International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(6), 395-407.

Renewable Energy in Nepal: Current State and Future Outlook

Asif Raihan[1], Sadman Anjum Joarder[2], Tapan Sarker[3], Blanka Gosik[4], Dariusz Kusz[5], Grzegorz Zimon[5]*

[1]Institute of Climate Change, National University of Malaysia, Bangi 43600, Selangor, Malaysia, [2]Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi 6204, Bangladesh, [3]School of Business, University of Southern Queensland, QLD 4300, Australia, [4]Department of Regional Economics and the Environment, Faculty of Economics and Sociology, University of Lodz, Poland, [5]Department of Computer Science in Management, Faculty of Management, Rzeszow University of Technology, 35-959 Rzeszow, Poland. *Email: gzimon@prz.edu.pl

Received: 28 April 2024 **Accepted:** 19 September 2024 **DOI:** https://doi.org/10.32479/ijeep.16500

ABSTRACT

Nepal's energy mix is predominantly based on traditional and inefficient biomass and fossil fuels. As a result, there is a notable prevalence of energy scarcity in the country. Within the literature, there exists a lack of a comprehensive review of the potential of renewable energy in the country while the relatively less contribution of renewable energy resources, making the country more vulnerable to adopt a more carbon-intensive energy policy. Consequently, in this study, we conduct a thorough review of existing literature to provide a comprehensive assessment of the current status of renewable energy and the energy mix in Nepal. We also discussed the potential for the country to transition to a sustainable energy system. This review analysis exclusively focused on scholarly articles and research reports that specifically addressed the topic of renewable energy in Nepal. Despite the rapid decline in the cost of solar photovoltaics, Nepal's renewable energy share currently stands at only 3.2%. This paper argues that Nepal needs proactive and favorable strategies and policies to effectively implement clean energy, based on the given premises and the country's aspirations for sustainable energy. This involves a substantial amount of solar power production combined with battery storage, supplemented by storage methods such as off-river pumping hydropower technology. The study emphasizes the significance of renewable energy in achieving the United Nations' Sustainable Development Goals (SDGs). This review also emphasizes the obstacles in the advancement of Nepal's renewable energy industry and offers suitable policy suggestions to address these obstacles, hence facilitating a sustainable shift in energy.

Keywords: Renewable Energy, Solar, Hydropower, Technology, Energy Transition, Sustainable Development
JEL Classifications: L9, O13, P18,Q00

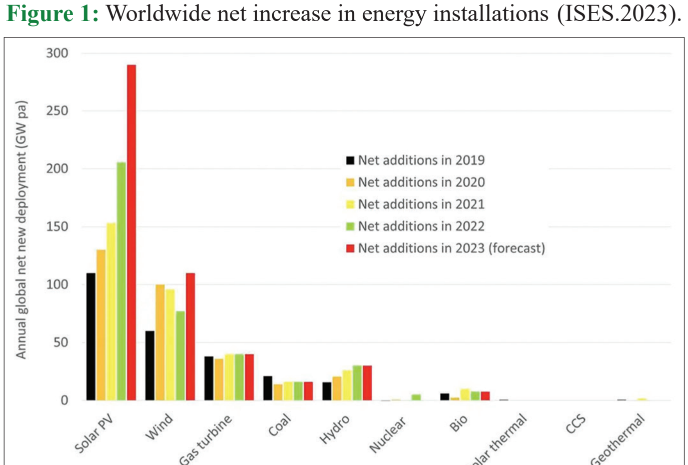
1. INTRODUCTION

Energy is a vital resource that fulfills essential human requirements and facilitates productive endeavors (Dincer and Aydin, 2023). Global energy consumption is seeing a significant surge due to the recent and rapid growth in population and economy worldwide, particularly in developing market countries (Haldar et al., 2023; Salehi et al., 2022). Energy resources are interconnected with the security of nations, both domestically and internationally, as well as with economic progress and a country's ability to fulfill its citizens' fundamental needs (Raihan and Tuspekova, 2022; Zimon et al., 2023). However, over 80% of the world's primary energy is derived from fossil fuels (coal, oil, and gas), despite compelling evidence of escalating environmental harm caused by their utilization (Holechek et al., 2022). Hence, there is a growing need to address the worsening environmental circumstances linked to the utilization of conventional energy sources (Raihan and Tuspekova, 2022a). Unfortunately, at the moment, for many governments around the world, the most important thing is still economic benefits, not environmental protection and the health of residents. However, awareness is slowly emerging in all parts of the world that changes towards renewable energy are needed, as evidenced by the change in the energy structure of many countries, which is confirmed by numerous studies.(Zimon and Zimon, 2020; Khan et al., 2023; Khan et al., 2020; Zimon and Salehi, 2023, Walasek et al. 2023). These conditions encompass issues such as regional and indoor air pollution, localized ecosystem damage, and the risks posed by global climate change (Raihan and Tuspekova, 2022). Hence, the task of reconciling economic progress with environmental preservation presents a significant and intricate policy dilemma, with the energy aspect of this dilemma emerging as the most urgent concern for sustainable development on a global scale (Raihan and Tuspekova, 2022a).

A clean energy revolution is urgently needed to ensure long-term economic growth, address climate change threats, and accomplish the SDGs by replacing the current fossil-fuel dependent energy infrastructure. Significant global efforts have been made to conduct thorough research and development in renewable energy sectors (Bhattari et al., 2023). Wealthy nations are actively working to increase the availability of renewable energy in poor countries. In 2019, renewables accounted for around 20% of the total worldwide primary energy consumption (REN, 2021). Hydropower accounted for 2.5% of the total world energy supply, while solar, wind, geothermal, and other renewables collectively contributed 2.2% (IEA, 2021). Developed countries are currently primarily focusing their renewable energy research efforts on solar and wind technologies. The International Energy Agency (IEA) predicts that over 400 gigawatts (GW) of additional solar and wind capacity will be installed in 2023 (IEA, 2021). Figure 1 illustrates the global net growth in energy installations. The significant and increasing discrepancy in the rates at which solar and coal/gas/nuclear energy sources are being utilized indicates that almost all of the worldwide increase in electricity demand is being fulfilled by solar energy (with assistance from wind energy). The installed solar capacity is projected to reach approximately 6 Terawatts by 2030, surpassing the combined generation capacity of coal, gas, hydro, and nuclear energy sources. The rapid growth of solar energy is sufficient to achieve decarbonization of the global energy system by 2050, even if it is utilized to power an all-electric energy system catering to a population of 10 billion affluent individuals.

The 21st century is faced with a significant problem in the form of global warming and climate change, primarily caused by the buildup of greenhouse gases (GHG) in the atmosphere, with carbon dioxide (CO_2) being the dominant contributor (Raihan et al., 2024). In order to mitigate GHG emissions and mitigate climate change, it is imperative to fundamentally reposition the energy sector, which is responsible for approximately one-third of GHG emissions. According to the Intergovernmental Panel on Climate Change (IPCC), it has been determined that global human-caused emissions must decrease by 45% by 2030 compared to the level in 2010, and ultimately reach a state of no net emissions by 2050 (IPCC, 2018). This is necessary in order to restrict global warming to an additional 1.5°C. According to IEA (IEA, 2021), energy consumption is projected to increase by 25% in 2040 compared to 2010. This highlights the urgent and rapid need to shift towards a low-carbon economy, adopt renewable alternatives, and improve energy efficiency (Akpan and Olanrewaju, 2023).

Figure 1: Worldwide net increase in energy installations (ISES.2023).



Several governments have pledged to achieve net zero emissions between 2050 and 2060, and it is anticipated that additional countries will do the same in the near future. The task at hand will include advancing the date to the year 2040 (Raihan and Tuspekova, 2023). Fortunately, the current solar and wind revolution enables this change. In light of these worldwide patterns, Nepal has pledged to achieve a formidable objective of attaining net zero emissions by the year 2045 (Raihan, 2023b). The current study examines the possibility of transforming the energy industry in Nepal. It is crucial to recognize that the overall energy consumption in Nepal is now very low and needs to be raised in order to facilitate the country's economic growth goals. Nepal aims to transition from conventional energy sources to renewable energy for generating grid electricity, aligning with its objectives and current circumstances. The government aims to raise the per capita annual power usage from 267 kWh in 2019 to 1500 kWh by 2030. Currently, hydropower accounts for about 97% of the electrical energy generated in Nepal, and the national system extends its coverage to over 90% of households. Regrettably, hydropower is particularly vulnerable to disturbances caused by climate change. A grid that lacks diversification presents a potential threat to reliability, and it is not advisable to just rely on hydropower expansion to meet the growing electrical demand in Nepal. Instead, the energy composition should integrate contemporary renewable sources in addition to hydropower, and encompass a pioneering combination of energy storage methods, such as off-river pumped storage.

