# Decentralized Energy Generation in Nepal

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ABSTRACT

The paper conveys information and research work regarding decentralized energy generation in Nepal using a renewable source of energy that can contribute toward economic, environmental, and social prosperity in developing countries like Nepal. An advancement with electrical technology and day to day life of human beings has been an inseparable part of the economic, environmental, and social development of a country. Unfortunately, most of the electrical consumer relies on different non-renewable sources like fossil fuels and coal which can create an adverse impact on the environment. With the increment in use of non-renewable sources can cause different issues like increase in harmful greenhouse gases i.e., carbon dioxide and methane, water pollution, land pollution and other research questions. For the sole purpose of creating sustainable decentralized energy, the given thesis research about different renewable alternatives to those non-renewable energy sources for advanced ecological sustainability.

Keywords Decentralized energy, hydroelectricity, solar energy.

Pages 53 pages

**List of Abbreviations**

DEG: Decentralized Energy Generation

NEA: Nepal Electricity Authority

IPP: Independent Power Producers

GLOF: Glacial Lake Outburst Flooding

DoED: Department of Electricity Development

DoHM: Department of Hydrology and Meteorology

GoN/WECS: Government of Nepal/ Water Energy Commission Secretariat

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# 1 INTRODUCTION

The thesis “Decentralized Energy Generation in Nepal” focuses on the research work and investigates the major possibilities and future of renewable energy in Nepal which includes energy generation sources like solar, hydro, wind, and biogas. The implementation of renewable sources of energy not only serves and supports the day-to-day activities of the Nepalese people but also contributes to keeping a green environment. The use of renewable sources of energy can eventually help the governmental as well as a non-governmental organization to grow economically as well as ecologically.

Nepal (Gaudel, 2018) is rich in water resources and shows very good potential for hydroelectricity powerplants from economical or ecological perspectives. Nepal has been gifted (Bhatt R. P., Hydropower Development in Nepal - Climate Change, Impacts and Implications, 2017) with higher potentials of hydroelectricity powerplants and existing hydro powerplants. For example, “Parping” electricity production has increased from 500 kW to 782.45 MW since 1911.

## 1.1. Project Work Allocation

Both of us were majorly involved in the project’s research work and there was an accurate division of work between us. The project was divided into five phases: initial research, findings & proposal, project’s further research & planning, execution, analysis and closure. Each of the phases included several important activities. Each activity of the research work and secondary assessment of the journals was performed with the active participation of both of us. The proposal and literature review were generated with an equal contribution to the research. Sagar was majorly responsible for other sections of the research work and topics like methodologies, analysis of the result. Robit wrote the chapters on findings & conclusion along with the agile communication with each other.

## 1.2. Aims & Objectives.

The main purpose of the thesis “Decentralized Energy Generation in Nepal” is to make the reader aware of the different alternative methods that can be implemented or integrated to protect, conserve, and sustain our environment for the future. The thesis focuses on the following:

- To understand decentralized energy generation, its economic and ecological benefits
- To research the possibilities of decentralized energy, its capacities, and its implementation in different places of Nepal
- To understand the present situations of the renewable energy
- To generate future strategies and deductions for sustaining the non-renewable energy.

## 1.3. Problem Statements

The implementation of the “Decentralized Energy Generation in Nepal” study requires a proper understanding of different aspects that could affect the implementation of renewable sources of energy like technical, social, economic, and environmental aspects. (Figure 1.)

To understand, analyses, and depict the most feasible places that are best for decentralized energy production in Nepal various technical challenges like investigating energy availability, efficiency, and its reliability. It is not guaranteed that when any grid or hydro powerplant is built, it will receive constant amount of resource required for the targeted generation of electricity. Also, managing skilled manpower to operate the plant for a long term may arise some concerns and whenever some problem occurs for the maintenance of the plant, it is not sure how long it will take to rerun smoothly again. Or social challenges like accessibilities, social acceptances and affordability are a huge concern as well.

In the context of economy, the investments from the governmental departments for the project or from some private investors, the funds provided are not always

sufficient, which may lead to incompletion of required construction works for the plant. It may be under construction for a long period of time causing problems with the local community where its being built. There is not always sufficient transparency in the investment and the profit which may create unusual tension among the users and the investors. Lastly, the environmental aspect in this context, given the way Nepal geography is in the rural places, building the small-scale plant brings numerous concerns.

Figure 1. Problem Statements for DEG in Nepal


## 1.4. Project Scope & Limitations

The research work presented in this document will hence provide the readers with comprehensive information relating to the Decentralized Energy Production in Nepal including methods for decentralized energy production for economic and a balanced ecology in Nepal. The reader will be able to understand the potential of renewable energy in Nepal and feasibility studies for its implementation in different parts of the country. The thesis discussed the present situation and challenges for renewable energy implementations and future strategies for balanced environmental and economic growth in the country.

# 2 LITERATURE REVIEW

## 2.1 Decentralized Energy in Nepal

According to the research conducted by UNDP (UNDP, Poverty Reduction SCALING UP LOCAL INNOVATIONS FOR TRANSFORMATIONAL CHANGE, 2011 ), most of the rural areas in Nepal have been provided with decentralized renewable energy services for majority of the remote Nepalese population. This favours the uses with the lowest rate per capita electricity consumption throughout the world. The United Nations has declared universal access to reliable, economical, and modern means of energy production and distribution by 2030. The dependency on renewable sources of energy like hydro, solar, and wind energy can help not only support the daily energy requirement of the Nepalese population but also contribute an environmentally friendly production and utilization of the generated energy for the developmental work.

During the Nepalese fiscal year 2009/10, (ADDCN, 2009) the year remarks over the critical implementation of decentralization to the local population which eventually help for remote infrastructural and developmental works. The implementation of the micro-hydro project has eventually helped the local people and local government to supply a clean and reliable means of energy with an economical price scheme. This can help the remote areas to grow and expand thoroughly whereas the energy generated locally has been exported for in good price rate for highly energy-dependent areas like cities.

The investigation and research work conducted by Mr. Rana Bahadur Thapa (Upreti, 2020) and his colleague showed a geographical favourability for the implementation of the micro-hydropower, solar home, solar mini-grid, and wind-solar hybrid sources of energy which can eventually help for decentralization of clean and green renewables resources. The research concluded on the use of biomass for energy production is favoured by the least as an alternative renewable energy source for Nepal.

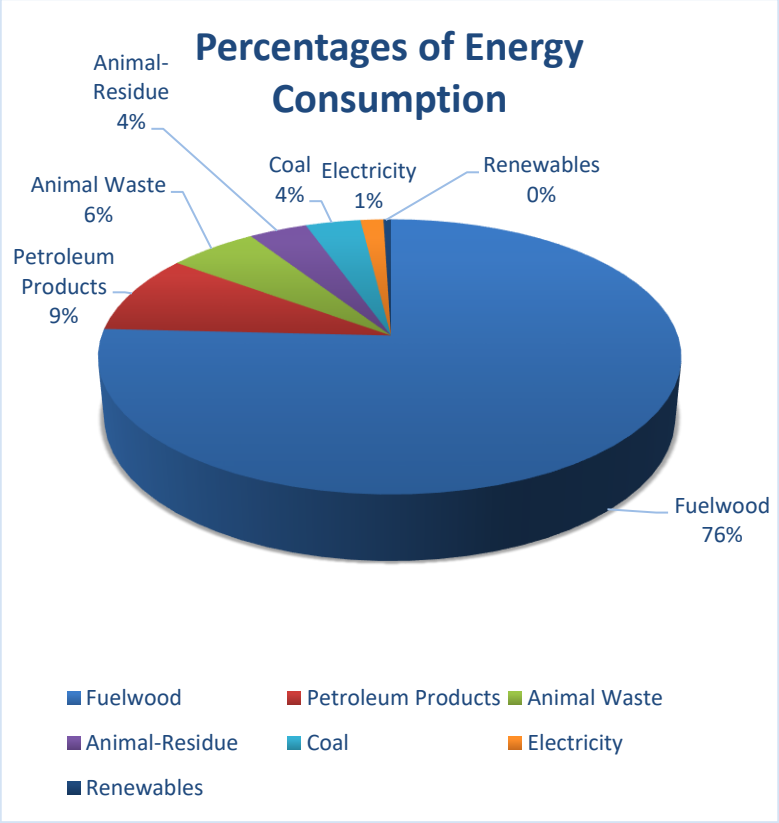
The finding from the Nepal Electricity Association's (NEA) case studies showed that the Rural Energy Development Programme (REDP) (Willcox, 2018) is aiming for an increment of energy access with the implementation of the micro-hydro system based on the mobilization process. This keeps the community at the centre of planning and implementation that favours a proper decentralization of renewable energy. The initiation of the rural energy development program during 1996 by REDP was conducted in five remote hill districts. It helped in operation, expansion, replication, and mainstreaming as well as institutionalization. This program expanded from five districts in the first phase to 40 districts during the third phase from 2007-11.

The research conducted by Mr. Kayastha (Kayastha, 2015) presented that the overall energy consumption of the rural resident sector for the year 2012 was 267 million Giga Joule (GJ) and is forecasted to become 433 million GJ by the year 2050. The accessibility of electrical energy has been increasing rapidly among the rural provinces of Nepal which increases a good possibility and economical surplus using a decentralization of the renewable sources of energy like a hydroelectricity power plant.

### 2.1.1 Energy Consumption Trend in Nepal

Extracted from the research work conducted in Nepal (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007), the given pie chart presents the overall percentages of the consumed energy that has been based on fuel type. The given Figure 2. presents that most of the primary energy in Nepal comes from biomass which includes firewood, animal, and agricultural residues. Since the data presented from the year 2004 shows the Nepalese population's dependency on petroleum products by 9% in context to other renewable and non-renewable energy sources. The given chart signifies a nearly null dependency on renewable sources of energy in comparison to other non-renewable sources i.e., animal waste, Agri-residue, petroleum products, coal, and fuelwood.

Figure 2. Fuel Energy Consumption in Nepal 2004 (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007)



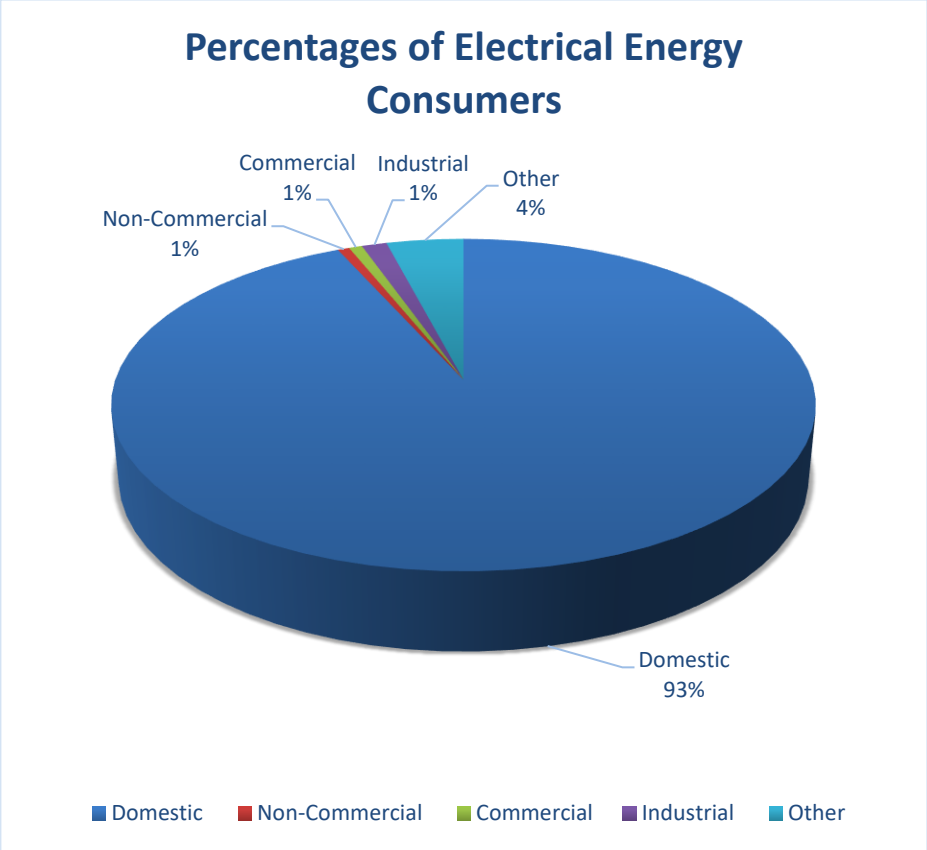

Since this data collection, the trend for energy consumption has drastically changed in Nepal. Development of many hydro powerplant, solar and wind grid brought a huge increase percentage of the population in using electricity. Although, the transition from 2004 to now had many problems like having a power cut for 14-18 hours a day to getting electricity without any power cut. It can be taken as huge step towards sustainable development of the country.

