CSOLAR POWER IN NEPAL TO MITIGATE CLIMATE CHANGE

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Sanogaucharan, Kathmandu

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Dal Bahadur Pandey
Symbol No. 4002
Registration No. 5-1-37-0466-96

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LETTER OF RECOMMENDATION

I certify that this dissertation entitled **Solar Power in Nepal to Mitigate Climate Change** has been prepared by **Dal Bahadur Pandey** under my supervision. I hereby recommend this thesis for final examination by the research committee at the APF Command and Staff College, Faculty of Humanities and Social Sciences, Tribhuvan University in the fulfillment of the requirements for MSDPS 570 Thesis for the Master's Degree in Security, Development and Peace Studies.

I recommend this thesis for its final evaluation and acceptance.

…………………

Dr. Naresh Rimal

Thesis Supervisor

APF Command and Staff College

Date: September 2022

DECLARATION

I hereby declare that this thesis paper entitled **Solar Power in Nepal to Mitigate Climate Change**, has been done by myself and no portion of the work contained in this document has been published or submitted in support of any application for any other degree or qualification of this or any other university or institution of learning. In case of other authors' information, ideas and arguments, the sources have been duly cited and acknowledged as per the requirements. The copyright of this research work belongs to the author.

Signature:

Name: Dal Bahadur Pandey

6th APF Command and Staff Course

Date: Bhadra 2079 (September 2022)

APPROVAL SHEET

This thesis entitled **Solar Power in Nepal to Mitigate Climate Change**, submitted by Dal Bahadur Pandey, has been accepted in partial fulfillment of the requirements for Master's Degree in Security, Development and Peace Studies.

EVALUATION COMMITTEE

…………………

Dr. Naresh Rimal

Supervisor

Date: September 2022

…………………

SP Lakesh Kumar Tumbahangphe

Internal Examiner

Date: September 2022

…………………

Prof. Dr. Sohan Kumar Karna

External Examiner

Date: September 2022

…………………

Prof. Dr. Kushum Shakya

External Examiner

Date: September 2022

ABSTRACT

Contemporary climate change includes both global warming and its impacts on Earth's weather patterns. The current changes are distinctly more rapid, caused by the emission of greenhouse gases. Burning fossil fuels for energy use creates most of these emissions. Many forms of disasters occur due climate change which could be mitigated if not prevented should climate change be controlled. As one of the prominent stakeholder of disaster management, climate change mitigation should be concern for APF, Nepal. Development of renewable energy results in significant energy security, climate change mitigation, and economic benefits. It is of high significance to the country from the import and trade deficit reduction perspective also. This research looks for answering the questions why climate change mitigation is important; how solar power production contributes in climate change mitigation and what is the solar power development potential in Nepal. This study is based on qualitative phenomenological research approach in which primary data are obtained from field visits and key informants interviews while secondary data are gathered from published books, online papers, articles and writings. Primary data were collected from the research site in Devighat, Nuwakot, by observation and interviewing officials available at the site. Key informants in various offices related with the topic were identified and additional data were obtained through research interviews. Most of the disasters in Nepal and around the globe are attributed to climate change. There are other various consequences of climate change that are threatening human life and existence. Development and promotion of solar power as a substitute to fossil fuel can substantially reduce the reliance on fossil fuels such as coal, natural gas, and oil. Sun's energy is limitless, unlike fossils and the change has a direct influence on the reduction of emission of harmful GHG. Nepal receives in an average 5 kWh of solar radiation per square meter per day, with roughly 300 days which is 50,000 terawatt-hours per year, which is 100 times larger than its hydro resource and 7,000 times larger than its current electricity consumption. Presently, solar plant cost per MW is approximately NRs. 80 Million which could be reduced to 5 Million with introduction of newly developed PV technology. These parameters are quite good for solar power generation in Nepal. This research has generated the theoretical concept of community solar based on community forestry and NEA.

Keywords: Climate change, Climate change mitigation, Renewable energy, Solar power, Fossil fuel substitution

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
ACE-CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
ACP	Alternative Compliance Payment
ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
APA	American Psychological Association
APF	Armed Police Force
AR5 SYR	Assessment Report 5 Synthesis Report
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CBS	Central Bureau of Statistics
CC	Climate Change
CCS	Carbon Capture and Storage
Cd	Cadmium
CDR	Carbon Dioxide Removal
CdTe	Cadmium Telluride
CH_4	Methane
CIGS	Copper Indium Gallium Selenide
CO_2	Carbon Dioxide
COP24	24^{th} Conference of the Parties to the UN Framework Convention on CC
COP26	26^{th} Conference of the Parties to the UN Framework Convention on CC
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
COVID-19	Corona Virus Disease of 2019

CPV	Concentrated Photovoltaic
CPVT	Concentrated Photovoltaics and Thermal
C-Si	Crystalline Silicon
CSP	Concentrated Solar Power
CTEVT	Council for Technical Education and Vocational Training
DC	Direct Current
DHM	Department of Hydrology and Meteorology
EPIA	European Photovoltaic Industry Association
ETS	Emission Trading Scheme
EU	European Union
EV	Electric Vehicles
FIT	Feed in Tariff
GDP	Gross Domestic Product
GEF	Global Environment Faculty
GHG	Green House Gas
GLOF	Glacial Lake Outburst Flood
GtC	Giga-ton Carbon
$GtCO_2e$	Giga-ton Carbon dioxide Equivalent
GW	Giga Watt
GWEC	Global Wind Energy Council
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
HSE	Health, Safety and Environment

ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
IEA	International Energy Agency
IMF	International Monetary Fund
IP	Industrial Process
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IPS	International Peatland Society
IRENA	International Renewable Energy Agency
ISCC	Integrated Solar Combined Cycle
KII	Key Informant Interview
KV	Kilo Volt
KW	Kilo Watt
LNG	Liquefied Natural Gas
LUC	Land Use Change
LUCF	Land Use Change and Forestry
MoEST	Ministry of Education, Science and Technology
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
MoPIT	Ministry of Physical Infrastructure and Transportation
$MtCO_2e$	Metric Tons Carbon Dioxide Equivalent
MVA	Mega Volt Amperes

MW	Mega Watt
MW_{AC}	Mega Watt Alternating Current
MW_p	Mega Watt Peak
N_2O	Nitrous Oxide
NASA	National Aeronautics and Space Administration
NDC	Nationally Determined Contribution
NEA	Nepal Electricity Authority
NF_3	Nitrogen Trifluoride
NPC	National Planning Commission
NPR	Nepalese Rupee
NRB	Nepal Rastra Bank
ODP	Ozone Depleting Potential
OECD	Organisation for Economic Co-operation and Development
OPHI	Oxford Poverty and Human Development Initiative
Pb	Lead
PFC	Perfluorocarbons
PPA	Power Purchase Agreement
PSC	Perovskite Solar Cell
PV	Photovoltaic
PVT	Photovoltaic Thermal
PWh	Peta Watt Hour (1000 TWh, or 1B MWh)
RoW	Right of Way
SAARC	South Asian Association for Regional Cooperation

SF_6	Sulfur Hexafluoride
SLCP	Short-Lived Climate Pollutants
SolarPACES	Solar Power and Chemical Energy System
SREC	Solar Renewable Energy Certificates
SRM	Solar Radiation Modification
SUT	Solar Updraft Tower
TJ	Tera Joules
TU	Tribhuvan University
TWh	Tera Watt Hour
UKCCC	UK Climate Change Committee
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Reducing Emissions from Deforestation and forest Degradation
US	United States
USAID	United States Agency for International Development
USDA	US Department of Agriculture
WHO	World Health Organization

CHAPTER I

INTRODUCTION

1.1 Background of the study

Armed Police Force (APF), Nepal is mandated for disaster management and relief work. Armed Police Force Act, 2058(2001) has stipulated APF role in disaster as "to render assistance to the relief of natural calamities or epidemic occurred or likely to occurred in any part of Nepal." The Ministry of Home Affairs has decided to entrust APF as a prime security agency in disaster management particularly in response phase.

With increasing global surface temperatures the possibility of more droughts and increased intensity of storms will likely occur. As more water vapor is evaporated into the atmosphere it becomes fuel for more powerful storms to develop. More heat in the atmosphere and warmer ocean surface temperatures can lead to increased wind speeds in tropical storms. Rising sea levels expose higher locations not usually subjected to the power of the sea and to the erosive forces of waves and currents.

Dixit (2022) mentioned that the climate-related disasters can broadly be caused by rapid-onset events and slow-onset events. Climate-dependent hazards that arise suddenly, or whose occurrence cannot be predicted far in advance, trigger rapid-onset disasters. They include cyclones and other windstorms, landslides, avalanches and floods. The warning time before these hazards strike ranges from a few seconds or minutes (in the case of landslides), to a few days (in the case of storms and floods). Most discussions of slow-onset disasters have focused on drought, whose results, in the form of water and food shortages and livelihoods lost, can take months or sometimes years to become evident. Rising temperatures, forest fires, regional sedimentation and accelerated melting of snow and glaciers can also result in slow-onset disasters whose cumulative impact may not be felt for decades although they may contribute to an increase in rapid-onset events such as flash floods.

One of the ways to mitigate climate change is to substitute fossil fuel consumption with renewable energy. Increase in the production and consumption of solar energy means reducing the use of fossil fuel which helps to mitigate climate change. Climate change mitigation ultimately contributes to disaster prevention and mitigation. Hence, the role of APF, Nepal is intertwined with disaster management, climate change mitigation and solar energy production and promotion.

1.1.1 Global Warming and Climate Change

Contemporary climate change includes both global warming and its impacts on Earth's weather patterns. There have been previous periods of climate change, but the current changes are distinctly more rapid and not due to natural cause (Allen et al., 2018). Instead, they are caused by the emission of greenhouse gases, mostly carbon dioxide (CO_2) and methane. Burning fossil fuels for energy use creates most of these emissions. Certain agricultural practices, industrial processes, and forest loss are additional sources (Ritchie, 2020). Greenhouse gases are transparent to sunlight, allowing it through to heat the Earth's surface. When the Earth emits that heat as infrared radiation the gases absorb it, trapping the heat near the Earth's surface. As the planet heats up it causes changes like the loss of sunlight-reflecting snow cover, amplifying global warming (Arias et al., 2021).

On land, temperatures have risen about twice as fast as the global average. Deserts are expanding, while heat waves and wildfires are becoming more common (Shukla, 2019). Increased warming in the Arctic has contributed to melting permafrost, glacial retreat and sea ice loss (Portber et al., 2019). Higher temperatures are also causing more intense storms and other weather extremes. Rapid environmental change in mountains, coral reefs, and the Arctic is forcing many species to relocate or become extinct. Climate change threatens people with food and water scarcity, increased flooding, extreme heat, more disease, and economic loss. Human migration and conflict can be a result. The World Health Organization (WHO) calls climate change the greatest threat to global health in the 21st century. Even if efforts to minimize future warming are successful, some effects will continue for centuries. These include sea level rise, and warmer, more acidic oceans (Seneviratne, 2021, p. 1517).

1.1.2 Renewable Energy

Renewable energy is energy that is collected from renewable resources that are naturally replenished on a human timescale. It includes sources such as sunlight, wind, rain, tides, waves, and geothermal heat. Although most renewable energy sources are sustainable, some are not. For example, some biomass sources are considered unsustainable at current rates of exploitation

(Ellabban et al., 2014). Renewable energy often provides energy for: electricity generation to a grid, air and water heating/cooling, and stand-alone power systems. About 20% of humans' global energy consumption is renewables, including almost 30% of electricity. About 8% of energy consumption is traditional biomass, but this is declining. Over 4% of energy consumption is heat energy from modern renewables, such as solar water heating, and over 6% electricity (Renewables, 2021).

Globally there are over 10 million jobs associated with the renewable energy industries, with solar photovoltaics being the largest renewable employer. Renewable energy systems are rapidly becoming more efficient and cheaper and their share of total energy consumption is increasing, with a large majority of worldwide newly installed electricity capacity being renewable. In most countries, photovoltaic solar or onshore wind is the cheapest new-build electricity (IEA, 2020).

Many nations around the world already have renewable energy contributing more than 20% of their energy supply, with some generating over half their electricity from renewables. National renewable energy markets are projected to continue to grow strongly in the 2020s and beyond. A few countries generate all their electricity using renewable energy (Sensiba, 2021). Renewable energy resources exist over wide geographical areas, in contrast to fossil fuels, which are concentrated in a limited number of countries. Deployment of renewable energy and energy efficiency technologies is resulting in significant energy security, climate change mitigation, and economic benefits. However renewables are being hindered by hundreds of billions of dollars of fossil fuel subsidies. In international public opinion surveys there is strong support for renewables such as solar power and wind power (Timperley, 2021). But the International Energy Agency said in 2021 that to reach net zero carbon emissions more effort is needed to increase renewables, and called for generation to increase by about 12% a year to 2030 (IEA, 2021).

Renewable energy is rapidly developing sector in Nepal. While Nepal mainly relies on burning biomass for its energy needs, solar and wind power is being seen as an important supplement to solve its energy crisis. The most common form of renewable energy in Nepal is hydroelectricity (Mausam, 2017). Nepal is one of three countries with the greatest increases in electricity access from 2006 to 2016, owing to grid-connected and off-grid renewable (Mackres et al., 2019).

Nepal gets most of its electricity from hydropower sources, but it is looking to expand the role of solar power in its energy mix. The average global solar radiation in Nepal varies from 3.6-6.2 kWh/m²/day, sun shines for about 300 days a year, the number of sunshine hours amounts almost 2100 hours per year with an average of 6.8 hours of sunshine each day and average insolation intensity about 4.7 kWhm²/day. The commercial potential for a solar power grid is about 2100MW (Subedi, 2019).

Power cuts with an average of 10 hours per day in the past time had been common in Nepal and Nepal Electricity Authority used to publish a time table for power cuts. Solar energy can be seen as a more reliable source of energy in Nepal than the traditional electricity. Private installations of solar panels are more frequent in Nepal. The People living in places such as Madi, Chitwan, where the Electricity Authority does not provide electricity because of Chitwan National Park, have been relying on solar power for several years (Subedi, 2019).

1.1.3 Nuwakot Solar Power Plant

Vaselina (2018) mentioned that in 2015, the World Bank announced it will extend a 38-year loan of USD 130 million to finance the 25MW solar project and grid upgrades aimed at reducing electricity distribution losses in Nepal. Nuwakot Solar Power Station is located at Bidur Municipality Ward No. 4 and 6 of Nuwakot District of Nepal. According to key informant, and Deputy Manager of Grid Solar and Energy Efficiency Project at Nepal Electricity Authority (NEA), it is the largest solar power plant of Nepal so far. The plant is owned by NEA.

A key informant and Site Manager at Risen Energy Company mentioned during the field visit that the solar panels are installed in seven locations within the premises of Devighat Hydropower Station which is also owned by the NEA. As of July 2022, the project has started to produce 21.5MW solar energy which is connected to the 66 KV sub-station of Devighat Hydropower Station. The solar station generates energy only during the daytime.

Another key informant and Accident Prevention Officer of Health, Safety and Environment (HSE) Department of Risen Energy Company stated that the contract was awarded to the Chinese contractor Risen Energy Company Limited for the installation, operation and maintenance of the plant for the first five years upon completion. After that, the plant will be handed over to the NEA. Construction of the station began in 2018. Its targeted construction duration was one year however there were delays due to environment studies and nationwide lockdown to prevent the spread of COVID-19 pandemic.

A key informant at NEA stated that the project cost is approximately NPR 4 Billion which is funded by the government through NEA and concessional loan from the World Bank. The loan is a part of an agreement with the World Bank made in February 2015 to provide $130 million to the government of Nepal to build solar stations to supply electricity to the Kathmandu Valley. Out of the total amount, $37 million was allocated for this solar station.

1.2 Statement of the Problem

Many of the impacts of climate change are already felt at the current 1.2 °C (2.2 °F) level of warming. Additional warming will increase these impacts and may trigger tipping points, such as the melting of the Greenland ice sheet. Under the 2015 Paris Agreement, nations collectively agreed to keep warming "well under 2 °C". However, with pledges made under the Agreement, global warming would still reach about 2.7 °C (4.9 °F) by the end of the century. Limiting warming to 1.5 °C will require halving emissions by 2030 and achieving net-zero emissions by 2050 (UNEP, 2021).

Making deep cuts in emissions will require switching away from burning fossil fuels and towards using electricity generated from low-carbon sources. This includes phasing out coal-fired power plants, vastly increasing use of wind, solar, and other types of renewable energy, switching to electric vehicles, switching to heat pumps in buildings, and taking measures to conserve energy (UNEP, 2019). Carbon can also be removed from the atmosphere, for instance by increasing forest cover and by farming with methods that capture carbon in soil. While communities may adapt to climate change through efforts like better coastline protection, they cannot avert the risk of severe, widespread, and permanent impacts (IPCC AR5 SYR, 2014).

Climate change is a major problem for Nepal as it is one of the most vulnerable countries to the effects of climate change. Globally, Nepal is ranked fourth, in terms of vulnerability to climate change. Floods spread across the foothills of the Himalayas and bring landslides, leaving tens of thousands of houses and vast areas of farmland and roads destroyed. In the 2019 edition of Germanwatch's Climate Risk Index, it was judged to be the ninth hardest-hit nation by climate calamities during the period 1999 to 2018 (Eckstein, 2019).

Nepal is a least developed country, with 28.6 percent of the population living in multidimensional poverty (NPC, 2020). Analysis of trends from 1971 to 2014 by the Department of Hydrology and Meteorology (DHM) shows that the average annual maximum temperature has been increasing by 0.056 °C per year (Department of Hydrology and Meteorology, 2017). Precipitation extremes are found to be increasing. A national-level survey on the perception-based survey on climate change reported that locals accurately perceived the shifts in temperature but their perceptions of precipitation change did not converge with the instrumental records. MoFE (2020) data reveals that more than 80 percent of property loss due to disasters is attributable to climate hazards, particularly water-related events such as floods, landslides and glacial lake outburst floods (GLOFs).

The floods of 2018 spread across the foothills of the Himalayas and brought landslides. They have left tens of thousands of houses and vast areas of farmland and roads destroyed. Nepal experienced flash floods and landslides in August, 2018 across the southern border, amounting to US$600 million in damages. There are reports of land which was once used for growing vegetables, and has become barren. Yak herders struggle to find grazing patches for their animals. Scientists have found that rising temperatures could spread malaria and dengue to new areas of the Himalayas, where mosquitoes have started to appear in the highlands (Sharma et al., 2020).

Renewable energy technology projects are typically large-scale, but they are also suited to rural and remote areas and developing countries, where energy is often crucial in human development. As most of the renewable energy technologies provide electricity, renewable energy is often deployed together with further electrification, which has several benefits: electricity can be converted to heat, can be converted into mechanical energy with high efficiency, and is clean at the point of consumption (Armaroli et al., 2016). In addition, electrification with renewable energy is more efficient and therefore leads to significant reductions in primary energy requirements. In 2021, China accounted for almost half of the increase in renewable electricity. In 2021, Norway, known for its production of hydroelectricity, consumed hydro energy worth 45% of its total energy supply (IEA, 2021).

In 2019, Nepal's Department of Electricity Development approved survey licenses for 21 locations to prepare for the possible installation of 56 solar plants, which could have a combined solar capacity of 317.14 MW. The largest planned solar energy project is a 120 MW solar PV station in Dhalkebar in Mahottari district (Subedi, 2019).

Although Nepal’s contribution to global greenhouse gas emissions remains negligible at 0.027% of the total, it grew from 26 to 54 metric tons of CO_2-equivalent between 1990 and 2016, according to the research group Climate Action Tracker. “While the government is showing some progress in the implementation of its mitigation policies, under current policies, emissions are expected to increase between 31-36% by 2030 above current levels,” (Bhushal, 2021).

As a key security agency APF, Nepal is to be concerned with the climate change mitigation measures. Huge portion of APF budget is spent in running offices, operating vehicles and to be used as fuel in the mess. Switching to renewable energy from fossil fuel is the demand of the time.

Increase in the production and consumption of solar energy means reducing the use of fossil fuel which helps to mitigate climate change. Climate change mitigation ultimately contributes to disaster prevention and mitigation. This complex relation among disaster, climate change and solar energy is the crux of this research.

1.3 Research Questions

This study has systematically illustrated the relationship between solar power and climate change mitigation from Nepal's perspective keeping back in mind the prime role of APF, Nepal in disaster management. It further discusses on the potentiality of solar energy production, its use, policy of the government and role to mitigate climate change. This research is guided by the following research questions.

1.3.1 Why is climate change mitigation important for Nepal?

1.3.2 How solar power production contributes in climate change mitigation?

1.3.3 What is the potential in Nepal?

1.4 Objectives of the Study

The general objective of the research is to study about the solar energy resources of Nepal and its implication on climate change mitigation. More importantly it focuses on the possibilities and challenges of solar power generation to mitigate climate change. The main objectives of this study are to:

1.4.1 Identify the importance of climate change mitigation to APF, Nepal.

1.4.2 Evaluate the role of solar power generation in climate change mitigation.

1.4.3 Study the solar power potential in Nepal by studying Nuwakot Solar Power Station.

1.5 Significance of the Study

While there may be some GHG emissions produced during the manufacturing and recycling of the solar system, the generation of energy results in zero GHG emissions and zero environmental impact. This research paper has diagnosed the solar power potential in Nepal and its role to mitigate climate change. Many forms of disasters occur due climate change which could be mitigated if not prevented should climate change be controlled. As one of the prominent stakeholder of disaster management, climate change mitigation is the concern of APF, Nepal.

Climate change is a burning issue in the contemporary world. It is already happening as temperatures are rising. Drought and wild fires are starting to occur more frequently, rainfall patterns are shifting, glaciers and snow are melting and the global mean sea level is rising. This has created serious challenges to the mankind as more frequent and intense drought, storms, heat waves, rising sea levels, melting glaciers and warming oceans can directly harm animals, destroy the places they live, and wreak havoc on people's livelihoods and communities. As climate change worsens, dangerous weather events are becoming more frequent or severe. The major causes of the climate change are burning fossil fuel and forest product as a source of energy to be used in various human activities.

Nepal is highly vulnerable to climate change and has already experienced changes in temperature and precipitation at a faster rate than the global average. Due to its geography, Nepal is exposed to a range of climate risks and water-related hazards triggered by rapid snow and ice melt. Millions of Nepalese are estimated to be at risk from the impacts of climate change including reductions in agricultural production, food insecurity, strained water resources, loss of forests and biodiversity, as well as damaged infrastructure. In Nepal, about half of greenhouse gas emissions come from the agriculture sector, followed by energy, land-use change and forestry, industrial processes, and waste. Nepal is importing huge scale of fossil fuel every year for which large amount of foreign currency is going out of the country, further deteriorating already troubled balance of payment due to excessive import of goods and services.

