Journal of Advanced College of Engineering and Management, Vol. 9, 2024

IMPLICATIONS OF NET-ZERO EMISSION STRATEGY FOR RESIDENTIAL SECTOR OF BAGMATI PROVINCE

Subash KC[1]*, Anita Prajapati[2]*

[1]M.Sc. in Energy System Planning and Management, Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal

[2] Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal

Email 1* : bms.subash@gmail.com

Email 2* : anita.praj@pcampus.edu.np

ABSTRACT:

With the growing concern of the rise in global temperatures, and in support of the Paris Climate Agreement, countries around the world have set national targets to cut down their emissions. The government of Nepal too has pledged to achieve net zero emissions by year 2045 and put into effect several plans and policies. These has their effect on the country's energy demand and economy. Using Bagmati province of the country as study area, energy demand and scenario analysis is conducted using LEAP framework. One business-as-usual (BAU) and two net zero scenarios are analysed, with existing (NZE) and additional measures (NZA). The energy demand, emissions, social costs of the scenarios are studied. Significant emission reductions are estimated in NZE scenario. However, existing measures alone are not found to be sufficient to achieve the targets. In terms of social costs, considerable benefits are estimated in implementing these scenarios.

Keywords: *LEAP, NetZero, Emission, Social Cost*

1. INTRODUCTION

A country's economic growth and its energy consumption are interrelated with each other [1]. A country's energy supply situation should be able to address its demand and there are environmental implications to be considered as well. Nepal is a landlocked, developing country. Electricity, petroleum and renewable, accounts around 20 % of total energy consumption of Nepal [2]. To provide energy access, and improving energy efficiency, various subsidy mechanisms are in effect. Along with that, the government has also set various milestones on the federal level to be met in different time frames [3]. MOEWRI has set the target to increase per capita electricity consumption from the current value of 700kWh to 1500kWh in the coming decade. MOPE has prepared a Low Carbon Economic Development Strategy, which promotes the use of clean renewable energy in all sectors. The second NDC targets to implement energy efficient clean technologies in residential sector [4]. The SDGs by National Planning Commission, to encourage switching to electric cooking in residential sector, targets to limit the use of LPG to less than 40% [5].

Nepal is divided into seven provinces by the Constitution of Nepal (2015), among which Bagmati is one, which is the major economic region of the country. The country is subdivided into seven economic sectors – residential, industrial, commercial, transport, agriculture and construction and mining. With over 63% of total energy consumption, residential sector is the major consumer of energy in Nepal [3]. According to WECS (2022), total energy consumption of Bagmati province is 83.53PJ. Containing major cities and industries, it has the highest province wise contribution to GDP, 36.15% [7].

In this province, most of the energy in residential sector comes from biomass, which is a major contributor to GHG emissions. Although, the growth of economic activities has resulted in decrease in percentage share of residential energy consumption from 89% in 2009 to 63% in 2021 [3], it is still increasing in absolute terms. The increase in energy consumption rate in residential sector of Nepal, is 2.2% per annum in the last two years which is higher than the population growth rate. In the province under consideration, numerous of efficiency improvement measures for residential sector are available through which energy consumption can be minimized without reducing the quality of lifestyle. The use of inefficient fuels such as biomass, which remains a major source of energy in rural areas of developing countries is undoubtably one of the major causes of health-related problems [8]–[11]. Considerable quantity of emissions can be reduced from implementing net-zero targets set by the Nepali government. However, the social-cost benefits of these targets need to be studied. The future energy demand necessitated by the net-zero targets and the required technology changes should be assessed based on the economic and geographic conditions of the country.

2. LITERATURE REVIEW

There have been several studies which studied the sectoral energy demand and performed scenario analysis of the country. R. Shrestha (1996) studied sectoral energy use patterns to study the associated emissions, however the study did not use comprehensive energy system model to estimate the future energy demand. R. M. Shrestha & Rajbhandari (2010) analyzed the sectoral energy consumption pattern and emissions for five different economic sectors, viz. – agriculture, residential, commercial, industrial and transport – using MARKAL framework. They found that the overall energy consumption per capita in the Kathmandu Valley would increase from 12.7 GJ/capita in 2005 to 25.6 GJ/capita in 2050, while the residential energy consumption per capita would decrease from 6.5 GJ/capita to 5.9 GJ/capita during the study period 2005-2050. Malla (2013) examined the household energy consumption patterns and its environmental implications of whole Nepal, dividing the country in 13 analytical sectors and energy consumption in three end uses. By developing 4 different scenarios in LEAP model, he also concluded on environmental implications. Rajbhandari & Nakarmi (2014) conducted a study to understand the energy consumption pattern of residential sector of Kathmandu valley using MAED and MARKAL. Shakya (2016) conducted a study to analyze the benefits of low carbon strategies in case of Kathmandu. The study analyzed energy, environmental and economic implications of adopting low carbon strategies. Shakya et al., (2023) studied environmental, energy security and energy equity benefits of net zero-emission strategy in the country and found substantial reduction in emissions and drastic improvement in energy security and energy equity.