### 2.1.2 Percentages of Electrical Energy Consumers 5th July 2020

According to the report published by Nepal Electricity Association (NEA) (NEA, 2019) in 2019, the majority of the electricity was consumed by domestic users, while a minority of the population used it for non-commercial, commercial, industrial, and other uses as

seen in Figure 3. Most of the energy that has been produced using hydroelectricity power plant (UNDP, Poverty Reduction SCALING UP LOCAL INNOVATIONS FOR TRANSFORMATIONAL CHANGE, 2011 ) has been generated from the rural areas and distributed to the local consumers at the most affordable prices and the rest of it has been deployed to consumers from the city areas.

Figure 3. Electrical Energy Consumers in Nepal 2019 (NEA, 2019)




## 2.2 **Decentralized Energy Generation and Distribution in Nepal**

The Decentralized Energy Generation and Distribution in Nepal have good potential and possibility in relation to different renewable energy sources like hydro, thermal, solar, and wind. The Nepalese energy consumers (NEA, 2019) are the most diversified when it comes to using resources like fuelwood, animal waste, animal residue and other renewable sources of energy through a rural decentralized energy production campaign (UNDP, Poverty Reduction SCALING UP LOCAL INNOVATIONS FOR TRANSFORMATIONAL CHANGE, 2011 ). Most of the remote areas in Nepal are targeted

with decentralized renewables energy distribution that can contribute to the daily energy need locally and to provide the consumers with electricity at a lower price rate. The UNDP announced that their priority is to implement a program that solely focuses on decentralized renewable energy production and distribution by 2030 to support the nation economically and ecologically.

According to the statistics published by NEA, (NEA, 2019) only 30% of the energy is generated using a clean hydro-electrical power plant and 62% of the energy from the hydro grid provided by NEA. The annual report also concludes that there is a very minor production of energy using a thermal, solar, and isolated hydropower plants in the remote areas which are inaccessible and have a lack of an active connection grid line.

The energy that has been utilized and distributed to the internal (NEA, 2019) as well as to external consumers from Nepal, comes directly from the hydropower plant, purchasing from insider and India. Only a few percentages of thermal energy are used for serving the nations. The report published by Nepal Electricity Association (NEA) in 2019 shows that 39% of the energy used in the nation comes directly from different hydroelectricity powerplants located in Nepal and 22% of the distributed energy has been from the purchase from India.

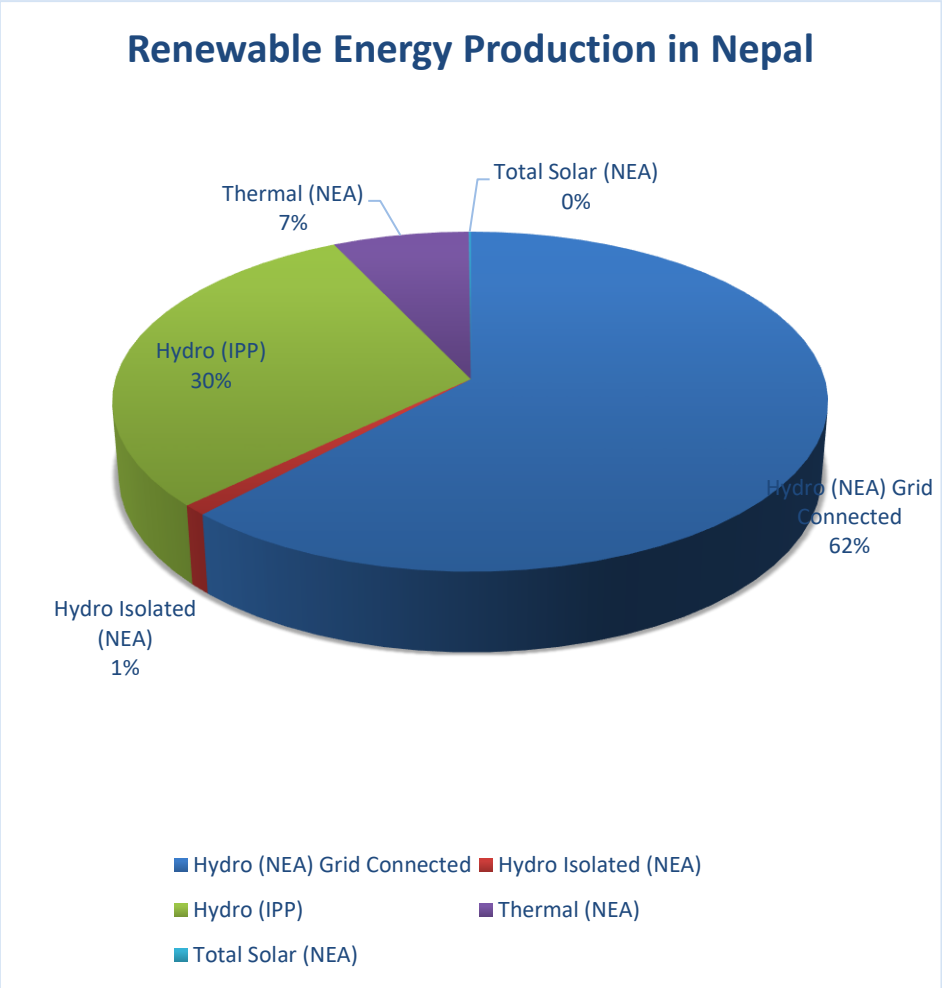
Most of the energy that has been produced (NEA, 2019) using a decentralized hydropower plant is used for internal sales. Very few proportions are used for export and self-consumptions. The measurement and analysis done by NEA in 2019 show that 83% of the energy produced using decentralized energy power grid lines is used for internal sales and 1% for self-consumptions as well as export whereas the remaining 15% of energy is wasted during system loss.

### 2.2.1 **Different Types of Renewable Energy Production in Nepal**

Different means of energy production have been implemented in Nepal (Energypedia, 2013) and the data published in 2013 by Energypedia shows that the mostof the

energy has been produced using a Hydro Grid by NEA. An overall 62% of the electricity has been produced by NEA using Hydro Grid Connections. Independent Power Producers (IPP) produce over 30% of energy using Hydroelectrical power plant as seen in Figure 4. Similarly, a few percentages of the energy have been produced by thermal, solar, and hydro isolated energy by the NEA.

Figure 4. Renewable Energy in Nepal (Energypedia, 2013)

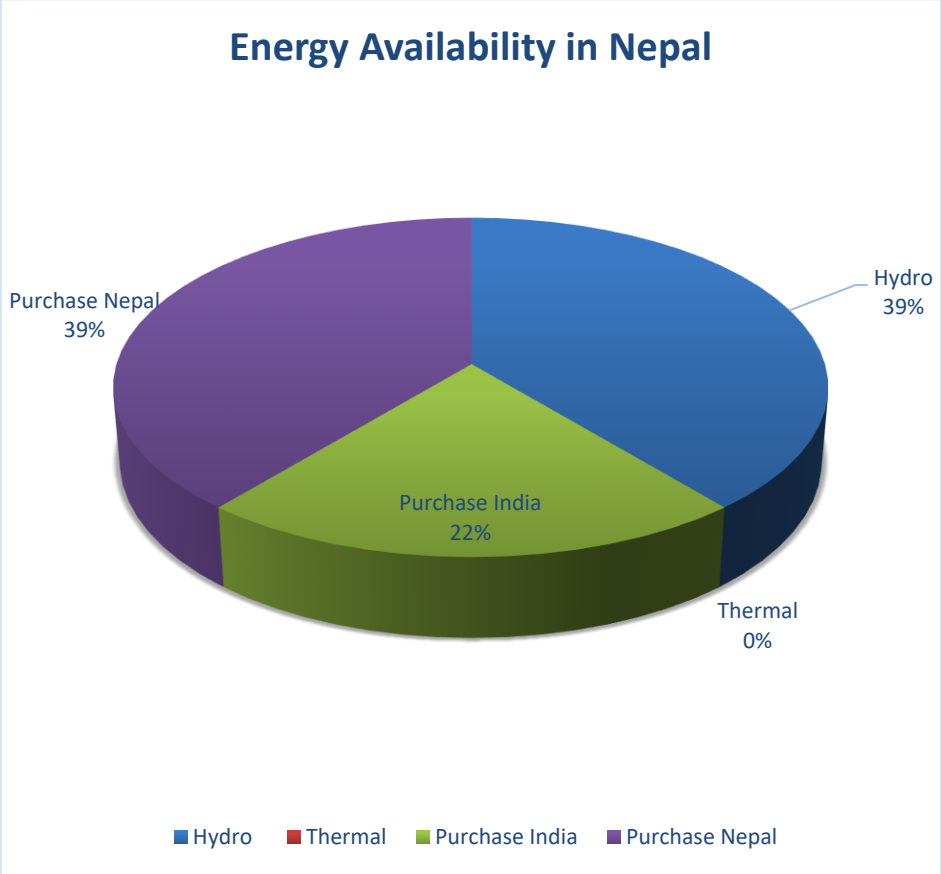



### 2.2.2 **Energy Availability in Nepal**

The Figure 5. below presents that only 39% of energy is available from the Hydroelectricity power plants, while 39% of the energy comes from the purchase via remote hydropower plant of Nepal, and 22% of the energy has been available to the

purchases made from India. The annual report published by NEA (NEA, 2019) shows a nibble availability of thermal energy in Nepal.

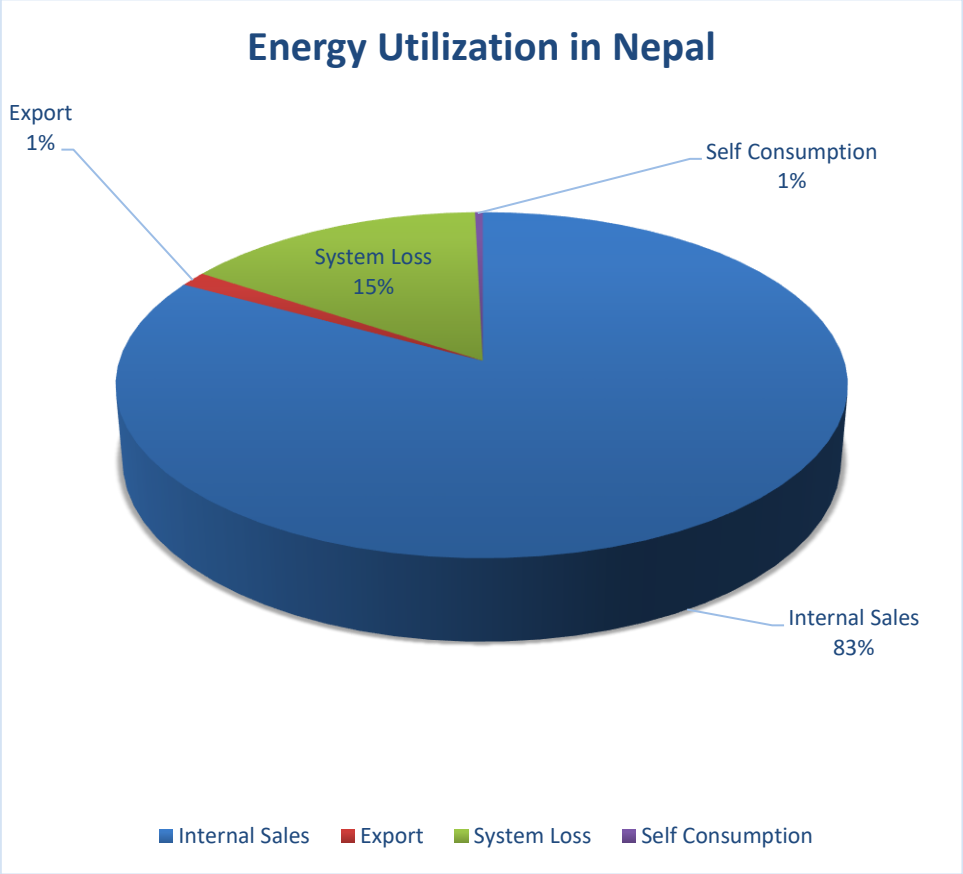
Figure 5. Energy Availability in Nepal (NEA, 2019)




### 2.2.3 **Energy Utilization in Nepal**

The annual report published by NEA shows that most of the energy (83%) (NEA, 2019) utilized in Nepal is for internal sales and only 1% of the energy is exported and used for self-consumption, while 15% of the energy is wasted due to a system loss. (Figure 6.)

Figure 6. Energy Utilization in Nepal (NEA, 2019)




## 2.3 **Economic and Ecological Benefit of Decentralized Energy Generation using Renewable Sources.**

The use of a decentralized energy system (NEEP, 2020) allows optimal utilization of renewable energy that can aid in the economic growth of Nepal as well as help reducing the use of fossil fuels. The energy that has been produced using renewable sources like hydroelectricity, solar and wind help not only the commercial business but also supports sustainable utilization of the natural resources.

The increasing dependency on electrical energy of the Indian population, as per data collected (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007) and illustrated from the year 1993 till 2017, presents a gradual increment in the energy requirement from 304006 GWh to 1318644 GWh. This

can provide the Nepalese Electricity producers with good opportunities for sales expansion of energy produced using renewable sources of energy.

Majority of the energy that has been produced in Nepal (NEA, 2019) which is mainly hydroelectricity powerplants, is used for sales in the industrial sector of 42% that helps for the industrial manufacturing and production. This eventually helps in both economic as well as ecological benefit in Nepal. Besides the industrial sector, energy produced in Nepal according to the NEA annual report 2019 shows all 36% of the produced energy are sold for a domestic purpose that includes household work, personal and private reasons. Similarly, 10% of the energy produced in Nepal are used for commercial purpose, 1% for export, 7% for other and 4% of non-commercial purposes.

