Socio-Economic Impacts of Micro Hydro Power (MHP) Electrification on the Rural Community of Pakistan: A Case Study of Village Lalkoo (Swat) 150 kW MHP Plant

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Reg # 00000275255

Session 2018-2020

Supervised by

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THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS/MPhil thesis written by Mr. **Bilal Ayaz Khan** (Registration No. 00000275255), of U.S.-Pakistan Center for Advanced Studies has been vetted by undersigned, found complete in all respects as per NUST Statues/Regulations, is within the similarity indices limit and accepted as partial fulfillment for the award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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Abstract

One of the most important components of socioeconomic growth is access to energy, particularly electricity. Micro hydro power **(MHP)**, as a green renewable energy source, has gained immense popularity in Pakistan in recent years due to its huge potential. However, there is limited awareness regarding the possible socioeconomic consequences of MHP electrification that must be investigated for the sustainable utilization of this resource. In this study, an existing 150 kW MHP was selected from village Lalkoo (Swat) to determine the socio-economic impacts of MHP based electrification on the targeted rural community. The primary data was collected using a questionnaire-based survey method. Results showed that MHP electrification has an overall positive impact on various socioeconomic elements of rural communities. MHP electrification was found to totally replaced kerosene and candles as the primary illumination source, thereby drastically decreasing their respective expenditures. Moreover, MHP electrification also had a beneficial effect on education with survey indicating significant improvement in children's study hours. Before, there was no power in the village, so residents had to rely on candles, firewood, and kerosene for cooking and lighting. Unlike firewood and kerosene, micro-hydroelectricity produces clean, smoke-free energy. So, health-related difficulties lessened after MHP electrification, according to 75% of respondents. Awareness regarding health issues also increased after electrification.The main soure of knowledge regarding health according to the respondnets was TV. MHP electrification also expanded public access to information and communication technologies. Only 2.2 percent of respondents owned a television before electrification, whereas nearly 60 percent of respondents owned one after MHP electrification. Access to electrification also improved security situation. In terms of economy, the responders' income showed improvement as a result of the MHP installation. However, even after electrification, there was little change in income-generating activities. Overall, the respondents were pleased with MHP's electrical service.

Keywords: Micro hydro power (MHP), electrification, socioeconomic, renewable energy, Pakistan

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ABBREVIATIONS

AEDB	Alternative Energy Development Board
SRSP	Sarhad Rural Support Program
PEDO	Pakhtunkhwa Energy Development organization
PCRET	Pakistan Council of Renewable Energy Technologies
MHP	Micro hydro power
SHPPs	Small Hydro power Plants

CHAPTER 1

INTRODUCTION

1.1 Background

Energy, particularly electricity is worldwide acknowledged as one of the most basic input for financial and social growth[1], [2]. The lack of power in faraway areas of evolving nations has been recognized as a critical element impeding on the road to a quality standard of living[3].Around 1.1 billion people worldwide lives without electricity[4]. Unfortunately, Pakistan is also one of those developing country whose huge population lives without electricity. The country is in a period of change, with growing electricity demand as a result of economic development. The present electric power demand of the nation is 25,000 MW and is predicted to increase to 40,000 MW in 2030[5]. There is an electricity shortfall of 5000-7000 MW in the country[6]. This electricity shortage cause’s severe electricity load-shedding in Pakistan's urban and rural areas. In metropolitan regions, load-shedding lasts about 8- 10 hours, whereas in rural places, it lasts about 18 hour. By 2050, Pakistan's energy need is predicted to be three times higher. According to the International Energy Agency (IEA), Pakistan's electricity requirement would more than triple by 2050, to 49,078 megawatts (MW)[7]. Energy consumption is expanding at a higher rate than energy production[8], [9].

Extensive use of traditional energy resources such as nuclear, petroleum and coal are declining as a result of rising energy demand[10]. Pakistan is a country that massively depends on fossil fuels for its energy requirements[11], [12].The energy mix of Pakistan is dominated by fossil fuels which has a share of 61% in total energy mix. Hydro power has share of 29% while renewable energy has only a share of 6% in the total energy mix as depicted in the **Figure 1.1**. The cost of coal-fired electricity generation is 4.27 R/KWh, high-speed diesel is 13.67 R/KWh, furnace oil is 8.73 R/KWh, gas is 5.35 R/KWh, 1.01 R/KWh, and bagasse is 5.47 R/KWh. Renewable energy sources have no fuel costs[13]. Increased use of these renewable resources will result in annual savings of billions of rupees. The use of these fossil fuels creates greenhouse gases which can harm the environment, ozone layer, ecological community and temperature of the earth[14]–[17]. Fossil fuel is the principal contributor of power generation in Pakistan and as a result of that the electricity sector of Pakistan is the main culprit in contributing to the greenhouse gas (GHG) emissions[18].Not only are fossil fuel-based power plants responsible for CO2 emissions, but they also generate noise, warmth, and unleash Sulphur dioxide (SO2), carbon monoxide (CO), nitrogen oxide (NOx), and particulate matter[19]. Every year, 12,000 people die as a result of air pollution in Pakistan[20]. Renewable energy resources (RERs) on the other hand, have no limits and are noncorrosive[10]. Because of continuous reductions in fossil fuels and the escalating rate of GHG emissions, most countries are moving toward RERs[21]. Hydropower meets 19% of the world's energy demand, which makes hydropower the most key Renewable energy resource (RER) for electricity generation on the planet[22]. Hydropower is a low-cost, environmentally friendly, and renewable energy source[23]–[25]. Modernized hydropower plants have an efficiency of around 85 percent, compared to 50 percent for typical fossil fuel-based power plants[26], [27]. As a result, hydropower is the globes most important clean energy source.

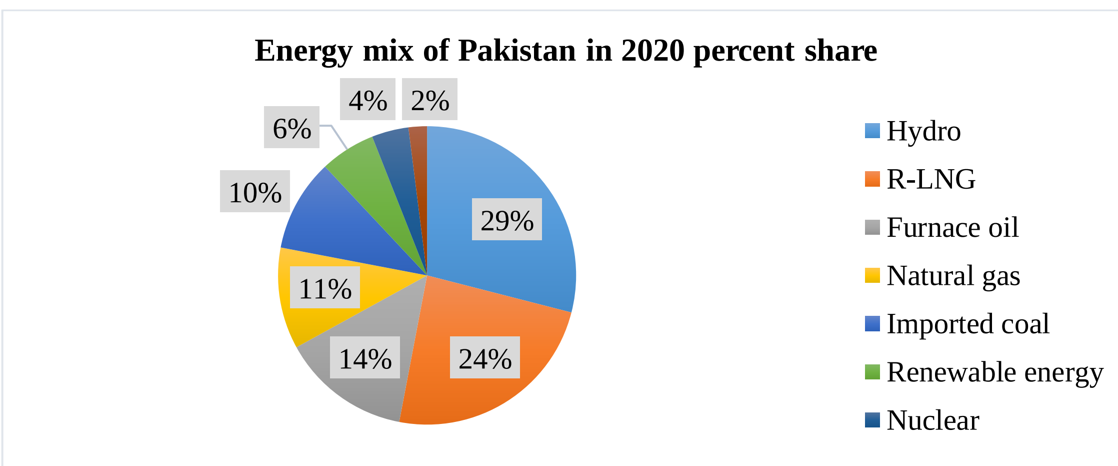

Figure 1.1 Energy mix of Pakistan [28]

1.2. Problem statement

Pakistan is one of those developing countries whose half population lives in rural area and mainly depend on conventional biomass for their energy requirements. In Pakistan nearly

51 million people lives without electricity. Pakistan is also experiencing a critical energy crisis, largely as a result of insufficient electricity inclusion in the energy system. There is consistent gap between the supply and demand. Pakistan is rich of multiple renewable energy sources. Renewable energy generation can be utilized to fulfill the energy demand of the country. Apart from large hydro power Pakistan also has huge potential for micro hydro power. Off-grid villages, isolated and rough places are all benefiting from small and micro hydropower. Micro-hydropower can energize settlements that are far away from the energy grid and near agrarian regions and irrigation canals with a high head. Different government and non-government organization are in charge of inspecting small hydropower in Pakistan. Three of the most popular are Sarhad Program of Rural Support (SRSP) and Renewable Energy Technologies Council of Pakistan and Pakhtunkhwa Organization of Energy Development (PEDO).The provisional government of KPK, through its Energy and Power department, has begun implementing 356 micro/mini hydro projects across 11 districts in the province. There were 356 projects in total, with a total established capacity of 34.7 MW. During the implementation phase, however, 24 MHP were left out because they were neither technically or socially practicable.

In Pakistan there has been little to no research about the impacts of these micro hydro power projects used for rural electrification. As a result, more research into the socioeconomic implications of these micro hydro power installations is required. Cross sectional survey method was adopted to reach the research goal. The core data is gathered through a questionnaire survey in this research, while secondary data is gathered from papers, journals, and organizations that are in charge of implementing these projects in rural areas.

1.3. Research Question

What are the socioeconomic impacts of micro hydro power electrification in rural KPK?

1.4. Objectives

- The main aim of the research is to assess the socioeconomic impacts of Micro hydro power (MHP) electrification in rural community of KPK

- The study also assess the energy sources used for lighting and cooking before and after MHP electrification.

