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ENERGY SECURITY AND SCENARIO ANALYSIS OF PROVINCE NO.1 OF FEDERAL REPUBLIC NEPAL

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Abstract

This paper presents the current energy security status of the province No.1 of Nepal using numerous indicators. In addition to that, with the development of six economic growth scenarios i.e. Business As Usual (BAU), Low growth (LOW), High growth (HIG), Accelerated growth (ACC), Normal growth (NOR) and Intervention scenario (INT), the future energy mix and energy security indicators for the year 2040 are also calculated. The paper also gives an overview of the variation/progress of the different indicators during the considered period of study. The study shows that the, energy intensity in the intervention scenario is brought down to 4.44 GJ/$1000 compared to that of 15 GJ/$1000. Also, the electricity consumption per capita is increased to 574 kWh from 116 in the base year. However, these values are only achieved if the provincial government helps implementing central government's plan of promoting the electrical systems instead of traditional fuel woods and fossil fuels system.

Keywords: *Energy mix; Fuel mix; Energy security ;Province level; Indicators; LEAP; Scenario; Policy Intervention*

1. Background

The Constitution of Nepal 2015 has restructured the nation into a Federal Republic and has divided the nation into seven provinces [1]. And along with that, various targets and milestones have been set by the government on the National/ Central level to be achieved in different time frames within the upcoming few decades [2]. So, the strategies and vision of the Central level will definitely influence and effect the policy and planning of the provinces. Moreover, in reverse the work plan and policies of the provinces must also be so as to comply with the National/Central level targets. Hence, now onwards the prosperity and development of the provinces will mainly depend on its own management of the available resources. And, the issues of the energy security will be of significant importance for the province's economic boom. Simultaneously, the provinces also have to work on the optimum utilization of its available resources in order to make it self-sustainable in the long run. As we know, energy mix is very helpful in understanding the current energy status and balance of the country [3]. In addition to that, the energy security indicators deduced from those energy data will further elaborate the scenario, which can eventually be used as a resource for drafting policies and action plans for the energy sector improvement leading to energy sustainability of the country. Although, there are some works done in this area of research, but the number of indicators used are very limited. So, there is still some room for doing study of the energy mix and energy security using a larger number of applicable indicators. Similarly, there is no any study conducted on the provincial level for the energy mix and security scenario. Since, it has not been that long the province division has been carried out. Thus, the energy mix and scenario analysis of the province would help to have a better picture of the energy security status of that region and can serve as a value addition for the province energy planning and policy making. And, the methodology which is used in doing the study of the Province No.1 can serve as a good resource for conducting a similar kind of study for other provinces/regions as well.

2. Energy Security and Its Indicators

In literal meaning, the term energy security itself looks self-explanatory. However, there are numerous definitions of energy security provided by different organizations and agencies. In general terms, energy security for the developing countries refers to enough energy supply to meet all requirements at all time of its citizens in affordable and stable prices [4]. And, for developed nations, energy security refers to resilient energy system and securing the amount of energy required for people's life, economic and social activities, defense and other purposes for acceptable prices[4]. Although, there are no any standard definition, among various definitions of energy security, the one presented by the IEA (International Energy Agency) is widely applied, which is defined as ‘‘the uninterrupted physical availability at a price which is affordable, while respecting environment concerns"[5].

Some of the energy security indicators were also highlighted in the reports of District Climate and Energy Plan [6] and Water and Energy Commission Secretariat [7]. And, those indicators are highlighted below:

- Final Energy Consumption Per Capita (GJ/Capita)
- Electricity Consumption per Capita (KWh/Capita)
- Energy Intensity (GJ/$1000)
- Electricity Intensity (KWh/$1000)
- Electricity Power Utilized (Percent)
- Total Energy Consumption/Value added in Industrial Sector (GJ/$1000 Value added)
- Total Energy Used/ Household (GJ/HH)
- Share of renewable energy in final total energy consumption (Percent)
- The ratio of net import to total primary energy supply (Percent)
- GHG emission for every ton of energy production and use/capita (GHG in Kg/Capita)

