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SCENARIO ANALYSIS ON ENERGY TRANSITION & ENERGY SECURITY: A CASE STUDY ON MADHESH PROVINCE OF NEPAL

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ABSTRACT:

The paper has taken Madesh province as the area of study and it presents the study of energy demand emission analysis along with the energy security state of the province. The government's Net-zero targets had been taken into account to create the scenarios where the overview of the province-level energy security indicators is calculated in the time frame taking 2019 as the base year and 2050 as the final year of analysis. The energy demand and emission of different sectors of Madhesh province are compared and the scenario and their impact on the energy security indicators are compared. The elasticity of the different sectors based on GDP is used to determine the baseline scenario of the study which is then compared with the government scenario to observe fuel savings and reduction of import of fuel can be seen. Thus, the study shows energy consumption can be reduced by 35.92% which results in an emission reduction of 87.01% in the year 2050. The energy intensity can be improved up to 36% compared to the no-intervention scenario if the policies are implemented and electricity consumption capacity will triple in the year 2050 compared to the baseline.

Keywords: *LEAP, NetZero, energy security indicators.*

1. Background

The development of the country is indicated by energy consumption. The energy-related database provides critical information for designing specialized strategies, setting provincial goals, and combining them to achieve the national goal [1]. As a result, a well-organized energy. The database serves as a foundation for policy development and long-term energy planning. As constitution of Nepal 2015 has divided the nation into seven provinces [2]. Along with various targets and milestones set by the government to be met in the energy sector. The use of biomass, a non-commercial energy type in Nepal, dominates the country's entire energy consumption. Traditional energy sources (fuel wood, agri-residue, and animal waste) continue to dominate. However, there is a clear move toward commercial energy (coal, petroleum products, and electricity), and renewable energy sources are expanding. Consumption of electricity has also recently increased at a rapid pace [3].

Energy transition towards cleaner sources improves individual living conditions and the economic growth of the nation, Nepal has a lot of water that could be used to make electricity, especially from hydropower. But because of various social and economic challenges, the country is finding it hard to tap into this potential. This is why people in Nepal use less electricity per person compared to other places [4]. To achieve sustainable development aspirations, a nation should lead the development agenda spearheading the policies in three dimensions − economy, society, and the environment. The energy security indicators derived from the energy data will further expand the scenario, which will finally be used as a resource for drafting policies and action plans for energy sector improvement, leading to the province's energy sustainability. Although considerable work has been done in this area of research, the number of indicators employed is quite limited. Numerous articles and publications that were published at the time described the crisis's potential causes and solutions. The energy crisis has had a significant impact on every economic sector, including commercial, industrial, residential sectors, etc, which has slowed down the country's economic growth. The energy consumption continues to rise in terms of absolute values. The increase in the energy consumption rate of Nepal is 2.2% per annum in the last two years which is higher than the population growth rate [1]. As a result, there is still some potential for further research into the energy mix and energy security utilizing a wider number of relevant indicators. Thus, the study of issues relating to the energy sector has been the main topic of study in the case of Madesh province.

2. Energy Security Indicators

The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. It classifies energy security into two aspects term which mainly deal with timely investments to supply energy in line with economic developments and environmental needs and short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance **[5]**. For sustainable development of a country energy security indicators become important aspects of the country or regions as energy security indicators analyze the advancement of energy which leads to improvement of energy efficiency in power consuming sectors **[6]**. For oil-importing countries like Nepal energy security became a hot topic after the energy crisis hit the world in 1970-73 after that every country became aware of energy security and energy planning, now energy security has become a global issue, and ensuring the supply of energy and to provide affordable, clean and sustainable energy are urgencies for a country like Nepal **[7]**. For developing countries, energy security means getting energy demand fulfilled by all citizens at an affordable and suitable price with a better quality of life without harming the environment **[8]**. IEA classifies energy security into two aspects, long-term energy security which mainly deals with supply, environmental needs, and economic developments and second one is short-term energy security which deals with the capability of energy supply that reacts to sudden changes in supply and demand balance **[5]**.

Some following energy security for Nepal are used by the Water and Energy Commission Secretariat (WECS) [9] and other research journals [10].

- Final energy demand/capita
- Final electricity demand/capita
- GHG emission
- Share of renewable energy in final total energy demand
- Share of electricity used/household
- Share of non-carbon energy in the primary supply
- The ratio of net import to total primary energy supply

Other research national journals highlight and discuss the different dimensions of energy security in Nepal [10].

1. Affordability dimension
2. Availability dimension
   i. oil imports value per unit of GDP
   ii. Oil Consumption /capita
   iii. Total Final Energy Consumption/capita
   iv. Share of domestic production of primary energy
   v. Import Dependency
   vi. Shannon- Weiner Index (SWI)

vii. Annual electricity deficit
viii. Average annual price of petroleum products
ix. Electricity Consumption/capita
x. Strategic Fuel Stock is the number of days of stock of petroleum products
xi. Electricity Consumption /capita
xii. The average annual price of electricity

3. Efficiency dimension
   i. Intensity of Residential energy consumption
   ii. Total final energy Intensity
   iii. Intensity of Industrial Energy Consumption
   iv. Intensity of commercial energy consumption
   v. Oil consumption /GDP
   vi. Distribution and Transmission and Distribution losses
4. Acceptability dimension
   i. Annual Co2 emission/capita
   ii. Carbon fuel portfolio
5. Accessibility dimension
   i. Access to modern cooking fuel
   ii. Access to electricity

Although there are many different energy security indicators, in this study eight different significant indicators have been used and comparative analysis has been carried out for all scenarios developed.

3. Research Methodology

The methodology used for the study is a flowing framework as shown below:

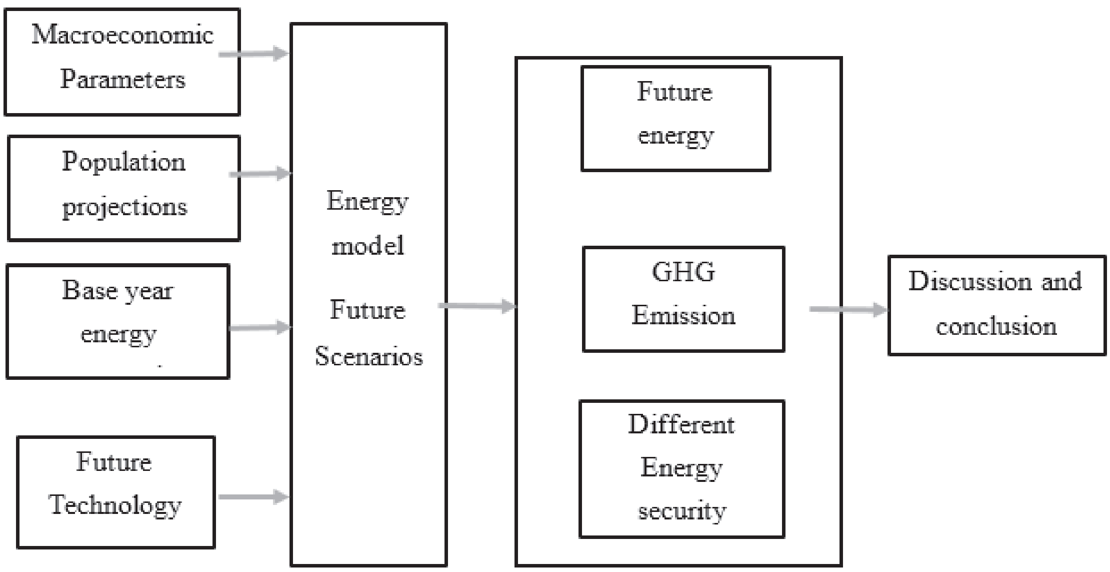

Figure 1 Research methodology

3.2 Data Collection

Madhesh province energy mix data is collected from WECS [9] and from different journals and reports for creating scenarios [11]. For economic growth during developing scenarios, the data is taken from reports of economic surveys [12]. The types of data collected are as follows.