The overall revenue that is generated from the decentralized energy power grid in Nepal, according to the NEA annual report 2019, 88% of the revenue has been collected from the net electricity sales, 5% from the financial income and 7% from other income. The revenue description (NEA, 2019) shows a good and progressive revenue collection from the hydroelectricity energy production and distribution in Nepal.

As the major electrical power distributor (NEA, 2019) in Nepal, the overall NEA expenditure shows that most of the expenses of the organization were invested for power purchase by 53%. Other expenditures of NEA included 8% for depreciation, 7% for interest, 2% for royalty, 8% for hidden and 22% were invested for other expenses.

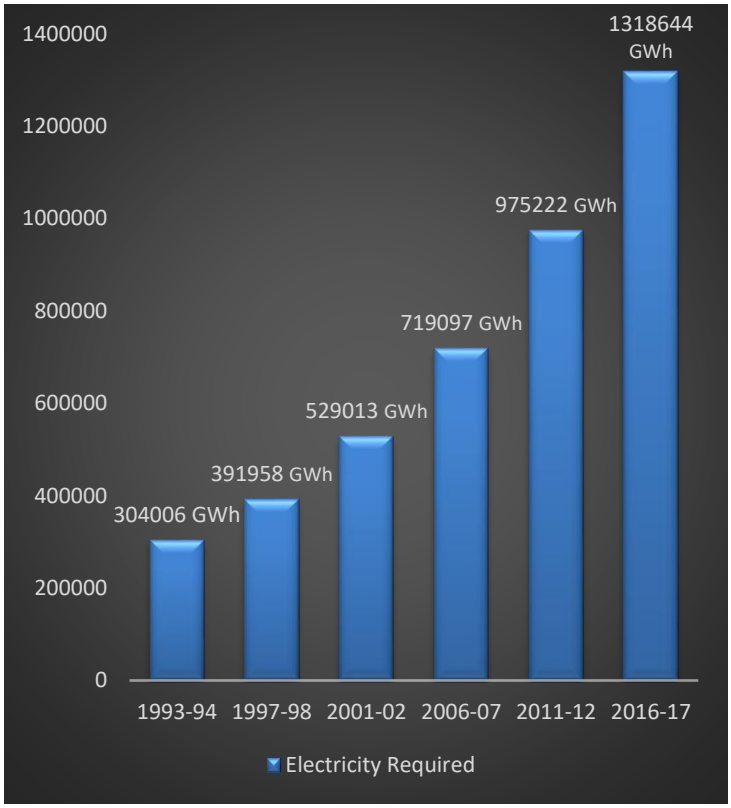
A dynamic system (Upreti, 2020) that is based on renewable energy sources, which in the case of Nepal includes hydroelectricity powerplant, wind, solar and thermal energy could provide potential economic growth as well as help sustain the limited fossil fuels, and reduce dependency on the non-renewable resources. This would help preserve natural resources for the upcoming generation.

The Nepalese government is allowing and attracting investments for the country's vast energy production using sustainable way to generate clean and green energy that can help the country and its residents in economic development and ecological balance.

### 2.3.1 **Energy Export as an Opportunities to India**

The present context of energy produced (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007) from hydroelectricity powerplant is not quite enough for the local consumers of Nepal. Some proportion of the hydropower plant has been conducted under the governance of India for its huge necessity in the coming future. The chart below presents the increase in electricity requirement in GWH for India, which is the neighbouring country of Nepal, from 1993 till 2017. The presented Figure 7. shows a gradual increment of the power necessity and a huge dependency on the energy from 1993 to 2017 that ranged from 304006 GWh to 1318644 GWh.

Figure 7. Electricity Requirement for India (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007)

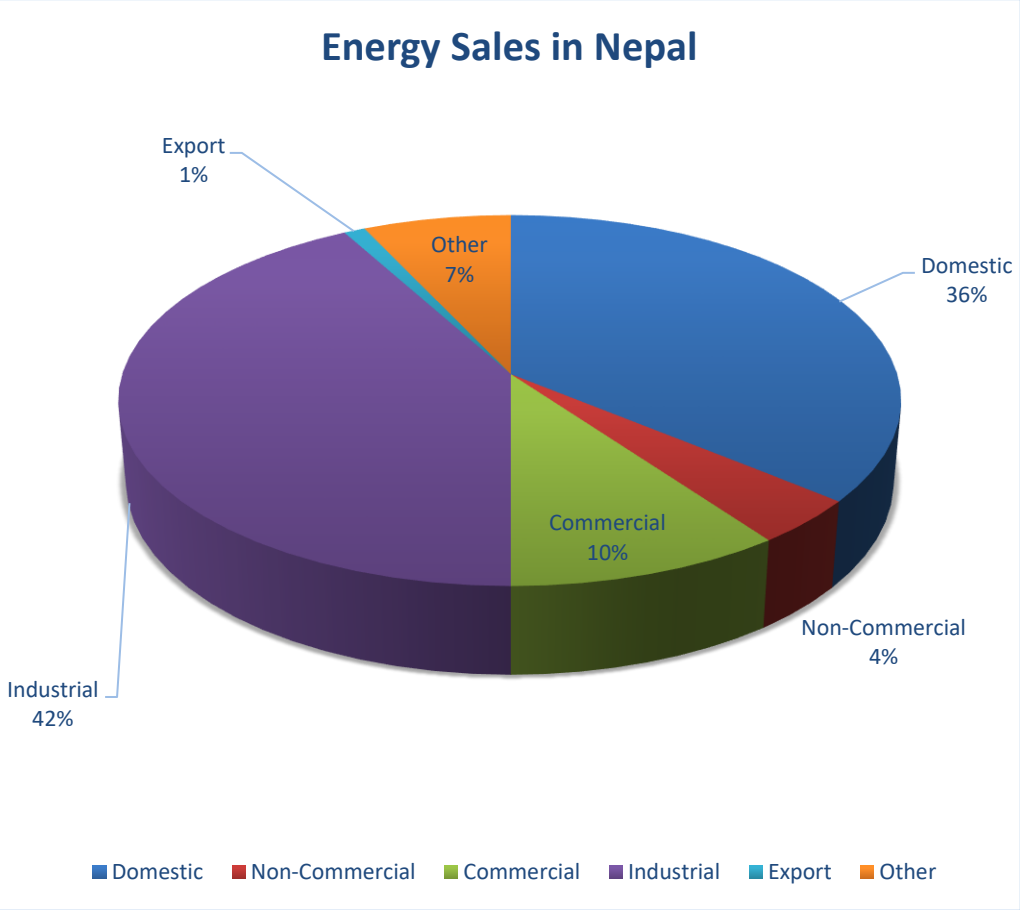



Electricity export and import with India takes place in huge amounts in recent years. India constantly invests heavily in the hydropower plants in Nepal because of the rich natural resources available in Nepal.

### 2.3.2 **Energy Sales in Fiscal Year 2019/20**

The given Figure 8. presents the energy sales in Nepal during 2019 (NEA, 2019) and shows that 42% of the produced energy was sold for industrial purposes. 36% of the energy production using a renewable source has been sold for the domestic purposes in 2019. This includes personal and daily household uses for the local consumers and residents. Similarly, the annual report published by NEA presents that 10% of the energy has been sold for commercial uses, 1%, for export and 7% for other purposes.

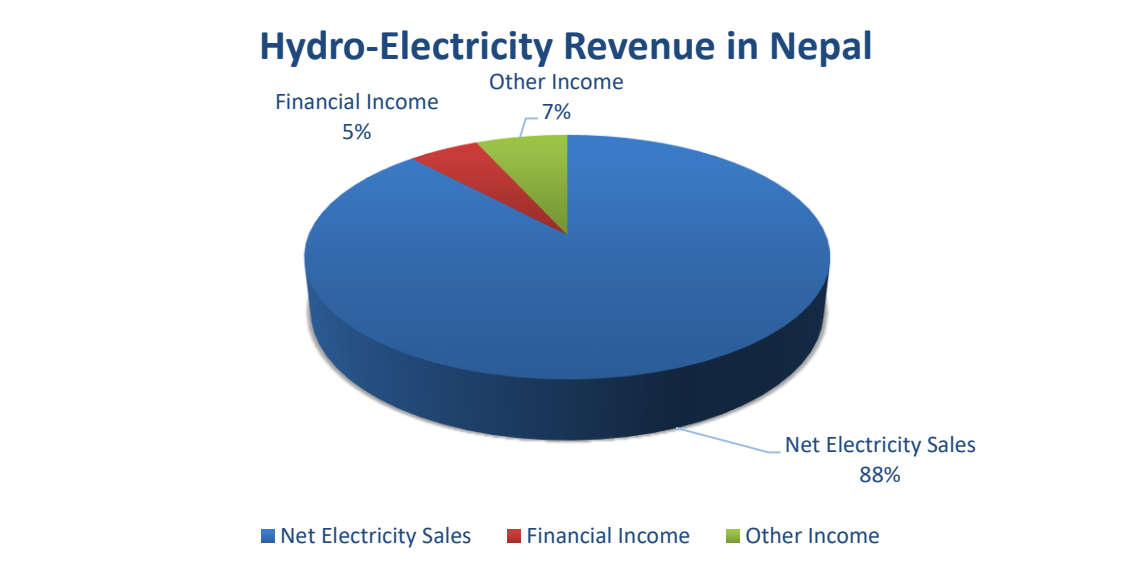
Figure 8. Energy Sales in Nepal (NEA, 2019)



### 2.3.3 Hydro-Electricity Revenue in Fiscal Year 2019/20

The presented Figure 9. (NEA, 2019) shows the electricity revenue of Nepal in 2019. It illustrates that 88% of the hydro-electricity revenue has been generated by net electricity sales along with 5% from financial income and 7% from other income.

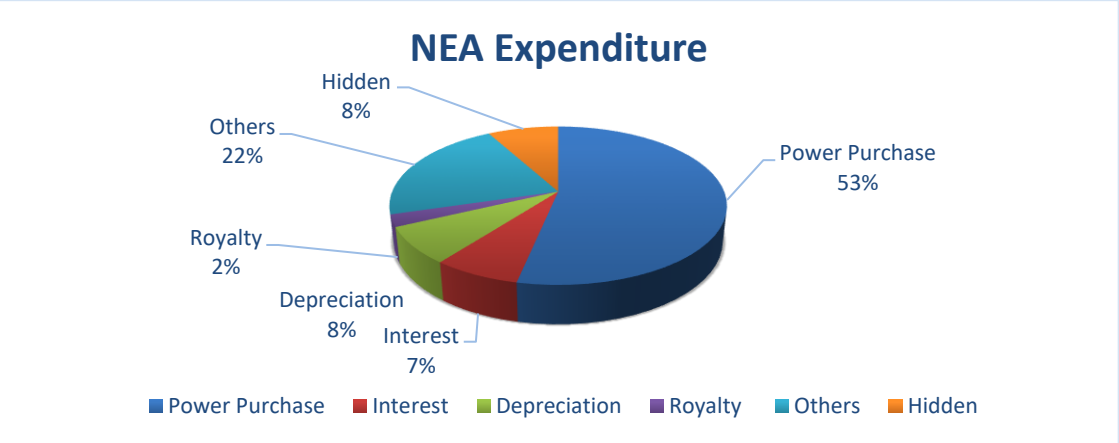
Figure 9. Hydroelectricity Revenue in Nepal (NEA, 2019)




### 2.3.4 NEA Expenditure 2019/20

The given Figure 10. presents the overall expenditure published by the Nepal Electricity Association (NEA) in their annual report of 2019 (NEA, 2019). It elaborates that the majority of the expenses were related to power plant purchases which were 53%. Similarly, another expenditure was spent on an interest that conquers 7% of the overall NEA expenditure, 8% for depreciation and hidden expenses. The given infographic published by the authorities of NEA shows 22% of the overall expenditure of NEA was invested for other materials.

