to 4.64% of total energy demand of residential sector RPP scenario. But still is the low with compare to other fuels.

But in the case of ELE, demand of electricity has risen rapidly. If we see the equivalent energy in GWh an annual average growth rate of 10.33% has been observed reaching upto 12463.2 GWH. Per capita

electricity consumption will reach to 369 KWh with this sector only which is about 90% of the estimated in National Water Plan.

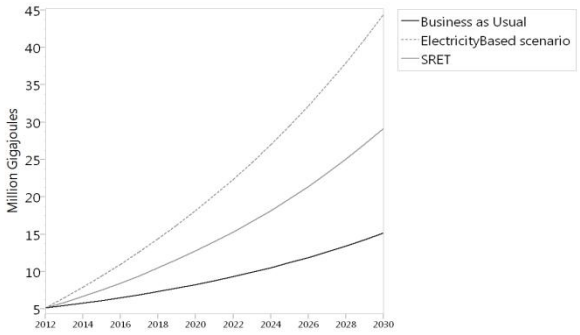

Figure 6: Projected Residential Sector Electricity Demand in different years of various scenarios

Table 11: Electricity forecasted data with various system losses

Electricity demand (000 GWh)/ELE				SRET
system loss(%)	25.03		13	25.03
Year	2012	2030		2030
Total Supply	1.9	16.6	14.5	14.2
T&D loss	-0.5	-4.2	-2.0	-2.7
Residential				
Urban	0.9	7.6	7.6	5.7
Rural	0.5	4.9	4.9	2.4
Total Demand	1.4	12.5	12.5	8.1

Considering the present system loss of NEA in 2030, 4.2 thousand GWh will be lost in transmission and distribution only. A total of more than 8 times energy would have to be supplied by the power system. The peak demand will reach upto 2730 MW with the present system loss.

If the losses to be maintained at the world average system loss of 13.8%, energy to be generated would reduces by12.6% of the calculated value and peak demand reaching upto 2370 MW.

In case of SRET scenario, electricity demand has raised up to8.1 thousand GWh with an annual average growth rate of 8.2%.

5.2 Residential Solar Power Projection

In case of solar used for lighting in ELE scenario, average annual growth rate of 10.8% would be required to meet the 5% of the demand. 9.2 GWh of energy would be needed to meet the solar energy demand in lighting in households.

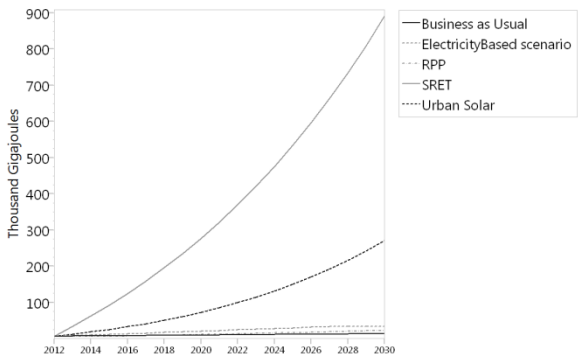

Figure 7: Solar Energy demand projection in different scenarios

Table 12: Solar Energy demand projection in different scenarios

Solar Energy demand in GWh		
Scenarios	2012	2030
Business as Usual	1.77	3.57
Electricity Based scenario	1.77	9.20
RPP	1.77	6.55
SRET	1.77	247.39
Urban Solar	1.77	75.16

The table below shows the total number of solar home system that will be required to install in ELE scenario at the following year:

Table 13: Solar Home system to be installed in stated year

Year	Solar HS (30 Wp)
2015	400000
2020	1000000
2025	1500000
2030	2000000

It is similar to that in expected to install in Renewable Perspective plan and estimated with the present and future scenario of RPP but with a Solar Home System of capacity 30 Wp.

But in case of Urban Solar Scenarios, a higher value of solar power system will be needed to install. Average annual growth rate of solar power consumption will be increased by 18.55% to the end year of the study period. It will reach upto 270.61 thousand GJ (75.16 GWh).

