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Contribution of Renewable Energy Technologies (RETs) in Climate Resilient Approach and SDG 7

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Abstract:
Renewable energy can contribute to adaptation to climate change, mitigation and development and may play an important role in resilient development ambition of Nepal. It has been emphasized in Nepal's Nationally Determined Contribution (NDC) and climate change policy but its potential impact on SDGs era has not been fully explored and implemented. The study used employed energy system modelling by using optimization software, reviewed literature and interacted with various experts.
It has been found that renewable energy technologies (RETs) provide socio-economic and environmental benefits to people that contribute to adopting and ensuring a better adaptation to climate change based on the local context. They contribute to adaptation processes by contributing to reducing the vulnerability of people, improving adaptive capacity, and minimizing climate change risk in line with SDG 7. But these are not without challenges either. Financial, technical, institutional, policy and legal issues are major challenges to promote RETs. This study shows that theoretically altogether 4.45 million tons of CO_2e of the GHG emission can be mitigated per year if all the remaining technical potential of deploying seven major RETs consisting of biogas, improved water mill, stand-alone micro-hydro plants, mini-grid micro-hydro plants, solar PV home systems, mud-ICS and metal-ICS were installed after 2012. Considering the average annual installation of these RETs, altogether 30.71 million tons of CO_2e can be mitigated between the periods of 2013 to 2030 at an annual additional installation equal to average installation done in recent past three years. The initial technology investment required for implementing the above mentioned RETs ranges from NRs 97 to NRs 23,247 per ton of CO_2e mitigation. This indicates that though a moderate level of the initial investment is required for promoting RETs, the GHG mitigation potential seems to be quite promising. There is no liberty of inaction, so RETs can be a good case for a triple win strategy to address mitigation – adaptation – development nexus for climate compatible development in Nepal.

Keywords: Adaptation to Climate Change, Mitigation Potential, Renewable Energy, Socio-Economic Development, Climate Risk, SDG

1 Introduction

Nepal's contribution to global climate change is very minimum. According to the Second National Communication report submitted to UNFCCC, Nepal's share on GHG emission is only 0.027% of the global total emissions [1]. But several studies revealed that Nepal is highly vulnerable to climate change [2,3]. A study carried out in Nepal provided a comprehensive analysis of the economic impact of climate change of the selected sector (agriculture, energy, and disaster). The estimated direct economic costs of these historical events have been very large, equivalent to 1.5% of current GDP/year on average (approximately US$270 million in 2013 prices). In exceptional years (e.g. the floods of 1993) the economic costs of extreme events and variability have been 5% of GDP equivalent or more [2].

Renewable energy is one of the most effective technologies to fight against climate change and to support SDGs but this has not received adequate attention. Nepal ratified the Paris agreement and submitted a Nationally Determined Contribution (NDC) in 2016 that emphasized clean energy development, afforestation measures, sustainable transport systems, climate-friendly practices in agriculture and waste management. Although slowly, Nepal has moved ahead and has shown some progress towards achieving its NDC sectoral commitments. For instance, the government launched the 'National Action Plan for Electric Mobility' in 2018 which supports the implementation of Nepal's NDC by promoting renewable energy, especially in terms of clean transport, energy diversity and air quality targets.

The reinforcement of adaptation and mitigation to climate change needs a strong effort to shift toward a low-carbon energy pathway – both in terms of the energy infrastructure, and the energy production and consumption patterns – that would support country's sustainable development while lessening the level of its GHG emission increases. In this context, RETs may represent an important development strategy for the country to support adaptation, enhance development and contribute mitigation objectives by using clean and resource-efficient technologies while ensuring social and environmental sustainability and improved social equity.

Given the high potential of RETs in Nepal to contribute to the triple objective of adaptation, development and mitigation, it is increasingly important to understand the clear role of these technologies in addressing the national and local development priorities while considering the ever-increasing climate change risks. Despite the potential contribution of RETs on these objectives, its potential roles it may play in resilient development ambitions especially in the SDG era have not been adequately explored. Hence, this study assessed the role of the RET in promoting climate-resilient development path by considering the triple objectives of adaptation, development, and mitigation.