Figure 10. NEA Expenditure (NEA, 2019)




## 2.4 **Possibilities of Decentralized Energy in Nepal with its Capacities**

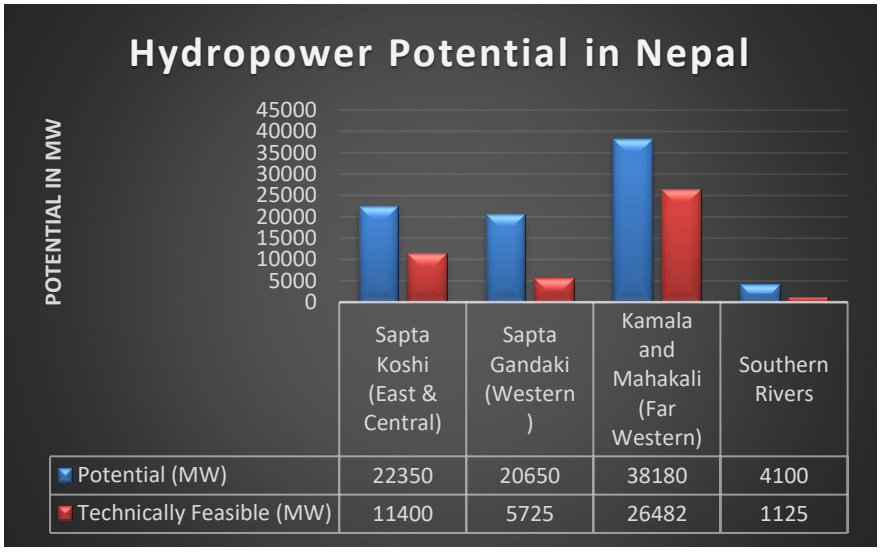
The geographical characteristics of Nepal (Shrestha, 2017) offer a humble and feasible potential to conduct numerous hydropower plants that can help boost not only the economic prosperity of the nation but also implement a sustainable means of energy extraction that sustains and helps environmental conservation. Due to the territorial differences and diversified land formation in Nepal, the nation is gifted with a number of fast-flowing rivers that naturally produce an immense amount of clean and free energies. The major hydropower plants in Nepal include Sapta Koshi Hydropower plant, Sapta Gandaki Hydropower plant, Kamala, and Mahakali Hydropower plant and another micro–Hydropower plant located in the Southern Rivers.

One of the highest producing Hydro Power Plant in Nepal is the Mahakali Hydropower plant that yields a potential of 38180 MW and shows the feasibility of 26482 MW followed by the Sapta Gandaki Hydropower plant, Sapta Koshi, and Southern River Hydropower plant.

### 2.4.1 **Hydropower Potential in Nepal:**

The presented Figure 11. presents the hydroelectricity potential (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007) and its capacities that shows the data published by Mr. Chhetri in 2007 that entails the major hydropower plants like Sapta Koshi (East & Central), Sapta Gandaki (Western), Kamala, and Mahakali (Far-Western), and Southern Rivers. The information depicted in the given bar graph shows the hydroelectricity produced in the Kamala and Mahakali located in the Far Western region with the potential of 38180 MW and technical feasibility of 26482 MW. Similarly, Sapta Koshi located in the East and Central region showed a potential of 22350 MW and technical feasibility of 11400 MW. Sapta Gandaki located in the Western region has a potential capacity of 20650 MW and technical feasibility of 5725 MW. The southern rivers in Nepal showed the potential of 4100 MW and technical feasibility of 1125 MW.

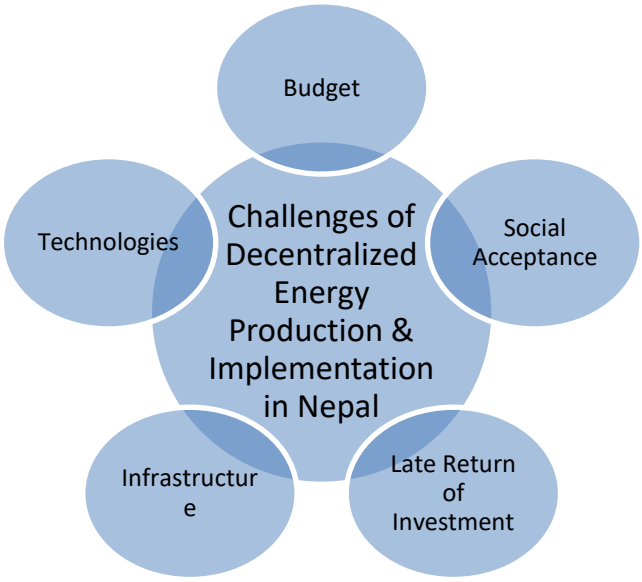
Figure 11. Hydropower Potential in Nepal (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007)



## 2.5 **Challenges of Decentralized Energy Production and Implementation in Nepal**

The geographical difference and diversified topology of land (Thapa R. B., IDENTIFYING THE BEST DECENTRALIZED RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN NEPAL, 2020) can create potential challenges for transmission of the energy from the fast-flowing rivers that are located in remote areas of Nepal. Some of the most commonly arriving challenges for decentralized production, implementation, and deployment could be impacted by the economic and social aspects. Most of the feasible areas for the implementation of Hydro Electricity are in a remote location, which mean a huge budget allotment for only delivery of the electrical energy which is conducted using a huge hi-tension grid-connected line.

Figure 12. Challenges of Decentralized Energy Production and Implementation in Nepal




Similarly, the implementation and production of energy utilizing the locally available resources in the remote locations operate from a community-based culture and traditions that can backlash a proper implementation of hydroelectricity. The organization related to hydroelectricity needs to actively advance Corporate Social Responsibility by providing support to social works i.e., Environment Sanitation, Locally Available Employment.

Due to the fragile geology of Nepal, the implementation of decentralized energy deployment for the city areas could be quite expensive and provide a late return of investment in case of project initiation to real-time operations. Other technical challenges related to technologies and infrastructure required for the construction of a huge hydro project that requires an artificial dam for the water reservations and an effective turbine to capture the current from the rivers or dam.

According to the Hydro feasibility (Thapa R. B., IDENTIFYING THE BEST DECENTRALIZED RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN NEPAL, 2020) in a different remote location of Nepal shows a bright possibility for its implementation. The major amount of the overall electrical energy that has been produced comes from 20 major hydropower plants including micro-hydropower plant. The overall hydropower potential in Nepal has been estimated to be higher than 50000 MW whereas the average electricity produced is 800 MW from 20 major hydropower plants.

Nepal is organically gifted with fanciful hydro resources which are yet to be implemented due to political imbalance in the nation and technical reasons like hydrologic variability, geotechnical constraint, difficult terrains, and sparse hydro-meteorological network. Meeting the major technical challenges in implementation of hydroelectricity in Nepal has been represented using the given Figure 12.

### 2.5.1 **Fragile Geology**

Nepal consists of (Uprety, 2000) diversified land formation and geology (Tejaswi, 2020) that creates differences in climate, vegetation, topography, and altitudes which has led tod sophisticated geology. With the variations and differences in the geological nature of terrain  in Nepal, the implementation of a minor hydropower plant could be geologically difficult in case of huge distance for electricity transmission. For the proper implementation, it is crucial to understand the selected geology and topological information to assess the feasibility of the project in that location. Most of the remote areas of Nepal are surrounded by mountains, hills, and also a flat land “Terai” whereas

the most suitable areas for hydropower plant implementation are situated between the Himalayan and the hilly regions in Nepal.

### 2.5.2 **Hydrologic Variability**

Hydrologic Variability (Agrawal, Development and Climate change in Nepal: Focus on Water Resources and Hydropower, 2003) means the changes in hydraulic pressure due to the melting of ice from the mountain region of Nepal. Global warming has led to the heavy melting of ice and increased the pressure of the fast-flowing river. The unexpected increase in the river's current can sometimes destroy the dam or turbine which has become the burning threat in the Terai Region of Nepal. The core reason of global warming has made the existing two thousand glacial lakes prone to Glacial Lake Outburst Flooding (GLOF)

### 2.5.3 **High Rate of Sedimentation**

A high rate of sedimentation decreases the capacity and lifespan of a reservoir which potentially causes erosion which eventually damages the turbine and other technological components. The main reason for the high rate of sedimentation in the dam or reservoir of a hydropower plant is due to the excessive number of sediments. This comes from the Himalayan rivers due to the presence of weak rocks, abrasive minerals, fragments, soil, and gradients. For an instance (Sthapit, 1996), during 1993 Monsson Rain, the Kulekhani reservoir was 519.35 ha-m which was out of the capacity range of the dam, and the capacity of the Kulekhani reservoir was reduced by 5.19 million cu.m to counter the potential harm to the dam as well as the residence nearby.

### 2.5.4 **Geopolitical Situation and Topographical Constraints**

Geopolitical situation and topographical constraints (Lewison, 2020) are other issues that could backlash the decentralized energy production and distribution in Nepal. Nepal has been surrounded by India and China's Tibet from three sides south, east, and west. Nepal is a landlocked country and that can create difficulties for major import and export in or out of the country. The main reason for decentralized energy

production based on the geopolitical situation is due to difficult terrains including dispersed settlements and requirements of a long transmission line. The overall cost of the connection to national or regional grids is two to five-times higher and requires a huge budget for the implementation. The most effective way to mitigate this issue for hydropower plants is a micro-hydropower plant with economical and small-scale productions.

### 2.5.5 **Stringent Environment Concerns**

Besides the geographical differences, the implementation of decentralized energy production i.e., hydro, solar, and wind energy has become quite difficult due to the imbalanced political situation of the country. Most of the bigger project (Dhungana, 2019) which are being conducted, or are to be conducted, are interfered by political and social factors including legal requirements, environmental screening and proper audit or transparency of work done. This issue can be eradicated with a proper analysis of the potential risks and a proper fulfilment of not only the legal and environmental aspects but also corporate social responsibility and protection for all kind of species.

### 2.5.6 **Lack of Policy Interventions:**

The recognition of the policy regarding the hydropower plant was issued in the early 1990s (Pokharel, 2001). It helped a lot in understanding the overall demand and supply of the energy generated. Similarly, the introduction of the hydropower plant advocate over the reduction of forest degradation and environmental pollution that also opened a fund-raising campaign to collect from the non-public sector for the infrastructure development of the power plant. The government of Nepal also has declared an open opportunity for the public sector to invest in the hydropower plant project for aiding decentralized energy production.

### 2.5.7 **Transmission Difficulties**

Another problem regarding the hydropower plant (Chalise, 2020) is the construction of transmission and deployment of energy for long-distance consumers. The hydropower

plant construction can be quite expensive whereas building a transmission line is also a challenge, because it occupies huge land areas and other potential hazards. A huge power plant has been used to transmit electricity from a high-tension line. Due to the diversified geographical situation of Nepal, transportation services including the construction of an electrical high-tension line could be expensive. The use of the decentralized concept by producing and deploying the electricity for a short distance can be a more convenient way.

## 2.6 **Strategies for Decentralized Electrification Technologies in Nepal**

The decentralized (ADDCN, 2009) energy production started after the local government act was issued and formulated in 1991. According to the AEPC Database 2018, from the date of the initiation of decentralized electrification, an overall 1805 micro-hydropower, 13 solar mini-grid, 10 wind-solar hybrid, 8 biomass, and 952,903 solar home systems were installed in a different remote location of Nepal. (Table 1.)

Table 1. AEPC Review on Decentralized Electrification Technologies in Nepal

| **S.N.** | **Technologies** | **Numbers** | **Capacity (KW)** | **Beneficiary Households** | **Electrification Category** |
|---|---|---|---|---|---|
| 1 | Micro Hydropower | 1,805 | 31,800 | 323,115 | Electrification |
| 2 | Solar Mini-Grid | 13 | 471 | 1,499 | Electrification |
| 3 | Wind-Solar Hybrid | 10 | 334 | 1,099 | Electrification |
| 4 | Biomass | 8 | 455.2 | 6 | Electrification |
| 5 | Solar Home System | 952,903 | 18,105 | 952,903 | Pre-Electrification |

The use of decentralized electrification technologies i.e., 1,805 micro hydropower produces 31,800 KW that serves 323,115 households, 13 solar mini-grid produces 471 KW that serves 1,499 households, 10 wind-solar hybrid produces 334 KW that serves 1,099, 8 biomass 455.2 KW that serves 6 households and 952,903 solar home system produces 18,105 KW that serves. 952,903 households.

### 2.6.1 **Micro-Hydropower Plant**

Micro-Hydropower Plant (UNDP, Integrated Sustainable Rural Development: Renewable Energy Electrification and Rural Productivity Zones, 2004) is a miniature grid solution that is operated in an isolated manner for small-scale energy production from 1 to 100 KW with a lower voltage distribution grid from 400 v or 11 kV. This is becoming a trending technology in decentralized energy production in Nepal. The energy produced from Micro-Hydropower Plant can efficiently be used to power a single community, a village, or even a small town. Though, micro-hydropower plants were initiated rarely before the formation of the Alternative Energy Promotion Centre (AEPC) in 1996 after which the micro-hydro power plant establishment started in rapid motion. After the formation of the AEPC, the micro-hydropower plant was widespread mostly over the hilly areas that cover 55 districts of Nepal. As the Terai region of Nepal is situated in the lower elevation where the river does not hold enough current. This is why micro-hydropower plants are mostly installed in the hilly region, so that enough energy could be generated and use for daily needs like lighting, operating kitchen appliances, and even running a small-scale industry along with the fulfilment of corporate social responsibilities.

### 2.6.2 **Solar Mini-Grid**

Solar Mini-Grid (UNDP, Integrated sustainable rural development: renewable energy electrification and rural productivity zones, 2014) can be used to generate electrical energy from 1 KW to 100 KW that operates with low voltage distribution line with about 400 V or 11 KV that can supply energy enough for a single community. The overall energy generated from the solar mini-grid can be used for the operation of small-scale industries and enterprises. The concept of a solar mini-grid is quite popular mostly in the remote areas of Nepal where it is difficult to connect a transmission line. Eventually, most of the solar home systems and solar mini-grids are widely used in the hilly and Himalayan regions of Nepal for the daily use and energy consumption for work.