Nepal has low per capita electricity, with rural area zones greatly reliant on traditional energy sources like firewood and agricultural residues. Nepal, situated in a mountainous region with steep gradients and abundant water resources, is renowned for its vast hydro-power generation capacity (Raihan, 2023b). However, Nepal was listed as one of the world's least developed nations as a result of its egregiously inadequate use of these massive hydropower resources. Nepal, despite its abundant hydropower resources and rich mountainous terrain, has been ranked among the least developed countries globally due to inadequate utilization (Mitra et al., 2023). Nepal's vast wind power potential of approximately 3000 MW is largely due to its numerous tall and windy mountains (Dincer and Acar, 2015). The country's 300 sunny days annually provide 3.60–6.20 kWh/m^2/day of solar irradiance, making suitable wind turbine deployment a significant resource utilization (Adhikari et al., 2013). Multiple studies have examined various situations regarding the advancement of renewable energy in Nepal. The studies provided a comprehensive overview of renewable energy resources and examined various technologies like solar, micro-hydro, bioenergy, wind energy, improved cooking stoves, and enhanced water mills (Surendra et al., 2011). Previous studies focused on the possibilities and obstacles of developing decentralized renewable energy technologies, without taking into account the potential for large-scale generation or integration into the power grid (Surendra et al., 2011). Since then, there have been significant changes in the energy situation and the availability of renewable energy technology in Nepal and worldwide. Additional research has also acknowledged the considerable capacity for producing renewable energy in Nepal by utilizing local resources. Nonetheless, it is noteworthy that previous research has not adequately recognized the potential for integrating renewable energy technology into the power grid to enhance the dependability of electricity delivery to consumers. In a wider regional context, Shukla et al. (2017) examined the possibilities and obstacles associated with renewable energy sources in South Asian nations, with a specific emphasis on policy, economic, human resource, and technical factors. The study focused exclusively on small-scale off-grid renewable energy and did not take into account the potential of market-driven, grid-connected renewable alternatives (Shukhla et al., 2017). Poudyal et al. (2019) conducted a study that examined the current and future large hydropower projects in Nepal. The study also analyzed the policies and government activities that are intended to promote and facilitate the development of these projects. While their focus was solely on hydropower, the research contended that renewable resources are vital for surmounting the present energy crisis in the nation and achieving energy autonomy (Poudyal et al., 2019).

The present study offers a thorough examination of renewable energy sources and their potential in Nepal. Besides, this article provides a synopsis of renewable energy sources integrated with the smart grid in Nepal. Eventually, this paper examines the necessary policy and legislative changes required to promote the progress of renewable energy technologies in the country at now. The research leads to a discussion on how investments in renewable energy technology might contribute to the attainment of all the 17 SDGs proposed by the United Nations. The primary insights of this study are: providing additional information on renewable energy technologies in Nepal, exploring the potential for transforming the country's energy sector through a unique approach of balancing excess energy from hydropower and renewable sources on a seasonal and daily basis, and discussing the connections and consequences of renewable energy development in Nepal for achieving the SDGs, emphasizing the necessity for greater integration in the planning processes for SDG attainment. This study offers important insights to policymakers and investors on the potential and future possibilities of renewable energy technology in Nepal, with the target of transitioning towards a more environmentally friendly energy system.

2. GLOBAL RENEWABLE ENERGY SCENARIO

Approximately 80% of the world's primary energy supply comes from fossil fuels. The projection from 2002 to 2030 indicates a nearly 60% increase in global energy demand, with a 1.6% annual increase (Raihan, 2023b). Renewable energy not only reduces CO_2 emissions but also decreases dependence on fossil fuels and energy imports, thereby promoting climate protection and economic growth (Salehi et al., 2023; Zimon et al. 2022). Renewable energies are predicted to contribute about 80% of total energy consumption by 2100 (Jones and Wamer, 2016).

Global commercial progress and rising population are expected to increase energy consumption by 30% by 2030, with renewable energy playing a crucial role in addressing this issue (Asghar et al., 2023). Renewable energy sources contribute to approximately one-fourth of the world's electricity generation. Figure 2 displays the total accumulated capacity of renewable energy globally, spanning from 2010 to 2022. The global installed capacity of renewable energy reached approximately 3372 GW in 2022, representing an almost 10 percent increase compared to the previous year. The renewable energy sector has witnessed a significant surge in growth in recent decades, mostly driven by the declining costs of renewable technologies and grow2ing apprehensions regarding the environmental consequences associated with conventional energy sources (Statista, 2023). By the end of 2024, the total global renewable capacity is projected to exceed 4500 GW (IEA, 2023). Furthermore, Figure 3 illustrates the worldwide renewable energy production capacity in 2022 categorized by various forms of renewable energy. Figure 4 shows that hydropower constitutes 35% of the global aggregate of renewable energy generation. The solar and wind energy sources supplied 33% and 26% respectively. Furthermore, bioenergy accounted for 4% of the overall renewable energy, with the remaining 1% being produced by other sources like geothermal and tidal energy.

3. CURRENT ENERGY SCENARIO OF NEPAL

Nepal's energy consumption in the 2019/2020 period amounted to 14.464 million tons of oil equivalent (Mtoe), a significant rise from 10.29 Mtoe in 2012 (MOF, 2021). This growth can be attributed

Figure 2: Global renewable energy capacity (Statista, 2023)

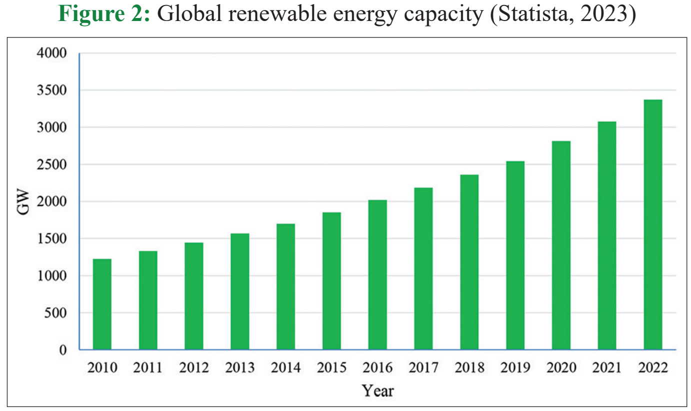


Figure 3: The annual trend of Nepal's energy mix (MOF, 2021)

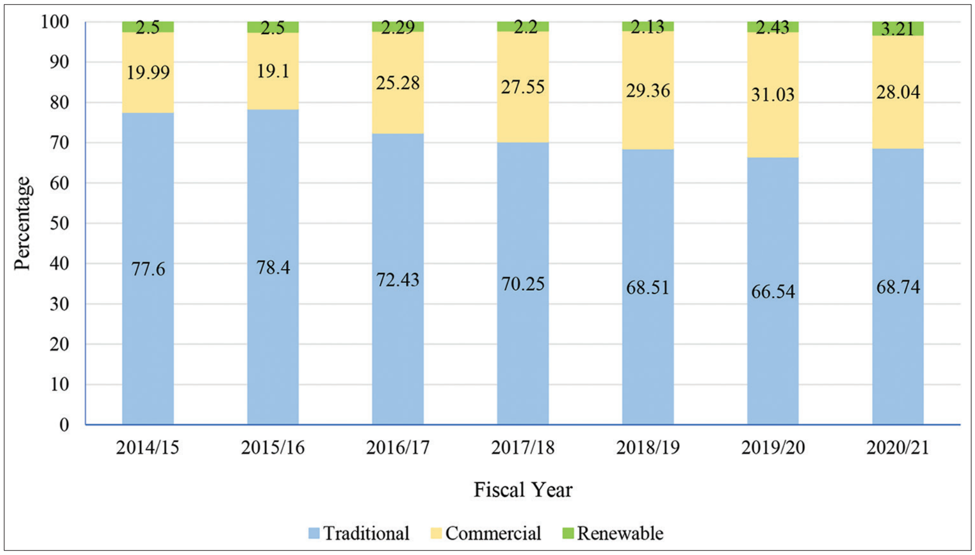
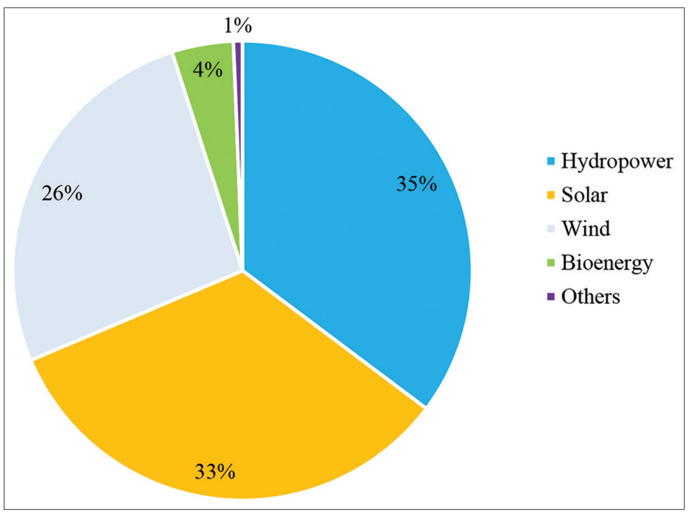


Figure 4: Global renewable energy production capacity by type (Statista, 2023)



to the country's limited number of businesses and energy-intensive sectors. Nepal mostly relies on biomass and imported fossil fuels as its main energy resources (Raihan and Tuspekova, 2022). The national energy mix is predominantly composed of traditional biomass, which includes firewood, animal manure, and agricultural leftovers. This biomass accounts for approximately 68% of the total energy supply and holds a dominant position in the energy sector (MOF, 2021). The majority of the remaining energy requirements are fulfilled through the importation of fossil fuels (such as petroleum and coal) from India. These imports constitute over 28% of the overall primary energy consumption. The remaining portion of the supply is derived from local energy generation, predominantly hydropower (3.5%) and distributed renewables (3%), consisting mainly of solar home systems and biogas (MOF, 2021).

