Development Effects of Electrification from Decentralized Renewable Energy Technologies in Nepalese Context

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Abstract

Purpose: Access to electricity is recognized as an important factor for socio-economic development that ultimately contributes to poverty reduction. But, the question is whether it contributes socio-economic development of rural people and if so to what extent? This research attempted to answer these questions, by evaluating development effect of electrification from decentralized renewable energy technologies in Nepal. The research also focused about the effects of electrification perceived by the consumers due to project intervention.
Methods: Accordingly, household data collected from 404 beneficiaries electrified by 84 projects based on a stratified random sample method was used. MS-Excel and IBM-SPSS-25 was used for analyzing data at $p = 0.05$. The results were presented as frequency, mean, minimum, maximum, and standard deviation.
Results: The empirical analysis and results revealed that access to electricity induces substantial welfare gains, which tend to be relatively skewed towards women. An increase in economic activities, improvements on economic status, contributing environmental conservation, enhanced social cohesion, and improvements in living standards of rural people were the key determinants of development effects from electrification.
Conclusion: However, access to electricity efforts should be embedded with complementary supports including awareness, training and fiscal incentives for enhancing the economic use of electricity. Furthermore, poverty is inversely proportional to electricity access that implies focusing on providing reliable, affordable, and modern energy access for combating rural poverty in developing countries like Nepal.

Keywords: Air pollution; Carbon emission; Decentralized; Drudgery; Employment

1 Introduction

Access to electricity is generally recognized as an important factor for economic and social development that ultimately contributes to economic growth and poverty reduction (Williams et al., 2015; Thapa, et al., 2019a). Adequate and affordable energy supply is a key for alleviating poverty, improving human welfare, reducing poverty, and increasing living standards (Bhattacharyya, 2013). It further emphasizes that energy is the key means of development of better health, high living standards, a sustainable economy and a clean environment. WB (2015) further states that lack of energy induces negative impacts in economic development by suppressing agricultural productivity, environmental sustainability, health care, education, and employment creation.
Being a member of the United Nations, Nepal has committed to providing affordable, reliable, and modern energy by 2030 (WECS, 2013). Poverty alleviation has been the essential target of the Nepalese development endeavors since the eighth five-year plan of 1992-1997, which would be contributed by the access to electricity for larger mass of people (Bridge et al., 2016). In spite of these commitments, only 72 out of 100 have accesss to reliable, affordable and uninterrupted access to electricity facility (WB, 2024 and Pinto et al., 2019) .
Nepal entirely relies on imports for supplying fossil fuel (oil, gas, and most of the charcoal), though it has plenty of renewable energy resources (ADB, 2017). It is heavily dependent on the traditional source of energy such as firewood, agricultural residue, animal dung (more than two-third share) (MoF, 2019). Additionally, the people, who live without access to modern, reliable, and affordable energy, are mainly those residing in the hills and mountains. They are fulfilling their lighting needs mostly by the use of kerosene and dry cell batteries. For agro-processing, mostly water mills pursued by diesel mills are used that are located down the hills, far away from the settlements. Due to the use of traditional fuels, including fossil fuels may result in many adverse effects (Pinto et al. (2019), WHO (2021), Venkata et al. (2015), Ranabhat et al. (2015), ESMAP (2017) as summarized hereunder:

(a) increased health problem due to indoor air pollution (WHO, 2021),

(b) increased deforestation due to the use of firewood for cooking, lighting, and heating,

(c) increased drudgery due to fuel collection, use, and agro-processing,

(d) increased pressure on the global environment due to burning of fossil fuel and firewood,

(e) reduced economic activities due to lack of awareness, resources and economic activities,

(f) reduced level of social coherence due to an independent surviving situation,

(g) reduced level of living standards due to lack of overall opportunities; consequently increase in poverty level.

Moreover, the poverty level further raises in remote and inaccessible communities, while the cost of electrification becomes high because of increased transportation and maintenance costs (Zahnd & Kimber, 2009). In spite, providing electricity access by expanding the central grid may not cost-effective because of geographical situations and scattered settlements in the hills and mountains of Nepal (Deshmukh et al., 2013). Therefore, ensuring electricity access by decentralized renewable energy (DRE) technologies is being a viable option in developing counties such as Nepal (Thapa et al., 2020). Moreover, electricity access in a rural area has several effects related to development such as improvements on socio-economic welfare, contribution to conversation of environment, and ultimately support in sustainable development (ESMAP, 2017; Peters & Sievert, 2016). For instance, as reported by Winkler et al. (2011), electricity access may have development effects at the micro and macro level in line with the following factors:

- Renewable energy results in health benefits because of reduced indoor air pollution, clean water, and refrigeration that induces direct benefits and higher productivity.
- It allows reallocation of saved time to better education and income generation activities; creates opportunities for economics of scale activities through energy-based enterprises; provides greater flexibility in time allocation, as well as better conditions for education and helps lowering transportation and communication costs, greater market size and access, more access to information.