This study is importance because developing solar energy helps to reduce the serious impacts of climate change, the disasters and many more. For the developing country like Nepal, the development of solar power energy also contributes to minimize trade deficit. As climate change causes many disasters and management of which is one of the prime mandates of APF, Nepal, this study is very important to add knowledge on disaster management from the perspective of prevention and mitigation. As this study reveals that the climate change has many consequences which have implications in national security, economy and social wellbeing and survival and existence of human being, the study is of significance not only to security personnel but also to different levels of government officials, planners, policy makers, business communities, researchers, academicians, private citizens and so forth.

1.6 Limitation of the Study

The limitations of the study are the barrier for the researcher to carry out an in-depth analysis in the concerned subject matter. The research also has certain limitations as outlined below.

1.6.1 This research is limited to the study of the causes of climate change; importance of its mitigation and measures to mitigate It has not considered the adoption measures of dealing with climate change.

1.6.2 Furthermore, role of renewable energy, especially solar power to mitigate climate change, its potentials and development possibilities in Nepal have been studied with reference to Nuwakot Solar Power Station of Nepal Electricity Authority located at Devighat, Nuwakot. Other renewable energies such as hydropower, bio fuel, biogas, wind power, and small scale home solar system etc. as options of fossil fuel substitution and climate change mitigation; are not the focus of this study.

1.6.3 Solar power development could have multiple benefits apart from climate change mitigation such as contribution in import and trade deficit reduction; light and energy access to remote areas, social and economic development of the country, improvement in health and education etc. but those are not given due emphasis in this research.

1.6.4 Based on this study and personal experiences of rural livelihood the researcher has proposed Community Solar Model for Nepal incorporating some features of Community Forestry and Rural Electrification. The study does not cover the detailed analysis of possible impacts of such community solar on rural people, women, children, and marginalized group of people. So, further study specific to Community Solar is needed prior to implementation.

1.7 Organization of the Study

As discussed in the previous section, this study intends to evaluate the potential of solar power in Nepal to mitigate climate change. This study has been organized into seven chapters. Each chapter is devoted to some aspect of the study. The first chapter introduction consists of general background, statements of problems of the study, and objectives of the study, significance of the study, limitation of the study and organization of the study.

The second chapter review of literature deals with of the related existing studies. Therefore, this chapter includes the review of major journals, research work, and research etc along with conceptual framework. The third chapter represents the methodology adopted for the research design, sources and technique of data collection, population and sample. Chapters four, five and six are thematic chapters which deal in the main analysis, findings and discussions of the study. The fourth chapter includes presentation and analysis of primary and secondary data related to climate change mitigation. The fifth chapter is dedicated to presentation and analysis of primary and secondary data related to solar power in Nepal. The sixth chapter is the blending of chapter four and five where the intertwined relationship between solar power generation and climate change mitigation has been established. The seventh chapter summarizes the research with conclusion.

CHAPTER II

LITERATURES REVIEW

Global Environment Facility (2021) explained that mitigating climate change is about reducing the release of greenhouse gas emissions that are warming our planet. Mitigation strategies include retrofitting buildings to make them more energy efficient; adopting renewable energy sources like solar, wind and small hydro; helping cities develop more sustainable transport such as bus rapid transit, electric vehicles, and bio fuels; and promoting more sustainable uses of land and forests.

Global Environment Facility (GEF) further mentioned that about 1.4 billion people around the world rely on traditional fuels like coal and wood to meet their basic energy needs. This is not only harmful to the environment; it can also lead to premature deaths for millions of people, especially women and children. By 2035, global energy demand is projected to grow by more than 50 percent, and even faster in developing countries. All these new consumers need clean energy that will not hurt them or the environment (GEF, 2021).

The Intergovernmental Panel on Climate Change (IPCC) explained in its report Special Report 2021 on 1.5 Degrees of warming highlights the urgency of the needed climate actions: global emissions will need to peak by 2030 and rapidly decrease to net-zero by 2050 if we are to be able to stay within the safety limits established by the Paris Agreement 2015 (IPCC, 2021).

Blakers & Lohani (2020) mentioned that the energy from coal, oil and gas is the primary cause of climate change. However, a radical transformation of the global energy system is underway. Solar photovoltaics and wind now comprise two-thirds of global net new electricity generation capacity additions because they are cheap. Deep renewable electrification of energy services, including transport, heating and industry, allows solar and wind to eliminate fossil fuels over the next few decades.

The Intergovernmental Panel on Climate Change (IPCC) highlighted that to limit global warming to 1.5 degrees Celsius, rapid reductions in greenhouse emissions are required. Because solar energy is so cheap, developing countries such as Nepal can bypass a fossil fuel era and transition directly to zero emission solar (IPCC AR5 SYR, 2014).

Solar energy is cheaper than fossil fuels, nuclear and hydro. According to the 2020 World Energy Outlook from the International Energy Agency, “For projects with low cost financing that tap high quality resources, solar PV is now the cheapest source of electricity in history" (IEA, 2021c).

According to Climate Links (2019), a global knowledge portal for climate and development practitioners funded by USAID, Nepal's total GHG emissions in 2014 were 44.06 million metric tons of carbon dioxide equivalent ($MtCO_2e$), totaling 0.09% of GHG emissions. In Nepal, 50.1 percent of GHG emissions come from the agriculture sector, followed by the energy, land-use change and forestry (LUCF), industrial processes (IP) and waste sectors which contribute 29.6 percent, 14.8 percent, 3.6 percent and 1.9 percent respectively.

Nepal's GHG emissions fluctuated but decreased overall, by 22% (12.30 $MtCO_2e$) from 1990 to 2014 driven by a sharp drop in emissions in the LUCF sector due to the lack of reported change in forest area from 2005 onward. According to multiple sources there is significant uncertainty in LUCF change over time. The average annual change in total emissions during this period was -0.4%, with sector-specific average annual changes as follows: agriculture 1.4%, energy 5.6%, LUCF -3.4%, waste 2.1% and IP 22.1% (Climate Links, 2019).

Climate Links further stated that Nepal describes its plans to reduce GHG emissions and build climate change adaptation and resilience. The NDC does not commit to an economy-wide GHG mitigation target but includes a list of 14 goals, including participation in UN-REDD+ activities that could reduce about 14 Mt CO_2e by 2020. REDD+ is a climate change mitigation solution that many initiatives, including the UN-REDD Programme, are currently developing and supporting.

Blakers & Lohani further mentioned that the solar energy is by far the largest and most sustainable energy resource in Nepal. Nepal is a country with high solar potential, moderate hydro resources and small wind and bio energy resources. Nepal has enormous and low-cost solar energy resources and its potential in Nepal is 50,000 terawatt-hours per year, which is 100 times larger than Nepal's hydro resource and 7,000 times larger than Nepal's current electricity consumption. Solar can easily meet all future energy needs in Nepal.

Nepal is a country with high solar potential, moderate hydro resources and small wind and bio energy resources. Hydroelectricity struggles to compete with the flexibility and low-cost of solar, particularly because the cost of solar continues to decline. And solar energy has far lower environmental and social impact than damming Himalayan rivers. Small-scale solar systems for individual households or villages provide electricity for lighting, computing, telecommunications, water pumping, grain grinding and refrigeration. Small amounts of solar electricity cost relatively little but make a large difference to living standards. As living standards rise, families can purchase more solar panels to mount on their rooftops. This incremental growth in solar energy capacity allows energy supply to increase in step with family income (Blakers & Lohani, 2020).

Blakers & Lohani, (2020) also explained that the Nepali people can expect to achieve a much higher living standard in the future. When Nepal catches up with the developed countries, each person will consume about 15 megawatt-hours per person per year of electricity, which is 70 times larger than today. Clean solar electricity will be used to light and heat homes, cook food, power electric vehicles and drive industry, just like in the developed countries.

Over the next 50 years, Nepal will need to install 200 watts of solar panels per person each year (about one square metre of panel per person per year).This is a similar deployment speed as in Australia, where deployment of solar and wind systems is driving down the cost of electricity. All parts of Nepal are favourable for solar energy. The area of solar panel required to match the energy consumption per person in developed countries is 40- 50 square metres per person with a nominal power capacity of about 10 kilowatts (Blakers & Lohani, 2020).

Much of this solar panel area can be located on rooftops. Some can be on the ground. Some can be floated on lakes and hydroelectric reservoirs. Some solar systems can be located in food growing areas (agrivoltaics) where widely spaced solar panels shade 10 per cent of the crop but cause little loss of production because they reduce wind speeds and evaporation rates. Balancing high levels of solar energy over every hour of every year is straightforward. Strong transmission across Nepal allows the smoothing out of local weather and demand variability. Storage via pumped hydro energy storage and batteries allows the daily solar cycle to be accommodated (Blakers & Lohani, 2020).

Pumped hydro energy storage is far cheaper than batteries, hydrogen or other storage technologies for overnight and longer-term storage, which is why it has 95 per cent of the global storage market. According to the Global Pumped Hydro Atlas, Nepal has 2,800 good storage sites, which is 50 times more than needed even after Nepal catches up with the developed countries. Importantly, none of these sites requires any rivers to be dammed, which eliminates a high environmental and social cost (IHA, 2021).

Most of the major economies around the world have pledged to reach zero greenhouse emissions by 2050. This requires the solar industry to become 30 times larger during the 2020s. Because of this massive scale-up, the price of solar panels will halve again, and the cost of solar energy in Nepal will decline far below any other energy source. Solar energy has far lower risk because solar panels can be installed incrementally. The era of hydroelectricity from damming rivers is ending. The speed of development of the global solar industry and the rapid price reductions are so fast that previous reports on energy options for Nepal require updating. Solar energy in Nepal is abundant and cheap. There is more than enough solar energy for every Nepali to enjoy the same energy consumption as in the developed countries, but without burning any fossil fuels or damming any Himalayan rivers (Blakers & Lohani, 2020).

Pandey et al. (2021) mentioned that Nepal's new NDC is more ambitious and progressive than its previous commitment, both in terms of its targets as well as coverage. It includes quantified mitigation targets and supporting policies that will be implemented within this decade to reduce the country's emissions and increase its carbon sink. Key among these targets is Nepal's ambition to increase clean and renewable energy production (from hydropower, solar, wind and bio-energy) tenfold to 15,000 MW by 2030. This would meet around 15% of the total energy demand of the country.

Among other things, this clean energy would help Nepal adopt more electric transportation and cooking technologies, replacing a significant proportion of fossil fuel imports. In its revised NDC, Nepal aims to ensure that 90% of private and 60% of public vehicle sales will be electric by 2030. Within the same timeframe, it also commits to have 25% of Nepali households use electric stoves as their primary mode of cooking. Through such interventions the government aims to reduce almost a third of the emissions from the transportation sector and more than a fifth of the emissions from cooking (Pandey et al, 2021).

From the literatures reviews it is noted that the solar power potential of Nepal has been studied to some extent. There is also an existing knowledge that solar power is a renewable energy which emits zero GHG. Furthermore, lots of research works have been already done on climate change impacts and mitigation measures. Yet, there is no study found which illustrates why climate change mitigation is important for APF, Nepal. Also, there is lack of thorough study on how solar energy generation could be a viable option to mitigate climate change and its impact, especially disasters, from the perspective of its huge potential in Nepal.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the approach used to investigate the research questions outlined in the introductory chapter. Primary data were gathered from key informants and stakeholders within Nepal such as Risen Energy Company, Bidur Nuwakot; Alternative Energy Promotion Centre, Kathmandu; Nepal Electricity Authority; Ministry of Energy, Water Resources and Irrigation; Ministry of Forest and Environment; Department of Hydrology and Meteorology etc. by employing the methods of semi-structured interviews. Secondary data were collected from international as well as Nepali Newspapers, various government official websites, reports, journals and articles.

The research is basically based on descriptive method, analyzing information collected from primary and secondary sources. Collected information, literatures and data are analyzed through the principle of social building block epistemology, ontology, methodology, and methods. The process of content analysis involved investigating, recording and analyzing past events with the view to discovering generalization that were significant in understanding of the past and the present in order to predict and deal with the issue under consideration.

The research is based on primary data obtained from field visits and key informants interviews as well as secondary data gathered from published books, online papers, articles and writings. The research is explanatory and descriptive which is done by employing qualitative research design. Primary data collected from the field study are mixed and analyzed with secondary data, documents and records to develop final research paper. The data from the field study of a specific solar power station are generalize to develop the theory, thus this research paper is inductive.

3.2 Research Design

Research design is the framework that has been created to find answers to research questions. This study is based on qualitative phenomenological research design. Phenomenological research is a design of inquiry coming from philosophy and psychology in which the researcher describes the lived experiences of individuals about a phenomenon as described by participants. This description culminates in the essence of the experiences for several individuals who have all experienced the phenomenon. This design has strong philosophical underpinnings and typically involves conducting interviews. Grounded theory is a design of inquiry from sociology in which the researcher derives a general, abstract theory of a process, action, or interaction grounded in the views of participants. This process involves using multiple stages of data collection and the refinement and interrelationship of categories of information.

The design of this research is qualitative phenomenological research based on grounded theory. It is descriptive since the available information is described as per requirement. At the same time, it is analytical as the information originate from various sources are synchronized and analyzed properly. The overall research work is conducted through collection of primary and secondary data.

Qualitative method design is adopted because qualitative data are the part of the study as per the demand of the research topic and the research questions. The research is inductive as the study is done on a particular Solar Power Station at Nuwakot district and the findings are generalized to generate theory. The rationale of choosing this particular power station is that this is among the largest solar power stations in Nepal with proposed full strength capacity of 25 MW. Another reason is location which is in mountainous district Nuwakot of the mountains dominated country Nepal.

During the research work field visits were conducted, two times. Pictures of the solar power station were taken which are included in the research to make the research more realistic. The officials and employees at the power plant were interviewed by asking open end questions as per the demand of the study. Prior to field visit, official arrangement was completed with the help of APF Command and Staff College. Collected data are presented in pictorial, tabular and descriptive analytical form. The primary data obtained from the field are utilized to validate the researcher's hypothesis, experience and existing theories.

3.3 Area of Study

Nepal is mostly a mountainous country and more than two-third part of the country lies in the mountainous region with specific height and climatic condition. So the field research of the study was Nuwakot Solar Power Station which lies at Devighat of Nuwakot district in the mountain region and is also the largest solar power station proposed in the country so far. Based on the sample study, the generalization has been made on the solar power potential/probability in the country and its possibility to contribute in climate change mitigation. As such, the study revolves around the study of climate change impacts, challenges posed by it, the possibility of solar power development in the country and the role of solar power in mitigating climate change impact.

3.4 Nature and Sources of Data

Primary data were collected for sampling purpose by visiting the research site at Nuwakot Solar Power Station in Devighat, Nuwakot district. Seven different solar farms of the 25 MW solar power project were observed and some pictures were also taken. Informal and formal interviews were conducted with the site manager; health, safety and environment officer and other employee available at the scene. The answers to the interview questions were noted on the notebook. Additionally, subject matter expert on solar power and climate change were identified as key informants in Risen Energy Company Limited; Alternative Energy Promotion Centre (AEPC); Nepal Electricity Authority (NEA); Department of Hydrology and Meteorology (DoHM), Ministry of Energy, Water Resources and Irrigation (MoEWRI); and Ministry of Forestry and Environment (MoFE). Arrangement for the key informant interview (KII) was made and the research interviews were conducted to obtain primary data. Furthermore, open ended questions were prepared and sent to the key informants through email. The list of questions sent to key informants is attached in Appendix "A". The responses were received on the filled up forms through reply email.

Central Bureau of Statistics (CBS), Nepal Rastra Bank (NRB), TU Central Library, APF Command and staff college library, AEPC, NEA, Ministry of Education, Science and Technology (MoEST), Ministry of Energy, Water Resources and Irrigation (MoEWRI), Ministry of Forests and Environment (MoFE), Ministry of Physical Infrastructure and Transportation (MoPIT), and various online sources are the secondary sources of data for the study. Various books, journals and articles related to solar power and climate change mitigation which were published at the international as well as national institutions were taken as reference of this study.

Available data were studied according to qualitative phenomenological research based on grounded theory and were critically examined to have expected conclusion of this research.

3.5 Data Processing, Analysis and Presentation

The research paper of the study is based on APA 7th Edition for the citation and referencing. Additional basis has been incorporated according to the guidance from the supervisor and APF Command and Staff College.

As the design of this research is qualitative phenomenological research based on grounded theory the data are analyzed using descriptive and analytical method. The data are processed, classified and presented according to their nature. Presenting the data includes the pictorial representation by using figures, charts, pictures and other methods but the logical and chronological arrangements is maintained. Guidance from the supervisor/s at APF Command and Staff College is taken into due consideration.

3.6 Ethical Consideration

The researcher adopted the code of ethics of American Psychological Association (APA) 7th edition during this research. There was no any mal-intention of the researcher in the outcome of the research. This is purely academic research and there was no sponsorship during the study. For acknowledgement, the rights are protected as per the existing laws during the data collection and later stages. The study has protected the secrecy of individuals and organization as per the gravity. Informants were not discriminated on the basis of sex, race and ethnicity. The study has protected the anonymity of the informants and individuals. Misleading information, exaggeration, deception and biased data are avoided. All communication related to research were done with honesty and transparency. Researcher has respected the intellectual property rights as per the APA model and there was no any dishonest practice during entire research period. The sources and data are kept confidential as per the ethics of the research. Thus, the research is conducted by adopting the general principles of ethics as responsibility, integrity, justice and the respect to intellectual property rights, conscious on multiple roles, rule of consent, confidentiality and privacy. Due acknowledgement have been given to all who guided and advised to carry out this research. Any mistakes and lapses that remain are mine own.

CHAPTER IV

CLIMATE CHANGE MITIGATION

4.1 Introduction

Climate change is the long term shift in temperatures and weather patterns, more specifically global warming and adverse weather patterns to mankind and living beings at large. This is happening because of mainly two reasons: natural and human caused. There are two ways of dealing with climate change: adaption and mitigation. Climate change adaptation is the process of adjusting to current or expected effects of climate change. In contrary, climate change mitigation consists of actions to limit global warming and its related effects.

Site Manager of Risen Energy Company, Devighat Nuwakot, stated during the key informant interview described:

> *The sea level is increasing due to rapid melting of iceberg in the polar region. Due to this the coastal regions are submerging. Many of the species are facing difficulties to adapt the rapid change in climate. This has led to shrinkage in their habitat and increase competition for food and space. This will cause the loss of species. The biodiversity and hence food chain will be affected. The high Himalayas glaciers are melting rapidly which is the main source of drinking water and farming. The increase temperature is causing the glacier to disappear. This will impact on food security of the people settling downstream. These changes go rapid and impacts are immense.*

Edenhofer et al. (2014) mentioned that climate change mitigation consists of actions to limit global warming and its related effects. This is mainly reductions in human emissions of greenhouse gases (GHGs) as well as activities that reduce their concentration in the atmosphere. It is one of the ways to respond to climate change, along with adaptation. IRENA (2019) mentioned that fossil fuels emit most carbon dioxide (CO_2) and greenhouse gas as a whole. The most important challenge is to stop burning coal, oil, and gas and use only clean energy. Due to massive price drops, wind power and solar photovoltaics (PV) are increasingly out-competing oil, gas and coal though these require energy storage and improved electrical grids. As low-emission energy is deployed at large scale, transport and heating can shift to these mostly electric sources. Mitigation of climate change may also be achieved by changes in agriculture (to reduce greenhouse gas emissions from agriculture), transport, forest management (reforestation and preservation), waste management, buildings, and industrial systems. Methane emissions, which have a high short-term impact, can be targeted by reductions in dairy products and meat consumption. According to Harvey (2019) the current trajectory of global greenhouse gas emissions is not consistent with limiting global warming to below 1.5 or 2 °C despite the limit being economically beneficial globally and to many top GHG emitters such as China and India.

Political and economical responses to date include forms of carbon pricing by carbon taxes and carbon emission trading, reductions of fossil fuel subsidies, making national promises and laws, subsidies, simplified regulations for the integration of low-carbon energy and divestment from fossil fuel finance. Almost all countries are parties to the United Nations Framework Convention on Climate Change (UNFCCC). The ultimate objective of the UNFCCC is to stabilize atmospheric concentrations of GHGs at a level that would prevent dangerous human interference with the climate system. In 2010, Parties to the UNFCCC agreed that future global warming should be limited to below 2 °C (3.6 °F) relative to the pre-industrial level (UNFCCC, 2013). With the Paris Agreement of 2015, this was confirmed.

Carbon sequestration is the process of storing carbon dioxide in solid and dissolved forms for very long periods. It is a tremendous process which could reduce the anthropogenic carbon footprint at a stable state. However, the cost of the process could be cost inefficient and the safety of the process on other ecological cycles is uncertain (UC DAVIS, 2021).

4.2 Contributors of Global Warming and Climate Change

According to Leob et al. (2021) climate change is driven by greenhouse gas emissions; loss of carbon sinks such as of tropical forests; various smaller factors such contrails of airplanes (earth's albedo and the solar cycle can also have an effect on the climate but are not considered responsible for current climate change) and feedback effects in the earth system that alter any of the above and/or climate inertia whereby mitigation at certain degrees or types becomes difficult or only causes slow response by the climate system.

Senior Divisional Meteorologist at Department of Hydrology and Meteorology, during KII described about the contributors of climate change as:

> *Burning of fossil fuels (coal, oil and gas) which is known as the principal contributor (>75%), deforestation, livestock farming, luxurious equipment and products (they emit fluorinated gases), modern living and fertilizers are the major contributors of global warming and climate change.*

One of the key informants and Joint Secretary at Ministry of Energy, Water Resources and Irrigation mentioned that greenhouse gases like carbon dioxide, methane, nitrous oxide etc. are the major contributor of the climate change that are emitted from the burning of fossil fuel, burning coal, vehicle emission etc. A project manager at AEPC stated that CO_2 released due to human activity is the major contributor of the climate change. Some other contributors are: deforestation, massive use of fertilizers containing Nitrogen, use of the coals and petroleum products and uncontrolled livestock farming.