Average solar irradiance in Nepal: 4.35 KWh/sq. m/day (AEPC, 2014)

Generating days per year: 300 days

Generation factor: 0.85 Wh for every KWh/sq. m/day

For the generation of such a demand, considering the present value as below 16 MWp till 2020 and 60 MWp till 2030 of the solar power system will be required.

In general, Lighting and Electrical appliances that is used in most of the household has been used to determine the system power. Facilities that can be provided with 300 Wp solar is as follows:

Table 14: General End use Appliances Rating

Load	Power Rating(W)	Quantity	Usage Hour/day
TV	80	1	5
Laptop	40	1	5
Lights	10	5	5
Router	15	1	6

If we generate these powers from individual house hold, 194,000 house hold in urban hill part of Nepal should have a Solar PV power system of 300 Wp. This is around 13.56 % of the total household in urban hill area of the Nepal In 2030 with a household size of 4.04 as present in NHPC, 2011.

In case of SRET scenario with higher intervention of solar power in lighting end-use of residential sector, solar energy demand has rise to 247.36 GWh. An annual growth rate ff 25.2% will be required to meet the demand. At the end of the study period, a total of 190 MW solar power plants will be needed to meet the 30% of the lighting demand as stated in Scaling up Renewable Energy Program. By using the annual average solar energy measuring 4.95, 5.44, 5.19 and 4.61 kWh/m2/day is found in Biratnagar, Pokhara Kathmandu and Lukla respectively (Poudyal, 2011), following table values is calculated.

Table 15: Energy and Power required for 30% of the lighting load in various region

Region	Energy Required at 2030(GWh)	Solar Power Plant required (MW)
Urban Hill	109	70
Urban Terai	57.84	48
Rural	10.08	7.3
Rural Hill	45.12	28.9
Rural Terai	24.96	20.8
Total	247.36	175

Fuel wood demand has decreased to some extent with share of 73.77% which is 10% lower than the reference year in RPP. It is mainly due to intervention of energy technology like IC and Biogas plant in Rural Cooking. In ELE, fuel wood consumption decreased by 23 % to reference year due to fuel switching to electricity which is also the case for SRET scenario.

5.3 Forecasted Energy Mix

In BAU scenario, there has been some decrease in share of wood in energy mix having 79.14% of the share. Electricity and LPG has shown some rise in share but still traditional Fuel wood has shown the dominance in the mix.

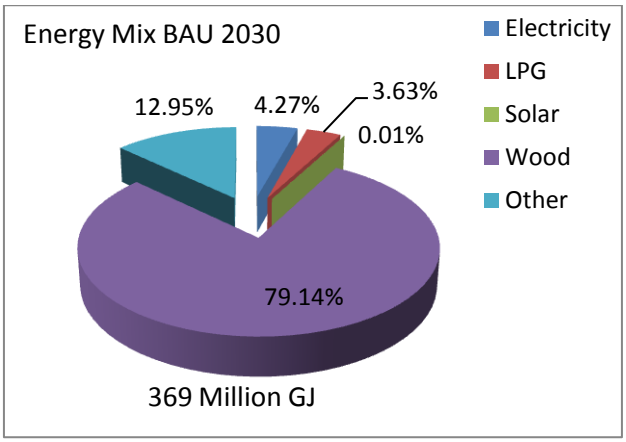

Figure 8: Energy Mix in BAU in year 2030

If the hydro-power resources are developed as per the plan and most of the people will have access to electricity as assumed in the scenario, the energy mix will be quite different. Electricity will have a determining share value of 14% and decreasing the wood consumption to 69.5 % of the total energy consumption. This is the scenario which is possible if the hydropower development goes with the plan.

