Renewable Energy over Climate Change and Vulnerabilities; Need, Relevance and Efforts in Nepal

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Abstract:
Least Developed Countries (LCD) are suffering from impact of climate change in an alarming rate. Industrialization, human civilization and other anthropogenic activities are adversely affecting the composition of atmosphere through the increased liberation of greenhouse gases, thereby accelerating the Global Warming. Nepal, however do not have considerable contribution to the net emission of GHGs, but impact of global warming is very vulnerable to the country, where land and atmospheric variations is influencing degradation of agricultural land, forest and other land covers, retreat of glaciers and loss of bio-diversity. Energy has also been found one of the responsible sectors among all the sectors to enhance the liberation of GHGs in Nepal, which is due to prolonged dependency on traditional energy sources/technologies. In order to reduce susceptibility to livelihood due to climate change different options can be put forward, among which promotion of green and alternative energy technologies can play a vital role not only in reducing emissions but also for sustainable development.

Key words: Climate change, global warming, green house gases, renewable energy, adaptation, mitigation, Nepal

1. Background:

Climate change is regarded as an induced imbalance in physiochemical composition of atmosphere due to different anthropogenic activities, primarily because of emissions of greenhouse gases (GHGs) from fuel combustion, deforestation, urbanization and industrialization resulting variations in solar energy, temperature and precipitation. Water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Chlorofluorocarbons (CFCs) are the major gases that play important role in the greenhouse effect. Among the GHGs CO_2, CH_4 and N_2O are the 3 major gases, which contribute about 88% roles in global warming [1]. World Data Center of Greenhouse gases reported recent global abundance of CO_2, CH_4 and N_2O is 377.1 ppm, 1.783 ppm and 318.6 ppb respectively [2]. Concentration of the CH_4 gas in the atmosphere is presently increasing at the rate of 3% per year. It is predicted that by the year 2100 methane levels may rise by 3.0 to 4.0 ppm that may have a significant effect on climate change [2].

The consequences of climate change is increasing at an alarming rate with a real threat to the lives in the world, thereby affecting the water resources, agriculture, coastal regions, freshwater habitats, vegetation and forests, thinning of snow cover, melting of snow, accelerated landslide, desertification and floods. All these threats are leading towards the long-term affect in the food supply chain and food insecurity as well in human civilization.

Anthropogenic emission of Nepal however, does not contribute greater stake in the global concentration, global emission liberated especially by developed and industrialized world, will affect in overall ecology and ecosystem of the country.

2. Evidences of Climate Change in Nepal

Intergovernmental Panel on Climate change (IPCC) provides a comprehensive review of climate models with a projection on temperature and precipitation trend [3]. In this context, the Atmosphere Ocean Coupled General circulation Models (AOGCM) shows greater than the average warming in the South Asian Region in summer. Different studies on the global temperature rise shows that the mean temperature increase for the period 2071 to 2100 relative to the period 1961 to 1990 is in the range of 3^0- 4^oC. Organization for Economic Co-operation and Development (OECD) performed assessment of 12 recent general circulation models (GCM) [4].

The best 7 GCMs results pronounced that there is significant and consistent increase in temperature projected for Nepal for the years 2030, 2050 and 2100 in various models adopted by OECD. This analysis also shows somewhat larger warming in winter months than the summer months. It also agrees with the study on climate change assessment conducted with US country studies programme [5]. The projected change above the baseline average is 1.2°C for 2030, 1.7°C for 2050 and 3.0°C for 2100. This analysis also agrees with the IPCC analysis in the projection of precipitation change, i.e. less significant change and high standard deviation among the model results.

In addition to this some of the facts that supports the affects of climate change in Nepal are as follows [6]

- Twelve warmest years since 1975 to 2007 (eg. 2006 was the warmest year)
- Late or pre-monsoon, unusual precipitation, decreased rainy days and intense rainfall events caused more runoff and low groundwater recharge.
- Extreme fog conditions have recently been observed in the terai regions.
- Traditional rainfalls of Jestha and Ashar (mid July) have been shifted in Shrawan and Bhadra in Kathmandu. It has affected negatively in the paddy production.
- Receding snowfall and retreating of the glaciers (small glacier mountain shrinking at alarming rate) due to increase in atmospheric temperature in mountain environment.
- Kathmandu valley frost day decreasing, winter cold shifted to a month later than regular and snowfall in Kathmandu (Feb 2007, after 60 years).
- Recently Darchula district of the country faced unusual snow fall affecting collection of precious medicinal herbs Yarsa gumba (Kantipur news may 2008)
- Mosquito from Terai and Mid-hill being able to survive in high- hills (Ilam, Mustang and Helambu area)