- Total Energy demand in different sectors
- GDP of Nepal at different points in time

- GDP growth rate.
- GDP contribution from different sectors
- Population of Nepal
- Household Size

3.3 Development of Scenario

Analyzing energy demand from 2019 to 2050, the study considered past trends, population growth, and economic growth (GDP) by which a baseline scenario is created in which the population and GDP growth rates are 1.35% and 6.3% is taken from the WECS report [9]. The household size growth rate is taken the same as the population growth rate.

Other scenarios are made to meet the government target of net zero emission by 2050 in which, two scenarios WAM and WEM are made [13] [7].

The assumption for baseline scenarios

- Urbanization of Madhesh province is expected to be 90 % [14].
- Urbanization is considered a uniform growth rate for easy calculation.

The assumption for Net- Zero with existing measures scenarios

Residential

- In urban households:- The fuel mix is 20% LPG, 70% electric cooking, and 75% Electrification in space heating and water heating.
- In rural households:- The fuel comprises 10 % ICS, 40% LPG, 40% Electric cooking, 50% electric space heating and 25% electric water heating.

Industrial Sector

- In food and beverage 100% electrification in process heat and motive power, 50% in electric boiler.
- In Textile and leather products 100% electrification in process heat, motive power, boiler.
- In Industrial Chemical rubber and plastics 50% electrification in process heat, 100% in motive power, 50% in boiler.
- In Mechanical engineering, Process heat is 50% electrified, and motive power electrification is 100%.
- In Electrical Engineering Products: Process heat and motive power 100% electrification.
- In Wood products and paper, Process heat is 50%, motive power 100%, and 50% boiler electrification.

Transport Sector

- Due to a lack of data for intercity and intracity transportation for simplicity, it is assumed that in Madhesh province intercity transportation is dominated by intracity transportation so for all Public passenger and private transport the scenario is based on intracity transportation.
- In Public transport and Private Transport 35% in an electric bus, 20% in an electric car, 5% in Electric motorbikes,

Commercial Sector

- 100 % electrification in all sectorial demand.

Agriculture sector

- In water pumping 40% electric, 40 % by solar PV Pumping, and 25% electricity in farm machinery.

The assumption for NetZero with additional measures scenarios

Residential

- 100% Electric cooking and lighting in both urban and rural areas.

Industrial Sector

- In food and beverage, Textile and leather products, Industrial Chemical rubber and plastics, Mechanical engineering, Electrical engineering Products, Wood products and paper 100% electrification.

Transport Sector

- In Public transport and Private Transport 48% in electric bus, 20% electric car, 10% Electric motorbike.

Commercial Sector

- 100 % electrification in all sectorial demand.

Agriculture sector

- In water pumping 60% of the electricity, 40 % by solar PV Pumping, and 100% electricity in farm machinery.

3.4 Energy Demand Calculation

Energy Demand has been formulated using the LEAP framework, the methodology involves a fundamental equation that serves as the basis for estimating energy demand in different sectors.

$$Energy\ Demand = Total\ Activity * Energy\ Intensity$$

This equation highlights the essential connection between the scope of a specific activity and its energy consumption. For the residential sector, the parameter "Total Activity" is defined as household size. Conversely, in the agricultural, commercial, and industrial sectors, "Total Activity" corresponds to the proportionate contribution of each sector to the provincial Gross Domestic Product (GDP). This approach establishes a direct and evident link between the scale of an activity and its energy requirements, thereby presenting valuable insights into the energy dynamics across these sectors.

Energy demand forecast in baseline scenario is carried out taking elasticity of Madhesh province each sector GDP.

Energy demand (t) = Energy demand (0)*(GDPt/ GDP0) elasticity

Sectors elasticity is taken from (Shrestha and Raj Bhandari, 2010) [15].

3.5 Emission calculation

The emission from each sector in the net–zero and baseline scenarios is calculated through LEAP using IPCC guidelines for the Asian subcontinent.

4. Research Framework

This study uses the LEAP modeling tool used for energy policy analysis and climate change mitigation assessment. That can be used to track energy consumption, production, and resource extraction in all sectors of an economy [34]. Also, the initial data requirements are quite low, which helps in getting the maximum insight despite having a low volume of data. Hence, a lot of future scenarios can be modeled based on limited data and whose results can be used for gaining a better understanding of the interventions and policies undertaken.

In the Key Assumptions section of the LEAP Model, the following parameters are used based on data compilation

- Population:-6.125 Million
- Average Household Size:-5.8
- Number of Households:-1.06 Million
- GDP of Madhesh Province:-3939.1 Million US$
- Share of Agriculture GDP:-40% of province GDP
- Share of Commercial GDP:-47.5% of province GDP
- Share of Industrial GDP:-7.8% of province GDP

To develop the energy model in LEAP, the Energy demand in the residential, Industrial Commercial, and Agriculture sectors is disaggregated into different–use service demands from which each of the end-use is further subdivided into different fuel types. The disaggregation of the sector and the disaggregation of the end-use sector by fuel types used in LEAP.

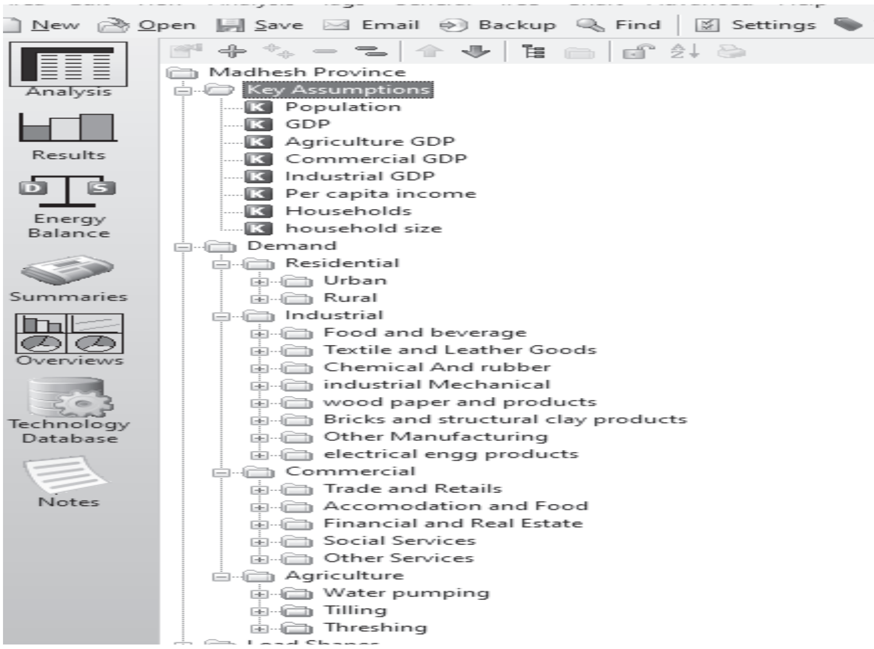

Figure 2 Division of Energy consuming sector in LEAP

5 Discussion and Results

Baseline, NZE, and NZA scenarios emission and final energy demand are calculated and compared between them which shows how much difference in emission and energy demand from different sectors from the baseline, scenario to the other two scenarios

Energy security indicators are calculated for Baseline, NZE, and NZA scenarios in the base year and final year for each indicator and comparison between them to find out deviation from the baseline scenario.

