Technical investigation of Nepalese electricity market – A review

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Abstract. The article reviews the options of renewable energy technologies with the background of long-lasting power shortages that Nepal has been facing and examines the energy-related policies of Nepal and provisions to promote renewable energy technologies in Nepal and its regulatory framework. It analyses the pertinent energy policies related to energy generation and distribution. The research focuses on the context of the renewable energy sector of Nepal and its future. The research has found a positive role in renewable energy policies for adoption of renewable energy technologies and poses a positive impact on electricity generation. The article has also reviewed and analyzed the trend of electricity generation, peak demand and the resulted import to meet the gap. The almost linear electricity generation of Nepal Electricity Authority (including generation of Individual Power Producers against the steep gradient of peak power demand has ultimately increased the power purchase from India pushing towards unsustainability. It shows that energy policies are not up to the optimal. The research has further analyzed the impact of per capita GDP on electricity per capita by regression analysis. The analysis has found, higher the GDP per capita would increase the consumption of electricity per capita. The paper discusses issues and barriers for promotion of rural electrification and suggested economical, technical and geographical to be the three most pertinent barriers in developing countries.

Keywords: Energy Policy, Electricity per capita, GDP per capita, Regression Analysis.

1. Introduction

Electricity demand in Nepal has been rising rapidly with an exponential increase in electrical appliances. However, the electricity generation capacity of Nepal does not meet the demand and would need to be increased substantially. Energy security has been an emerging issue throughout the world. The issue has been found driven by geopolitical developments and supply shortages. In some cases, the issue has been raised due to institutional and regulatory failures as well. Energy demand has been ever-increasing, but the source of energy is limited, which may lead to potential threats to supply security [1]. Nepal has a huge potential of energy resources (83,000 MW hydro, 2100 MW Solar, 3000 MW wind), whereas per capita energy consumption is only 14.8 GJ. The total energy requirement of Nepal has remained in the periphery of 500 million GJ, about 87% of which is met from traditional fuels. The source of traditional fuels has further been sub-categorized into fuelwood (77%), agricultural residue and animal waste (9%) [2,3]. Further, 12.1% of energy demand has been met by commercial energy sources like electricity and fossil fuels. Annual peak demand in fiscal year 2017/18 was 1444.10 MW and the projected peak
demand for fiscal year 2018/19 is 1508.16 MW. Out of total annual peak demand of 1444.10 MW of 2017/18, 2,305.45 GWh was generated by NEA itself, 2,175 GWh and 1,777.24 GWh was purchased from India and IPPs, respectively [4]. In Nepal, more than 83% of people live in rural areas [5]. Due to various difficulties like sparsely settled population, geographical variations, illusive electricity development strategy, poor transportability, lack of enough capital and fragmented settlements, it has been a to meet the energy demand of Nepal [6].

To solve this electricity deficiency problem in Nepal, mostly in the rural context, the Government of Nepal (GoN) has introduced the production and distribution of contextual renewable energy technologies. In Nepal, to date, there is no dedicated policy for rural electrification. Rural Energy Policy 2006 and other sector policies and acts make several provisions for access to modern energy sources and electrification of rural areas in the form of an open statement with no fixed time-bound targets and action plans. Outcomes of these provisions are not monitored and analyzed to find their effectiveness for further improvement [7].