2 Methodology

For assessing the role in mitigation, mitigation total energy system cost and technology investment requirement the RETs is estimated by developing energy system model representing all the existing and potential RET in the country is developed by using optimization software; developing a base case scenario is developed considering continuity of the existing policies and without introduction of any new policy till target year for mitigation potential; determining different mitigation achievable by introducing RET in the target year is determined based on the present available study documents and information; developing mitigation scenario for each potential RET intervention, and developing a GMC curve with cumulative mitigation potential.

For assessment of the contribution of RETs on adaptation and development, a meta-analysis was carried by using a diverse range of literature at national and international sources along with some interactive discussions with experts. A systematic review of many studies was carried. For this, research questions were framed based on study objectives, searched (Google Scholar and other sources), determined the quality of the information in these articles/ reports by using a judgment of their internal validity considering heterogeneity, publication bias and finally conducted a subgroup analysis. The comprehensive analysis of RETs and climate change in Nepalese context was carried out by considering the possibility of contribution to people's livelihoods (social and economic) and natural resources (environmental) management. The review explored how these impacts helped to enhance the adaptive capacity at community and household level and broader development objective of SDG 7.

3 Review of the literature

The global climate is strongly influenced by greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, which are increasingly being emitted because of human activities. Climate scenarios predict a significant change to the climate, severe consequences for the Earth's ecosystem and new challenges for mankind [4]. There has however been increasing commitment from the countries to reduce greenhouse gas emissions in the short-term and the long-term (the year 2050) by global communities. To achieve these targets, a long-term transition towards an energy system based on renewable energy and high energy efficiency is necessary [5]. Nepal being one of the developing countries with high renewable energy possibilities, there are ample opportunities from the renewable energy sector to support not only on the longer-term management of disturbance and disruption of energy systems but it would also help to reduce GHGs emission, improve the adaptive capacity of people and finally contribute to improving their livelihoods.

According to [6] resilience is having the capacity to persist in the face of change and to continue to develop with ever-changing environments. Resilience thinking is about how periods of gradual changes interact with abrupt changes and the capacity of people, communities, societies, cultures to adapt or even transform into new development pathways in the face of dynamic change. Besides, the resilience approach has mainly 3 elements. They are i) persistence: resilience is about persisting with change on the current path of development, adapting, improving, and innovating on that path. It is about having the capacity to continue to learn, self-organize, and develop in dynamic environments faced with true uncertainty and the unexpected; ii) the adaptability concept in resilience thinking captures the capacity of people in a social-ecological system to learn, combine experience and knowledge, innovate, and adjust responses and institutions to changing external drivers and internal processes; and transformability is about shifting development into new pathways and even creating novel ones. In this case, the RETs can provide support in coping and adaptation services during climate and other types of shocks and stresses.

Climate risks are indispensable due to the ever-increasing adverse impact of climate change mainly due to rising temperature, precipitation patterns and associated disaster risks. Adaptation, although the term that is understood differently by different practitioners, in the context of human dimensions of climate change can be defined as — a process, action or outcome in a system (household, community group, sector, region or country) for the system to better cope with, manage or adjust to some changing conditions, stress, hazard, risk or opportunity [7]. Adaptation, in natural or human systems in response to actual or expected climatic stimuli or their effects, moderates harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous, and planned adaptation.

The poor and climate-vulnerable communities mainly in the developing countries are bearing the brunt of the adverse impact on their livelihoods despite their negligible contribution to climate change [8]. So, failure to address adaptation will affect the development process in the developing countries [9]. A diverse range of literature is available related to climate change adaptation but there has been very little work carried out on how renewable energy can contribute to climate change adaptation and increase the adaptive capacity of people and communities. For example, [10,11] have carried out some studies to establish the relation RETs with adaptation and develop but the relationship between renewable energy and its potential impacts on adaptation and development are not explored in Nepalese context.

The literature provides several definitions of renewable energy. Renewable energy as 'energy obtained from the continuing or repetitive currents of energy occurring in the natural environment' [12]. The Dictionary of Energy edited by Cleveland and Morris [13] mentioned that renewable energy is 'any energy source that is naturally regenerated over a short time scale and either derived directly from solar energy (solar thermal, photochemical, and photoelectric), indirectly from the sun (wind, and photosynthetic energy stored in biomass), or from other natural energy flows (geothermal, tidal, wave, and current energy)'.