5.1 Energy mix in different scenarios

Table 1 Energy mix in different scenarios in Terajoules

Branch	Base Year(2019)	End Year NZE(2050)	End Year NZA(2050)
Industrial	16096.90	78095.93	69479.59
Commercial	2186.70	6307.64	6307.64
Agriculture	789.46	3811.53	1899.42
Residential	39250.30	36534.64	29184.18
Transport	5749.00	17112.10	15741.78

Table 1 shows the baseline scenario, the final energy demand's average annual growth at the rate is 3.59% and reaches 191347.16 Terajoules from base year 64072.36 Terajoules. This is because the industrial sector has a high energy consumption annual growth rate. After all, Madhesh province is a hub for the industrial sector. In the NZE and NZA scenario growth rate in final energy demand is 2.59% and 2.11% respectively which is less in comparison to the baseline scenario due to implementing efficient fuels like electricity, and solar in both scenarios an average annual energy consumption growth rate is lower than baseline scenario.

In energy mix in different scenarios in the baseline industrial sector has the highest annual growth rate of 5.98% in baseline scenarios

5.2 Comparison between energy sectors in baseline and with different scenarios

5.3 Sector-wise comparison of energy consumption

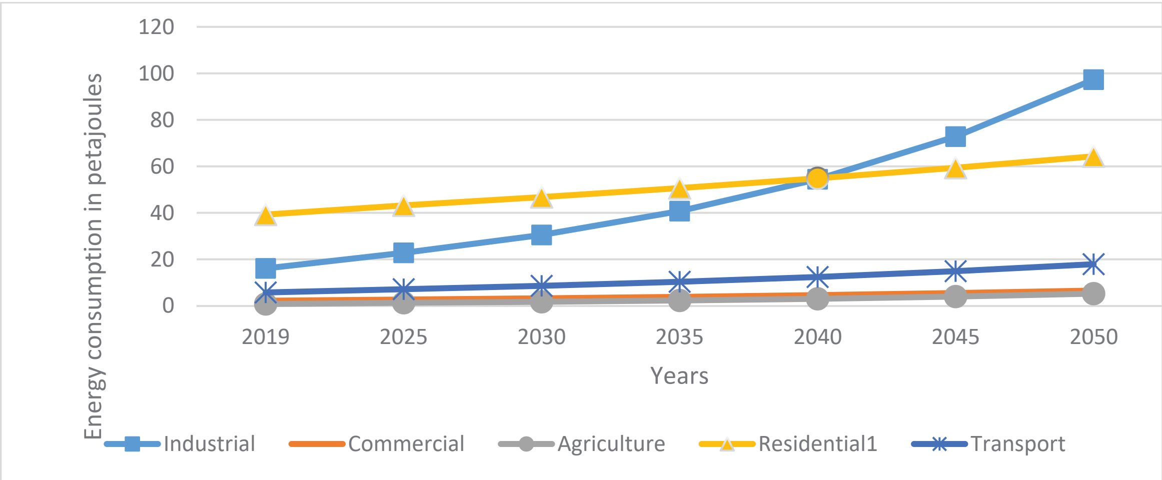

Figure 3 Sector-wise energy consumption baseline scenario

Figure 4 shows the Madhesh province total final energy demand is 64.074 PJ in the base year as shown in Figure 4 above. The highest consumption is in the residential sector. All sectors are expected to grow significantly over the next 30 years, with the Industrial sector growing the fastest at a rate, the Industrial sector led in energy consumption, utilizing 16.0969 PJ, and this consumption steadily increases throughout the projection period, reaching 97.3076 PJ by 2050. The Commercial sector, starting at 2.1867 PJ in 2019, also experiences a consistent rise, reaching 6.5593 PJ by 2050. Similarly, the Agriculture sector starts at 0.78946 PJ in 2019 and climbs to 5.2515 PJ by 2050. Residential energy consumption, beginning at 39.2503 PJ in 2019, shows a gradual increase, reaching 64.3181 PJ by 2050. Lastly, the Transport sector, with an initial consumption of 5.749 PJ in 2019, will see a notable escalation, reaching 17.9106 PJ by 2050.

5.4 Fuel mix comparison

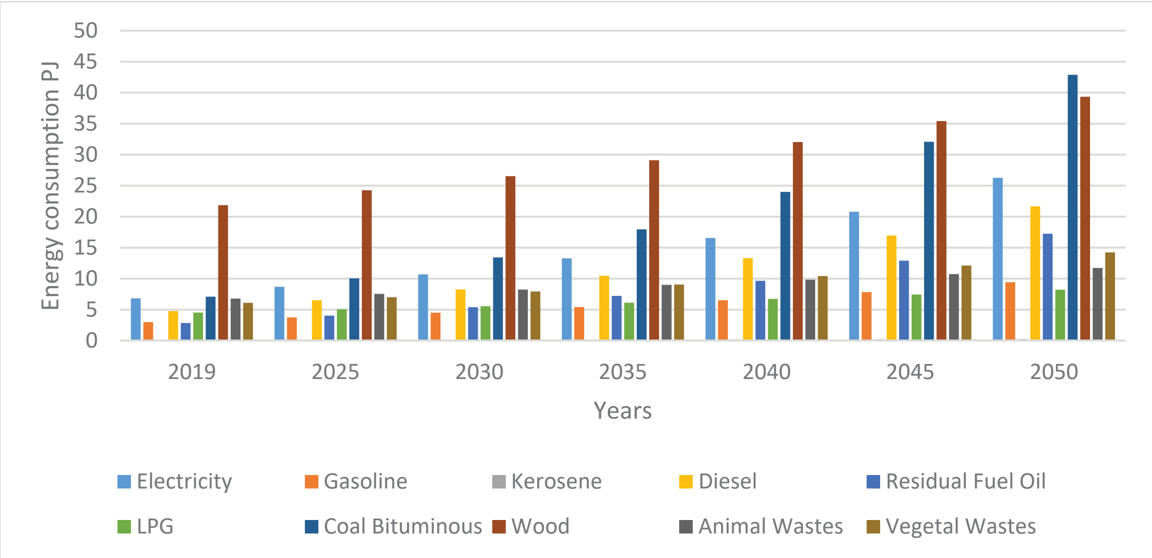

Figure 4 Energy consumption by fuel type in the baseline scenario

Figure 5 shows the fuel consumption in petajoules (PJ) across diverse categories from 2019 to 2050 in the baseline scenario is shown in Figure 6. Electricity consumption experiences consistent growth, starting at 6.8386 PJ in 2019 and reaching 26.2697 PJ by 2050. Gasoline consumption follows a steady upward trajectory, ascending from 3.01 PJ in 2019 to 9.4394 PJ in 2050. Diesel consumption increases significantly, starting at 4.7807 PJ and reaching 21.6708 PJ by 2050. Residual Fuel Oil consumption rises from 2.8550 PJ to 17.2589 PJ over the same period. LPG consumption increased from 4.5298 PJ in 2019 to 8.2255 PJ in 2050. Coal Bituminous sees substantial growth, escalating from 7.0988 PJ to 42.8814 PJ. Wood consumption rises gradually from 21.8598 PJ to 39.3428 PJ. Animal Wastes and Vegetal Wastes consumption also show upward trends, reaching 11.7352 PJ and 14.2458 PJ, respectively, by 2050.

