ENERGY AND EMISSION ANALYSIS OF RESIDENTIAL SECTOR: A CASE STUDY FOR RESHUNGA MUNICIPALITY IN NEPAL

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Abstract

This paper presents energy consumption in a municipality within hilly region and also analyzes GHG emission under different scenario. For the purpose of study Reshunga municipality was taken, situated in Gulmi district of Nepal occupying an area of 82.74 sq.km. For collection of data, 368 houses were surveyed and the locals were interviewed on their annual consumption. The total energy consumption was 214.8 TJ where 78.25% was supplied by wood. LPG shared 16.14% of demand. Cooking (58%) and water boiling (26%) were the most demanding task. Most of the houses were equipped with ICS, with share 55% of energy demand in cooking. Four different scenario were studied viz. BAU, DSM, BSP and SDG. In, BAU scenario, the energy consumption will reach 245.3 TJ. In DSM scenario and BSP scenario the final energy demand will reduce to 230.7 TJ and 216.2 TJ. In SDG scenario, energy demand is reduced by 23.14%. The share of LPG increases to 22.36 % and electricity demand becomes more than doubles from reaching 10.64% in SDG. From year 2017-2030, there will be total accumulative increase of electricity requirement by 47.4 TJ, whereas total cumulative decrease of 433.5 TJ equivalents can be resulted in consumption of wood in SDG scenario. Cost-Benefit analysis study revealed that DSM will require an investment of 43.03K US$ for demand technologies and will reduce emission by 8.69 tCO2e. DSM will be cheapest in terms of cost per GHG reduction. SDG will cost 645.46K US$ and results in reduction of GHG by 47.79K tCO2e.

Keywords: *demand, cost-benefit, accumulative, tones of Carbon-dioxide equivalent (tCO_2e)*

1. Introduction

Energy is very essential for day to day work in every field. It forms the basis of development and progress. Thus, energy resources are regarded as the key to all round development and economic growth. It is essential to have sufficient energy to meet the demands so that the progress and development is not hindered. So, studies relating to the analysis of energy demand and supply are invariably needed to utilize the resources in effective and efficient manner. The production and consumption of energy results in emission of GHGs which degrade the environment and cause climate change. Hence along with the utilization of energy one needs to be concerned with the adverse effect it may bring to the nature that we live in.

1.1 Problem Statement

Energy Consumption per capita determines the development of progress of any country. Thus, there is trend of increasing consumption of energy in every region, area, country. Nepal is aspiring to graduate from Least Developed Country (LDC) category by 2022 and thus will require an increase in energy consumption. So, it is necessary to know energy requirement under different situation so that suitable plans and policies may be formulated accordingly. Residential sector alone accounts for 80.36% of total energy in year 2011/12 [1]. The high energy consumption in residential sector is primarily because of use of fuel-wood for cooking, water-boiling, etc. and use of inefficient technologies. Hence, with analysis of energy consumption structure one can devise different ways to reduce demand, increase efficiency and utilize the sources efficiently and effectively.

1.2 Objectives

The primary objective of this study is to analyze Residential Sector Energy consumption, projection of energy demand and emission analysis under different scenarios.

2. Literature Review

2.1 Brief Description of Reshunga

Reshunga Municipality is situated in Gulmi District of Nepal. The municipality is named after the holy place Reshunga. It was established by merging 4 Village Development Committees (VDC) viz. Arkhale, Dubichaur, Simichaur and Tamghas on May 2014. Later on (2073/74 BS) two new region viz. Paralmi VDC and ward no. 8 and 9 of Nayagaun VDC were added into Reshunga Municipality increasing its area to 82.74 sq. km. There were 8353 households and 32548 people in year 2011[2]. There are 14 wards in the municipality. Different wards within Reshunga are shown in Figure 1.