4.2.1 Greenhouse Gases

Interview with a key informant and site manager of Risen Energy Company revealed that greenhouse gases like carbon dioxide, methane, nitrous oxide etc. are the major contributor of the climate change that are emitted from the burning of fossil fuel, burning coal, vehicle emission etc. Carbon dioxide (CO2) is the dominant emitted greenhouse gas, while methane (CH4) emissions almost have the same short-term impact. Nitrous oxide (N2O) and fluorinated gases (F-Gases) play a minor role.

With the Kyoto Protocol, the reduction of almost all anthropogenic greenhouse gases has been addressed. GHG emissions are measured in CO_2 equivalents determined by their global warming potential (GWP), which depends on their lifetime in the atmosphere. Estimations largely depend on the ability of oceans and land sinks to absorb these gases. Short-lived climate pollutants (SLCP) including methane, hydrofluorocarbons (HFCs), tropospheric ozone and black carbon persist in the atmosphere for a period ranging from days to 15 years as compared to carbon dioxide which can remain in the atmosphere for millennia. Reducing SLCP emissions can cut the ongoing rate of global warming by almost half and reduce the projected Arctic warming by two-thirds. GHG emissions in 2019 were estimated at 57.4 $GtCO_2e$, while CO_2 emissions alone made up 42.5 Gt including Land Use Change (LUC). While mitigation measures for decarbonization are essential on the longer-term, they could result in weak near-term warming because sources of carbon emissions often also co-emit air pollution. Hence, pairing measures that target carbon dioxide with measures targeting non-CO_2 pollutants short-lived climate pollutants, which have faster effects on the climate, is essential for climate goals (Dreyfus, 2022).

a. Carbon Dioxide: Olivier (2020) mentioned fossil fuel such as oil, gas and coal (89%) are the major drivers of anthropogenic global warming with annual emissions of 35.6 $GtCO_2$ in 2019. Cement production (4%) is estimated at 1.42 $GtCO_2$. Land-use change (LUC) is the imbalance of deforestation and reforestation. Estimations are very uncertain at 4.5 $GtCO_2$. Wildfires alone cause annual emissions of about 7 $GtCO_2$ non-energy uses of fuels, carbon losses in coke ovens, and flaring in crude oil production.

b. Methane: Methane has a high immediate impact with a 5-year global warming potential of up to 100. Given this, the current 389 Mt of methane emissions has about the same short-term global warming effect as CO_2 emissions, with a risk to trigger irreversible changes in climate and ecosystems. For methane, a reduction of about 30% below current emission levels would lead to stabilization in its atmospheric concentration. Fossil fuels (32%), again, account for most of the methane emissions including coal mining (12% of methane total), gas distribution and leakages (11%) as well as gas venting in oil production (9%). Livestock (28%) with cattle (21%) are the dominant sources, followed by buffalo (3%), sheep (2%), and goats (1.5%). Human waste and wastewater (21%): When biomass waste in landfills and organic substances in domestic and industrial wastewater is decomposed by bacteria in anaerobic conditions, substantial amounts of methane are generated. Rice cultivation (10%) on flooded rice fields is another agricultural source, where anaerobic decomposition of organic material produces methane (Olivier & Peters, 2020).

c. Nitrous Oxide: N_2O has a high GWP and significant Ozone Depleting Potential (ODP). It is estimated that the global warming potential of N_2O over 100 years is 265 times greater than CO_2. For N_2O, a reduction of more than 50% would be required for stabilization. Most emissions (56%) are by agriculture, especially meat production: cattle (droppings on pasture), fertilizers, animal manure while combustion of fossil fuels (18%) and bio fuels. Industrial production of adipic acid and nitric acid also emit Nitrous oxide (Thompson et al., 2019).

d. F-Gases: Fluorinated gases include hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). They are used by switchgear in the power sector, semiconductor manufacture, aluminium production and a large unknown source of SF_6. Continued phase down of manufacture and use of HFCs under the Kigali Amendment to the Montreal Protocol will help reduce HFC emissions and concurrently improve the energy efficiency of appliances that use HFCs like air conditioners, freezers and other refrigeration devices (Olivier & Peters, 2020).

e. Black Carbon: Black carbon is formed through the incomplete combustion of fossil fuels, biofuel, and biomass. It is not a greenhouse gas but a climate forcing agent. Black carbon can absorb sunlight and reduce albedo when deposited on snow and ice. Indirect heating can be caused by the interaction with clouds. Black carbon stays in the atmosphere for only several days to weeks. Emissions may be mitigated by upgrading coke ovens, installing particulate filters on diesel-based engines, reducing routine flaring, and minimizing open burning of biomass (Ramanathan & Carmichael, 2008).

4.2.2 Other Characteristics

The responsibility for anthropogenic climate change differs substantially among individuals, e.g. between groups or cohorts.

a. Generational: Researchers report that, on average, the elderly played "a leading role in driving up GHG emissions in the past decade and are on the way to becoming the largest contributor" due to factors such as demographic transition, low informed concern about climate change and high expenditures on carbon-intensive products like energy which is used i.e. for heating rooms and private transport. They are less affected by climate change impacts, but have e.g. the same vote-weights for the available electoral options (Zheng et al., 2022).

b. Wealth: Studies find that the most affluent citizens of the world are responsible for most environmental impacts, and robust action by them is necessary for prospects of moving towards safer environmental conditions. According to a 2020 report by Oxfam and the Stockholm Environment Institute, the richest 1% of the global population have caused twice as much carbon emissions as the poorest 50% over the 25 years from 1990 to 2015. This was, respectively, during that period, 15% of cumulative emissions compared to 7%. The bottom half of the population is directly-responsible for less than 20% of energy footprints and consume less than the top 5% in terms of trade-corrected energy. The largest disproportionality was identified to be in the domain of transport, where e.g. the top 10% consume 56% of vehicle fuel and conduct 70% of vehicle purchases. However, wealthy individuals are also often shareholders and typically have more influence and, especially in the case of billionaires, may also direct lobbying efforts, direct financial decisions, and/or control companies (Gore, 2020).

c. Companies, Investors and politicians: Sometimes, top contributors to greenhouse gas emissions are identified as the companies emitting most GHGs. Similarly, investing asset management firms are often identified as controllers of large amounts of contemporary financial value with insufficient dedication to climate change targets. However, it may not necessarily be the structural interest of these companies to help mitigate climate change sufficiently instead of striving to generate near maximum profit in the contemporary socioeconomic system, a globalized competitive consumption demanding environment, and use all legal means to delay climate change action if such is beneficial their products are being bought by consumers. The stock market likely underestimates social benefits of climate mitigation. They are regulated by governments, and don't have as much power as many large states which have capacities of law enforcement and military, customs, legal frameworks and for business, media, education, global, trade and industrial policies. A fraction of such policies or measures are invariably initially at least partly unpopular, and in the contemporary decision-making environment of politics, unpopular decisions may be difficult for politicians to enact directly or help facilitate indirectly. The question of the largest responsibility or driver may be about who is holding the power to create and change the systems that cause climate change, such as the transportation system. While it has been pointed out that blaming drivers may not be constructive in terms of climate change mitigation, understanding these links of the supply chain may allow better understanding of the complex system or untangling the structures of power and decision making that inhibit climate action (Baines & Hager, 2022).

4.3 Importance of Climate Change Mitigation

Bamber et al. (2019) stated that the intended effects and purpose of climate change mitigation is to prevent and mitigate detrimental direct and indirect effects of climate change, especially effects on humans and human civilization (e.g. national security) or, broadly, to enable a just future for all on a thriving planet. It has been described as protection of humanity.

IPCC (2018) mentioned that **c**limate change mitigation is important to avoid significant human interference with the climate system, and "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. Currently human activities are adding CO_2 to the atmosphere faster than natural processes can remove it. In 2018, human activities were estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels, with a likely range of 0.8 °C to 1.2 °C. Different disasters such as floods, landslides, avalanches, heat waves, cold waves and epidemics could be attributed to global warming and climate change. So climate change mitigation is important, also to reduce the impact of deadly disasters.

According to the emissions gap report of the United Nations Environment Programme for limiting warming to 1.5 °C GHG emissions should be cut from the level of 2020 by 76% by 2030. According to the Special Report on Global Warming of 1.5 °C limiting warming below or close to 1.5 °C (2.7 °F) would require to decrease net CO_2 emissions by around 45% by 2030 from the level of 2010 and reach net zero by 2050. For limiting global warming to below 2 °C (3.6 °F), CO_2 emissions should decline by 25% by 2030 and by 100% by 2075. Non-CO_2 emissions need to be strongly reduced at similar levels in both scenarios (IPCC, 2018). In 2022, the Intergovernmental Panel on Climate Change (IPCC) released its Sixth Assessment Report on climate change, warning that greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030, in order to likely limit global warming to 1.5°C (2.7°F).

The IPCC works with the concept of a fixed carbon emissions budget. If emissions remain on the current level of 42 $GtCO_2$, the carbon budget for 1.5 °C could be exhausted in 2028. The rise in temperature to that level would occur with some delay between 2030 and 2052. Even if it was possible to achieve negative emissions in the future, 1.5 °C must not be exceeded at any time to avoid the loss of ecosystems (IPCC, 2018). In the Special Report on Global Warming of 1.5 °C, the IPCC emphasized the benefits of keeping global warming below this level. Emissions pathways with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure including transport and buildings, and industrial systems. Pathways that aim for limiting warming to 1.5 °C by 2100 after a temporary temperature overshoot rely on large-scale deployment of carbon dioxide removal (CDR) measures, which are uncertain and entail clear risks (IPCC, 2018).

Climate change mitigation scenarios from the IPCC Fifth Assessment Report state that there will be 1.5 °C (2.7 °F) of warming by the end of the 21st century if emissions immediately decline and go to net zero by 2050. In the other end of the scenarios, there will be a 4.8 °C (8.6 °F) amount of warming if emissions continue upwards until they are triple current levels. The amount of sea level rise will also depend on the future emissions scenarios.

Nepal is a landlocked country with a range of climatic zones ranging from the tropical Terai plains to the alpine mountainous region of the Himalayas. Despite being globally responsible for a very low proportion of greenhouse gas emissions, Nepal is currently and will continue to be disproportionately affected by climate change. Significant threats of climate change in Nepal include rising atmospheric temperature, changes in rainfall cycle and the impact of glacial lake outburst floods and landslides triggered by climatic extremes (World Bank Country Overview, 2015). Millions of Nepalese are estimated to be at risk from the impacts of climate change including reductions in agricultural production, food insecurity, strained water resources, loss of forests and biodiversity, reduced tourism and damaged infrastructure and their associated impacts on health (Nepal Climate Change Policy, 2011).

Nepal is highly vulnerable to climate change impacts and recent studies by the Asian Development Bank suggested Nepal faces losing 2.2% of annual GDP due to climate change by 2050. Nepal ratified the Paris Climate Agreement and its Second Nationally Determined Communication (NDC) in 2020. Nepal’s Second National Communication to the UNFCCC 2014 identifies the country’s energy, agriculture, water resources, forestry and biodiversity and health sectors as the most at risk to climate change (MoHP, 2022).

According to WHO (2015) human health is profoundly affected by weather and climate. Climate change threatens to exacerbate today’s health problems, deaths from extreme weather events, cardiovascular and respiratory diseases, infectious diseases and malnutrition, whilst undermining water and food supplies, infrastructure, health systems and social protection systems. Climate variability and climate change influence diseases such as diarrhea, malaria, dengue and malnutrition. In 2014, the prevalence of under nutrition, stunting and wasting among children under five years was 30.1%, 37.4% and 11.3% respectively, and the percentage of children under age 5 with diarrhea in the last 2 weeks was 12%. The burden of malnutrition and diarrhea diseases in Nepal is expected to increase under climate change scenarios. Currently, vector-borne diseases like malaria, dengue, chikungunya, Japanese encephalitis, viceral leishmaniasis, lymphatic filariasis are endemic in the lowland Terai and hills of Nepal with an estimated 80% of the population at risk. The population at risk will likely increase in the future due to the shifting of disease vectors into highland areas, already detected at levels of 2000 m above mean sea level in Nepal.

Chief of Climate Change Section, Ministry of Forest and Environment described in KII about the significance of climate change mitigation as:

> *Nepal is one of the most vulnerable countries due to climate change. Global temperature change is causing unpredictable weather events in Nepal such as heavy rainfall, longer drought, less snow and high rain in high altitude areas where there were only snow in past causing heavy floods and landslides such as in Manang and Mustang last year. Paris Agreement is one of the instrumental tools to control global warming and has aimed to limit the global temperature rise upto 1.5 degree Celsius as compared to pre-industrial age. Studies has proven that even 1.5 degree rise in global*

average it will be around 2 - 2.1 in our Himalayan region causing heavy snow melt, glacier retreat GLOFs. Therefore CC mitigation (reduction in overall global green house gas) is important.

During the key informant interview, Senior Divisional Meteorologist at Department of Hydrology and Meteorology said that the significance of climate change mitigation is to mitigate the adverse impact of climate change in various sectors such as energy, water resource, agriculture, health, etc. A Project manager at AEPC mentioned climate change is one of the major challenge in the world impacting the life forms and also the affecting the climate of the world. If this trend continues, lifecycle of most of the species will be hampered and may also result in extinction of some of them. Hence, to preserve the life of the species of the world and to reduce the rapid and unusual climate cycle, climate change mitigation is very important.

4.4 Mitigation Measures of Climate Change

Climate change mitigation means avoiding and reducing emissions of heat-trapping greenhouse gases into the atmosphere to prevent the planet from warming to more extreme temperatures. The more we reduce emissions right now, the easier it will be to adapt to the changes we can no longer avoid. Mitigation actions will take decades to affect rising temperatures, so we must adapt now to the change that is already upon us and will continue to affect us in the foreseeable future.

4.4.1 Fossil Fuel Substitution

Site manager of Risen Energy Company and one of the key informants explained that solar has a very significant role in climate change mitigation. Main source of greenhouse gas emission is from burning the fossil fuel for energy generation. In Nepal major contribution is from burning wood for cooking which can be replaced by improved biomass stove and clean electric stove utilizing the electricity from renewable source. Furthermore, he mentioned that solar PV system is renewable source of energy which relies on the radiant energy from sun. Hence no fossil fuel is used in energy generation, thus the consumption of fossil fuel is reduced. Key informant from department of hydrology and meteorology mentioned that solar is a kind of energy which can be used in replace of fossil fuel in many of the cases. So, it helps to reduce the use of fossil fuel and ultimately contribute to reducing GHG emission and promotes climate change mitigation.

As most greenhouse gas emissions are due to fossil fuels, rapidly phasing out oil, gas and coal is critical. In a system based on fossil fuels, demand is expected to double until 2050. Switching to renewable energy combined with the electrification of transport and heating can lower the primary energy demand significantly. Currently, less than 20% of energy is used as electricity. A global transition to sustainable energy across all sectors is feasible well before 2050. With dropping prices for wind and solar energy as well as storage, the transition no longer depends on economic viability but is considered as a question of political will. The sustainable energy system is more efficient and cost effective than the existing system. Investors in fossil fuels face a growing risk of stranded assets (Storelvmo et al., 2016).

Wind and sun can be sources for large amounts of low-carbon energy at competitive production costs. But even in combination, generation of variable renewable energy fluctuates a lot. This can be tackled by extending grids over large areas with a sufficient capacity or by using energy storage (see also: forms of grid energy storage) and by other means. Load management of industrial energy consumption can help to balance the production of renewable energy production and its demand. Electricity production by biogas and hydro power can follow the energy demand. Both can be driven by variable energy prices. The deployment of renewable energy would have to be accelerated six-fold though to stay under the 2 °C target. The global primary energy demand exceeded 161,000 TWh in 2018. This refers to electricity, transport and heating including all losses. In transport and electricity production, fossil fuel usage has a low efficiency of less than 50%. Large amounts of heat in power plants and in motors of vehicles are wasted. The actual amount of energy consumed is significantly lower at 116,000 TWh. The competitiveness of renewable energy is a key to a rapid deployment. In 2020, onshore wind and solar photovoltaics were the cheapest source for new bulk electricity generation in many regions. Storage requirements cause additional costs. A carbon price can increase the competitiveness of renewable energy (He et al., 2018).

a. Solar Energy: Solar photovoltaics (PV) has become the cheapest way to produce electric energy in many regions of the world, with production costs down to 0.015 US$/KWh in desert regions. The growth of photovoltaics is exponential and has doubled every three years since the 1990s. In the summer, PV power generation follows the daily demand curve. A different technology is concentrated solar power (CSP) using mirrors or lenses to concentrate a large area of sunlight onto a receiver. With CSP, the energy can be stored for a few hours, providing supply in the evening. This can outweigh the higher costs compared to PV. Solar water heating has doubled between 2010 and 2019. Total installed solar water heating systems provide a capacity of 501 GW, with 67% of the global share in China. Photovoltaic thermal hybrid solar collectors combine PV and solar heating (Renewables, 2021).

b. Wind Power: Regions in the higher northern and southern latitudes have the highest potential for wind power. Installed capacity reached 650 GW as of 2019. Offshore wind power currently has a share of about 10% of new installations. Offshore wind farms are more expensive but the units deliver more energy per installed capacity with less fluctuation. In most regions, wind power generation is higher in the winter when PV output is low. For this reason, combinations of wind and solar power are recommended (Global Wind Energy Council [GWEC], 2019).

c. Hydro Power: Hydroelectricity, or hydroelectric power, is electricity produced from hydropower. In 2020 hydropower generated one sixth of the world's electricity, almost 4500 TWh, which was more than all other renewables combined and also more than nuclear power. Hydroelectricity plays a leading role in countries like Nepal, Brazil, Norway and China. But there are geographical limits and environmental issues. Tidal power can be used in coastal regions. Hydropower, or hydroelectric power, is one of the oldest and largest sources of renewable energy, which uses the natural flow of moving water to generate electricity. Hydropower currently accounts for 31.5% of total U.S. renewable electricity generation and about 6.3% of total U.S. electricity generation (Birol, 2021).

Nepal is rich in hydro-resources, with one of the highest per capita hydropower potentials in the world. The estimated theoretical power potential is approximately 83,000 MW. However, the economically feasible potential has been evaluated at approximately 43,000 MW (Adhikari, 2021).

d. Bio-energy: Biogas plants can provide dispatchable electricity generation, and heat when needed. A common concept is the co-fermentation of energy crops mixed with manure in agriculture. Burning plant-derived biomass releases CO_2, but it has still been classified as a renewable energy source in the EU and UN legal frameworks because photosynthesis cycles the CO_2 back into new crops. How a fuel is produced, transported and processed has a significant impact on lifecycle emissions. Transporting fuels over long distances and excessive use of nitrogen fertilizers can reduce the emissions savings made by the same fuel compared to natural gas by between 15 and 50 per cent. Renewable bio-fuels are starting to be used in aviation (Environment Agency, 2009).

e. Nuclear Power: In most 1.5 °C pathways of the Intergovernmental Panel on Climate Change's Special Report on Global Warming of 1.5 °C the share of nuclear power is increased. The main advantage of nuclear energy is the ability to deliver large amounts of base load when renewable energy is not available. On the other hand, environmental and security risks could outweigh the benefits. As of 2019, no country has found a final solution to nuclear waste which can cause future damage and costs over more than one million years. The Fukushima disaster is estimated to cost taxpayers $187 billion and radioactive waste management is estimated to cost the EU $250 billion by 2050 (Meckling, 2019).

Nuclear power avoided 2–3% of total global GHG emissions in 2021. Limited uranium-235 supply inhibits substantial expansion scenarios with novel nuclear technologies. Nevertheless, China is building a significant number of new power plants, albeit significantly fewer reactors than originally planned. As of 2019 the cost of extending nuclear power plant lifetimes is competitive with other electricity generation technologies, including new solar and wind projects. New projects are reported to be highly dependent on public subsidies (Meckling, 2019).

4.4.2 Carbon Sink and Removal

Ou et al. (2021) stated carbon sequestration is the storing of carbon in to a reservoir called a carbon sink such as growing forests, swamps, wetlands/peatlands (due to which some call for bans of the sale/supply of turf), and (cultivated) algae or through artificial carbon dioxide removal such as direct air capture. Carbon dioxide removal is vital in climate change mitigation even with the best case scenarios of reducing carbon dioxide emissions as levels of CO_2 in the atmosphere are already at damaging levels.

Collins and Mitchard (2017) stated conserving areas by protecting areas can boost the carbon sequestration capacity. The European Union, through the EU Biodiversity Strategy for 2030 targets to protect 30% of the sea territory and 30% of the land territory by 2030. In 2021, seven countries (the G7) pledged to protect or preserve at least 30% of the world's land and 30% of the world's oceans to halt biodiversity loss. A survey by the United Nations Development Programme of public opinion on climate change found that forests and land conservation policies were the most popular solutions of climate change mitigation.

a. Carbon Storage in Land Ecosystem: Harris and Gibbs (2021) mentioned that globally, protecting healthy soils and restoring the soil carbon sponge could remove 7.6 billion tons of carbon dioxide from the atmosphere annually, which is more than the annual emissions of the US.

Trees capture CO_2 while growing above ground and exuding larger amounts of carbon below ground. Trees contribute to the building of a soil carbon sponge. The carbon formed above ground is released as CO_2 immediately when wood is burned. If dead wood remains untouched, only some of the carbon returns to the atmosphere as decomposition proceeds.

i. Afforestation: Afforestation is the establishment of trees where there was previously no tree cover. However, these are not considered a viable alternative to aggressive emissions reduction, such as the Trillion Tree Campaign, as the plantations would need to be so large, they would eliminate most natural ecosystems or reduce food production (Gabbatiss, 2019).

ii. Preventing Deforestation and Desertification: Avoided deforestation reduces CO_2 emissions at a rate of 1 tonne of CO_2 per $1–5 in opportunity costs from lost agriculture. Cutting trees for woodfuel, the main source of energy for the poor, and clearing forests for agriculture are major drivers of desertification and deforestation. Tropical deforestation leads to substantial warming from non-CO_2-impacts. The deforestation to prevent for climate change mitigation is the tropical deforestation. Standing tropical forests help cool the average global temperature by more than 1°C (Yoder, 2022).

iii. Preventing Permafrost Leaks: The global warming induced thawing of the permafrost, which stores about two times the amount of the carbon currently released in the atmosphere, releases the potent greenhouse gas, methane, in a positive feedback cycle that is feared to lead to a tipping point called runaway climate change. While the permafrost is about 14 degrees Fahrenheit, a blanket of snow insulates it from the colder air above which could be 40 degrees below zero Fahrenheit. A method proposed to prevent such a scenario is to bring back large herbivores, where they keep the ground cooler by reducing snow cover height by about half and eliminating shrubs and thus keeping the ground more exposed to the cold air. For this purpose, de-extinction and/or rewilding the Arctic would be used which have been criticized for likely being both inefficient and ineffective (University of Southampton, 2021).

iv. Reforestation: Gillis (2016) mentioned reforestation is the restocking of existing depleted forests or where there were once recently forests. Reforestation could save at least 1 $GtCO_2$/year, at an estimated cost of $5–15/$tCO_2$.With increased intensive agriculture and urbanization, there is an increase in the amount of abandoned farmland. By some estimates, for every acre of original old-growth forest cut down, more than 50 acres of new secondary forests are growing.