The most important RETs in the context of Nepal are related to micro hydropower, biomass energy (biogas, briquettes, improved cookstoves), solar energy (solar water heaters, dryers, cookers, generators and pumps), wind energy (wind turbines, windmills). These RETs have a large potential to contribute to sustainable development (SD) of specific territories by providing with a wide variety of socioeconomic and environmental benefits [14]. According to them, RETs can be a good approach for contributing local sustainability. RETs can contribute to the reduction of local and global pollutions (GHGs emissions), increasing employment, improving livelihoods asset base (i.e. social/cultural and human) at the household level, increase household income and reducing vulnerability, among others, and finally improving the quality of life of people.

Renewable energy technologies can provide energy to rural populations to which it is technically or economically infeasible to extend the electricity grid. Electricity can be used for applications ranging from lighting to a wide array of productive uses to energy services supporting health, education, and sanitation [11]. IPCC fourth assessment report also recognized the complexity of the interaction of various sector in adaptation and mitigation including energy and there is a co-benefits such as improved energy efficiency and cleaner energy sources may lead to reduction reduced emissions of health-damaging climate-altering air pollutants [15].

Nepal's Sustainable Development Goals – Status and Road Map (2016-2030) stated that nearly three-fourths (74.7 per cent) of households in the country use solid fuels as the primary source of energy for cooking, while one-fifth (18%) use LPG for cooking. Nearly three fourths (74%) of the households have access to electricity, the actual supply of electricity is however inadequate. In rural areas, electricity supply from off-grid hydropower plants is limited and used mostly for lighting and to charge small appliances like mobile. Goal 7 has provided some specific targets which include increasing substantially the share of renewable energy in the global energy mix by 2030. For this Nepal will have 15000 MW installed capacity of hydropower by 2030. Besides, there will be international cooperation to facilitate access to clean energy research and technology, including renewable energy, and energy efficiency.

The Climate Change Policy of 2011 [16] was the most important documents which recognized the potential role of renewable energy in climate change adaptation as well as mitigation. It aims to "improve livelihoods by mitigating and adapting to the adverse impacts of climate change, adopting a low-carbon emissions socio-economic development path and supporting and collaborating in the spirits of country's commitments to national and international agreements related to climate change". The policy has emphasized to promote renewable energy for adaptation and mitigation. Local Adaptation Plans of Action (LAPA 2011) aimed to connect the national perspective of the NAPA to communities. The LAPA has considered the role of renewable energy both for mitigation and adaptation and the local plans have considered renewable energy sources as an important mechanism for local level climate-resilient intervention. In the energy sector, Nepal has adopted Rural Energy Policy (2006), Rural energy subsidy policy and subsidy delivery mechanism. The Policy intends to streamline energy supply to the rural areas through the rationale use of RETs. The policy specifically targets the installation of improved biomass technologies to meet cooking and heating needs, off-grid micro-hydro for rural electrification capable of being grid-connected when the grid is extended, solar home systems and white-LED and photovoltaic-based solar lights replacing kerosene lamps. The program of small solar systems based on small photovoltaic and white-LED as an immediate and intermediate solution will be more affordable to the poor. The policy recognizes solar home systems as a mainstream electrification option for many rural areas, where grid connection and micro-hydropower are not an option for the foreseeable future. But these climate change, resources management and energy policies have not considered the possible contribution of RETs that can play important roles in climate change adaptation and mitigation aspects.

The constitution of Nepal (2015) has mentioned that 'every person shall have the right to live in a healthy environment' and these broader commitments are translated through various development policies and strategies. Nepal after the Paris Climate Agreement (2015) and the adoption of SDGs, renewable energy has become an important development theme. While the Paris agreement has emphasized renewable energy for both adaptation and mitigation purpose, SDGs has come up with a separate goal of 'ensuring energy' which also focused on renewable energy. One of the important commitments of ‘no one left behind’, although it is not legally binding, in sharing the development benefits has opened up the opportunity that RETs are to be available to communities where central grid not accessible. NDC has also focused RETs and has proposed some targets of promotion of renewable energy such as solar, mini and micro-hydro, water mills, improved cooking stove and biogas. With the changing governance process, the government of Nepal enacted the Local Government Operation Act (2017) which provided authorities to local governments to plan, implement and monitor renewable energy at the local level.