3. Sectoral Classification of Emission in Nepal

The Initial Communication (INC) to United Nations Framework Convention on Climate Change (UNFCC) submitted by Nepal in 2004 reveals that there are 5 major categories distinguished for the GHGs inventory of Nepal's, which are: Energy activities, Industrial Processes, Agriculture, Land-use change and Forestry, and Waste Management [5, 6]. More elaborately the GHG emission by gas and sectors as presented by UNFCC is depicted on Plate-1 and 2.

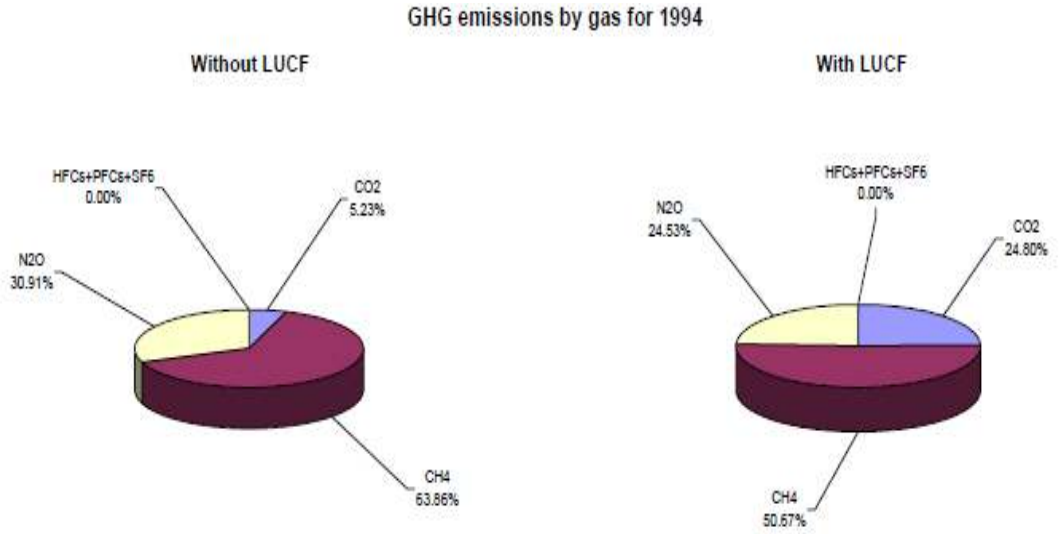
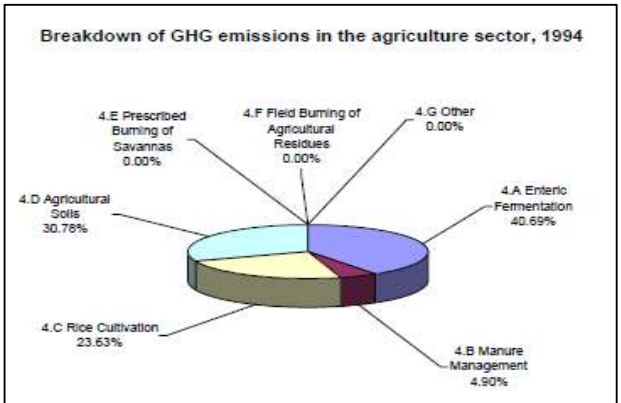
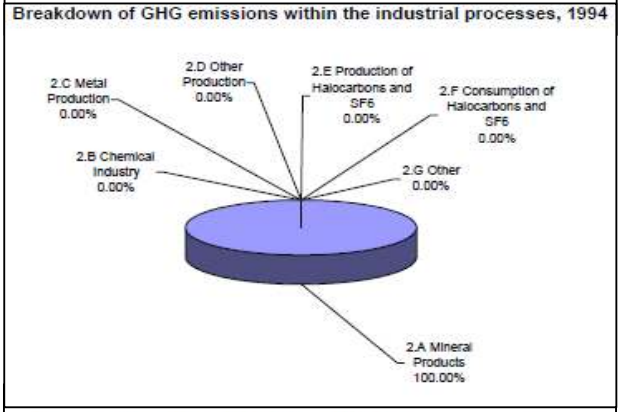
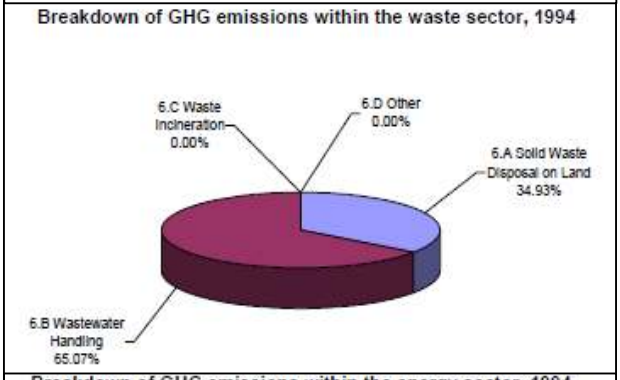