The current trend in the energy mix of the national energy consumption is presented in Figure 4. As demonstrated, the proportion of traditional energy has declined by around 10% during this 6-year timeframe, and this decline has been offset by a corresponding rise in the proportion of commercial energy. Throughout this time frame, the proportion of renewable energy sources has remained quite constant. The main factors responsible for the observed changes are the rising vehicle population and the growing adoption of liquefied petroleum gas (LPG) for cooking, gradually replacing biomass energy, especially in urban regions.

Furthermore, Figure 5 illustrates the overall yearly electricity usage across different industries. The domestic sector is the primary consumer of power, with the industrial sector being a close second. Despite the overall underdevelopment of Nepal's economy, the industrial sector experienced consistent growth in power usage until 2019. However, in 2020, there was a 6% reduction in energy usage due to the COVID-19 epidemic, which resulted in significant losses for the industrial sector. Despite the relatively low levels of energy consumption, individuals have been compelled to endure extended periods of electrical blackouts as a result of significant energy shortfalls and suppressed demands. The negative effects of this have had a detrimental impact on both the overall standard of living and the economic progress of the nation (Koyrala and Acharya, 2022). The aforementioned data unequivocally indicates that solar, wind, and other renewable energy sources are currently insufficient in their contribution to Nepal's energy composition.

3.1. Solar Energy

Solar energy is a sustainable and perpetual energy source that does not emit harmful GHGs or toxic gases like CO_2, SO_2, and NOx during energy generation (Shahsavari and Akbari, 2018). Nepal possesses the greatest capacity for renewable energy generation through solar power, particularly in the regions of Kathmandu and the northwestern area, which exhibit higher levels of solar radiation and PV potential compared to other parts of the nation. Figure 6 displays the solar energy capacity in Nepal. Theoretical solar capacity surpasses the combined potential of all other resources by a factor of 100. Solar PV power generation is currently more cost-effective than other energy sources, save for the most advantageous hydropower locations. Nepal has the potential to develop four

Figure 5: Nepal's electricity usage across several sectors (MOF 2021).

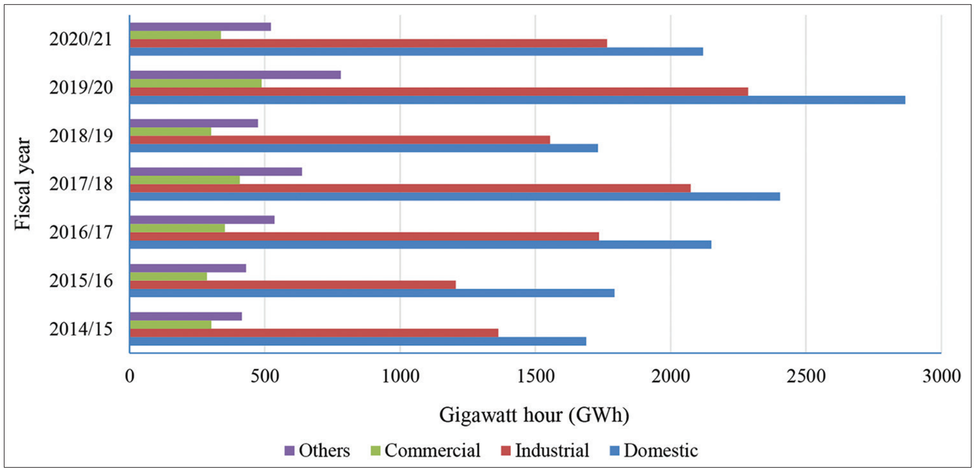
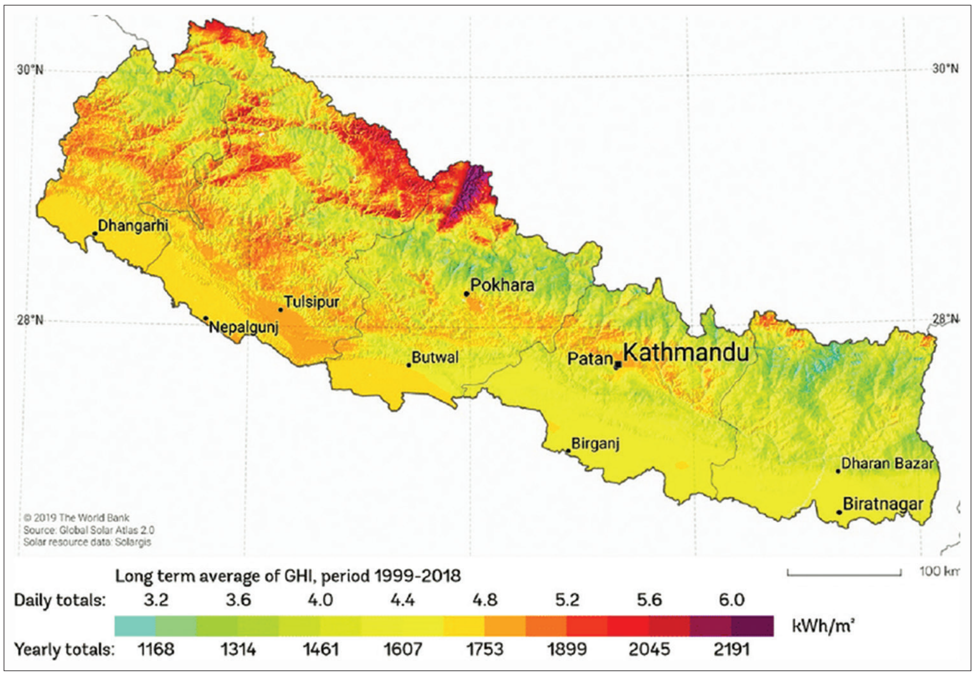


Figure 6: Solar energy potential in Nepal (Global Solar Atlas, 2019)

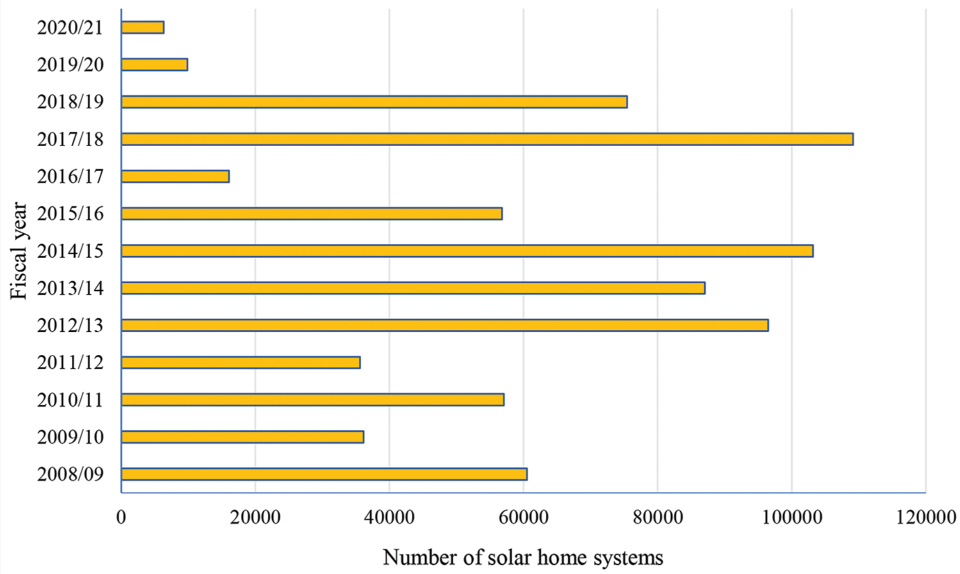


types of solar energy technology: grid-connected PV, solar water heaters, solar lanterns, and solar home systems. Nepal is located at a latitude of 26–30°N and experiences over 300 days of sunlight annually. The area has a rather high level of solar radiation, with an insolation of approximately 4.7 kWh/m^2 day (17 MJ/m^2 day). Additionally, it receives an average of 6.8 h of sunshine each day (SEMAN 2019).

Nepal's off-grid families are increasingly adopting solar PV systems, with 60 MWp of off-grid PV and 20 MW of grid-connected systems deployed by 2019 (SEMAN, 2019). Currently, there are over 1.1 million households equipped with solar home systems. A significant number of institutional systems have been implemented in educational institutions, health facilities, residential accommodations, and other locations. Additionally, over 10,000 solar streetlights have been deployed (AEPC, 2021). Figure 7 illustrates the significant increase in the number of solar household systems installed from 2011 to 2014, followed by a less consistent pattern since 2014/2015 (MOF, 2021). Following 2018, the Nepal Energy Authority (NEA) made significant enhancements and expansions to the provision of energy through the grid system. Therefore, based on these data, solar technology may appear to be financially rewarding.

