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Assessing the Role of Information Technology in Promoting Sustainable and Renewable Energy in Helambu Rural Municipality, Nepal

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Abstract

The study examines the role of Information Technology (IT) in Kutumsang village, Helambu Rural Municipality, in terms of energy problems, access, and affordability. The research methodology employed for this study was the combination of primary and secondary data collection methods. Primary data collection methods were a Key Informant Interview (KII) session with the elected head of the Helambu Rural Municipality and a Q/A session with the local people of Ward 7 in Kutumsang village. The results show that hydropower is the primary energy source, while the use of the solar energy is very limited and there has been a decline in biogas systems due to climate factors; however, diesel and gasoline are still demanded for transport. The study suggests that lack of institutional support, high prices, and unreliable supply are the major issues faced by the community. One significant outcome of the research is the identification of a very limited role for IT in the local energy management systems even though it has the potential to greatly assist in planning, monitoring, and service delivery. The findings suggest that IT-based tools such as digital data systems, GIS-supported spatial planning, smart monitoring, and mobile-based reporting could bring about substantial improvements in energy governance, transparency, and operational efficiency. The researchers, therefore, point out that the combination of renewable energy with IT-enabled systems can improve local sustainability, reliability and also the quality of decisions made. The study adds to the existing literature on the rural energy assessment from an IT perspective

providing a context-specific framework for IT-supported sustainable energy development in Nepal as its main contribution.

Keywords: Renewable Energy, Energy Access, Information Technology, Rural Development, Sustainable Energy Management

Introduction

Helambu Rural Municipality is an area with a bit of urbanization located mainly in the Sindhupalchok district of Nepal. The place has a population of approximately nine thousand people. The district has its own beauty forms and is also favored for trekking and climbing. The locals mainly depend on agriculture and animal husbandry and these are the primary sources of income. IT has been supporting rural development through various sectors like energy management, communication, education, and service delivery. Over the years its role has become more and more significant (Kazlauskienė & Atkočiūnienė, 2025).

Kutumsang is a small rural village in the municipality with a population that consists mainly of Hindus, Buddhists and Christians in large numbers (Shrestha, 2021). The Tamang are the largest ethnic group, followed by the Sherpas, Gurungs, and Brahmins. The main languages spoken in the area are Tamang, Sherpa, and Nepali. The community consists of people of all ages, but the largest group is under 40 years old. The residents of Kutumsang have actively engaged in agriculture, tourism, and small businesses, but access to education and digital infrastructure is still limited. This makes it hard for them to make effective use of modern information technologies, as most of them have not completed basic education or lack computer skills (Joshkun et al., 2024).

The geographical location, cultural diversity, and socio-economic conditions of the region clearly indicate the necessity of a context-sensitive and technology-supported approach to development planning. More specifically, it is very important to comprehend the ways in which Information Technology can facilitate the decision-making, monitoring and service delivery processes related to energy. IT-based tools like digital data systems, mobile applications, smart monitoring devices and GIS platforms have the potential to improve the efficiency of planning, increase the transparency of the process and allow more people to take part in the energy governance (Billanes et al., 2025). So, the applicability of IT in the field of energy sources gives a more solid basis for the enhancement of sustainability and resilience in Helambu Rural Municipality.

Importance of energy sources (with IT Perspective)

In Helambu Rural Municipality, energy is the most important factor that comes into play for the support of economic activities, the rise of living standards, and the practice of sustainable development. Currently, the people in the community mainly rely on firewood and kerosene, which are traditional energy sources, for cooking and lighting. These sources are detrimental to the environment and these are the main reasons why the indoor air pollution leads to health

hazards. Furthermore, the lack of IT-enabled monitoring and management systems also prevents the efficient use and planning of the available energy resources.

There is a great demand for the exploration of alternative cleaner and more efficient energy sources which would be supported by IT-based solutions. Smart technologies, digital monitoring tools, and data-driven energy management systems can provide renewable energy systems like solar, micro-hydropower, and wind with a big boost. IT-based solutions facilitate the monitoring of energy generation and usage, identification of system breakdowns, minimization of losses, and enhancement of the reliability of the entire system.

Moreover, access to reliable and digitally controlled energy systems is of utmost importance in calamity prone regions such as Helambu which are susceptible to quakes, slides, and harsh weather conditions. Also, the use of IT in energy systems makes it possible to have early warnings, communications, remote monitoring, and fast response in case of an emergency. This strengthens disaster preparedness as well as resilience.