1.5. Motivation

The transition to renewable energy technology is critical in the face of climate change. Pakistan has a lot of potential for micro hydro power. It is unquestionably required to fully harness the potential of micro hydro power in Pakistan to overcome the country's energy problems. Micro hydropower aids people's economic and social development. Micro hydro power's socioeconomic implications in Pakistan's rural communities have received much too little attention. As a result, this study will be conducted in a remote village in KPK to determine the socioeconomic effects of micro hydro power.

1.6. Scope of the study

The current study collects useful data and helps us better understand the socioeconomic implications of micro hydro power electrification. The study focuses on the effects of micro hydro power electrification on education, health, security, ICTs, income, and revenue-generating activities. The study will also evaluate lighting and cooking energy sources before and after electrification. Implementers and policymakers of micro hydro power projects will benefit greatly from this research. It will enable them to plan successfully for future projects.

1.7. Limitations of the study

- The research was restricted to only one village because of limited time and budgetary constraints. It could have resulted in much better generalization of the results if the sample size was larger.
- The study was based on before and after situation with no base line data which is also a limitation in this research.
- A bias in the responses to the questions could be another drawback. Despite the fact that I stated clearly that I am not representing a government agency, respondents may have replied to the preferred option.

1.8. Thesis Outline

Thesis outline is presented in **Figure 1.2** below.

Chapter 1	• This chapter provides background of the research, statement of problem, research questions and goal of the research. • The chapter also provide information about the study limitation and scope.
Chapter 2	• This chapter starts with history of hydropower, it also outlines major types of hydropower. • The chapter also discusses Global and Pakistan hydropower potential. The chapter also reveals status and potential of small hydropower in Pakistan. The chapter also highlight barriers for using small hydro power plants
Chapter 3	• This chapter defines the methodology used in the study. This chapter outline the research instrument used for data collection. The chapter also defines the formula used for sample size calculation. • This chapter also defines the sampling technique used in this research
Chapter 4	• All the results obtained in this chapter are presented in the form of tables and figures and are discussed.
Chapter 5	• This chapter conclude all the research findings • The study also gives future recommendation for upcoming research areas

Figure 1.2 Thesis Structure

Summary

This chapter gives a brief research background. It discusses that Pakistan's energy mix is dominated by fossil fuels. The share of fossil fuel in the energy mix is 61% while that of renewable energy is only 6%. The chapter also discuss the harmful effects of fossil fuels on the environment and health of people. The study's problem statement and objectives are also defined in this chapter. The main goal of the research is to assess the socioeconomic impacts of micro hydro power on a rural community. The research's scope and limitations are also highlighted in this chapter. The limitation of the research as discussed are lack of bassline data and secondly because of limited time and budget constrains the research was restricted to only one village as discussed in the chapter 1 above.

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CHAPTER 2
LITERATURE REVIEW

2.1. Overview of Hydropower

2.1.1. History of Hydropower

The wooden waterwheel was the first source of hydropower. Waterwheels of various designs had been used for milling grain in numerous parts of Europe and Asia for over 2,000 years. Waterwheel technology had progressed to the point where, by the time of the technological turn over, efficiencies of up to 70% were being obtained in the many tens of thousands of waterwheels in use. Modern turbines were developed as a result of improved engineering abilities in the nineteenth century, as well as the necessity to produce smaller and faster machines to generate power. Benot Fourneyron, who dubbed his device a hydraulic motor, designed the first hydro-turbine in France in the 1820s. Many mills began to replace their waterwheels with turbines around the end of the century, and governments started to review how hydropower can be utilized for substantial power generation. The first half of the twentieth century was the golden age of hydropower, before oil replaced it as the primary source of energy. Dams and hydropower stations were erected at a quick pace in Europe and North America, utilizing up to 50% of the theoretically possible capability. Hundreds more equipment vendors sprang up to meet the demands of this burgeoning market. While large hydro producers have maintained their work on export markets, specifically in evolving nations, production of small hydro has been on slip since the 1960s.Limited nations (notably Germany) have raise this division in current years with appealing policies supporting "green" electric power supply[1].

2.1.2. Major Types of Hydropower Plant

Hydropower is classified into four kinds.

- Run of river
- Storage (reservoir) based

- Pumped storage
- Instream technologies hydrokinetic

Hydropower plants can also be classed by size (Micro small, Pico, big) and head (medium, low and high), however due to differing policies in different nations, there is no direct agreement on plant size (established capacity, MW) or head classification. Size classification is straightforward, but it is irrational to some extent: terms like "little hydro" and "big hydro" are not scientifically or practically correct measure of effects, economics, or other qualities[2]. Hydropower projects range in size from 1kW to megaprojects like China's Three Gorges, which has a 22.5-GW established capacity (22,500,000kW) and generates 93.5 TWh per year[3].

2.1.2.1 Run of River Hydropower Plant

A Run-of-river power plant is one that has no or limited water storage and produce energy from the river's available motion. Short-term storage, or pondage is sometimes included in such facilities, with storing extent spanning from daily variability to limited hours in changing production to the required profile. If it is part of a cascade, the generating depiction will be mostly governed by Natural River discharge state or circulate it from upstream storage. Unavailability of upstream reserves or pondage, production is solely dependent on discharge, which can vary significantly on a daily, monthly, seasonal, and yearly basis[4].

2.1.2.2. Hydropower facility with storage

Hydropower with storage include a reservoir and a dam to hold water, which is saved and ejected as required. Reservoir water provides the mobility to generate electricity on need and minimize dependence on inflow irregularity. Large reservoirs can contain inflow for years, but they are typically built for transient storage to provide water during dry periods. Hydropower with storage are more adjustable compared to run-of-river plants and can be used to generate both baseload and peak load electricity due to their capacity to shut down and restart instantly, depending on power system demand. Storage reservoirs are continually established as multipurpose scheme because of their capability to handle water movement, giving other benefits such as control of surge, water discharge, irrigation, navigation, and recreation. The capability to store considerable quantity of energy and adjust to varied load requirements, from day peaking to seasonal and weekly variations, is the fundamental benefit of hydropower plants with storage. Reservoirs like these are becoming progressively useful and precious for storing energy from renewables[4].

2.1.2.3. Pumped- Storage Hydropower Plant

When electricity generation surpass the requirement, water is pumped from a lower reservoir into an upper reservoir and if the demand is more than provision then water is discharge from upper reservoir through turbines in a hydropower with pumped-storage (PSH) system. Natural inflow to the higher reservoir may be possible in some PSH projects, increasing generation. The water capacity stored in the higher reservoir and the height distinction among reservoirs are directly correlated to the energy stored in a PSH. PSH had commonly been utilized to provide peaking power during the day, allowing large fossil and nuclear facilities to operate close to steady load. PSHs have the added benefit of being able to interface with other inconsistent clean energy sources. PSHs can store the surplus energy in times of high wind and high insolation, making it accessible for instant release when other variable power sources are lacking[4].

2.1.2.4. Instream (hydrokinetic) Hydropower Plants

The motion of water in rivers and canal can be utilized to produce in-stream energy. Conventional hydropower facilities depend on the height differentiation between the intake and outlet. Hydrokinetic plants are located straight in the motion of water, and energy is obtain utilizing turbines. The main difference among ocean and river current is that river currents are one-way. The kinetic energy in moving water is shifted to mechanical power, and then it is utilized to power a generator and produce electricity. As a result, no dams and head difference is required for the functioning of this plant, and the river's natural channel is preserved. Only a few of these power facilities are functioning in rivers so far, but they show an intriguing substitute for collecting energy from the vast number of canals where typical low-head HPPs are unable to operate[4].

2.1.3. Classification of Hydropower According to Size

Small, large and medium (Pico, mini and micro) hydropower plants are the most common classifications for hydropower facilities based on their established power generation capacity. Large hydro is defined as a power plant with a generating capability of more than 50 megawatts (MW). Medium-hydro are those with an installation capability of between 50 MW and 10 MW[5]. Small hydro has yet to be defined worldwide; the highest range varies between 2.5 and 25 megawatts. The most frequently acknowledged number worldwide is a maximum of 10 MW; however, China's official definition is 30 MW. Mini plants often refers to projects with a capability less than 2 MW, micro-hydro below 500 kW, and pico-hydro less than 10 kW, according to industry jargon. Many of the ideas involved apply to both bigger and smaller facilities, therefore these are unpredictable divides[1].

2.2. Global established capacity and generation of hydropower in 2020

The **Table 2.1** below depicts the global status of hydro power. The highest capacity is available in East Asia and pacific. Then followed by Europe with the second highest established capacity which is 254,454. The region with the least established capacity is in Africa. Overall the world total established capacity is 1,330,106 megawatt. While the total generation is 4,370 Twh.