A study conducted of household sector in Panauti municipality by Dhaubanjar et al. (2019) found that all electrification of the sector can significantly reduce energy demand and GHG emissions all the while saving considerable cost on fuel import. Dulal & Shakya (2020) found that by increasing the share of electricity in residential cooking, heating, industrial boiler, motive power, and transport, the energy intensity can be significantly lowered. Maharjan & Bhattrai (2022) performed energy consumption, energy demand and scenario analysis of the residential sector of Province 1 over the period 2019-2030 using the LEAP model. The study used four different scenarios - Business-as-usual (BAU), LPG substitution scenario, Improved Cooking Stove (ICS) scenario and Sustainable Energy Development Scenario (SEDS) and concluded that the substitution of inefficient devices and technologies in residential sector significantly reduces final energy demand while reducing GHG emissions. WECS (2022) conducted study on sectoral energy demand of Bagmati province and studied the environmental and cost implications for four different scenarios. This study lacks the detailed consideration of residential sector of Bagmati province and effects of various mitigations measures on residential sector specifically. The results of this study are also required to be recalculated based on the recent census data.

3. METHODOLOGY

3.1 Study Area

The Bagmati province is located at 26^0 55' to 28^0 23' north latitude and 83^0 55' to 86^0 34' east longitude. It constitutes major cities of the country such as the capital Kathmandu, Bhaktapur, Lalitpur, Hetauda and Narayengadh. The province is geographically distributed into hilly, mountainous and terai regions. Residential sector is the highest energy consuming sector with 42.26% of energy consumption out of the total 82.53 PJ. The total consumption of energy for residential sector is about 35.3 PJ. Cooking consumes most of the energy, nearly 65% of 35.3 PJ, animal fed preparation comes second followed by electrical appliances. Most of the energy comes from fuelwood, followed by LPG. The share of electricity is only 13%.

3.2 Data Collection

The data used in this study comes from secondary sources. The household size and population of the province is obtained from CBS and NHPC reports [21], [22]. The energy demand and energy mix data are taken from WECS reports [3], [23].

3.3 Research Framework

This study uses LEAP, which is a modeling tool used for energy policy analysis and climate change mitigation assessment. The residential sector is disaggregated into three geographic regions (Terai, Hilly and Mountain). Each of these geographic regions are divided into urban and rural areas each of which are then subdivided into end-use service demand, i.e., cooking, lighting, animal fed preparation, electrical appliances, space heating, space cooling, social occasion, water boiling and food and agro-processing. Each of the end use is further subdivided into different fuel types. The overall research framework is as shown in Figure 1.

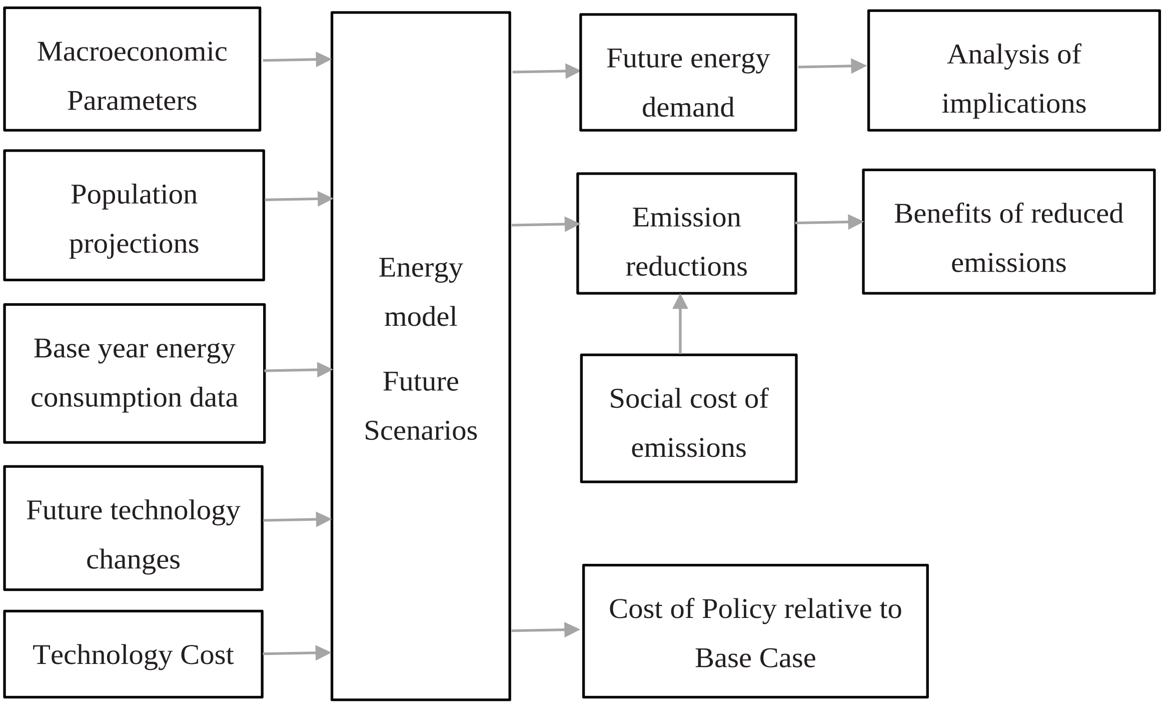

Figure 1: Research Framework [35]

The aggregate energy intensities and fuel shares for each end uses of residential sector are taken from WECS report [23] and energy efficiencies taken from relevant sources [24]–[27]. Economic analysis is conducted by considering externality cost and demand technology costs. The externality costs are the monetized values of the net harm to the society due to the addition of GHG gases into the atmosphere in a given year. It includes the value of all climate change impacts, including effects on human health, energy system disruptions, environmental mitigations, risk of conflict, changes in net agricultural productivity, property damage from increased flood risk natural disasters, and the value of ecosystem services [28]. The emission factors used in this analysis are taken from national and international documents, and as much as possible, these are selected to be country and technology specific [29]–[31].