Apart from those vision and strategy documents, some national and international papers and reports highlights and explains about the different indicators that help to understand the energy security status of a certain region in a critical manner. Author B. Kruyt in his paper "Indicators for Energy Security" [8] discusses about the different dimensions and themes of the energy security indicators:

i. Availability- geological elements
ii. Accessibility- geopolitical elements
iii. Affordability- economical elements
iv. Acceptability- environmental elements

And on the basis of those dimensions, the paper suggests some indicators which are illustrated below:

i. Resource Estimates
ii. Reserves to Production Ratios
iii. Import Dependence
iv. Political Stability
v. Energy price
vi. Aggregated Indicators
vii. Shannon Index
viii. Supply/Demand Index
ix. Willingness to pay
x. Oil Vulnerability index

Author S. Kumar in his paper "Thailand Energy Security Indicators" [9] discusses about the indicators based on different themes as compared to the B. Kruyt paper. It has categorized the indicators into four basic themes:

- Energy Demand
- Availability of Energy Supply

- Energy Market
- Energy Price
- And on the basis of these dimensions, they have suggested four indicators:
- Net Energy Import Ratio (NEIR)
- Shannon-Weiner Index (SWI)
- Herfindhal-Hirshman Index (HHI)
- Reserve to Production Ratio
- Similarly, a report from Asia Pacific Energy Research Council (APERC) [10] highlights a different set of indicators:
- Diversification of Primary Energy Demand (DoPED)
- Net Energy Import Dependency (NEID)
- Non-Carbon Intensive Fuel Portfolio (NCFP)
- Net Oil Import Dependency (NOID)

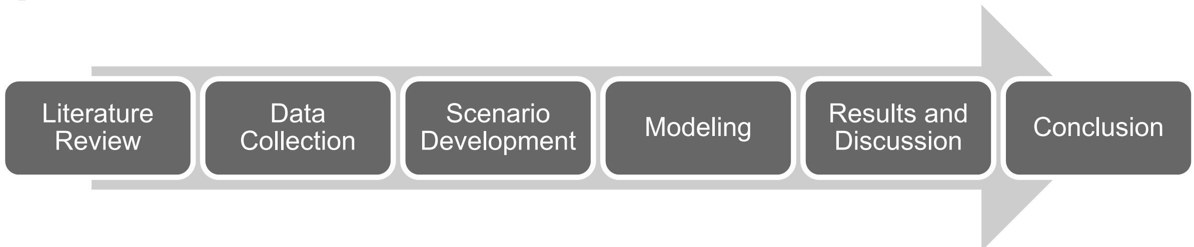
Those papers and reports were mainly focused for international context. However, author Shakya, S.R. in his paper " Transport sector electrification in a hydropower resource rich developing country: Energy security, environmental and climate change co-benefits" [11] highlighted and narrowed down some of the indicators useful in the context of Nepal such as:

- Shannon–Wiener Index (SWI)
- Net energy import ratio (NEIR)
- Oil consumption per capita (OCPC)

All of these indicators may not be relevant in the context of Nepal and eventually to the context Province No.1. And, some indicators require certain type of data, which are quite difficult to find from the currently available sources. Thus, only sixteen energy security indicators are used for this study.

3. Methodology

The methodology followed for doing the study can be understood from the flowchart drawn and the explanations followed.



3.1 Data Collection

In order to know the present information on the energy mix of the Province No.1, the reports of various organizations were used for the reference. Since, most the data available online and in the publications, reports of the Government authorities and agencies, data of Nepal as a whole is generally presented, it's difficult to get the data information at the level of disaggregation from the government offices itself as required for this specific study purpose. However, the data obtained from the Alternative Energy Promotion Centre through their publications like District Climate and Energy Plan [6] of various districts and the report of National Survey of Energy Consumption done by Water and Energy Commission Secretariat (WECS) [12] in 2013 was really helpful. Also, while creating the scenarios for the economic growth of the Province No.1 in the study, the reports of Economic Survey

[13] published by the Ministry of Finance and also from the reports of Asian Development Outlook [14] [15] published by Asian Development Bank were taken as reference.