Promoting regrowth on abandoned farmland could offset years of carbon emissions. Russia, the United States and Canada have the most land suitable for reforestation.

v. Proforestation: Moomaw et al., (2019) mentioned pro-forestation is promoting forests to capture their full ecological potential. Restoring all degraded forests all over the world could capture about 205 GtC (750 GtCO2). Secondary forests that have regrown in abandoned farmland are found to have less biodiversity than the original old-growth forests and original forests store 60% more carbon than these new forests. Allowing proforestation in some secondary forests will increase their accumulated carbon and biodiversity over time. Strategies for proforestation include rewilding, such as reintroducing apex predators and keystone species as, for example, predators keep the population of herbivores in check (which reduce the biomass of vegetation). Another strategy is establishing wildlife corridors connecting isolated protected areas.

b. Carbon Storage in Water Ecosystem: The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE-CRC) estimated in 2013 that one-third of humankind's annual emissions of CO_2 are absorbed by the oceans. Absorption by phytoplankton is very uncertain but may be 40% of all CO_2 emissions. However, dissolved CO_2 in water leads to ocean acidification, which harms marine life as acidification lowers the level of carbonate ions available for calcifying organisms to form their shells such as the plankton species that contribute to the foundation of the ocean food webs and acidification also impacts on a broad range of other physiological and ecological processes. Blue carbon refers to carbon dioxide removed from the atmosphere by the world's ocean ecosystems through plant and macro algae growth and the accumulation and burial of organic matter in the soil (Chami et al., 2019).

c. Synthetic Carbon Dioxide Removal: Different ways of synthetic carbon dioxide removal are briefly described below:

i. Direct Air Capture: IEA (2021) mentioned that direct air capture is a process of capturing CO_2 directly from the ambient air (as opposed to capturing from point sources) and generating a concentrated stream of CO_2 for sequestration or utilization or production of carbon-neutral fuel and wind gas. Artificial processes vary, and concerns have been expressed about the long-term effects of some of these processes.

ii. Carbon Capture and Storage: Carbon capture and storage (CCS) is a method to mitigate climate change by capturing carbon dioxide (CO_2) from large point sources, such as cement factories or biomass power plants, and subsequently storing it away safely instead of releasing it into the atmosphere. The IPCC estimates that the costs of halting global warming would double without CCS. Norway's Sleipner gas field, beginning in 1996, stores almost a million tons of CO_2 a year to avoid penalties in producing natural gas with unusually high levels of CO_2 (Carrington, 2016).

iii. Enhanced Weathering: Enhanced weathering is the removal of carbon from the air into the earth, enhancing the natural carbon cycle where carbon is mineralized into rock. The CarbFix project couples with carbon capture and storage in power plants to turn carbon dioxide into stone in a relatively short period of two years, addressing the common concern of leakage in CCS projects which stores carbon as a gas instead. While this project used basalt rocks, olivine has also shown promise (Carrington, 2016).

4.4.3 Geo-engineering

Solar geoengineering, or solar radiation modification (SRM) is a type of climate engineering in which sunlight (solar radiation) would be reflected back to space to limit or reverse human-caused climate change. It is not a substitute for reducing greenhouse gas emissions, but could act as a temporary measure to limit warming while emissions of greenhouse gases are reduced and carbon dioxide is removed. The two most studied methods for SRM are stratospheric aerosol injection and marine cloud brightening (National Academies of Sciences, Engineering and Medicine, 2021).

4.4.4 De-carbonization by Sector

Forthcoming paragraphs are devoted to briefly explain the ways of sector wise de-carbonization which are as follows:

a. Transport: Transportation emissions account for 15% of emissions worldwide. Increasing the use of public transport, low-carbon freight transport and cycling are important components of transport decarbonization (Mattioli et al., 2020).

i. Electric Vehicles: Between a quarter and three-quarters of cars on the road by 2050 are forecast to be electric vehicles. EVs use 38 megajoules per 100 km in comparison to 142 megajoules per 100 km for ICE cars. Hydrogen can be a solution for long-distance transport by trucks and hydrogen-powered ships where batteries alone are too heavy. GHG emissions depend on the amount of green energy being used for battery or fuel cell production and charging. In a system mainly based on electricity from fossil fuels, emissions of electric vehicles can even exceed those of diesel combustion (Sternberg et al., 2019).

ii. Shipping: In the shipping industry, the use of liquefied natural gas (LNG) as a marine bunker fuel is driven by emissions regulations. Ship operators have to switch from heavy fuel oil to more expensive oil-based fuels, implement costly flue gas treatment technologies or switch to LNG engines. Methane slip, when gas leaks unburned through the engine, lowers the advantages of LNG. Hybrid and all electric ferries are suitable for short distances. Norway's goal is an all electric fleet by 2025. The E-ferry Ellen, which was developed in an EU-backed project, is in operation in Denmark (Chambers, 2021).

iii. Air Travel: In aviation, current 180 Mt of CO_2 emissions (11% of emissions in transport) are expected to rise in most projections, at least until 2040. Aviation biofuel and hydrogen can only cover a small proportion of flights in the coming years. The market entry for hybrid-driven aircraft on regional scheduled flights is projected after 2030, for battery-powered aircraft after 2035. In October 2016, the 191 nations of the ICAO established the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), requiring operators to purchase carbon offsets to cover their emissions above 2020 levels, starting from 2021. This is voluntary until 2027. The environmental impact of aviation increases at high altitudes. Contrails, not only airplane greenhouse gas emissions, have a significant impact on climate change (Lührs et al., 2021).

b. Energy: Energy consumption will need to be halved by 2050 for avoiding warming of 1.5 degrees above preindustrial levels. While this will slow economic growth it will not necessarily lead to a lower life level if it will be done in the right way (Knight, 2022).

i. Heating and Cooling: Rogelj et al., (2018) mentioned the buildings sector accounts for 23% of global energy-related CO_2 emissions. About half of the energy is used for space and water heating. A combination of electric heat pumps and building insulation can reduce the primary energy demand significantly. Generally, electrification of heating and cooling would only reduce GHG emissions if the electric power comes from low-carbon sources. A fossil-fuel power station may only deliver 3 units of electrical energy for every 10 units of fuel energy released. Electrifying heating and cooling loads may also provide a flexible resource that can participate in demand response to integrate variable renewable resources into the grid.

ii. Heat Pumps: A modern heat pump typically produces around two to six times more thermal energy than electrical energy consumed, giving an effective efficiency of 200 to 600%, depending on the coefficient of performance and the outside temperature. It uses an electrically driven compressor to operate a refrigeration cycle that extracts heat energy from outdoor air and moves that heat to the space to be warmed. With a market share of 30% and clean electricity, heat pumps could reduce global CO_2 emissions by 8% annually. Using ground source heat pumps could reduce around 60% of the primary energy demand and 90% of CO_2 emissions of natural gas boilers in Europe in 2050 and make handling high shares of renewable energy easier. Using surplus renewable energy in heat pumps is regarded as the most effective household means to reduce global warming and fossil fuel depletion (Sternberg and Bardow, 2015).

iii. Cooling: Refrigeration and air conditioning account for about 10% of global CO_2 emissions caused by fossil fuel-based energy production and the use of fluorinated gases. Slashing HFC consumption by 80% by midcentury could avoid more than 0.4 °C of global warming by the end of the century. About 90% of the emissions occur at the end of the equipment's life. Solutions include investing in proper disposal and refrigerants that are less polluting. A shift to renewable energy in the cooling sector comes with two advantages: Solar energy production with mid-day peaks corresponds with the load required for cooling. Additionally, cooling has a large potential for load management in the electric grid (IEA, 2020).

iv. Electric Resistant Heating: Radiant heaters in households are cheap and widespread but less efficient than heat pumps. In areas like Norway, Brazil, and Quebec that have abundant hydroelectricity, electric heat and hot water are common. Large scale hot water tanks can be used for demand-side management and store variable renewable energy over hours or days.

c. Agriculture: Rosane (2021) stated as 25% of greenhouse gas emissions (GHGs) are coming from agriculture and land use, it is impossible to limit temperature rise to 1.5 degrees without addressing the emissions from agriculture. During 2021 United Nations Climate Change Conference, 45 countries pledged to give more than 4 billion dollars for transition to sustainable agriculture. With 21% of the global methane emissions, cattle are a major driver on global warming. When rainforests are cut and the land is converted for grazing, the impact is even higher. This results in up to 335 kg CO_{2eq} emissions for the production of 1 kg beef in Brazil when using a 30-year time horizon. Other livestock, manure management and rice cultivation also produce relevant GHG emissions, in addition to fossil fuel combustion in agriculture.

Investment in improving and scaling up the production of dairy and meat alternatives leads to big greenhouse gas reductions compared with other investments. Also, photovoltaic-driven microbial protein production could use 10 times less land for an equivalent amount of protein compared to soybean cultivation. Important mitigation options for reducing the greenhouse gas emissions from livestock include genetic selection, introduction of methanotrophic bacteria into the rumen, vaccines, feeds, toilet-training, diet modification and grazing management. Other options include just using ruminant-free alternatives instead, such as milk substitutes and meat analogues. Non-ruminant livestock (e.g. poultry) generates far fewer emissions (Leger et al., 2021)

USDA (2022) stated that agroforestry is one way to achieve sustainable intensification, which is farming method that can both boosts yield to supply the growing population and reduce greenhouse gas emissions. Agroforestry is the practice of integrating trees and shrubs into crop and animal farming systems, creating environmental benefits. Trees can absorb carbon dioxide from the air, leaves from the trees can enrich the soil, manure from livestock can nutrient crops and trees. Nitrogen can also be fixed by trees, which benefits crops. This method intensifies agriculture productivity while prevents deforestation, which all largely contribute to rising of CO_2. Methane emissions in rice cultivation can be cut by implementing an improved water management, combining dry seeding and one drawdown, or a perfect execution of a sequence of wetting and drying. This results in emission reductions of up to 90% compared to full flooding and even increased yields.

d. Urban Planning and Building Design: Effective urban planning to reduce sprawl aims to decrease the distance travelled by vehicles, lowering emissions from transportation. Personal cars are extremely inefficient at moving passengers, while public transport and bicycles are many times more efficient. All of these are encouraged by urban/community planning and are an effective way to reduce greenhouse gas emissions. Inefficient land use development practices have increased infrastructure costs as well as the amount of energy needed for transportation, community services, and buildings. Switching from cars by improving walkability and cycling infrastructure is either free or beneficial to a country's economy as a whole (UKCCC, 2020).

UKCCC (2020) categorized urban mitigation options into three broad strategies as: first, reducing urban energy consumption across all sectors, including through spatial planning and infrastructure; second, electrification and switching to net zero emissions resources; and third enhancing carbon stocks and uptake through urban green and blue infrastructure, which can also offer multiple co-benefits. Reducing the number of cars on the road, for example through proof of parking requirements, corporate car sharing, road reallocation from only car use to cycling road, circulation plans, bans on on-street parking or by increasing the costs of car ownership can help in reducing traffic congestion in cities (Walker, 2019).

Rosenfeld (1997) mentioned that new buildings can be constructed using passive solar building design, low-energy building, or zero-energy building techniques, using renewable heat sources. Existing buildings can be made more efficient through the use of insulation, high-efficiency appliances particularly hot water heaters and furnaces, double- or triple-glazed gas-filled windows, external window shades, and building orientation and siting. Renewable heat sources such as shallow geothermal and passive solar energy reduce the amount of greenhouse gasses emitted. In addition to designing buildings which are more energy-efficient to heat, it is possible to design buildings that are more energy-efficient to cool by using lighter-coloured, more reflective materials in the development of urban areas (e.g. by painting roofs white) and planting trees. This saves energy because it cools buildings and reduces the urban heat island effect thus reducing the use of air conditioning.

4.4.5 Governmental Action

Political choices that effectively delay mitigation have the largest effect on the share of costs and risks of mitigation options, followed by geophysical uncertainties, social factors influencing future energy demand and technological uncertainties. Climate Action Tracker described the situation on 9 November 2021 as: the global temperature will rise by 2.7 °C by the end of the century with current policies and by 2.9 °C with nationally adopted policies. The temperature will rise by 2.4 °C if only the pledges for 2030 are implemented, by 2.1 °C if the long-term targets are also achieved. If all the announced targets are fully achieved the rise in global temperature will peak at 1.9 °C and go down to 1.8 °C by the year 2100 (Climate Action Tracker, 2021)

a. Paris Agreement and Kyoto Protocol: In 2015, two official UNFCCC scientific expert bodies came to the conclusion that, "in some regions and vulnerable ecosystems, high risks are projected even for warming above 1.5 °C". This expert position was, together with the strong diplomatic voice of the poorest countries and the island nations in the Pacific, the driving force leading to the decision of the Paris Conference 2015, to lay down this 1.5 °C long-term target on top of the existing 2 °C goal (Climate Analytics, 2015).

The Paris Agreement has become the main current international agreement on combating climate change. Each country must determine, plan, and regularly report on the contribution that it undertakes to mitigate global warming. Climate change mitigation measures can be written down in national environmental policy documents like the nationally determined contributions (NDC). The Paris agreement succeeds the 1997 Kyoto Protocol which expired in 2020. Countries that ratified the Kyoto protocol committed to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. How well each individual country is on track to achieving its Paris agreement commitments can be followed on-line (UNFCCC, 2019).

b. Additional Commitments: In addition to the main agreements, there are many additional pledges made by international coalitions, countries, cities, regions and businesses. According to a report published in September 2019 before the 2019 UN Climate Action Summit, full implementation of all pledges, including those in the Paris Agreement, will be sufficient to limit temperature rise to 2 degrees but not to 1.5 degrees. After the report was published, additional pledges were made in the September climate summit and in December of that year (Farland, & Sauer, 2019).

In December 2020 another climate action summit was held and important commitments were made. The organizers stated that, including the commitments expected in the beginning of the following year, countries representing 70% of the global economy will be committed to reach zero emissions by 2050. In September 2021 the US and EU launched the Global Methane Pledge to cut methane emissions by 30% by 2030. UK, Argentina, Indonesia, Italy and Mexico joined the initiative, "while Ghana and Iraq signaled interest in joining, according to a White House summary of the meeting, which noted those countries represent six of the top 15 methane emitters globally" (Mason & Alper, 2021).

c. Carbon Pricing: Additional costs on GHG emissions can lower competitiveness of fossil fuels and accelerate investments into low-carbon sources of energy. A growing number of countries raise a fixed carbon tax or participate in dynamic carbon Emission Trading Scheme (ETS) systems. In 2021, more than 21% of global GHG emissions were covered by a carbon price, a major increase due to the introduction of the Chinese national carbon trading scheme (The World Bank, 2021).

Trading schemes offer the possibility to limit emission allowances to certain reduction targets. However, an oversupply of allowances keeps most ETS at low price levels around $10 with a low impact. This includes the Chinese ETS which started with $7/tCO_2$ in 2021. One exception is the European Union Emission Trading Scheme where prices began to rise in 2018, exceeding €63/tCO_2 (72$) in 2021. This results in additional costs of about €0.04/KWh for coal and €0.02/KWh for gas combustion for electricity, depending on the emission intensity (Shepherd, 2021).

Latest models of the social cost of carbon calculate a damage of more than $3000 per ton CO_2 as a result of economy feedbacks and falling global GDP growth rates, while policy recommendations for a carbon price range from about $50 to $200. Most energy taxes are still levied on energy products and motor vehicles, rather than on CO_2 emissions directly. Non-transport sectors as the agricultural sector, which produces large amounts of methane, are typically left untaxed by current policies (Kikstra, 2021). The revenue of carbon pricing can used to support policies that promote carbon neutrality. In another approach the concept of a carbon fee and dividend which includes the redistribution on a per-capita basis. As a result, households with a low consumption can even benefit from carbon pricing.

d. Enacting State of Emergency: Enacting a state of emergency may be composed of two elements: declaring a state of emergency that has formulated real-world i.e. legal effects and the associated enabling or ensuring of rapid complementary large-scale changes in human activity for the articulated purposes. To date, many governments have acknowledged, sometimes in the form of tentative text-form "declarations", that humanity is essentially in a state of climate emergency. In November 2021, Greta Thunberg and other climate activists asked the United Nation to declare a level 3 system wide climate emergency. It has been proposed that the national security sector could play a unique role in the development of a global climate-emergency mobilisation of labour and resources to build a zero-emission economy and enact decarbonization. Commentators and the Climate Mobilization have suggested mobilisation of resources on the scale of a war economy and other related exceptional or effective measures (Frangoul, 2021).

e. Cost-Benefit Comparison: Globally, the benefits of keeping warming under 2 °C exceed the costs. However, some consider cost benefit analysis unsuitable for analysing climate change mitigation as a whole but still useful for analysing the difference between a 1.5 °C target and 2 °C. The OECD has been applying economic models and qualitative assessments to inform on climate change benefits and tradeoffs (Sampedro et al., 2020).

One way of estimating the cost of reducing emissions is by considering the likely costs of potential technological and output changes. Policy makers can compare the marginal abatement costs of different methods to assess the cost and amount of possible abatement over time. The marginal abatement costs of the various measures will differ by country, by sector, and over time. Mitigation costs will vary according to how and when emissions are cut: early, well-planned action will minimise the costs. Many economists estimate the cost of climate change mitigation at between 1% and 2% of GDP. In 2019, scientists from Australia and Germany presented the "One Earth Climate Model" showing how temperature increase can be limited to 1.5 °C for 1.7 trillion dollars a year. According to this study, a global investment of approximately $1.7 trillion per year would be needed to keep global warming below 1.5°C (Chow, 2019).

According to the Stern Review, inaction can be as high as the equivalent of losing at least 5% of global gross domestic product (GDP) each year, now and forever (up to 20% of the GDP or more when including a wider range of risks and impacts), whereas mitigating climate change will only cost about 2% of the GDP. Also, delaying to take significant reductions in greenhouse gas emissions may not be a good idea, when seen from a financial perspective. Mitigation solutions are often evaluated in terms of costs and greenhouse gas reduction potentials, missing out on the consideration of direct effects on human well-being (Creutzig et al., 2021).

Mitigation measures may have many health co-benefits potential measures can not only mitigate future health impacts from climate change but also improve health directly. Climate change mitigation is also an issue of intergenerational justice with nonintervention thought by some to violate future people's freedom conversely, mitigation may preserve societal freedoms and range of viable basic choices (Sanson & Burke, 2020).

One of the aspects of mitigation is how to share the costs and benefits of mitigation policies. Rich people tend to emit more GHG than poor people. Activities of the poor that involve emissions of GHGs are often associated with basic needs, such as cooking. For richer people, emissions tend to be associated with things such as eating beef, cars, frequent flying, and home heating. The impacts of cutting emissions could therefore have different impacts on human welfare according to wealth (UKCCC, 2019).

4.5 Challenges of Climate Change Mitigation

A key informant at ministry of forest and environment explained that as per the provision of Paris Agreement 2015, every country party has to set ambitious mitigation targets through their Nationally Determined Contributions (NDCs). Nepal has negligible contribution in overall global

GHG emission. Developed countries and other developing countries such as China, USA, India, Brazil etc are the major GHG contributors. Unless they phase out the use of coal and reduce fossil fuel consumption, it is very difficult to reduce global warming. Therefore, high emitting countries should come forward with highly ambitious emission reduction targets and should come with long term low emission to attain net zero in mid century. For country like Nepal, availability of sufficient international climate finance is challenging to meet its NDC targets.

Site Manager of Risen Energy Company explained that the main challenges are in the policy and its effective implementation. The policy should be stable to mitigate the short and long terms impacts governed by stable governments, such as providing incentive to the clean energy production, promotion of electric vehicle, subsidy in electric stove. According to a key informant at AEPC unavailability of the other energy sources rather than coals and petroleum in the large area of the world, lack of the sources to promote the other forms of energy such as hydropower, solar energy etc. as it is highly costly source during the production phase are some of the major challenges of climate change mitigation. A key informant and assistant director at AEPC mentioned the challenges of climate change mitigation as CO_2 is a global pollutant that can't be locally contained, for now, climate change is still hypothetical, there is no direct link to smoking gun, developing countries contribute to a large share of pollution, and modern living is a part of problem.

Senior divisional meteorologist at hydrology and meteorology opined that Nepal's contribution to Green House Gas (GHG) emission is negligible. Developed and developing countries are denying to cut-off/reduce their GHG emission. Investment cost of switching fossil fuel to renewal energy is very high. Developing countries like Nepal are in daunting need of development which is also the cause of GHG emission. Lack of knowledge on definitive culprit (specific environmental disaster) and lack of awareness, etc. are other challenges of climate change mitigation.

It has been suggested that the main barriers to implementation of climate change policies are uncertainty, institutional void, short time horizon of policies and politicians and missing motives and willingness to start adapting. When information on climate change is held between the large numbers of actors involved, it can be highly dispersed, context specific or difficult to access causing fragmentation to be a barrier. The short time horizon of policies and politicians often means that climate change policies are not implemented in favour of socially favoured societal issues. Statements are often posed to keep the illusion of political action to prevent or postpone decisions being made. There may be cause for concern about metal requirement for relevant technologies such as photovoltaics. Many developing nations have made national adaptation programs which are frameworks to prioritize adaption needs (Tokimatsu et al., 2017).

An international policy to allocate carbon budgets to individual countries has not been implemented. This question raises fairness issues. With a linear reduction starting from the status quo, industrial countries would have a greater share of the remaining global budget. Using an equal share per capita globally, emission cuts in industrial countries would have to be extremely sharp.

In 2019, oil and gas companies were listed by Forbes with sales of US$4.8 trillion, about 5% of the global GDP. Net importers such as China and the EU would gain advantages from a transition to low-carbon technologies driven by technological development, energy efficiency or climate change policy, while Russia, the USA or Canada could see their fossil fuel industries nearly shut down. On the other hand, countries with large areas such as Australia, Russia, China, the US, Canada and Brazil and also Africa and the Middle East have a potential for huge installations of renewable energy. The production of renewable energy technologies requires rare-earth elements with new supply chains (Mercure et al., 2018).