The study outlines basically two aspects of the energy sector in Nepal. Firstly, it analyzes the gap between national generation and the peak load, which is being balanced by external and internal power purchases. Further, analysis of the impact of increment of per capita GDP (GDP) on electricity per capita (EPC) has not been researched. Thus, the article has analyzed the same through econometric modelling. Secondly, the research analyses the pertinent policies supporting electricity generation in Nepal and the major barriers affecting the promotion of renewable energy technologies. Numerous factors based on a review of available resources have been pertinent in identifying the current scenario of the energy policy & provisions. EPC and GDP have been considered as dependent and independent variables and analysis of the review have been carried out through regression analysis. The analysis is done over time series data of 10 years to trace the level of impact of GDP on EPC. The objective of the research is focused on tracing the policy barriers that have led to the current pullback of renewable energy promotion in Nepal despite the government’s declarations of firm interest in it. The method was to trace interlink of energy development and the policy provisions for clear know-how of the influential policy barriers impacting the development of renewable energy in Nepal. Semi-structured interviews, formal and informal meetings, focus group discussions, secondary data collection from literature reviews and the current energy policies remained the source of data for further analysis. Necessary energy data has been collected from different government agencies such as Centre of Bureau of Statistics (CBS), NEA, Ministry of Energy, Water Resources and Irrigation (MoEWRI), Alternative Energy Promotion Centre (AEPC). Further relevant peer-reviewed journal articles, reports and websites of various national and international agencies were selected to represent central government, renewable energy technology manufacturers, individual power producers, I/NGOs, academicians, and other experts. Qualitative research and analysis have been done referring to the relevant energy policies ensuring no single interaction was considered in isolation. The analysis of energy scenario backed up with prominent energy policies followed by the analysis of the impact of GDP on EPC through regression analysis inhabits the thrust of the article.

2. Energy sector in Nepal

2.1. Renewable energy scenario.
Nepal’s energy sources have been characterized as (i) traditional, (ii) commercial and (iii) alternative energy sources. Alternative energy is identical to renewable energy sources. This categorization is based on the use of resources in extracting the energy contents from the sources. The traditional source of energy includes biomass fuels, particularly fuelwood, agricultural residues, and animal dung. These sources of energy are used in direct combustion traditionally. Whereas traditional energy sources are further transformed into modern types. Fossil fuel and hydropower fall under commercial sources of energy. Solar power, wind power, micro-hydro, bioenergy resources fall under the category of alternative energy sources. Despite Nepal’s huge potential for hydropower production, its exploitation is very below than optimal. This is the main reason behind the maximum exploitation of traditional
energy resources such as biomass. This massive exploitation has augmented the depletion of natural resources and finally acting as a major cause for the degradation of the environment. Biomass dominates the overall energy supply and consumption in Nepal. Figure 1 shows the total energy supply and their share of energy consumption by fuel types in Fiscal Year 2014/15 [2].

Figure 1 shows the breakdown of Nepal’s energy consumption scenario by fuel types for the fiscal year when the total energy consumption remained around 500 million Giga Joule (GJ). Out of total energy consumption, fuelwood is the largest energy resources and occupies about 70.47% of total energy demand. Other sources of bio-masses were agricultural residues and animal dung, which contributed about 3.48% and 3.68%, respectively. Petroleum fuels in the total energy system occupy about 12.53%. Other sources of commercial energy are coal and electricity from hydropower, which contributed about 3.97% and 3.39% respectively in the total energy supply. In aggregate, the share of traditional fuel is 77.63%, commercial fuel (coal, petroleum, and electricity) is 19.88 % and renewable (Solar, Biogas, Micro-hydro, Wind) is 2.49% [2].

Figure 1. Nepal’s energy consumption scenario by fuel types in 2014/15 [2]

This shows that, in the Nepalese context, traditional fuel is dominant with huge potential of hydro yet to be harnessed to meet national energy demand. Alongside, there is a threat of increased import of commercial fuels.

2.2. Electricity trend analysis.

In the history of nearly 108 years of hydropower establishment starting from Pharping Hydro Power Project in 1911 AD, only little more than 1000 MW of hydropower is being generated in the country [4-7].