However, the questions are "whether access to electricity by DRE technologies is able to contribute to the socio-economic development?", and if so to what extent? What is it's welfare effect in a rural area? This study tries to answer these questions, by assessing the development effects of electrification from DRE technologies based on micro-hydro power for rural electrification in Nepal. To the best of authors' knowledge, there are limited studies performed that focus on the development effects of adopting DRE technologies in the rural areas in developing countries like Nepal.

In this paper, we had focused on assessing development effects perceived by the consumers before and after the DRE project intervention by using a set of structured questionnaires. The survey was conducted during February to July 2019 covering the beneficiaries from three provinces (Far Western, Gandaki, and Koshi). It incorporates the projects operating for the last 6.5 years (operation initiated from the year 2007 to 2019 with an average of the year 2012 and a half). Altogether, responses from 404 respondents were collected during the survey period from 81 operational projects, as three projects were found not functional during survey time due to natural calamities. In this study, ten variables were examined such as (i) drudgery, (ii) health, (iii) affordability, (iv) employment creation, (v) income, (vi) awareness on environmental concern, (vii) global impact, (viii) social services, (ix) social integrity, and (x) living standard.

This research findings contributes to the existing knowledge in two ways. First, it introduces micro-level representative samples instead of case studies that cover the situation of the off-grid rural electrification of the country. While numerous past investigations on electrification were either based on case studies or limited to a certain geography or macro-level or using secondary information (e.g. Bridge et al., 2016; Bhandari et al., 2017; Gurung et al., 2011; Zahnd & Kimber, 2009; Kanagawa & Nakata, 2008; Diallo & Moussa, 2020; Jha et al., 2016; Aguirre, 2014). Second, this research assessed the effect of DRE technologies on the welfare of rural people with relatively sufficient variables. While several past research have estimated the benefits of rural electrification (either grid-based or other than hydro) based on limited variables. For instance, in past studies (Diallo & Moussa, 2020; Peters & Sievert, 2016; Barron & Torero, 2014; Banerjee et al., 2010; Sovacool et al., 2011; Aguirre, 2014; Grogan & Sadanand, 2013; Rud, 2012; Akpan et al., 2013; Bastakoti, 2006), they did not directly assess the development effects of off-grid rural electrification at micro-level covering representative samples.

Furthermore, the remainder of the paper is organized as follows. Section-2 presents the materials and methods used for the study. The subsequent section focuses on empirical results followed by discussions based on descriptive statistics on the development effects of electrification from DRE technologies and finally, Section-5 contains the concluding remarks.

2 Methodology

2.1 Establishing a theoretical framework

Access to electricity from decentralized renewable energy (DRE) technologies can influence the welfare of people through different channels. Generally, access to electricity helps to improve socio-economic situations through its effect on key components of poverty namely health, education, income, and environment (Kanagawa & Nakata, 2008). Taking care of this situation, the theoretical framework has been constructed in this exploration that is based on the result chain principle of electrification interventions as access to electricity is transformed into poverty reduction by means of various pathways. The framework for evaluating the development effect of electrification from DRE technologies based on various pathways (channels) is outlined in Figure 1.

2.2 Theoretical Framework

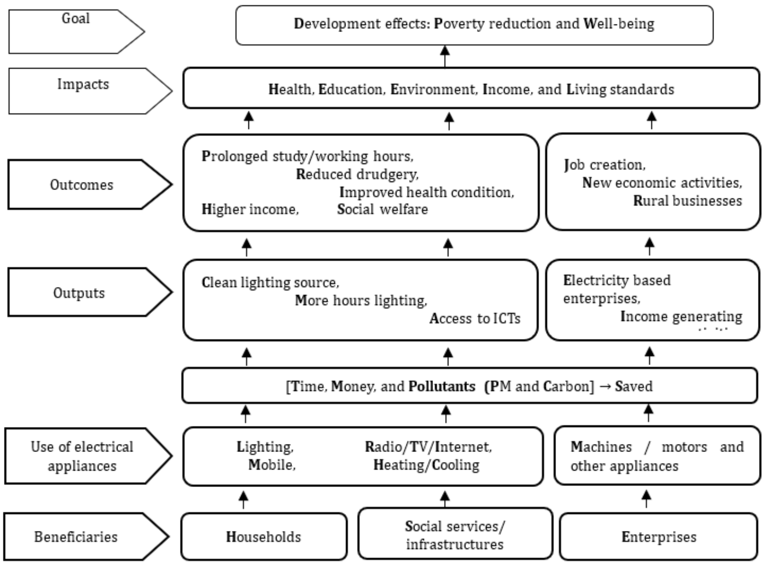

Figure 1: Pathways to development effects of electrification from DRE technologies

The framework involves the following prospects :

(a) In rural settings of developing countries, three kinds of beneficiaries (households, social services, enterprises) of electricity are found. These beneficiaries need basic appliances like lighting, mobile, TV/radio/internet, heating/cooling, cooking, refrigerator, and machines/ motors. Social services include the institutions proving social services e.g. health, education, agriculture, public offices, information communication technologies (ICT), etc.