The Renewable Energy Subsidy Policy, 2073 (2016) aims to develop the renewable energy sector and encourage very poor households to use renewables by providing subsidy for deployment. It revises the subsidy and credit mobilization guidelines. Now, the subsidy would cover about 40% of the total costs; around 30% coming from credit and around 30% from contribution from the demand side (cash or in-kind). The policy primarily focusses on off-grid applications and provides subsidies for mini/micro hydropower, improved water mill, solar energy (home systems, mini-grids, grid-connected), biogas, biomass energy, wind energy and wind-solar hybrids.

4 Study findings

4.1 Renewable energy and climate change adaptation

Based on the literature review, review of the case studies of various RETs and discussions with experts, RETs revealed clear co-benefits that can help to address the negative impacts of climate change and they include: produce less or no GHGs; they can be deployed at the point of use (decentralized benefits) in rural and urban environments and serve the local needs – especially the need of women and vulnerable groups; can address range of households level service (lighting, heating, clear air) and productive needs (education, health, agriculture, communication). All these attributes are useful to enhance the ability of an individual or households to improve their living environment, information access and income-generating activities which are an important component of adaptive capacity. Besides, the RETs also help in managing water resources, air quality, land resource management. For instance, renewable energy provides energy for water pumping and post-harvest processing, which in turn provides new water resource management options and livelihood opportunities. Better lighting expands educational opportunities, improved health condition of human being, reduced exposure to indoor air pollution, reduced the drudgery of women and enhance livelihood options. Collectively these interactions contribute to increased adaptive capacity for climate change and poverty reduction. Adaptive capacity also reflects the resilience of communities to variability, and change (including but not limited to climate change) and is a function of environmental, social and financial assets and the ongoing capability to transform these assets into human well-being (Fig 1).

RETs support to the adaptation to climate change and sustainable development. Based on the literature reviewed during the study provides the following examples.

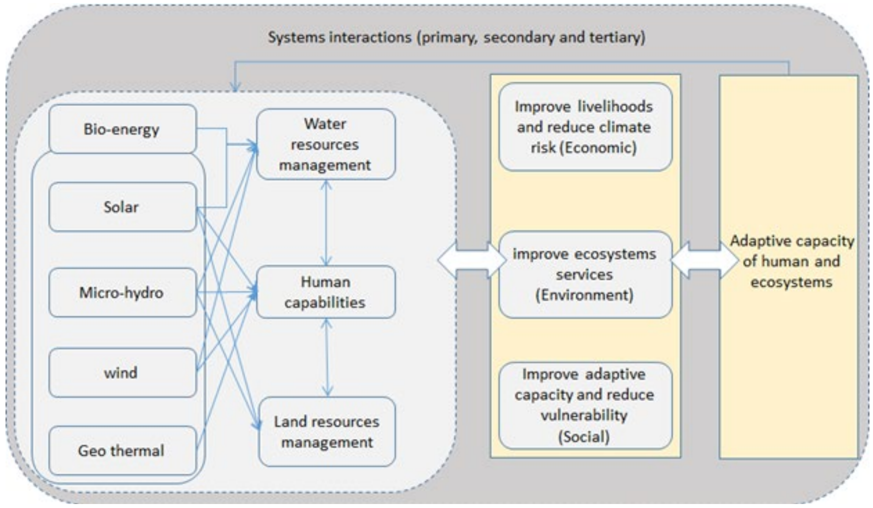

Figure 1: RETs, human capability, resources and system interactions and climate change adaption.

4.2 Impact on environmental services and socio-economic development

The level or extent of environmental impacts of RETs varies depending on technologies, geographic location, size of the technologies and so on. The review revealed that RETs can effectively avoid or minimize negative environmental impacts by reducing hazardous gases which helped to reduce GHGs emission and indoor air pollution and provision of socio-economic benefits through provision improving livelihoods assets, and adaptive capacity for coping and adaptation. Some case studies related to the contribution of RETs on adaptation, mitigation and development are provided below.

Provision of Environmental Services:

Case study 1: Lessening pressure on natural forests/manage environmental services: Renewable energy improves agricultural productivity by providing energy for irrigation pumping and postharvest processing. These productivity improvements can, in turn, reduce pressure to convert forest to agricultural land otherwise required to maintain or increase productivity. The reduction of biomass consumption, both for cooking and heating, has had a positive impact on the environment. For example, in Ladakh, India, solar intervention helped to reduce about 1.37 MT of biomass was saved by one household each year. Generating electricity for household lighting or the introduction of improved cook-stoves/biogas: efficient use of traditional biomass all limits the exposure to air pollution and toxic products of traditional biomass combustion [17-21].