Table 2.1 Global established capacity and generation of hydro power in 2020 [6]

Region	Established Capacity (Megawatt)	Generation (Twh)
South and Central Asia	154,421	498.11
Africa	38,174	139.54
East Asia and pacific	501490	1643
South America	176,757	690
Europe	254,454	674
North and central America	204,811	724
World (Total)	1,330,106	4,370

2.3. Hydropower Potential in Pakistan

Pakistan has 60,000 MW of hydropower potential[7], which is dispersed throughout the country. The **Figure 2.1** depicts the province by province hydro power potential[7]. Hydro power is present in six locality of Pakistan namely[8]

- Khyber Pakhtunkhwa (KPK)
- Gilgit-Baltistan (GB)
- Punjab
- Azad Jammu Kashmir (AJ and K)
- Sindh
- Balochistan

The hydro power Potential is led by KPK and GB.KPK has the highest potential of 24,736 MW[7]. KPK has 142 hydropower potential sites with varying head. 19 of these 142 projects are operational, 27 are in the implementation phase under the public sector, 11 are in the implementation phase under the private sector, 81 raw sites have been identified, and 4 solicited sites have been identified. In Punjab province, approximately 330 potential sites are present. The total capacity of which is 7291 MW. Only 8 of these 330 facilities are functioning, with a total capacity of 1699 MW. In AJ and K, 68 hydropower sites totaling 6450 MW have been identified. Majority of these sites location lies in river Jhelum and river Poonch[7].

In GB, 278 plant sites with an overall capacity of 21,125 MW were determined with varying heads. With an overall capacity of 133 MW, 98 projects were operational. In Sindh, 18 sites have been determined with an overall capacity of 193 MW. Balochistan province has not a great amount of hydro power potential. The total hydro potential of Balcohistan is 0.50 MW[7].

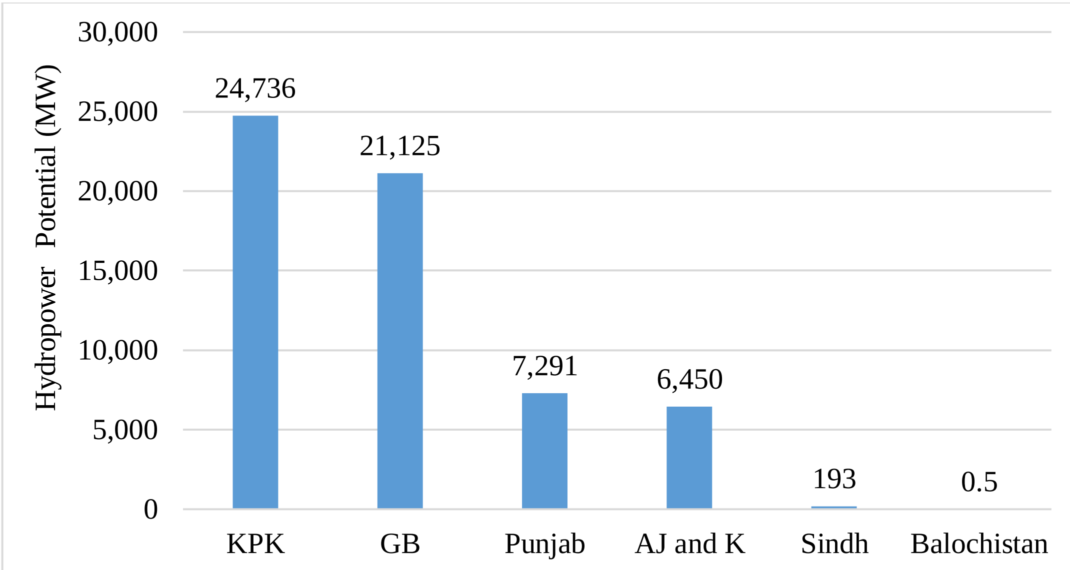

Figure 2.1 Province wise hydro power potential[7]

2.4. Major Hydropower Projects in Pakistan

The **Table 2.2** below shows the major hydro power projects established capacity in MW as on 30th June 2020.

2.5. Small/Mini/Micro Hydropower Potential in Pakistan

Aside from large hydropower, there are clear opportunities to establish mini/small/micro hydropower projects. Small hydropower is regarded as one of the most profitable ways to produce electricity. Like large hydro power Pakistan also has great potential for micro hydro power. The **Table 2.3** [10] below shows the province wise potential of micro hydro power. Small hydropower is typically managed by provisional governments. There are different government and private organization involved in taking care of these small hydro power plants. Three of the most popular are Sarhad Program of Rural Support (SRSP) and Renewable Energy Technologies Council of Pakistan which are private organization and Pakhtunkhwa Organization of Energy Development (PEDO) which is a government organization.

Table 2.2 Major hydro power projects in Pakistan as on 30th June 2020 [9]

Power plant	Area	Type of facility	Installed capacity (MW)
Tarbela	Tarbela,KPK	Reservior	3478
Chashma	Chashma,Punjab	Runoff river	184
Tarbela 4th Ext	Tarbela,KPK	Reservior	1410
Khan khwar	Shangla KPK	Reservior	74
Ghazi Barotha	Ghazi,Punjab	Runoff river	1450
Allai khwar	Battagram,KPK	Resrvior	121
Mangla	Mangla,AJK	Reservior	1000
Jinnah hydel	Mianwali,Punjab	Runoff river	96

Table 2.3 Potential of Micro hydro power in Pakistan[10]

Area	**Potential sites**	**Capacity range (MW)**	**Overall capacity (MW)**	**Source type**
G.B	200	0.1-38	1300	Natural/falls
Sindh	150	5-40	120	Canal
AJ &K	40	0.2-40	280	Natural/falls
KPK	125	0.2-32	750	Natural/falls
Punjab	300	0.2-40	560	Canal

2.6. Small/Mini/Micro hydropower projects in Pakistan

Public as well as private sectors are striving hard to establish SHPPs across Pakistan. In the range of (5-100 Kilowatt) Renewable Energy technologies Council of Pakistan (PCRET) installed 678 SHPPs [11]. **Table 2.4** below lists the plants that PCRET has installed. SRSP has also played a key role in uplifting the rural communities. SRSP has completed 353 micro hydro projects with a total generation capacity of 29 MW and almost 927,495 people benefit from these projects[12]. The provisional government of KPK, through its Energy and Power department, has begun implementing 356 micro/mini hydro projects across 11 districts in the province.

Table 2.4 SHPPs installed by PCRET[11]

Area	Total SHPPs Installed	Established power in (Kw)	Electrified homes
KPK &Fata	553	8239.5	65,337
AJ &K	50	786	4758
Baluchistan	3	80	800
Gilgit	72	401.5	4010
Total	678	9507	74,905

There were 356 projects in total, with a total installed capacity of 34.7 MW. During the implementation phase, however, 24 MHP were left out because they were neither technically or socially practicable. As a result, the total number of projects was amended to 332, with a total capacity of 32.5 MW[13]. The **Table 2.5** below shows the detail of project by PEDO. The interim administration of KPK is utilizing another six micro hydro projects with an overall capacity of 118 MW, while the Punjab local government is working tirelessly to implement four micro hydro projects having an overall capacity of 20 MW. With a wealth of experience and knowledge, plants are believed to finish with in due time[14], [15].

Table 2.5 Implementation status as of September 2021[13]

District	Total number of sites	Completed sites	Under construction
Buner	18	17	1
Chitral	54	54	0
Battagram	58	58	0
Swat	45	45	0
Abbottabad	15	15	0
Shangla	25	25	0
Upper Dir	49	37	12
Kohistan	35	33	2

2.7. Hurdles in Using Small hydropower Plants

In spite of the fact that various hydro sources have been identified in Pakistan that can contribute significantly to the production of electric power, there are a number of obstacles that are preventing or delaying the spread of SHPPs. These include a plan and monitoring framework, funding, policies and regulations for SHPPs, a lack of hydro resource data, and societal hurdles.

2.7.1. Plan and Monitoring Framework

The lack of a plan and monitoring structure is a key impediment to adopting SHPPs. In this respect, there are frequently inadequate designs and structures that can effectively govern SHPP projects[16]. Because of the insufficient regulatory framework, the manufacturer lacks sufficient knowledge of the SHPP design and structural requirements that should be implemented, and must work in an irregular regulatory environment[17].

2.7.2. Funding

The lack of enough funds to boost the SHPP business is a widespread issue. Because the SHPP business is reliant on available money, the money are typically assigned to a specific town and area, which is insufficient to alleviate the country's energy needs[18]. However some members of the local community also spend money on building of a SHPP(less than 1 MW), revenue creation is an affirmative step towards growing the SHPP business[19]. Another option is to seek alternative funding sources, such as encouraging private investors to spend money in this area[16].

2.7.3. Policies for Regulation of SHPP

Rural electrification is impossible without a thorough understanding of SHPP's capabilities. Political decision-makers are primarily interested in seeable large hydropower systems, and they are uninterested in developing, improving, and implementing legislation and regulations to promote SHPPs[20]. On the technical side, there is never a strategy for constructing and running SHPPs. The lack of economical turbine and generator is a stumbling block to the rapid and economical establishment of a SHPP project. For the durable growth of this industry, it is vital to make SHPP-related machinery available at a reasonable cost across the country[21].

2.7.4. Lack of Hydro Resource Data

The lack of data on hydro resources, such as seasonal variations in river and stream flow, energy consumption, geology, and geography, is one of the challenges to the development of SHPPs[22], [23].

2.7.5. Societal Hurdles

One of the most significant obstacles to the SHPP is local community resistance. One of the causes is a quarrel over the sharing of water resources between upstream and downstream villages. Another prevalent reason is that the majority of the residents refuse to let the local distribution line to cross through their property[24].