In 2021, the Department of Electricity Development (DoED) granted survey licenses to 34 grid-tied solar projects, totaling 1101.7 MW, and building permits to 22 projects, totaling 137.56 MW (NEA, 2021). The Nepalese government is currently constructing a solar PV facility with a capacity of 25 MW in the Nuwakot district. This project, once completed, will be the largest solar plant in Nepal, aligning with the government's strategy to integrate advanced renewable energies into the national grid (NEA, 2021). The adoption of isolated solar technologies has been promoted by international donors and the government primarily due to their lower initial cost and immediate installation. Over the past few decades, Nepal has implemented various solar energy

Figure 7: Installation of solar home systems in Nepal (MOF 2021)



technologies, including household solar lights, water pumping systems, solar disinfection of drinking water, domestic space and water heating, and electro-chlorination of water supply systems (Bhattarai et al., 2023a).

3.2. Hydropower

Nepal's most common form of renewable energy is hydropower, but only 2% of the country's national hydro resources are currently utilized. A viable alternative for Nepal's future economic development is the hydro resource. The high Himalayan-based rivers make up 2.2% of global water resources, a four-fold increase from the world's average water resources. Nepal's hydropower generation is significantly enhanced by over 6000 rivers flowing from north to south, showcasing its vast hydropower potential. Nepal possesses a highly rugged topography, with elevations ranging from 60 m above sea level (masl) to 8848 masl at the peak of Mount Everest. This significant variation in elevation occurs across a relatively short north-south distance of <150 m. The annual water supply of 225 billion cubic meters flowing out of the nation, along with the high elevation, is very advantageous for generating hydropower in Nepal. Hydropower is currently the primary source of electricity in Nepal and is expected to remain a significant component of the energy mix. The country's theoretical hydropower capacity is estimated to be 83 GW, with 45 GW considered commercially viable. According to the DoED (DoED, 2021), large-scale hydropower projects generated 563 MW of electricity, small hydropower plants produced 581 MW, and off-grid micro hydropower schemes generated 72 MW. Figure 8 displays the primary hydropower projects in Nepal, including those that are now operational, under development, and planned.

In 2018, a significant achievement in the power industry occurred with the activation of the Dhalkebar-Muzaffarpur cross-country transmission line connecting Nepal and India. The significance of this transboundary transmission line lies in its ability to enable the export of excess power to adjacent nations in South Asia. This presents a potential for the country to experience economic growth and achieve a favorable international trade balance (IHA, 2019). Nevertheless, comprehending and strategizing for the adverse social and environmental consequences of extensive hydropower initiatives is crucial. Given that solar energy is now cheaper than the majority of hydropower systems, implementing less invasive solar projects could be more widely accepted and contribute to achieving the objective of a more varied national energy portfolio. Moreover, hydro projects often give rise to land and environmental issues, such as flooding occurring at or in close proximity to dam sites. A further worry arises from the absence of a varied energy mix in Nepal, mostly due to the prevailing dominance of hydropower.

3.3. Wind Energy

Wind energy is a widely adopted renewable energy source globally. Over the past decade, the global production of wind energy has significantly increased to over 20% annually (IEA, 2023). The location of wind farms is a difficult topic in Europe because local residents often protest against such a solution. This is a big problem, for example, in countries such as Poland.

Nepal's wind power expansion is limited, but its capacity is relatively high because of its geographical and topographical features (Poudyal et al., 2019). A wind-solar hybrid power system of significant size was erected in Hariharpurgadi, located in the Sindhuli district of Nepal. This system has the capacity to generate 110 kilowatt-hours (KWh) of energy per day ADB 2017). Similarly, in the remote town of Dhaubadi, a small-scale wind-solar system produces 43.6 KWh of electricity daily (WPN, 2016).

3.4. Bioenergy

Biomass is widely recognized as a potential alternative energy source globally. Biomass is derived from living organisms like wood, agricultural crops, forest residues, animal waste, municipal solid waste, aquatic plants, algae, and waste from biomass-based industries (Raihan, 2023). Figure 9 presents different kinds of

Figure 8: Major hydropower projects in Nepal (Hydro Review, 2019)

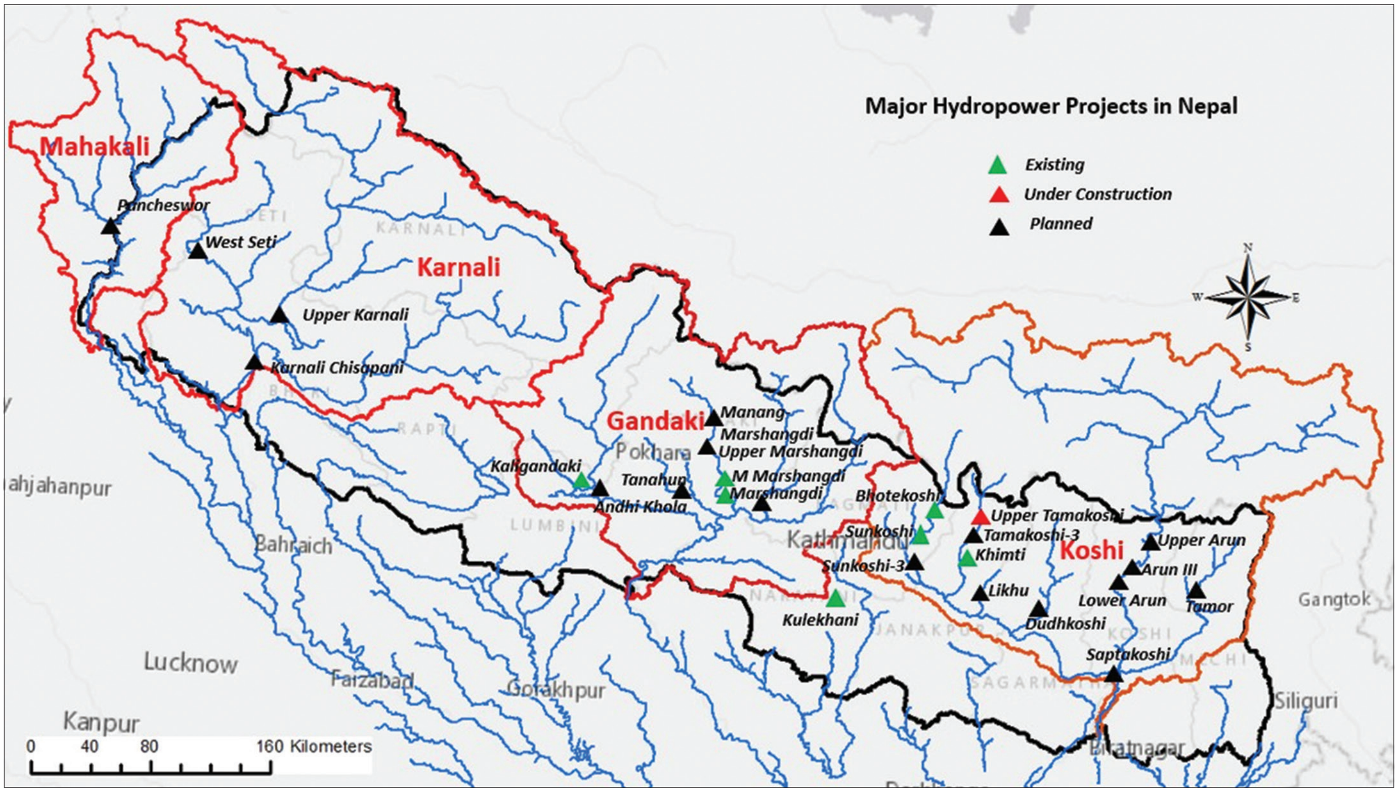
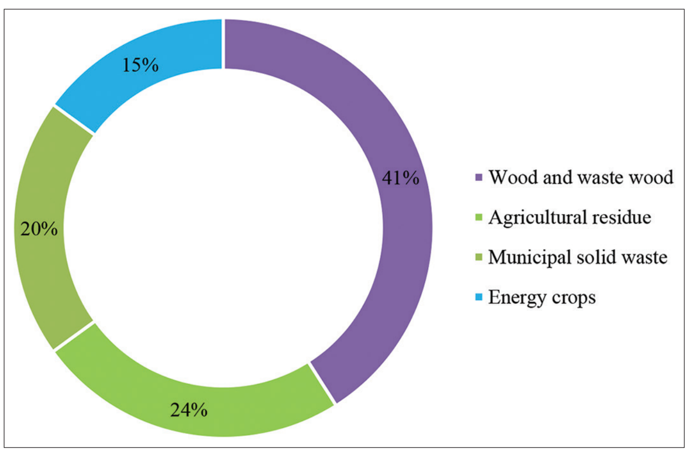


Figure 9: Biomass usage for the global energy generation (Perera et al., 2023)



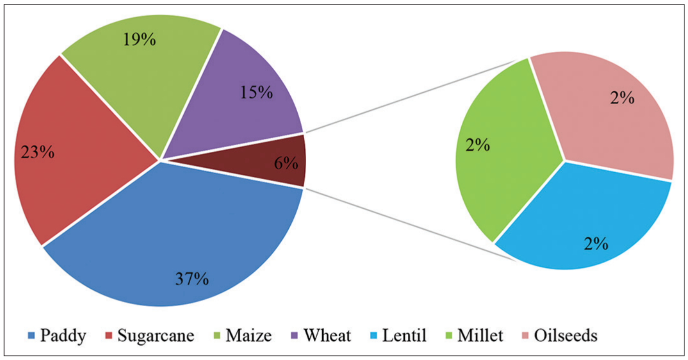
biomass usage for global energy generation. Approximately 3.5 million homes, out of a total of 5.4 million households in Nepal dependent on biomass for cooking. The conventional utilization of biomass for cooking purposes is characterized by inefficiency and is associated with household air pollution, resulting in around 24,000 fatalities per year. Additionally, this practice leads to deforestation and forest degradation, leading to habitat loss and a net increase in GHG emissions (Raihan and Tuspekova, 2022; Zimon et al., 2023). An alternative method that is more effective involves generating biogas by subjecting material to anaerobic digestion.