3.4 Description of the Scenarios

The energy demand from the base year 2022 to 2050 is studied. Based on historical trends, population and GDP growth rates, business-as-usual scenario (BAU) is created. The Scenario, Net Zero with Existing Measures (NZE) is created based on the targets set by government to achieve net zero emission. An additional scenario, Net Zero with Additional Measures (NZM) in which penetration of the technology is calculated based on the SDG and second NDC goals is also used.

For the BAU scenario, the household income is assumed to grow at a rate of 1.4%, population at 0.97% [21]. The maximum urbanization expected of the province, considering its current progress, population distribution and in comparison, with other countries [32], is assumed to be 90%. NZE scenario is based on considerations taken from the net-zero emission strategy of government of Nepal [33]. To further curtail the emissions to meet the net-zero target, an additional scenario is created in which the penetration of energy is calculated based on second NDC [4] and SDG [5] of Nepal. The assumptions for this scenario are formulated based on all possible technology intervention that can be made in every end use of residential sector. The considerations for the scenarios are presented in Table 1.

Table 1: Net Zero Scenario Considerations for year 2050

NZE -2050	NZA -2050
Urban • Cooking by 70% electricity and 20% LPG • 75% electrification in Space heating **Rural** Cooking by 40% electricity, 40% LPG and 20% ICS Share of other end uses in end year, which are not mentioned in the policies, are assumed to occupy the proportionate share of total intensity as in the base year	**Urban** • 90% electrification in cooking, water heating and space heating • 90% electrification in social occasion, agriculture, and food processing and animal feed preparation • Complete replacement of wood, agriculture residue, animal wastes and biogas stoves **Rural** • 60% electrification in cooking • 50% electrification in space heating • 80% electrification in water boiling • Traditional CS are replaced completely by ICS • Complete replacement of kerosene, animal wastes, agriculture residue

4. RESULT AND DISCUSSION

4.1 Scenario Comparison of Final Energy Demand

The final energy demand of different scenarios is shown in Figure 2. Figure 2 shows the comparison of fuel demand of scenarios in urban (U) and rural (R) areas. Bagmati province's final energy demand of residential sector in year 2022 was 35.3 PJ, with 19.7 PJ from urban and 15.6 PJ from rural areas, which is expected to rise to 39.1 PJ in year 2050 in BAU scenario, with 29.9 PJ from urban and 9.2 PJ from rural areas, which is slightly less as compared to previous estimate [23]. Energy demand is primarily dominated by cooking. Electrical appliances are also expected to have increased demand, whereas significant decrease in demand is expected in space heating due to the use of efficient electricity as fuel.

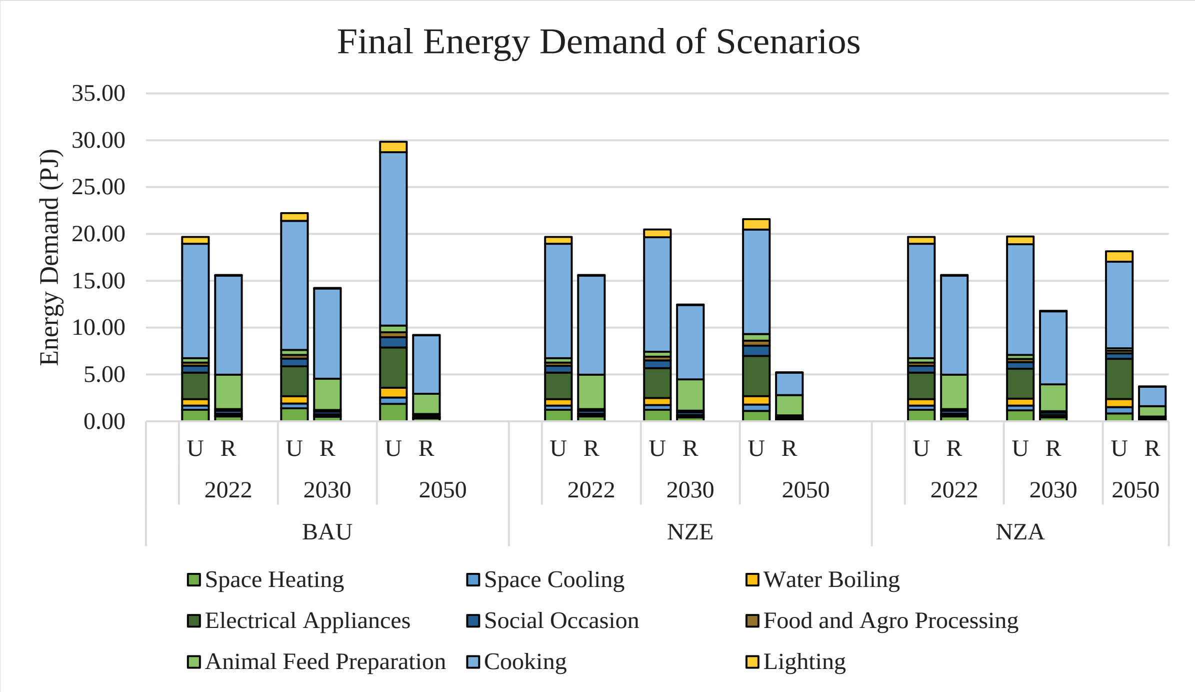

Figure 2: Final Energy Demand of Different Scenarios

In NZE scenario, the urban energy demand is expected to be 80.48% of total demand by year 2050. The share of cooking in urban areas is expected to reduce to nearly 52% of urban energy demand. The demand for space heating is also expected to decline. All other end use sectors of urban areas are expected to experience increase in demand. The replacement of wood and other inefficient fuels by electricity in cooking and space heating is the cause of decrease in demand in those end use sectors.