2.8. Micro hydro power socioeconomic impacts

Anup Gurung[25] conducted a case study in village Tangting where the main objective of the study was to access the socioeconomic impacts of MHP. Questionnaire was used to gather information from the respondents. 150 household were selected randomly. The findings of the study revealed that MHP had a positive impact on health, education and income. There were also positive environmental benefits observed as a result of MHP in the village. The health of the respondents were improved as a result of MHP electrification. Major health problems were decreased drastically. There were also major reduction reported by the respondents in terms of firewood, dung and kerosene. Dung and kerosene usage were decreased by 100%. There was also significant work load reduction for women after MHP installation. Education was also effected positively after MHP installation. Reading hour of children improved as a result of electric light.

The study was conducted Sikles [26] and the main goal of the study was to measure the socioeconomic impacts of MHP plant in a remote village located in Nepal. Structured questionnaire were used and household selection was done randomly. The findings of the study showed that electrification has positive impacts on rural people living. The usage of kerosene lamp was entirely discarded. Significant reduction were also seen in firewood consumption. Extra reading and working hours were provided thanks to electric lighting which extended the day for respondents. There was significant work load reduction reported for women.

As, MHP electrification aids people economic and social development. However, in Pakistan there has been little to no research about socioeconomic implications of these MHP used for rural electrification. Majority of the studies in Pakistan focuses on the technical side of MHP [27]–[30]. So the main motivation of this paper is to close this gap by addressing this key aspect which has remained unanswered in Pakistan. We are optimistic that the results of this study will be of great importance to those researchers in Pakistan who are keen to understand the socioeconomic impacts MHP electrification on rural people. The implementers and policy makers of MHP projects will also benefit greatly from the results of this research. It will enable them to plan successfully for the future projects.

Summary

This chapter covers a wide range of topics about Hydro power. The chapter starts with the History of hydro power. The chapter also discusses major types of hydro power. Classification of hydro power according to size is also discussed in brief in this chapter. It also shed some light on the global hydro power potential. This chapter also discusses the potential of hydro power in Pakistan. It also lists down the major hydro power plants in Pakistan. It also gives a brief overview of small/mini/micro hydropower projects. The chapter also discusses the challenges for using SHPPS. The chapter also discusses the socioeconomic impacts of MHP.

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CHAPTER 3

RESEARCH METHODLOGY

3.1. Survey

Cross sectional survey method was adopted in this research. Surveys are extremely important and fundamental aspect of experimental study related to social science focused energy analysis. Structured questionnaire were used to conduct survey. The questionnaire was constructed based on available literature [2]–[5]. The questions in the questionnaire were mostly close ended. With close ended questions one can obtain numerical information [6]. The questionnaire had a total of 38 questions which addressed a variety of socioeconomic and demographic areas. Likert scale questions were also part of the questionnaire. Likert scale is a type of scale which shows the level of agreement (which can range from strongly disagree to strongly agree) of the respondents[7], [8]. It took 30-35 minutes to complete the questionnaire. The questionnaire was pretested on thirty respondents before the full scale study. Pretesting the questionnaire is extremely important it can help modify the questionnaire and highlight mistakes in the questionnaire[9].

3.2. Sample Size and Sampling Strategy

A sample is a statistically selected part of a population about which the researcher wants to make observations and draw statistical conclusions. The best possible sample is that which can fully fulfill the requirements of representativeness, adjustability, efficacy and dependability. It is very important for the researcher to determine a suitable margin of error and an adequate level of confidence when calculating the sample size. When deciding on the sample size for a research study, keep the criteria of interest in mind. When determining the sample size, budgetary restrictions must always be taken into account[10].

In this study the sample size is calculated using the Taro Yamane formula[11]. The confidence interval chosen for this study is (95%) and the margin of error is (5% =0.05).

$$n = \frac{N}{(1+Ne^2)} \quad (1)$$

Where,

n= sample size

N= total population

e= margin of error (0.05)

The total number of household connected to micro hydro power were 206.Based on the above formula the sample size of my research was 136.

After calculating the sample size simple random sampling was the sampling technique used to choose the household head. The participant were chosen using simple random sampling which is the most fundamental type of probability sampling technique where each unit of population has an equal chance of being included in the sample[12]. The data was collected by means of questionnaire which was conducted face to face with the head of the household. If the person was unavailable or unable to respond, another member of the household was asked to complete the questionnaire.

Excel was used to draw a random sample. First the list of the household head was obtained from the village head which was our sampling frame. The household head list was entered into excel and in the next column random numbers were generated using rand () formula in excel. Based on this formula random numbers were generated for each household head. Then after generating the random numbers the random numbers were sorted and the required sample was obtained.

3.3. Types of Data

There were two categories of data in this study primary and secondary data. The respondents' primary data was acquired using a questionnaire survey. Each respondent was informed about the study's goal and significance before the primary data was collected. Secondary data was gathered for this study via reports, journals, and organizations in charge of implementing these projects. Data has three main measure that is nominal, ordinal and measurement (The measurement type data include ratio and interval data)[13]. This research has used all these three types of data.

3.4. Data Analysis

The data analysis was analyzed in Statistical Package for Social Sciences (SPSS, version 23). The data collected from the respondents were coded in SPSS. SPSS is very efficient for examining the information of the surveys[14]. The data is entered in the SPSS using the window Data view. The Data view consist of rows and columns. The columns include the number of participants and the rows include the number of variables in your study[15]. The analysis was carried out by opening the software's analyze window and selecting the descriptive statistics option. Descriptive statistics simply interpret the material in the form of graph and numbers[16]. Descriptive statistics is the best possible method for compiling quantitative information [17] .The information gathered was examined using frequency, percentages, and averages. Tables and graphs were used to present the information.

3.5 Study Area

The study was administered in district Swat which is located in the north of Pakistan. Saidu Sharif is the HQ of Swat. The total population of district Swat is 1.26 million [18], [19]. The rain fall on average in the district swat spread from 1000 -1200 mm yearly[20], [21]. The population of the Swat is widely dependent on natural resources such as agriculture and forestry[22], [23]. Agriculture is one of the principal source of income and 42% of the respondents are employed in agricultural activities[24]. Swat is a forested zone and plays a vital role in the livelihood of these locals. Majority of the people are reliant on these means for fuel wood and fodder[25]. The village selected in district swat for our research was Lalkoo. The village is reachable by about 26 Km from the main town of Matta[26]. Lalkoo village is in the wet temperature territory and hence has snowfall in the winter and also monsoon in the summer. Two of the most common class are Miangan and mirokhel. Agriculture is the principle income source in the village. The fuelwood demand of the residents are met from forests which put an immense amount of pressure on them to meet the requirement of these locals[26]. In the community, a 150 KW micro hydro power plant has been erected. Rupees (RS) 40 million were spent on the project. PEDO and SRSP were in charge of the project's development and implementation. In

August of 2016, the project began. The household are charged a fix monthly tariff of RS 300. The MHP operates for approximately 22 hours every day.

Summary

This chapter discusses the complete methodology used in this research. This chapter reveal the type of research instrument used for primary data collection. The chapter also discusses the types of questionnaire and survey method used in this research. The chapter also reveal the formula used for sample size calculation. Apart from this it also give a brief detail about the study area selected for this research and also gives details about the project erected in the study location. It also discusses the sampling procedure used for the research. Simple random sampling procedure was the approach used in this research. The chapter also mention how the random sample was obtained by using excel. It also highlight how the data was entered into the software by using the data view window. It also mention the type of analysis and graphical representation of the data. Descriptive statistics was used in the research and the data was presented in the form of graph and tables.

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CHAPTER 4

Results and Discussion

4.1. Demographic Analysis

In our survey, 66.2 percent of respondents are male and 33.8 percent are female. 34.6% of respondents in our study were in the age of 42-52. Almost 88% of the respondents in our study were married. 36 percent of the respondents have a family in the range of 6-7. Only 13.2% of the respondents have a family size in the range of 2-3. Almost 27% of the respondents were farmer by occupation. While 25% of the respondents were involved in business. 12.5% of the respondents were daily wagers. 57.4% of the respondents had 3-5 male children in their household while 52.9% of the respondents had 3-5 female children in their household. **Table 4.1** illustrate the demographics of the respondents.