The types of data collected are presented below:

- The demographic, political and geographical information of the province.
- Energy Consumption at different disaggregation level possible.
- Energy Supply data from different government authorities
- Fuel prices projections
- Gross Domestic Product of Nepal and the contribution from different sectors.
- Growth rate of GDP of Nepal in different point of times.
- GDP growth rate of South Asian Countries at different point of time.
- GDP growth rate of Developing Asian Countries

3.2 Scenario Development

Various documents and reports published by different organizations like World Bank, Asian Development Bank, Ministry of Finance, Nepal, Water and Energy Commission Secretariat (WECS) and Alternative Energy Promotion Centre (AEPC) , etc. are taken as reference for the making different growth scenarios. Four different growth scenarios and one intervention scenario in addition to the Business As Usual scenario are used in the formulation of energy mix of the province. Business As Usual (BAU) Scenario, Low economic growth scenario (LOW), High economic growth scenario (HIG), Accelerated economic growth scenario (ACC) and Normal economic growth scenario (NOR) with economic growth rate of 4.2%, 4.5%, 6.8%, 8.5% and 5.8% respectively are taken for the scenario building. And, an intervention scenario, which mainly focuses on increasing the share of electricity in residential cooking, industrial boilers, heating and motive power, and transport sector [2][3], is introduced in the normal economic growth scenario in order to see the effect of governmental interventions through policies and actions.

Table 1: GDP Growth Rate of Nepal in Different Fiscal Years [13]

Fiscal Year	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
GDP Growth Rate	5.8	3.9	4.26	3.85	4.61	3.76	5.72	2.97	0.01	6.94

As per the reports of World Bank published on 2016,

- The average GDP growth rate of a lower middle income country is around 5.1%.
- The average GDP per capita of a lower middle income country is US$ 2078.8.
- The average GDP growth rate of fastest growing economies like Bhutan, Ethiopia, Ghana, India, Myanmar, etc. in the recent years is around 8.5%. [16]

3.3 Modeling

LEAP was used for generating the energy mix of the province for different scenarios developed. The software is easy to use and also the interface of the software enables the user to easily input data and generate scenarios. And for the input of data, a proper disaggregation level was used to get good results of the energy and fuel mix of the end year in different scenarios and interventions.

In the Key Assumptions Section of the LEAP Model, following parameters are used

- Population: 4.707 Million

- Average Household Size: 4.63
- Number of Households
- GDP: 534.2 Billion NPR
- Share of Agriculture GDP:48.31%
- Share of Commercial GDP:37.75%
- Share of Industrial GDP:13.94% [6][13]

4. Results and Discussion

4.1 Overview of energy demand in different scenarios

Table 2: Overview of energy demand in different scenarios

Scenarios	2017	2020	2025	2030	2035	2040
BAU	80.2	81	82.7	84.9	87.7	91.2
Low Economic Growth Scenario	80.2	81.3	83.6	86.5	90.1	94.5
High Economic Growth Scenario	80.2	81.9	85.8	91.2	98.6	108.9
Accelerated Growth Scenario	80.2	82.4	87.6	95.5	107.2	124.8
Normal Economic Growth Scenario	80.2	81.7	84.8	89	94.5	101.8
Intervention Scenario	80.2	80.1	80.5	81.6	83.7	86.8

4.2 Energy mix in normal growth scenario (NOR) and intervention scenario (INT)

Table 3: Energy mix in NOR and INT Scenario

Branches	2017	2040(NOR)	2040(INT)
Residential	69	69.3	59.1
Commercial	2	7.2	5.7
Transport	3.1	3.1	2.7
Agricultural	1	3.7	3
Industrial	5	18.4	16.4
Total	**80.2**	**101.8**	**86.8**