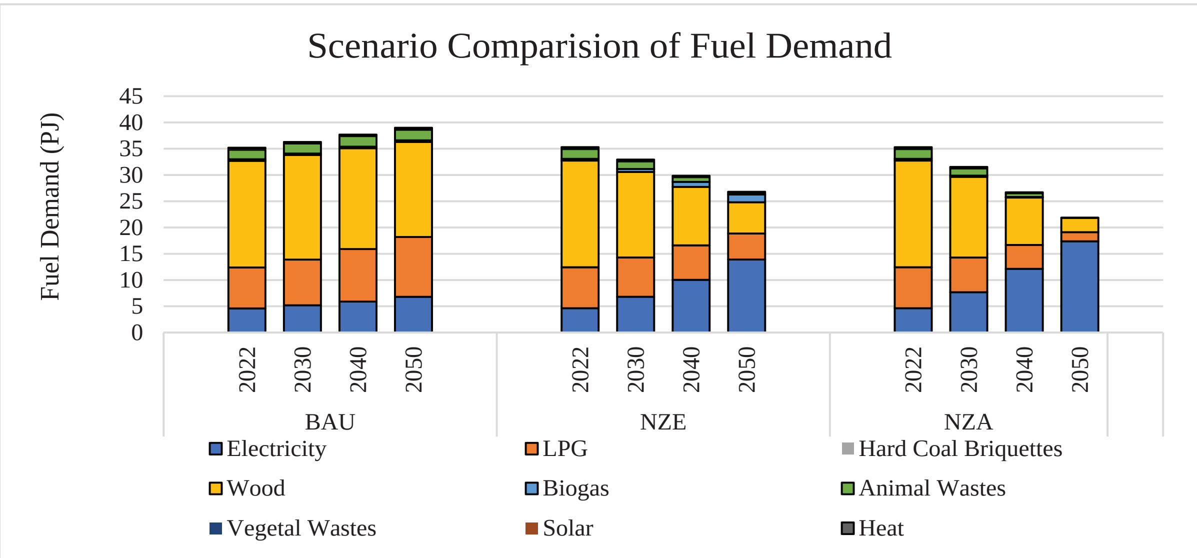

Figure 3: Fuel Demand Comparison

Significant decline in rural cooking demand, nearly 77% is expected by the year 2050. All other end use sectors are expected to have some decline in energy demand. In year 2050, the share of cooking in rural areas reduces to nearly 46% of total rural demand, whereas animal feed preparation occupies second highest share (41%) which presents further potential for reduction in energy consumption.

In case of NZA scenario, the final energy demand is 21.88 PJ in year 2050, the share of urban and rural areas being 83% and 17% respectively. More than half of the demand is from cooking activities. In urban areas, electrical appliances are expected to consume nearly 24% of total urban energy demand. The energy demand from space cooling, electrical appliances and lighting uses is expected to increase by nearly 52%. Nearly 24% increase is expected on water boiling. Whereas decrease in energy demand by 32%, 20%, 17%, 46% and 24% is expected in space heating, social occasion, food and agro processing, animal feed preparation and cooking respectively.

In rural areas, apart from cooking, animal feed preparation is expected to occupy second largest share of total energy demand (nearly 30%). Decrease in energy demand in year 2050, is expected of all applications. Cooking and water boiling applications are expected to consume nearly 80% less energy. Fuel switching and urbanization are the main factors responsible for this decline in energy consumption.

4.2 Environmental Benefits of Net Zero Scenarios

Based on the 100-yr GWP, the GHG emissions of different scenarios is shown in **Error! Reference source not found.**. GHG emissions from residential sector of Bagmati province in BAU scenario in year 2050 are expected to reach 1039.23 thousand MT of CO_2 equivalent. In NZE scenario, 46% reduction in emissions is achievable by year 2045. Which does not fall in line with the aim of achieving net zero emissions by year 2045.

To achieve the government target, implementation of additional mitigation options is essential. The NZA scenario, devised with a view to achieve this target, will further reduce the emission with 68% lesser emissions in year 2045 compared to BAU which will increase to 84% by year 2050. Further measures such as 100% electrification [17] can help to achieve net zero, whereas policies such as carbon tax can help curb the emissions [34]. Considering geography of the region and societal needs, the feasibility of 100% electrification in Nepal may not be entirely plausible. However, considering large area of the country has forest cover, and taking into account of the sequestration by forest, the net zero target is within the capability of country.