In addition, the combination of IT and renewable energy can lead to new economic opportunities by the way of enhancing digital skills and local innovation. Hence, it is crucial to look at energy sources through an IT lens for Helambu Rural Municipality's energy access, affordability, resilience, and sustainable development in the long run to be gradually improved.

Objectives

1. To identify the current sources of energy used in the area
2. To assess the potential for renewable energy sources such as solar, wind, and hydro power
3. To evaluate the economic and environmental feasibility of different energy sources
4. To examine the role of Information Technology in improving energy access, management, and sustainability
5. To explore the potential of IT-based solutions for renewable energy development

Literature Review

Prior Studies/Research

Sustainable development has been recognized as significant not only for the environment but also for the society, thus the topic of its impact on energy consumption has been very an extensive discussions among scholars. On several occasions infrastructural development and educational initiatives have been presented as the primary factors through which sustainable development can be achieved (Malla & Bhatta, 2020; Dhungana et al., 2021). During the years of research Helambu municipality has been looked upon but still, there is a little knowledge about the energy use in Kutumsang village and no detailed analysis has been done so far. A study by Paudel (2018) has led to a partial understanding of the local energy consumption in the area; however, more research is needed, especially around the Kutumsang village, to have a clear picture of the energy demand

and the possibilities for the development of renewable energy sources in the region, thus the local community will feel empowered.

Paudel (2018) examined the socio-economic impacts of small hydropower station construction in Helambu, a neighboring municipality of Kutumsang. The research pointed out that such a development would be small in size but very significant for the local community in terms of sustainability, income, and living standards. From this I was able to conclude that the main energy source for the local people in Helambu was wood, and hydropower might fill in the gap of energy needs such as electricity and creating job opportunities for the locals. Dhungana et al. (2021) surveyed the difficulties and possibilities of electrifying rural areas in Nepal. As per the authors, the implementations of renewable energy technology were the only way to drag the rural areas into the modern world. Hence, the authors have strongly advocated to bring about the change through renewable energy technology in rural communities in Nepal (Dhungana et al., 2021). Besides, Malla and Bhatta (2020) considered rural Nepal as a sustainable development zone where the latter might be a source for sustainable tourism. Thus, the use of renewable energy technology indicates one of the main roads to the sustainable tourism development plan in rural Nepal. This would not only lessen the local community's carbon emissions but also open up new avenues for the community to make a profit through tourism.

Furthermore, specific energy sources utilized in small rural towns like Kutumsang in Nepal's Helambu Rural Municipality need further research. The agricultural and tourism sectors are the main industries in Nepal, but the Kutumsang inhabitants are stuck with a lot of infrastructural, employment, and sustainability problems which together limit their economic options. Further to this, it was found during our field trip that, similarly to Paudel's (2018) study, the locals still prefer fuelwood over LPG gas. The area has a low consumption of electricity which was contrary to the article's forecast owing to irregular power outages, hence making fuelwood a more dependable energy source for cooking and heating. Moreover, solar panel installation as an alternative source of energy is still a distant dream notwithstanding the existence of solar street lights and heaters in certain villages and households. Thus, this research intends to explore the energy sources in use in Kutumsang and Helambu Rural Municipality while estimating the current renewables-based power generation.

Role of Information Technology in Sustainable Energy Systems

In the past, the majority of research was concerned mainly with energy access and renewable technologies; however, the more recent literature highlights the increasing importance of the Information Technology (IT) sector in energy planning, management, and sustainability. IT has been recognized as a crucial factor in the shift to more sustainable and renewable energy systems. Technology such as smart meters, the Internet of Things (IoT) devices, edge computing, and data analytics are providing the necessary infrastructure for effectively monitoring energy generation, transmission, and consumption. Recent research points out that smart grids supported by IT are

capable of enhancing the reliability of the system, cutting energy wastes, and allowing the smooth integration of renewable energy types like solar and wind (Dhungana et al., 2021).

Geographic Information Systems (GIS) are highly effective in determining the proper sites for renewable energy projects, especially in difficult and hilly areas such as Nepal. GIS mapping provides necessary information for decision-making about solar panel placement, micro-hydropower construction, and wind energy usage by a comprehensive study of the landscape, solar rays, the possibility to reach and use the land, and landuse types (Bhatta & Lohani, 2025).