Table 4.1 Demography of respondents

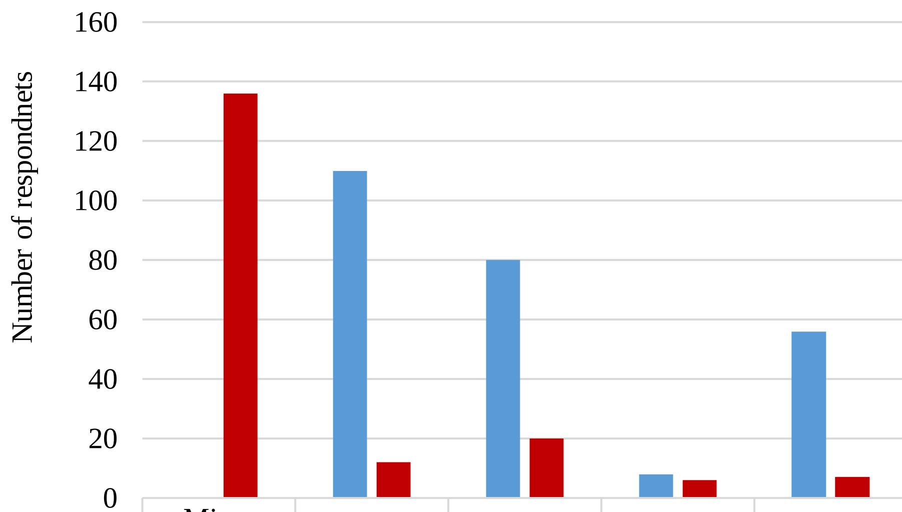
Variable	Description	Frequency	Percentage
Gender	Male	90	66.2
	Female	46	33.8
Age of respondent	<20	9	6.6
	20-30	18	13.2
	31-41	28	20.6
	42-52	47	34.6
	>52	34	25

Respondent marital status	Married	119	87.5
	Unmarried	17	12.5
Household size	2-3	18	13.2
	4-5	43	31.6
	6-7	49	36
	7 plus	26	19.1
Occupation	Farmer	36	26.5
	Business	34	25
	Shopkeeper	8	5.9
	Govt servant	7	5.1
	Daily wager	17	12.5
	Unemployed	1	0.7
	Housewife	33	24.3
Male children	0-2	53	39
	3-5	78	57.4
	5 plus	5	3.7
Female children	0-2	63	46.3
	3-5	72	52.9
	5 plus	1	0.7
Elderly male	0-1	101	74.3
	2-3	34	25
	>3	1	0.7
Elderly female	0-1	93	68.4
	2-3	43	31.6

4.2. Fuel Choice for Lighting and Cooking Before and After Electrification

The most prevalent usage of electricity among the responders was for lights. **Figure 4.1** shows the lighting sources used before and after the MHP was installed. There has been a significant shift in the energy sources used for lighting after electrification. The traditional sources of energy for lighting has been replaced by clean and smoke free electricity. Kerosene and candles were the primary sources of lighting in the village prior to MHP. Kerosene, candles and firewood were only used as backup after MHP installation. Prior to having access to MHP 110, households relied on kerosene for lighting. However, just 12 households used kerosene as a lighting source after being given access to MHP. Prior to the installation of the MHP, 56 homes relied on firewood for lighting. Only 7 households used firewood as a source of lighting after MHP electrification. Similarly, before MHP installation 80 household used candle prior to the installation of the MHP, but after MHP only 20 household used it as lighting source. The lighting provided by electricity is far superior over other sources. The light provided by a light bulb has a clear advantage over a candle light. Candle light is not efficient enough to light up the room and lack the ability of providing effective lighting which will allow more than one reader to read at night[1], [2]. The findings show that MHP electricity has totally replaced kerosene, candle, and firewood as the primary energy sources. These results are in line with the study conducted in Rwanda that after access to solar home system (SHS) respondent's primary source of illumination was SHS. Before access to SHS 116 respondents relied on kerosene but after access to SHS only 2 respondents used kerosene. Similar situation was also noticed in the consumption of candles before access to SHS 99 respondents relied on candles but after access to SHS only 10 respondents used kerosene as an illumination source[3], [4]. Respondents of the study area did not use these tradtional energy sources before having access to MHP because of their dependability rather they used it only because of their avaliability.

However, unlike lighting sources, there is little evidence of the same movement in cooking fuels, implying that having access to a modernized electric power does not imply having access to modernized cooking fuels as well. When compared to alternatives, firewood is the most widely used because of its easily available and also free of cost. The **Figure 4.2** below shows that the primary source for cooking in the village was fuel wood. Fuel wood was primarily used for cooking before and after electrification. It is evident from the figure that all the respondents relied on fuel wood for their cooking purpose even after MHP electrification. Before MHP installation 136 household used fuel wood as their cooking fuel and after MHP installation 134 homes used fuel wood as their cooking source. There was a significant shift in the case of lighting from kerosene and candles to electricity but in case of cooking there is no shift from fuel wood to electricity. These results are similar to a study conducted in Rwanda where firewood remained as the principal source of cooking even after having access to SHS [3]. Therefore, electrification did not have any impact on shift from fuel wood as a primary source of cooking to electricity.



	Micro hydro power	Kerosene	Candles	Generator	Firewood
Before Electrification	0	110	80	8	56
After Electrififcation	136	12	20	6	7

Figure 4.1 Fuel choice for lighting before and after MHP installation

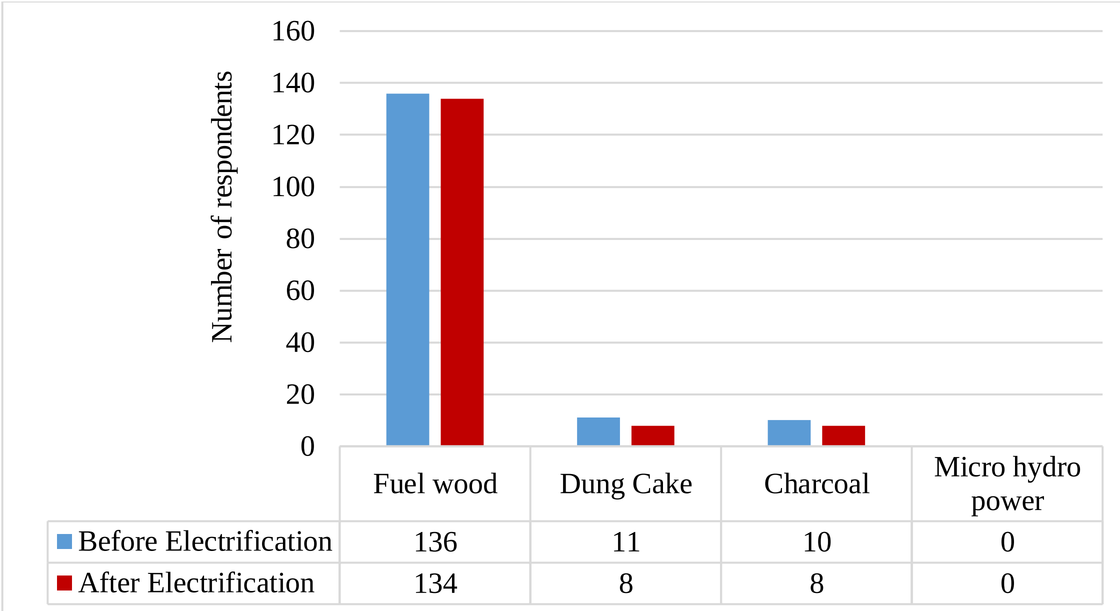


Figure 4.2 Fuel choice for cooking before and after MHP installation

4.3. Impact on Kerosene and Candles Expenditure

The reduction in expenditure on supplemental sources as a result of the quitting of kerosene and candle use is one of the most significant effects. Before MHP installation kerosene and candles were the primary fuel used for lighting. However, after installation of MHP there was major shift from kerosene and candle to electricity as the primary source of lighting which was supplied by MHP. According to 75.7 percent of the respondent energy expenses decreased thanks to MHP electrification. In terms of money spent on kerosene after MHP was also significantly reduced. It can be seen in the below **Table 4.2** that before MHP installation fifty two people spend in the range of 400-600 RS on kerosene per month and after MHP installation only two people spend 400-600 RS per month on kerosene. This means that people were able to save money in terms of spending on kerosene per month. Electrification reduces expenditure on kerosene. These results are similar to study conducted in India. The study findings shows that before PV lighting. majority of the respondents spent on kerosene in the range of INR 80-150 per month but after PV lighting there was a significant reduction in kerosene expenditure per month where majority of them spent in the range of INR 30 per month[5].

Table 4.2: Expenditure on Kerosene and candle per month before and after MHP

Category	**Expenditure in PKR**	**Frequency**	
		Before	**After**
Kerosene	0-200	3	7
	200-400	13	3
	400-600	52	2
	600-800	24	0
	800-1000	15	0
	>1000	3	0
		Before	**After**
Candle	0-200	25	18
	200-400	45	2
	400-600	10	0

A study conducted in Bolivian communities also reported 54% reduction in energy expenditure that is on candles and kerosene[6]. A study conducted in communities of Hispaniola also reported significant reduction on expenditure of kerosene. Before access to electricity they spend US$ 12-30 per month on dirty fuels but after access to electricity they spent US$ 3-6 per month resulting in saving in terms of expenditure on kerosene[7].MHP also reduced the expedniture per month on candles. Before MHP installation forty five people spend in the range of 200-400 Rs per month and after MHP installation only two people spend in the range of 200-400 Rs per month as depcited in the **Table 4.2**. So,electrification also plays a postive role in reduction of expedniture on candles. These results are in line with [6], [7]. So overall MHP installation results in saving on lighting.This is also suggested by[8].

