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Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal

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ABSTRACT

The aim of this paper is to analyze the role of renewable energy technologies (RETs) such as biogas, improved cooking stoves (ICSs), micro hydro (MH) and solar power (SP) in helping rural communities in Nepal to adapt to climate change. The analysis considers the energy efficiency of different RETs as well as their socio-economic and environmental impacts. The efficient use of biomass in new technology, such as biogas and ICSs for cooking, has increased energy security and reduced the negative effects of traditional biomass usage. MH and SP systems are replacing candles and kerosene lamps, and are the most promising RET models for electricity generation in rural Nepal. The improved illumination from these technologies also produces better education, health, environments, and social harmony in rural communities. This study uses the Long-range Energy Alternatives Planning model (LEAP) model to develop a plan for long-term RETs use in Nepal, and specifically focuses on household energy use in rural areas. It assesses the role of biogas and ICSs in rural communities and climate change adaptation in Nepal, along with the potential role of MH and SP technologies. According to the LEAP analysis, the planned implementation of MH for 20-year long-term will result in the reduction of 2.553 million tons of CO_2 emissions. Similarly SP, biogas, and ICSs will result in a reduction in CO_2 emissions of 5.214 million tons, 35.880 million tons, and 7.452 million tons, respectively.

1. Introduction

Millions of rural communities in developing countries such as Nepal still lack access to safe and reliable energy. Access to energy is as fundamental to human welfare as clean water, agricultural productivity, health care, education, job creation, and environmental sustainability. Rural communities in Nepal spend more than one third of their household expenditure on energy services. Moreover, they devote a large portion of their time to energy-related activities, with women and young girls spending more than 6 h a day gathering wood and water, cooking, and processing agricultural products. Access to modern energy services can therefore make a real difference to the lives of people in rural communities in Nepal [1].

In general, energy use has positive effect on living standards, but research has also shows that energy consumption and climate change have a cause–effect relationship [2]. For this reason, one of the key sustainability challenges is to increase energy access for rural communities without causing negative impacts on the environment. Moreover, the depletion of natural resources and a changing climate has created more energy security challenges, especially in developing countries such as Nepal [3]. The traditional use of biomass fuel and imported petroleum fuels in rural Nepalese households has caused high carbon emissions [4]. These traditional techniques need to be replaced by energy efficient technologies, which can protect natural resources and reduce carbon emissions. If traditional biomass and petroleum fuels are not replaced with affordable and efficient alternatives, they will continue to negatively affect the environment, and the livelihoods of people who depend on it for their income and survival.

Climate change adaptation technologies and practices differ between individual communities and countries, and depend upon access to financing and technological knowledge [5]. Alternative and improved RETs can provide opportunities for communities to adapt their lifestyles to the changing climate. Thus, there is a need

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to assess and evaluate current energy systems, and ensure that societies can adapt to climate change impacts [1]. Furthermore, understanding the impact of climate change on clean energy generation is important for climate resilience planning. Such planning increases the longevity of energy systems and ensures a sustainable supply [6]. The development of long-term strategies for low carbon-emission energy systems is therefore very important.

Energy planners and decision makers use various models to perform demand and supply analysis, develop forecasts, identify gaps in demand and supply, produce options for intervention, and perform impact assessments. Several key models have been developed in recent years for energy planning, including the Long-range Energy Alternatives Planning model (LEAP), which is used to predict the future pattern of energy consumption, the problems associated with this pattern of energy use, and also the potential impacts of national or regional energy planning policies [7,8]. This system also tracks long-term energy demand and supply in a given region, and has been used to identify the most effective measures to mitigate global warming [8,9]. LEAP is designed around the concept of long-range scenario analysis, whereby scenarios are self-consistent storylines of how an energy system might evolve over time. Using the LEAP model, policy analysts can create and evaluate alternative scenarios by comparing their energy requirements, social costs and benefits, and environmental impacts [10].

This study uses the LEAP model to develop a plan for long-term RETs use in Nepal, and specifically focuses on household energy use in rural areas. It assesses the role of biogas and ICSs in rural communities and climate change adaptation in Nepal, along with the potential role of MH and SP technologies.