4.6 Relevance of Climate Change Mitigation to Nepal

Chief of Climate Change Section, Ministry of Forests and Environment mentioned during the key informant interview that Nepal is one of the most vulnerable countries due to climate change. Global temperature change is causing unpredictable weather events in Nepal such as heavy rainfall, longer drought, less snow and high rain in high altitude areas where there were only snow in past causing heavy floods and landslides such as in Manang and Mustang last year. Paris Agreement is one of the instrumental tools to control global warming and has aimed to limit the global temperature rise upto 1.5 degree Celsius as compared to pre-industrial age. Studies has proven that even 1.5 degree rise in global average it will be around 2 - 2.1 degree Celsius in our Himalayan region causing heavy snow melt, glacier retreat GLOFs. Therefore CC mitigation (reduction in overall global GHG) is especially important for Nepal.

Site Manager of Risen Energy Company at Devighat Nuwakot described the importance of climate change mitigation in Nepal as:

> *In high Himalayas the increasing temperature is rapidly melting the glacier. Due to this the perennial source of river will dry out and heavy rain will cause the flash flood in rainy season. The downstream fertile land will dry out. Frequent flooding and landslides occur. This will rise in the*

drinking water and food scarcity. The increasing temperature will heavily impact on the ecology of high Himalaya. The deaths of yaks have rise due to increased temperature. The livelihood of high Himalayas people who relies on these livestock are very susceptible. So, Perennial River changes to periodic river, flash floods, landslides, food and drinking water scarcity makes Nepal very vulnerable to climate change. Thus, climate change mitigation is important.

One of the key informants and senior divisional meteorologist highlighted during KII that climate change mitigation is more important to Nepal because of its climate characteristics and topography, its poor adaptive capacity (might be related to weak economic condition), lack of knowledge and information (such as hazard and risk information and early warnings), lack of research and development, unplanned and unmanaged development works (such as construction of reads) and lack of awareness.

A key informant at AEPC explained as Nepal is especially vulnerable to changes in precipitation patterns and rates and timing of glacial melt, which could impact agriculture, biodiversity, and hydropower energy production. Floods and landslides are common in Nepal, often triggered by heavy rains, while droughts are also becoming more frequent. A project coordinator at AEPC explained that Nepal lies between highly developing powerhouses of the world (China and India). These two countries are developing in such a way that the pollution and byproducts released is affecting the climatic situation of the Nepal very badly. Also, Nepal is highly dependent on the traditional form of energy like burning woods and coals which is impacting the environment in a bad way. So, Nepal is very vulnerable to climate change impact.

German Watch, (2020) mentioned that climate change in Nepal is a major problem for Nepal as it is one of the most vulnerable countries to the effects of climate change. Globally, Nepal is ranked fourth, in terms of vulnerability to climate change. Floods spread across the foothills of the Himalayas and bring landslides, leaving tens of thousands of houses and vast areas of farmland and roads destroyed. In the 2020 edition of Germanwatch's Climate Risk Index, it was judged to be the ninth hardest-hit nation by climate calamities during the period 1999 to 2018. According to OPHI (2018) Nepal is a least developed country, with 28.6 percent of the population living in multidimensional poverty. Analysis of trends from 1971 to 2014 by the Department of Hydrology and Meteorology (DHM) shows that the average annual maximum temperature has been increasing by 0.056 °C per year. Precipitation extremes are found to be increasing. A national-level survey on the perception-based survey on climate change reported that locals accurately perceived the shifts in temperature but their perceptions of precipitation change did not converge with the instrumental records. Data reveals that more than 80 percent of property loss due to disasters is attributable to climate hazards, particularly water-related events such as floods, landslides and glacial lake outburst floods (GLOFs) (Shrestha et al., 2019).

Sharma et al. (2002) stated that the floods of 2018 spread across the foothills of the Himalayas and brought landslides. They have left tens of thousands of houses and vast areas of farmland and roads destroyed. Sharma et al. (2002) further mentioned that Nepal experienced flash floods and landslides in August, 2018 across the southern border, amounting to US$600 million in damages. There are reports of land which was once used for growing vegetables, and has become barren. Scientists have found that rising temperatures could spread malaria and dengue to new areas of the Himalayas, where mosquitoes have started to appear in the highlands.

As Nepal alone can't fight the effects of climate change with its limited resources and knowledge, it needs to secure international support and cooperation. There is a need to build a wide international network through robust diplomacy, which in turn must focus on securing resources to gain access to the latest available technology, all in order to deal with climate-induced disasters. So, the issue of climate change should be an integral part of the country's engagement at bilateral, regional, and multilateral levels. However, except for participating in international platforms, Nepali diplomats don't prominently raise the issue. For the first time, Nepal's foreign policy unveiled in 2020 incorporated a separate section on climate diplomacy. The policy envisioned Nepal's proactive role in the policy formulation process of the United Nations and other international platforms for the acquisition of resources and technology for mitigation and adaptation plans. It also says Nepal shall lead mountainous countries to implement the principle of 'polluters-pay'. But, a key challenge, like always, is implementation. First, the present government did not owned the policy introduced by the previous administration. As the current foreign minister said he has initiated consultations to draft a new foreign policy.

Sagarmatha Sambad (2020) stated that to highlight Nepal's issues and build an international network, the former government had initiated the Sagarmatha Sambad, a flagship annual international program to highlight Nepal's agenda, including climate change. The first edition of the program, scheduled for 2-4 April 2020 on the theme of 'Climate Change, Mountains and the Future of Humanity', and a separate mechanism was set up for the same purpose before it was postponed due to the Covid-19 pandemic. After the easing of international travel, the then government had organized a conference just before the UN Framework Convention on Climate

Change COP-26 to highlight Nepal’s agenda. At COP-26, Nepalese Prime Minister committed to holding the summit, but so far no such summit has been held.

But Nepal should step up its diplomatic efforts, most vitally in carbon trade. Nepal’s forests store over 500 million tonnes of carbon and it is eligible to sell carbon credits to developed countries that want to offset their emissions. The ‘mountain agenda’ is also not getting due attention in climate-related international negotiations. Though Nepal repeatedly urges the world to recognize specific climate vulnerabilities of high mountains, it has not been given priority in international policy frameworks (Sagarmatha Sambad, 2020).

Nepal has committed to achieving net-zero emission by 2045 a move estimated to cost $25 billion. Most targets set by Nepal are conditional: it can achieve them only with international support. But as Nepal graduates from the list of Least Developed Countries bloc, it will face additional hurdles in getting international support for its mitigation programs. It is not only about finance. Nepal also needs to secure technological means and knowledge on capacity-building. The Green Climate Fund, Global Environment Facility, and Adaptation Fund are the potential fund sources. Similarly, there are bilateral/multilateral agencies and development partners before whom Nepal will have to display its capability to secure funds.

MoFA (2018) stated President Bidya Devi Bhandari participated in the 24th conference of the state parties to the United Nations Framework Convention on Climate Change (COP24) held in Katowice of Poland. The speech delivered by the president on the said event is included in Appendix "B". In the conference’s inaugural session the President viewed that:

> *Although Nepal has made a big contribution to controlling global temperature, the Nepali were paying the penalty for the wrong they had never done. She stated that Nepal is a least developed country comprising the mountains, hills and the Tarai flatland. It is suffering from the adverse impact of climate change. Although it is a low-carbon emitting country, it is suffering from the problem of melting glaciers, the snow-capped Himalayas were turning rocky and devoid of snow cover and the possibility of glacier melting has increased.*

Embassy of Nepal (2021) mentioned present Prime Minister addressing the COP26 Summit, stated that "*the loss and damage have become a key concern due to increased phenomena of climate-induced disasters and this subject must find a place under article 4.8 of the Convention*". Full version of the prime minister's speech is attached in Appendix "C". Now, Nepal is raising this issue through the Least Developed Countries (LDC) group on climate change. The Least

Developed Countries are 46 nations that are especially vulnerable to climate change but have contributed the least to the phenomena. Similarly, Nepal is a member of the G-77 group on climate change issues. Nepal's climate diplomacy through the LDC group and G-77 is not yielding results so Nepal should start leading the climate change dialogue. We can create a separate mechanism under the Prime Minister's Office by incorporating climate change experts and other technical manpower. Nepal needs to deal with major powers like the United States, United Kingdom, China, and other countries to secure their support.

Regional organizations such as SAARC and BIMSTEC could also play an instrumental role in highlighting Nepal's agenda both regionally and globally. The problem is that the two organizations are now largely dysfunctional. During the 18th SAARC summit in Kathmandu in 2014, member countries had discussed climate change. In the declaration document the top executives of member countries directed the relevant bodies/mechanisms for effective implementation of SAARC Agreement on Rapid Response to Natural Disasters, SAARC Convention on Cooperation on Environment and Thimphu Statement on Climate Change, including taking into account the existential threats posed by climate change to some SAARC member states. But, the problem was again in the implementation of the agreed goals.

4.7 Importance of Climate Change Mitigation to APF, Nepal

As it is evident from the experts' opinions and studies of the available literature that climate change has direct linkage with most of the frequently occurring disasters in Nepal. Loss of life is the most extreme consequence of disasters. The strong rise in disaster incidence, potentially due to climate change, has overcome the effect of decreasing vulnerability due to economic growth and progress in disaster risk reduction and climate change adaptation and caused the rise in disaster mortality.

As climate change accelerates, its impacts exacerbate existing social, economic, and environmental challenges in many contexts, which can contribute to insecurity at local levels, or even internationally. Security concerns linked to climate change include impacts on food, water and energy supplies, increased competition over natural resources, loss of livelihoods, climate-related disasters, and forced migration and displacement. Despite growing recognition of the inter-linkages between climate change, peace and security, few examples of integrated programmatic approaches that address specific risks at the intersection of climate change and insecurity exist. Conflict and crisis affected contexts are more susceptible to being overwhelmed by climate change. Insecurity hinders climate change adaptation efforts, leaving already vulnerable communities even poorer and less resilient to interlinked climate and security crises, but climate change adaptation initiatives often fail to fully integrate security.

One of the prime mandates of Armed Police Force, Nepal is to respond in disasters apart from other various kinds of security responsibilities. In the past also APF, Nepal had mobilized to control spread of COVID-19 pandemic, to rescue peoples from fire, landslide, flood, inundation, avalanche including heat waves and cold waves. APF, Nepal has established disaster training school at Kurintar, Chitwan where specialized trainings in disasters are conducted. Almost all APF personnel are ready to be deployed to response disasters, anytime, across the country. As APF, Nepal and disaster management has body and blood relationship, so is the relationship of APF, Nepal with climate change mitigation. Additionally, anything that impacts in national security is the domain of APF, Nepal.

4.8 Chapter Summary

Mitigation or reducing climate change involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases or enhancing the sinks that accumulate and store these gases. The goal of mitigation is to avoid significant human interference with Earth's climate, stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. Fossil fuels such as coal, oil and gas are by far the largest contributor to global climate change, accounting for over 75 percent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions. As greenhouse gas emissions blanket the Earth, they trap the sun's heat. This leads to global warming and climate change. The world is now warming faster than at any point in recorded history. Warmer temperatures over time are changing weather patterns and disrupting the usual balance of nature. This poses many risks to human beings and all other forms of life on earth. Generating power, manufacturing goods, cutting down forests, using transportation, producing food, powering buildings and consuming too much are some of the causes of global warming and climate change.

Mitigation strategies include retrofitting buildings to make them more energy efficient; adopting renewable energy sources like solar, wind and small hydro; helping cities develop more sustainable transport such as bus rapid transit, electric vehicles, and biofuels; and promoting more sustainable uses of land and forests. The effects of greenhouse gases (GHGs) on both drought and flooding events have been found in Nepal, including severe winter drought and excessive monsoon flooding. Climate change has been alarming in the context of global warming. In Nepal, large portion of greenhouse gas emissions are from agriculture and forestry sectors. The consequences of global warming have had the most impact in developing and mountainous countries like Nepal, which has high intensity rainfall during rainy season. It has resulted in heavy floods, landslides and soil erosion. It is also common to find drought in many parts of Nepal that comes from the impacts of climate change and it impacts sectors like forest, water resources, agriculture, human health and biodiversity.

It is a great challenge to cope with climate change induced hazards and extreme events. Climate change is a threat to national security and now is the time to take sensible action, to integrate it into national security frameworks, and to build the necessary capacity and resilience to address it responsibly in the future. Projected climate change poses a serious threat to national security. Climate change acts as a threat multiplier for instability in some areas of the country. Climate change, national security, and energy dependence are a related set of global challenges. As such, Armed Police Force, Nepal as an elite security agency of the country, has direct and straight concern with the climate change mitigation.

CHAPTER V
SOLAR POWER

5. 1 Introduction of Solar Power

According to Department of Energy (2022) solar power is the conversion of renewable energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Photovoltaic cells convert light into an electric current using the photovoltaic effect whereas concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight to a hot spot, often to drive a steam turbine.

Figure 1

A solar photovoltaic system

Note: A solar photovoltaic system array on a rooftop in Hong Kong

Source: Electrical and Mechanical Services Department Headquarters, Hong Kong

Carbon Brief (2020) mentioned Photovoltaics were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Carbon Brief further stated that commercial concentrated solar power plants were first developed in the 1980s. Since then, as the cost of solar electricity has fallen, grid-connected solar PV systems have grown more or less exponentially. Millions of installations and gigawatt-scale photovoltaic power stations have been and are being built so far. According to Carbon Brief solar PV has rapidly become a viable low-carbon technology, and as of 2020, provides the cheapest source of electricity in history.

Dave (2022) stated that as of 2021, solar generates 4% of the world's electricity, compared to 1% in 2015 when the Paris Agreement to limit climate change was signed. Along with onshore wind, the cheapest levelised cost of electricity is utility-scale solar. The International Energy Agency stated in 2021 that under its "Net Zero by 2050" scenario solar power would contribute about 20% of worldwide energy consumption, and solar would be the world's largest source of electricity.

Assistant Director of Alternative Energy Promotion Center and one of the key informant stated that solar energy is naturally more sustainable than fossil fuel energy sources and is more environmentally sustainable. It converts the sun’s energy into electrical energy and makes use of the greatest, most sustainable resource on the planet, sunlight. According to another key informant and Site Manager of Risen Energy Company Limited, Bidur Nuwakot, Nepal has good potential of solar generation. He further stated that solar generation is high in higher altitude region than in Terai while the solar generation is good during March to June and little less in monsoon but it is severely affected by weather conditions. He also said that the solar energy in large scale is relatively new to Nepal but the ample skilled manpower is in the market. The solar panel and major electrical components are not manufactured in Nepal, so need to import.

A key informant and senior divisional engineer of the Ministry of Energy, Water Resources and Irrigation said that presently 40 MW of power is generated from solar and is connected to national grid in Nepal. Also, many individual solar home systems have been installed in isolated areas. All the solar panel has to be imported and number of skilled manpower in this sector is increasing. Another key informant who is also Project Coordinator of Alternative Energy Promotion Centre stated that Nepal has a huge potential on solar power, as it is located at favorable latitude that receives ample amounts of Solar radiations. Human resources in Nepal are technically skilled now. Government of Nepal, AEPC with close coordination with CTEVT, provides Level -1 and level-2 technical solar installation training to improve the technical skilled of the manpower. Most of the solar panel and its accessories are imported from China and India (e.g. MS Power solar, Blue sun, Alpex, Trina,Vikram solar etc).

5.2 Mainstream Solar Technologies

Many industrialized nations have installed significant solar power capacity into their grids to supplement or provide an alternative to conventional energy sources while an increasing number of less developed nations including Nepal have turned to solar to reduce dependence on expensive imported fuels. Long distance transmission allows remote renewable energy resources to displace fossil fuel consumption. Solar power plants use one of two technologies: Photovoltaic (PV) systems which use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power and Concentrated Solar Power (CSP, also known as "concentrated solar thermal") plants which use solar thermal energy to make steam, which is thereafter converted into electricity by a turbine.

5.2.1 Photovoltaic Power Station

Wolfe (2020) mentioned that a photovoltaic power station, also known as a solar park, solar farm, or solar power plant, is a large-scale grid-connected photovoltaic power system also known as PV system designed for the supply of commercial power. Wolfe further stated that they are differentiated from most building-mounted and other decentralised solar power because they supply power at the utility level, rather than to a local user or users. The generic expression utility-scale solar is sometimes used to describe this type of project. The solar power source is via photovoltaic modules that convert light directly to electricity. However, this differs from, and should not be confused with concentrated solar power, the other large-scale solar generation technology, which uses heat to drive a variety of conventional generator systems. Both approaches have their own advantages and disadvantages, but to date, for a variety of reasons, photovoltaic technology has seen much wider use in the field. As of 2019, concentrator systems represented about 3% of utility-scale solar power capacity (Wolfe, 2020).

Wolfe (2020) stated that in some countries, the nameplate capacity of a photovoltaic power station is rated in megawatt-peak (MW_p), which refers to the solar array's theoretical maximum DC power output. In other countries, the manufacturer gives the surface and the efficiency. However, Canada, Japan, Spain and the United States often specify using the converted lower nominal power output in MW_{AC}, a measure directly comparable to other forms of power generation. A third and less common rating is the megavolt-amperes (MVA). Wolfe further mentioned that most solar parks are developed at a scale of at least 1 MW_p. As of 2018, the world's largest operating photovoltaic power stations surpass 1 gigawatt. As at the end of 2019, about 9,000 plants with a combined capacity of over 220 GW_{AC} were solar farms larger than 4 MW_{AC} (utility scale). Most of the existing large-scale photovoltaic power stations are owned and operated by independent power producers, but the involvement of community and utility-owned projects is increasing. Previously almost all were supported at least in part by regulatory incentives such as feed-in tariffs or tax credits, but as levelized costs fell significantly in the 2010s and grid parity has been reached in most markets, external incentives are usually not needed (Wolfe, 2020).

Figure 2

Risen Solar Power Station, Devighat, Nuwakot, Nepal

Note: One of the seven solar farms of NEA in Devighat, Nuwakot. Almost 12 Bigha of land is covered by 25 MW solar farms. The picture was taken during field visit on July 2022.

Source: Field Visit

Figure 3

Utility-Scale Solar PV Farm

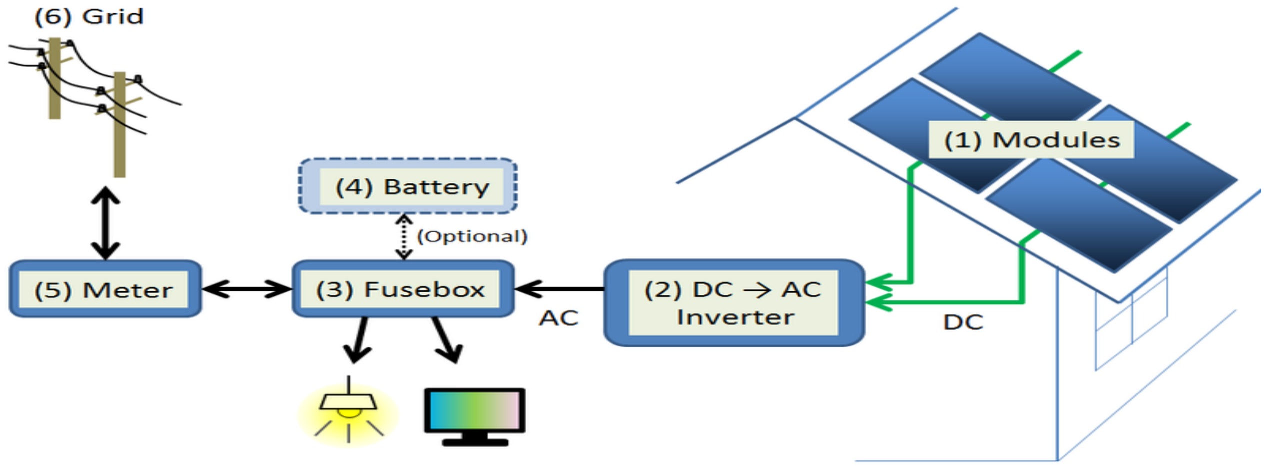
Note: The picture shows how Solar PV could be installed in hilly terrain.
Source: https://www.dnv.com/feature/utility-scale-solar.html

Black (2016) defines a solar cell, or photovoltaic cell (PV), as a device that converts light into electric current using the photovoltaic effect. According to him the first solar cell was constructed by Charles Fritts in the 1880s. The German industrialist Ernst Werner von Siemens was among those who recognized the importance of this discovery. In 1931, the German engineer Bruno Lange developed a photo cell using silver selenide in place of copper oxide, although the prototype selenium cells converted less than 1% of incident light into electricity. Following the work of Russell Ohl in the 1940s, researchers Gerald Pearson, Calvin Fuller and Daryl Chapin created the silicon solar cell in 1954. These early solar cells cost US$286/watt and reached efficiencies of 4.5–6%. In 1957, Mohamed M. Atalla developed the process of silicon surface passivation by thermal oxidation at Bell Labs. The surface passivation process has since been critical to solar cell efficiency (Black, 2016).

The array of a photovoltaic power system, or PV system, produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase. Many residential PV systems are connected to the grid wherever available, especially in developed countries with large markets. In these grid-connected PV systems, use of energy storage is optional. In certain applications such as satellites, lighthouses, or in developing countries, batteries or additional power generators are often added as back-ups. Such stand-alone power systems permit operations at night and at other times of limited sunlight (IEA, 2022).

Figure 4

PV System Schematic Residential



Note: Simplified schematic diagram of a residential PV system

Source: Solar Cells and their Applications Second Edition, Lewis Fraas, Larry Partain, Wiley, 2010

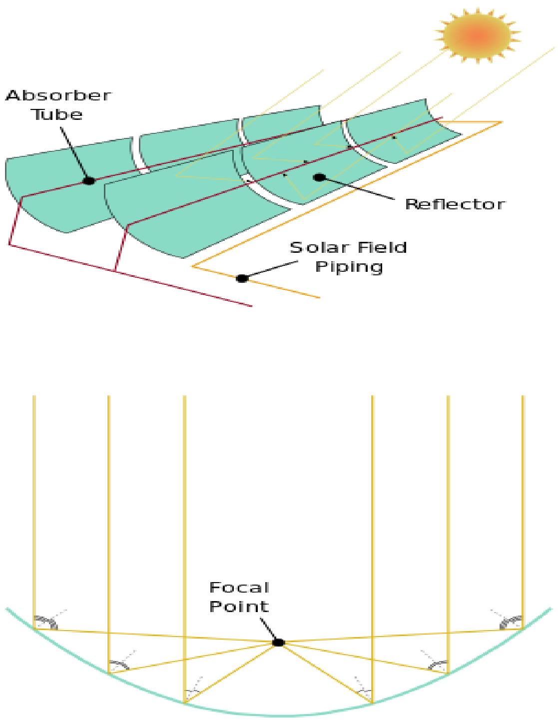
5.2.2 Concentrated Solar Power

According to HelioCSP (2019) commercial concentrating solar power (CSP) plants, also called "solar thermal power stations", were first developed in the 1980s. The 377 MW Ivanpah Solar Power Facility, located in California's Mojave Desert, is the world's largest solar thermal power plant project. Other large CSP plants include the Solnova Solar Power Station (150 MW), the Andasol solar power station (150 MW), and Extresol Solar Power Station (150 MW), all in Spain. The principal advantage of CSP is the ability to efficiently add thermal storage, allowing the dispatching of electricity over up to a 24-hour period. Since peak electricity demand typically occurs at about 5 pm, many CSP power plants use 3 to 5 hours of thermal storage (HelioCSP, 2019).