4.4. Electricity Usage

Electricity is commonly used for lighting in the study area. According to all of the respondents, they use electricity mainly for lightning purpose as depicted in **Figure 4.3**. Charging mobile phone was the second most common use of power. Electricity also increased access to information and entertainment appliances. Households can watch TV thanks to electricity, and members can take pleasure in watching current news and entertainment shows. 81 respondents indicated that they use electricity to watch TV, as depicted in the **Figure 4.3** below. Very few number of consumers used electricity for their shops. These results are more or less similar to a study conducted in Pangan-an Island in Philippines where the most common use of electricity was for lighting. 100%

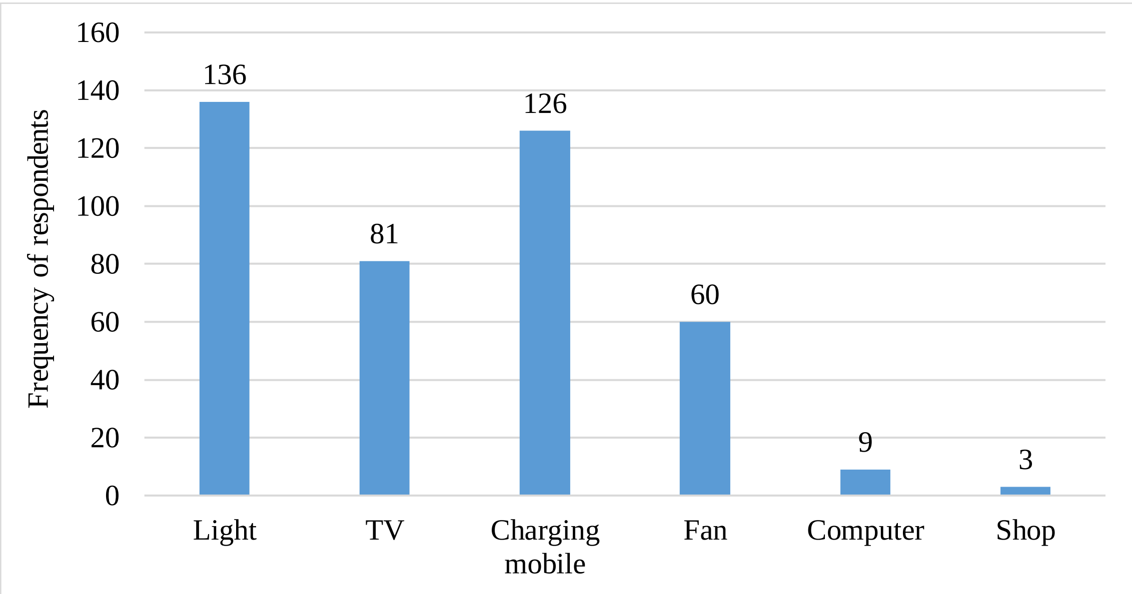


Figure 4.3 Usage of electricity

users used electricity for lighting. More than 50% users watched TV for entertainment. Similarly only a small number of users used electricity for their businesses[9]. A study conducted in Bangladesh also reported that the most common use of electricity provided by SHS was for illumination. 100% users used electricity for lights. Similarly 85% of the respondents reported that they used electricity for charging their mobile phone. While 41% respondents used it for watching TV[10].

4.5. Impact on Education

Village electricity has a noteworthy effect on youngster's education. Traditional kerosene light which was ineffectual and harmful to children's health was replaced by clean, bright, and economical electricity. Micro hydro systems have benefited students by giving them more time to study. Electrification increased the study hours of children. Prior to electrification majority of the children studied in the range of 1-2 hours but after electrification it changed from 1-2 hours range to 3-4 hours range as show in the **Figure 4.4**. 83.8% of the respondents agreed that children can study more hours after MHP electrification. These positive results are also shown by a study conducted in India. Before PV lighting majority of the children study in the range of 0-2 hour. But after PV lighting most of them studied in the range of 2-4 hours [5]. The positive results of electricity on the study time of children is also shown by a study conducted in Madagascar. The study shows that children with electricity spend more time on home work than children without electricity[11]. Furthermore we asked respondents about their opinion in a Likert scale question. 90.4% of the respondents agreed that electricity is very important for children education. Only 3.6% participant did not agreed with the statement. These positive results are similar to a study conducted in Philippine where 97.7% of the respondents agree that electrification is important for children education[12]. While households can watch television as a form of pleasure thanks to electricity therefore we asked respondents about whether television hamper study time of children. 76.5% of the respondents disagree with the statement that television hamper study time of children as depicted in the **Figure 4.5** Only 7.3% of the respondents agree with the statement. This is similar to study conducted in Bangladesh where 79% of the respondents disagree with the statement that television can hamper study time [4], [12]. So micro hydro electrification does have some positive impact on education and it is suggested by [8], [13]

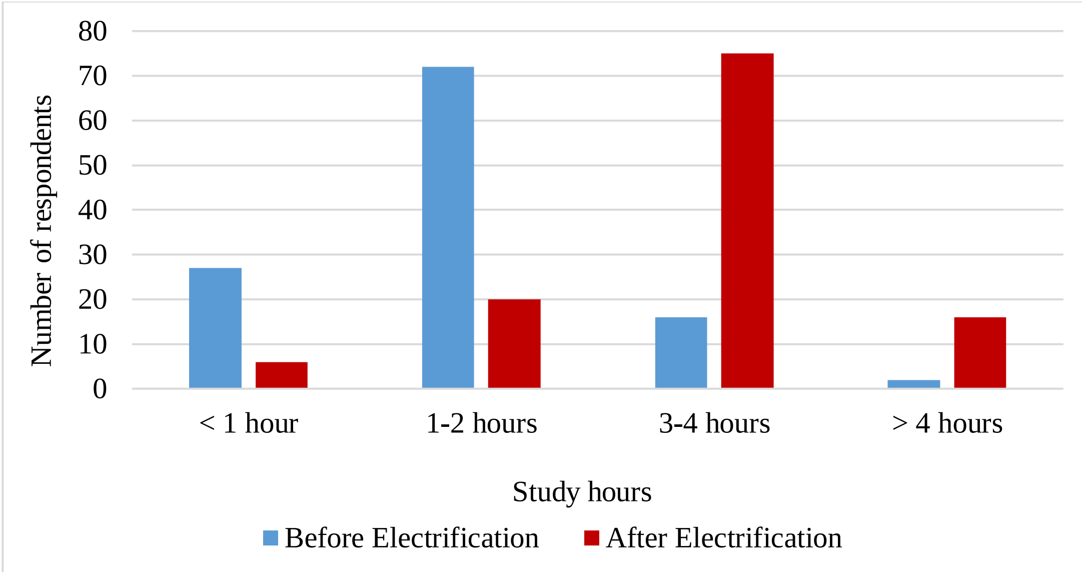


Figure 4.3 Study hours before and after MHP installation

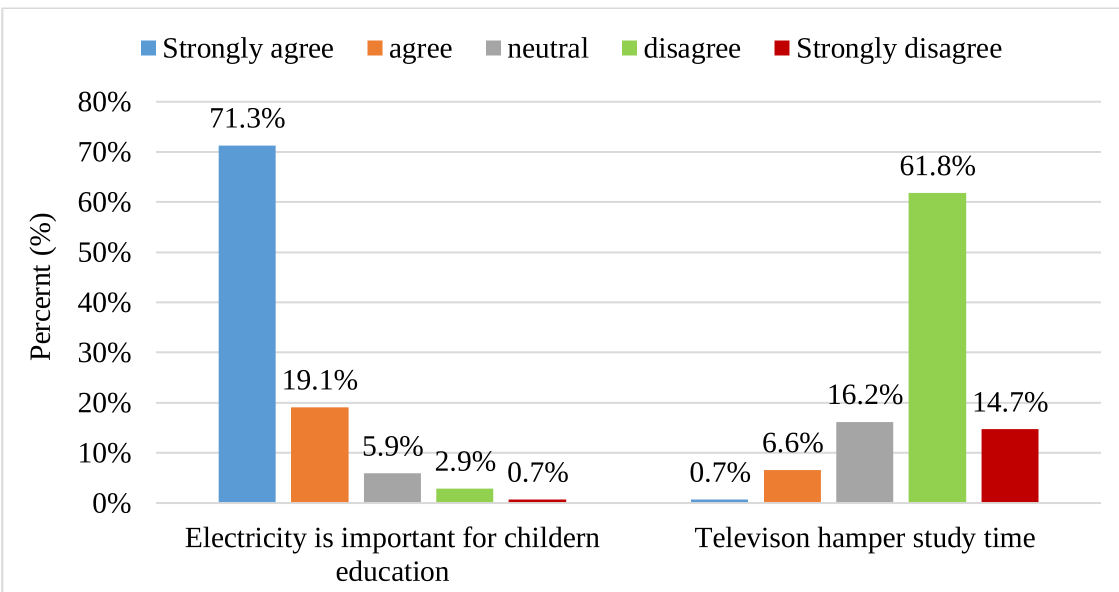


Figure 4.4 Respondents opinion on impact of electrification on children's education

4.6. Impact on Health

Before, there was no power in the village, so residents had to rely on firewood, candles and kerosene for cooking and lighting. The availability of affordable power, has considerably benefited the town. Unlike firewood and kerosene, micro-hydroelectricity produces clean, smoke-free energy. As a result, installing an MHP plant aids in the reduction of indoor air pollution, lowering the prevalence of visual and respiratory disorders. The respondents were asked if they thought health-related difficulties have lessened as a result of electrification. Health-related difficulties lessened after MHP electrification, according to 75% of responders as shown in the **Figure 4.6**. This is in line with the study conducted n in Bolivia and Philippines where the health related issues were significantly reduced. 75% of the respondents agreed that they now have less health related issues after MHP electrification[8]. Micro hydro power replaced kerosene as a lighting source which has a negative impact on air and blasts[14], [15].We also asked respondents about electrification impact on health care services.61.8% of the respondents agreed that health care services were improved after electrification. So electrification improves health care services. These positive results are similar to a study conducted in Afghanistan where 59% of the respondents reported that health care services were improved after electrification[16], [17].Awareness regarding health issues also increased after electrification according to 64.7% of the respondents. This result is in line with study conducted in indian village where electrification has increased lnowldege about