(b) Due to the availability of clean electricity, the people are benefited by saved time, money, emission of pollutants.

(c) The output of these saved components can avail clean lighting, more hours lighting, and access to ICT. Moreover, the increase in electricity-based enterprises and income generation activities (IGAs) are the outcome of saved resources.

(d) The outcomes can be in the form of prolonged study & working hours, reduced drudgery, improved health conditions, social welfare, higher income, job creation, new economic activities, and rural business.

(e) The ultimate impact can be perceived as better health, improved education, environmental protection, increased income and improved living standards of rural people.

(f) Consequently, it contributes to achieving the development goal of enhancing economic growth, reducing poverty, and enhancing well-being.

2.3 Research design:

This study is an outcome of the data collected during February to July 2019 by covering 404 beneficiary households electrified from 84 DRE technologies based on Micro-hydro selected from stratified random selection method. This research follows a mixed-method approach in which both qualitative and quantitative data have been utilized. As far as possible, continuous types of data were collected, otherwise, category-based options were considered to have respondents' perceptions. Such kinds of questionnaires are able to collect beneficiaries' perceptions due to project intervention on a Likert scale 1 to 5 (5 being the best).

2.4 Site selection:

While selecting sites, the purposive random selection method was adopted. Out of seven, three provinces were picked up based on the availability of technologies and possibly representing the entire situation. Similarly, while selecting projects, low and high hill was balanced so that all the casts and geography are covered. Accordingly, 19 districts were selected that incorporates 4-districts from Far Western, 8-districts from Gandaki, and 7-districts from Koshi.

2.5 Determination of variables

Determination of variables: to measure the development effect in the form of welfare impact for the project intervention, ten variables namely drudgery, health, affordability, employment, income, awareness on environmental concern, global impact, social services, social integrity, and living standards were considered.

2.6 Statistical analysis:

after collection of such information, data were compiled and analyzed with the help of a MS-Excel spreadsheet and IBM-SPSS-25 was used for the analysis data at p = 0.05. As far as possible, data were analyzed using descriptive statistics and inferential statistics. The results were presented as frequency (count), mean, minimum, maximum, and standard deviation. The mean ($\bar{x}$) and standard deviation (σ) of the population were estimated using the following formulas:

$$\bar{x} = \frac{\sum x}{n} \quad \} \tag{1}$$

$$\sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} \quad \} \tag{2}$$

Where, x is each of the values, $\bar{x}$ is the mean of x and n is the number of those values.

3 Results

3.1 Consumers' attitude and perception towards reduction on drudgery

Before electrification, people used to spend hours for agro-processing mainly in water mill, which is generally located down the hill far from the settlements. Agro-processing has been convenient because of the electric mill at the village, which helped to be quicker than the traditional mill. Similarly, fuel collection used to take hours before the electrification. Consumers' attitudes and perceptions towards a reduction in drudgery due to a decrease in time for fuel collection, burning, and agro-processing facility available nearby the village after the project has been computed. The outcome of the empirical analysis is presented in the following Table 1.

Table 1: Consumers' attitude and perception regarding time saving based on thte response obtained from a questionnaire survey, 2019

Attitude and perception		Frequency	Percentage (%)
Opinion about time saved after the project?	Yes	363	89.9
	No	41	10.1
	Total	**404**	**100**

The result shows that almost all respondents felt that time has been saved after the project. On average, 9.67 and 9.87 hours per week have been saved for men and women respectively, which shows women are benefited slightly more than men. Similarly, in the case of agro-processing time saving, women (2.74) have benefited more than men (1.26) have. The result nearly coincides with the findings from HCPL (2006) that shows 80% of respondents agreed on time-saving, 7 hours, and 9 hours per week time saved for males and women respectively. The result shows that the time has been saved remarkably which means the drudgery has been reduced after the project. However, the question arises, "how are the people utilizing the saved time?" To explore it, we have observed the following facts (Table 2).

The result shows that around half of the saved time has utilized on IGAs and more interestingly females are utilizing more (8%) than males. Likewise, males are spending more time in rest (> 3), whereas they utilize more time for study (> 2). Moreover, there is no shift in the agro-processing role because females are taking care of it more than males (around double). The results were compared with past studies, for instance, Rao et al. (2016) in their report mentioned that women spent almost twice as much time in IGAs, but the time remained below one hour per day (Rao et al., 2016). Likewise, Barron & Torero, (2014) have observed that women have increased time for IGAs as a result of electrification.