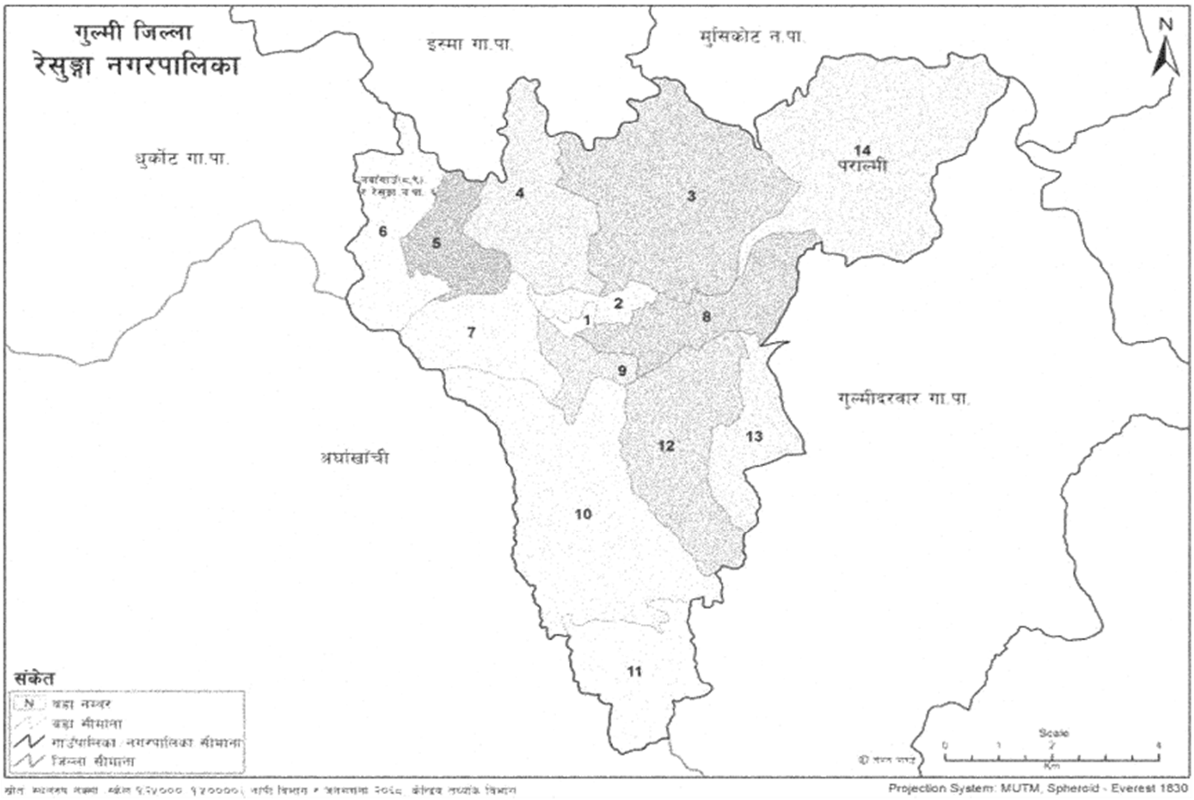


Fig 1: Map of Reshunga

2.2 Gap

In paper [3], Bhattarai projects demand for each sector by taking the data from different sources. LEAP was used as modeling tool. Four different growth scenarios are considered and Population and GDP are taken as factors affecting the demand. Similar approach is followed in energy demand projection for Commercial and Industrial Sector [6], [7]. In Paper by Rajbhandari & Nakarmi [5], Kathmandu was taken as study area and it was shown that with optimization energy demand reduction by 27% was possible. Energy consumption in Bhaktapur is studied in [8]. In his paper [9] Silwal analyses energy requirements during graduation period from 2017-2030 and benefit in terms of emission reduction. Shakya in his paper [11] presented the benefits of low carbon and potential emission reduction taking the case of Kathmandu.

Similarly, many other studies are undertaken in the field of energy analysis yet study focusing on consumption, emission and costing at Municipality level are rare which is attempted in this study taking in the case of municipality in hilly region of the country.

3. Research Methodology

Research methodology follows commonly followed steps in research. The steps followed in this study are literature review, area of research and gap identification, sample size calculation for the area, questionnaire development, primary/secondary data collection, and primary calculation, development of LEAP model, energy and emission analysis and final documentation.

Reshunga Municipality of Gulmi District was taken as the study area. For the study, 368 houses were surveyed and the locals were interviewed directly on their yearly consumption of different fuels for different end use services. The number of HHs surveyed was found by using the standard formula by [10]

$$S = \frac{\chi^2 NP}{d^2(N-1) + \chi^2 P(1-P)}$$

3.1 Selection of modeling tool

LEAP software was used for the modeling purpose. LEAP was used primarily because of its features like:

1. Flexibility and ease of Use
2. Low initial data requirement
3. Widely adopted tool for medium and long term energy planning

3.2 Formulation of LEAP Model

For the analysis of energy demand and emission LEAP software was used. Demand branch consisted of each wards divided into end uses each containing respective technology branches. End user demand was divided into six main end-uses viz. cooking, lighting, water boiling, space heating, space cooling, and water pumping. Figure 2 shows LEAP model for Reshunga.