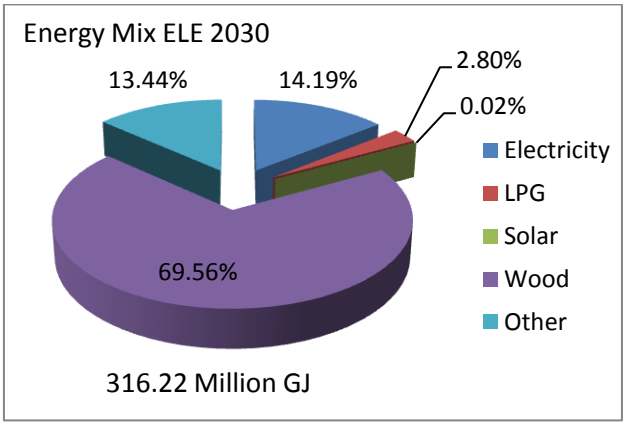

Figure 9: Energy Mix in ELE in year 2030

In SRET scenario, where renewable ad alternative energy are focused, can also decrease the overall energy demand. Electricity has little bit fewer shares than of ELE scenario but still a good share value. Solar power has shown some increment with a value of 0.27% greater than any other scenario. Its impact will be observable in term of electrical energy produced and especially in lighting end-use.

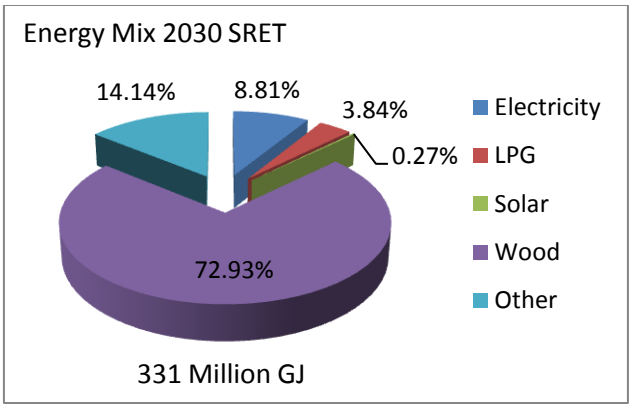

Figure 10: Energy Mix in SRET in year 2030

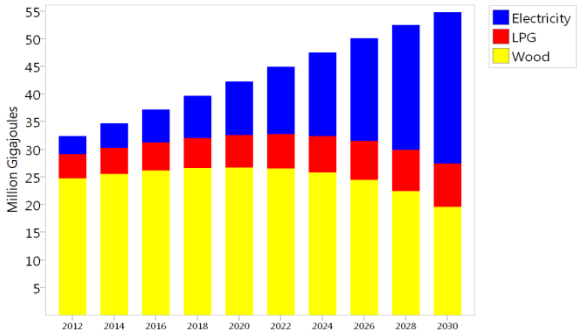

Figure 11: Change in fuel consumption over the year in Urban sector ELE

As ELE scenario was focused on cleaner fuel, it impact was most observed in Urban sector of the structure. Fuel switching to electricity will be greater in area where it is easily accessible and used in the past as well. That why the patter in energy consumption is as shown in figure. Overall demand of Urban sector is increasing with increasing population and Urbanization but it shows a decreasing trend of wood and an increasing trend of cleaner fuel electricity.

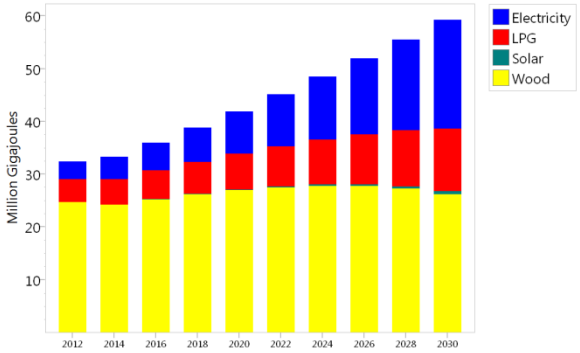

Figure 12: Change in fuel consumption over the year in Urban sector SRET

In SRET scenario, overall energy demand is increasing but as figure shows the wood demand is somewhat same, the increasing demand by population and urbanization in fulfilled by the cleaner fuels.