Socio-economic development:

Case study 2: Impact of small hydro on the local sustainability of regions in the North of India – an improvement on various assets including financial, natural, social, physical, and human. Reduction of migratory flows from rural to urban areas, the creation of local employment opportunities (by improving access to electricity) and local capacity building. Positive but modest impacts on local income [19].

Case study 3: Improved access to clean and renewable sources of lighting and cooking energy have positive health impacts on communities and reduced expenditure on fossil fuels. It is found that on average, a project participant household annually saves 44 litres of kerosene for the household lighting, which means annually the household members, especially mothers and children are less exposed to carbon dioxide emission by 110 kg CO2, as compared to the non-participant households. In terms of money, annually a project participant household saves an average amount of NPR 4,111 (40 Euro) by reducing the consumption of 44 litres of kerosene, 187 numbers of wax candle and 16 numbers of dry cell batteries [22].

Case study 4: An improved water mill used for milling grain also produces up to 12 KW of electricity for lighting 120 households. The scheme is run by a cooperative, which collects a fee from each household and invests its profits in education, agriculture and to promote small businesses, such as poultry farming. Women literacy was also possible due to the availability of electricity during the night time (Field study note, 2013).

Case study 5: Solar greenhouses for improved family income, food security and nutrition [23].

Case study 6: Passive solar energy project in Ladakh India: solar technologies helped to improve the quality of life of people, increase energy access and reduce the vulnerability of communities –especially women group.

The main outcome was improving room temperature in winter. The average minimum indoor temperature in a (passive) solar house was reached to 5°C when the temperature outside the house was -15°C so creating a 20 °C temperature difference. Household fuel consumption was reduced on average by 50%. The fuel collection time was reduced by half and some villagers used - saved time for productive activities such as daily wage labour or social networking. The health risks related to cold and indoor air pollution were found to be reduced significantly. Diseases like arthritis and cough, for example, were reported to be less prevalent and the number of visits to doctors and/or Amchi was reduced after the introduction of solar technology. Women, who spent most of their time within the house, were mostly benefitted. The solar technology intervention helped to reduce buying traditional fuels (timber, LPG gas) and saving about 50 Euros annually per household [24].

Case study 7: A study on micro-hydro reported that households having MH have got a wide range of benefits and they include economic, education, health, and women's empowerment. MH access increased households' non-farm income by 11 per cent and consumption expenditure by about 6 per cent. Girls completed schooling years to up to 0.24 grades because of MH connectivity. Women and children from MH households suffer less from respiratory problems than their counterparts from non-MH households. Women's contraceptive prevalence, involvement in income-generating activities, and decision-making independence all go up because of the MH connectivity [25].

Case study 8: Solar house systems (SHS) on access to information, it is evident that SHS has had an important role in increasing access to information for rural households where there is no regular supply of electricity. This helps in the empowerment of rural people. Education is another sector where SHS has had a significant impact. Students with Solar Home System are 15 minutes more likely to study every day than without SHS, with the magnitude of the impact different for male and female students. This figure justifies the 2 more-percentage secured by students in their exams. Findings show that with Solar Home System, passing rate increases and school dropout rate decreases. Impact on farm income and income through own business is estimated separately. SHS is likely to increase the probability of initiating own business by 3 per cent [18].

Case study 9: A positive implication of the Micro Hydro Plant (MPH) for the households in terms of saving women's labour and time [26,27].

4.3 Barriers to the integration of RETs in development and adaptation process

The traditional development paradigm based on fossil fuel has still dominated development plans and programmes to enhance economic growth. There have been some changes in thinking of integrating new and clean and efficient technologies recently, but the existing structure, institution and mindset are found be the main barriers to promote renewable energy in Nepal. Policy inconsistency and inadequate harmonization of renewable energy in the relevant sectors are other prominent challenges. There has been very weak collaboration and coordination with other sectoral ministries such as agriculture, irrigation, energy, and local development. There is no clear policy guidelines, frameworks, methods, and tools to integrate RETs in climate change adaptation planning and management.