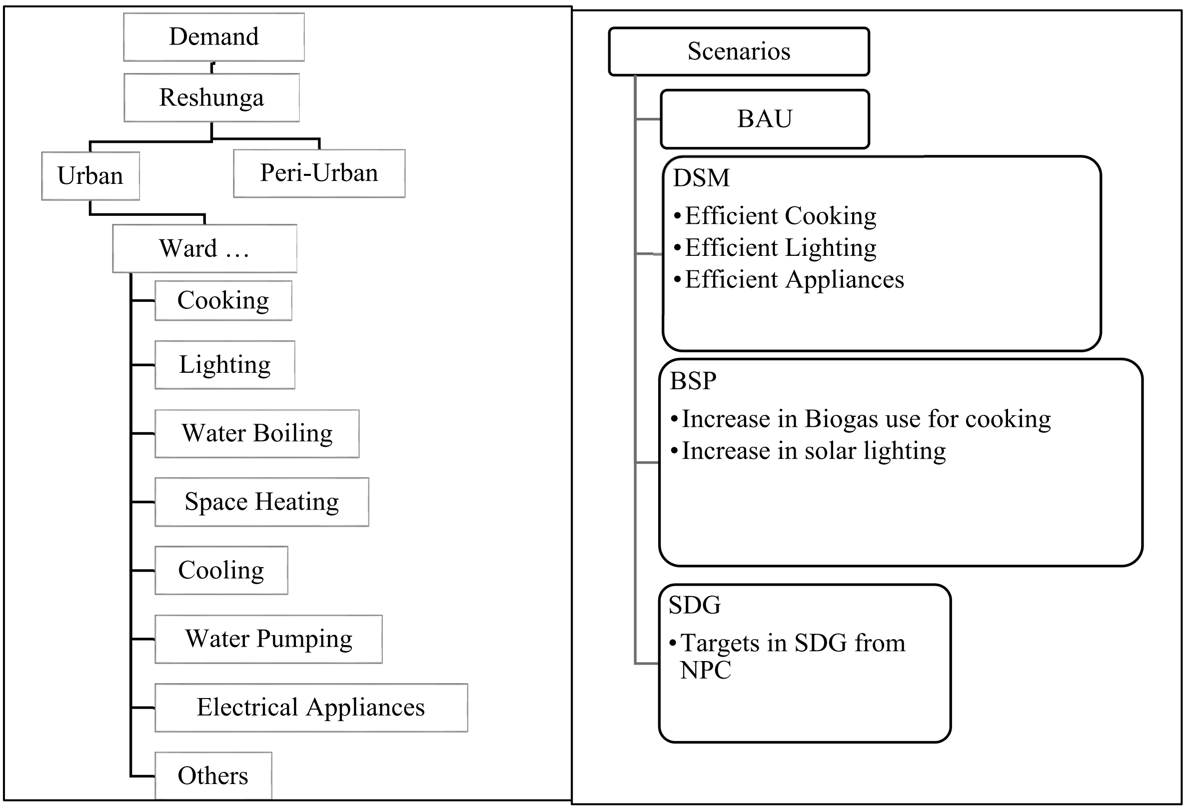
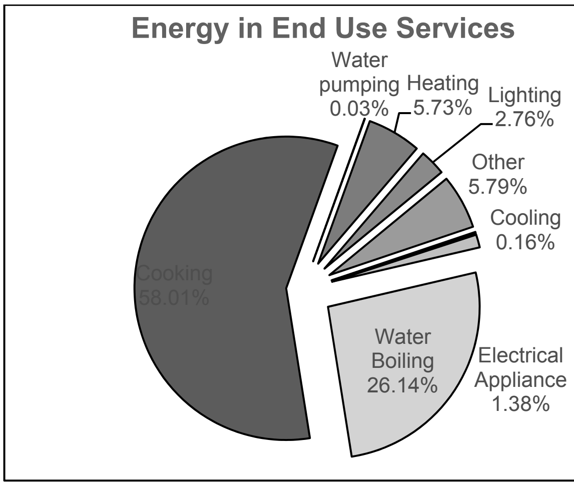


Fig. 2: LEAP model for Energy Analysis

4. Results and Discussion

4.1 Energy Demand for Base year (2017)

Total of 214.78 TJ of energy was consumed in the Reshunga area. Fuel wood provides 168.07 TJ of energy of which 142.33 TJ was consumed in peri-urban while 25.74 TJ in urban. Fuel wood provided 78.25% of the total energy followed by LPG 16.14% and electricity 4.84%. Figure 3 shows energy share by fuel type.



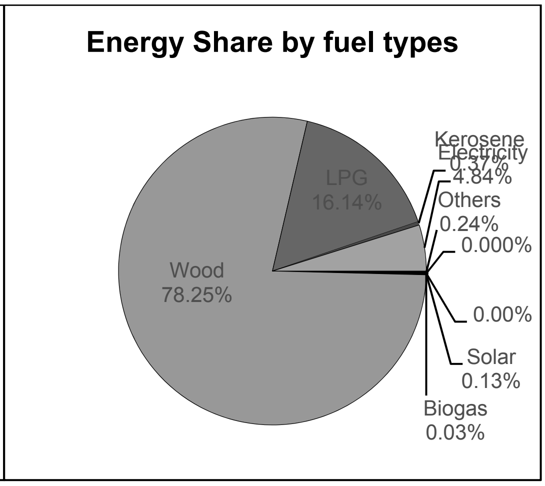


Fig. 3: Energy Share by Fuel

Fig. 4: End Use Energy Share

Cooking was the most demanding task consuming 58.01% of the total Energy followed by Water Boiling and heating consuming 26.14% and 5.73% respectively. Figure 4 presents energy demand by end uses. In cooking, 95 TJ was supplied by wood followed by LPG supplying 28 TJ. Lighting consumed 2.76% of total energy i.e. 1647.91 MWH (5.93 TJ). In Space Heating 12.32 TJ was consumed. Fuel-wise demand for each end uses is presented in Table 1.