Figure 2. The total energy available and peak demand [4]
In this article, the electricity trend in Nepal for the last 10 years has been reviewed as presented in Figure 2. More specifically, Figure 2 shows annual electricity generated from NEA, purchased from IPPs, imported from India and the annual peak demand for the period of 2009 to 2018. The figure 2 shows almost linear electricity generation of NEA (including IPPs) against the steep gradient of peak power demand has ultimately increased the power purchase from India. Until now, NEA has been importing electricity from India to meet the gap. To meet the gap, power purchase is ever increasing, as reflected in Figure 2. The overall available energy since 2009 follows the increasing trend. The electricity demand may be full-filled by grid extension in case of densely populated areas and by stand-alone systems for sparsely populated areas [8]. Literature has also traced that increased import of commercial fuel has decreased consumption of traditional fuel despite its abundant availability [9]. Increased use of traditional fuel and renewable energy contributes to reducing greenhouse gas emissions providing institutional arrangements to energize clean development mechanisms [10]. But in contrary, Nepal seems to be moving in the opposite direction by increasing import of commercial fuel and decreasing use of traditional fuel.

2.3. Regression analysis.

The regression analysis of electricity per capita (EPC) over GDP per capita (GDP) has been conducted to trace the impact on EPC for increment on GDP. GDP gives a country’s economic output, which accounts for the total population. In other words, it gives the prosperity of the people of that country whereas EPC is the unit (kWh/year) of electricity consumed by one person of that country averaging the whole population of the country. Electricity per capita usage is often considered as a key indicator of development. Nepal, as one of the least developed countries its EPC, which is 244 kWh/year is far less than the global average energy per capita [11]. Low EPC has found a direct impact on the country’s economy and development [12]. Thus, this article has further analysed the impact of GDP on EPC through a regression analysis where EPC is a dependent variable and GDP is an independent variable. The econometric model for the regression analysis is developed as follows:

$$EPC = \alpha + \beta GDP + \epsilon$$  

The regression analysis gives the following output:

**Table 1. Regression analysis of GDP on EPC.**

| Variables | Constant (\(\alpha\)) | Coefficient. (\(\beta\)) | SEE | F-value | Adj-R\(^2\) |
|-----------|------------------------|---------------------------|-----|---------|------------|
| GDP       | -28.18                 | 0.27***                   | 0.03| 104.31***| 0.92       |

(* *** significant at 1% level of significance (…) Parenthesis values are t-stat

Table 1 shows a positive and significant relationship between GDP per capita and electricity per capita. This reveals that one-dollar increase in GDP increases 0.27 kWh consumption of electricity. The Adj-R2 shows the goodness of fit of the developed model; this indicates that the GDP explains 92% of the variation in consumption of electricity. The modeling indicates that higher the GDP per capita, higher would be the consumption of electricity.

2.4. Energy policies in Nepal.

To regulate energy projects and industries in Nepal, the government has formulated numerous policies, acts and regulations. Currently, the Nepalese government and the policymakers are exploring the hybrid models and promoting off-grid renewable energy and mini-grid models [13]. Considering that the current Nepalese energy plans and policies will be implemented effectively, it is likely that current and future electricity demand of Nepal is fully met. In the given energy context of Nepal, existing Nepalese
energy policies and provisions which remain appropriate in promotion of the overall energy sector have been summarized with specific policy concentration is given below in Table 2.