In the context of rural energy governance, digital platforms and mobile-based apps are again among the main actors as they facilitate billing systems, maintenance reporting, awareness campaigns, and communication between service providers and users. In several developing countries, IT-based monitoring systems assist local municipalities in tracing the energy consumption patterns, pinpointing system breakdowns, and making service delivery more transparent and efficient (Goel et al., 2024).

Rural energy scenarios still suffer from slow IT adoption due to underdeveloped digital infrastructure, poor technical skills, financial issues, and weak institutional capacity, among others. Therefore, introducing Information Technology for renewable energy planning in rural areas like Kutumsang requires an integrated approach consisting of capacity-building programs, policy support, and institutional development. It is believed that this step will not only make energy use more efficient but also enhance the decision-making process and thus play a part in the long term sustainable development.

Methodology

Study Area

The research was executed at Kutumsang, a little agrarian village in the Helambu Rural Municipality of the Sindhupalchok district in Nepal. Its total area is around 523.52 square kilometers and it is positioned between 800 to 3800 meters above the sea level. The village is covered with hills and mountains, this giving it a very picturesque and panoramic view. Kutumsang experiences a cool climate almost all year long with the mercury level varying from -5°C to 25°C. Kutumsang's geographical coordinates are 27°55'47.8"N and 85°29'06.9"E, it is located in the northern hilly region of Sindhupalchok district and is under the jurisdiction of the Langtang National Park. The village is located in a hilly area characterized by very steep slopes and rough terrain. The area flora is mainly composed of coniferous forests, which include trees like pine, oak, and rhododendron. Besides all this, Kutumsang is a viewpoint for the Langtang Himalayan range consisting of peaks like Langtang Lirung, Gangchenpo, and Dorje Lakpa.
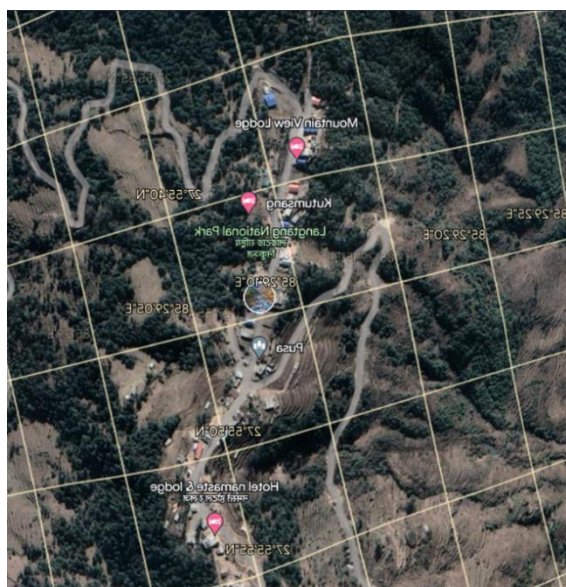
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Research Method

The study employed a mix of both primary and secondary sources for data collection and the primary data from a Key Informant Interview (KII) with the elected leader of the municipality Mr. Nima Gyaljen Sherpa and a question-and-answer (Q&A) session with the local community in Ward 7 of Kutumsang village including the local energy system were the main methods used in this context. These methods together not only gave the researcher a clearer picture of the energy situation in the area but were also crucial in helping him to factor in the social, cultural, and political aspects that influence energy use and the associated decision-making in rural communities.

In order to back the field data, Digital records, online reports, satellite maps, and GIS-based location data were IT-oriented tools that helped to enhance the understanding of the location and context. The tools played a major role in making visible the geographical characteristics, the settlement patterns, and the infrastructure distribution that were linked with the access and consumption of energy.

Moreover, academic journals, report of government and non-government institutions, and online databases were used as sources for secondary data that served as a complement to the main findings. The use of these sources supported the triangulation and comparative analysis of the energy situation with other rural areas of Nepal. The access to online academic databases, government portals, and digital repositories also allowed for cross-verification, thereby enhancing data reliability.

Combination of primary and secondary sources results in a thorough understanding of the energy situation in Helambu Rural Municipality and indicating interventions and policy development areas. The application of IT-based tools has also contributed to the accuracy, organization, and trustworthiness of the analysis to a greater extent.