Table 1: Fuel-wise Demand for Base Year

Reshunga Municipality Energy Demand of Reshunga for base year (in TJ)									
	Cooking	Water pumping	Heating	Lighting	Other	Cooling	Electrical Appliance	Water Boiling	Total
Biomass	0.157	-	0.301	-	-	-	-	-	0.458
Coal	0.010	-	-	-	-	-	-	-	0.010
Wax	-	-	-	0.042	-	-	-	-	0.042
Solar	-	-	-	0.276	-	-	-	-	0.276
Biogas	0.063	-	-	-	-	-	-	-	0.063
Wood	95.08	-	11.07	-	7.866	-	-	54.05	168.1
LPG	28.05	-	0.879	-	4.081	-	-	1.665	34.68
Kerosene	0.251	-	-	0.102	0.423	-	-	0.008	0.785
Electricity	0.981	0.068	0.064	5.512	0.067	0.336	2.958	0.415	10.40
Total	124.6	0.068	12.32	5.932	12.44	0.336	2.958	56.14	214.8

4.2 Scenarios

Four scenarios viz. BAU, DSM, BSP and SDG were considered.

4.2.1 Energy Demand Projection

In BAU scenario, the energy demand will be 245.3 TJ in year 2030. With DSM and BSP scenario implemented the energy demand will decrease to 230.7 TJ and 216.2 TJ respectively. Table 2 presents energy demand up to year 2030 for different scenario.

Table 2: Demand Projection under Different Scenario

Energy Demand in TJ under different projection scenario								
Scenarios	**2017**	**2019**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
BAU	214.8	219.2	221.5	226.1	230.7	235.5	240.3	245.3
BSP	214.8	217.0	216.9	216.7	215.8	215.6	215.9	216.2
DSM	214.8	218.3	219.6	222.0	224.4	226.6	228.7	230.7
SDG	214.8	214.9	212.9	208.4	203.6	198.6	193.4	187.9

Figure 5 shows energy demand for each scenario with BAU scenario as baseline. Maximum energy can be saved with SDG in place, 23.19% lesser energy is required compared to BAU in year 2030 alone. Decrease in demand by 21.2 TJ and 14.54 TJ can be achieved in year 2030 under DSM and BSP scenario.

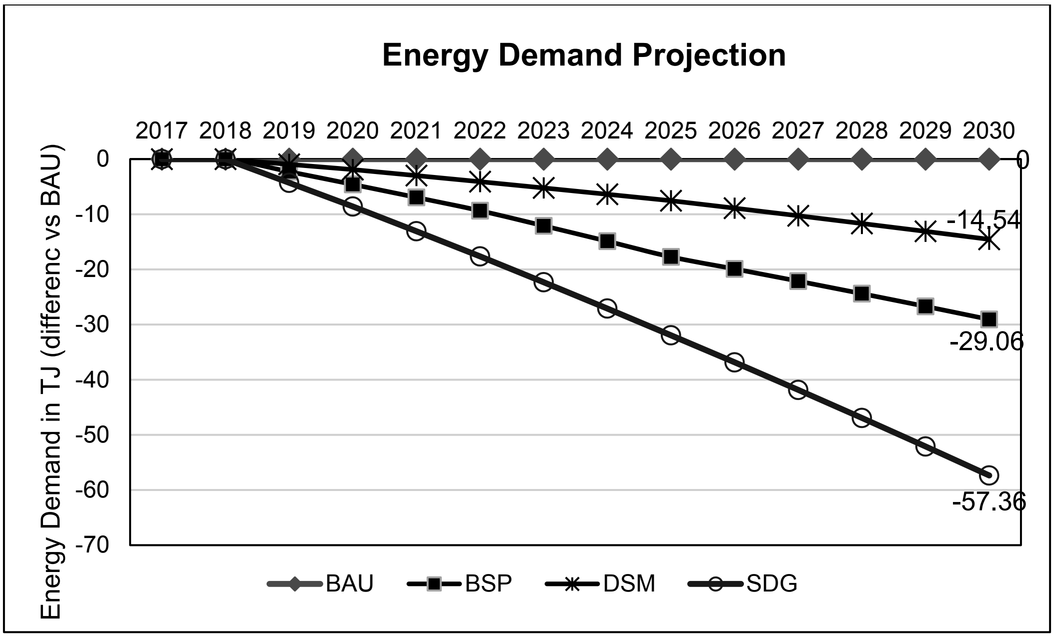


Fig. 5: Demand Projection (difference v_s BAU)

4.2.2 Business as Usual (BAU)

In BAU, energy demand will be 245.26 TJ in year 2030. Energy Demand from wood will rise to 188.7 TJ in year 2030 from 168.1 TJ in base year. LPG and electricity demand will be 42.1 TJ and 12.4 TJ respectively in year 2030. Table 3 below shows demand projection for fuels in BAU scenario.