5.5 Comparison in total energy consumption between different scenarios with the baseline scenario

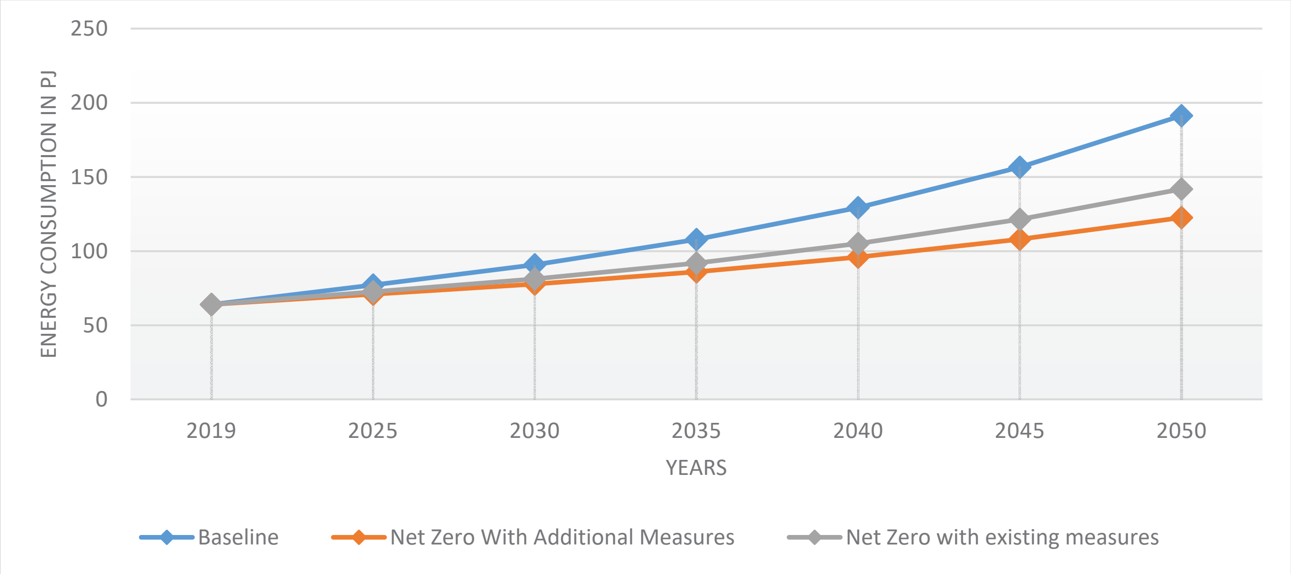

Figure 5 Comparison between different scenarios

Figure 6 shows energy consumption patterns in petajoules (PJ) across three distinct scenarios Baseline, Net Zero with Additional Measures, and Net Zero with Existing Measures from the years 2019 to 2050. In the Baseline scenario, there is a consistent upward growth in energy usage, commencing at 64.07236 PJ in 2019 and culminating at 191.34715 PJ by 2050. Conversely, the Net Zero with Additional Measures scenario, despite initiating with the same energy consumption as the Baseline in 2019, exhibits a distinguishable reduction, reaching 122.61261 PJ by 2050, which indicates the uses of additional measures and efficiency improvement in selected fuel type in additional measures. In contrast, the Net Zero with Existing Measures scenario, while still achieving a reduction compared to the Baseline, concludes with higher energy consumption at 141.86184 PJ in 2050.

5.6 GHG Emission 100-year GWP: Direct (at point of emission) in Baseline Scenario

Table 2 GHG emission in 000 metric tonnes CO2 equivalent

GHG in Thousand Metric Tonnes Co2 Equivalent	2019	2025	2030	2035	2040	2045	2050
Carbon Dioxide	1740.0	2316.4	2941.9	3756.0	4818.6	6209.2	8032.9
Methane	452.2	509.6	563.6	624.0	691.8	768.3	855.0
Nitrous Oxide	73.1	84.1	94.9	107.4	122.0	139.3	159.9

Table 2 shows the growth of greenhouse gas (GHG) emissions in thousand metric tonnes of Co2 equivalent from year base year 2019 to 2050 in the baseline scenario for the three GHGs.

Carbon Dioxide increased significantly over the period from 1740 in base year to 8032.9 in 2050. This represents an average annual growth rate of 5 percent. Similarly, Methane and Nitrous oxides have an average annual growth rate lower than Carbon Dioxide which is 2% and 3% respectively. The growth of Carbon Dioxide is driven by the increasing use of fossil fuels.

5.7 Comparison of GHG Emission in baseline scenario with different scenarios

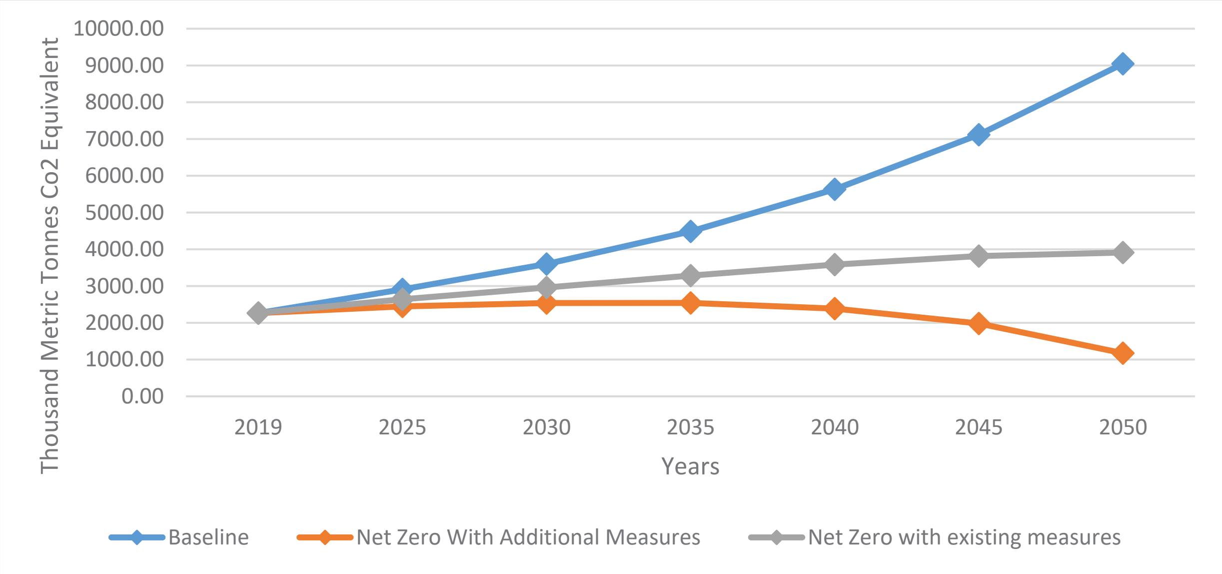

Figure 6 Comparison GHG emission of baseline to other two scenarios

Figure 7 shows the growth of greenhouse gas (GHG) emissions in thousand metric tonnes of Co2 equivalent from year base year 2019 to 2050 in three distinct scenarios. In which baseline scenarios have substantial growth in GHG emission with an annual average growth rate of 5%. In contrast to the baseline in Net-Zero with existing Measures scenario emission decrease at the end year 2050 though it has same GHGs emission in the base year. This is because it assumes to implementation of existing measures to reduce GHG emissions such as promoting renewable sources of energy.GHG emission is even lower in Net-Zero with existing measures scenarios than in Net-Zero with existing Measures scenarios.