Table 2: Utilization of saved time by the consumers as per the response obtained from a questionnaire survey, 2019

Utilization of saved time	Gender	Mean (Hours/week)	Percentage (%)	Min.	Max.	St. Deviation
Study	Male	2.65	27.4%	0.0	8.0	1.50
	Female	2.10	21.2%	0.0	8.0	1.42
Rest	Male	2.28	23.6%	0.0	8.0	1.36
	Female	2.14	21.7%	0.0	7.0	1.28
Income generation activities (IGA)	Male	4.74	49.0%	0.0	10.0	1.94
	Female	5.63	57.0%	0.0	10.0	1.93

3.2 Effects of electrification on health

According to the energy ladder (WB, 2008), more efficient and clean fuels pollute less, have positive environmental and health effects. It further explains that health benefit from DRE technologies is possible from (i) better health due to cleaner air (lighting, cooking, and heating), (ii) improvements on health facilities, (iii) increased health knowledge through access to TV and radio, (iv) better nutrition from improved knowledge and storage facilities.
In this research , the respondents' perceptions were collected on the Likert scale: 1 to 5 on the statement, "the health condition has improved after the operation of the project". The summary of the results from the consumers' perception is presented in the following Table 3.

Table 3: Effect on health due to electrification from a DRE technology as per the response obtained from a questionnaire survey, 2019

Provinces	Count	Mean (Score)	Min.	Max.	St. Deviation
Koshi	169	4.0	2.0	5.0	0.748
Gandaki	130	4.0	4.0	4.0	0.000
Far Western	105	4.2	2.0	5.0	0.513
National	404	4.1	2.0	5.0	0.42

It shows that the respondents have highly agreed on the statement. The result would also confirm with the past results Peters & Sievert (2016), and Diallo & Moussa (2020). A research performed by HCPL (2006) showed 60% of respondents agreed that their health condition has improved. Likewise, another study shows that after two years, indoor air pollution was substantially (66%) reduced, consequently respiratory infections among children were reduced by 8-14% (Barron & Torero, 2017). Moreover, comparing the mean score among the three-provinces, respondents from Far-Western have scored with fairly higher.

3.3 Consumers' attitude and perception towards affordability

Affordability is a characteristic of energy supply that refers capacity of the consumers to pay for the energy needed (Bhatia & Angelou, 2015). It can be estimated in terms of readiness to pay or portion of investment in fuel consumption in a certain period. In this research, we attempted to collect both the information. Affordability in terms of readiness to pay is gathered through consumers' perception on the Likert scale: 1 to 5. Likewise, the percentage of 'expenditure on fuel' is computed by collecting annual family income and their expenditure on fuel. Considering the definition of energy poverty, the consumer investing up to 5% of their income is considered to be affordable (Bhatia & Angelou, 2015).
The summary of findings has been presented in Table 4 and Table 5.

Table 4: 'Affordability' in terms of willingness to pay as per the response obtained from a questionnaire survey, 2019

Provinces	Count	Mean (Score)	Min.	Max.	St. Deviation
Koshi	169	3.5	2.0	5.0	0.757
Gandaki	130	4.0	4.0	4.0	0.000
Far Western	105	4.0	1.0	5.0	0.612
National	404	3.8	1.0	5.0	0.456

Table 5: 'Affordability' in terms of percentage investment in fuel as per the response obtained from a questionnaire survey, 2019

Provinces	Count	Mean (% expenditure)	Min.	Max.	St. Deviation
Koshi	169	4%	1%	30%	3.78%
Gandaki	130	5%	1%	35%	5.74%
Far Western	105	6%	1%	30%	6.19%
National	404	5%	1%	35%	5.18%

The outcomes from both tables reveal that all the consumers irrespective of geography are willing to pay the tariff, though the users in the Far Western have a low level of affordability in terms of their income. It can be argued that tariff is not affordable for people from Far Western in terms of their income level, but they are ready to pay the tariff based on willingness to pay response. The electricity tariff for the people from the rest of the province is affordable for both income level and willingness to pay. The affordability in terms of the percentage of expenditure confirms the past findings (3 to 4%) of Rao et al. (2016).