Table 3: Fuel Demand for BAU Scenario 2017-2030

Energy Demand Final Units, BAU scenario, Units: Tera Joule								
Fuels	**2017**	**2019**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
Electricity	10.40	10.69	10.84	11.14	11.45	11.77	12.09	12.43
Kerosene	0.785	0.806	0.817	0.839	0.862	0.886	0.910	0.935
LPG	34.68	35.73	36.27	37.37	38.51	39.68	40.89	42.13
Wood	168.1	171.1	172.7	175.8	179.0	182.2	185.4	188.7
Biogas	0.063	0.065	0.066	0.069	0.071	0.073	0.075	0.078
Solar	0.276	0.285	0.289	0.298	0.307	0.317	0.326	0.336
Others	0.510	0.527	0.535	0.552	0.570	0.588	0.606	0.626
Total	**214.8**	**219.2**	**221.5**	**226.1**	**230.7**	**235.5**	**240.3**	**245.3**

Compared to base year the total energy demand share of fuel wood will decrease to 76.95% from 78.25% in base year. The demand of LPG will increase by 1.04% from base year reaching 17.18% in final year. Figure 6 shows fuel share for Base year (2017) and Final year (2030)for BAU.

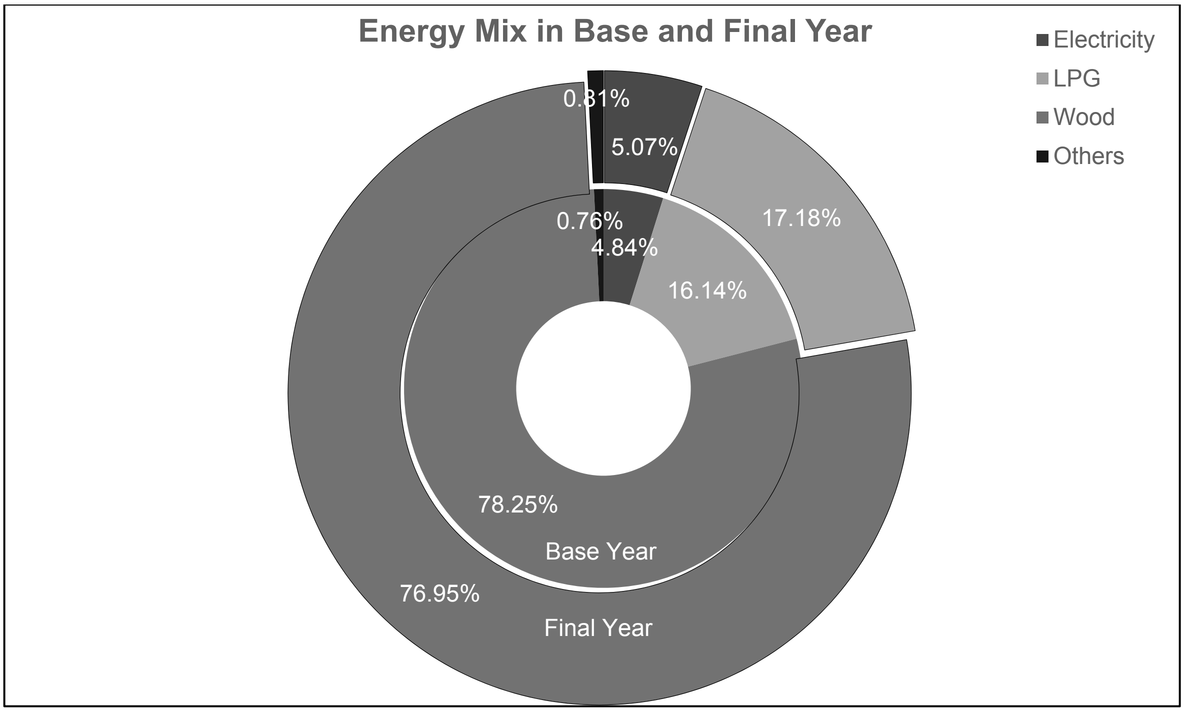


Fig. 6: Fuel Share for Base and Final year, BAU Scenario

4.2.3 Demand Side Management (DSM)

In DSM scenario, electricity demand will rise to 11.1 TJ in year 2030. Final energy demand for wood will increase to 230.7 TJ. Table 4 shows fuel wise demand for DSM scenario upto year 2030.