5.8 Environmental effects (Emission in Physical Units) Sector Wise in the baseline scenario

Table 3 Environmental emission

Environment Effects (Emissions)in Thousand Metric Tonnes	2019	2025	2030	2035	2040	2045	2050
Industrial	1211.5	1716.1	2294.0	3066.3	4098.8	5478.8	7323.5
Commercial	17.7	21.9	26.2	31.3	37.3	44.6	53.2
Agriculture	59.6	100.3	132.0	173.8	228.8	301.3	396.6
Environment Effects (Emissions)in Thousand Metric Tonnes	2019	2025	2030	2035	2040	2045	2050
Residential	3903.2	4278.1	4617.4	4983.0	5377.0	5801.5	6258.7
Transport	433.8	540.5	649.2	779.8	936.6	1125.0	1351.4

Table 3 shows environmental effects in thousand metric tonnes which include emissions like Carbon Dioxide Biogenic, Carbon Dixoide, Carbon Monoxide, Methane Non-Methane Volatile Organic Compounds, Nitrogen Oxides, Nitrous Oxide, Tot Suspended Particulates, and Sulfur Dioxide. The highest emission in the base year is from the Residential sector which is 3903.2. The residential sector has the highest emission in comparison to other sectors in the baseline scenario. This is because it has the highest energy consumption in the base year but at the end year 2050 industrial sector emits more emissions due to the high energy consumption growth rate and the emissions is 7323.5 Thousand metric tonnes in 2050.

5.9 Comparison of Environmental effects (Emission in Physical Units) in different scenarios.

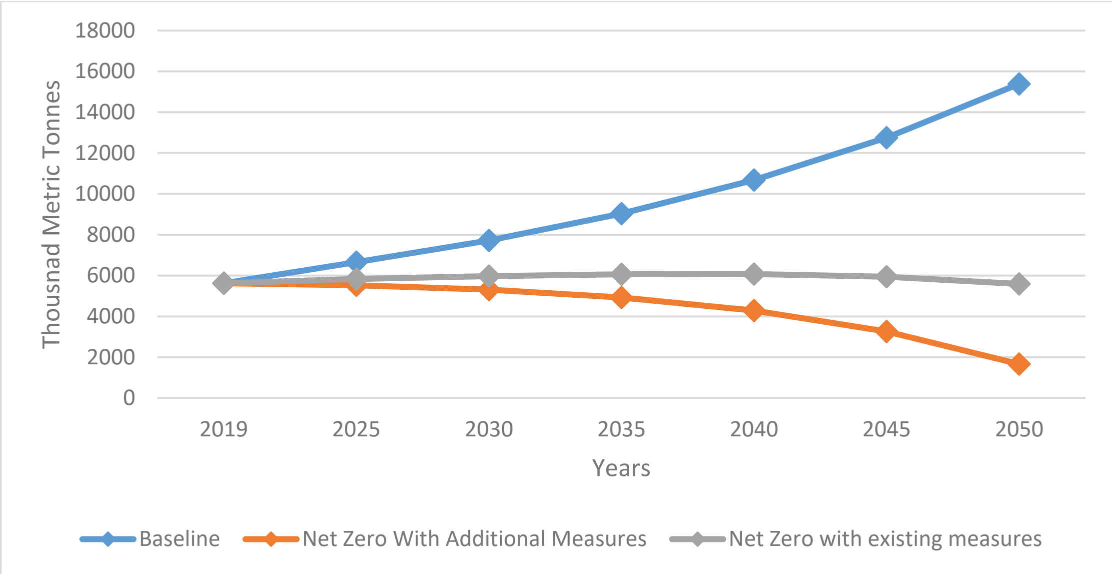

Figure 7 Environmental effects comparison in different scenarios

Figure 8 shows environmental emissions in thousand metric tonnes from year base year 2019 to 2050 in three distinct scenarios. In which baseline scenarios have substantial growth in emission with an annual average growth rate of 3%. In contrast to the baseline in Net-Zero with the existing Measures scenario, emission decreases at the end year 2050 though it has the same emission in the base year. This is because it assumes to implement existing measures to reduce emissions such as promoting renewable sources of energy. Emission is even lower in Net-Zero with exiting measures scenarios than Net-Zero with existing Measures scenario.

5.10 Energy Security Indicators

5.10.1 Overview of Energy security Indicators in different scenarios

Table 4 Energy security indicators values in base year and End year in NZE and NZA scenario

		Baseline		End Year (NZE)	End Year (NZA)
Indicators	Unit	Base Year	End Year		
Energy Consumption Per Capita	GJ/Capita	10.39541185	18.13117852	13.44217679	11.61820848
Electricity Consumption Per capita	Kwh/Capita	308.2005105	691.4432039	1291.245777	2693.406769
Energy Intensity	GJ/$1000	16.19651909	7.278498147	5.396166539	4.663960968
Electricity Intensity	Kwh/$1000	480.1902536	277.5698267	518.3518538	1081.229009
Share of Renewable Energy in Final Energy consumption	Percent	64.94%	47.87%	65.03%	86.77%
GHG emission	GHG in KG/Capita	367.5283	857.3200598	370.7568725	111.3253887
GHG Intensity	GHG in KG/$1000	572.6256174	344.1586801	148.8349589	44.68995959
Shannon -wiener Index(SWI)		1.99	2.05	1.97	0.71

5.10.2 Energy consumption per capita comparison

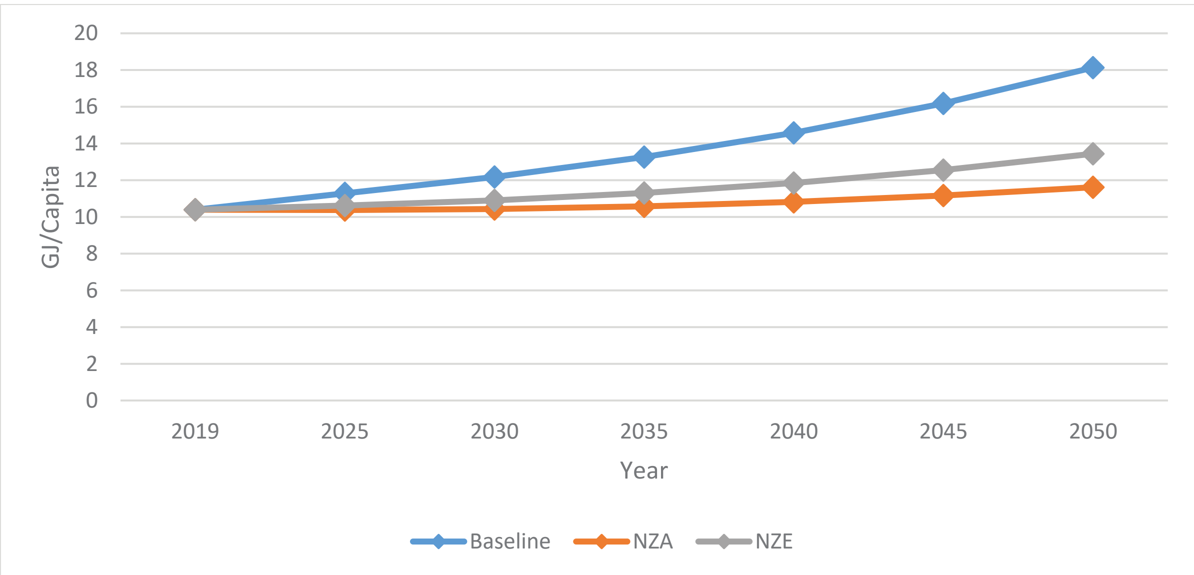

Figure 8 Energy consumption per capita in different scenarios

Figure 9 shows the total energy consumption per capita consumption of Madhesh province is highest in baseline scenarios. This is because in the baseline scenario less use of efficient fuels like electricity in every sector than other two scenarios so Net-zero with existing and Net-zero with additional measure has lower energy consumption per capita because these two scenarios implement uses of fuel type electricity in each sector though in between NZA and NZE scenarios NZA implement more efficient sources of fuel than NZE like solar, electricity.