Firewood combustion is the principal method for generating household energy in Nepal, accounting for 66.2% of the country's primary energy. This is mainly due to its abundant availability. Usage in distant and mountainous places, particularly, exceeds 80%. Firewood serves as the predominant source of fuel for cooking and heating, but it also plays a significant role in deforestation and causes substantial environmental and health consequences. Firewood fuel accounts for over 80% of the total energy share in 49 out of 77 districts in Nepal (Nepalmap, 2021) Mugu district has the biggest proportion, accounting for 98.8%, while the capital city, Kathmandu, has the lowest proportion, amounting to 7.6% (Nepalmap, 2019).

The utilization of agricultural leftovers as fuel is most prevalent in the low-lying Terai, which is characterized by highly fertile terrain, whereas it is least common in the arid mountainous regions. The agricultural residues available in the year 2019/2020 were expected to be 23.5 million tons, which is equivalent to 5803 kilotons of oil equivalent (MoAD, 2021). If these sources were effectively transformed into energy, they could potentially meet around 61% of Nepal's total energy consumption (MoAD, 2021). Figure 10 illustrates the respective contributions of several crops to the overall output of residue in the year 2019/2020. Paddy, sugarcane, wheat, maize, and grain legumes are the top crops contributing to crop residue production.

In rural Nepal, dried animal excrement is mostly utilized as a source of fuel in areas where clean and economical energy options are limited. Dung cakes are composed of desiccated animal excrement combined with agricultural remnants. These are utilized as a source of fuel for both cooking and heating purposes. Dung cakes are widely regarded as highly inefficient as an energy source due to the emission of noxious fumes and compounds during

Figure 10: Crop contributions to residue production (MoAD, 2021)



combustion, which have detrimental effects on human health. According to the Ministry of Finance (MOF), dried animal dung accounted for 2.95% of Nepal's entire energy utilization in the year 2019/2020 (MOF, 2021). Utilizing anaerobic digestion to produce biogas is a far more efficient method of converting fresh animal manure into energy.

Biogas has a significant historical presence in Nepal, dating back to 1955 when the first plant was built at Saint Xavier's school. Since the 1990s, the Government of Nepal has been actively pushing the biogas support program with the assistance of various donor-supported initiatives. By the end of the fiscal year 2019/20, there were a total of 431,000 household biogas plants erected. These plants varied in size, ranging from 4 to 10 m^3, and collectively produced over 100 MW of energy equivalent (AEPC, 2019). Figure 11 displays the annual installation of biogas plants inside the country. A study conducted among around 6000 families in Nepal revealed that the utilization of biogas for cooking resulted in a roughly 50% reduction in the consumption of fuel wood and contributed to the achievement of forest conservation goals. Biogas is a viable and efficient option for providing residential energy in rural homes that have enough land and cattle. Commercial biogas facilities with digester sizes over 3000 m^3 are a relatively young and developing industry in Nepal, when compared to smaller home biogas plants. To date, a total of five expansive biogas facilities have been established, with numerous further ones now being constructed in various towns. These facilities are designed to convert organic municipal solid waste into biogas.

The generation of biogas from livestock manure can enhance electricity production, provide thermal energy, and serve as a substitute for fossil-based transportation systems.

4. RENEWABLE ENERGY SOURCES INTEGRATED WITH SMART GRID IN NEPAL

A smart grid enhances infrastructure and electrical energy systems, fostering a more intelligent environment. A smart grid modernizes electrical power infrastructure and services, enhancing reliability and efficiency (Dudin et al., 2019). Renewable energy sources offer increased efficiency and convenience, but they also increase energy prices and contribute to the greenhouse effect. The most effective method involves utilizing wind generators, hydroelectric, solar energy, and biofuels for electricity generation. The extensive adoption of these inventions depends on three key factors: Demand-side capacity planning, distributed energy storage, and distributed energy management. This connects various energy sources to the electricity grid (Du et al., 2021). The smart grid's energy storage system significantly supports the growth of renewable energy technologies, enhancing the overall efficiency and sustainability of the system (Vedanarayanan et al., 2022).

Figure 12 displays Nepal's power transmission network map, showcasing the inhomogeneity of the country's distributed networks, including both existing and proposed networks. Major hydropower stations, the primary electricity sources, are located in the Himalayan region because of the abundance of perennial rivers. Load centers like industries, commercial areas, and large residences are located far from generating stations, necessitating longer transmission lines for power supply. It is dispersed sporadically in other locations and congested in commercial and industrial centers like KaV, Butwal, and Hetauda. As of 2019, around 75% of the lengthy transmission lines run at 132 kV. A mere 12% of transmission lines function at 220 kV or above, leading to a transmission loss of 4.64%, beyond the permissible threshold of approximately 2% (NACAA, 2015). The increasing usage of renewable energies and aging transmission infrastructure make it challenging to maintain grid stability and flexibility. The lack of control and increased costs of acquiring high-voltage transmission lines also pose restraints (Bhattarai et al., 2023).

Nepal's power system faces significant concerns such as a fragile network, high loss, aging infrastructure, power theft, poor penetration of renewable energy sources, and severe dependence on fossil fuels (Zimon et al., 2023; Bhattarai et al., 2023). The Nepal Electricity Authority (NEA) plans to establish 5 million smart meters in stages by 2025 to address energy-related issues. The plan is to install 98,000 smart meters in two distribution centers in Kathmandu Valley by May 2020 and 450,000 smart meters in 10 centers by May 2021. Despite the COVID-19 pandemic causing complexities, only 60,000 smart meters have been deployed, resulting in immediate benefits like lower reading costs and reduced losses. The company plans to establish 3 million smart meters by May 2023 and 5 million smart meters by May 2025. The National Environment Agency (NEA) has set a target to undertake several pilot projects. The Kathmandu Valley Substation Automation Project aims to enhance grid reliability, reduce operating costs, and extend equipment service life. Numerous high-voltage transmission lines (400 kV) have been completed, and more are currently being built or proposed (NEA, 2021).

Nepal's Ridi Hydropower Company connected its first 8.5 Megawatt private-owned solar power plant to the national transmission line in Butwal, demonstrating the potential of renewable energy sources. The Nepali government has granted construction licenses to 15 solar power projects, totaling approximately 92 MW. Geotechnical investigations and hydrological studies are ongoing in the 150 MW BegnasRupa Pump Storage Hydroelectric Project, while a Memorandum of Understanding has been signed for the Kulekhani-Sisneri Project (NEA, 2021).