3.4 Effects of electrification on local employment generation

Rural electrification is a key means for the creation of local employment. Local employment creation wa explored in this study by collecting direct and indirect jobs as presented in Table 6.
Table 6: Local employment created by electrification from a DRE technology as per the response obtained from a questionnaire survey, 2019

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Local job created from project intervention	N	Mean (No. of job/project)	Min.	Max.	St. Deviation
Direct job	81	2.9	1	12	1.511
Indirect job	79	5.1	1	25	5.422
Total jobs created	81	7.9	1	29	5.762

The result revealed that about eight local jobs have been built up from each project that includes about three direct and five indirect jobs (Cronbach's alpha = 0.765, N = 81). The result also confirm the previous findings of Bastakoti (2006), ERMC (2017). For instance a study carried out by ERMC pointed out that 7.6 (2.4 direct and 3.8 indirect) local jobs were created. Comparing the average numbers of local job creation among the three provinces, Far Western is behind (5.5 jobs per project) the rest of the provinces. Koshi is leading in terms of creating jobs with a value of 9.1 jobs per project followed by Gandaki with 8.3 jobs per project. The main reason for the lower level of job creation in Far Western is due to limited numbers of business activities available. Similarly, jobs created by SMEs are mostly self-employment rather than formal employment, consequently, the actual number of jobs could be relatively higher than this result. Therefore, it can be concluded that each DRE technology produces around eight jobs in the society contributing to reducing the poverty level.

3.5 Effects of electrification on consumers' income

Electrification enables livelihoods by stimulating employment, productivity, and IGAs (Bridge et al., 2016; Diallo & Moussa, 2020). Moreover, energy lager (WB, 2008) signifies that per capita income and electricity consumption has a direct relation. Similarly, electricity access enhances the economic condition of users due to enhanced IGAs, increased knowledge from TV and radio. In this study, the respondents' perceptions were collected in the Likert scale: 1 to 5 on the statement, 'economic status of beneficiaries has improved after the operation of energy technology'. The summary of the empirical results has been presented in Table (7).

Table 7: Effect on economic status of consumers due to electrification as per the response obtained from a questionnaire survey, 2019

Provinces	Count	Mean (Score)	Min.	Max.	St. Deviation
Koshi	169	3.9	2.0	5.0	0.775
Gandaki	130	4.0	4.0	4.0	0.000
Far Western	105	4.0	1.0	5.0	0.544
National	404	4.0	1.0	4.7	0.440

Table (7) shows that the respondents have highly agreed on the statement that reveals income has been increased after the project. Moreover, comparing the mean value of the three provinces, it varies from 3.9 to 4.0 score. This finding affirms with the results from HCPL (2006) and Kabir et al. (2017) that shows 80% and 71% responded towards enhanced economic status after the project. Additionally, a separate study carried out by Sovacool et al., (2011) shows that there is a significant raise (52%) in household income that is much higher than the national average. Therefore, the income level of the users' has increased with slightly different grades in all provinces after the intervention of the project.
Similarly, consumers' income was found to be directly proportional to the level of education and seen as positively correlated (Pearson correlation coefficient = 0.533). The results also confirm the findings of CBS (2011). Looking after the income level with respect to respondents' occupation, it was found that jobholders are earning the highest (US$ 405.71/month) followed by business people (US$ 310/month). The agriculture-based families are earning the lowest (US$ 218.86/month). The changes in household income after electrification are somehow linked to poverty. For this, access to electricity and poverty level were compared and presented in the Figure (2).

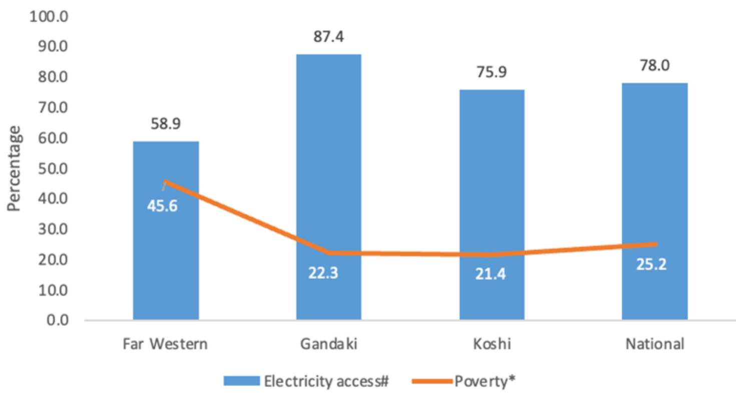

Figure 2: Model of national, state and local government relationship

#Nepal Electrification Statistics 2019; *Nepal Living Standard Surveys (CBS 2011) The result revealed that Far Western has the least access and highest poverty. Furthermore, the level of poverty is inversely proportional to electricity access (r = - 0.907) which implies to focus on providing clean energy access for combating rural poverty in developing countries like Nepal.

3.6 Consumers' awareness level on environmental effect

DRE projects help to increase consumers' awareness of benefits and cost of the development projects. In regards to environmental effects due to project intervention, the consumers' awareness level is so important from the inception phase to the post-construction phase. In order to explore the environmental effects due to DRE technologies, the respondents' perception were collected in the Likert scale: 1 to 5 (strongly disagree to strongly agree) based on the two statement (i) beneficiaries are well aware of environmental impact, (ii) greenhouse gas (GHG) emission is avoided. After empirical analysis, the summary of the results is presented in the Figure (3).