Major technological advances such as cost-competitive technologies are needed to accelerate the adoption of renewable technologies. The biggest challenge to promote RETs is upfront establishment cost of these technologies. The sector also affected by other additional costs due to decentralized mechanisms, remoteness, and dispersed settlements. Fluctuation or less carbon price in the international carbon market is also considered as a barrier. Besides, accessing finance in a remote area and lack of risk-sharing mechanisms (such as insurance in the changing context of climate-induced disasters) are also considered as barriers for expanding RETs.

4.4 Renewable energy and climate change mitigation potential and cost

Considering twelve renewable energy related cleaner technology options consisting of biogas, improved cooking stoves, solar PV home systems, solar thermal systems, solar PV pumping, wind electric generator based on the available data the study shows that altogether 4.45 million tons of CO_2e of the GHG emission can be mitigated per year if all the remaining technical potential of deploying them were installed after 2012 till 2030. In terms of shares of the RETs in GHG mitigation, biogas can contribute the most with GHG mitigating potential of 2.29 million ton of CO_2e (51.4% of the total GHG mitigation potential from RET) with the installation of 822,774 number of biogas plants after 2012 (Figure 2). This is followed by the installation of 898,487 ICS with the GHG mitigation potential of 1.84 million ton of CO_2e (share of 41.4%). The stand-alone and mini-grid micro-hydro plants can contribute 170 thousand ton of CO_2e (3.8% of the GHG mitigation potential) by installing 73.2 MW of their combined capacity. IWM and Solar PV home system can contribute 114 thousands ton of CO_2e (share of 2.6%) and 114 thousands ton of CO_2e (share of 0.8%) of the estimated GHG mitigation potential from selected RETs by installing 22.7 kW of IWM and 215,903 solar PV home system respectively. Dissemination of these RET options are constrained by limitation in the existing infrastructure and human resource in the real-world implementation. If we consider the average annual installation of these RETs in the recent past three years as the annual installation capacity, it has been found that 19,932 number of biogas plants, 30,711 numbers of ICS, 291 kW of standalone MHP, 2,325 kW of mini-grid MHP, 1.079 kW of IWM and 48,313 number of solar PV home systems can be installed in a year. Considering these, altogether 30.71 million tons of CO_2e can be mitigated between 2013 to 2030 by deploying above mentioned RET options at an annual additional installation equal to average installation done in recent past three years.

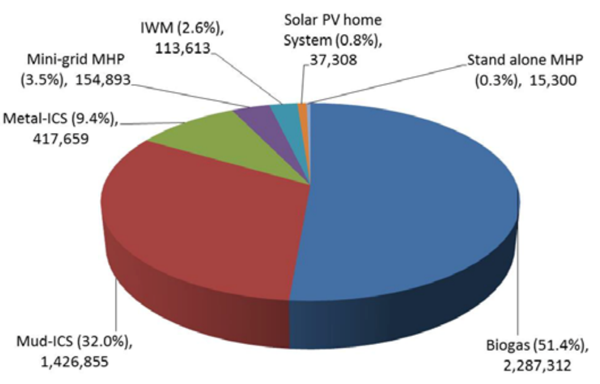

Figure 2: RETGHG Mitigation Potential of Renewable Energy Technologies in Nepal, ton CO₂e [28,29]

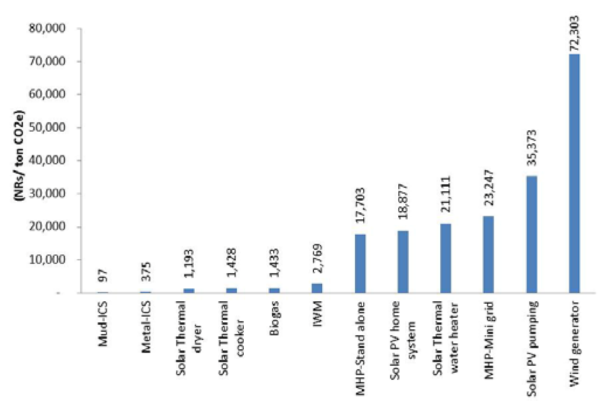

Figure 3: Annualized Technology Investment Cost @ 10% interest rate, NRs/ ton CO_2e [28, 29]