Figure 11: Installation of biogas plant in Nepal (MOF, 2021)

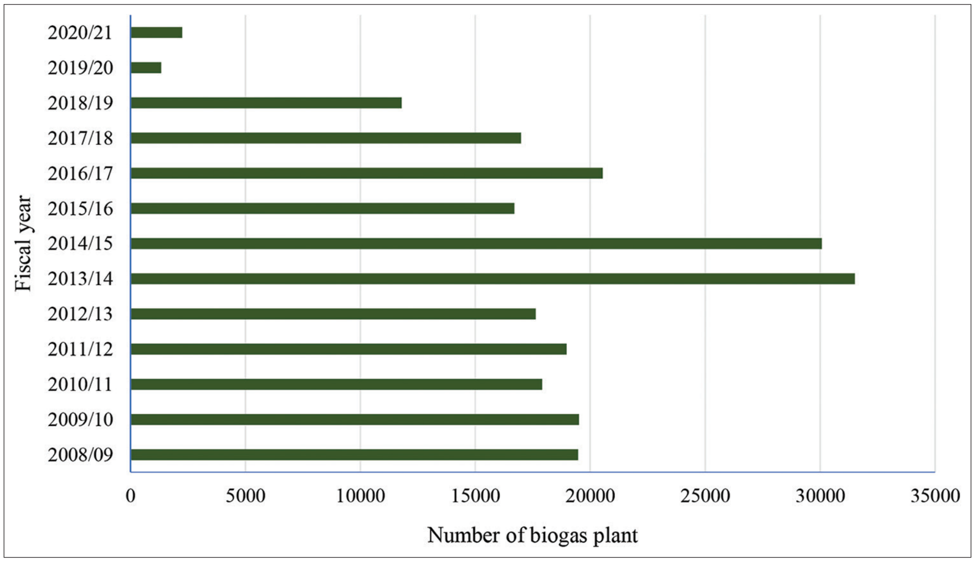
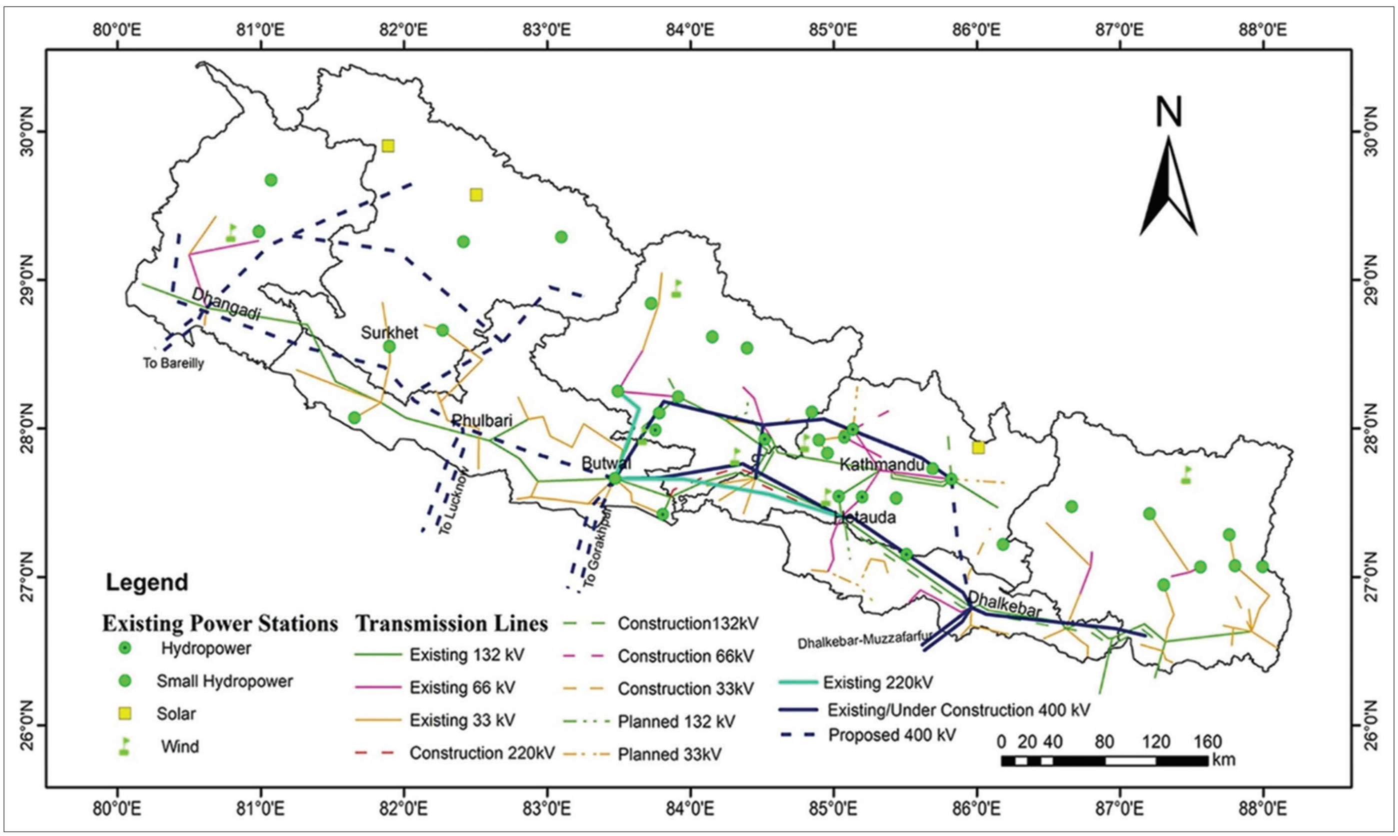


Figure 12: Nepal's power transmission network map (Bhattarai et al., 2023)



5. CHALLENGES AND RECOMMENDATIONS

The Nepalese government has been actively endeavoring to advance renewable energy technologies at the federal, provincial, and local levels in collaboration with pertinent partners. In order to enhance and encourage the renewable energy industry, many policies and strategies have been devised. The Nepali government is implementing various legal frameworks and progressive programs to accelerate the adoption of renewable and clean energy initiatives. Nepal has set a significant goal of generating 127 MW of solar power, with the government investing the most in this form of energy. This indicates that solar energy is becoming the primary component of Nepal's energy mix. In addition to solar power, the country is embracing various kinds of renewable energy generation in order to achieve its climate objectives, with a particular emphasis on promoting sustainable energy expansion.

Nevertheless, the current accomplishments remain inadequate, underscoring the necessity for novel approaches that enhance the adoption of contemporary energy solutions. In relation to renewable energy and its associated sustainable development goal (SDG 7), the government set a target to increase the proportion of renewable energy in final energy consumption to 22.1% by 2019. According to the 2020 National Review of Sustainable Development Goals by the Government of Nepal, renewable energy now accounts for barely 5% of the overall energy mix. This exemplifies the ineffectiveness of policies and tactics un significantly boost the utilization of renewable energy. The failure may be attributed to insufficient vertical and horizontal coordination across various ministries, departments, and stakeholders in formulating and executing a strategy and action plan that aligns with energy policy. Another possible factor could be the establishment of too ambitious objectives without the presence of specific strategies and initiatives to achieve those objectives.

Nepal faces challenges in incorporating renewable energy, including policy, economic, and technological aspects. Prioritizing conventional energy sources like firewood, agricultural leftovers, and dung cakes, and implementing clean cooking solutions is crucial. The business sector should also focus on renewable energy, replacing coal and petroleum with electric vehicles, biogas, and electric cooking. Nepal's majority of electricity consumption is met by hydropower, with limited alternative sources. The country has the greatest solar power capacity, making it crucial to include it in the national energy portfolio. Innovations like solar rooftop systems, building-integrated solar PV, and PHES can help maintain energy balance. Islam et al. (2021) provides evidence that biomass can be used to produce renewable energy, hence can be adopted in Nepal. Moreover, Nepal can also explore the opportunity to utilize its geothermal energy. There are 29 geothermal springs being identified in Nepal. But this would require financing such projects, hence public-private partnership can be adopted (Taghizadeh-Hesary et al., 2020).

The government is promoting renewable energy development through the Central Renewable Energy Fund and the Sustainable Energy Challenge Fund, aiming to replace nonrenewable energy sources with renewables. However, thorough monitoring and policies supporting market-driven commercial renewable energy solutions are needed to maximize their benefits. Nepal's renewable energy sector is in its early stages of development, with most technology and infrastructure imported. The government would concentrate on capacity-building and enhancing renewable energy research, education, and start-ups. The country's policy document lacks a comprehensive framework for promoting renewable energy usage, and its objectives are modest. Developing policies and strategies that leverage Nepal's unique characteristics is crucial for renewable energy growth.

6. RENEWABLE ENERGY FOR ACHIEVING SDGS

Energy serves as the fundamental pillar of environmental preservation, economic advancement, and social fairness, since it profoundly influences every facet of human existence, including the environment, education, health, commerce, security, food production, and employment generation (Raihan et al., 2023). Utilizing renewable resources is the optimal alternative to fossil fuels and the inefficient utilization of traditional fuels like firewood, agricultural leftovers, and animal dung (Raihan et al., 2022). This approach guarantees an energy supply that is efficient, abundant, environmentally friendly, and sustainable (Raihan et al., 2023). An optimal combination of renewable energy technologies can ensure consistent and dependable energy access. Renewable energy is intricately linked to SDG 7, which pertains to the provision of accessible and environmentally friendly electricity. As the population increases, the demand for energy will inevitably rise. Therefore, it is crucial to invest in renewable energy technology development, improve energy efficiency, and provide universal access to energy in order to accomplish SDG 7. In addition to SDG 7, the utilization of renewable energy contributes to the progress of other SDGs, both directly and indirectly (Figure 13).

Renewable energy contributes to the attainment of SDG 1 (no poverty) by guaranteeing water supply through watershed management and climate resilience, while also providing power to small industries and enterprises to generate revenue and employment opportunities. Renewable energy contributes to the attainment of SDG 2 (zero hunger) by facilitating the lifting of water for irrigation, providing clean drinking water, and supporting food processing and storage. Renewable energy contributes to the attainment of SDG 3 (health and well-being) by powering medical equipment and providing storage for vaccinations, facilitating access to telemedicine, and ensuring suitable living conditions through water and space heating. In South Asia, 40% of the population now lacks access to clean cooking energy. The utilization of solid fuels in conventional cooking is accountable for nearly four million premature deaths worldwide. Additionally, it promotes the development of noncommunicable diseases such as heart disorders, chronic obstructive pulmonary disease (COPD), and lung cancer (WHO 2018). Utilizing renewable energy systems for cooking and lighting in clean technologies significantly decreases the emission of particulate matter, carbon monoxide, and other detrimental gases. This reduction in harmful emissions lowers the likelihood of respiratory diseases and early deaths. This fosters the enhancement of individuals' health and overall well-being.