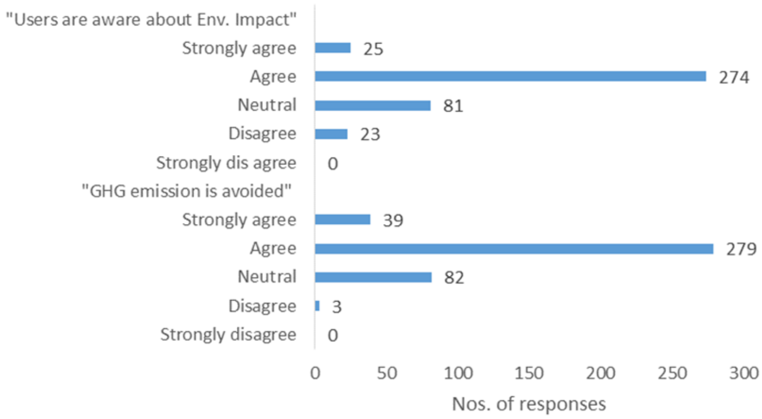

Figure 3: Effect on environment by electrification from DRE technologies based on the response obtained from a questionnaire survey, 2019

The finding shows that the most of the consumers have agreed on the statements (i) and (ii) showing a good

level of awareness (74.4%, 79.1%) on environmental effects of the energy project.
Moreover, province wise mean score (Likert 1-5) were computed in order to see the difference in users' awareness of environmental effects from the project intervention. By comparing the mean score among the three-provinces, respondents from Koshi have scored with fairly lower (3.3 score) than the rest of two (4.0 and 4.1 score). The result confirms that people from Koshi have a relatively lower level of environmental awareness than the rest of the two provinces.

3.7 Effects of electrification on global environment

WB, (2008) spells that DRE technologies displace mostly kerosene, creating a global environmental benefit that is calculated in terms of CO2 emission avoided per Households (HHs) or per installed capacity (kW). The effect of electrification due to DRE technologies on the global environment is computed based on kerosene and dry cell batteries saved in each electrified HHs. Monthly consumption of kerosene and dry cell (battery) per HH was compared before and after (Cronbach's alpha = 0.754, N = 404) and presented in the first row of Table 8.

Table 8: Effect on global environmental by electrification from a DRE technology as per the response obtained from a questionnaire survey, 2019

Environment benefit	Counts	Mean	Min.	Max.	St. Deviation
Kerosene saving (Liter/HHs)	402	3.60	0.5	22.3	2.42
Dry cell batteries saving (Nos./HHs)	375	5.28	2.0	26.0	2.05
CO2 avoided (kg CO2 / HHs)	402	9.648	1.34	59.764	6.65

From the analysis, in an average 3.6 liters of kerosene per household has been saved in a month ($t_{401} = 29.88, p < 0.001$). The mean saving of kerosene is seen as strongly and positively correlated ($r = 0.732, p < 0.001$). This result nearly the same with past studies in which 3.5 liters of kerosene is saved (Sovacool et al., 2011) and it would also confirm the findings of Obeng et al., (2008), but the impact level is quite low (10-12% reduction of kerosene) in the African context (Peters & Sievert, 2016). Similarly, in average 5.28 dry cell batteries per household is found to be saved in a month ($t_{401} = 36.08, p < 0.001$). The result nearly coincides with the findings from HCPL (2006) and SA (2011) that shows 3.8 and 2.9 liters of kerosene respectively, and 5 dry cell batteries saving per household in a month respectively.
Looking into gross kerosene saving due to DRE technologies (Micro-hydro) from all over the country, about 15 million liters should have been saved each year, which is equivalent to NRs 1.5 billion (price as of 1 January 2020). Additionally, about 22 millions of dry cell batteries have been abandoned. This shows electrification from DRE technologies significantly contributes to energy security as well as the trade balance of the developing countries like Nepal.

3.8 Effects of electrification on social services

Rural electrification is a key means for the functioning of social services because poverty is strongly linked with access to facilities that also include social services (CBS, 2011). Access to electricity to social services ensures the smooth functioning of necessary equipment and machines. In this research, several social services benefited from the electrification have been assessed and a summary of the result is presented in the Figure (4).