### 2.6.3 **Wind-Solar Hybrid**

Wind-Solar Hybrid (Thapa K. B., 2020) is a mini-grid system that generates 1 KW to 100 KW of electricity with voltage distribution line consumption of 400 V or 11KV that can be used to power a community. Wind-Solar Hybrid is used in the areas where other means of energy transfer are difficult like in Mustang where better wind resources are available. It has been used for powering the villages, communities, and enterprises with electricity.

### 2.6.4 **Biomass**

Biomass (Marathe, 2014) refers to the plants and their products that can be used for energy production and that are mostly created from agricultural products and municipal waste for electricity and heat production. The use of biomass for electricity production is quite new in Nepal but popular in most other countries that are rich in biomass. The implementation of biomass is beneficial and successful for the production of electricity and heat from a waste collection in countries like Japan, the Republic of Korea, and Australia. Whereas the implementation of biomass is still very few in numbers, which may be due to the requirement for collecting heavy loads of waste. The collection of biomasses not only could produce energy but could also help a lot in environmental sanitization campaigns.

### 2.6.5 **Solar Home System**

A Solar Home System (Regmi, 2016) is a standalone off-grid solution that can be used for providing electricity at the point of consumption for a single building or a house. The solar home system is dependent on a battery-powered system that is charged from the Sun’s UV rays and stored in the battery pack to allow users to consume the energy for their daily household as well as official uses. Solar Home System is quite expensive and not an economical method for rural areas. Due to the transmission inabilities, different remote areas of Nepal have been offered a discounted solar home system so that the consumers from remote would not get deprived of the services.

# 3 METHODOLOGIES

For the commencement and achievements of the research work, it is not attainable to obtain the predefined target without proper selection and implementation of the research methodologies. The standard way to conduct research involves a proper selection of research method, research philosophy, research approach, data analysis, data collection method, validity & reliability. help the research work to achieve the project goals and deliverables.

To conduct the given research work about Decentralized Energy Generation in Nepal, common steps have been taken for the analysis and attainment of the research goal. The following line elaborates the methodologies and techniques that have been used in the research for Decentralized Energy Generation in Nepal.

## 3.1 Research Method

For the implementation of the research work required for Decentralized Energy Generation in Nepal, different methods can be utilized like experimentation, survey, questionnaires, interviews, and case study whilst due to the project's standards and requirements information mined specifically from the case studies of a different organization has been extracted. The specific case study on Nepal Electricity Association has been extracted to compare and calculate the numbers and figures regarding the decentralized energy generated using hydropower plants. The paper illustrates particularly the data and information that has been published in the annual report of the relevant corporation and specific data published by UNDP. The document provides factual information that has been researched and interpreted by the professional researchers on a similar topic that has enabled the research work with a humble amount of reliable data and facts interpretations.

## 3.2 **Research Philosophy**

The research philosophy that has been used for the Decentralized Energy Generation in Nepal is based on pragmatism research philosophy which is the combination of utilizing both positivist and interpretivism philosophy. The pragmatism research philosophy method has been selected for Decentralized Energy Generation in Nepal due to the research work nature and its requirement. The research searches for data and facts about the decentralized energy initiation, implementation along with its remarks. The thorough information gathering and interpretation in the research work "Decentralized Energy Generation in Nepal" have been conducted for the collection of reliable information both i.e., Quantitative & Qualitative data so that the document can equally present and deploys its main objective. It helps the readers to understand the present situation of renewable energy, the economic benefit from the decentralized energy generation including its ecological benefits and to produce a future strategy for sustaining the non-renewable energy available in Nepal.

## 3.3 **Research Approach**

The research approach can be classified as deductive and inductive approaches as well as abductive approaches. Based on the research necessity and requirement of Decentralized Energy Generation in Nepal, the Inductive Approach will offer the project with the generation of new ideas presented by the recent authorities working in Nepal. The use of the inductive approach will support the project with inductive reasonings that will provide a fact collected from the data to generate a general principle that can be used for deducting potential strategies which can be used in the coming future for healthy decentralized energy production and distribution in Nepal.

## 3.4 **Data Analysis**

A data analysis technique used in the research work will enable the reader to understand the analysis and evaluations made from the figures, statistical calculations, and facts collected from reliable sources. Data analysis techniques that have been selected and used in the research work in the given paper are quantitative analysis.

The quantitative data analysis in the research work has been used to collect fact information from a legit source i.e., overall energy utilized in Nepal on a particular year.

### 3.5 **Data Collection Method**

The data collection method implemented in the research work for Decentralized Energy Generation in Nepal is the secondary data collection method which has offered the project abundant access to the information that is available from other relevant research papers, reports, online books, pdf, journals, articles, and authorities. The secondary data collection method employed in the project has offered a dynamic range of data in a predetermined schedule. Most importantly secondary data collection method has provided the project with saving cost and time as the primary data collection requires a field visit and direct data collection in a first-hand situation which could be troublesome and become limited in a particular range of research work.

### 3.6 **Validity and Reliability**

The Decentralized Energy Generation in Nepal has been produced using open-source data and information that has been made available via the internet, research papers, publications, books, pdf, and other digital sources using a proper reference to the owner of the work. The API reference has been taken in the documents that have enabled an exact credit to the creator of the referenced author which eventually helps a lot to select, use and illustrate from a reliable source with the data interpretation by the professional's researcher.

## 4 **ANALYSIS**

The research work regarding the Decentralized Energy Generation in Nepal has been analysed based on the information that has been collected and recorded by the authorities, particularly the Nepal Electricity Association (NEA). According to the

annual report published by NEA, different information has been collected based on the infographics in 2019.

The reports include different factors like percentages of electrical energy consumers in Nepal, energy availability, energy utilization, hydroelectricity revenue, NEA expenditure, challenges of DEG, and strategies for Decentralized Electrification Technologies in Nepal.

## 4.1 **Percentages of Electrical Energy Consumers in Nepal from Data 2019**

According to the statistical analysis published by NEA, the majority of the electricity that has been generated in Nepal, which mostly uses hydroelectricity, has been used for domestic purposes and only one percent for commercial/ non-commercial, industrial, and 4% for other uses. Based on the analysis conducted in 2019 by NEA, the maximum utilization of the decentralized energy production in Nepal goes for domestic purposes and very few percentages of the energy are used for commercial as well as non-commercial purposes. According to the research work performed by UNDP, it has been analysed that most of the remotely operated hydroelectricity in Nepal has been promoting a cheaper price scheme for electrical energy production and distribution in Nepal.

Most of the economical distribution of electrical energy that has been locally generated in rural places in Nepal has been performed to help in poverty reduction for promotions of local innovations for a transformation changes as per the research work conducted in 2011. Due to relatively lower consumption of electrical energy in remote places in Nepal in comparison to the urban areas, the surplus energy is transmitted using a high-tension grid line for sales in a slighter higher profit than the local selling price. The energy production using a decentralized energy production like Hydroelectricity has been used mostly for the internal sales in Nepal. This has contributed to progressive infrastructure development for renewable energy.

## 4.2 **Overall Energy Availability in Nepal from Data 2019**

According to the statistical analysis of energy availability in Nepal, the overall energy that has been produced in Nepal has not been able to serve and fulfil the demand of Nepalese consumers. Nonetheless, the energy that is available in Nepal, according to the data published by NEA in 2019, shows an analysis that only 39% of the energy comes from Hydro Electricity, 39% from the purchase made from Nepalese energy providers which mostly operates from the private sector investor investing in the Hydropower plant. The 22% of the energy that has been available in Nepal is conducted by purchasing the energy from the neighbouring country. Similarly, an untraceable percentage (0%) of thermal energy is available in Nepal.

The prior analysis of the data published by NEA in the 2019 annual report, depicts information about how the energy that has been used in Nepal, including the purchases made from outside and inside of Nepal, and energy that has been directly produced using Hydro Power Plant. Eventually, the data collected by NEA, 2019 illustrated a tiny availability of thermal energy in Nepal with lies below 1% of about 0.60% in comparison to hydro electrical energies and imported energies.

## 4.3 **Overall Energy Utilization in Nepal from Data 2019**

The research work and analysis made by NEA in 2019 shows overall energy produced majorly using hydroelectricity has been used for internal sales that occupy a total of 83%, 1 % for export, 1 % for the self-consumptions, and 15% of the energy goes on a system loss. According to the depiction, the energy utilization information in Nepal, as per the data published by NEA, a majority of the energy that has been produced using renewable source of energy is not enough even for the insider users and that the most of the energy is spent by the Nepalese consumers for their daily needs and fulfilments.

Similarly, the annual report published by NEA shows that 15% of the energy produced is lost due to system technical issues. An effective review and analysis on how the system has been led towards a heavy system loss may reduce the chances of higher system loss. Moreover, the NEA and the government need to implement reliable

strategies so that the Nepalese consumer can be provided with sufficient energy that can contribute to poverty reduction and for progressive growth via decentralized energy production and distribution.

### 4.4 **Overall Energy Sales in Nepal from Fiscal Year Data 2019**

The overall energy that has been produced in Nepal using Decentralized Energy System in Nepal has been sold for various reasons i.e., commercial, non-commercial, domestic, export, industrial, domestic, and others. Most of the energy produced in Nepal has been sold for industrial purposes which occupies an overall 42%. This has helped a lot for the industrial operations and development in Nepal. Similarly, the energy produced in Nepal using the Decentralized Energy Generation (DEG) system goes for domestic sales which are 36% out of 100% of energy sales in Nepal. The domestic sale of electrical energy in Nepal has helped the Nepalese citizens to engage in private business including small to large scale enterprises that includes personal and domestic utilities.

From the overall energy sales, 10% of the energy produced by the Nepal Electricity Association has been sold for commercial utilities that help Nepalese consumers to develop and expand their commercial business. According to the fiscal year of 2019/20, most of the energy sales in Nepal show higher sales in the industrial field and most fewer sales for export of energy sales in Nepal. The overall depiction made by NEA based on the annual report 2019 shows that 7 % of the energy has been sold for various purposes. The increase in the production of green energy in Nepal can eventually help the Nepalese government and related authorities to benefit from different perspectives including progressive economic growth and infrastructural development of the country.

### 4.5 **Hydro Electricity Revenue in Nepal from Data 2019**

The Hydro Electricity Revenue in Nepal during the year 2019 was collected from net electricity sales (88%), financial income (5%), and other income (7%). Most of the revenue that has been collected in Nepal comes from the net electricity sales and from

the financial income and other income. Even though, Nepal has the potential to generate 43,000 MW of electricity whereas only 787 MW is being produced representing half of the demand. According to research work, the only growth of peak power demand will reach 3400 MW whereas the average electricity requirement is 16,000 GWh in 2020. The revenue collected from the Hydro Electricity sales in the nation can be used for the potential growth of the country's economy and for the supply of clean and green energy not only for Nepal but also for countries abroad that are dependent on non-renewable means of energy production.

### 4.6 **Nepal Electrical Association Expenditure from Data 2019**

An overall expenditure of Nepal Electrical Association as per the statistical analysis report published in the annual report in 2019, 53% of the corporation expenses goes on power purchase followed by 8% for Depreciation, 7% for Interest, 2% for Royalty, 22% for other and 8% of expenses are hidden and unrecognized. The annual report also shows that there is less in-house production of electrical energy, which mostly comes from the hydroelectricity power plant that makes 53% of the profit made by the corporation goes to power purchase. Finding the potential solution for increment in the Hydro Electricity Power Plant production in Nepal is needed to counter the problem of higher expenses and huge yearly cut-off from the profit.

### 4.7 **Challenges of Decentralized Energy Production and Implementation in Nepal**

The major challengefor proper decentralized energy production and implementation in Nepal is thebudget required for the project, acceptance bythe society, the late return of investment, infrastructure, and techniques required. Due to the geographical variation of Land's topology in Nepal, the implementation of decentralized energy production and implementation is quite complex and difficult, mostly in the case of the construction of an electrical connection grid. Most of the hydroelectric power plants have been used as a grid line to transmit energy from the remote areas to the urban areas for the fulfilment of energy requirements. According to the research work and review of the literature about the challenges of decentralized energy production and

distribution in Nepal, various aspects can stop the project from growing and expanding as it is ought.

The most conflicting challenges for Decentralized Energy Production (DEG) and Implementation in Nepal are caused due to the fragile geology of Nepal which has become the core reason and main obstacle for the proper decentralized energy implementation in Nepal. Without prior information about the geographical status of the land and feasibility analysis, the development and implementation of the DEG in Nepal could be quite difficult.

Most of the regions in Nepal are covered with hills and mountains. These mountains are the main source of the fast-flowing rivers that flow from the Himalayan region to the Terai Region of Nepal. The rivers flowing after the ice melting from the mountain region of Nepal could create a hydrological variability and lead toward a rapid increase of the liquid tension based on the different seasons like winter, summer, and the rainy season. The main reason for such an abnormal increase in ice meltdown is caused due to global warming and the unwanted production of harmful gases in the atmosphere.

From the research work conducted by NAPA (Nepal National Adaptation Programs of Action) (NAPA, 2010) in the official report conducted in September 2010 in National Planning Commission, Ministry of Environment, Kathmandu that Nepal is becoming victim to the climate changes by creating problem regarding the differentiation in liquid tension in the fast-flowing rivers causing vital damages in the reservoirs.