Table 4: Fuel wise Demand Projection, DSM Scenario

Energy Demand Final Units, Units: Tera Joule								
Fuels	**2017**	**2019**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
Electricity	10.40	10.57	10.59	10.64	10.78	10.94	11.11	11.29
Kerosene	0.785	0.806	0.817	0.839	0.862	0.886	0.910	0.935
LPG	34.68	35.73	36.27	37.37	38.51	39.68	40.89	42.13
Wood	168.1	170.3	171.0	172.2	173.3	174.1	174.7	175.3
Biogas	0.063	0.065	0.066	0.068	0.071	0.073	0.075	0.078
Solar	0.276	0.285	0.289	0.298	0.307	0.317	0.326	0.336
Others	0.510	0.527	0.535	0.552	0.570	0.588	0.606	0.626
Total	**214.8**	**218.3**	**219.6**	**222.0**	**224.4**	**226.6**	**228.7**	**230.7**

4.2.4 Biogas & Solar Promotion (BSP)

With BAU as baseline, from year 2017-2030 cumulative saving of 190 TJ is possible. 230.8 TJ accumulative energy can be saved over the years by the reduced use of fuel-wood. In year 2030 alone total of 29.06 TJ of energy demand reduction over BAU is possible. Figure 7 shows the energy demand projection for kerosene, biogas and solar. Use of kerosene will decrease as seen.

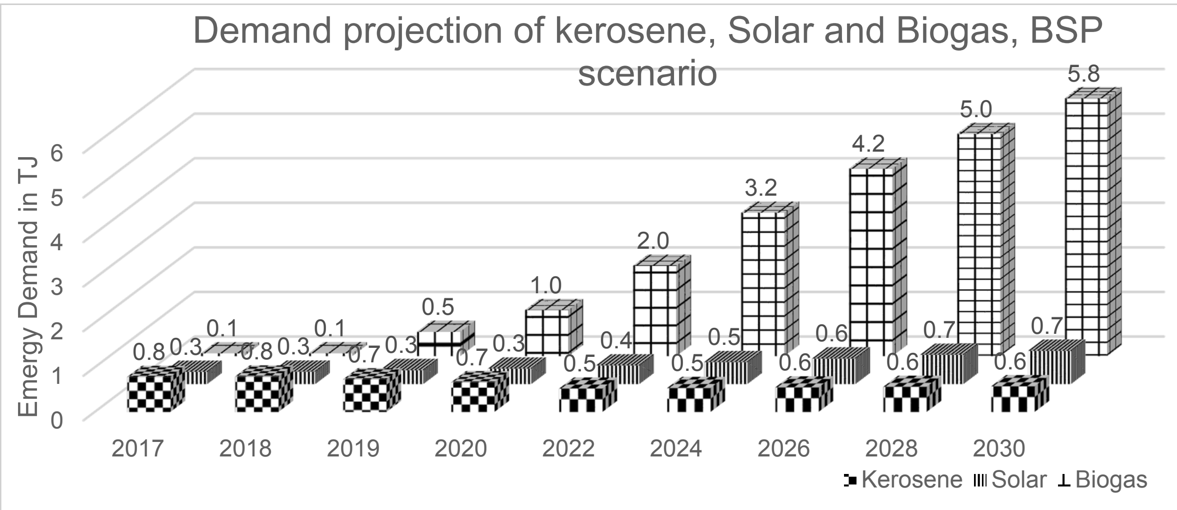


Fig. 7: Solar, Biogas and Kerosene Demand, BSP Scenario

Energy supply from bio-gas will reach 5.8 TJ in year 2030 from 0.1 TJ in base year. Share of solar in lighting reaches 9% in final year from 4.6% in base year. The share of wood decreases to 70.9% while LPG and Electricity increases to 19.5% and 6.07% in final year. Electricity demand increases by 564 MwH in final year from base year. Table 5 presents demand projection of fuels for BSP scenario.

Table 5: Fuel Demand Projection for BSP Scenario

Energy Demand Final Units, Units: Tera Joule								
Fuels	**2017**	**2019**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
Electricity	10.40	10.73	10.93	11.33	11.75	12.19	12.65	13.13
Kerosene	0.785	0.732	0.665	0.526	0.538	0.551	0.564	0.577
LPG	34.68	35.73	36.27	37.37	38.51	39.68	40.89	42.13
Wood	168.1	168.4	167.2	164.6	160.9	157.9	155.7	153.4
Biogas	0.063	0.545	1.032	2.026	3.216	4.205	4.984	5.782
Solar	0.276	0.313	0.347	0.418	0.493	0.573	0.658	0.747
Others	0.510	0.506	0.493	0.465	0.463	0.462	0.460	0.457
Total	**214.8**	**217.0**	**216.9**	**216.7**	**215.8**	**215.6**	**215.9**	**216.2**

4.2.5 Sustainable Development Goals (SDG)

LPG Demand increases to 42 TJ in year 2030, which is lower than that in BAU scenario. Demand of fuel wood is decreases by 28.6% from base year value. Table 6 shows demand projection for fuels in SDG scenario.