Findings

Current sources of energy used in the area

Helambu rural municipality presently relies chiefly on hydropower which is the primary source of energy as far as the energy situation in Kutumsang is concerned. Hydroenergy and very little solar energy through the use of street lights and hot water in a few houses are the energy sources that are still being employed in the area. Biogas has been used in the past but it is not currently being used due to cold weather.

The community struggles to access energy, especially during heavy rainfall or storms as they may result in power outages. Moreover, the use of solar energy is still minimal because of the high installation costs and the lack of support from local authorities for its promotion.

From the viewpoint of Information Technology, the hydropower plant being an electrifying source, still the nonexistence of IT-supported surveillance and reporting systems causes slow fault detection and power outage for a longer time. The region is deprived of digital infrastructure like smart meters, online complaint systems, and real-time monitoring tools which together with the limited digital infrastructure create an impediment to energy management and maintenance done in time.

Potential for renewable energy sources such as solar, wind, and hydropower

Helambu rural municipality (Kutumsang) has the possibility of utilizing solar energy and wind energy as the main source of renewable energy. The decision to bring in the green energy sources to the site will be influenced by the factors like resource availability, cost savings and technology acceptance. Solar is an option with good prospects as the area has plenty of sunshine, but the initial capital for set up might be quite a bit. Wind power, on the other hand, could only be practical in a few localities and would also involve a substantial outlay upfront. The use of biogas could be a cheap alternative since the local organic waste will be the source of energy, but the climate might not be conducive to its production.

The combination of Information Technology with Renewable Energy sources can lead to a completely different level of assessment and deployment. The installation of Solar energy systems can be easily monitored and controlled with IoT-based smart meters, as well as digital monitoring tools that can track the performance and alarm for faults in real time. The wind energy potential can be estimated with the help of digital sensors, GIS tools and data analytics that are able to forecast wind patterns and recommend suitable areas. Mobile reporting and monitoring systems are very beneficial for biogas plants as they allow for scheduling of maintenance and tracking of

operational efficiency. IT-supported energy management platforms can make it simpler for the local authorities to keep track of the production, consumption, and maintenance needs through digital monitoring.

Economic and environmental feasibility of different energy sources

One of the main benefits of renewable energy usage in Helambu rural municipality is the diminished dependency on fossil fuels, which will be replaced by a reliable power supply, less carbon emissions, and probably cheaper energy bills in the long run. Besides, it may also bring about local economic development through the creation of new jobs and the establishment of new industries in the renewable energy sector.

In Helambu rural municipality (Kutumsang), the only non-renewable energy sources available are gasoline and diesel for motor vehicles, and liquefied petroleum gas (LPG) for cooking as well as kerosene for lighting. The adoption of non-renewable energy sources in the region is solely based on the fuel's access and economic factors. Diesel and gasoline are obtainable from cities nearby but are quite costly because of the transportation charge. LPG and kerosene are also costly and cause health problems through indoor air pollution.

The rural municipality of Helambu faces several problems when it comes to utilizing non-renewable energy sources. Among these problems is the high cost, the enormous environmental damage caused by the use of fossil fuels, and the fact that they have to rely on external sources for the supply of fuel. The heating and cooking requirements for the rural population are, however, only met through small-scale deliveries of the often-less-than-adequate and expensive fuel. This, in turn, leads to a lack of energy security and hinders the economic development of the area.

Moreover, Information Technology assists to a great extent in the economic and environmental assessment through the increase of data-based planning and measurement. The impact of digital platforms and data analytics can be seen when comparing the costs, emissions, and long-term sustainability of renewable and non-renewable energy sources. Application of environmental monitoring systems and sensors allows the tracking of greenhouse gas emissions and indoor air pollution levels, thus making decision-making more scientific and rigorous. IT technologies make it easier for political leaders to better assess environmental trade-offs and make their energy strategies sustainable.

Role of Information Technology in improving energy access, management, and sustainability

Energy accessibility and affordability are the major challenges the Helambu rural municipality (Kutumsang) community is facing. The community primarily uses LPG gas for cooking and kerosene for lighting but the price of these non-renewable energy sources is exorbitant mainly because of the high transportation cost. In addition, the limited public transportation in the area restricts the access to the energy sources.