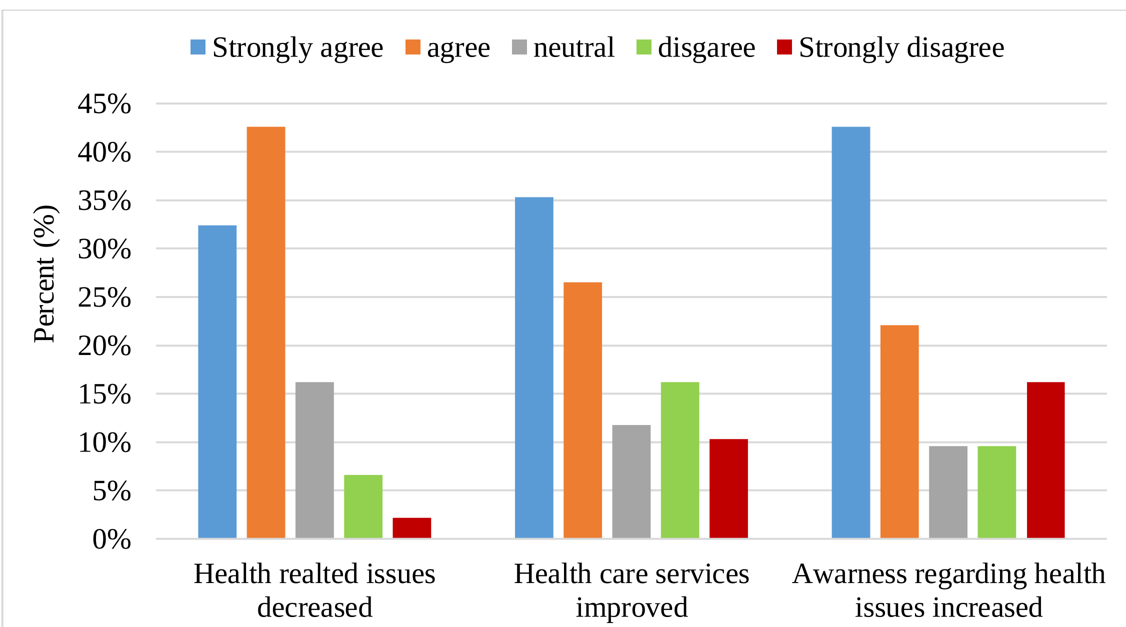


Figure 4.5 Opinion of respondents related to health

health realted issues. 70% of the respondents think that there knowledge regarding health issues increased[18]. The main soure of knowledge regarding health according to the respondnets was TV as shown in the **Figure 4.7**. So, Television has a significant impact on the health knowledge sector. It is also suggested by [19] where electrified household are more aware regardig health issues as compared to not electrified. This is also show in a study conducted in Bangladesh where SHS system increased access to TV. By having TV in their home 57% of the respondents reported that they watch TV to get up to date news[20].

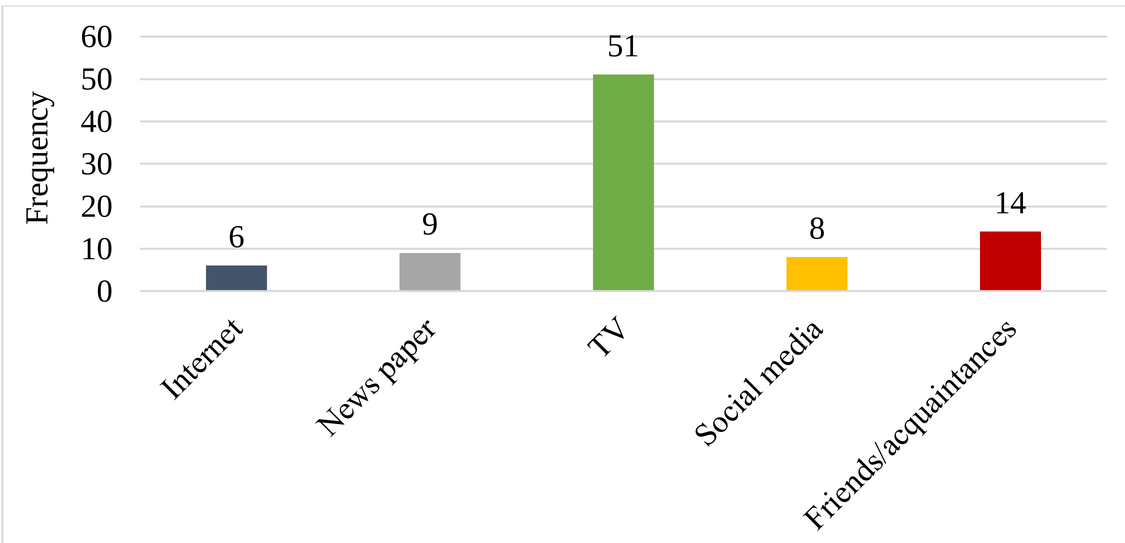


Figure 4.6 Source of Knowledge regarding health

After the MHP plant was installed, the principal health problems such as cough, eye infection and headache were found to be minimized. As shown in **Figure 4.8** , 54.4% of the respondents reported reduction in the eye infection after micro hydro electrification. 42.7% of the respondents reported reduction of respiratory problems. While 44.9% of the respondents decrease in cough.The least reduction was seen in the back problem (33.1%) according to the respondents. These positive results are also evident from a study conducted in Nepal (Tangting) where after MHP installation considerble reduction was seen in different health problems.According to the study in Nepal the eye infection was decrease by 53.33%. While respiratory disease was reduced according to 49.99 percent of the respondents. Similarly cough problem was also decreased accoring to 48.66% of the respondents[13]. **Table 4.3** below also shows the number and percentage of respondents opinonin regarding differnet health problems. 74 respondnets were off the opinonin that eye infection was decreased after MHP installation. While 19 respondnets were of the opinion that there has been no change. 58 respondnets reported that their has been reduction in the respiratory problem after electrification while 39 respondnets recorded no change after MHP installation. Similary respondnets also reported reduction of cough. 61 respondnets reported that cough issues has decreased after MHP installation. While 32 respondnets recoreded no change. According to the findings of our survey, after electricity, respondents stopped using kerosene and only utilized it as a backup fuel

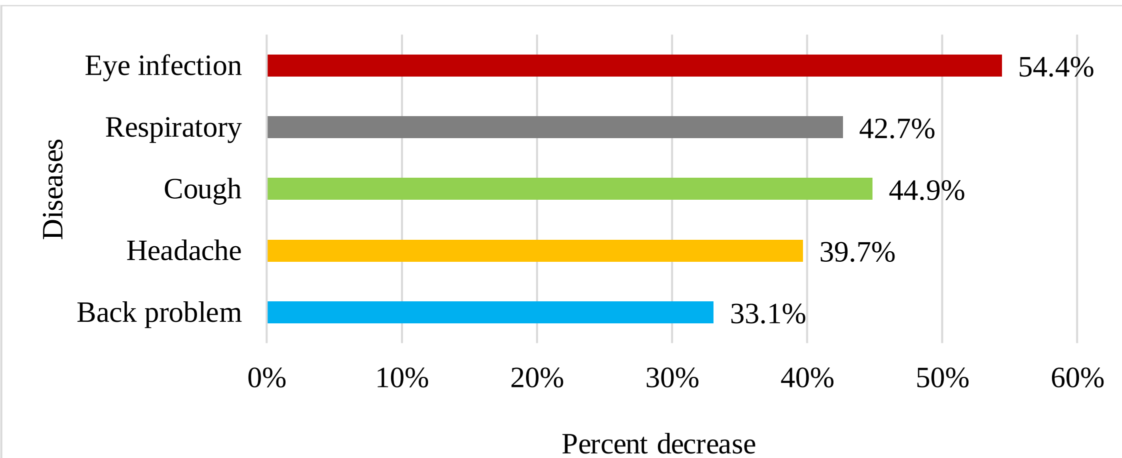


Figure 4.7 Health problem decrease after MHP installation

Table 4.3 Health Problems faced by the Respondents. Values with and without parenthesis show the number of respondents and percentage (%) respectively.

Diseases	**Increased**	**Decreased**	**No change**	**No disease**
Eye Infection	8 (5.88%)	74 (54.41%)	19 (13.97%)	35 (25.74%)
Respiratory	4 (2.94%)	58 (42.65%)	35 (25.74%)	39(28.68%)
Cough	4 (2.94%)	61 (44.85%)	32 (23.53%)	39 (28.68%)
Headache	2 (1.47%)	54 (39.71%)	27 (19.85%)	53 (38.97%)
Back problem	5(3.68%)	45(33.09%)	26(19.12%)	60(44.12%)

source. As a result, the community's residents saw decrease in energy expenses and improved health. These positive results are also reported by [13]. Kerosene can cause different health and saftey issues a study conducted in Indonesia reported that after the introduction of solar lights the health problems experienced by respondents due kerosene base lighting was considerbly reduced[21].