In the normal economic growth scenario, the total final energy demand increases by almost 27% and reaches 101.8 million GJ in the end year. Due to the good economic growth assumption, the share of industrial demand significantly increases from 6.3% to 18.1% towards the end year. Similarly, the growth in the share of commercial sector demand from 3.9% to 7.1% also accounts for the huge jump in total demand of the province in this particular scenario. In the intervention scenario, the total final energy demand increases by only 8.3% at the end year. And, due to the increase use of electricity in the residential sector for cooking and lighting instead of fuel wood and animal waste, the energy intensity in the residential sector is reduced significantly eventually resulting in the reduction of share of residential energy demand from 86.1% to 68% in the total energy mix

4.3 Fuel Mix in normal growth scenario (NOR) and intervention scenario (INT)

Table 4: Fuel mix in NOR and INT Scenario

Fuels	2017	2040	2040
Electricity	2	4.4	9.8
Gasoline	1.1	1.2	0.9
Jet Kerosene	0.1	0.1	0.1
Kerosene	0.2	0.4	0.2
Diesel	3.7	8.5	4.2
LPG	1.2	2.2	1.2
Oil	0	0.1	0
Coal Bituminous	2.2	8.2	7.1
Wood	58.9	65.9	59.8
Biogas	0.9	0.9	0.3
Animal Wastes	6.1	6.1	1.4
Solar	0	0	0
Petroleum Coke	0.1	0.2	0.2
Biomass	3.7	3.7	1.7
Total	**80.2**	**101.8**	**86.8**

In the normal economic growth scenario, the share of fuel wood reduced to 64.8% from 73.5% in the end year. However, demand of diesel and coal significantly increased due to the growth of industrial sector resulting in the fuel share rise of diesel and coal i.e. 4.6% to 8.4% and 2.74% to 8.1% respectively.

In the intervention scenario, the share of electricity has increased drastically from 2.5% to 11.3% in the end year. However, the share of diesel is not so high in the end year as compared to the normal economic growth without intervention. And, the possible reason for this is the introduction of electric boilers, electric motive powers in industries and also the increased use of electrical appliances for cooking and heating purposes in the residential sector.

4.4 Overview of energy security indicators

Table 5: Values of Energy Security Indicators in base and end year in normal and intervention scenario

S.N.	Indicators	Unit	Base Year	End Year (NOR)	End Year (INT)
1	Final Energy Consumption Per Capita	(GJ/Capita)	18.19	21.53	18.35
2	Electricity Consumption per Capita (KWh/Capita)	(KWh/Capita)	116.6	256.88	574.1
3	Energy Intensity	(GJ/$1000)	15	5.21	4.44
4	Electricity Intensity	(KWh/$1000)	102.8	62.2	138.95
5	Electricity Power Utilized	(Percent)	70.49	11.37	25.42
6	Total Energy Consumption/Value added in Industrial Sector	(GJ/$1000 Value added)	6.71	6.76	6.02
7	Total Energy Used/ Household	(GJ/HH)	78.86	99.7	85.01
8	Share of renewable energy in final total energy consumption	(Percent)	89.1	79.6	83.98
9	GHG emission for every ton of energy production and use/capita	(GHG in Kg/Capita)	371.8	592.8	385.2
10	Ratio of value if oil imports to GDP		0.11	0.088	0.048
11	Oil consumption per unit GDP in USD	GJ/GDP	0.012	0.0065	0.0035
12	Oil Share in total energy supply	Percent	7.98	12.38	7.83
13	Net energy import ratio (NEIR)		0.1	-0.13	-0.17
14	Oil consumption per capita (OCPC)	GJ/Capita	1.36	2.66	1.44
15	Net Oil Import Dependency (NOID)		1	1	1
16	Shannon–Wiener Index (SWI)		1.101	1.341	1.160