**Table 2. Nepalese existing policies and provisions [14-21].**

| SN | Policy Provisions | Policy Concentration |
|----|-------------------|----------------------|
| 1  | Nepal Electricity Authority Act, 1984 | NEA Act 1984 created scope to manage activities related to electricity generation and distribution in the country. |
| 2  | Water Resources Act, 1992 | Water Resources Act, 1992 expedite the scope for the balanced utilization and conservation, of water resources in the country. |
| 3  | Hydropower Development Policy 1992 and 2001 | Hydropower Development Policy 1992 and 2001 encourages the private sector investment through various fiscal and other incentives for the development of hydropower in the country. |
| 4  | Electricity Act 1992 and 2001 | Electricity Act 1992 and 2001 provides legal arrangements to endorse Hydropower Development Policy 1992 and 2001. |
| 5  | Local Self-Governance Act, 1998 | Local Self-Governance Act, 1998 provided local authority for the formulation, implementation, distribution and maintenance of mini and micro hydropower projects. |
| 6  | NEA Community Electricity Distribution Bye-Laws, 2003 | NEA Community Electricity Distribution Bye-Laws, 2003 provided opportunity for community electrification through country and community participation. |
| 7  | National Water Plan 2005 | National Water Plan 2005 is the only document with a time-bound target for rural electrification. |
| 8  | Rural Energy Policy 2006 | Rural Energy Policy 2006 has provisioned for rural energy and electrification activities in rural areas through Renewable Energy Technologies (RETs). |
| 9  | Renewable Energy Subsidy Policy 2000-2016 | Renewable Energy Subsidy Policy 2000-2016 has provisioned for a direct financial subsidy to off-grid electrification in rural areas. |
| 10 | RE Subsidy Delivery Mechanism for Special Program 2018 | RE Subsidy Delivery Mechanism for Special Program 2018 has provisioned in subsidy for special renewable energy programs. |
| 11 | National Energy Efficiency Strategy 2018 | National Energy Efficiency Strategy 2018 has a national target of energy efficiency in Nepal, which is to double by the year 2030 A.D. |

The study has analyzed the existing pertinent energy policies as listed in table 2. The study has further tried to relate the role of energy-related policies and trace its impact and the implications on electricity generation. The study shows that in Nepalese context, institutional coordination and synergies of energy policies with the institutional coordination is vital for its better implementation [22]. The research has shown that policy intervention has significant roles in removing market barriers [23]. Meaning, proper policy interventions in the energy sector could also mitigate the existing barriers and move towards higher electricity generation. The research has also analyzed renewable energy policies and has suggested some definite models reduce various burden and barriers for adoption of the same [24]. Such implementation has forecasted to increase the use of renewable energy as well. Research over-evaluation of renewable energy policy has revealed that better policy interventions increase the total amount of electricity generation [25]. Research has also concluded that the regular performance of different energy policies instruments the dissemination of new energy technologies [26]. In US evaluation of energy policies has shown that polices ultimately reduces the financial burden for the energy technologies and
make them adaptable. In the meantime, improper policies being implemented has also harmed the sustainable economy of the country. Thus renewable energy policies should focus on energy efficiency, improving energy structure and reshaping energy industry [27]. Other researches have also shown a positive implication over the adoption of various renewable energy technologies [28,29].

In a nutshell, the analysis of various renewable energy policies shows that better policies always have a positive impact on the adoption of existing energy technologies as well as reflect positive impact over electricity generation. In the Nepalese context, there might be numerous reasons behind the gap in the generation and the demand, but policies show a significant impact on it. Based on this evidence and current electricity scenario of Nepal, it is claimed that Nepalese energy policies are not up to the optimal, else the gap would not have been visible.

3. Barriers of the energy sector in Nepal
Based on the literature, formal and informal consultation with experts, focus group discussions and interviews, various relevant barriers for promotion of energy sector in Nepal has been traced [30]. Relevant literature has been analyzed [9,31,32]. Based on such primary and secondary data collection and subsequently followed analysis, the position of the power sector remains unsatisfactory because of high tariffs, high system losses, high generation costs, high overheads, overstaffing, and lower domestic demand. Based on the status of the energy sector of Nepal, following three major thematic barriers are identified for promotion of energy sector in Nepal has been concluded to be the most prominent ones.

3.1. Technical Barriers.
In the case of remote areas in underdeveloped and developing countries like Nepal, grid connection often is technically prohibitive. Due to this technical issue, an alternative model has been evolved with the maturation of contextual stand-alone energy systems [32]. Such stand-alone systems generate energy locally facilitating the supply of local energy demand. By the passage of time, communities are switching energy sources from traditional to modern/commercial. Depending upon available renewable energy sources communities are using improved cookstoves (efficient use of traditional fuels), micro or pico-hydro, small wind energy systems, solar photovoltaic, etc. These modern renewable energy systems are environment-friendly and technically matured alternatives for grid expansion, even at an economical rate [31]. But grid integration of electricity generated from such off-grid technology has been successful just in pilot-scale and full fledge implementation of grid integration has remained as a major technical challenge for maturation in Nepal.