The reservoir can lead toward faster decrement in the lifespan of the reservoir and the components of a reservoir. The main problem for the hydroelectric power plant is caused during the monsoon that could increase the volume of water in the reservoir causing an overflow of water and leading to unexpected accidents. Most of the hydropower plants need to be monitored using an advanced internet of thing technologies to become actively aware of the condition and status of the reservoir. The geopolitical situation and the topographical constraints in Nepal has created a huge issue not only relating to the implementation of the DEG in Nepal but related to other infrastructural development in the nation. Being landlocked by two countries

i.e., India and China, Nepal experiences disturbances in different trade and transportation activities . Moreover, the use of seaway transportation is not directly accessible in Nepal which has created a disadvantage for the proper development of Nepal. The topographical conditions of the hilly and Himalayan region in Nepal have created an inaccessibility to various services and potentially discouraged remarkable projects like DEG in Nepal.

### 4.8 **Strategies for Decentralized Electrification Technologies in Nepal**

There are major difficulties that have been created by a lack of policy intervention and most importantly due to difficulties in the transmission that is caused by the huge number of terrains and the stringent environment in Nepal. The initiation of the DEG in Nepal started after the governmental act was formulated in 1991. The current situation of decentralized electrification includes an overall 1805 micro-hydro power plant, 13 solar mini-grid, 10 wind-solar hybrid, 8 biomass, and 952903 solar home system installed in a different rural part of Nepal as per the data published by AEPC.

Due to the huge possibilities and potential for Hydro Electricity Power Plant in Nepal, the implementation of micro-hydropower plants is becoming popular and supported by governmental bodies to achieve the target successfully. The micro-hydro power plants implemented in Nepal cannot be only beneficial for the local consumers from the community level but also help fulfill the requirement of energy in urban areas that are used for personal, commercial, and even small-scale industries that are operating in Nepal. The encouragement for implementation of the micro-hydropower plant is only feasible at the location where there are fast-flowing rivers that are situated mostly in the Himalayan Region and Hilly Region.

The major hydropower plant operating in Nepal are Sapta Koshi East & Central Hydro Power Plant, Western Sapta Gandaki Hydro Power Plant, Far Western Kamala, and Mahakali Hydro Power Plant, and southern rivers that have been used for supplying the required energy to the Nepalese consumer. The ineffective governance and political instability are becoming the main lagging reasons for infrastructure development in Nepal including development as well as production of the

hydroelectricity. The production is notable to fulfil the current consumer demand which is fulfilled by importing energy from the neighbouring country like India.

From the proper implementation of the Decentralized Energy Production and Distribution in Nepal, it is essential to implement good governance including the proper feasibility of the project along with precise determination on the project budget, cost, and scope that it can help in economical, ecological, and environmental concerns.

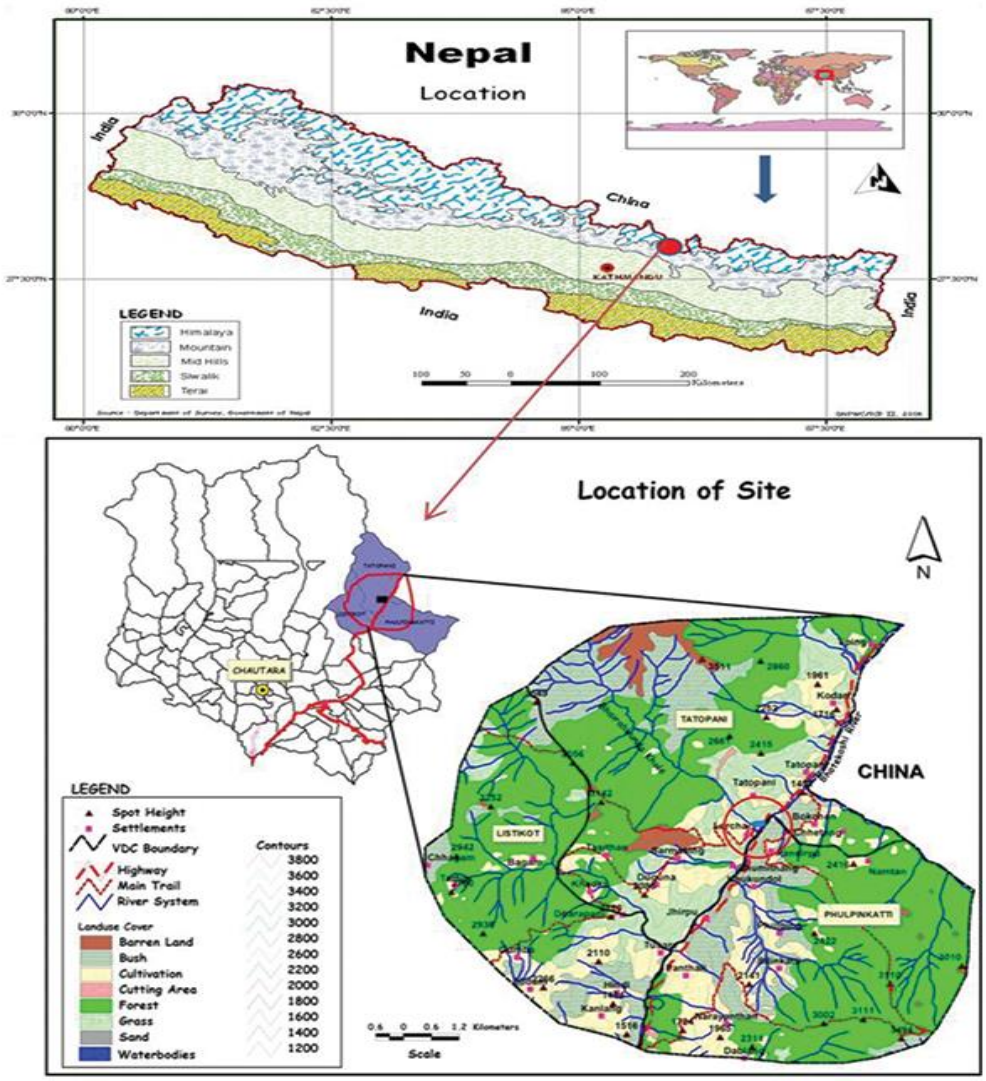
## 4.9 **Case Study on Upper Bhote Koshi Hydro Power Plant:**

### 4.9.1 **Overview of Upper Bhote Koshi Hydro Electricity Power Plant:**

The Upper Bhote Koshi Hydro Electricity Power Plant is based on a run-of-the-river system that is opened using the Bhote Koshi river as a tribute to the Sun Koshi River located in the Sindhupalchowk district in Nepal. The Upper Bhote Koshi Hydro Electricity Power Plant is about 500 m downstream at the convergence of Bhote Koshi River and Jun Khola near Tatopani VDC.

The Upper Bhote Koshi Hydroelectricity Power Plant is constructed with a scheme that collects the surface powerhouse through a headrace conveyance system in where the surface de-sanding basin situated together to a weir which is a 3.3 KM long headrace tunnel that thrust the water to two rotatory turbines. The generator units operate to produce overall 36 MW as a Power Purchase Agreements (PPA) according to the Nepal Electricity Authority (NEA). The Upper Bhote Koshi Hydro Power Plant was synchronized to the NEA grid on 3$^{rd}$ January 2001 and was commercially started on 24$^{th}$ January 2001.

Figure 13. Upper Bhote Koshi Hydro Power Plant (Bhatt R. P., Hydropower Development in Nepal - Climate Change, Impacts and Implications, 2017)




The above Figure 13. shows the location of Upper Bhote Koshi which is situated in the Himalayan region and flows over toward Tatopani VDC leading towards China. The salient features of the Upper Bhote Koshi Hydro Power Plant include total production of 224.970 GWh.

### 4.9.2 **Validity of Case Studies on Upper Bhote Koshi Hydro Power Plant:**

The information that has been depicted in this research paper has been gained by performing baseline studies on the open-sources made available through the

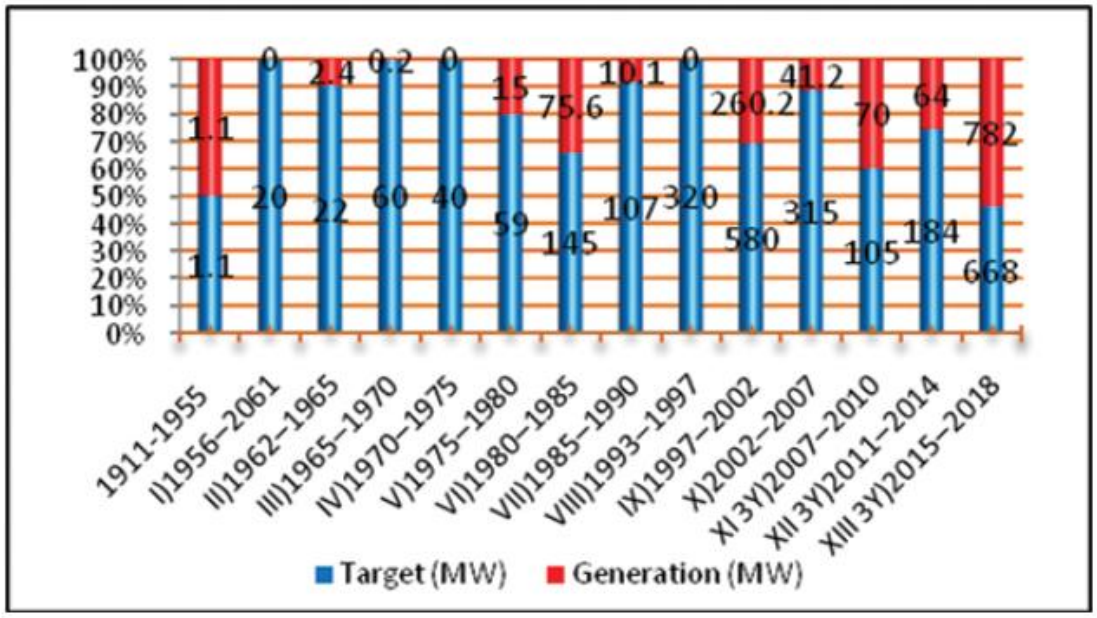
internet. The research conducted for “Case Study of Upper Bhote Koshi Hydro Power Plant” has been implemented based on a plan, policies, sectoral guidelines, and strategies whilst the data were compiled as well as cross-checked from the past reports till the current timeline. The analysis of this case study will eventually help the reader to understand the present situation of decentralized energy production and distribution in Nepal including its impacts and implications along with the precise planning, statistical analysis, computational simulation, and final publication of the information provided by an authorized source such as Nepal Electricity Association (NEA).

The data interpreted in “Decentralized Energy Generation in Nepal is based on the secondary assessments of case studies discussed by Ramesh Prasad Bhatt in a report (Bhatt R. P., 2017) particularly from the research paper and report published by the Department of Electricity Development (DoED), Department of Hydrology and Meteorology (DoHM), Government of Nepal/ Water Energy Commission Secretariat ( GoN/WECS), Nepal Electricity Authority (NEA), and other hydropower developing agencies.

### 4.9.3 Technical Analysis of Upper Bhote Koshi Hydro Electricity Power Plant:

The electricity produced from the “Upper Bhote Koshi Hydro Electricity Power Plant” was considered to generate about 16.6% of total electricity that is 70% of the majority of renewable electricity (REN, 2016) with an annual increment for the next 25 years. Due to the increase in population that has been predicted to be 8.8 billion by 2035 which simultaneously requires an equal need for energy to conduct people's daily life whereas it has been predicted that there will be a 34% of raise in energy consumption between 2014 – 2035. Similarly, the average energy production has been predicted to increase to 43% between the period 2016-2040 including other alternative sources of energy like geothermal, hydro, and biomass electricity. (Figure 14.)

Figure 14. Hydro Power Plant Development in Nepal (1911- 2016)(Bhatt R. P., 2017)




The initiation of the Hydro Power Plant (Bhatt R. P., 2017) project started from 1911 which generated about only 1.1 MW between the five years of interval whereas during the consecutive years between 1911 till 2014 was quite difficult to meet the expected target of production.

Finally, the 13$^{th}$ plan for hydroelectricity production till five years of an interval between 1911 till 2018 was to generate 668 MW as an expected target whereas the fiscal year of 2018 lead toward the production of 782 MW electricity which was 114 MW extra electrical energy. From the year 1911 until 2014, it took nearly 100 years for effective production and to meet the expected energy production.

To promote the usability of sustainable energy production, infrastructural development, and deployment of the energy as per the strategies set by the Water and Energy Commission Secretariat (WECS) in 2012 predicted an assumption of decrement in fossil fuel energy by 20% by 2020 and 30% by 2030.

# 5 FINDINGS

## 5.1 Economic and Ecological Benefit of Decentralized Energy Generation in Nepal

The overall hydropower plant potential (Seth, 2018) in Nepal is predicted to escalate to 50000 MW whereas the actual production output is about 1200 MW from 20 major hydroelectricity power plants including micro-hydropower plants. The expected electrical production in Nepal has been disturbed due to the political instability and geopolitical reason. If is settled it can be helpful for the country to export energy to its neighbouring countries like India due to its gradual increase in energy consumption rate in the future. According to the International Finance Cooperation discussed a great potential for the energy-starved South Asia holds the potential to produce and supply the energy required for the South Asian countries.