4.5 Comparison of variation in different energy security indicators value over time in NOR and INT scenarios

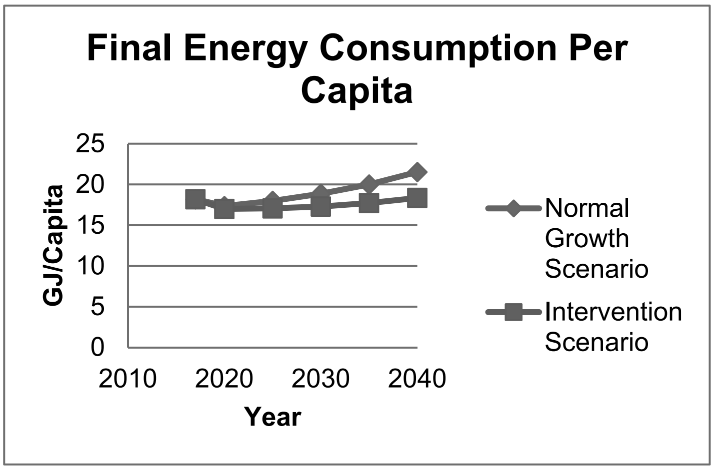


Fig1: Final Energy Consumption Per Capita

The energy security indicator graphs explain how the consumption of energy and electricity per capita varies while moving towards the end year in two different scenarios. The figure 1 shows that the energy consumption per capita increases in the normal economic growth scenario. However, it tends to remain the same in the case of intervention scenario because of the increased use of more efficient fuels like electricity in the industrial as well as the residential sectors. Similarly, in figure 2, introduction of electric trains and buses for the freight and passenger transport, and total electrification in commercial sector, etc. increased the electricity consumption per capita in the intervention scenario in contrast to the normal growth scenario.

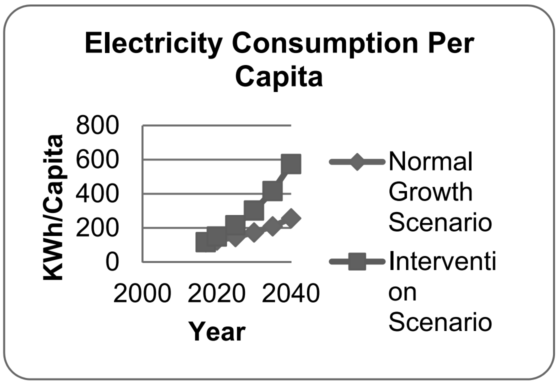


Fig. 2: Electricity Consumption per capita

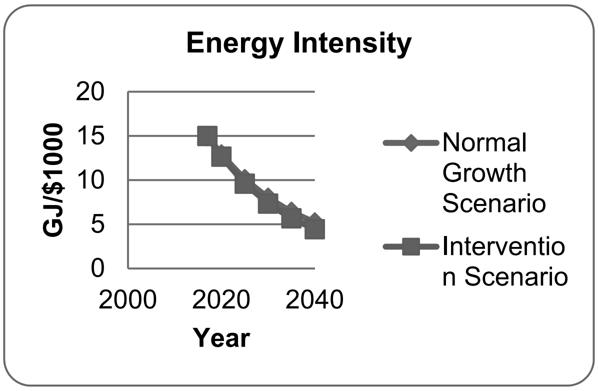


Fig. 3: Energy Intensity

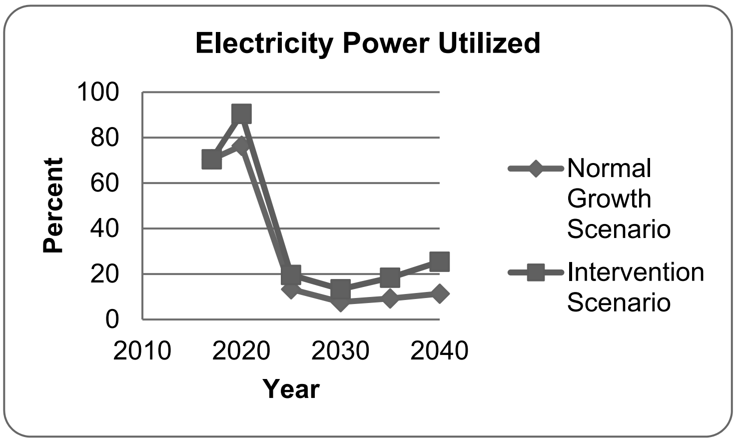


Fig 4: Electricity Power Utilized

In figure 4, the utilization of electricity is quite high in the start however, around 700MW of hydropower plants are expected to be completed and connected to the grid in between 2020-2025 and another 800MW of hydropower plants are expected to be completed and connected in the grid after 2025 resulting in the underutilization due to excess production of electricity in the province.