Renewable energy contributes to the attainment of SDG 4 (quality education) by enhancing the availability of technical and vocational education, fostering the utilization of multimedia and interactive learning platforms, and expanding chances for remote learning. Renewable energy contributes to the attainment of SDG 5, which focuses on gender equality, by reducing labor-intensive tasks and alleviating monotonous work, enhancing access to information, and advocating for women's involvement as energy producers and consumers. Renewable energy contributes to the attainment of SDG 6 (clean water and sanitation) by powering water pumping and treatment facilities, promoting innovative approaches and strategies for the diverse utilization of water, and facilitating the conversion of waste into energy. Renewable energy contributes to the attainment of SDG 8 (decent work and economic growth) by efficiently distributing energy to businesses and creating employment opportunities. It also encourages the use

Figure 13: The link between renewable energy and SDGs (UNDP, 2023)

of efficiency and automation practices and supports the financing of renewable energy projects. Renewable energy contributes to the attainment of SDG 9 (industry, innovation, and infrastructure) by providing clean energy for enhancing value through productive applications, promoting the transition from firewood to electricity as a fuel source, implementing distributed generation to minimize energy loss, and implementing demand side management to optimize energy efficiency.

Renewable energy contributes to the attainment of SDG 10 (reduced inequality) by facilitating the development of gender equality and social inclusion (GESI) oriented renewable energy projects. It supports the establishment of women-led firms that operate on renewable energy and provides assistance to barefoot renewable energy technicians. Renewable energy contributes to the attainment of SDG 11 (sustainable cities and communities) through the promotion of electric vehicles, the advancement of energy efficiency, the establishment of waste-to-energy systems, and the enhancement of clean water accessibility. Renewable energy contributes to the attainment of SDG 12 (responsible consumption and production) by fostering the adoption of an energy prosumer model within communities. This model combines the roles of energy producer and consumer, thereby boosting energy efficiency, waste reduction, recycling, and the utilization of information technology. Renewable energy contributes to the attainment of SDG 13 (climate action) by facilitating the implementation of early warning systems for disaster risk reduction and enhancing the accessibility of information.

Renewable energy contributes to the attainment of SDG 14 (life below water) by promoting the use of water pumps in aquaculture and improving technologies for recycling, waste management, and oxygenation of stagnant water. Renewable energy contributes to the attainment of SDG 15 (life on land) through the promotion of watershed management, the establishment of water recharge systems, and the provision of clean and efficient energy solutions for buffer zones. Renewable energy contributes to the attainment of SDG 16 (peace and justice strong institutions) by promoting transparency and accountability in renewable energy initiatives. Renewable energy contributes to the attainment of SDG 17 (partnerships for the goal) through various means. Firstly, it facilitates the incorporation of renewable energy sources as an alternative to traditional sources. Secondly, it establishes a renewable energy fund at the central, provincial, and local levels. Thirdly, it strengthens partnerships for both international and domestic carbon markets. Lastly, it supports research and development efforts for technology adaptation and field testing.

7. CONCLUSION

The prevailing use of fossil fuels in the worldwide energy provision and the concerning phenomenon of rapidly increasing global climate change necessitate an immediate shift towards a renewable and highly efficient energy source. Despite its minimal contribution to global GHG emissions, Nepal is confronted with the harsh reality of climate change caused by the release of GHGs. Transitioning to renewable energy is beneficial for both the country and the world. Furthermore, the adoption of renewable energies, along with the implementation of appropriate energy storage technologies, will not only enhance the resilience of society to climate change but also enhance energy security and reliability, both of which are crucial for sustainable development.

The growing utilization of renewable energy technologies will also contribute to achieving SDGs. Currently, traditional energy sources contribute significantly to the energy consumption in Nepal. The country possesses significant potential to facilitate a shift from conventional energy sources to renewable energy through the utilization of hydropower, solar, wind, and biogas for energy generation. Furthermore, considering the decreasing cost and increasing efficiency of solar PV, it is more advantageous in the long term to choose solar PV with PHES as a storage technology for broader implementation, as opposed to relying primarily on hydropower. Moreover, the utilization of biomass can offer a sustainable and environmentally friendly solution for cooking energy, thereby incentivizing the public to transition away from conventional and harmful energy sources. Therefore, by augmenting the proportion of renewable energy in Nepal's energy composition, the country may effectively attain both net-zero emissions and SDGs.

REFERENCES

ADB. (2017), Nepal's Largest Wind-Solar Hybrid Power System Switched On to Connect a Small Village to the World. Asian Development Bank (ADB). Available from: https://www.adb.org/news/nepals-largest-wind-solar-hybrid-power-system-switched-connect-small-village-world [Last accessed on 2023 Dec 27].

Adhikari, K.R., Bhattarai, B.K., Gurung, S. (2013), Estimation of global solar radiation for four selected sites in Nepal using sunshine hours, temperature and relative humidity. Journal of power and Energy Engineering, 1(3), 1-9.

AEPC. (2019), Biogas Plant Installation. Alternative Energy Promotion Centre (AEPC). Available from: https://www.aepc.gov.np/statistic/biogas-plant [Last accessed on 2023 Dec 27].

AEPC. (2021), Progress at a Glance: A Year in Review FY 2018/2019. Alternative Energy Promotion Centre (AEPC). Available from: https://www.aepc.gov.np/documents/annual-progress-report-aepc [Last accessed on 2023 Dec 27].

Akpan, J., Olanrewaju, O. (2023), Towards a common methodology and modelling tool for 100% renewable energy analysis: A review. Energies, 16(18), 6598.

Asghar, R., Sulaiman, M.H., Mustaffa, Z., Ullah, N., Hassan, W. (2023), The important contribution of renewable energy technologies in overcoming Pakistan's energy crisis: Present challenges and potential opportunities. Energy and Environment, 34(8), 3450-3494.

Bhattarai, T.N., Ghimire, S., Mainali, B., Gorjian, S., Treichel, H., Paudel, S.R. (2023), Applications of smart grid technology in Nepal: Status, challenges, and opportunities. Environmental Science and Pollution Research, 30(10), 25452-25476.

Bhattarai, U., Maraseni, T., Apan, A., Devkota, L. P. (2023a), Rationalizing donations and subsidies: Energy ecosystem development for sustainable renewable energy transition in Nepal. Energy Policy, 177, 113570.

Dincer, I., Acar, C. (2015), A review on clean energy solutions for better sustainability. International Journal of Energy Research, 39(5), 585-606.

Dincer, I., Aydin, M.I. (2023), New paradigms in sustainable energy systems with hydrogen. Energy Conversion and Management, 283, 116950.

DoED. (2021), Department of Electricity Development (DoED). Ministry of Energy, Water Resource and Irrigation, Government of Nepal. Available from: https://www.doed.gov.np/license/15 [Last accessed on 2023 Dec 27].

Du, X., Qi, Y., Chen, B., Shan, B., Liu, X. (2021), The integration of blockchain technology and smart grid: Framework and application. Mathematical Problems in Engineering, 2021, 1-12.

Dudin, M.N., Frolova, E.E., Protopopova, O.V., Mamedov, O., Odintsov, S.V. (2019), Study of innovative technologies in the energy industry: Nontraditional and renewable energy sources. Entrepreneurship and Sustainability Issues, 6(4), 1704.

Global Solar Atlas. (2019), Global Horizontal Irradiation of Nepal. Available from: https://globalsolaratlas.info/map [Last accessed on 2023 Dec 27].

Haldar, A., Sucharita, S., Dash, D.P., Sethi, N., Padhan, P.C. (2023), The effects of ICT, electricity consumption, innovation and renewable power generation on economic growth: An income level analysis for the emerging economies. Journal of Cleaner Production, 384, 135607.

Holechek, J.L., Geli, H.M., Sawalhah, M.N., Valdez, R. (2022), A global assessment: Can renewable energy replace fossil fuels by 2050? Sustainability, 14(8), 4792.

Hydro Review. (2019), Hydro Review: The Way Forward for Nepal's Hydropower Development. Hydro Review.

IEA. (2021), Key World Energy Statistics 2021. International Energy Agency (IEA). Available from: https://www.iea.org/reports/key-world-energy-statistics-2021 [Last accessed on 2023 Dec 27].

IEA. (2023), Renewable Energy Market Update Outlook for 2023 and 2024. International Energy Agency (IEA). Available from: https://www.iea.org/reports/renewable-energy-market-update-june-2023

IHA. (2019), Hydropower Status Report. International Hydropower Association (IHA). Available from: https://www.hydropower.org/news/iha-releases-2019-hydropower-status-report-charting-growth-in-renewable-hydro [Last accessed on 2023 Dec 27].