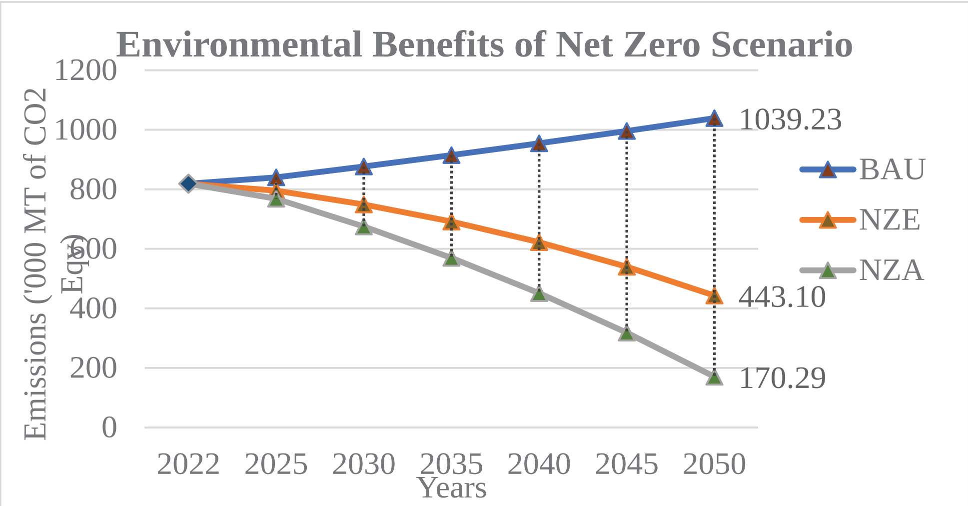

Figure 4: Environmental Benefits of Net Zero Scenarios

The emissions of all pollutants in different scenarios from residential sector of Bagmati province is shown in Figure 5. With Existing measures, Biogenic CO_2 can be reduced by 62% in year 2050 compared to BAU. Additional measures are expected to further reduce these emissions by 87%. CO_2 emissions can be reduced by 57% by existing measures and by 85% by additional measures. Likewise, with existing measures, CO, CH4, NOX, N2O, NMVOC and TSP emissions can be reduced by 65%, 56%, 68%, 53%, 63% and 71% respectively compared to BAS. Whereas additional measures are expected to reduce these emissions by 81%, 77%, 89%, 79%, 84% and 87% respectively.

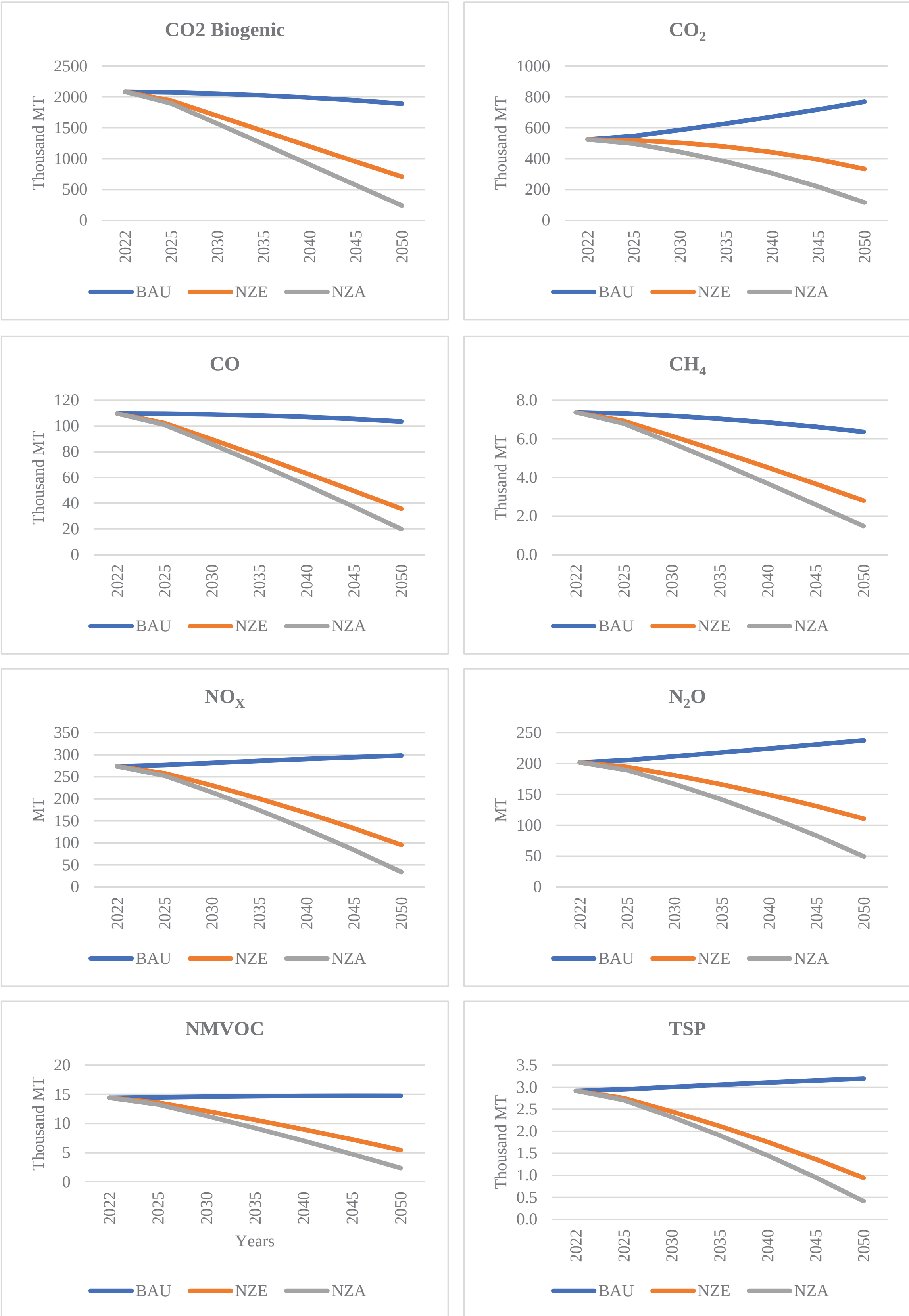

Figure 5: Pollutant Emissions

4.3 Economic Benefits of Net Zero Scenarios

The implementation of net zero emission strategy has economic benefits in terms of reduced externalities as well as reduction in demand technology costs. The externalities of emissions in BAU scenario in year 2050 is expected to be 853.06 billion NPR, 8% lesser compared to base year, primarily due to urbanization. The existing measures of net zero strategy are expected to reduce these costs by 59% compared to BAU scenario. Whereas additional measures can further cut down these costs by 80%. The externality and demand technology costs of different scenarios are shown in Figure 6.