Solar Power and Chemical Energy System (SolarPACES, 2022) mentioned that Concentrated solar power (CSP), also called "concentrated solar thermal", uses lenses or mirrors and tracking systems to concentrate sunlight, then use the resulting heat to generate electricity from conventional steam-driven turbines. A wide range of concentrating technologies exists: among the best known are the parabolic trough, the compact linear Fresnel reflector, the dish Stirling and the solar power tower. Various techniques are used to track the sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage. Thermal storage efficiently allows up to 24-hour electricity generation.

Figure 5

A parabolic collector type of CSP



Note: A parabolic collector concentrates sunlight onto a tube in its focal point.

Source: Riflettore parabolico.svg

Compact Linear Fresnel Reflectors are CSP-plants which use many thin mirror strips instead of parabolic mirrors to concentrate sunlight onto two tubes with working fluid. The advantage is that flat mirrors which are much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used. Concentrating linear fresnel reflectors can be used in either large or more compact plants. The Stirling solar dish combines a parabolic concentrating dish with a Stirling engine which normally drives an electric generator. The advantages of Stirling solar over photovoltaic cells are higher efficiency of converting sunlight into electricity and longer lifetime. Parabolic dish systems give the highest efficiency among CSP technologies (Global Climate and Energy Project, 2006).

A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned along the focal points of the linear parabolic mirror and is filled with a working fluid. The reflector is made to follow the sun during daylight hours by tracking along a single axis. Parabolic trough systems provide the best land-use factor of any solar technology (SolarPACES, 2022).

A solar power tower uses an array of tracking reflectors (heliostats) to concentrate light on a central receiver atop a tower. Power towers can achieve higher (thermal-to-electricity conversion) efficiency than linear tracking CSP schemes and better energy storage capability than dish stirling technologies. The PS10 Solar Power Plant and PS20 solar power plant as given in the figure below are examples of this technology (SolarPACES, 2022).

Figure 6

Spain's Solnova Solar Power Station

Note: Aerial view of the unit I, III, and IV, of Abengoa Solar's Solnova Solar Power Station. The two towers and reflective mirrors in the background are the PS10 and PS20 solar power plants, also owned by Abengoa Solar. This region is also sometimes known as the Solar Platform.

Source: https://www.abengoa.com/web

5.2.3 Hybrid Systems

A hybrid system combines (C) PV and CSP with one another or with other forms of generation such as diesel, wind and biogas. The combined form of generation may enable the system to modulate power output as a function of demand or at least reduce the fluctuating nature of solar power and the consumption of non-renewable fuel. Kraemer et al. (2008) mentioned commonly used hybrid systems as below.

a. CPV/CSP system: A novel solar CPV/CSP hybrid system has been proposed, combining concentrator photovoltaics with the non-PV technology of concentrated solar power, or also known as concentrated solar thermal.

b. Integrated solar combined cycle (ISCC) system: The Hassi R'Mel power station in Algeria is an example of combining CSP with a gas turbine, where a 25-megawatt CSP-parabolic trough array supplements a much larger 130 MW combined cycle gas turbine plant. Another example is the Yazd power station in Iran.

c. Photovoltaic thermal hybrid solar collector (PVT): Also known as hybrid PV/T, convert solar radiation into thermal and electrical energy. Such a system combines a solar (PV) module with a solar thermal collector in a complementary way.

d. Concentrated photovoltaics and thermal (CPVT): A concentrated photovoltaic thermal hybrid system is similar to a PVT system. It uses concentrated photovoltaics (CPV) instead of conventional PV technology, and combines it with a solar thermal collector.

e. PV diesel system: It combines a photovoltaic system with a diesel generator. Combinations with other renewables are possible and include wind turbines.

f. PV-thermoelectric system: Thermoelectric, or "thermovoltaic" devices convert a temperature difference between dissimilar materials into an electric current. Solar cells use only the high frequency part of the radiation, while the low frequency heat energy is wasted. Several patents about the use of thermoelectric devices in tandem with solar cells have been filed.

The idea of hybrid system is also to increase the efficiency of the combined solar/thermoelectric system to convert the solar radiation into useful electricity.

5.3 History of Solar Power Development

Glenn (2014) mentioned that the early development of solar technologies starting in the 1860s was driven by an expectation that coal would soon become scarce, such as experiments by Augustin

Mouchot. According to him Charles Fritts installed the world's first rooftop photovoltaic solar array, using 1%-efficient selenium cells, on a New York City roof in 1884. However, development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum.

Levi (2021) wrote by the 1970s, solar power was being used on satellites, but the cost of solar power was considered to be unrealistic for conventional applications. In 1974 it was estimated that only six private homes in all of North America were entirely heated or cooled by functional solar power systems. However, the 1973 oil embargo and 1979 energy crisis caused a reorganization of energy policies around the world and brought renewed attention to developing solar technologies. Other efforts included the formation of research facilities in the United States, Japan, and Germany. Between 1970 and 1983 installations of photovoltaic systems grew rapidly. Levi explained in the United States, President Jimmy Carter had a 32-panel solar water heater installed on the White House roof in 1979, and set a target of producing 20% of U.S. energy from solar by the year 2000. His successor, Ronald Reagan, removed both the solar panels and the funding for research into renewables. Falling oil prices in the early 1980s moderated the growth of photovoltaics from 1984 to 1996 (Levi, 2021).

In the mid-1990s development of both, residential and commercial rooftop solar as well as utility-scale photovoltaic power stations began to accelerate again due to supply issues with oil and natural gas, global warming concerns, and the improving economic position of PV relative to other energy technologies. In the early 2000s, the adoption of feed-in tariffs a policy mechanism, that gives renewables priority on the grid and defines a fixed price for the generated electricity led to a high level of investment security and to a soaring number of PV deployments in Europe (Levi, 2021).

Timperley (2021) mentioned for several years, worldwide growth of solar PV was driven by European deployment, but then shifted to Asia, especially China and Japan, and to a growing number of countries and regions all over the world. The largest manufacturers were located in China. Although concentrated solar power grew more than tenfold it remained a tiny proportion of the total. Despite the rising cost of materials, such as polysilicon, during the 2021–2022 global energy crisis; the cost of some other energy sources, such as natural gas, rose more thus making utility scale solar the cheapest energy source in many countries. However growth continued to be hindered by fossil-fuel subsidies (Timperley, 2021).

5.4 Current Status and Forecasts of Solar Power

About half of installed capacity is utility scale. Most new renewable capacity between 2021 and 2026 is forecast to be solar. Utility scale is forecast to become the largest capacity in all regions except sub-Saharan Africa. According to a 2021 study global electricity generation potential of rooftop solar panels is estimated at 27 PWh per year at cost ranging from $40 (Asia) to $240 per MWh (US, Europe). Its practical realization will however depend on the availability and cost of scalable electricity storage solutions (IEA, 2021).

A forecast done by European Photovoltaic Industry Association (EPIA) / Greenpeace, shows that in the future, the most enterprising outlook for the increased use of solar technology depends on existing market support continuing to rise and grow, and the encouragement of the addition of other market support mechanisms towards the growth of solar PV. This positive outlook could take the capacity of solar PV to 1845 GW by 2030. If less political support exists in the future, the outlook would still be near 1000 GW by 2030. Another joint study done by Greenpeace International and the European Renewable Energy Council, estimates that by 2050 solar PV growth could hit 2033 GW (Timilsina, 2012).

5.5 Economics of Solar Power

Following section deals with the various aspects of solar power related to production cost, administrative, repair and maintenance cost including economic viability of solar power generation in comparison to other energy sources.

5.5.1 Cost per Watt

IEA (2021) stated the typical cost factors for solar power include the costs of the modules, the frame to hold them, wiring, inverters, labour cost, any land that might be required, the grid connection, maintenance and the solar insolation that location will receive. Photovoltaic systems use no fuel, and modules typically last 25 to 40 years. Thus upfront capital and financing costs make up 80 to 90% of the cost of solar power.

According to a key informant and also a Project Coordinator of Alternative Energy Promotion Centre, Solar panels have around 20 to 30 years life expectancy on an average 25 years, whereas around 10 to 20 percent of the power capacity will be decreased periodically. Hence, life cycle of solar plant is around 25 years is perfect weather conditions. Site Manager of Risen Energy Company Limited, Nuwakot mentioned that generally the life cycle of solar power plant is considered 25 years. Most of the PV modules linearly degrade to the 20% of its original efficiency at the end of life.

5.5.2 Installation Prices

Expense of high power band solar modules has greatly decreased over time. Beginning in 1982, the cost per kW was approximately 27,000 American dollars, and in 2006 the cost dropped to approximately 4,000 American dollars per kW. The PV system in 1992 cost approximately 16,000 American dollars per kW and it dropped to approximately 6,000 American dollars per kW in 2008. In 2021 in the US, residential solar cost from 2 to 4 dollars/watt (but solar shingles cost much more) and utility solar costs were around $1/watt (EcoWatch, 2022).

During the survey, different subject matter experts gave differing opinion concerning the solar power plant installation cost in Nepal. According to key informant Assistant Director of AEPC, the installation cost of solar plant is approximately NRs.80 Million per MW for the grid connected solar whereas project coordinator of the same office said it to be NRs. 45 Million only. While Site Manager of Risen Energy Company Limited, Nuwakot mentioned the cost per installation per MW is around NRs.70 Million to NRs. 100 Million depending upon the site condition.

5.5.3 Productivity by Location

Lipponen (2017) stated the productivity of solar power in a region depends on solar irradiance, which varies through the day and year and is influenced by latitude and climate. PV system output power also depends on ambient temperature, wind speed, solar spectrum, the local soiling conditions, and other factors. Onshore wind power tends to be the cheapest source of electricity in Northern Eurasia, Canada, some parts of the United States, and Patagonia in Argentina: whereas in other parts of the world mostly solar power (or less often a combination of wind, solar and other low carbon energy) is thought to be best. The locations with highest annual solar irradiance lie in the arid tropics and subtropics. Deserts lying in low latitudes usually have few clouds, and can receive sunshine for more than ten hours a day. These hot deserts form the Global Sun Belt circling the world. This belt consists of extensive swathes of land in Northern Africa, Southern Africa, Southwest Asia, Middle East, and Australia, as well as the much smaller deserts of North and South America. Africa's eastern Sahara Desert, also known as the Libyan Desert, has been observed to be the sunniest place on Earth according to NASA. So solar is (or is predicted to become) the cheapest source of energy in all of Central America, Africa, the Middle East, India, South-east Asia, Australia, and several other places (Lipponen, 2017).

According to a key informant of Alternative Energy Promotion Center the solar potential in Nepal is 50,000 terawatt-hours per year, which is 100 times larger than its hydro resource and 7,000 times larger than its current electricity consumption. Site Manager of Risen Energy Company Limited, Nuwakot mentioned during KII that the average irradiance in Nepal is from around 4.5 to 5.5kWh/m2/day. According to senior divisional engineer and key informant, of the Ministry of Energy, Water Resources and Irrigation, Nepal receives 3.6 to 6.2 kWh of solar radiation per square meter per day, with roughly 300 days. These parameters are quite good for solar power generation. Nepal has potential of 28000 MW of solar power. A key informant and Senior Divisional Meteorologist of the Department of Hydrology and Meteorology mentioned that climatologically, Nepal is favorable place for solar energy generation compared to other nations. However, there is slight variation of sunshine hours among the seasons and places.

5.5.4 Self Consumption

In cases of self-consumption of solar energy, the payback time is calculated based on how much electricity is not purchased from the grid. However, in many cases, the patterns of generation and consumption do not coincide, and some or all of the energy is fed back into the grid. The electricity is sold, and at other times when energy is taken from the grid, electricity is bought. The relative costs and prices obtained affect the economics. In many markets, the price paid for sold PV electricity is significantly lower than the price of bought electricity, which incentivizes self consumption. By increasing self consumption, the grid feed-in can be limited without curtailment, which wastes electricity. However, batteries are expensive and profitability may require the provision of other services from them besides self consumption increase. Hot water storage tanks with electric heating with heat pumps or resistance heaters can provide low-cost storage for self consumption of solar power. Shiftable loads, such as dishwashers, tumble dryers and washing machines, can provide controllable consumption with only a limited effect on the users, but their effect on self-consumption of solar power may be limited (Salpakari & Lund, 2016).

5.5.5 Energy Pricing and Incentives

Government of Nepal has formulated and implemented Renewable Energy Subsidy Policy 2016 which has provided different kind of subsidies for the solar power generation according to the accessibility to the grid system. Furthermore the government has been implementing zero-duty rate in solar panels import to Nepal. According to Clean Energy (2012) the political purpose of incentive policies for PV is to facilitate an initial small-scale deployment to begin to grow the industry, even where the cost of PV is significantly above grid parity, to allow the industry to achieve the economies of scale necessary to reach grid parity. The policies are implemented to promote national energy independence, high tech job creation and reduction of CO_2 emissions. Three incentive mechanisms are often used in combination as investment subsidies: the authorities refund part of the cost of installation of the system, the electricity utility buys PV electricity from the producer under a multiyear contract at a guaranteed rate, and Solar Renewable Energy Certificates (SRECs).

a. Net Metering: In net metering the price of the electricity produced is the same as the price supplied to the consumer, and the consumer is billed on the difference between production and consumption. Net metering can usually be done with no changes to standard electricity meters, which accurately measure power in both directions and automatically report the difference, and because it allows homeowners and businesses to generate electricity at a different time from consumption, effectively using the grid as a giant storage battery. With net metering, deficits are billed each month while surpluses are rolled over to the following month. Excess credits upon termination of service are either lost or paid for at a rate ranging from wholesale to retail rate or above, as can be excess annual credits (Clean Energy, 2012).

b. Solar Renewable Energy Credits (SRECs): Alternatively, Solar Renewable Energy Certificates (SRECs) allow for a market mechanism to set the price of the solar-generated electricity subsidy. In this mechanism, renewable energy production or consumption target is set, and the utility (more technically the Load Serving Entity) is obliged to purchase renewable energy or face a fine (Alternative Compliance Payment or ACP). In principle, this system delivers the cheapest renewable energy since all solar facilities are eligible and can be installed in most economic locations. Uncertainties about the future value of SRECs have led to long-term SREC contract markets to give clarity to their prices and allow solar developers to pre-sell and hedge their credits (Clean Energy, 2012).

5.5.6 Cost-Return Comparison between Solar and Hydro Electricity in Nepal

A comparative study between hydroelectricity and solar energy production in Nepal is depicted in *table 1* in this section. All data, facts and figures on hydroelectricity are based on secondary data available, annual reports of the respective hydro power companies and government policies and provisions related to hydro power. In contrary, data, facts and figures on solar power are based on field study and key informant interviews. Furthermore, according to existing policy of the government a hydropower company should hand over to government by hydropower developer after the 30 years

Table 1

Comparative Cost-Return Analysis of Solar and Hydro in Nepal

	Rasuwa gadhi Hydro	**Assumed Hydro**	**Upper Tamakoshi**	**Solar Electricity (Same Capacity as of Upper Tamakoshi Hydro)**			
Capacity	111 MW	1 MW	456 MW	456	456	456	456
Cost per MW	**180 M**	**130 M**	**185 M**	**@80 M**	**@70 M**	**@60 M**	**@50 M**
Total Cost	**20 B**	**130 M**	**85 B**	**3.648 B**	**3.192B**	**2.736 B**	**2.280 B**
Annual Production In Units	0.614 B (Annual Report 2021/22)	5.256 M (@60%)	2.281 B (Annual Report 2021/2022)	0.9576 B (7 hrs X 300 Days)	0.9576 B (7 hrs X 300 Days)	0.9576 B (7 hrs X 300 Days)	0.9576 B (7 hrs X 300 Days)
25 Years Production	15.342 B	131.4 M	57.025 B	23.94 B	23.94 B	23.94 B	23.94 B
Depreciation Adjustment	Not Needed 1st Yr production = 25th Yr production			21.0672 B	21.0672 B	21.0672 B	21.0672 B
@Rs.10	153.419 B	1.314 B	570.251 B	210.672 B	210.672 B	210.672 B	210.672 B
25 Yr Return in investment (in Times)	**7.67**	**10.12**	**6.7**	**57.75**	**66**	**77**	**92**

Note: The table shows cost-return analysis of Solar Electricity at varying per MW cost level in comparison with hydro. Large scale solar plant with equal capacity of Upper Tamakoshi is considered as an example. An assumed hydropower with just 130M per MW cost is also compared together with 111 MW Rasuwagadhi Hydro which is still under construction.

Source: Researcher

Assumption is made that 5 years is needed in an average to complete a hydro project, Upper Tamakoshi took quite more than that. So, it is assumed that the hydropower company can operate the project only for 25 year which is same as the life of solar panel. Solar panel can generate electricity in an average only for 300 days in a year, 7 hours in a day. Additionally, solar energy output is reduced by 0.8-1 % every year so at the end of 25 years the production will be just around 80% of the full capacity. That is incorporated by making adjustment of 12.5 % in the 25 years aggregate production. In contrary, it is considered that efficiency of hydropower will not reduced over 25 years and will continue to operate at the same capacity as in the first year. But it is assumed that Run-of-River (RoR) based hydropower will produce only 60 % of its full capacity annually due to low water level during dry seasons. For Upper Tamakoshi and Rasuwagadhi actual data are taken which are also just around 60% of the full capacity.

Average annual administrative, repair and maintenance cost of solar project upon completion is 3-5 % of project cost as revealed by KII. Based on the experts' opinions and experiences the administrative, repair and maintenance cost of hydroelectricity is much higher than solar. In this analysis other factors such and inflation, cost of fund, opportunity cost; environmental factors etc. in addition to regular repair, maintenance and administrative costs are not taken into consideration. In table 1, Upper Tamakoshi, the largest hydropower of Nepal so far with its full capacity of 456 MW is taken as basis for comparison with same capacity of assumed solar power plants under different per MW cost rates shown by the study. The cost per MW for solar is based on KII whereas the secondary sources data show per MW cost of hydroelectricity in Nepal ranges from 130M to 250 M and in an average much higher than 160 M. The produced electricity is considered to be sold at an equal rate of Rs. 10 per unit. In reality the rate is much lower in Nepal but that has same impact for solar and hydro. From the table1 it is obvious that electricity production from solar power is much less than from hydropower but the efficiency in term of return at the end of 25 years is much higher from solar which is 92 time to 57.75 times of investment as compared to 6.7 times to 10.12 times only from hydropower.

5.6 Grid Integration

The overwhelming majority of electricity produced worldwide is used immediately because traditional generators can adapt to demand and storage is usually more expensive. Solar power is source of variable renewable power, meaning that all available output must be used locally, carried on transmission lines elsewhere to be used, or stored (e.g. in a battery). Since solar energy is not available at night, storing its energy is potentially an important issue particularly in off-grid and for future 100% renewable energy scenarios to have continuous electricity availability (Ray, 2013).

Solar electricity is inherently variable but somewhat predictable by time of day, location, and seasons. Solar is intermittent due to day/night cycles and unpredictable weather. How much of a special challenge solar power is in any given electric utility varies significantly. In places with hot summers and mild winters, solar is well matched to daytime cooling demands (Tyler and Ken, 2022).

In an electricity system without grid energy storage, generation from stored fuels (coal, biomass, natural gas, nuclear) must go up and down in reaction to the rise and fall of solar electricity. While hydroelectric and natural gas plants can quickly respond to changes in load, coal, biomass and nuclear plants usually take considerable time to respond to load and can only be scheduled to follow the predictable variation. Depending on local circumstances, beyond about 20–40% of total generation, grid-connected intermittent sources like solar tend to require investment in some combination of grid interconnections, energy storage or demand side management. Integrating large amounts of solar power with existing generation equipment has caused issues in some cases. For example, in Germany, California and Hawaii, electricity prices have been known to go negative when solar is generating a lot of power (Johnston, 2017).

Conventional hydroelectric dams work very well in conjunction with solar power; water can be held back or released from a reservoir as required. Where suitable geography is not available, pumped-storage hydroelectricity can use solar power to pump water to a high reservoir on sunny days, then the energy is recovered at night and in bad weather by releasing water via a hydroelectric plant to a low reservoir where the cycle can begin again (Fares, (2015**)**. This cycle can lose 20% of the energy to round trip inefficiencies, this plus the construction costs add to the expense of implementing high levels of solar power.

Concentrated solar power plants may use thermal storage to store solar energy, such as in high-temperature molten salts. These salts are an effective storage medium because they are low-cost, have a high specific heat capacity, and can deliver heat at temperatures compatible with conventional power systems. This method of energy storage is used, for example, by the Solar Two power station, allowing it to store 1.44 TJ in its 68 m^3 storage tank, enough to provide full output for close to 39 hours, with an efficiency of about 99% (Electricity Storage Association, 2022).

In standalone PV systems batteries are traditionally used to store excess electricity. With grid-connected photovoltaic power system, excess electricity can be sent to the electrical grid. Net metering and feed-in tariff programs give these systems a credit for the electricity they produce. This credit offsets electricity provided from the grid when the system cannot meet demand, effectively trading with the grid instead of storing excess electricity. Credits are normally rolled over from month to month and any remaining surplus settled annually (Sandia National Laboratory, 2011). When wind and solar are a small fraction of the grid power, other generation techniques can adjust their output appropriately, but as these forms of variable power grow, additional balance on the grid is needed. As prices are rapidly declining, PV systems increasingly use rechargeable batteries to store a surplus to be later used at night. Batteries used for grid-storage can stabilize the electrical grid by leveling out peak loads for around an hour or more. In the future, less expensive batteries could play an important role on the electrical grid, as they can charge during periods when generation exceeds demand and feed their stored energy into the grid when demand is higher than generation.