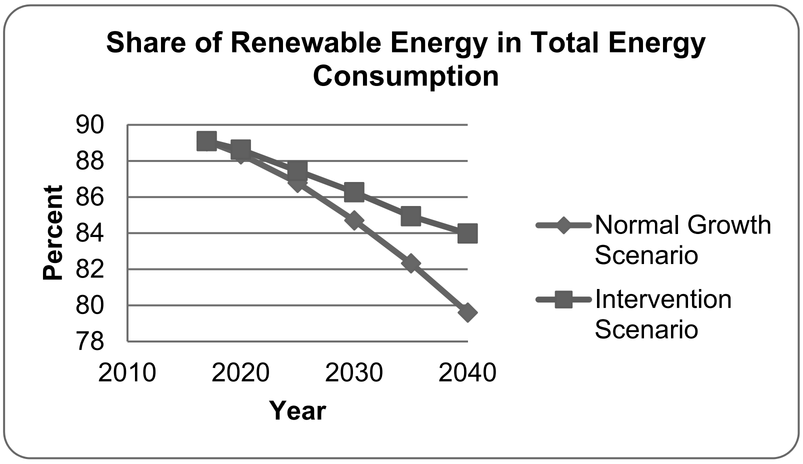


Fig. 5: Share of Renewable Energy in Total Energy Consumption

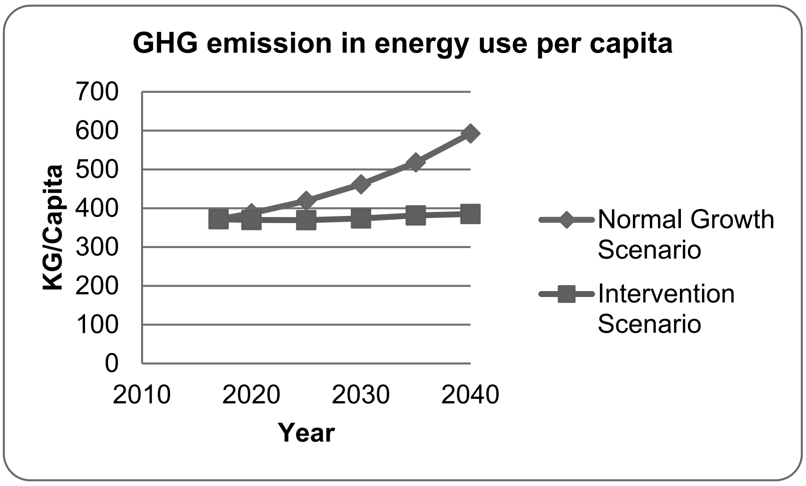


Fig. 6: GHG emission in energy use per capita

The figure 5 above shows that the share of renewable energy can go below 80% in the normal growth scenario. Because of increase in the consumption of fossil fuels in the industrial and transport sector, the share of oil consumption increases resulting in the decrease of share of renewable. However, in the intervention scenario, due to the introduction and increased use of electric boilers, electric motive powers, electric heating, there is reduction in the use of fossil fuels as compared to the normal growth scenario, which help in maintaining the share of renewables above 80% in the end year.

This graph in figure 6 is directly related to the energy consumption per capita and thus shows the similar pattern. In normal growth scenario, due to the increase in the energy consumption per capita, the emission also increases in the similar manner. And, in the intervention scenario, due to the increased use of efficient renewable fuels i.e. electric stoves, Improved Cooking Stove, electric space heating, etc. the GHG emission is maintained.