IPCC. (2018), Summary for policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge, UK, New York, USA: Cambridge University Press. p3-24.

Islam, K.N., Sarker, T., Taghizadeh-Hesary, F., Atri, A.C., Alam, M.S. (2021), Renewable energy generation from livestock waste for a sustainable circular economy in Bangladesh. Renewable and Sustainable Energy Reviews, 139, 110695.

ISES. (2023), Solar PV Dominates New Generation Capacity, International Solar Energy Society (ISES). Available from: https://www.pv-magazine.com/2023/10/16/solar-panel-waste-is-not-a-significant-problem [Last accessed on 2023 Dec 27].

Jones, G.A., Warner, K.J. (2016), The 21st century population-energy-climate nexus. Energy Policy, 93, 206-212.

Khan, A.S., Salah, B., Zimon, D., Ikram, M., Khan, R., Pruncu, C.I. (2020), Sustainable distribution design for multi-quality multiple-cold-chain products: An integrated inspection strategies approach. Energies, 13, 6612.

Khan, A.U., Jan, Q.M.U., Abas, M., Muhammad, K., Ali, Q.M., Zimon, D. (2023), Utilization of biowaste for sustainable production of coal briquettes. Energies, 16, 7025.

Koirala, D.P., Acharya, B. (2022), Households' fuel choices in the context of a decade-long load-shedding problem in Nepal. Energy Policy, 162, 112795.

Mitra, M., Singha, N.R., Chattopadhyay, P.K. (2023), Review on renewable energy potential and capacities of South Asian countries influencing sustainable environment: A comparative assessment.

Sustainable Energy Technologies and Assessments, 57, 103295.
MoAD. (2021), Statistical Information on Nepalese Agriculture (2019/20). New Delhi: Ministry of Agricultural Development (MoAD).
MOF. (2021), Economic Survey 2020/21. New Delhi: Ministry of Finance (MOF), Government of Nepal. Available from: https://www.mof.gov.np/uploads/document/file/1633341980_economic%20survey%20(engslish)%202020-21.pdf
NACAA. (2015), Reduce Losses in the Transmission and Distribution System. National Association of Clean Air Agencies (NACAA). Available from: https://www.4cleanair.org/wp-content/uploads/documents/chapter_10.pdf
NEA. (2021), Nepal Electricity Authority - A Year in Review Fiscal Year 2020/21. Nepal Electricity Authority (NEA). Available from: https://www.nea.org.np/admin/assets/uploads/supportive_docs/annual_report_2021-22.pdf
NepalMap. (2019), Map View According to Cooking Type. Available from: https://nepalmap.org/data/map
Perera, S.M., Wickramasinghe, C., Samarasiri, B.K.T., Narayana, M. (2021), Modeling of thermochemical conversion of waste biomass-a comprehensive review. Biofuel Research Journal, 8(4), 1481-1528.
Poudyal, R., Loskot, P., Nepal, R., Parajuli, R., Khadka, S.K. (2019), Mitigating the current energy crisis in Nepal with renewable energy sources. Renewable and Sustainable Energy Reviews, 116, 109388.
Raihan, A. (2023b), An overview of the energy segment of Indonesia: Present situation, prospects, and forthcoming advancements in renewable energy technology. Journal of Technology Innovations and Energy, 2(3), 37-63.
Raihan, A., Begum, R.A., Said, M.N.M., Pereira, J.J. (2022), Dynamic impacts of energy use, agricultural land expansion, and deforestation on CO_2 emissions in Malaysia. Environmental and Ecological Statistics, 29, 477-507.
Raihan, A., Muhtasim, D.A., Pavel, M.I., Faruk, O., Rahman, M. (2022c), Dynamic impacts of economic growth, renewable energy use, urbanization, and tourism on carbon dioxide emissions in Argentina. Environmental Processes, 9, 38.
Raihan, A., Pavel, M.I., Muhtasim, D.A., Farhana, S., Faruk, O., Paul, A. (2023c), The role of renewable energy use, technological innovation, and forest cover toward green development: Evidence from Indonesia. Innovation and Green Development, 2(1), 100035.
Raihan, A., Tuspekova, A. (2022), Nexus between economic growth, energy use, agricultural productivity, and carbon dioxide emissions: New evidence from Nepal. Energy Nexus, 7, 100113.
Raihan, A., Tuspekova, A. (2022), Role of economic growth, renewable energy, and technological innovation to achieve environmental sustainability in Kazakhstan. Current Research in Environmental Sustainability, 4, 100165.
Raihan, A., Tuspekova, A. (2022a), Dynamic impacts of economic growth, energy use, urbanization, tourism, agricultural value-added, and forested area on carbon dioxide emissions in Brazil. Journal of Environmental Studies and Sciences, 12(4), 794-814.
Raihan, A., Tuspekova, A. (2022b), Toward a sustainable environment: Nexus between economic growth, renewable energy use, forested area, and carbon emissions in Malaysia. Resources, Conservation and Recycling Advances, 15, 200096.
Raihan, A., Voumik, L.C., Zimon, G., Sadowska, B., Rashid, M., Akter, S. (2024), Prioritising sustainability: How economic growth, energy use, forest area, and globalization impact on greenhouse gas emissions and load capacity in Poland? International Journal of Sustainable Energy, 43(1), 2361410.
REN21. (2021), Renewables 2021, Global Status Report. Available from: https://www.ren21.net/wp-content/uploads/2019/05/gsr2021_full_report.pdf
Salehi, M., Fahimifard, S.H., Zimon, G., Bujak, A., Sadowski, A. (2022), The effect of CO_2 gas emissions on the market value, price and shares returns. Energies, 15, 9221.
SEMAN. (2019), Solar Energy technology in Nepal. Solar Electric Manufacturer's Association Nepal (SEMAN). Available from: https://www.semannepal.org.np/publications/solar-energy-technology-in-nepal [Last accessed on 2023 Dec 27].
Shahsavari, A., Akbari, M. (2018), Potential of solar energy in developing countries for reducing energy-related emissions. Renewable and Sustainable Energy Reviews, 90, 275-291.
Shukla, A.K., Sudhakar, K., Baredar, P. (2017), Renewable energy resources in South Asian countries: Challenges, policy and recommendations. Resource-Efficient Technologies, 3(3), 342-346.
Statista. (2023), Cumulative Renewable Energy Capacity Worldwide From 2010 to 2022. Available from: https://www.statista.com/statistics/1094331/global-renewable-capacity-cumulative [Last accessed on 2023 Dec 27].
Surendra, K.C., Khanal, S.K., Shrestha, P., Lamsal, B. (2011), Current status of renewable energy in Nepal: Opportunities and challenges. Renewable and Sustainable Energy Reviews, 15(8), 4107-4117.
Taghizadeh-Hesary, F., Mortha, A., Farabi-Asl, H., Sarker, T., Chapman, A., Shigetomi, Y., Fraser, T. (2020), Role of energy finance in geothermal power development in Japan. International Review of Economics and Finance, 70, 398-412.
UNDP. (2023), Renewable Energy and SDGs. United Nations Development Programme (UNDP). Available from: https://www.undp.org/nepal/publications/renewable-energy-and-sdgs [Last accessed on 2023 Dec 27].
Vedanarayanan, V., Vibhakar, C., Sujaatha, A., Chavda, J.K., Karthik, M., Pramila, P.V., Raghavan, I.K. (2022), Utilization of sustainable resources for promoting energy efficiency in environment using smart technologies. International Journal of Photoenergy, 2022, 1-9.
Walasek, R., Sadowska, B., Stępnicka, N., Zimon, D. (2023), exploring the effects of oil prices on road freight in Poland amidst covid-19 and Russo-Ukrainian war. Humanities and Social Sciences, Research Journal, 30(4), 383-401.
WHO. (2018), Household Air Pollution and Health. World Health Organisation (WHO). Available from: https://www.who.int.news https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health [Last accessed on 2023 Dec 27].
WPN. (2016), Nepal Wind Mapping. Wind Power Nepal (WPN). Available from: https://www.windpowernepal.com/nepal-wind-mapping-2015-2018 [Last accessed on 2023 Dec 27].
Zimon, G., Pattak D.C., Voumik, L.C., Akter, S., Kaya, F., Walasek, R., Kochański, K. (2023), The impact of fossil fuels, renewable energy, and nuclear energy on South Korea's environment based on the STIRPAT model: ARDL, FMOLS, and CCR approaches. Energies, 16(17), 6198.
Zimon, G., Salehi, M. (2023), The Impact of ISO 9001 on financial liquidity of smes operating in the renewable energy sector in the Podkarpackie province. Modern Management Review, 28(3), 89-99.
Zimon, G., Tarighi, H., Salehi, M., Sadowski, A. (2022), Assessment of financial security of SMEs operating in the renewable energy industry during COVID-19 pandemic. Energies, 15, 9627.
Zimon, G., Zimon, D. (2020), The impact of purchasing group on the profitability of companies operating in the renewable energy sector--The case of Poland. Energies, 13, 6588.