Common battery technologies used in today's home PV systems include nickel-cadmium and lithium-ion batteries. Lithium-ion batteries have the potential to replace lead-acid batteries in the near future, as they are being intensively developed and lower prices are expected due to economy of scale provided by large production facilities such as the Gigafactory 1. In addition, the Li-ion batteries of plug-in electric cars may serve as future storage devices in a vehicle-to-grid system. Since most vehicles are parked an average of 95% of the time, their batteries could be used to let electricity flow from the car to the power lines and back. Other rechargeable batteries used for distributed PV systems include, sodium–sulfur and vanadium redox batteries, two prominent types of a molten salt and a flow battery, respectively (Hoppmann et al., 2014).

The combination of wind and solar PV has the advantage that the two sources complement each other because the peak operating times for each system occur at different times of the day and year. The power generation of such solar hybrid power systems is therefore more constant and fluctuates less than each of the two component subsystems. Solar power is seasonal, particularly in northern/southern climates, away from the equator, suggesting a need for long term seasonal storage in a medium such as hydrogen or pumped hydroelectric (Kasper et al., 2019). The Institute for Solar Energy Supply Technology of the University of Kassel pilot-tested a combined power plant linking solar, wind, biogas and pumped-storage hydroelectricity to provide load-following power from renewable sources.

Grid integration of solar energy in Nepal is in starting stage. According to Senior Divisional Engineer Babu Raj Adhikari of Ministry of Energy, large project is connected to national grid. There are many individual solar home systems. Alternative Energy Promotion center has established mini grid system to distribute electricity to isolated system in different part of country. According to Pritam Wangdi Lama Battery is generally used for energy storage in Solar system for night time. However, it's not financially attractive to store large amount of energy in batteries. It's better to supply power through hydro in night and peak time. Assistant Director Dr. Laxman Ghimire of AEPC mentioned that in Nepal there are two types of distribution system as on-grid and off-grid. Solar energy is provided off-grid in the Solar Home System and through solar mini-grid whereas for the accessible area solar plant provides electricity to the grid.

5.7 Emerging Technologies

Some of the emerging solar technologies in contemporary time are as follows:

5.7.1 Concentrator Photovoltaic

Concentrator photovoltaics (CPV) systems employ sunlight concentrated onto photovoltaic surfaces for the purpose of electrical power production. Contrary to conventional photovoltaic systems, it uses lenses and curved mirrors to focus sunlight onto small, but highly efficient, multi-junction solar cells. Solar concentrators of all varieties may be used, and these are often mounted on a solar tracker in order to keep the focal point upon the cell as the sun moves across the sky. Luminescent solar concentrators (when combined with a PV-solar cell) can also be regarded as a CPV system. Concentrated photovoltaics are useful as they can improve efficiency of PV-solar panels drastically (Timilsina et al., 2012). In addition, most solar panels on spacecraft are also made of high efficient multi-junction photovoltaic cells to derive electricity from sunlight when operating in the inner Solar System.

5.7.2 Floatovoltaic

Floatovoltaics are an emerging form of PV systems that float on the surface of irrigation canals, water reservoirs, quarry lakes, and tailing ponds. Several systems exist in France, India, Japan, Korea, the United Kingdom and the United States. These systems reduce the need of valuable land area, save drinking water that would otherwise be lost through evaporation, and show a higher efficiency of solar energy conversion, as the panels are kept at a cooler temperature than they would be on land. Although not floating, other dual-use facilities with solar power include fisheries (Solar Server, 2015).

5.7.3 Solar Updraft Tower

The solar updraft tower (SUT) is a design concept for a renewable-energy power plant for generating electricity from low temperature solar heat. Sunshine heats the air beneath a very wide greenhouse-like roofed collector structure surrounding the central base of a very tall chimney tower. The resulting convection causes a hot air updraft in the tower by the chimney effect. This airflow drives wind turbines, placed in the chimney updraft or around the chimney base, to produce electricity. As of mid 2018, although several prototype models have been built, no full-scale practical units are in operation. Scaled-up versions of demonstration models are planned to generate significant power. They may also allow development of other applications, such as to agriculture or horticulture, to water extraction or distillation, or to improvement of urban air pollution

5.7.4 Perovskite Solar Cells

A perovskite solar cell (PSC) is a type of solar cell which includes a perovskite-structured compound, most commonly a hybrid organic-inorganic lead or tin halide-based material, as the light-harvesting active layer. Perovskite materials, such as methyl ammonium lead halides and all-inorganic cesium lead halide, are cheap to produce and simple to manufacture (Weaver, 2017).

Solar cell efficiencies of laboratory-scale devices using these materials have increased from 3.8% in 2009 to 25.7% in 2021 in single-junction architectures, and, in silicon-based tandem cells, to 29.8%, exceeding the maximum efficiency achieved in single-junction silicon solar cells. Perovskite solar cells have therefore been the fastest-advancing solar technology as of 2016. With the potential of achieving even higher efficiencies and very low production costs, perovskite solar cells have become commercially attractive. Core problems and research subjects include their short- and long-term stability (National Renewable Energy Laboratory. 2022).

5.8 Environmental Effects

A key informant at Risen Energy mentioned during the field visit highlighted that different studies show emission of solar PV system is about 40g CO2 eq/kwh compared to 1000g CO2 eq/kwh that of coal. Solar energy is available throughout the world and has promising future due to technological advancement in panel and the reduction in the cost. The installation requires less structure and time. It can replace the current fossil fuel plants to reduce the carbon emission and hence play a pivotal role in greenhouse gas emission reduction. So, it has positive impact on the climate change but the large-scale tree cutting cause the loss of habitat of flora and fauna. So, there may be loss of biodiversity. The loss of forest will also contribute in carbon emission. A AEPC key informant stated that solar energy is considered the cleanest form of energy, no any production of harmful gases and no any harmful pollution is released which will help to counter the climate change impact. But Land use and habitat loss, water use, and the use of hazardous materials in manufacturing and destruction of the plant life might impact the global climate altogether.

Concentrated solar power may use much more water than gas-fired power. Unlike fossil fuel based technologies, solar power does not lead to any harmful emissions during operation, but the production of the panels leads to some amount of pollution (Solar Server, 2008).

5.8.1 Greenhouse Gases

The life-cycle greenhouse-gas emissions of solar power are less than 50 gram (g) per kilowatt-hour (kWh). Whereas (without carbon capture and storage) a combined cycle gas-fired power plant emits around 500 g/kWh, and a coal-fired power plant about 1000 g/kWh (Alsema et al., 2006). The most critical parameter is the solar insolation of the site: GHG emissions factors for PV solar are inversely proportional to insolation (Garvin, 2021). Similar to all energy sources where their total life cycle emissions are mostly from construction, the switch to low carbon power in the manufacturing and transportation of solar devices would further reduce carbon emissions.

5.8.2 Land Use

Life-cycle surface power density of solar power is estimated at 6.63 W/m2 which is two orders of magnitude less than fossil fuels and nuclear power. As result, PV requires much larger amounts of land surface to produce the same nominal amount of energy as sources with higher surface power density and capacity factor. According to a 2021 study obtaining 80% from PV by 2050 would require up to 2.8% of total landmass in European Union and up to 5% in countries like Japan and South Korea. Occupation of such large areas for PV farms would be likely to drive residential opposition as well as lead to deforestation, removal of vegetation and conversion of farm land. However these countries are very unlikely to need 80% from PV on their own land, as they have other low-carbon power such as offshore wind and may also import solar power from sparsely populated countries. Worldwide land use has minimal ecological impact (Frangoul, 2021).

Utility-scale photovoltaic farms use vast amount of space due to relatively low surface power density and occasionally face opposition from local residents, especially in countries with high population density or when the installation involves removal of existing trees or shrubs. Construction of Cleve Hill Solar Park in Kent (United Kingdom) composed of 880,000 panels up to 3.9 m high on 490 hectares of land faced opposition on the grounds of destroying the local landscape. The solar farm divided Greenpeace (which opposed) and Friends of the Earth (which supported it). Similar concerns about deforestation were raised when large amounts of trees were removed for installation of solar farms in New Jersey and others (Dunnett, 2022).

According to site manager of Risen Energy Company Limited, land acquisition, deforestation, solar energy versus food etc are the main challenges of solar power development in Nepal. Conflict due to excessive demand of project affected people is also one of the challenges in the project implementation. The main challenges are in the compensation. Public are not satisfied with the amount they get from the compensation. Also, people do not want to get their land acquired, as the farm land/ home will be lost which they cannot replenish from the compensation as well as the social value is also added in their land. Due to land acquisition, there will be no/less land for the agriculture farming, so less sufficiency on food through farming for a family. On the positive side there is increased job opportunity during the construction and operation phase.

Senior Divisional Engineer of the Ministry of Energy mentioned that solar project becomes costly if land has to purchase. Also there is ceiling of land purchase by single company. It is quite difficult to find government land on lease near substation. Also current policy prohibits development of solar projects in agricultural land. Project coordinator of AEPC stated that land cost may be high and available land may not be flat as well in the required direction to obtain the required result from the installed power station. Issues of the resettlement in another area if large area of land is being used and challenges to find the land which won’t affect the productivity and quality of life of people (cultivable land should be avoided as far as possible). Assistant Director of

AEPC stated that Connectivity for evacuating power generated, attaining environmental and local clearance from authorities, right of way (ROW) for the transmission line, overlap of land record and lack of technology or digitalization are some issues related to land being used while generating solar energy.

5.8.3 Manufacturing and Recycling

According to assistant director of AEPC, firstly solar cells have very low efficiency resulting in extremely high cost. Second, it has several long-term environmental problems. Solar cells consist of various heavy metals including synthetic chromium, lead among others. Synthetic silicon which the solar panels are made of is not easily biodegradable. The storage batteries also consist of heavy metals such as lead and chromium and toxic acids. These metals and acids are eventually discharged at some point resulting in water, land and air pollution.

One issue that has often raised concerns is the use of cadmium (Cd), a toxic heavy metal that has the tendency to accumulate in ecological food chains. It is used as semiconductor component in CdTe solar cells and as a buffer layer for certain CIGS cells in the form of cadmium sulfide. The amount of cadmium used in thin-film solar cells is relatively small (5–10 g/m^2) and with proper recycling and emission control techniques in place the cadmium emissions from module production can be almost zero. Current PV technologies lead to cadmium emissions of 0.3–0.9 microgram/kWh over the whole life-cycle. Most of these emissions arise through the use of coal power for the manufacturing of the modules, and coal and lignite combustion leads to much higher emissions of cadmium. Life-cycle cadmium emission from coal is 3.1, lignite 6.2, and natural gas 0.2 microgram/kWh (Naila, 2018).

In a life-cycle analysis it has been noted, that if electricity produced by photovoltaic panels were used to manufacture the modules instead of electricity from burning coal, cadmium emissions from coal power usage in the manufacturing process could be eliminated. In the case of crystalline silicon modules, the solder material, that joins the copper strings of the cells, contains about 36 percent of lead (Pb). Moreover, the paste used for screen printing front and back contacts contains traces of Pb and sometimes Cd as well. It is estimated that about 1,000 metric tons of Pb have been used for 100 gigawatts of c-Si solar modules. However, there is no fundamental need for lead in the solder alloy (Naila, 2018).

Manufacturing of solar panels requires rare-earth elements, producing low-level radioactive waste during the mining process. International Energy Agency study projects the demand for mined resources such as lithium, graphite, cobalt, copper, nickel and rare earths will rise 4 times by 2040 and notes insufficient supply of these materials to match demand imposed by expected large-scale deployments of decentralized technologies solar and wind power, and required grid upgrades. According to a 2018 study significant increase of PV solar power would require 3000% increase in supply of these metals by 2060, thermal solar 6000%, requiring significant increase in mining operations (IEA, 2021).

5.9 Chapter Summary

The Sun is an infinite source of energy that is pivotal for sustaining life on our planet earth. It has been harnessing energy from the sun since ancient times to this modern era of ever evolving technologies. Solar radiation can be converted into useful energy such as solar collectors can provide hot water or air heating, solar photovoltaic cells can generate electricity.

Much of this solar panel area can be located on rooftops, on the ground, floated on lakes and hydroelectric reservoirs or in food growing areas (agrivoltaics) where widely spaced solar panels shade 10 per cent of the crop but cause little loss of production because they reduce wind speeds and evaporation rates. Balancing high levels of solar energy over every hour of every year is straightforward. Strong transmission across Nepal allows the smoothing out of local weather and demand variability. Storage via pumped hydro energy storage and batteries allows the daily solar cycle to be accommodated.

Most of the major economies around the world have pledged to reach zero greenhouse emissions by 2050. This requires the solar industry to become 30 times larger during the 2020s. Because of this massive scale-up, the price of solar panels will halve again, and the cost of solar energy in Nepal will decline far below any other energy source. Solar energy has far lower risk because solar panels can be installed incrementally.

Nepal is blessed with solar resource as it lies at around 30◦ Northern latitude which is ideal and there are over 300 days of sunshine annually. Further the annual average solar insolation is 5kWh/m2 per day. These conditions are perfect for harnessing solar energy for various conversion technologies.

CHAPTER VI

ROLE OF SOLAR POWER TO MITIGATE CLIMATE CHANGE

6.1 Significance of Solar Energy in Nepal

Energy plays a vital role in the survival as well in the economic development. Nepal being a developing country, technological and economical hindrances cause generation of the renewable energy extremely difficult. The traditional sources of energy such as biomass are frequently used in Nepal, especially in household purpose. This has led to the degradation of the natural resources. On the other hand, for the commercial purpose, the fossil fuels such as petrol, diesel, kerosene and LPG are used for the running of vehicles, stationary engines, boilers, cooking, lightening etc. These fuels need to be imported from other countries, so that huge amount of the foreign currency is being gone out of the country for these petroleum products. Also, most of the solar systems have controls that keep the panels at an even temperature however; even area with extremes temperature may not be enough to mitigate the wear and tear. Active solar heating systems are most cost-effective in cold climates with good solar resources when they are displacing the more expensive heating fuels, such as electricity, propane, and oil. Further, for the installation of the solar panel technical personnel's are not required. It can be easily installed by the trained workers, which also reduce the cost.

A project coordinator at AEPC mentioned during the interview:

> *Solar power is pollution-free and causes no greenhouse gases to be emitted after installation which can reduce dependence on foreign oil and fossil fuels. Solar power is renewable clean power that is available every day of the year even cloudy days produce some power. It can provide return on investment unlike paying for utility bills. Solar panels contain no moving parts and thus produce no noise so in the long run, solar power is economical. The solar energy industry creates jobs and helps local economies by generating income and employment opportunities. There is no need of importing fossil fuel to generate solar energy.*

Site manager of Risen Energy Company, Nuwakot mentioned that "*PV module and other. electrical component are not manufactured in Nepal, we need to depend on the import. But after the project is implemented, it can avoid the import of fossil fuel like coal and oil during generation phase.*"

As shown by the study, Nepal lies in such a location that the average solar radiation is between 3.6 - 6.2 KWh/m2/day thus the land in Nepal is suitable for the solar installation. Thus the development of solar energy technology is reasonably favorable in many parts of the country. Solar panels are very safe. It provides the required energy without burning fossil fuels and releasing harmful emissions into the environment in comparison with the other energy sources like nuclear power plant, oil plants which release harmful radioactive substances, green houses gases, carcinogens and carbon dioxide which are very harmful to the human health and to environment. Solar panels are primarily made of silicon so there is no danger of leaking toxins or flumes. In addition to this, they are environmental friendly as they only use solar power to generate energy.

Solar energy is most effective and efficient in Nepal. Nepal receives 3.6 to 6.2 kWh of solar radiation per square meter per day, with roughly 300 days of sun a year, making it ideal for solar energy. These parameters are quite good for solar power generation. Nepal has potential of 28 GW of solar power. Presently 40 MW of power is generated from solar and is connected to national grid. Also, many individual solar home systems have been installed in isolated areas. All the solar panel has to be imported and number of skilled manpower in this sector is increasing. It contributes to increased electricity supply in country. If we can export energy to neighboring countries it will contribute to reduce trade deficit. In wet season Nepal is exporting electricity to India around NRs 1.75 Arab in a month. But for this increase in number of high voltage cross border transmission line is necessary and India should be willing to buy power from Nepal.

Main problem regarding energy production from solar is its unpredictability due to weather condition. Also it produces reactive power and national grid can absorb only 15-20% solar energy. Furthermore, due to capacity of national grid big solar plant cannot be in a single point. Hydro and solar are most effective renewable sources of energy in Nepal. The solar is less reliable than hydro due to intermittent in nature. Nepal is rich in hydro resource and the plant utilization factor is also high. Solar on the other hand despite intermittent in nature, available throughout the region, and rapid and easily installation can be done. From the energy mix point of view also solar should be considered. Solar power is accepted world widely as clean alternate energy source to replace coal and other fossil fuel generated electricity. It will contribute to reduce green house gas emission. We can enter into the global carbon market if solar power is used to replace fossil fuel energy in industrial processes and product use (IPPU) sector.

6.2 Contribution of Solar Energy to Mitigate Climate Change

Climate change is the global problem now in the modern world which is impacting life system directly or indirectly. To counter out the problems of climate change, it is highly effective to use cleaner version of energy and solar energy and renewable energy can be considered one of the cleanest energy source. Hence, use of the solar energy should be promoted as far as possible. Solar energy is one of the renewable form of energy which is considered clean version of the energy .Since it is the purest form of energy it won't hamper the environment cycle and helps to mitigate climate change problem. It is the cleanest form of the energy which won't release any harmful gases and other hazardous byproduct to the environment and hence it is the fundamental source of energy for the mitigation of climate change.

Solar produces less life-cycle GHG emissions than conventional fossil fuel energy sources. While there may be some GHG emissions produced during the manufacturing and recycling of the solar system, the generation of energy results in zero GHG emissions and zero environmental impact. Use of solar energy eases reliance on fossil fuels such as coal, natural gas, and oil. The change has a direct influence on the reduction of emission of harmful gases to the atmosphere. There is a reduction in gas emissions, and the sun's energy is limitless, unlike fossils. Renewable energy can supply two-thirds of the total global energy demand, and contribute to the bulk of the greenhouse gas emissions reduction that is needed between now and 2050 for limiting average global surface temperature increase below 2 °C. The production of solar energy is clearly a way to diminish our dependency to fossil fuels, and is a good way to mitigate global warming by lowering the emission of greenhouse gases.

According to senior divisional engineer at ministry of energy solar energy contributes to increase electricity supply in the country. Fossil fuel consumption can be reduced if we can promote electric vehicles and electric cooking. But for this we need policy intervention from government and huge investment in transmission and distribution system is required. Site manager of Risen Energy Company stated referring to different studies that emission of solar PV system is about 40g CO2 eq/kwh compared to 1000g CO2 eq/kwh that of coal. So, it has positive impact on the climate change. Senior divisional meteorologist at department of hydrology and meteorology opined that use of renewal energy can be an alternative to reduce the GHG emission but it should be promoted globally as it is a global issue. We can't stop global warming by doing climate action in a nation as climate has no boundary. At the same time, we have to have a clear plan to manage the waste of producing renewal energy.

Chief of climate change section at ministry of forest and environment explained that solar power is accepted worldwide as clean alternate energy source to replace coal and other fossil fuel generated electricity. It will contribute to reduce green house gas emission. We can enter into the global carbon market if solar power is used to replace fossil fuel energy in industrial processes and product use (IPPU) sector.

6.3 Relevancy of Solar Energy Development to APF, Nepal

APF, Nepal is a key security agency of the country with large number of personnel and offices. Its personnel and offices are deployed across the seven provinces and seventy seven districts. APF personnel stay in barrack system and the food is served through mess. So far, LPG gas is used as fuel in all messes which is being fossil fuel not free from GHG emission. It is not locally available in the country, so it has to be imported that contributes in foreign trade deficit of the country. To run all the offices across the country huge amount of energy is required to APF, Nepal. The vehicles used by APF, Nepal are based on fossil fuel which emits GHG. Some of the APF offices of APF, Nepal are located in remote areas where the grid line electricity is either unavailable or not reliable. As a state party of Paris Agreement 2015, Nepal will also have to transition to electric vehicles at some point of time. This will compel APF, Nepal also to switch into electric vehicles. Recently, APF, Nepal has signed an agreement with NEA regarding the construction and operation of electric vehicle charging stations and assistance in the use of induction stoves in various units of the Armed Police Force Nepal. The agreement was made with the aim of reducing non-renewable energy and increasing renewable energy consumption. The details of the news released in APF, Nepal official webpage is attached in Appendix "D".

Under the aforementioned pretext, solar energy is extremely significant to APF, Nepal. Some of the spacious and remote area units of APF, Nepal could be transformed into fully solar energy dependant units. At some point of time in near future, the renewable energy to APF will no more be requirement but compulsion. As a responsible government agency, APF should be a role model to promote, protect and strengthen government policies and obligations. APF, Nepal will also need to move with the tide of worldwide transition to renewable energy, especially solar.

6.4 Findings

Based on this study it is found that the solar energy production and promotion could be a viable option to mitigate climate change. Solar power as a source of renewable energy with zero GHG emission has potential to mitigate, if not replace, traditional use of forest product as fuel in the rural areas as well as fossil fuel consumption in the urban areas at once. Effective and efficient way of producing and promoting solar energy in Nepal could be achieved through Community Solar.

A community solar project, farm or garden is a solar power installation that is run by and provides benefits to multiple customers, including individuals, businesses, nonprofits, and other investors in a specific community. Participants can typically invest in or subscribe to a certain KW capacity or KWh generation of remote solar electrical production. The project's power output could be credited to investors in proportion to their investment, with adjustments to reflect ongoing changes in capacity, technology, costs and electricity rates. Community solar will provide direct access to the renewable energy to customers who cannot install it themselves. Companies, cooperatives, governments or non-profits organizations can operate a particular solar farms established in a remote village locality.