As per the spring meeting held in Washington DC (IFC, 2020) where the CEO of the IFC Jin-Yong Cai is keen to support hydro-powered projects which will help in the production of green electrical energy to fulfil the energy demands for the countries situated in south Asia. Jin Yong Cai from IFC also suggested the finance minter Ram Sharan Mahat of Nepal help the country for earning the much-needed foreign exchange of revenue from exporting power.

The implementation of renewable sources of energy like Hydroelectricity, Solar, and Thermal will help not only for the collection of revenue but also helps in the creation of employment opportunities. The diversified geographical topology of the Himalayan and Hilly region has helped the country to conduct a limited number of small-scale to large-scale hydroelectricity power plants which have provided opportunities for the local people around the power plant for the various technical and non-technical field.

More importantly, the benefit of using renewable energy and its production can help in generating energy without greenhouse gas emissions that can reduce global warming and encouragement for the reduced use of fossil fuels. Other benefits of using Decentralized Energy Production based on renewable energy such as Hydro Electricity Power Plant, Thermal, Solar and Wind can help in diversifying the energy

supplies as well as reduce dependency on imported fuels that are limited on earth's crust. The implementation of the Decentralized Energy Production and Distribution using Hydro Power Plant project in Nepal helps in the assessment of the availability of locally renewable resources which is not limited and replenish in the environment naturally.

The ecological benefit of DEG in Nepal will contribute toward the reduction of CO2 emission which has been encouraged due to heavy uses and dependency on fossil fuel. With a dependency on renewable sources of energy which will help a lot for a clean and green environment with control over air pollutions that significantly help in the improvement of the public health as most of the health issues are raised from air and water pollution.

Renewable source of energy that is abundant and feasible in Nepal is Hydro Electricity Power Plant and in addition to it, the usability of wind and solar energy also contributes to the generation of energy which can help in countering technical difficulties behind the implementation of the Hydro Electricity Power Plant.

## 5.2 **Possibilities of Decentralized Energy, Capacities and Implementation in Different Places of Nepal**

Nepal due to the geographical complexity has provided an abundant number of fast-flowing rivers covering over 395,000 ha (48%) area within 4,5000 km in length. The naturally scenic country holds 6000 rivers with 170 billion m3 annual run-off and 45,610 MW that is feasible for hydroelectricity production. Nepal has endowed (CBS, 2005) with renewable water resources with a higher potential for electricity generations that possess about 2.27% of the world's freshwater resources.

Most of the rivers situated in Nepal flows from the High Himalayan Region that covers 818,500 ha that covers around 48% of Nepal's total areas which has provided the country with a boon for hydropower developments. There are about 33 total rivers which consist of their drainage areas (194,471 square KM) that exceed 1000 square km. Each of these 33 rivers consists of a respective drainage system and other

remaining water flows toward India and China naturally. The overall annual average discharge of Nepalese rivers is about 7124m3/s along with a total basin area of about 5479 m3/s excluding the areas that are not located in Nepal.

According to the research and analysis on renewable energy production in Nepal, that 62% of renewable energy is produced using Hydro Electricity Connected Grid that is conducted and operated by NEA, 30% of the renewable energy production in Nepal comes from IPP Hydro Electricity Power Plant and a minor availability of other sources of renewable energy are used like thermal energy (7%), total solar NEA (0%) and Hydro Isolated NEA by 1%.

The energy that has been used by Nepalese consumer is made possible by extraction of energy using Hydro Electricity Power Plant, 39% of energy using purchasing from the private sector in Nepal, 22% of the energy are made available to the consumer by purchasing from India and very unnoticeable amount of thermal energy are available in the Nepal that is used daily the consumer living in Nepal. Most of the energy sales in Nepal are done for domestic sales by 36%, commercial sales by 10%, non-commercial by 4%, industrial for 42%, export by 1%, and other purposes by 7%.

The Nepalese government collects a huge revenue from the net electricity sales by 88% and other revenues are collected from financial income by 5% and other income by 7% from Hydro Electricity Power Plant in Nepal.

The implementation of the Hydro Electricity Power Plant (Chhetri, Decentralization of Energy Systems for Sustainable Economic Development in Nepal, 2007) has been encouraged and currently running in different locations such as East Sapta Koshi and Central Sapta Koshi Hydro Power Plant with a capacity of 22350 MW, Western Sapta Gandaki Hydro Power Plant with a potential capacity of 20650 MW and other southern rivers with a potential of 4100 MW according to the research conducted by Arjun B. Chettri in 2007.

The majority of the remote Nepalese citizen is used biomass as a source of energy by 85% which can eventually deteriorate their health through polluted air consisting of CO2 where the electricity generated from the Hydro Electricity Power Plant can be safe and green that can contribute towards good public health as well as maintaining the ecological balance in Nepal.

### 5.2.1 **Present Situation of Renewable Energy**

The rivers in Nepal consist of the storage capacity of the 202,000-million-meter cube which consists of about 74% amount that is collected from Gandaki, Koshi, and Karnali rivers. According to the geographical analysis of Nepal, the perennial nature of rivers located in Nepal has been estimated with an annual runoff accounting for up to 170-billion-meter cube that flows from the steep gradient and rugged topography that is currently providing toward overall 45,610 MW. The feasibility studies conducted, and measurement performed showed a potential of 83,290 MW production of hydroelectricity in Nepal. The majority of hydroelectricity systems that are running in Nepal is dominated by run-of-river schemes and the storage schemes that used to benefit for the flood control, irrigations facilities, water supplies, aquaculture, tourism, recreation and generate revenue. The initiation of the Hydro Electricity Power Plant can be traced to the 22$^{nd}$ of May in 1911 that was done by the installation of 500 KW electricity at the Pharping which was recognized as Chandra Jyoti. Whilst, after 25 years the prime minister Dev Shamsher with the initiation of 640 KW which was recognized as Sundarijal Hydropower plant with an overall capacity of 900 KW during 1936. After the work progress in the Sundarijal was delayed and within several years Morang Hydropower Company (Pradhan, 2006) was established in 1936 and completed the third Letang Hydropower Plant with an installed capacity of 1800 KW during 1943 AD with an open investment opportunity for public/private partnership.

The rise of average electricity production (BP, 2016) using Hydro Power Plant, Geothermal & Biomass Electricity from 42% to 43% whereas it has been predicted that the average capacity utilization rate will be to 43% during 2016 – 2040. The overall production capacity (EIA., 2016) of renewable source of energies i.e., Geothermal, Hydropower, and Biomass which was 1079,14 and 52 GW will eventually increase to

1473,132 and 275 GW on a global scale as a depiction made for 2040. Amongst different renewable source of energy that is feasible in Asia, that Hydro Power Plant provides a significant potential and sufficiently supplies the energy required for the consumer with an installed capacity of 542 and 2204 GW potential.

Table 2. Electricity Demand, Consumption, Production and Physical Structures (MOE, 2016)

| Particulars | Fiscal year | | | | |
|---|---|---|---|---|---|
| | 2010/2011 | 2011/2012 | 2012/2013 | 2013/2014 | 2014/2015* |
| Production (MW) | 697.85 | 705.57 | 746 | 746 | 782.45 |
| Transmission line (km) | 1917.62 | 1987.36 | 1987.36 | 1987.36 | 1987.36 |
| Customer number | 1,854,275 | 2,053,259 | 2,599,152 | 2,713,804 | 2,789,678 |
| Distribution line (km) | 89,108.86 | 95,815.98 | 11,4160.40 | 116,066.64 | 116,090.64 |
| Available energy (GWH) | 3389.27 | 3858.37 | 4260.45 | 3092.47 | 3228.9 |
| High demand (MW) | 946.1 | 1026.00 | 1094 | 1200.98 | 1291.1 |
| Demand supply gap (MW) | 248 | 320.43 | 348 | 454.98 | 508.65 |

The given table 2 represents the electricity production in MW, Transmission Line in KM, Total Consumers, Distribution Line (KM), Available Energy (GWH) and High Demand in MW, and Demand Supply Gap in MW and which shows data from the fiscal year between 2010 to 2015.

Nepal consists of 42000 MW hydropower potentials whereas 100 MW of Micro hydropower including 2100 MW of solar power for the grid and 3000 MW of wind power renewable energy which is commercially useable in Nepal. According to Nepal's 9$^{th}$ Plan that addresses overall 2200 MW electricity production by the year 2017 whereas other studies show an estimation of 10,000 MW electricity between 10 years of interval and 17000 MW till 2030. Similarly, the government of Nepal has a plan and implemented a policy that focuses on small Hydro Electricity Production that ranges from 1 MW to 25 MW that encourages an open investment opportunity for private sectors and applies for support from large hydropower projects.

Table 2 depicts how the overall produce electrical energy is not able to meet the expected demand between the interval of five years. As at the end of the five years of

interval, 782.45 MW energy was produced whereas the highest demand rate was predicted as 1291.1 MW that shows a demand-supply gap of 508.65 MW.

### 5.2.2 **Future Strategies & Deductions for Sustaining Non-Renewable Energy**

The majority of the population and businesspersons are gradually becoming interested in fossil and fuel industries which has a long history of dependency and has become the most preferable areas of investment for most of the investor. For the decrease in consumption rate over the non-renewable energy that the majority of the population needs to understand the dark side of using the limitedly available non-renewable source of energy like Fossil-fuel. As in the present situation, fossil fuel has been abundantly used for powering many consumer products. Different international and national campaigns have been launched to encourage and spread awareness about the sustainable use of renewable energy as well as supporting different developing countries like Nepal which is rich in fast-flowing rivers for using renewable sources of energy for daily uses.

Another most important tactic that the developing country like Nepal needs to acknowledge is to create an aware group of people who are well-educated about the sustainable development for renewable energies and governmental bodies need to create a public-oriented decision for the encouragement to invest in decentralized energy production investments in Nepal. The production from green and eco-friendly hydroelectricity can eventually gain a good market space worldwide as most of the environment degrading industries are being shut down due to increased contribution to different types of pollutions like air pollution, sound pollution, water pollution, and so on.

Most of the fast-flowing rivers majorly expand from the Himalayan and the hilly region of Nepal which requires a proper feasibility study before the implementation and investing in such sector due to issues regarding the transmission line and connection grids. The hydropower project implementation requires a critical analysis from professional and experienced individuals to develop, implement, and for producing eco-friendly energy. The remote areas which are rich in fast current rivers need to be well-positioned with transportation facilities and a proper solution for the safest,

fastest, economical, and more importantly sustainable production of renewable energy which helps the country's economic growth and ecological balance.

The governmental bodies have implemented acts and regulations regarding open-investment options and share for the public interest in the Hydro Electricity Power Plant of Nepal. The initiation of such a program can help the government of Nepal or developing countries like Nepal to collect the required budget and comply with it for the progressive and sustainable development of the Hydro Electricity Power Plant and Micro-Hydro Electricity Power Plant.

# 6 CONCLUSION AND RECOMMENDATION

The implementation of Decentralized Energy Production and Distribution in Nepal has a feasible implementation due to the presence of several fast-flowing rivers for Hydroelectricity powerplant that comes directly from the Himalayan region. The use of renewable sources of energy can eventually contribute to the production of green and eco-friendly energy. It can support and encourage for minimal use of non-renewable resources like fossil fuel, coal, and another resource that are limitedly available.

The overall understanding of the status of natural resources and sources of renewable energy in Nepal can help increasing dependency in the renewable source of energy i.e., hydro, wind, solar, and thermal which has been initiated since 1991 and even supported by the international campaign. The decentralized energy production in Nepal can contribute hugely nationally and the collection of international revenues can help the country grow not only to be prosperous but also help in environmental conservations with ecological benefits.

The possibilities of decentralized energy generation started in 1911 (Bhatt R. P., 2017) shows a gradual increase in production and meet the minimum requirement after 2014 that has somehow withstood the present energy necessities in Nepal. The wise implementation and sale of the energy generated using renewable sources of energy, and most importantly the hydropower plant, can contribute towards economic

prosperity and help in countering the global threat situation of higher global warming. Some of the most convenient solutions and recommendation for Decentralized Energy Production and Distribution using renewable source of energy has been presented below.

## 6.1 **Present Status of DEG in Nepal**

The present analytical statistic and infographics published (Bhatt R. P., 2017) on an annual report of NEA show that the highest rate of overall electrical energy has been consumed by Nepalese consumers for domestic work. The Nepalese consumer needs to be aware of the present situation of energy usability trends and dependability in it which can lead toward the awareness and reduction on unnecessary or misuse of the produced energy. The overall surplus energy which has been carefully saved can be used for sales as well as export in a good price schemes that can aid a huge profit for international revenue exchange in Nepal.

Besides the information that most of the electricity has been consumed for domestic work and shows a very nimble amount of energy has been consumed by the industrial sector that can create negative progress for the economical sustainability of the country. The government of Nepal and particularly the department of renewable energy (Bhatt R. P., 2017) needs to focus on creating a strong policy and implement a campaign that supports in growth and advancement of micro hydropower projects and other power plants that is based on renewable energy. The wise decision and awareness for saving electricity in Nepal can help and contribute to escalating the uses of surplus energy in the commercial and non-commercial work in the nation that can double the profit from the manufactured goods and its sales at a national and international market.