5.10.3 Electricity consumption per capita comparison

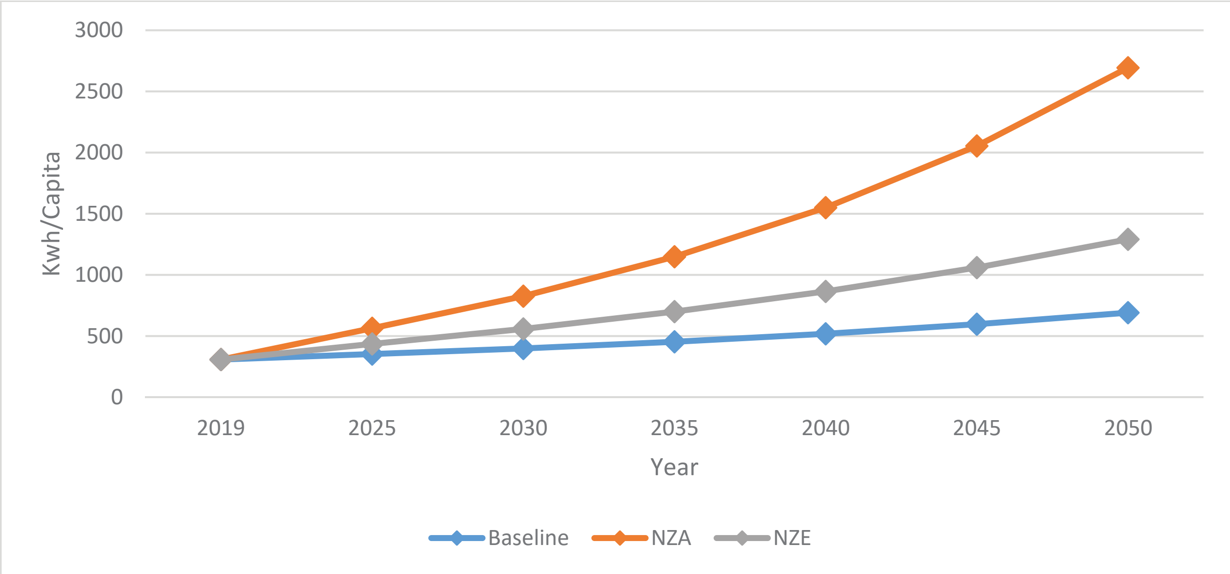

Figure 9 Electricity consumption per capita in three different scenarios

Figure 10 the total Electricity consumption per capita of Madhesh province is the highest in the NZA scenario. This is because in NZA scenario implements a higher use of efficient fuels like electricity in every sector than the other two scenarios so Net-zero with existing and Baseline scenario has lower electricity consumption per capita because these two scenarios implement the use of fuel type electricity in each sector though in between NZE and baseline scenarios NZA implement more efficient sources of fuel than NZE like solar, electricity.

5.10.4 Energy Intensity Comparison

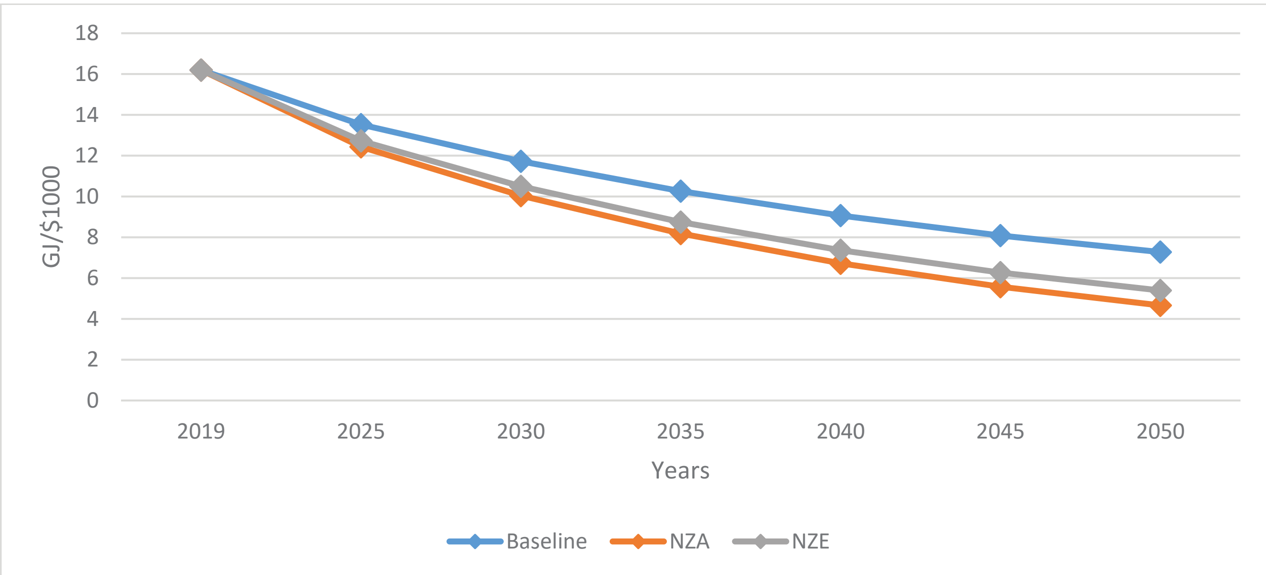

Figure 10 Energy intensity in three different scenarios.

In Figure 11shows , the graph shows the variation trend of energy intensity of Madhesh province in the baseline scenario in the base year it has 16.19 GJ/$1000. And it decreased to 7.27 in the year 2050. The a similar decreasing trend in the other two NZE and NZA scenarios. The decreasing trend shows that the share of renewable energy in the electricity mix is increasing and there is a growing shift to an electric vehicles in the Transportation sectors.

5.10.5 Electricity Intensity Comparison

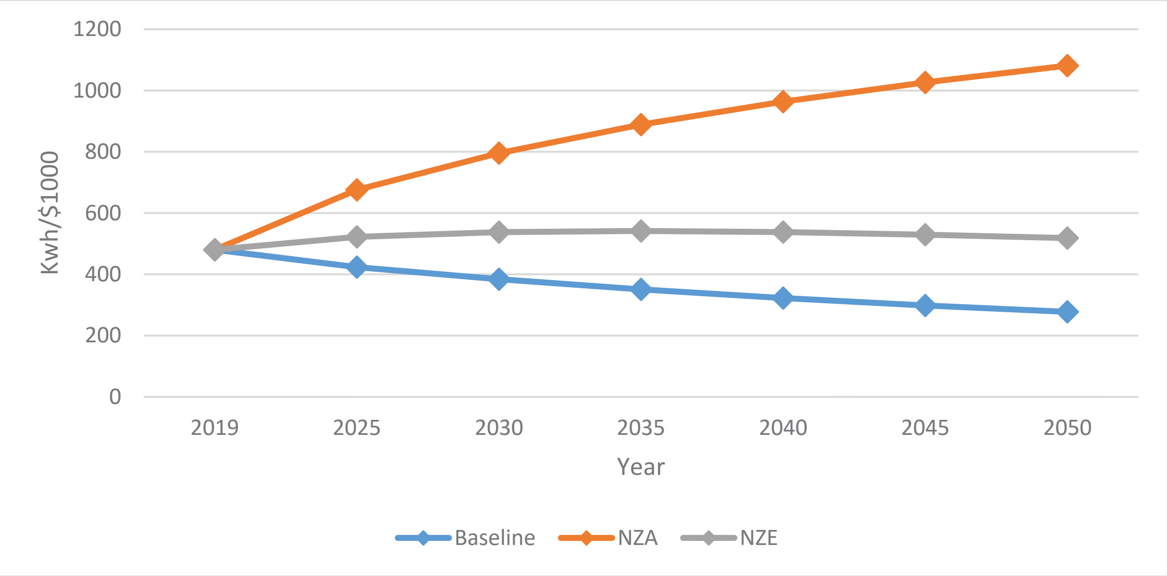

Figure 11 Electricity Intensity

Figure 12 shows the electricity intensity variation in different scenarios. The value of electricity intensity in the baseline scenario in the base year 2019 is 480.19 Kwh/$1000 and its value decreases to 277.56 Kwh/$1000 at the end year 2050. The two NZE and NZA have a similar increasing trend in NZE electricity intensity is 518.35 Kwh/$1000 and in NZA electricity intensity is 1081.22 Kwh/$1000. This is because the NZA scenario implements higher electricity fuel types for energy demand in each sector.