Plate-1: GHG Emission by gas 1994, Nepal;







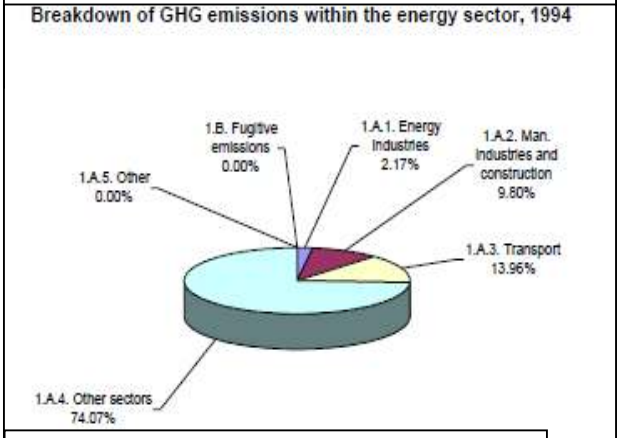


Plate-2: GHG Emission by sectors 1994, Nepal;

The national GHG inventory represents emission data for primarily three gases having direct Greenhouse effects: Carbon dioxide, Methane and Nitrous Oxide. Emission of these GHGs and major contributor are;

Carbon dioxide: In accordance to UNFCC, for the base year 1994/1995, the net emissions of CO_2 in the country were estimated at 9747 Gg (25%) of the net emission (39,265 CO_2 equivalents) with LUCF. The major contributor to this includes the transport sector (31%), Industrial sector (27%), Residential sector (22%), Commercial sector (11%) and the remaining (9%) is shared by Agriculture sector [5].

Methane: In the same base year, the estimated total methane emissions in Nepal were at 948Gg. Agricultural sector have been found contributing about 91.45 percent alone (867Gg) At the meantime, energy related combustion activities, such as biomass burning; incomplete combustion of fossil fuels had also contributed in methane production. Lower amount of methane was also estimated from solid waste disposal and waste water treatment [5, 6].

Nitrous Oxide: Agriculture soils have been found as the major source of nitrous oxide emissions in 1994/95 from where 27 Gg of Nitrous oxides were released to the atmosphere. Also 2 Gg of N_2O emissions were estimated from manure management for the same year. Indirect N_2O emissions from human sewage were estimated to be 1.10 Gg for the base year [5].

Furthermore, in accordance to a study conducted at Nepal Agricultural Research Council (NARC) at Khumaltar showed average seasonal methane emission from rice fields was 28kg/ha/season in rain-fed condition and also found average maximum methane emission from rice field was 49.03 kg/ha in the field supplied with 50% nitrogen + 15 cm stubble. Minimum of 7.7 kg/ha of methane gas was found in the control fields [6]. Seasonal methane emission of Thailand and India were 49 and 45 kg/ha respectively. Lower emission in Nepal was due to lack of irrigation facilities and minimum fertilizer application as compared to developed countries. Highest methane

emission from rice was showed 367 kg in Korea. It may be due to maximum use of chemical fertilizer and better irrigation facilities [6].