2. The cause and effect relationship between energy and climate change

Human-driven energy use, including the supply, transformation, and delivery of energy, is the dominant contributor to climate change and currently represents around 60% of greenhouse gas (GHG) emissions [6,11]. Energy-related GHG emissions have been growing steadily, but vary considerably among regions and countries.

2.1. Global perspective

Current patterns of energy production and consumption are unsustainable and threaten local, regional, and global environments. Excessive uses of biomass and fossil fuels have particularly negative environmental impacts, contributing to GHG emissions, land degradation, air pollution, and water and soil acidification [6]. In developing countries such as Nepal, the risk of environmental degradation from energy consumption is particularly high, and the use of cleaner and more efficient technologies such as ICSs, biogas, MH, and SP can mitigate these environmental risks.

Climate change has a considerable effect on energy supply and demand. For example, the projected change in precipitation patterns coupled with glacial retreat means that hydropower (HP) production could increase by 5% or more in northern Europe, and decrease by 25% or more in southern Europe [12]. These changes in energy supply will affect large areas of Europe that rely on HP for energy generation. Extreme events have a major impact on centralized power systems that serve large areas and use resources that are sensitive to climate change [12]. The consumption of energy in climate-sensitive regions is also likely to change: the amount of energy required for space and water heating will decrease, while the energy required for space cooling and industrial water cooling (e.g., in thermal power plants or industrial mills) will increase. The energy required for other climate-sensitive processes such as pumping water for irrigation and municipal uses will also increase. Changes in energy consumption will also occur in other sectors of the economy, such as transportation, construction, and agriculture [13].

2.2. Nepalese perspective

Nepal is responsible for only about 0.025% of annual global GHG emissions, but is highly vulnerable to climate change [14]. Increasing temperatures, especially in mountain areas, is resulting in the recession of glaciers and snowfields [15]. This will affect the supply of water for irrigation, household use, and hydroelectricity. In addition, receding glaciers often leave behind large glacial lakes that can break through terminal moraines and cause catastrophic floods. Global climate change will also result in shifting monsoon precipitation patterns that will threaten Nepal's current agricultural practices, infrastructure, and bio-diversity [16].

Renewable energy resources in Nepal will be directly affected by climate change [4]. Changes in river flow, for example, will have a direct impact on MH projects. Increases in the number of cloudy days and changes in the precipitation type (e.g., from snowfall to hailstones) will affect solar power generation. Furthermore, the increased incidence of forest fires will threaten the availability of wood for fuel.

Climate adaptation planning is very important for the sustainable development of RETs in Nepal, and is essential to climate change impact and vulnerability assessments. The urgent assessment of potential climate change impacts on rural communities is therefore paramount for the survival of rural communities [17].

3. RETs for rural areas in Nepal

3.1. Current energy use in rural Nepal

Nepal is one of the least developed countries in the world, and the residential sector accounts for a very high proportion (89%) of primary energy consumption [18]. Biomass is the main source of energy, and contributes around 87% of the total energy consumption [19]. Approximately 75% of rural communities use firewood for cooking [20].

Because traditional cooking technologies consume a large amount of biomass, rural people spend a considerable amount of time and energy collecting fuel. Due to the burden of fuel collection, women and children are prevented from engaging in educational, social, and income-generating activities. Hazardous emissions from biomass fuels used for cooking and heating can also cause health problems, such as acute respiratory problems, increased child mortality, and eye ailments [21,22].

The introduction of grid electricity into rural areas in Nepal is also very costly because of the difficult mountainous terrain and the erratic distribution of rural communities [22]. Without electricity, young people use kerosene lamps or candles to study, which are expensive and do not provide sufficient illumination [23].

Lack of domestic fossil fuel reserves, and the low purchasing capacity for imported fuels, has compelled Nepal to look for RETs such as MH, SP, biogas, and ICSs. However, Nepal is rich in renewable energy sources, with an estimated 42,000 MW of commercially exploitable hydropower, 100 MW of MH, 2100 MW of SP, and 3000 MW of wind power annually. It is also estimated that 1.1 million domestic biogas plants could be developed in Nepal [19]. Due to the abundance of renewable energy sources, Nepal could provide sustainable energy to rural areas by promoting the use of RETs [5]. The potential use of RETs in Nepal has been considered as an important approach for sustainable development of the rural communities.