5.10.6 Share of Renewable Energy Consumption

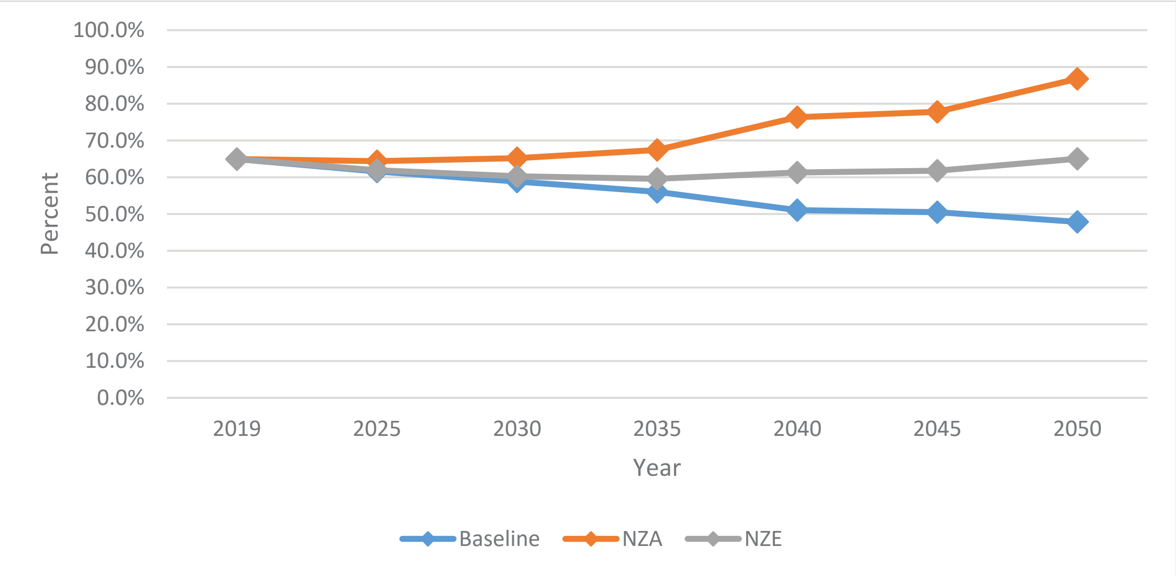

Figure 12 Share of Renewable Energy Consumption

Figure 13 shows the share of renewable energy including traditional biomass in the total energy fuel mix. In the baseline scenario, it is in a decreasing pattern because the share of traditional biomass has decreased as the year exceeds in end year the share of renewable energy is 47.9% from the base year share of renewable energy 64.9%. In NZA and NZE scenarios the share of renewable energy is increasing order the growth rate between the years 2040 to 2045 decreases due to traditional fuels less, after that again share of renewable energy electricity increases, and shows the increasing pattern as shown figure.

5.10.7 GHG Emission per capita

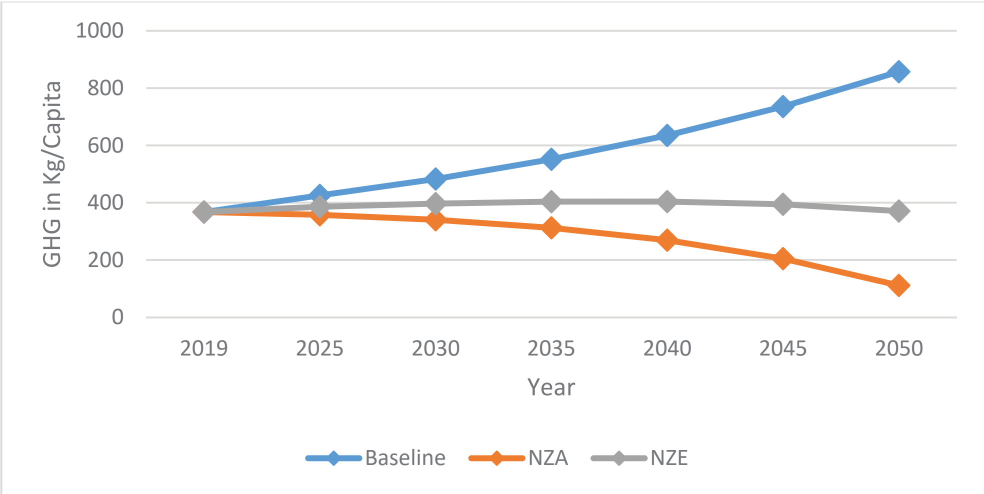

Figure 13 GHG Emission per capita

Figure 14 shows GHG emission kg per capita in three distinct scenarios. The graph has an upward trend in baseline scenarios while NZA and NZE scenarios have a downward trend in GHG emission per capita because NZA and NZE scenarios use fewer fuel types that produce GHG emissions like electricity, and solar energy. In baseline, in the base year, it was 367.52 kg and in the end year, it increased to 857.32 kg. Likewise, GHG emission decreased in NZA scenario 111.32 kg in the end year from the base year. It shows that implementing the NZA scenario will drastically reduce GHG emissions by 2050 year which help to get the target Net-Zero emission set by the government of Nepal.

5.10.8GHG Intensity

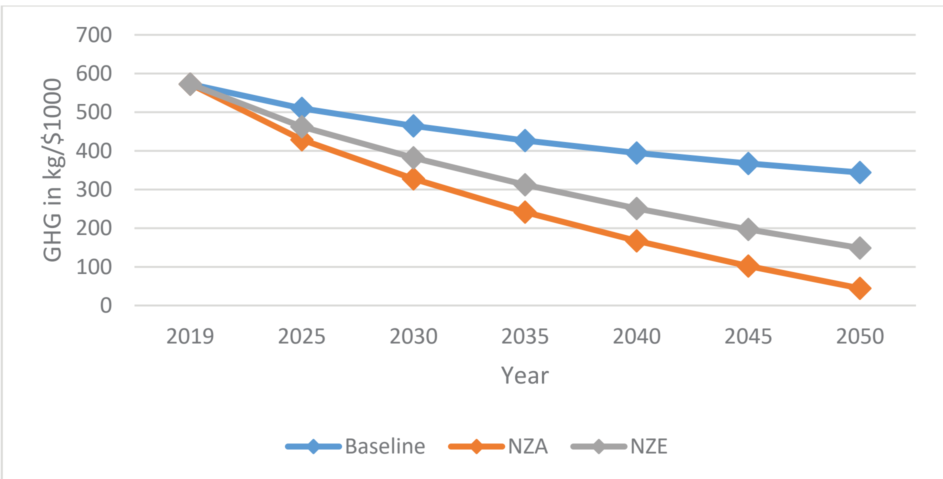

Figure 14 GHG intensity

Figure 15 shows GHG intensity in GHG in kg per $1000. The graph shows the variation trend of GHG intensity of Madhesh province in the baseline scenario in the base year it has 572.62 kg/$1000. And it decreased to 344.15 kg/$1000 in the year 2050. The a similar decreasing trend in the other two NZE and NZA scenarios. The decreasing trend shows that the share of renewable energy in the electricity mix is increasing and there is a growing shift to electric vehicles in the Transportation sectors. So GHG emissions are less than in both NZA and NZE than the baseline scenario which is 44.68 kg/$1000 and 148.83 kg/$1000 by end year 2050 respectively.