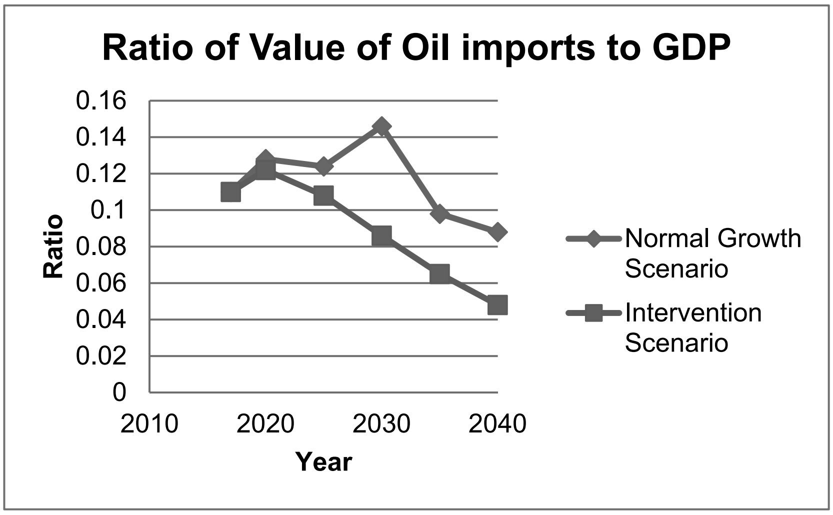


Fig. 7: Ratio of Value of Oil imports to GDP

As of today, around 11% of the GDP is expended in importing Oil for meeting the 8% of the energy demand of the province. In the normal growth scenario, as shown in figure 8, the value is still around 9%. Thus, the problem that can arise due to import dependency is minimal in the intervention scenario in which only 5% of the GDP is expended in end year for importing expensive oils by maintaining a good share of renewables in the fuel mix.

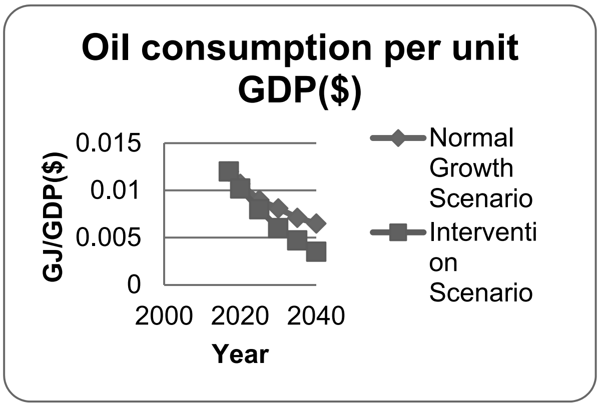


Fig 8: Oil consumption per unit GDP ($)