Table 6: Fuel Demand Projection for SDG Scenario

Energy Demand Final Units, Units: Tera Joule								
Fuels	**2017**	**2019**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
Electricity	10.40	11.23	12.01	13.60	14.99	16.53	18.23	19.99
Kerosene	0.785	0.710	0.621	0.435	0.400	0.364	0.325	0.284
LPG	34.68	35.74	36.28	37.38	38.51	39.65	40.82	42.02
Wood	168.1	166.0	162.3	154.4	146.2	137.8	129.0	120.0
Biogas	0.063	0.496	0.934	1.827	2.758	3.547	4.190	4.848
Solar	0.276	0.294	0.309	0.338	0.370	0.402	0.437	0.472
Others	0.510	0.496	0.472	0.422	0.398	0.371	0.342	0.311
Total	**214.8**	**214.9**	**212.9**	**208.4**	**203.6**	**198.6**	**193.4**	**187.9**

The total share of wood will decrease to 63.85% from 78.25%. The decrease in wood energy is balanced by increase in demand of electricity and other (solar, biogas, etc.). LPG share will rise to 22.36% while electricity share in final year will be more than double the share in base year.

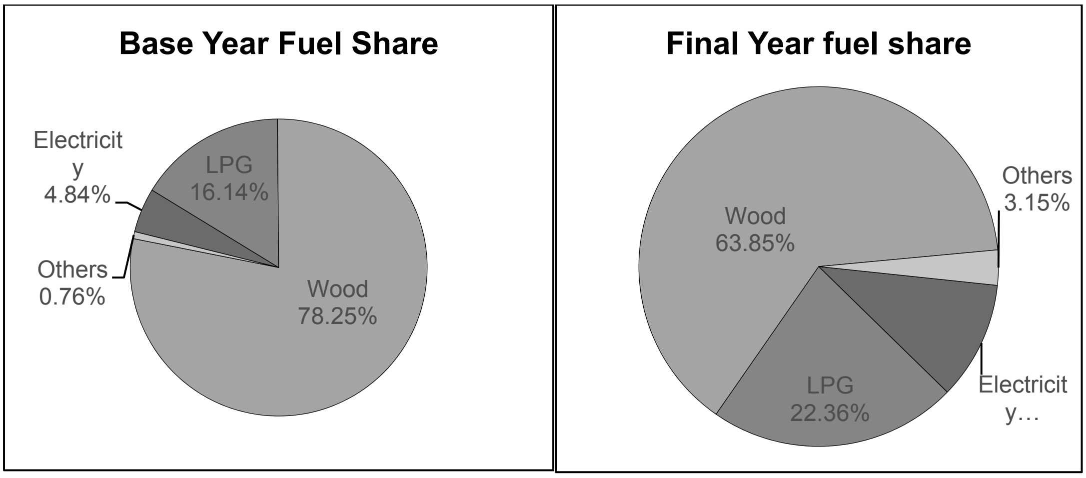


Fig. 8: Fuel Share for Base and Final Year, SDG Scenario

The demand of Electricity and Biogas will increase. An increase of electricity demand (accumulative) of 47.4 TJ and decrease of LPG by 0.3 TJ over BAU scenario is expected. Total energy of 360 TJ (accumulative over year 2017-2030) can be saved with implementation of SDG scenario.

4.3 Emission

In BAU scenario, GHG emission of 23.4 tCO2e takes place in year 2030. Total emission from year 2017-2030 in BAU scenario will be 308.05 tCO2e. SDG scenario reduces emission by 47.79 Thousand Metric tCO2e of GHG from year 2017-2030. BSP scenario where TCS are substituted by Bio-gas for cooking reduces 25.4 Thousand Metric tCO2e of GHG.