4. Changes Observed

Temperature

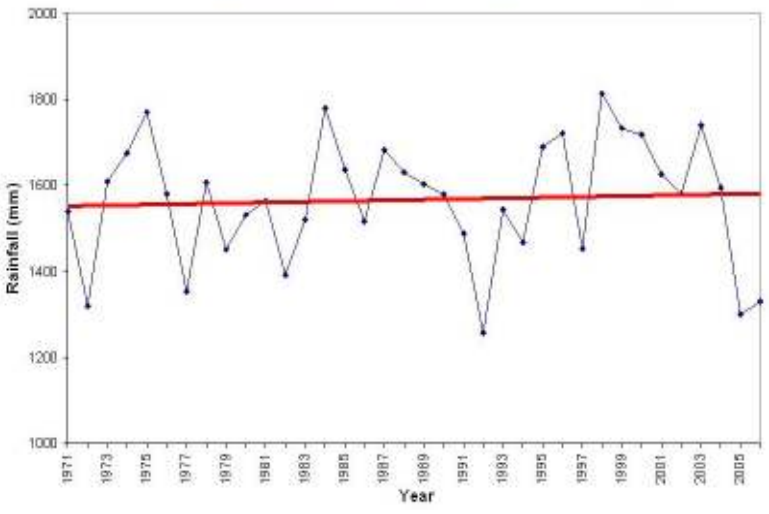
The US Country Study of Nepal (USCSP, 1997) has evaluated the records from 22 Department of Hydrology and Meteorology (DHM) stations for the time period of 1971-1990. The temperature differences have been found most pronounced during the dry winter season, and least during the height of the monsoon. The study indicates on spatial variation and spelled out that temperatures will increase faster at higher altitudes than at lower altitudes. In accordance to the same source, it has also been found that "Jumla with elevation of 2300 m confirms the highest value of temperature change, whereas the station over the southern plain region like Biratnagar, Janakpur with the altitude of around 80 m shows the lowest value of temperature change." This indicates that, in general, greater warming may be expected in the northern mountainous parts of the country [5]. The regional mean temperature trend of Nepal for the period of 1977-1994, is portrayed in Table-1.

Regions	Seasonal				Annual
	Winter	Pre-monsoon	Monsoon	Post-monsoon	Jan-Dec
	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov	
Trans-Himalaya	0.12	0.01	0.11	0.10	0.09
Himalaya	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwalik	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0.00	0.01	0.07	0.04
All-Nepal	0.06	0.03	0.051	0.08	0.06

Table-1: Regional Mean Temperature Trend for the Period (1977-1994) ^{0}C per Year. [5]

Precipitation

Fig-1: All Nepal Monsoon Rainfall (1971-2006) [6]



The annual average precipitation of the country is 1,907 mm, with 80% of it falling during the monsoon season from June to September. Projection of annual precipitation has been reported to increase significantly if CO_2 concentration doubles; it will likely become drier during the dry season, with a significantly wetter monsoon season (as much as three times the current rainfall). The distribution of rainfall throughout the year is a reliable factor in determining the risk of floods. The pattern of precipitation would likely cause droughts during the winter months and floods during the monsoon.

5. Vulnerability

When we talk about the vulnerability of these kinds of emissions, there are ample of facts on the rising trend of temperature due to various anthropogenic activities, which are altering the physiochemical composition of the atmosphere. These global rises in temperature are adversely affecting mainly agriculture, water resource, forestry and health domain.

Agriculture Sector

In the context of Nepal, majority of the people are pursuing their economic activity primarily based on agriculture, which is expected to be adversely affected due to changes in physiochemical properties of soil like loss of the top humus/fertile soil because of erosion, landslides and floods. Agricultural production since is directly affected by the quality of soil, degradation in the soil properties eventually decline the productivity of the country. In addition to this, it has also been found that crop yield reduces with every 4 degree rise in temperature, which will affect the low thermo resistant crops (for e.g. Maize) of the country [6].

Decrease in grain filling period due to increase in respiration process, fertilizer use efficiencies, shift in agricultural zone, increase in insect pest population, desertification, increase in soil erosion, evapo-transpiration and cause malnutrition in a world overflowing with food due to reduction of protein and decrease in mineral nutrients content in different crops are negative effects [7].

A contrary has also been found in the relation of global warming and productivity, for e.g*; the rising temperature and emission of CO_2 to some extent is also helpful in production of major crops. In this regard, increase in agricultural production by enhancing photosynthetic processes, water use efficiency, shortening physiological period and soil microbial activities* [7]. The impacts on agriculture are thus the decrease of productive land in some region and increase in other region. So, it is a complex problem to the world. Rising CO_2 promotes plant growth and if the CO_2 gas doubles, yields will increase by 40% [7].