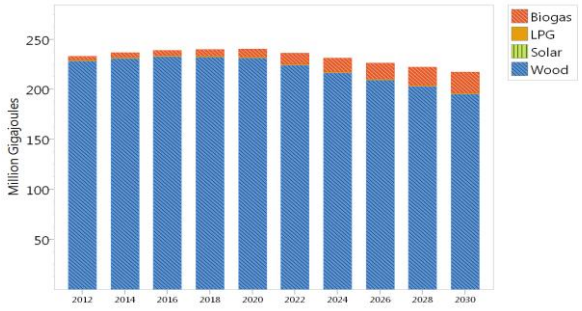

Figure 13: Change in fuel consumption over the year in Rural sector RPP

5.4 *Region wise Energy Demand*

Table 16: Region Wise Total energy demand

	Total Demand in Million GJ				
Region	2012	2030			
Scenarios	Base	BAU	ELE	RPP	SRET
Urban	33.1	80.38	55	80.38	61
Hill	17.2	42	31.4	42	33.7
Terai	15.87	38.3	23.6	38.3	27.3
Rural	269	288.66	261.2	258.2	269.9
Mountain	20.45	23.73	19.5	23.6	22
Hill	110.1	116.9	106	108.3	108
Terai	138.5	148	135.6	126.2	139.8
Total	302.1	369	316.22	338.6	331

As seen in table above, ELE and SRET has major impact on urban sector in both hill and Terai region. There has been influential change in the energy consumption. Energy consumption has also decreased in rural area of Mountain, hill and Terai as well. The RPP scenario has also shown in effect in rural energy consumption.

Table 17: Region Wise Total Electricity and solar energy demand

In GWh		**Electricity demand**			**Solar demand**				
Year	**2012**	**2030**			**2030**				
Scenarios	Base	BAU	ELE	SRET	BAU	ELE	RPP	URB	SRET
Urban	916.8	3469	7605	5729				103.6	167.2
Rural	516.6	909.9	4857	2371.3	6.73	16.83	12.69	1.99	80.17
Total	1433	4379	1246	8101.1	6.73	16.83	12.69	105.7	247.4

5.5 *GHG emission*

Due to increasing use of clean fuel, GHG emission has also been reduced. Switching has mostly done with electricity for Biomass which has high GHG emission.

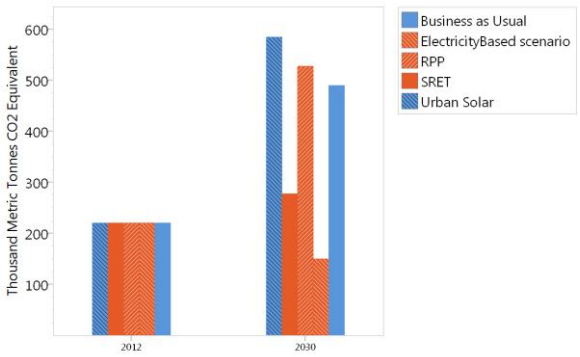

Figure 14: GHG emission in various scenarios

Table 17: Emission Saved in various scenarios

Million Tones CO2e GHG	BAU	ELE	RPP	SRET
emission saved		6.2	3.8	4.3
Total Emission	64.7	58.5	60.9	64

6. Conclusion and Recommendation

Residential sector is the most energy consuming sector in Nepal and with the present will be in future. Implementing the strategies developed by various national organization, can decrease the amount of energy consumption in various endues but still a huge amount of energy will be needed to be supplied. Electricity demand is seen continually increasing with increasing use of cleaner fuel like Solar; the Fuel wood is seen as the dominating fuel in the future. There has been some decrease in amount of fuel wood consumption through intervention of electricity. But still huge sum of population still will have to rely on traditional source of Energy. Increasing use of electricity as is the most easily accessible source will increase the demand of electricity. So a higher electricity generation and proper planning will be required with the increasing peak load demand. Similar to Renewable perspective Plan, other plan are need to be implemented in parallel. Intervention of

Solar in Urban Lighting could be also one of the solutions to increase the load factor. Its effect will be analyzed in the future. Energy balance with the system Load curve has also been analyzed with present data available.

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