5.10.9 Shannon –Weiner Index (SWI)

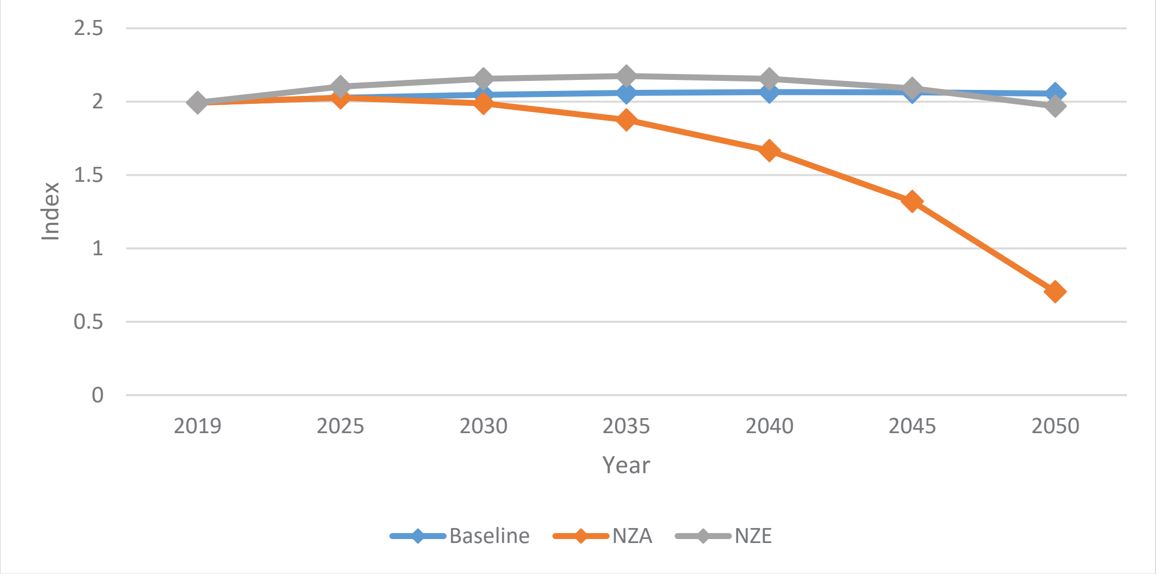

Figure 15 Shannon- wiener Index in different scenarios

Figure 16 shows the Shannon- Weiner Index which represents the diversity of fuels in the Madhesh province. It indicates the greater the value higher the security in the province. In contrast in NZA and NZE scenarios, it is decreasing from base year 1.99 to 0.70 and 1.96 respectively. This means the diversity of fuel is not improved in both scenarios but it shows improvement in diversity in the baseline scenario which increases to 2.05 from base year 2019. NZE and NZA have good results and values in other security indicators.

5. Conclusion

Energy consumption patterns in Madhesh Province reveal the significant impact of urbanization on residential energy demand, the growth in industrial and commercial sectors, and rising energy needs in agriculture. Importantly, addressing energy security challenges tied to fossil fuel reliance is highlighted, particularly in the context of achieving net-zero emissions. Analyzing the energy consumption pattern under the baseline scenario the energy consumption is 64,072.36 TJ in 2019 has an increment of about 200% in 2050 and the emission is seen to increment of 300% on its value of 2,265 million metric tonnes CO_2 equivalent.

Analyzing the NZE scenario, it is observed that energy consumption can be reduced by 25.86% in the year 2050 which will reduce emissions by 56.75% and the NZA scenario will decrease the consumption by 35.92% which results in an emission reduction of 87.01% in the year 2050. In this study, the analysis of the energy sector is carried out without analyzing the non-energy sector thus the state of the net-zero emission target is not seen in the year 2050 in this province.

References

1. G. o. Nepal, "Energy sector synopsis report," WECS, 2022.
2. N. o. Government, "The Constitution of Nepal," 2015.
3. G. o. Nepal, "NEPAL`S ENERGY SECTOR VISION 2050 A.D," 2010.
4. T. R. P. Tika Ram Pokharel, "Energy Transition toward Cleaner Energy Resources in Nepal," Sustainable Integration of Renewable Power Generation Systems, 11 April 2021.
5. IEA, "Emergency response and energy security," 2023. [Online]. Available: https://www.iea.org/about/emergency-response-and-energy-security.
6. B. L. Sujeetha Selvakkumaran, "Energy security and co-benefits of energy efficiency improvement," Renewable and Sustainable Energy Reviews, vol. 20, pp. 491-503, 2013.
7. A. M. N. S. R. S. Kiran Gautam, "Future Energy Supply Possibilities and their Implications on Nepal’s Energy Security," Strategic Planning for Energy and the Environment, vol. 42, no. 3, pp. 405-430, 2023.
8. M. S. Weiwei Lu, "Energy security assessment: A review," Advanced Materials Research, Vols. 724-725, pp. 1211-1215, 2013.
9. Nepal, Government of, "Energy consumption and supply situation in Federal system of Nepal Province 2," 2021.
10. T. R. B. Shova Darlamee, "Energy Security Assessment of Nepal for the Perid of 2005-2030," Journal of Advanced College of Engineering and Management, vol. 6, pp. 199-211, 2021.
11. A. M. N. ,. A. P. ,. B. B. P. ,. U. S. R. ,. M. R. ,. M. G. L. Shree Raj Shakya, "Environmental, energy security, and energy equity (3E) benefits of net-zero emission strategy in a developing country: A case study of Nepal," Elsevier, vol. 9, December 2023.
12. G. o. Nepal, "Economic Survery 2019/20," 2019.
13. Government of Nepal, "Nepal's Long-term Strategy for Net-zero Emissions," 2021.
14. United Nations, "World Urbanization Prospects," Department of Economics and social affairs, 2018.
15. S. R. S. R. M. Shrestha, "Transport sector electrification in a hydropower resource rich developing country:Energy security, environmental and climate change co-benefits," Elsevier Inc, 2011.
16. G. o. G. P. Policy and Planning Commission, "SUSTAINABLE DEVELOPMENT GOALS," Pokhara, Nepal, 2019.
17. "https://www.rff.org/publications/reports/global-energy-outlook-2023/," [Online].
18. R. Pandey, "Energy Security and Hydropower Development in Nepal," 2019.
19. S. R. Shakya, "Benefits of Low Carbon Development Strategies in Emerging Cities of Developing Country: a Case of Kathmandu," 2016.
20. S. R. Shakya, ", Benefits of Low Carbon Development Strategies in Emerging Cities of Developing Country: A case of Kathamandu," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 4, no. 2, 2016.
21. G. o. Nepal, "NATIONALLY DETERMINED CONTRIBUTIONS," 2016.
22. G. o. Nepal, "Second Nationally Determined Contribution (NDC)," 2020.

23. T. M. L. D. A. A. Utsav Bhattarai, "Energy Security of Nepal and Prospects of Cross-Border Contribution to Assuage Energy Hungry South Asia," SSRN, 2022.

24. W. a. E. C. S. Government of Nepal, "Energy consumption and Supply Situtation in Federal System of Nepal Province 02," Kathmandu.

25. G. o. Nepal, "Energy consumption and supply situation in Federal system of Nepal Province 2," 2021.