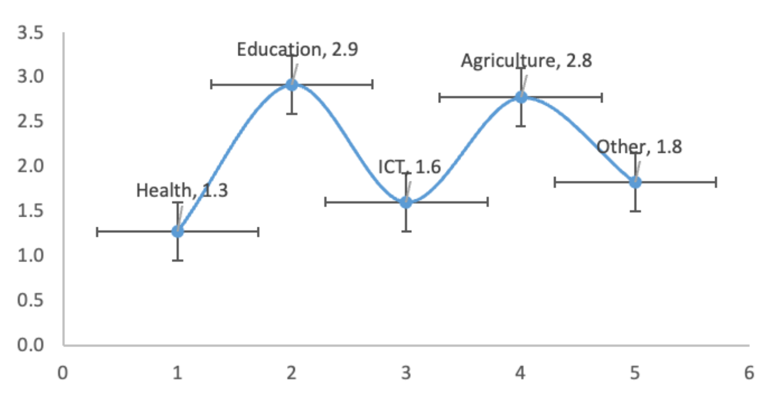

Figure 4: Numbers of social service benefited from a project based on the response obtained from a questionnaire survey, 2019

The result shows that on average 5.1 number of social services have got electricity access from a project. The distribution of social services includes health (health post, hospitals), education (schools, colleges), ICTs, agriculture, and others. The results show that the education and agriculture sectors are mostly benefited by DRE technology followed by ICT, health, and others.

3.9 Effects of electrification on social integrity

Most of the DRE technologies are developed and managed by the communities because 95% of projects are community-managed (Rao et al., 2016). Such projects are well known for the implementation of a participatory approach that enables an environment for building social integrity. In this study, the respondents' perceptions were gathered on the Likert scale: 1 to 5 on the statement, 'Social integrity has improved after the operation of energy technology'. The summary of the results is presented in the following Table 9.

Table 9: Effect on social integrity by electrification from a DRE technology as per the response obtained from a questionnaire survey, 2019

Provinces	Count	Mean (Score)	Min.	Max.	St. Deviation
Koshi	169	4.2	3.0	5.0	0.642
Gandaki	130	4.0	3.0	4.0	0.088
Far Western	105	4.2	3.0	5.0	0.411
National	404	4.1	3.0	4.7	0.380

The finding shows that the respondents have highly agreed on the statement. A past study performed by Koirala et al. (2019) shows that social integrity in the form of social capital has been formed due to increased sharing experiences, knowledge, information, etc. after the establishment of community-owned MH-Projects in Nepal. The result would also confirm the findings (90%) of HCPL (2006), which shows 81% of respondents had felt improvements in their social integrity. Moreover, comparing the mean score among the three-provinces, respondents from Far Western and Koshi (4.2 scores) have scored with fairly higher than the Gandaki (4.0 score). Descriptive statistics show that there is a significant difference in the mean score among the three provinces ($F_{2,\,400} = 8.829, p < 0.05$) that confirms that people from Far Western and Koshi provinces have relatively better integration or cohesion than Koshi.

3.10 Effects of electrification on consumers' living standards

In this study, the respondents' perception were collected in the Likert scale: 1 to 5 on the statement, 'Living standards of beneficiaries have improved after the operation of energy technology'. The summary of the empirical results is displayed in the Figure (5).

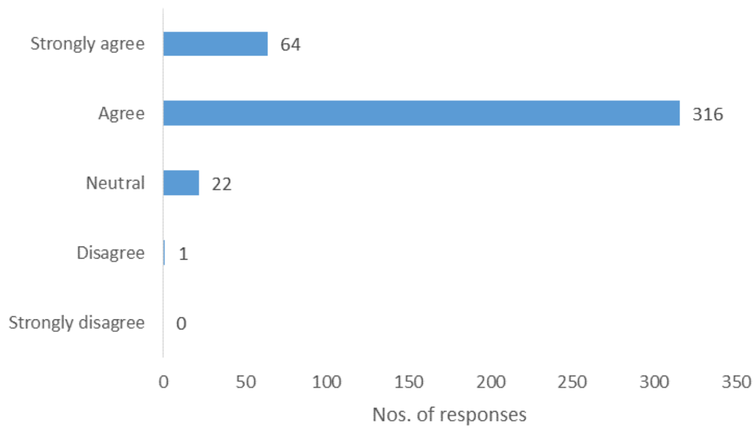

Figure 5: Effect on living standards of consumers due to electrification based on the response obtained from a questionnaire survey, 2019

The analysis reveals that most of the users felt that their living standards have improved after the project. A study by Adusah-Poku & Takeuchi (2019) shows that electrification improves the welfare of the society resulting in uplifting the living standards. Similarly, another study affirms the findings with improved results in the form of welfare by solar PV intervention in Cote D'Ivoire (Diallo & Moussa, 2020). Moreover, province wise mean score (Likert 1-5) were computed to see the difference in users' perception of the statement from the project intervention. By comparing the mean value of the three provinces, it varies from 4.0 to 4.2 score. Therefore, it shows that the living standard of the users has increased in all provinces after the project, but the level of improvements is higher in Far Western than the rest of the two provinces.

4 Discussion

Electrification by DRE projects can enable the development effects in various ways for instance by stimulating the benefits to the society in the form of saving time, money, and pollutants (Peters, J., & Sievert, M., 2016). The characteristics features of development effects include essential outcomes like: higher income, better education, improved health, reduced drudgery, increased well-being, reduced poverty, enhanced social cohesion, improved living standards, and sustainable use of local resources (Diallo, A., & Moussa, R. K., 2020).