3.2. Economical Barriers.
Renewable energy (e.g. sun, wind, water, etc.) is abundantly available and applicable in the stand-alone system, which is the reason for it to be a better option for energy access where grid extension is not feasible. Solar home system (SHS) has contributed to more than 3 million households for energy access [32]. Clean electricity is the core of attraction for utilization of SHS for lighting. Depending upon the size of SHS, its use can be further expanded towards utilization for other modern technologies like telecommunications. The high upfront cost of stand-alone systems like solar PV and wind turbine along with battery backup has always remained as a common issue throughout the world. However, the high upfront cost is a barrier for grid electrification/extension as well. In countries like Nepal with difficult geographic terrain and low population density, stand-alone systems for energy access could be a better alternative. Stand-alone systems could ensure energy access not only for such sparsely settled population but also for various community entities like health posts, schools, community centres, and micro-business enterprises [33]. Despite these possibilities for energy access for rural communities through stand-alone systems, it is difficult for the rural dwellers to manage the high upfront cost for energy access. Additionally, these small stand-alone systems could mitigate lighting issues at the micro-level. But macro-level energy access and planning, which could possibly support rural enterprises and access a higher level of energy access (Tier wise) always come with economic barriers for underdeveloped
countries. Thus, an economic barrier has remained as another pertinent barrier to the development of macro-scale renewable energy technologies in Nepal.

3.3. Geographical Barriers.
Nepal is a country with most of the land in the hilly and mountainous region followed by a sparsely settled population. To ensure energy access to all those regions has always remained a major issue for the Nepalese government. Thus, geographical barriers for development to maturity of the energy sector in Nepal is one of the most challenging barriers for the long run.

The literature and the discussion above witness the existence of various issues and barriers for rural electrification and the promotion of renewable energy systems. Economical, technical and geographical are the major issues and barriers for renewable energy system promotion in Nepal.

4. Conclusion
Plenty of opportunities for the development of energy technologies in Nepal exists through numerous policy and provisions. The Nepalese government has given high priority for the upliftment of the overall energy sector through White Paper 2018 an Energy Efficiency Strategy, 2019 as the latest policy provisions. Barriers to the development of the energy sector based on literature review and formal and informal interactions have been presented in the article. The article has ultimately traced technical, financial and geographical as the most important barriers to be addressed to meet the ambitious target of 15000 MW in the next 10 years as put forward in White Paper 2018. Several advantages and positive features have been highlighted against each policy provisions along with the limitations. Existing energy sector policy provisions seem challenging to meet the government target on time. The study has concluded the existing polices being not optimal has led to almost linear electricity generation of NEA (including IPPs) against the steep gradient of peak power demand. The trend analysis of energy scenario of Nepal shows that the Government of Nepal (GoN) should emphasize on electricity production as the electricity demand is continuously increasing. Further, the regression analysis reveals a positive and significant relationship between GDP and EPC. Thus, it is recommended that higher the GDP per capita, higher would be the consumption of electricity, highlighting the fact that GoN should prioritize to increase its per capita income.