6.4.1 Prospect of Community Solar Power in Nepal

The Community Solar Program in Nepal could be a global innovation in participatory environmental governance. The program might address the four goals together such as: energy supply, forest conservation, climate change mitigation and poverty reduction. As more than 70 percent of Nepal's population depends on agriculture for their livelihood, community management of solar could be a critically important intervention. Through legislative developments and operational innovations, the program could evolve from a renewable energy-oriented, climate change mitigation-focused agenda to a much more broad-based strategy for public or private land use, enterprise development, and livelihood improvement. As Nepal is a village dominated country, large number of population could participate in the program, directly managing large area of unused land including rooftops. The immediate livelihood benefits derived by rural households bolster strong collective action wherein local communities actively and sustainably manage solar energy. Community solar can become the source of diversified investment capital for new market-oriented livelihoods. Community solar can show traits of political, financial, and ecological sustainability, including emergence of a strong legal and regulatory framework, and robust civil society institutions and networks. However, the implementation challenge is to ensure equitable distribution of benefits to women and marginalized groups. Success of the program will depend on experiential learning, establishment of a strong civil society network, flexible regulation to encourage diverse institutional modalities, and responsiveness of government and policymakers to a multi-stakeholder collaborative learning process.

6.4.2 Potential Benefits of Community Solar

A community solar can function similarly to hydroelectricity energy as it provide energy remotely, requiring no installation or maintenance on the part of the consumer. Because of its remote nature, the physical limitations of solar installation for consumers disappear. Also, due to its subscription functionality, community solar can increase access to solar energy for low-income households. These projects benefit initial investors too. As consumer rates for solar energy become lower through distribution of generated community solar, initial investors in community solar projects experience higher returns in the long run because the administrative, maintenance and running cost after the start of solar energy generation will be very low. According to key informant at AEPC the administrative, repair and maintenance cost remains as low as about 3% of total project cost for.

Centralizing the location of solar systems can thereby create advantages over residential installations. Below are some of the primary, logistical, financial and social or community benefits of community solar:

i. Remote, rural, low-income and marginalized people/ community gain access to renewable energy. This helps to improve their social, financial and ultimately living standard.
ii. Local ownership in community solar and expanding participation to include renters and others who are not residential property owners could be achieved. Community ownership helps to reduce conflict due to excessive demand of project affected people which is also one of the major challenges in the solar power project implementation in business model.
iii. Women are the most vulnerable and marginalized groups in remote areas who are often home makers in addition to other varieties of livelihood responsibilities. Substantial portion of their time is spent in cooking, cleaning and collecting woods as fuel. Burning woods for cooking and the smoke coming out of it severely deteriorate their health. Access to renewable energy from community solar will contribute to their improved health and enhanced social status.
iv. Community solar will have an ability to generate jobs as some of the local people could be employed in various jobs such as cleaning of module; cleaning of inverter /transformer station; tree branches and twig trimming to clear overhead transmission line; monthly, semi-annual and annual inspection of PV farm for condition based maintenance; corrective

maintenance of the electrical components; surveillance and security of the property, operation and administration etc.

v. Community solar contributes to provide access to educational resources to remote and marginalized people as the solar energy could be utilized to operate various electronic devices such as TV, Computer, Wi-Fi router, Mobile and internet etc.

vi. Reduced installation costs and maintenance requirements due to locally available cheap labors and security of the solar farm by local people who are also the owner.

vii. Return-on-investment as the billing system could be established based on the solar energy consumed by a particular consumer or client, same way as practiced by NEA.

viii. Transformation of remote area people from forest product user as a primary source of fuel to renewable solar energy user. This will control destruction of forest which has multifaceted implications such as environment protection, climate change mitigation, increased water sources and preservation of wild flora and fauna.

ix. Community people could decide appropriate and suitable land to install solar farm which will help to best utilize the unused barren land.

x. Social cohesion and harmony will be enhanced as community solar increases the interconnectedness among community people.

xi. The problem of grid line connection will not arise as the solar energy generated by the community will be consumed locally for lighting, cooking, charging and operating various electrical devices and equipments such as refrigerator, iron, water pump, electric mills, electric vehicles, micro oven, TV, computer, mobile etc and run other local level enterprises. This will help to make solar energy cheaper as the long distance and large transmission lines are very costly.

xii. Women and children in the remote areas devote their substantial portion of time is to collect drinking and cleaning water. Community solar could also contribute to improve their social and economic status as community solar could be utilized to water lifting projects in those areas.

xiii. Because of the smaller size, even the local level government also can allocate budget for such community program. Such projects could be operated in public-private partnership between local government and community people. NEA can do partnership with local community and run such project. As community solar will be focused on remote, rural and under-privileged community people to generate renewable energy with zero GHG emission, it is highly likely that such projects will be sponsored and funded by developed countries and donor agencies including UNDP, World Bank, IMF and ADB etc.

6.5 Chapter Summary

Solar energy is of high significance in Nepal. As it has potential to replace fossil fuel, it will definitely contribute in climate change mitigation. Solar power development is relevant to APF, Nepal also as it can contribute in national security, economic and social enhancement of people including disaster prevention/ mitigation through climate change mitigation. Based on the analysis in this chapter following conclusions are drawn which are intended to APF, Nepal organization level as well as the Nepal government level.

6.2.1 Community Solar: Community Solar incorporating some features of community forestry and NEA rural electrification is required. Operational innovations, legislative developments and subsequent implemented is needed across the country. This could be a global innovation in participatory environmental governance which will address the multiple goals such as: energy supply, forest conservation, climate change mitigation, poverty reduction, mainstreaming of marginalized people, improved health, social harmony and economic development together.

6.2.2 Entrepreneurship Development and Employment Generation: The Community solar could be directed toward entrepreneurship development and employment generation such as local mills, cottage industries, drinking water lifting and irrigation.

6.2.3 Establishment of solar PV farm in APF offices: APF, Nepal could conduct in-depth study on the possibility of solar power plants establishment, especially in the offices located in remote areas where the hydro-electricity supply is not reliable. Recent agreement with NEA regarding the construction and operation of electric vehicle charging stations and assistance in the use of induction stoves in various APF, units can integrate the installation of Solar PV in APF units by NEA.

6.2.4 Transition to EV and electric stove: APF, Nepal needs to be proactive by planning to switch from its internal combustion engine (ICE) vehicle to electric vehicle as early as possible. Use of LPG gas in government offices including messes of the security organizations could be phased out and electric cooking system based on solar and hydroelectricity mix could be introduced.

6.2.7 New PV technology and large solar plant: Recently developed, more efficient and cheaper solar PV technology can easily compete with hydro power. So the emphasis is needed in introducing latest efficient solar PV technology and establishment of large sized grid solar plant.

CHAPTER VII

SUMMARY AND CONCLUSION

In the previous chapters, the introduction, review of literature research methodology and presentation and analysis of data have been explained. Summary of each thematic chapter was included at the end of the respective chapter. This chapter presents the summary of the entire research work and conclusions from the analysis of primary and secondary data regarding the solar energy in Nepal and its role to mitigate climate change.

7.1 Summary

Contemporary climate change includes both global warming and its impacts on Earth's weather patterns. Burning fossil fuels for energy use creates most of these emissions. Climate change threatens people with food and water scarcity, increased flooding, extreme heat, more disease, and economic loss. Mitigation or reducing climate change involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases or enhancing the sinks that accumulate and store these gases. The goal of mitigation is to avoid significant human interference with Earth's climate, stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

The effects of greenhouse gases (GHGs) on both drought and flooding events have been found in Nepal, including severe winter drought and excessive monsoon flooding. Climate change has been alarming in the context of global warming. Large portion of greenhouse gas emissions are from transportation, agriculture and forestry sectors. The consequences of global warming have had the most impact in developing and mountainous countries like Nepal, which has high intensity rainfall during rainy season. It has resulted in heavy floods, landslides and soil erosion. It is also common to find drought in many parts of Nepal that comes from the impacts of climate change and it impacts sectors like forest, water resources, agriculture, human health and biodiversity. Millions of Nepalese are estimated to be at risk from the impacts of climate change including reductions in agricultural production, food insecurity, strained water resources, loss of forests and biodiversity, as well as damaged infrastructure.

Climate change is a threat to national security and now is the time to take sensible action, to integrate it into national security frameworks, and to build the necessary capacity and resilience to address it responsibly in the future. Projected climate change poses a serious threat to national security. Climate change acts as a threat multiplier for instability in some areas of the country. Climate change, national security, and energy dependence are a related set of global challenges. As such, Armed Police Force, Nepal as a key security agency of the country, has direct and straight concern with the climate change mitigation.

A radical transformation of the global energy system is underway. Solar photovoltaics and wind now comprise two-thirds of global net new electricity generation capacity additions because they are cheap. Deep renewable electrification of energy services, including transport, heating and industry, allows solar and wind to eliminate fossil fuels over the next few decades. To limit global warming to 1.5 degrees Celsius, rapid reductions in greenhouse emissions are required. Nepal has enormous and low-cost solar energy resources and its potential in Nepal is 50,000 terawatt-hours per year, which is 100 times larger than Nepal's hydro resource and 7,000 times larger than Nepal's current electricity consumption. Solar can easily meet all future energy needs in Nepal. Hydroelectricity struggles to compete with the flexibility and low-cost of solar, particularly because the cost of solar continues to decline. And solar energy has far lower environmental and social impact than damming Himalayan rivers. Solar panels can be kept on rooftops, on the ground, floated on lakes and hydroelectric reservoirs or placed in food growing areas (agrivoltaics) where widely spaced solar panels shade 10 per cent of the crop but cause little loss of production because they reduce wind speeds and evaporation rates.

The Sun is an infinite source of energy that is pivotal for sustaining life on our planet earth. It has been harnessing energy from the sun since ancient times to this modern era of ever evolving technologies. Solar radiation can be converted into useful energy such as solar collectors can provide hot water or air heating, solar photovoltaic cells can generate electricity. Nepal is blessed with solar resource as it lies at 30◦ Northern latitude which is ideal and there are over 300 days of sunshine annually. Further the annual average solar insolation is 5kWh/m2 per day. These conditions are perfect for harnessing solar energy for various conversion technologies.

7.2 Conclusion

Nepal does not produce fossil fuel so it has to depend totally on import that contributes in foreign trade deficit of the country apart from the adverse impacts of GHG emissions. To cook food, run vehicles and offices across the country APF, Nepal requires huge amount of energy. APF has to work in remote areas also where the grid line electricity is either unavailable or not reliable. Recently, APF, Nepal has signed an agreement with NEA regarding the construction and operation of electric vehicle charging stations and assistance in the use of induction stoves in various units of the Armed Police Force Nepal. Solar power generation and promotion should be integrated into it soon.

Nepal has huge solar potential which can replace fossil fuel. Solar energy is becoming more efficient and cheaper than ever before. Solar energy generation and its promotion have multiple benefits. It can replace fossil fuel and contribute in climate change mitigation, fulfill energy demand in all geographic areas of the country, contribute in economic development and social empowerment of rural women, children and vulnerable communities. Investment and development of community solar and large scale solar plants will definitely help country in multiple ways.

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APPENDICES

Appendix "A"

(Refers to page No. 17)

Government of Nepal
Ministry of Home Affairs
APF Command and Staff College

Ph.No. :01-4513159
Fax No .:01-4414129
paacademic2015@gmail.com

Acedemic Section
Sanogaucharan, Kathmandu

Ref. No.: - (078/079)/596

Date:-2079/03/ 17

Respected Sir/Madam,

TO WHOM IT MAY CONCERN

I am pleased to introduce myself as the Course Coordinator of APF Command and Staff College, Sanogaucharan, Kathmandu, Nepal.

It is our pleasure to inform you that Armed Police Force, Nepal has been running APF Command and Staff College **"Master of Security, Development and Peace (MSDPS)"** a two year, four semester Master's Level program, affiliated to the Tribhuvan University, Faculty of Humanities and Social Sciences.

In this regard, the Student Officers of 6th APF Command and Staff Course are undergoing through a research-writing assignment according to the curricula of this MSDPS study. Regarding our Student Officers, they are actively serving Armed Police Force, Nepal for more than 15 years. They are all responsible government service holders and any information provided will be used for the research and study purpose only.

Therefore, I would highly appreciate if you provide some relevant information and data that may be required to their research study.

For any further query, it would be my pleasure to avail my service.

Anticipating and appreciating your kind cooperation and assistance to the student concerned.

Any information regarding the subject can be obtained from its official website: - **http://csc.apf.gov.np**

Name of the Student : Dal Bahadur Pandey

Rank : Superintendent of APF, Nepal (SP)

Thesis Title : Renewable Energy Contribution to Mitigate Climate Change in Nepal

Respectfully,

Raju Ram Suwal
Deputy Inspector General of APF, Nepal (Retired)
Academic Program Coordinator
APF Command and Staff College, Sanogaucharan, Kathmandu
Contact No. 9851269999

List of Questions (Open ended)

Part I Solar Energy

1. What is the possibility of solar power generation in Nepal? (Weather conditions, seasonal variations, availability of skilled manpower, solar panel and other materials etc.)
2. How long is the life cycle of solar power plant?
3. What are the sustainment measures of solar power plant?
4. How much is the initial investment required per MW? (Cost of solar energy production)
5. What is the running (administrative, repair and maintenance etc.) costs associated with solar power generation?
6. What is the solar power energy distribution system throughout the country?
7. How is solar power stored for night time and peak hour consumption?
8. What are the issues and challenges of solar power generation and distribution in Nepal?
9. What are the issues and challenges of land acquisition to install solar power station?
10. What are the impacts of large scale solar power station on local communities?
11. How can solar power generation contribute to reduce fossil fuel consumption?
12. What is the implication of solar power generation in import reduction and trade deficit control?
13. What are the environmental and climate change issues related to solar power generation?
14. How can solar energy generation contribute to climate change impact?
15. Which renewable energy is most effective and efficient in Nepal and why?
16. Anything else worth mentioning regarding solar energy and climate change.

Part II Climate Change

17. Why climate change mitigation is important?
18. What are the contributors of climate change?
19. What are the challenges of climate change mitigation?
20. What is the role of renewable energy to mitigate climate change?
21. How can solar energy generation contribute to climate change mitigation?
22. How is Nepal more vulnerable to climate change impact?
23. Any suggestion to the researcher regarding climate change and renewable energy?

Name: Designation and Office:

Date: 2079/03/

Appendix "B"

(Refers to page No. 45)

Statement by the President of Nepal Rt. Hon. Mrs. Bidya Devi Bhandari at the 24th Conference of Parties to The United Nations Framework Convention on Climate Change (UNFCCC) Katowice, Poland, 3 December 2018

Mr. Chairperson,

Nepal is a least developed country, comprised of the Himalayas, mountains and the plains known as the Terai.

We have been bearing the brunt of disproportionate impacts of climate change despite being a low carbon-emitting country.

Himalayan glaciers are melting; snow-capped mountains are becoming dark and dull; the possibility of glacial lake outbursts is high; and the river- basin system is adversely affected.

Avalanches, floods and landslides, and droughts have become more erratic than ever before.

The rural drinking-water system has been disturbed because of the undesirable impacts on natural resources.

We are compelled to spend significant amount of our national income in addressing disasters-induced problems.

Main productive land of Terai, 'the granary' of Nepal, is frequently affected by floods and inundation. Even more severe is the impact on agriculture sector.

Such disasters and incidences have more direct bearing on women and indigent people. We know the hardship of rural women, who are compelled to spend hours to fetch water for household consumption.

We feel as if we have been penalized for the mistakes we never made.

I would like to reiterate that it is incumbent upon the international community to ensure justice is done.

We believe that the commitment to maintain the threshold of 1.5 degree Celsius as outlined in the recent IPCC Special Report will further encourage the world community to traverse resolutely in the path of low carbon emission.

We are a country that has been immensely contributing to controlling global warming.

Himalayan Ranges and high mountains including the Mt. Everest contribute to keeping air and water cool, refreshing and pure.

In fact, mountains and oceans form organic linkages to influence climate and weather patterns.

These mountains melt slowly yet continuously to recharge and humidify the land.

This water recharging system has a prime importance in controlling the temperature of the earth.

Value of such natural phenomenon should be realized by the high carbon emitting countries as well as the developed ones and ensure that the environment of mountainous countries is not exacerbated.

We are effortful in minimizing the vulnerability of climate change through the design and implementation of model projects as well as through measures such as National and Local Adaptation and Mitigation Plans of Action.

With a view to effectively implement the Paris Agreement, we are planning to review the Policy and update Nationally Determined Contributions to make them more relevant in the present context. A long-term strategy is being formulated for their implementation.

We have already started the use of electric vehicles at the President's Office and we have a policy to extend this to other areas as well.

The Government of Nepal has initiated the President Chure Conservation Program with a view to implementing, in an integrated way, the environment conservation and livelihood programs in the Chure area, popularly known as Shiwalik in Nepal. We believe that this project will contribute to the protection and conservation of the environment of not only the Chure area but also the neighboring countries.

We are confident that the support and cooperation of the international community will be there in mobilizing knowledge, skills, technology and climate finance in our efforts to promoting study of Himalayan hydrological sciences, supporting sustainable mountain economy, pursuing economic and social development for shifting into renewable energy, employment generation, and ensure access of all Nepal is to clean energy.

We also believe that climate finance is critical also for developing e-mobility, reducing vulnerability of women and the poor, improving public health, and promotion of forests and natural system in the form of carbon sink.

Nepal remains committed to make the project implementation climate friendly and development efforts compatible with the Sustainable Development Goals.

It is our collective responsibility to protect our own and that of the future generations' right to live in clean and safe natural environment.

Nepal is confident that CoP 24 will find pathways for the effective and faithful implementation of the Paris Accord.

Finally, I hope that this Conference will be able to make significant contributions to the global campaign of environment protection and conservation. I would like to extend my best wishes for the success of this Conference.

I thank you all.

(Source: https://mofa.gov.np/statement-delivered-by-rt-hon-president-mrs-bidya-devi-bhandari-at-the-cop-24-katowice-poland/)

Appendix "C"

(Refers to page No. 45)

Statement by Rt. Hon. Sher Bahadur Deuba, Prime Minister and Leader of Nepali Delegation at the World Leaders Summit during the 26th Conference of Parties (COP 26) of the UN Framework Convention on Climate Change (UNFCCC)
Glasgow, United Kingdom, 01 November 2021

Mr President,
Excellences,

Nepal remains firmly committed to the implementation of Paris Agreement. We have submitted an ambitious NDC that plans to decarbonize our economy in all sectors. Nepal aims to reach a net zero emission by 2045. We will ensure that 15% of our total energy demand is supplied from clean energy sources and maintain 45% of our country under forest cover by 2030.

With abundant water, forest and biodiversity resources, Nepal can be a leader in sharing clean, green and nature-based climate solutions in the region.

With temperatures rising higher than global average, glaciers are receding, snowfall is decreasing and permafrost is melting in the Himalayan region. Extreme climate events are increasing, causing huge loss to economy, ecology and human lives. Around 80% of Nepal's population is at risk from natural and climate-induced hazards. During the last 40 years, natural disasters have caused close to US$ 6 billion physical and economic damages in my country alone.

Mr. President,

Rapid warming in the Himalayas poses serious threat to food, water, energy and human security of the entire region. Glacier melting also contributes to the existential threat to the coastal and island countries due to sea level rise.

I, therefore, urge the world leaders to recognize the specific climate vulnerability in the high mountains and accord high priority to the mountain agenda in all climate-related negotiations. Keeping the global temperature below 1.5° celcius is vital for mountain people. It is an issue of our survival. To raise awareness on the climate crisis in the Himalayas, my government will host Sagarmatha Sambad – a dialogue named after Mt. Everest.

An LDC, Nepal is making sincere efforts to balance the development and climate actions. We have mechanisms to ensure that international climate finance is channelled to support transformational approaches in implementing adaptation, mitigation and disaster management actions together.

We are engaging with all stakeholders including private sector, indigenous people, disadvantaged communities, women and youth in all our climate actions. Recognizing the value of nature to both adapt and mitigate climate change, we have decided to create a dedicated institution for working on Nature Conservation and Climate Change together.

Mr. President,

Loss and damage has become a key concern due to increased phenomena of climate induced disasters. This subject must find a place under article 4.8 of the Convention. We call upon the Parties to agree on making Loss and Damage a stand-alone agenda for negotiations and support the framework of additional financing for it. The COP 26 must ensure adequate support for adaptation in the most vulnerable counties by scaling up financial, technological and capacity-building resources.

We can deliver on our goals only through quick, direct and easy access to climate finance. We urge the Parties to agree on a clear roadmap for a new collective, quantified and ambitious goal on climate finance before 2025.

In closing, Mr. President, the decisions we make at COP 26 must do justice to those affected now, the future generations and the Mother Nature. The future of our planet depends on what we decide at this conference.

I totally agree with Prime Minister Boris Johnson that this is the last change to save the earth.

I thank you.

(Source: https://uk.nepalembassy.gov.np/statement-by-the-rthon-prime-minister-sher-bahadur-deuba-at-the-world-leaders-summit-during-the-26th-conference-of-parties-cop-26/)

Appendix "D"

(Refers to page No. 76)

Construction and Operation Agreement of Electric Vehicle Charging Station between Nepal Electricity Authority and Armed Police Force, Nepal

Kathmandu, Nepal Electricity Authority and Armed Police Force Nepal have signed an agreement regarding the construction and operation of electric vehicle charging stations and assistance in the use of induction stoves in various units of the Armed Police Force Nepal. The agreement was made with the aim of reducing non-renewable energy and increasing renewable energy consumption. Executive Director of Nepal Electricity Authority Kulman Ghising and Inspector General of Armed Police Raju Aryal signed the agreement during a program held on 10th of Bhadra at Armed Police Force Nepal Head Office Halchok. In the program, Ghisingh, executive director of the authority, mentioned that an agreement has been signed with the Armed Police Force of Nepal according to the concept of smart charging, and said that the authority is working in accordance with the goal of reducing gas consumption and increasing electricity use. On the same occasion, Inspector General of Armed Police Aryal stated that this type of agreement is a suitable opportunity to work together with the authority and expressed his belief that coordination and cooperation will continue in the future. According to the agreement, a total of 17 charging stations will be constructed at the currently operated 2 petrol pumps of the Armed Police Force and other suitable locations.

It is mentioned in the agreement that Nepal Electricity Authority will bear all the expenses for the construction of the electric vehicle charging station, while its security and operation will be done by the Armed Police Force of Nepal. In the first phase, the Armed Police Force Nepal Headquarters, the National Armed Police Force Academy and all the Provincial Headquarters, Training schools, Battalions and in the second phase, the authority will connect transformers for all the Companies.

The program was attended by Shri Ram Pokhrel, Head of Energy Efficiency and Leakage Control Department of Nepal Electricity Authority, Additional Inspector General of Armed Police Narayandatta Paudel and Chandra Prakash Gautam, senior officers of Armed Police Force Nepal and officials of Nepal Electricity Authority.

(Source: https://apf.gov.np/ReadNews/1290)