The expected demand technology cost in BAU scenario in year 2050 is expected to be 4.47 billion NPR, nearly 38% increase compared to base year value. The gradual shift to electric technologies and the

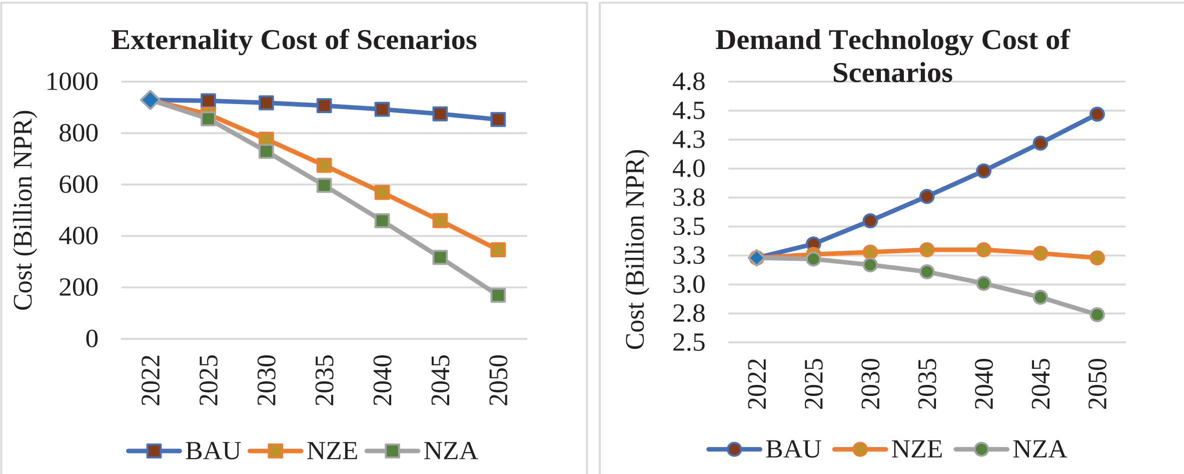

Figure 6: Social Cost of Scenarios

subsequent cut down in fuel costs with existing net zero measures is expected to reduce the technology cost by 28% compared to BAU. Additional measures are expected to further reduce this cost up to 39%.

The cumulative cost from 2022-2050 discounted at 10% to base year 2022 for different scenarios is shown in Table 2. In BAU scenario, the cumulative cost for demand technology is 34.99 trillion NPR, environmental externality is 8.99 trillion NPR, with total NPV being nearly 44 trillion NPR.

With existing measures, the demand technology and externality cost are expected to be 32.12 trillion NPR and 7.58 trillion NPR with total NPV being 39.70 trillion NPR. Additional measures are expected to reduce cumulative demand technology cost to 30.93 trillion NPR, externality costs to 7.10 trillion NPR with total NPV being 38.03 trillion NPR.

Table 2: Cumulative Cost 2022-2050 (in Trillion NPR)

Sector	BAU	NZE	NZA
Demand Technology	34.99	32.12	30.93
Environmental Externalities	8.99	7.58	7.10
Total Net Present Value	**43.98**	**39.70**	**38.03**

The total NPV with existing measures is 9.73% less compared to BAU whereas, additional measures are expected to reduce NPV up to 13.52%. In terms of monetary value nearly 4.28 trillion NPR is expected to be saved due to net zero measures. Additional measures are further expected to save the costs up to 5.95 trillion NPR.

4.4 Additional Electricity Requirements

The annual electricity requirement for residential sector of Bagmati province for different scenarios is shown in Figure 7. The base year requirement is 1282 GWh. By the year 2050, urbanization and the subsequent preference to electric power by urban population, is expected to increase the electricity requirement up to 1881 GWh. With the penetration of electric technologies in existing measures (NZE), 3849 GWh electricity is needed in year 2050. Electricity requirement for the year 2045 is 3290 GWh, i.e., additional 2007 GWh is required in year 2045 for residential sector of Bagmati province to implement net zero strategy.

Additional measures in NZA scenario demand the required electricity to be 4809 GWh in year 2050. With the province's existing capacity of 252.27 MW and 1882 MW of capacity in pipeline [23], this demand lies within the capability of the province.