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References
[1] Cherni J A and Kentish J 2007 Renewable energy policy and electricity market reforms in China Energy Policy 35(7) 3616–29
[2] Water and Energy Commission Secretariat (WECS) 2010 Energy Sector Synopsis Report
[3] Schillings C, Meyer R and Franz T 2004 Solar and Wind Energy Resource Assessment (SWERA) DLR-activities within SWERA
[4] Nepal Electricity Authority 2018 Annual Report NEA
[5] CBS 2012 National Population and Housing Cencus 2011; National Planning Commission Secretariates, Central Bureau of Statistics
[6] Parajuli R 2011 Access to energy in Mid/Far west region-Nepal from the perspective of energy poverty Renew. Energy 36(9) 299–304
[7] GoN 2017 Government of Nepal Water and Energy Commission Secretariat Electricity Demand Forecast Report
[8] Sanjel N, Baral B, Acharya M and Gautam S 2019 Analytical modelling for optimized selection
between renewable energy systems and the conventional grid expansion  

J. Phys. Conf. Ser. 1266(1)

[9] Sanjel N and Baral B 2019 A review of renewable energy sector of Nepal Nawaraj International (SAARC) Youth Scientific Conference (IYSC) 2019, Conference Proceedings (Peer Reviewed) 115–20

[10] Hussain A 2019 Hydropower development in the Hindu Kush Himalayan region: Issues, policies and opportunities Renew. Sustain. Energy Rev 107 (February) 446–61

[11] Surendra K C, Khanal S K, Shrestha P and Lamsal B 2011 Current status of renewable energy in Nepal: Opportunities and challenges Renew. Sustain. Energy Rev 15(8) 4107–17

[12] Ahmed S, Islam M T, Karim M A and Karim N M 2014 Exploitation of renewable energy for sustainable development and overcoming power crisis in Bangladesh Renew. Energy 72 223–35

[13] Poudyal R, Loskot P, Nepal R, Parajuli R and Khadka S K 2019 Mitigating the current energy crisis in Nepal with renewable energy sources Renew. Sustain. Energy Rev 116(April) 109-388

[14] Government of Nepal 2006 Rural Energy Policy

[15] Nepal Electricity Authority 1991 Nepal Electricity Authority Act

[16] WECS 2005 National Water Plan - Nepal

[17] Government of Nepal 2003 Irrigation Policy, 2060

[18] Government of Nepal 1992 Water Resources Act, 2049 (1992)

[19] Nepal Department of Electricity Development 1992 Electricity Act - Nepal, 1992

[20] Government of Nepal 2006 The hydropower development policy, 2001

[21] Government of Nepal 2018 National Energy Efficiency Strategy

[22] Shrestha S and Dhakal S 2019 An assessment of potential synergies and trade-offs between climate mitigation and adaptation policies of Nepal J. Environ. Manage. 235 535–45

[23] Bukarica V and Tomšić Ž 2017 Energy efficiency policy evaluation by moving from techno-economic towards whole society perspective on energy efficiency market Renew. Sustain. Energy Rev. 70 968–75

[24] Alyamani T, Damgacioglu H, Celik N, Asfour S, and Feiock R 2016 A multiple perspective modeling and simulation approach for renewable energy policy evaluation Comput. Ind. Eng. 102 280–93

[25] Carley S 2009 State renewable energy electricity policies: An empirical evaluation of effectiveness Energy Policy 37(8) 3071–81

[26] Neij L and Astrand K 2006 Outcome indicators for the evaluation of energy policy instruments and technical change Energy Policy 34(17) 2662–76

[27] Chen C C 2011 An analytical framework for energy policy evaluation Renew. Energy 36(10) 2694–702

[28] Lee S C and Shih L H 2010 Renewable energy policy evaluation using real option model - The case of Taiwan Energy Econ. 32(supp 1) S67–78

[29] Zhang M, Zhou D, and Zhou P 2014 A real option model for renewable energy policy evaluation with application to solar PV power generation in China Renew. Sustain. Energy Rev. 40 944–55

[30] National Rural Renewable Energy Program-Government of Nepal 2019 Renewable Energy for Rural Livelihoods (RERL)

[31] Schwan S 2011 Overcoming Barriers to Rural Electrification

[32] Wijesinghe N 2014 Rural Electrification - Sri Lanka : A Case study & Scenario Analysis

[33] International Energy Agency 2016 International Energy Agency, Secure Sustainable Together