Water Resources

The changes in temperature and precipitation are expected to alter the hydrological cycle and water resources. The total water reserve capacity of the country is 200 billion m^3, and runoff provides 72% of water reserve (144 billion m^3) while snow provides 12% (24 billion m^3) [9]. The monthly variability of runoff is quite high, for example, with the Sapta Koshi varying from 400 m^3/sec in February to 4300 m^3/sec in August. Mean monthly discharges show that global warming would shift the peak discharge month from August to July, due to the fact that the snow cover on mountain tops would melt earlier. This could lead to increased flooding and variations in water availability throughout the year. In some areas, drought could become a problem [5].

Furthermore, depletion of water resources hence is one of the consequences that have been felt in the country due to unbelievable changes in the hydrological cycles, which can be regarded as a pinnacle in environmental cycle due to global warming.

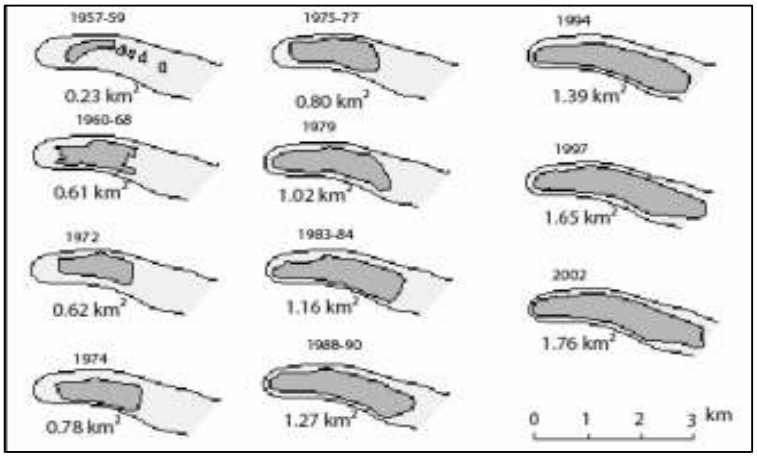


Plate-3: Growth of Tsho Rolpa glacier lake from late 1950s to 2002 [8]

There are about 3,252 glaciers in Nepal, which cover a total area of 5,323 sq.km. The Glaciological Expedition in Nepal, a collaboration between Japan, Intergovernmental Panel on Climate Change and Nepal, regularly studied glaciers in Nepal in the Hidden Valley of Dhauligiri region, Langtang region, Khumbu region and Kanchenjunga region since early 1970s. The study also shows that there is significant retreat of these glaciers than that of 1978, estimated on the basis of thinning of glacier surface. The INC of Nepal carried out a vulnerability and impact analysis of water resources with aspect to the changes in climate using water balance and deterministic models to the three (snow-fed) major river basins namely, the Karnali, Kosi and the Narayani and in one (rainfed) small Bagmati river basin, which have suggested that the hydrological regime of the studied basins are more sensitive to changes in precipitation rather than temperature changes [8,9]. In addition to this the rising temperature trend have potential threat that almost 20% of the present glaciated area lying 5,000 m altitude are likely to be snow-and glacier-free areas with an increase of air temperature by 1^{o}C. Similarly, 3^{o}C and 4^{o}C rise in temperature could result into a loss of 58% of snow, and 70% of glaciated areas [8,9]. Growth in area of the Tsho Rolpa Glacier Lake across the period of 1950 to 2005 is shown in the Plate-3. This eventually contributes to the potential Glacier lake Outbrust Flood (GLOF), flood hazards, by which more than 1.5 billion people could be affected.

Forest Resources

Forest and vegetations are potential carbon absorbing source in the nature, but forest of Nepal has been depleting due to different human interventions. Vulnerabilities like changes in the forest composition, annihilation of different wild species etc are some of the examples that we can feel at the moment. Other potential vulnerabilities in the forestry sector are; Tropical wet forest and warm temperate rain forest would disappear, and cool temperate vegetation would turn to warm temperate vegetation. It has been predicted that the vegetation patterns would be different under the incremental scenario (at 2^{0}C rise of temperature and 20% rise of rainfall) than the existing types [8]. Furthermore, migration of vegetation and decline in biodiversity will have further adverse impact on wildlife. One study has found that 2.4% of biodiversity may be lost with climate change [5, 6, 10].