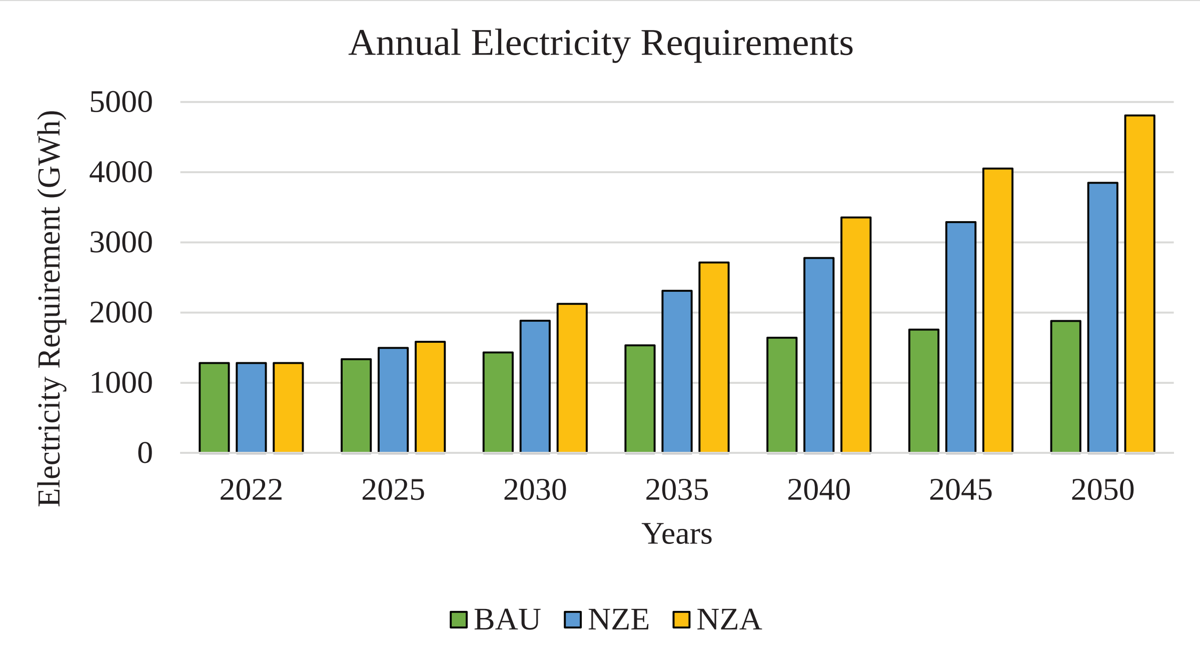

Figure 7: Annual Electrical Power Requirement

5. Conclusion and Recommendations

5.1 Conclusion

Compared to BAU scenario, nearly 31% lesser energy demand is expected in NZE, whereas nearly 44% lesser energy demand is expected in NZA. With existing measures of net zero strategy indicated in government targets, nearly 57.4% reduction in GHG emissions is expected. Additional measures can reduce the emissions up to 84%. From the NPV calculated using environmental externalities and demand technology costs, nearly 2.3 trillion NPR can be saved with existing measures of net zero strategies, which can further be increased to 3.2 trillion NPR with additional measures. Considering the difficulty in entirely replacing polluting technologies used in different end uses of residential sector by cleaner technologies, sequestration options should be encouraged. With significant forest cover available in the province, forestation may be the most viable option to curtail the emissions that cannot be reduced by technology changes alone.

5.2 Recommendations

This study analyzed the demand, emissions, and costs only for the residential sector of Bagmati province. Further studies can be conducted for other sectors. The environmental externality cost of pollutants and cost of demand technology used in this study is based on current prices. The variation in future prices due to technology changes could be included in further studies.

6. References

[1] N. Apergis and J. E. Payne, “Energy consumption and economic growth: Evidence from the Commonwealth of Independent States,” *Energy Econ*, vol. 31, no. 5, pp. 641–647, Sep. 2009, doi: 10.1016/j.eneco.2009.01.011.

[2] N. Sanjel, A. Sharma, S. S. Bhat, and M. Das Manandhar, “Nepal Energy Outlook 2022,” Aug. 2022.

[3] WECS, “Energy Sector Synopsis Report 2021/2022,” Kathmandu, Jun. 2022.

[4] Government of Nepal, “Second nationally determined contributions,” Kathmandu, 2020.

[5] NPC, “Sustainable Development Goals Status and Roadmap: 2016-2030,” Kathmandu, 2017.

[6] Constituent Assembly, *Constitution of Nepal*. Nepal: Nepal Government, 2015.

[7] CBS, “National Accounts Statistics of Nepal (2021/22 Annual Estimates).” Accessed: Feb. 21, 2023. [Online]. Available: https://cbs.gov.np/national-accounts-statistics-of-nepal-2021-22-annual-estimates/

[8] J. Kyayesimira and F. Muheirwe, “Health concerns and use of biomass energy in households: voices of women from rural communities in Western Uganda,” *Energy Sustain Soc*, vol. 11, no. 1, p. 42, Dec. 2021, doi: 10.1186/s13705-021-00316-2.

[9] M. Elbayoumi and A. H. Albelbeisi, “Biomass use and its health effects among the vulnerable and marginalized refugee families in the Gaza Strip,” *Front Public Health*, vol. 11, Apr. 2023, doi: 10.3389/fpubh.2023.1129985.

[10] D. G. Fullerton, N. Bruce, and S. B. Gordon, “Indoor air pollution from biomass fuel smoke is a major health concern in the developing world,” *Trans R Soc Trop Med Hyg*, vol. 102, no. 9, pp. 843–851, Sep. 2008, doi: 10.1016/j.trstmh.2008.05.028.

[11] D. Shindell *et al.*, “Health Benefits of Reducing Emissions to Mitigate Climate Change,” *Proc Natl Acad Sci U S A*, vol. 118, no. 46, Nov. 2021, doi: 10.1073/PNAS.2104061118.

[12] R. Shrestha, “Air pollution from energy use in a developing country city: The case of Kathmandu Valley, Nepal,” *Energy*, vol. 21, no. 9, pp. 785–794, Sep. 1996, doi: 10.1016/0360-5442(96)00023-0.