Access to clean electricity creates an inductive environment with better lights to increase time in the evening for study and IGAs (Rao et al., 2016). It inspires local job creation, productivity, and IGAs by which people build assets. Further, the availability of clean lighting, agro-processing facility and water nearby the village, and creating opportunities to set up a new business are likely to reduce drudgery (especially women and children) and enhancing the economic status and well-being (Sovacool et al., 2011). Moreover, social integrity is enhanced that helps to minimize social issues, as it is a well-accepted social infrastructure. This statement is supported by the previous studies in which it is claimed that despite the long Maoist civil war, none of the community based micro-hydro was disturbed (Sovacool et al., 2011). As per James (1995), rural electrification can have higher agricultural production mainly through three means. These means include: (a) utilizing electric machines in the process of agricultural production e.g. water pumps, fodder choppers, and threshers, (b) increased knowledge through radio/TV or increased study time due to better lights, (c) utilizing rural agro-processing thereby adding value to agricultural products and creating rural employment. This statement is confirmed by Koirala et al. (2019) study, which shows community-owned micro-hydropower contributes to increasing agricultural productivity significantly (36.5%).

Therefore, it can be argued that providing access to electricity in a rural area in the developing countries is neither sufficient to stimulate economic growth nor enough for attaining anticipated development effects without providng access to clean energy. In order to combat this situation, the government of Nepal has given particular emphasis to DRE technologies including micro-hydro projects with around 50% investment subsidy, technical assistance, tariff suggestion, quality assurance, and partial post-construction support to establish electricity-based rural enterprises to ensure affordable, reliable and clean electricity (Rao et al., 2016). But, the average plant load factor of the Nepalese micro-hydro projects is found to be 27.2% (Thapa et al., 2019b) which means more than two-thirds of the energy is being wasted. This result affirms the previous studies performed by Sovacool et al., (2011) and Banerjee et al., (2010). This further suggests focusing on enhancing the economic use of electricity especially during daytime by suitable means.

In such situations, along with building infrastructure for clean electricity services, some complementary supports like training, awareness and fiscal incentives become essential elements for creating better impacts. This has been confirmed by previous studies as well for instance study carried by Bhattacharyya (2013), Feron et al., (2016), and Bastakoti (2006). They argue that complementary supports are necessary especially during the post-construction phase for enhancing the economic use of electricity, which supports not only economic activities but also helps to increase the plant load factor of the DRE project. These services include sensitization about the advantages and disadvantages of economic use of electricity amongst the household beneficiaries, public institutions, enterprises including commercial users (Feron et al., 2016). Moreover, the post-construction support could also be in the form of fiscal incentives (investment subsidy, tax rebate, soft loan, and repair and maintenance provision) and coordination and linkage to other governmental and non-governmental institutions (Bhattacharyya, 2013). Therefore, in order to meet universal access to affordable, reliable, sustainable and clean electricity access to all by 2030, and combating rural poverty, there is a need of joint efforts by all stakeholders including public, private, civil societies and more importantly, these efforts should be well accepted by the local people (Feron et al., 2016).

5 Conclusion

The results of the research revealed that rural electrification seems like an appropriate means for inducing development effects in society by improving socio-economic conditions and enhancing living standards of rural people of developing countries.

The empirical analysis shows positive effects in reducing drudgery and time-saving, improving public health, increased awareness, avoiding pollutants ($PM_{2.5}$, carbon), and enhanced availability of social services (health, education, ITC, agriculture, etc.), and local job creation. Moreover, an increase in economic activities, improvements in economic status, enhanced social cohesion, and improvements in living standards of rural people are the key determinants of development effects from electrification based on DRE technologies in developing counties like Nepal. Women have more welfare benefits especially in terms of time-saving, reducing drudgery, improvements in health, and involvement in income generation activities.

Despite the low level of the economic situation and less penetration of electricity access in Sudoor Paschim province, the people have shown positive aspects in terms of willingness to pay (affordability), environmental concern, social integrity, and level of living standards more than the rest of the two provinces (Gandaki and Province-1). Thus, it can be concluded that electrification in the off-grid area has been able to increase in economic activities, create local jobs, and access to ICT, which have contributed significant improvements to economic situation of rural people resulting to reduce the poverty, consequently leading towards sustainable development. Additionally, the level of poverty is found to be inversely proportional to electricity access. However, the access to electricity efforts should be embedded with post-construction complementary supports including awareness, training, and fiscal incentives. The results showing the specific magnitude of positive effects before and after the electrification would be certainly beneficial for concern policy-makers in the developing countries for refining future renewable energy policies and strategies.

5.1 Conflict of Interest

The authors declare that there is no conflict of interest.

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