Livelihood and Socio-culture

Some of the other potential impacts due to climate change are impact on livelihood and socio-cultural environment of Nepal. This could be because of degradation in agricultural productivity, poor livestock management, floods and hazards, risks of diseases (Malaria, Kalazaar, Japenese Encephalitis, primarily in subtropical and temperate region) etc. Poor people are vulnerable to loss of physical capital (because of damage to shelter and infrastructure), human capital (because of malnutrition and diseases), social capital (because of displacement of communities), natural capital (because of loss of productivity in agriculture and fisheries) and financial capital (because of more disasters and lower income). Degradation of livelihoods by climate change will thus leave poor people with less of the assets they need to withstand shocks and stresses [5, 10].

6. Efforts towards Climate Change and Role of Renewable Energy

Adaptive and mitigation measures are essential for lowering down the vulnerability due to climate change in the water resource sector, agriculture, forestry, bio-diversity and livelihood. With the realization of impact of climate change, the Government of Nepal is also providing its attention to the associated potential climate change and conducting series of activities that have been successful to draw attention and build international cooperation to some extent. In this regard, organization of Cabinet Meeting on Kalla Pathhar (Base Camp of Mt. Everest) on Dec, 2009 has been regarded one of the successful event to bring the world dutiful towards Nepal.

Apart from this other interventions like disaster management are given priority. Some of the relevant activities that have been brought into action by the government of Nepal are formulation of several national and sector development plans like Master Plan for Forestry Sector, National Water Plan, and Agriculture Perspective Plan, Energy Perspective Plans, which have been hopefully expected being relevant on any way to the adaptation to climate change. In the 9th and 10th Plans, climate-relevant issues were indirectly mentioned, e.g. energy switching has been emphasized with several alternative energy sources to reduce the domestic use of fuel wood and fossil fuels and encourage greater use of hydropower and biogas [5].

Government of Nepal has given due attention and priority in the promotion of alternative and renewable energy technologies from the last 15 years. In this regard, Alternative Energy Promotion Centre (AEPC) under the umbrella of Ministry of Environment (MoE), GoN has been successful to contribute in the total electrification coverage of the country (about 40%) by 7% through the alternative energy technologies [11]. Likewise about 200,000 biogas plants have been installed under the Renewable Energy Sector Support Program (RESSP) of AEPC, supported by Netherlands Development Organization (SNV) and implemented by Biogas Sector Partnership Nepal across the country till November 2009, contributing to the annual saving of about 1.198 million tCO_2[1]. Similarly, more than 97,000 Solar Home System (SHS), about 200,000 Improved Cook Stoves (ICCs) [2]have been installed under the Energy Sector Assistance Programme (ESAP) [11].

Till date 19,396 biogas plants have been awarded by CDM fund, which include a reduction of 93,883 tCO_2e annually, with the joint effort of AEPC as the project entity and the Community Development Carbon Fund of the World Bank with a unit price of $7/certified emission reduction (CER). Similarly, micro-hydropower CDM project is at the validation stage and AEPC has developed the project with support from the ESAP and Rural Energy Development Programme (REDP) for a total capacity of 15 megawatts (MW) of which ESAP has been found responsible to develop 8.5 MW. An Emission Reduction Purchase Agreement (ERPA) has been signed by AEPC and Community Development Carbon Fund with a unit price of $10.25/ certified emission reduction (CER) with a total reduction of 191,000 tCO2e [5], which is hopefully under the process of registration

The Interim Plan (2008-2010) has also set target for the alternative energy technologies for the low carbon liberation, where increasing access to additional 5% of the rural population from mini/micro hydro power plants (11.5 W of power from Mini/micro hydro power in 54 districts), installation of 90,000 SHS, 140,000 Solar Tuki, 50 Solar drinking water and irrigation projects, 810 institutional SHS, 15,000 solar dryer, wind power equivalent to about 50 kW and 300,000 ICS in the country [11].
Furthermore AEPC, GoN has set up its target for ESAP-II (2007-2012) as shown in Table-2, which can be regarded as a complimentary effort towards reducing the impact of climate change in the country.