[13] R. M. Shrestha and S. Rajbhandari, “Energy and environmental implications of carbon emission reduction targets: Case of Kathmandu Valley, Nepal,” *Energy Policy*, vol. 38, no. 9, pp. 4818–4827, Sep. 2010, doi: 10.1016/j.enpol.2009.11.088.

[14] S. Malla, “Household energy consumption patterns and its environmental implications: Assessment of energy access and poverty in Nepal,” *Energy Policy*, vol. 61, pp. 990–1002, Oct. 2013, doi: 10.1016/j.enpol.2013.06.023.

[15] U. Rajbhandari and A. Nakarmi, *Energy Consumption and Scenario Analysis of Residential Sector Using Optimization Model – A Case of Kathmandu Valley*. 2014.

[16] S. R. Shakya, “Benefits of Low Carbon Development Strategies in Emerging Cities of Developing Country: a Case of Kathmandu,” *Journal of Sustainable Development of Energy, Water and Environment Systems*, vol. 4, no. 2, pp. 141–160, Jun. 2016, doi: 10.13044/j.sdewes.2016.04.0012.

[17] S. R. Shakya *et al.*, “Environmental, energy security, and energy equity (3E) benefits of net-zero emission strategy in a developing country: A case study of Nepal,” *Energy Reports*, vol. 9, pp. 2359–2371, Dec. 2023, doi: 10.1016/j.egyr.2023.01.055.

[18] P. Dhaubanjar, A. M. Nakarmi, and S. B. Bajracharya, “Energy Scenarios of Household Sector In Panauti Municipality For Sustainable Development and Energy Security,” *Journal of*

Advanced College of Engineering and Management, vol. 5, pp. 89–100, Dec. 2019, doi: 10.3126/jacem.v5i0.26692.

[19] S. Dulal and S. R. Shakya, “Energy Security and Scenario Analysis of Province One of Federal Democratic Republic of Nepal,” *Journal of the Institute of Engineering*, vol. 15, no. 3, pp. 104–121, Oct. 2020, doi: 10.3126/jie.v15i3.32158.

[20] K. Maharjan and N. Bhattrai, *Residential Sector Energy Demand and Scenario Analysis: A case study on Province 1 of Nepal*. 2022.

[21] CBS, “National Population and and Housing Census 2021 Results.” Accessed: Aug. 02, 2023. [Online]. Available: https://censusnepal.cbs.gov.np/results/population?province=3

[22] NPHC, “Urban/Rural Municipality,” Kathmandu, Nepal, 2021.

[23] WECS, “Energy Consumption and Supply Situation in Federal System of Nepal (Bagmati Province),” Kathmandu, Jun. 2022.

[24] WECS, “Status of Clean Energy Cooking Technologies used in major cities of Nepal (Pokhara and Butwal),” 2022. Accessed: Aug. 13, 2023. [Online]. Available: https://wecs.gov.np/source/Status%20of%20Clean%20Energy%20Cooking%20Technologies%20used%20in%20major%20cities%20of%20Nepal%20(%20Pokhara%20and%20Butwal).pdf

[25] S. Pokharel, “Energy economics of cooking in households in Nepal,” *Energy*, vol. 29, no. 4, pp. 547–559, Mar. 2004, doi: 10.1016/j.energy.2003.10.015.

[26] P. Adhikaria, A. Adhikaria, S. K. Dhitala, B. Shrestha, and H. B. Dura, “Design and performance analysis of institutional cooking stove for high hill rural community of Nepal,” *Kathmandu University Journal of Science, Engineering and Technology*, vol. 14, no. 1, Apr. 2020.

[27] X. Wang and R. Mendelsohn, “An economic analysis of using crop residues for energy in China,” *Environ Dev Econ*, vol. 8, no. 3, pp. 467–480, 2003, [Online]. Available: http://www.jstor.org/stable/44379507

[28] United States Government, “Social Cost of Carbon, Methane and Nitrous Oxide,” Feb. 2021.

[29] AEPC, “Biogas.” Accessed: Aug. 02, 2023. [Online]. Available: https://www.aepc.gov.np/biogas-technology

[30] IPCC, “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3: Reference Manual.” Intergovernmental Panel on Climate Change, 1996. Accessed: Aug. 02, 2023. [Online]. Available: http://www.iea.org/ipcc/invs1.html

[31] G. Leach and M. Gowen, *Household Energy Handbook*. World Bank, Washington, D.C., 1987. Accessed: Aug. 02, 2023. [Online]. Available: http://www.worldbank.org

[32] D. of E. and S. A. P. D. United Nations, “World Urbanization Prospects: The 2018 Revision,” New York, 2019.

[33] Government of Nepal, “Nepal’s Long-term Strategy for Net-zero Emissions Government of Nepal Kathmandu,” 2021, Accessed: Aug. 02, 2023. [Online]. Available: https://unfccc.int/sites/default/files/resource/NepalLTLEDS.pdf

[34] B. B. Pradhan, R. M. Shrestha, A. Pandey, and B. Limmeechokchai, “Strategies to Achieve Net Zero Emissions in Nepal,” *Carbon Manag*, vol. 9, no. 5, pp. 533–548, Sep. 2018, doi: 10.1080/17583004.2018.1536168.

[35] LEAP, “LEAP.” Accessed: Nov. 21, 2023. [Online]. Available: https://leap.sei.org/default.asp?action=introduction