In terms of initial technology investment required for implementing above mentioned RET options to mitigate GHG emission, ICS stoves requires annualized initial technology investment cost below NRs 400 per ton of CO_2e mitigation (Figure 3). Biogas and IWM would require annualized initial technology investment cost of NRs 1,433 per ton of CO_2e and NRs 2,769 per ton of CO_2e mitigation, respectively. The annualized technology investment cost for mitigating GHG emission from stand alone and mini-grid micro-hydro plants are estimated as NRs 17,703 per ton of CO_2e and NRs 23,247 per ton of CO_2e mitigation, respectively. Solar PV home system would require the annualized initial technology investment of NRs 18,877 per ton of CO_2e mitigation. Proper application of RETs not only helps to mitigating GHG emission but also provide multitude co-benefits consisting of reduction in unsustainable use of fuel wood helping to preserve forest, reduction in the use of fossil fuels thus improving energy security and economic vulnerability, reducing indoor air pollutions, promoting micro-enterprises, contributing positively to gender and social inclusion ultimately helping to enhances adaptive capacity to climate change.

4.5 Renewable energy and SDGs 7

The United Nations SDGs, adopted in 2015, provides a framework for assessing links between global warming of 1.5°C or 2°C and development goals including poverty eradication and reducing inequalities (IPCC, 2018). SDG 7, which calls for ensuring “access to affordable, reliable, sustainable and modern energy for all” by 2030, has a strong connection with the majority of SDGs, illustrating how energy is central to fostering the pathways necessary to keep the world well below 2°C of warming and meet a wide range of SDG targets. However, despite the availability of energy and renewable solutions, the world is currently not on track to meet SDG 7, and further improvements will require increased policy commitments, simultaneous with more funding and a willingness to embrace developing technologies widely [30].

NDCs and other climate-related targets are not ambitious enough to meet the necessary global targets. They should be upgraded to better reflect the level of ambition and improvements needed. Changes should take into account and be in line with three key pillars, namely - increasing the share of renewables in the energy matrix and reducing global energy demand through energy efficiency for the reduction of climate change and closing the sustainability gap.

Besides, economic development historically has been strongly correlated with increasing energy use and growth of GHG emissions, and renewable energy can help decouple that correlation, contributing to sustainable development. In this context, renewable energy offers the opportunity to contribute to social and economic development, energy access, secure energy supply, climate change mitigation, and the reduction of negative environmental and health impacts. It can also provide access to modern energy services that would support the achievement of the SDG 7.For example, renewable energy can contribute to social and economic development through cost savings in comparison to non- renewable energy use exist, in particular in remote and poor rural areas lacking centralized energy access. Costs associated with energy imports can often be reduced through the deployment of domestic RETs that are already competitive. Besides, renewable energy can help to access energy by the people who have been using traditional biomass.

In addition to the climate adaptation and mitigation benefits, the RETs also provide a wide range of public health benefits. Improving traditional biomass use can significantly reduce local and indoor air pollution (alongside GHG emissions, deforestation and forest degradation) and lower associated health impacts, particularly for women and children in developing countries. Increased access to renewable energy services can provide important benefits to a community or household. In Nepal, communities are isolated hence decentralized grids based on RE my help to access the energy by the remote communities. It is also noted that such energy can provide additional energy services such as using solar energy for water heating and fruit drying, cooking, lighting, and biogas. RETs can also provide other important environmental benefits which can produce significantly lower GHGs than those associated with fossil fuel options.

5 Conclusion

RETs have experienced remarkable growth with a reduction in its cost. RETs are becoming increasingly competitive and cheaper against fossil fuel-based energy systems. With increased in innovative approaches and technologies, the decreasing trend of RETs cost is expected to continue and coupled with the government incentives for renewable energy technologies such as electricity and solar. Although studies on the contribution of renewable energy to sustainable development have not been carried out in Nepal, there are possibilities that renewable energy can offer the opportunity to contribute to social and economic development, energy access, secure energy supply, climate change mitigation, and the reduction of negative environmental health impacts. The technologies can provide significant positive co-benefits to people especially in the remote and inaccessible area where grid facility is not available. The study showed the RETs can have a positive impact on strengthening livelihoods, improving environmental and enhancing the adaptive capacity and resilience of people which are necessary to address climate change risks. It is therefore important to make renewable energy-friendly policies and institutional framework considering the new role of the government to scale up the RETs, devise a mechanism to reduce the cost of technology and develop a mechanism for easy access to finance and risk-sharing mechanisms.

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