Similarly, the major proportion of the electricity that is generated using renewable source of energy in Nepal is produced and transmitted by NEA Connected Grid Line (62%), whereas 30% of the electricity is generated by Independent Power Producer that is a non-governmental agency that sales energy for its end users. Besides the hydroelectricity power production in Nepal, other various energies like thermal energy and solar energy are used to produce a tiny proportion of energy usability in the

Nation. The overall production of electrical energy in Nepal which is concerned with public and private sectors needs to be monitored and audited properly for a transparent operation of financial transaction that is related with renewable energy.

The present situation as published by NEA during 2019 shows that the majority of the energy is produced from hydropower plant (39%) in Nepal and the rest of the annual energy requirements are fulfilled from the purchase made outside the country where 22% energy is purchased from India and 39% of the energy are purchased internally from Nepal. The annual report of NEA publishes that 83% of electrical energy produced in the nation is used for internal sales that create very few percentages available for export of energy which is only 1%. Besides, an analysis from the earliest initiation of hydroelectricity powerplant from 1911 till 2021 shows a recent growth in energy production. The production meeting its target in 2014 shows a potential future for the proper management of energy produced from DEG system and eventually benefit the country hugely for exchange of international revenue in the southern part of Asia. The analysis between 1911 till 2021 shows that the dependability on India for electrical energy is somehow reducing, and a huge debt from the loan as well as its interest are being paid. This can be eventually overcame in the future with a transparent, stable, and effective governance from the Department of Renewable Energy in Nepal.

### 6.1.1 **Possibilities of Decentralized Energy, Capacities and Implementation in Different Places**

With proper governance and management of work for Decentralized Energy Production in Nepal using renewable source of energy can benefit the from multiple perspectives i.e., economic, social, environmental, and ecological. Similarly, the interpretation provided by the data published by the authority shows a growth in electricity production that meets with the target in 2014 longing from past century that the authority was able to maintain pace with the target. The analysis of the data which has been presented by the authority about the energy production in Nepal provides information regarding this century with a sign of great potential to supply energy for about half of the globe that can lead to a global contribution. Nepal has been gifted with a boon of the highest mountains and a number of mountains that

provides water for the fast-flowing rivers that provide an advantage to the country to build a hydropower plant that can provide an effective and clean electrical energy.

Moreover, the energy produced from the use of DEG and Hydro Electricity Power Plant helps in the production of green and eco-friendly means of energy production and utilization for daily electronics work throughout the Globe if managed appropriately.

With a theoretical potential of about 90000 MW in Nepal, the current overall energy production is estimated as 42000 MW which is economically and technically viable. The present situation of Hydro Electricity in Nepal has just been started to gradually progressing from 2014 (Bhatt R. P., 2017) which took nearly a century to achieve with more future possibilities. The bitter truth about it is that only 2% of overall electrical energy has been accessed in Nepal. The remaining 98% of the free energy is all going into vain while the majority of the population is relying on non-renewable sources of energy like fossils, fuel, coal, biomass, etc. for their daily way of life. The overall struggle lasted for nearly a century which has come to an end after strict implementation of 12 hours load shedding a day . It was a total blackout for the electrical dependent for most the commercial and non-commercial consumers. The potential amendment of the act for an open invitation for investment in the Hydro Electricity Power Plant in Nepal attracted a lot of private sectors and even individuals or the public were offered with an initial public offering option that helped the country to maintain the target of the generated electrical energy. The current situation and timeline are most suitable for organic growth of hydroelectric power plant in Nepal, as of whole south Asian countries are interested in investing in the Decentralized Energy Production & Distribution to different locations to reduce and eliminate the dependency on the non-renewable source of energy like fossils, fuel, biomass and anything limited as a natural resource. The most potential and favoring point for good possibilities of DEG in Nepal is that as the overall temperature of the Earth is rapidly increasing due to excessive CO2 emission creating a devasting problem and sustaining the lifespan of the planet by eradicating the industries and factories that relies on an excess amount of non-renewable source of energy for their product by alternating it with green electrical energy produced from the hydroelectric power plant.

### 6.1.2 **Economic and Environmental Benefits of DEG in Nepal**

The open invitation for the investment in the Hydroelectricity powerplant in Nepal for the private sector through a competitive basis and the proposal for tenders have increased the economic benefit for not only for the governmental sector but also for the private sectors to invest. This supports the government as well as the country to benefit from Hydroelectricity that promotes economy of the country and ecological balance worldwide. The implementation and encouragement of this act in Nepal have consecutively increased the targeted electrical energy production in Nepal by 2014 and shows a positive chance of advancement in the coming future.

In comparison, other sources of energy that are used for small-scale to large-scale production have maintained a negative impact on the environment as well as for contribution toward pollutions. Most of the social welfare organizations are focused on the environmental health of the earth as well as the living beings including human beings, that are living in same ecology. Similarly, an early campaign has already started by different social agencies like UNDP to reduce the dependence on the non-renewable sources of energy which potentially has provided a proposal of support and integration for the green energy production in Nepal.

The recent studies (UNDP, Poverty Reduction SCALING UP LOCAL INNOVATIONS FOR TRANSFORMATIONAL CHANGE, 2011 ) show a positive impact on the environment and ecological balance of nature contributed by the implementation of the DEG in Nepal. This was discussed in an open seminar whereas the higher authorities have already promised to support and aid in a hydro project for sufficient supply in not only Nepal but also for most of the countries situated in South Asia. The most remarkable thing about the future (Willcox, 2018) is that the international social welfare agencies are interested in the removal of remote poverty in Nepal by implementing and support aid program to conduct Decentralized Energy Production and Distribution is very lower price rate as well as by proving options for the local employment creation. The majority of the scholar suggests the hydropower development in Nepal contributes and help in yielding multiple benefits both economic and environmental in the country.

The invitation and initiation of the Hydroelectricity powerplant can favour on the infrastructural development like road, lines, supplies. It can also benefit the local people living in the remote areas whereas the people can be also facilitated with electrical energy which is clean and green that can potentially help the public to access electronics appliances like a computer, smartphones and internet connection that could help in the advancement of people living in a remote location with economic opportunities. Similarly, the revenues and surplus profit gathered from the Hydroelectricity powerplant established in the remote areas helps to contribute toward environmental sanitation and creating awareness on the critical situation about how non-renewable consumption could lead toward devasting consequences. Moreover, the water resources that are used for the production of electrical energy can also be used for the benefit of agriculture work in the country as it is considered as a good country for agricultural development in a nation.

### 6.1.3 **Future Strategies, Recommendation and Deductions**

The effective implementation of DEG in Nepal can contribute and promote different developmental work as well as help in the improvement of remote areas. The future potential for the DEG implementation particularly in Nepal could be beneficial not only to increase the country's revenue but to change habitual dependency on non-renewable energy. The implementation of smart appliances like IOT i.e., miniature computers, can help in creating a dynamic system which can communicate in real-time with the users for effective control and manipulations.

Similarly, the large-scale industries that are dependent on non-renewable energy of sources should consider moving toward energy that comes from a renewable source of energy that can contribute toward sustainable production and usability of the energy.

Another suggestion for proper governance and management of energy in Nepal, precise details like production, the target should be made available easily through internet technology or even it can be advertised for open public participation. The

amendment of the governmental acts and laws has helped and aid the governmental sector to stage and grow with the expected target of green energy production.

## References

ADDCN. (2009). *Decentralized Rural Energy.* KTM: Association of District Development Committees of.

Agrawal. (2003). *Development and Climate change in Nepal: Focus on Water Resources and Hydropower.* Reyoholds .

Agrawal. (2003). *Priority Ranking of Climate Change Impacts of Nepal.*

Agrawal. (2003). *Priority Ranking of Climate Change Impacts of Nepal.*

Agrawal. (2003). *Priority Ranking of Climate Change Impacts of Nepal .*

Bhatt, R. P. (2017). *Hydropower Development in Nepal - Climate Change, Impacts and Implications.* Institute of Ecology and Environment: Renewable Hydropower Technologies.

Bhatt, R. P. (2017). *Hydropower Development in Nepal - Climate Change, Impacts and Implications.*

Bhatt, R. P. (2017). *Hydropower Development in Nepal - Climate Change, Impacts and Implications.* KTM: Open access peer-reviewed chapter.

BP. (2016). *Statistical Review of World Energy June 2016. BP p.l.c, . ,* SW1Y 4PD, UK: St James's Square London.

CBS. (2005). *CBS. Statistical Year Book of Nepal. s.l.: Central Bureau of Statistics,.* Kathmandu, Nepal, .

Chalise, H. N. (2020). *COVID-19 Situation and Challenges for Nepal.*

Chhetri, A. B. (2007). *Decentralization of Energy Systems for Sustainable Economic Development in Nepal.* Halifax, Canada: Dalhousie University.

Chhetri, A. B. (2007). *Decentralization of Energy Systems for Sustainable Economic Development in Nepal.* Halifax: Dalhousie University.

Dhungana, H. (2019). H*ydropower Policy and Site-Level Contestation under the Political Transition .* ktm: Journal of Forest and Natural Resource Management.

EIA. (2016). *Annual Energy Outlook 2016. US Department of Energy, 2016.* Washington DC,: US Energy Information Administration,.

Energypedia. (2013). *https://energypedia.info.* Retrieved from https://energypedia.info: https://energypedia.info/wiki/Nepal_Energy_Situation#cite_note-NEA_2011-9

Gaudel, P. (2018). *Water Resources Development in Nepal: Myths and Realities.* Hydro Nepal Journal of Water Energy and Environment .

IFC. (2020). *Harnessing Nepal's Hydropower for Energy Starved South Asia.* Washington DC: IFC.

Kayastha, S. (2015). *Decentralized Energy Units Practice in Nepal with its Challenges,.* Pulchowk Campus: Department of Mechanical Engineering.

Lewison, E. (2020). *Geographical Scholarship in Nepal: Sustainability, Infrastructure, Disaster and Power.*

Marathe, S. D. (2014). *Biomass Energy Strategy (BEST) for Nepal.*

MOE. (2016). *Electricity demand, consumption, production, and physical structures.* KTM: Ministry of Energy.

NAPA. (2010). *Nepal National Adaptation Programme of Action (NAPA) Official Document – September 2010. National Planning Commission,.* Kathmandu, Nepal, .: Ministry of Environment,.

NEA. (2019). *NEA Annual Report .* KTM: NEA.

NEEP. (2020). *http://energyefficiency.gov.np/article-energy_situation_nepal.* Retrieved from http://energyefficiency.gov.np/article-energy_situation_nepal: http://energyefficiency.gov.np/article-energy_situation_nepal

Pokharel, S. (2001). *Hydropower for Energy in Nepal,.* ktm: Mountain Research and Development.

Pradhan. (2006). *Hydropower Development. ,.* Hydro Lab Pvt. Ltd. Kathmandu, Nepal, .: NTNU.

Regmi, S. (2016). *Solar Energy Potential in Kathmandu Valley, Nepal.*

REN. (2016). *Renewables 2016. Global Status Report. .* Rue Miollis, Paris France,: Renewable Energy Policy Network for 21th Century. Renewable Energy Policy Network, REN21 Secretariat, .

Seth, M. (2018). *Harnessing Nepal's Hydropower for Energy Starved South Asia.* IFC South Asia/Communications.

Shrestha, D. H. (2017). *Facts and Figures about Hydropower Development in Nepa.* KTM: HYDRO NEPAL.

Sthapit, K. M. (1996). *Sedimentation monitoring of Kulekhani reservoir.* International Conference on reservoir sedimentation fort Collins Colorado, USA.

Tejaswi, S. (2020). *Assessment of Challenges and Opportunities in Hydropower Sector in Nepal.* KTM.

Thapa, K. B. (2020). *Paper Modeling of Wind-Solar Hybrid Power System for Off-Grid in Nepal and a Case Study.*

Thapa, R. B. (2020). *IDENTIFYING THE BEST DECENTRALIZED RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN NEPAL.*

Thapa, R. B. (2020). *IDENTIFYING THE BEST DECENTRALIZED RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN NEPAL.*

UNDP. (2004). *Integrated Sustainable Rural Development: Renewable Energy Electrification and Rural Productivity Zones.* JARS.

UNDP. (2011 ). *Poverty Reduction SCALING UP LOCAL INNOVATIONS FOR TRANSFORMATIONAL CHANGE.* New York : UNDP.

UNDP. (2014). *Discussion Paper, Integrated sustainable rural development: renewable energy electrification and rural productivity zones.* Hasanuddin University : JARS.

UNDP. (2014). *Integrated sustainable rural development: renewable energy electrification and rural productivity zones.* JARS.

Upreti, B. R. (2020). *IDENTIFYING THE BEST DECENTRALIZED RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN NEPAL.* KTM.

Uprety. (2000). *The Physiography and Geology of Nepal and their Behaving on the Landslide Problem.*

Willcox, M. (2018). *NAE Case Study: Nepal, Rural Energy Development Programme.* Silvia: Energypedia.