S.N	ESAP II Programme	Target (2007-2012)	
		Capacity	Households
1	Biomass Technology	–	500,000
1.1	Improved Cooking Stoves		434,000
1.2	Institutional ICS		5,000
2	Solar Home Systems	–	150,000
3	Small Solar Home Systems	–	250,000
4	Mini Grid Electrification	Approx. 20 MW	150,000

Table-2: Target set for ESAP-II [12]

[1] Assuming the average annual saving of CO_2 at the rate of about 5.99 tCO_2 per plant.[5].
[2] ICS has been found successful in energy saving (fuel wood) to about 10-20% against traditional stoves in Nepal.

In addition to this, the major GHG emissions sectors in Nepal, which have technical potentiality for Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (REGA) technologies, are the transport, industry, and residential sectors. Transportation technologies like trolley buses and ropeways which can be potentially fueled by green electricity and battery-operated vehicles "Safa Tempos" are some of the best alternative to play vital role in reducing emissions by lowering dependency on fossil fuel. Electric vehicles can potentially substitute imported petroleum fuels with hydroelectricity in Nepal and make a net contribution to reducing global GHG emissions. Energy efficiency is significant for a country like Nepal, where around 60% of the total energy need in the industries is met by non-electricity sources resulting in huge GHG emissions. Industries in Nepal are the sector where saving of about 30% of their energy costs can be facilitated through the implementation of energy efficiency measures. A study shows that about 174 industries have been recommended for the energy efficiency improvement measures, which was audited by ESPS/Danida-Energy Efficiency program. The study also has shown potentiality to avert 48,000 tons of CO_2 emissions annually. Similarly, saving of 30-50 percent fuel can be ensured by an improvement in Brick Kiln technology alone [13].
On the basis of incremental CO_2 abatement cost calculations, the following REGA technologies and projects are presented in order of priority.

- Priority 1: Energy Efficiency in industries with abatement cost of US$ –9.79 per ton CO_2.
- Priority 2: Biogas with abatement cost of US$ 2.28 per ton CO_2.
- Priority 3: Safa Tempo with abatement cost of US$ 5.43 per ton CO_2.
- Priority 4: Micro-hydro with abatement cost of US$ 7.77 per ton CO_2.
- Priority 5: Trolleybus with abatement cost of US$ 21 per ton CO_2.
- Priority 6: Solar Home Systems with abatement cost of US$ 384.9 per ton CO_2. [13]

Similarly, a feasibility study on Trolley Bus in Ring road of Kathmandu also showed that about 128, 927 tCO_2 can be potentially reduced as shown in Table-3. [14]

Year	No. of bus displaced	No. of minibus displaced	Direct emissions/yr On-site	Direct emissions/yr Off-site	Total Emissions (TCO2)
2005 - 10	34	33	3,615	33	3647
2011 - 15	51	50	5,441	49	5490
2016 - 20	68	66	7,229	65	7294
2021 - 25	85	83	9,056	82	9137
Total Emissions from 2005 - 2025			**130,316**	**1,174**	**131,490**

Year	No. of Trolley bus	Project emissions Ton CO2 eq
2005 - 10	50	71
2011 - 15	75	107
2016 - 20	100	142
2021 - 25	125	178
Total Emissions from 2005 - 25		**2,563**

Table-3: Potential GHGs reduction through REGA [14]

Way Forward

Adaptation options should be the prime focus area for the country like Nepal, which have less contribution to global warming but have great threat due to emission of the developed countries. Some of the measures and activities that needs to adopt are; Promotion of- afforestation and forest conservation, water conservation and market-based water allocation, improvement in the irrigation efficiency (promotion of micro- irrigation technologies like sprinklers, drippers) on the basis of net water requirement, initiation and extension of programme for rain water harvesting in the most vulnerable areas, zero tillage concept in cultivation of paddy crops, promotion of organic fertilizers, promotion of early warning systems etc.

Even after there are a lot of predictions on the climatic variations in Nepal, there is strong realization and need of implementation for improving the observation and forecasting of hydrology and meteorological information. Presence of limited number of meteorological stations is unable to represent many remote areas that are regarded more fragile to climate change. It has

also been reported that there are often gaps in the data for the stations that do exist. All the forecasting and projections have been made on the basis of information gathered from about 263 meteorological stations and 47 hydrological stations of the country, which strongly provide logic to improve development of accurate information required for forecasting and projection with the extensions of DHM centres across the country.

Indeed other necessary measures, which needs due attention to reduce the vulnerabilities and combat possible threats of loss of lives and bio-diversity are development of infrastructures that mitigate the risk of GLOF, development of basin based hydro power, expansion of year round irrigation facilities and promotion of alternative energy technologies.