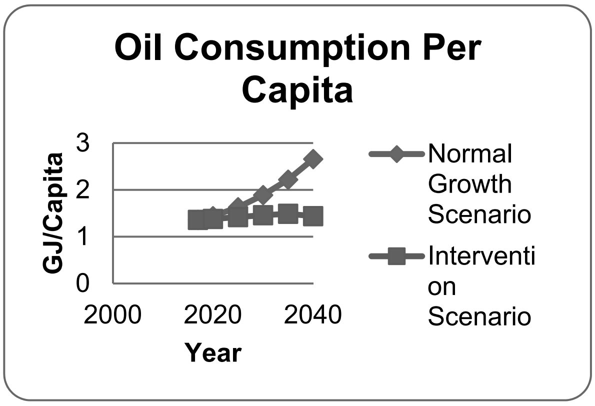


Fig. 9: Oil Consumption Per Capita

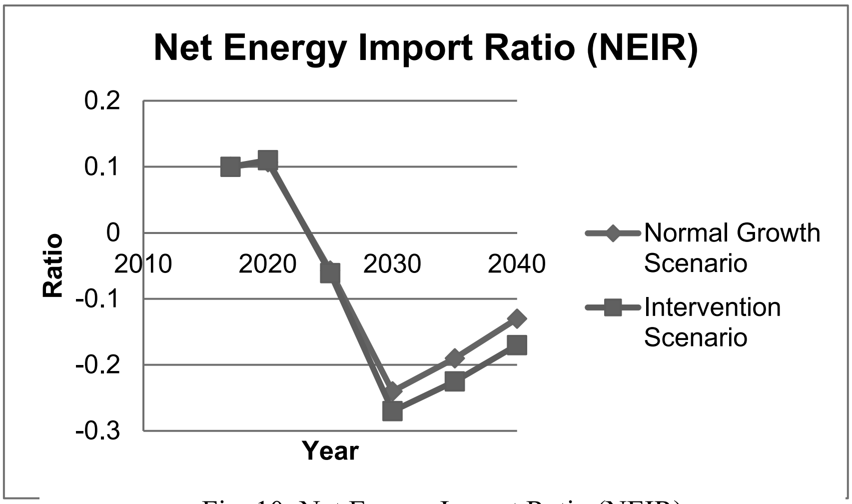


Fig. 10: Net Energy Import Ratio (NEIR)

It can be seen in the graph of figure 10 that the, value is in the positive axis until 2025 and goes to the negative side after 2025. Here, the positive value indicates that the region is an energy importer whereas; the negative value suggests that the region is an energy exporter. Thus, due to the expected addition of about 700MW hydropower in the grid in between 2020 to 2025, the province slowly transforms into the energy exporter. However, the exporting value starts to move towards zero after 2030 due to the increased consumption of electricity in the province resulting in less availability of exportable electricity.

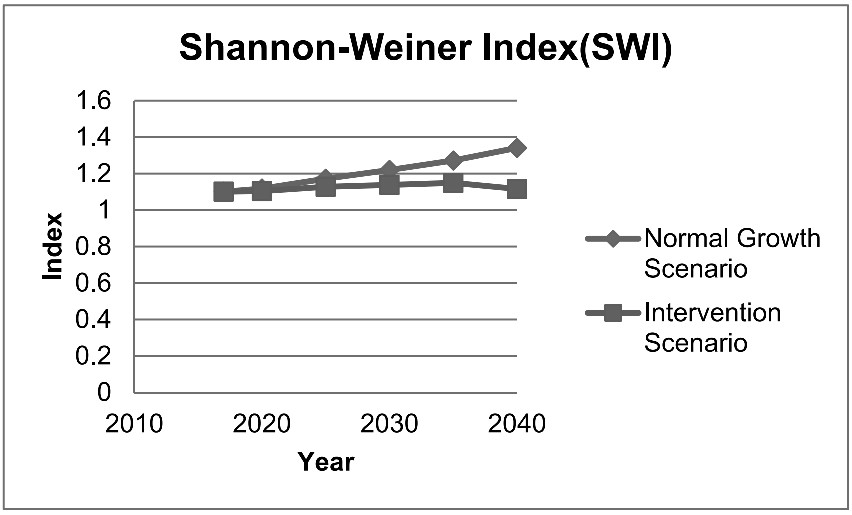


Fig. 11: Shannon-Weiner Index (SWI)

Shannon-Weiner Index in the above graph of figure 11indicates about the diversity of fuels/resources in the province. Greater the value of SWI, higher is the energy security of the region. In contrast to the increasing value of SWI for normal growth scenario, the diversity of the fuel is not improved in intervention scenario due to increased use of electricity and decreased use of fossil fuels. Although, the intervention scenario has better numbers and values in other energy security indicators, for the case of diversity of fuels, normal growth scenario is slightly better.

12. Conclusions

The energy demand increases by 26% in the normal growth scenario, however, with the proper implementation of plans of increasing the share of electricity in residential cooking, heating, industrial boiler, motive power, and transport, the energy intensity can be significantly lowered, which will eventually help to reduce the expending share from GDP for imported fuels. Moreover, it will also help the provincial government to maintain the share of renewable energy above 80% in the mix, thereby limiting the growth of Greenhouse gas emission per capita, which in the long run helps government to contribute towards the sustainable development goals. Hence, the province has the capacity to shift itself towards energy exporting region from the energy importing region in the coming seven years and can generate revenue up to NPR 39 billion yearly from the energy trade. And this strengthens the provinces economy as an energy secured and a self-sustainable region.

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