Energy unaffordability has a great influence on the whole community, especially on the poorest segments of the society. They cannot even afford the very basic services like lighting and cooking.

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This situation can lead to certain negative health scenarios, for instance, the use of kerosene for lighting can cause indoor air pollution, and the limited access to electricity for studying can also affect educational performance. The absence of public transport has also a negative effect on the economic situation because it bars people's movement to workplaces and markets.

Information Technology is a key factor in making energy access and affordability better and cheaper through prepaid metering, and mobile compensation payment. Smart meters allow local authorities to closely track their energy usage and manage their budgets effectively. Besides, IT systems will also allow more smooth cooperation among local governments, electricity companies, and residents, resulting in improved service provision and increased trust. Digital channels may additionally play a supportive role in the areas of planning, billing, complaint handling, and energy awareness campaigns in the form of education and outreach.

Potential of IT-based solutions for renewable energy development

In the Helambu rural municipality, the promotion of renewable energy sources as their most recent strategies for energy access and affordability improvement came up in the discussions. In this case, government support measures or subsidies would accelerate the process for households willing to use solar, wind or other similar energy. Also, better roads would indirectly help the energy sector by allowing easier transportation of fuels and providing access to energy services. Furthermore, encouraging energy-saving technologies and practices could be a considerable help in lowering the price of energy for families.

Technologies based on IT like smart grids, digital monitoring systems, GIS for energy planning, and data platforms will be able to drastically uplift the development of renewable energy. These technologies provide real-time tracking of power production and consumption, predictive maintenance, and decision-making based on data. Mobile and Web based platforms can be a great help to local administrations in keeping track of the performance of the projects and thus, boosting their accountability. These IT-enabled systems not only strengthen but also prolong the sustainability and efficiency of the renewable energy projects in the long run.

Discussion

The energy scenario in Helambu Rural Municipality (Kutumsang) at present is primarily based on hydropower with some minor contributions from solar energy for street lights and hot water in few households. Cold weather conditions have silenced the use of biogas that was previously common. Micro-hydropower is found to be a vital source of electricity in rural Nepal for off grid areas as it not only makes energy available but also helps local people to make a living (Bhandari, Saptalena, & Kusch, 2018).

The use of renewable energy sources like solar and wind is limited due to their expensive upfront costs and technology limitations. But, resource evaluations point out that the power of the sun and the wind along with decentralized power systems can be effective for electrifying villages in Nepal,

particularly (Sedai, 2023). Usage of IT devices, such as smart meters, IoT-based monitoring, and electronic maintenance reporting, can enhance the performance of the system, reduce its downtime, and make it more environmentally friendly (Bhattarai et al., 2023).

Among the non-renewable energy sources, LPG and kerosene are the most commonly used ones and still have considerable environmental and health hazards. The difficult terrain of Helambu makes it hard for the goods to be transported resulting in high fuel prices and loss of energy security at the same time. IT-based digital platforms have the potential to make a significant contribution in the areas of fuel supply optimization, usage monitoring, and thus, affordability and reliability facilitation (Basnet, 2024).

The use of energy is heavily influenced by environmental and economic factors. Through the integration of IT and renewable energy systems, it is likely that carbon emissions will be cut down, there will be improvements in off-site monitoring and local job creation in the system maintenance and data management areas (Adanma & Ogunbiyi, 2024). Smart grids and GIS-based site analysis will improve the planning of renewable energy projects and thus increase the overall technical and economic viability of rural towns (Sedai, 2023).

Overall, integration of IT is a great thing for the energy sector and it not only helps to govern but also promotes transparency and supports the taking of decisions based on evidence, leading to the sustainable development of Helambu Rural Municipality.

Conclusion

Kutumsang is experiencing problems with energy supply because of poor infrastructure, expensive non-renewable fuels, and unstable power supply. The renewable energy sources like solar, wind, and biogas are there but they need proper planning and investment. The information technology's can be playing a vital part in the energy management process through real-time monitoring, preventive maintenance, and empirical allocation leading to the efficiency and reliability improvement. Moreover, on the other hand, digital means are also helping the communities with their participation, billing, and consciousness programs which are all considered to be sustainable practices. IT and renewable energy systems together can transform the region into a more resilient, eco-friendly, and economically feasible one. The proper application of IT-based solutions determines the future energy sustainability and socio-economic improvements of rural Helambu.

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