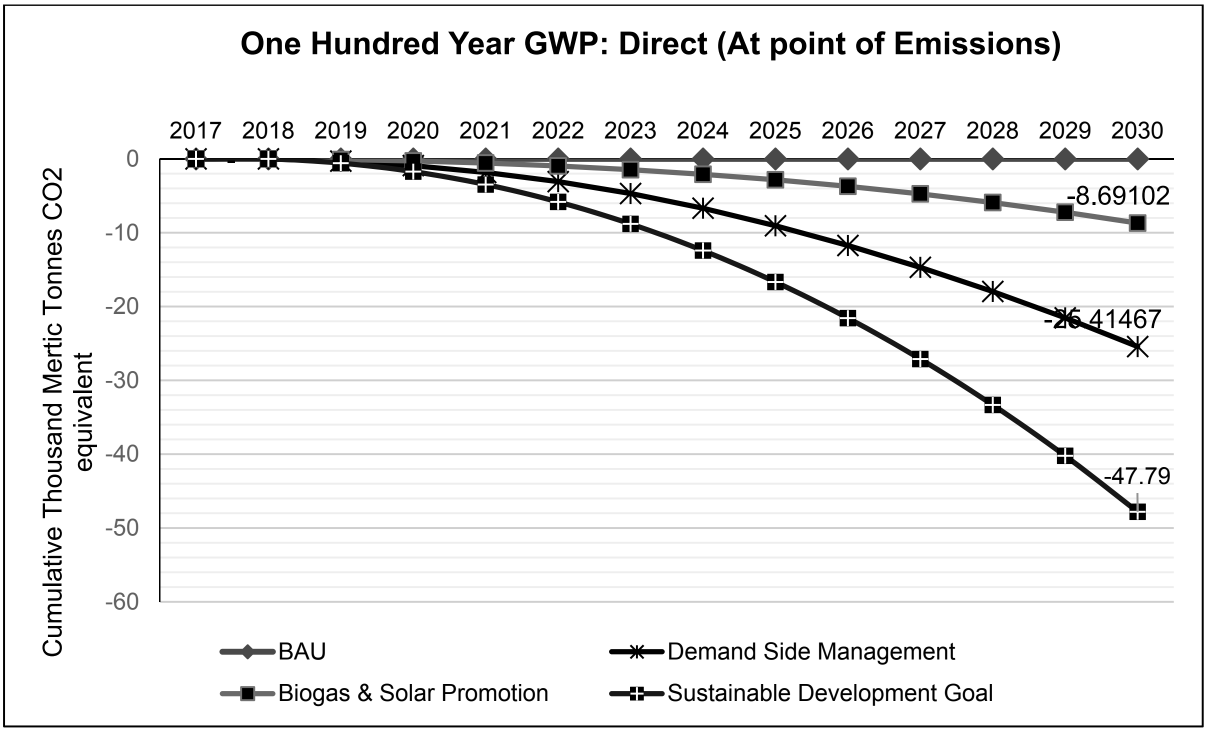


Fig. 9: GHG emission under different Scenario

4.4 Cost Benefit Analysis

Demand cost with respect to BAU scenario will be 43.03K US$, 142.75K US$ and 254.336K US$ for DSM, BSP and SDG scenario respectively. Use of efficient electrical appliances, lighting will result in 38.23KUS $ saving in electricity generation in DSM scenario. Implementation of DSM will reduce GHG emission by 8.69 thousand tCO2 at 0.55 US$/tCO2e. SDG will cost 645.46K US$ and will reduce GHG emission by 47.79K tCO2.The cost of GHG reduction per tone is higher in BSP than SDG scenario because of higher investment in Bio-gas plant and Solar PV.

Table 7: Cost-Benefit Analysis

Cumulative Costs and Benefits: 2017-2030 , Relative to BAU Scenario , Units: Thousand US $			
Scenario	DSM	BSP	SDG
Demand	43.03	142.75	254.33
Reshunga	43.03	142.75	254.33
Transformation	-38.23	18.63	108.46
Transmission and Distribution			
Electricity Generation	-38.23	18.63	108.46
Resources		-45.76	-70.61
Production			
Imports		-45.76	-70.61
Exports			
Unmet Requirements			
Investment Cost		428.28	353.28
Solar PV		59.68	33.50
Biogas Plant		368.60	319.78
Environmental Externalities			
Net Present Value	4.80	543.91	645.46
GHG reduction (Thousand Tonnes CO2e)	8.69	25.41	47.79
Cost of reducing GHGs (U.S. Dollar/Tonne CO2e)	0.55	21.40	13.51

5. Conclusion

There was high share of wood in cooking, water boiling, etc. and for lighting purpose people were still using incandescent light. Thus, there are possibilities of reducing demand by using devices with higher efficiency and efficient technology. From demand projection, emission and cost-benefit analysis, it can be seen that cost of Investment in efficient and renewable technology is higher but will help reduce energy requirement and dependency on imported fuels thus increasing energy security and it can also benefit by reduced emission. All in all, we can benefit over time with use of climate friendly and more efficient technology.

6. Recommendation

Others sectors like commercial, transportation, etc. can be studied in the area. The appliances used in the households have different power rating but for ease of research process an average of standard value is taken in order to calculate the power consumed by such devices. This research can further be upgraded by taking in detail status of equipment's rating and detailed use pattern. An experimental setup can be prepared in some houses measuring the quantity of fuel-wood and such other resources for some time span for more accurate and practical result. Large saving in energy along with reduction in emission is possible within year 2030. Hence, plans and policies like SDGs can be implemented in the area which will result in saving of energy, decrease in fuel wood consumption and it can also benefit through emission reduction aiding in climate change mitigation.

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