The interrelation of energy consumption and climate change (shown in Plate-4) shows that emission of GHGs through different end-use activities have greater role in the rising the temperature and other climatic parameters, but the solution for the same is proper management on demand and supply balancing of energy. GHGs emissions due to energy use in different sectors (as presented in the Plate-1) thus, can be potentially reduce through the use of efficient and convenient source of energy technologies, which not only ensure the reduction of GHGs but also to the sustainable development of the country.

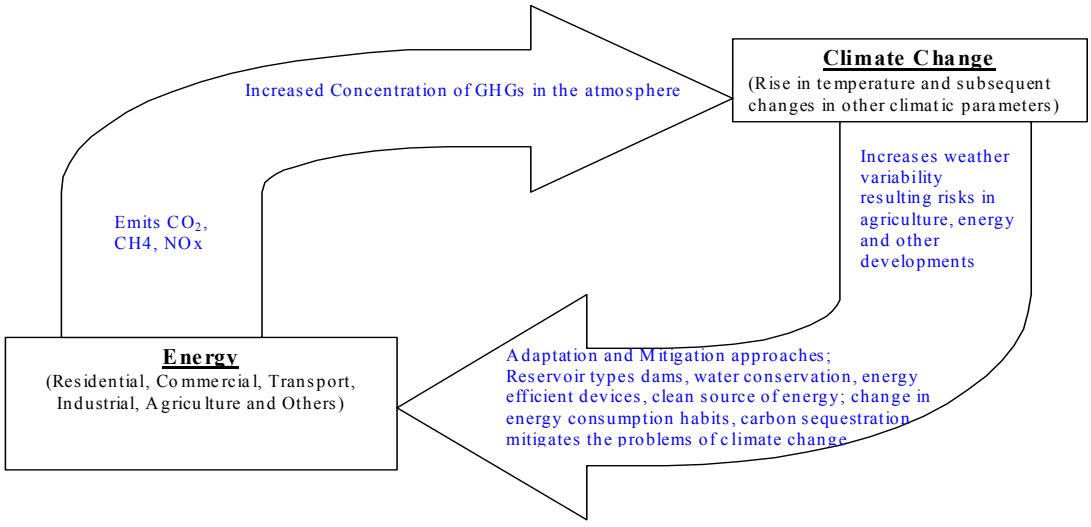


Plate-4: Interlink of Energy and Climate Change

Nepal needs to develop and implement plans and projects to harness its immense largely untapped water resources to generate electricity, explore, develop and exploit solar, wind power system and installing biogas plants. In this regard, the potentiality of various renewable energy technologies also favors the opportunities. For e.g., the assessment of Solar and Wind Energy Resource in Nepal based on geo-spatial database shows that there is wide potential of solar energy in Nepal. The possibilities of harnessing solar energy from about 37,501 sq. km area (25 per cent of the total area of Nepal) have been regarded as potential for Concentrated Solar Power. Similarly, for grid connected integrated photovoltaic potential, estimated on the basis of the urban areas, shows that if power generation per sq. km is considered to be 50 MW and 2 per cent of the land area is considered as suitable land, then an area of 2,100 sq. km could yield 2,100 MW of power. In addition to this, about 28,789 sq. km area of Nepal has been found not connected to the grid and population, over which the potentiality of remote Solar Photo Voltaic (SPV) can increase access to

population of about 2.4 million [15]. In regard to the same source, about 97 sq. km of area with power density of 300 Watt/m2 and with 5 MW of installed capacity per sq. km, has been regarded potential to yields wind energy, which comes to about 489 MW [15]. These enormous energy if can be harnessed for basic and productive needs can play a significant role in lowering the total emission of the country. Likewise, institutional strengthening and development of international cooperation for the promotion of potential biogas plants (1.9 million), exploration and exploitation of potential resource of liquid bio-fuel to reduce fossil fuel dependency, scientific energy auditing in commercial and industrial sectors of the country is utmost need.

These are viable options, which can provide clean energy to the people at large, increase the energy efficiency of its economy and increase forest cover if developed adequately for carbon savings and trading. Nepal should utilize the opportunity of exchanging and extending cooperation to the global community to minimize the climate change effect and seek some financial support and transfer of technologies for the same. But issues of political instability, insecurity and lack of commitment should be tackled down effectively.

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