4.7. Economic Impacts

After micro hydroelectricity, households reported an increase in income. The **Figure 4.9** shows that following micro hydro power electrification, 37.50 percent of the respondents have monthly incomes between 30,001 RS and 40,001 RS. Only 16.90% of respondents had income in that range prior to micro hydro electrification. These findings show that MHP initiatives have a favorable and considerable influence on household income in the studied area. One of the reasons is that MHP electricity was less expensive than kerosene, allowing the respondents to save money on non-productive expenses. So, Electrification increases household income. This is suggested by various studies[8], [22].64.7% of respondents reported that their income has increased after MHP installation [8].So, micro hydro power increases household income as suggested by [23], [24] The respodents were also asked about electrfication impact on income generation activties. Overall, it does not appear that electrification has had a significant impact on the initiation of income-generating activities as shown in the **Figure 4.10.** This can also be seen in the **Figure 4.11** that the number of households involved in different home-based income-generating activities is almost about the same before and after electricity. Sewing fabric, handicraft, and weaving are examples of home-based income-generating occupations. Electricity cannot be the driving element behind the formation of income-generating businesses. According to this evidence, electrification has had little impact on the initiation of income-generating activities. This indicates that additional conditions must be in place to facilitate the growth of income-generating activities. This is evident from a study conducted in Nimibia where comparsions is made between a solar,unelectrified and grid connected house hold. The study shows that the unelectrified household has the highest number of income generating activties among the three as suggested by [25].

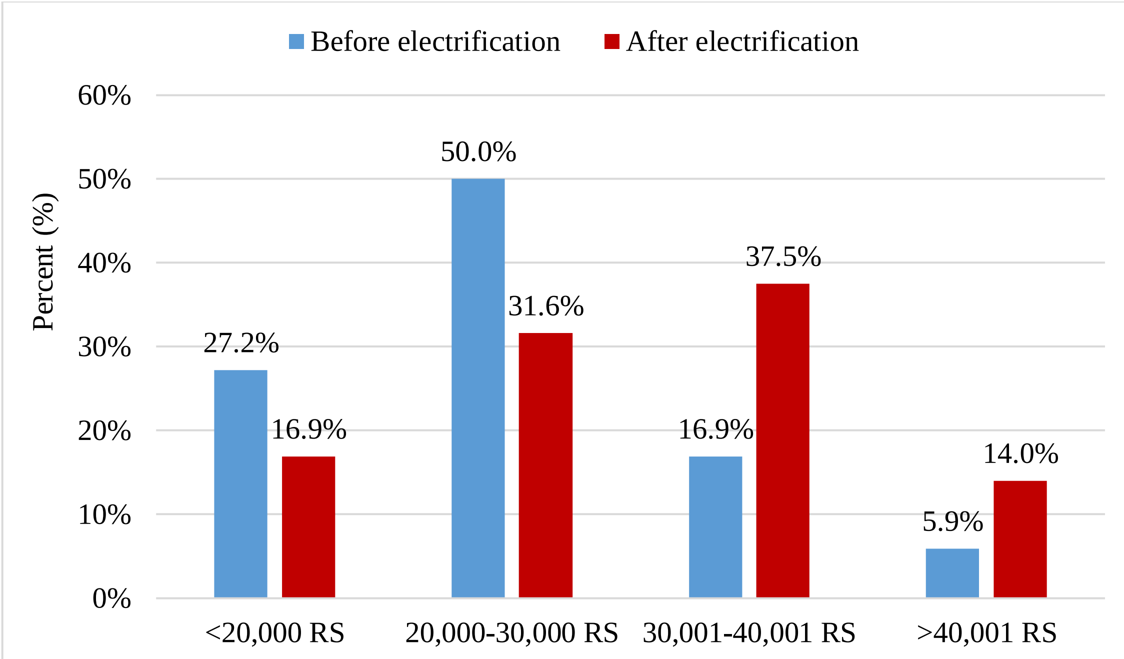


Figure 4.8 Income before and after MHP installation

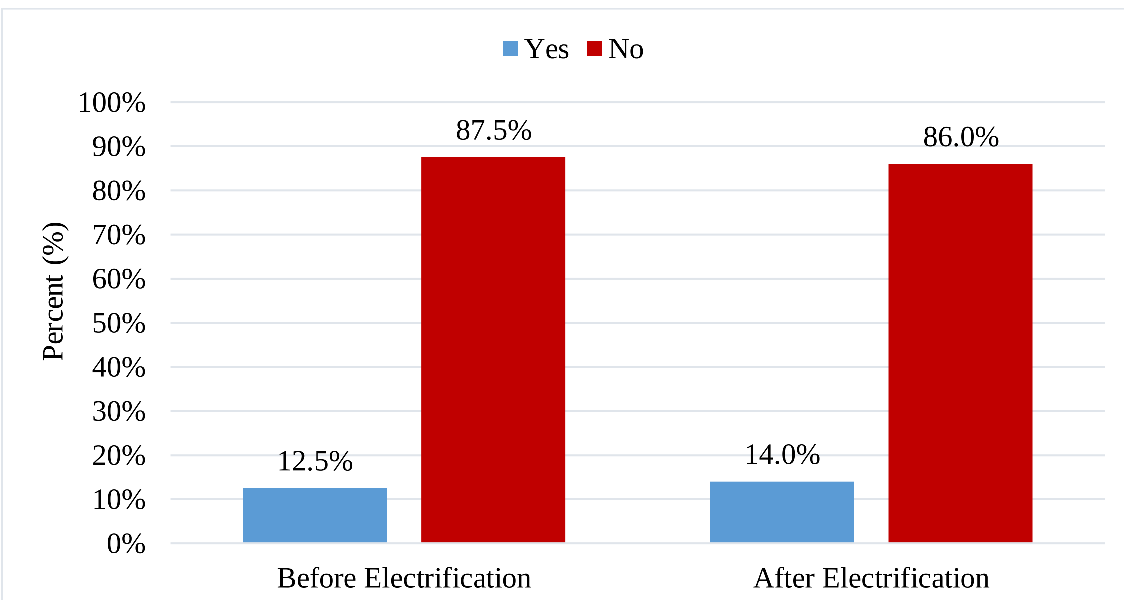


Figure 4.9 Home base income generation activities before and after electrification

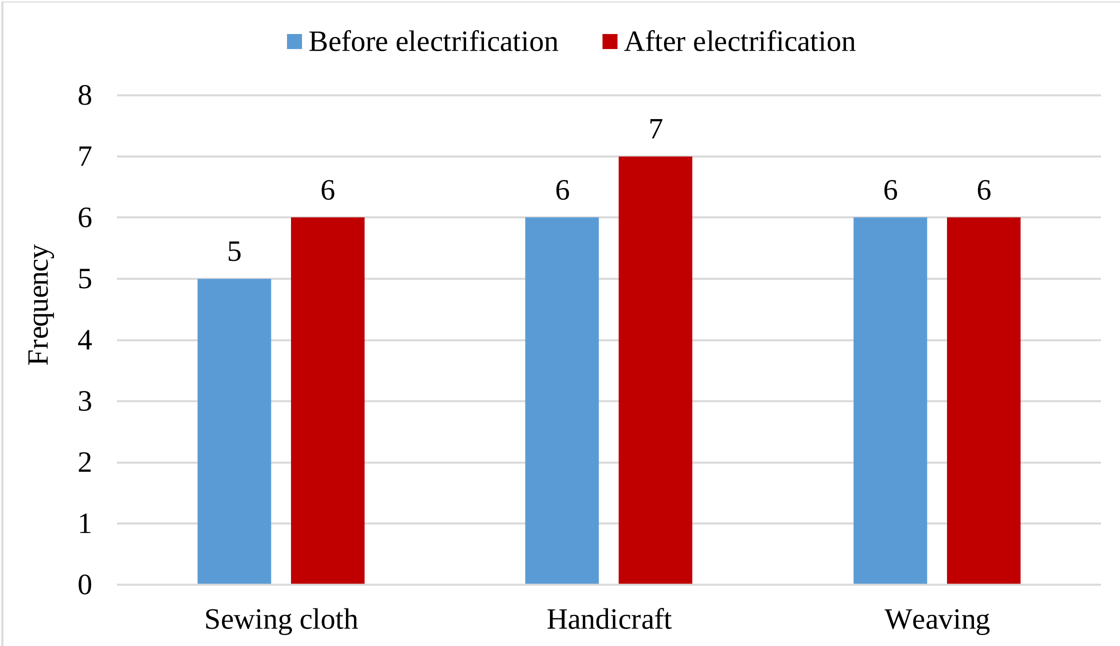


Figure 4.10 Type of income generating activities before and after MHP electrification

4.8. Impact on Security

MHP had a positive impact on security situation of the household. 83.1% of the respondents agreed that security situation has improved due to micro hydro power electrification as depicted in **Figure 4.12**.While only 9.6 % of the respondents disagree that security has improved due to micro hydro power electrification. Security of household improves after having access to electrification. This is evident from a study conducted in Afghanistan where 84% of the respondents agree that household security improved after electrification. The same kind of trend was also observed in a study conducted in Bangladesh where more than 80% of the respondents agree that security has improved after solar electrification [16], [26].The reasons stated for improved security by the respondents in our study is having street light outside the house and having light all night as depicted in the **Figure 4.13**.

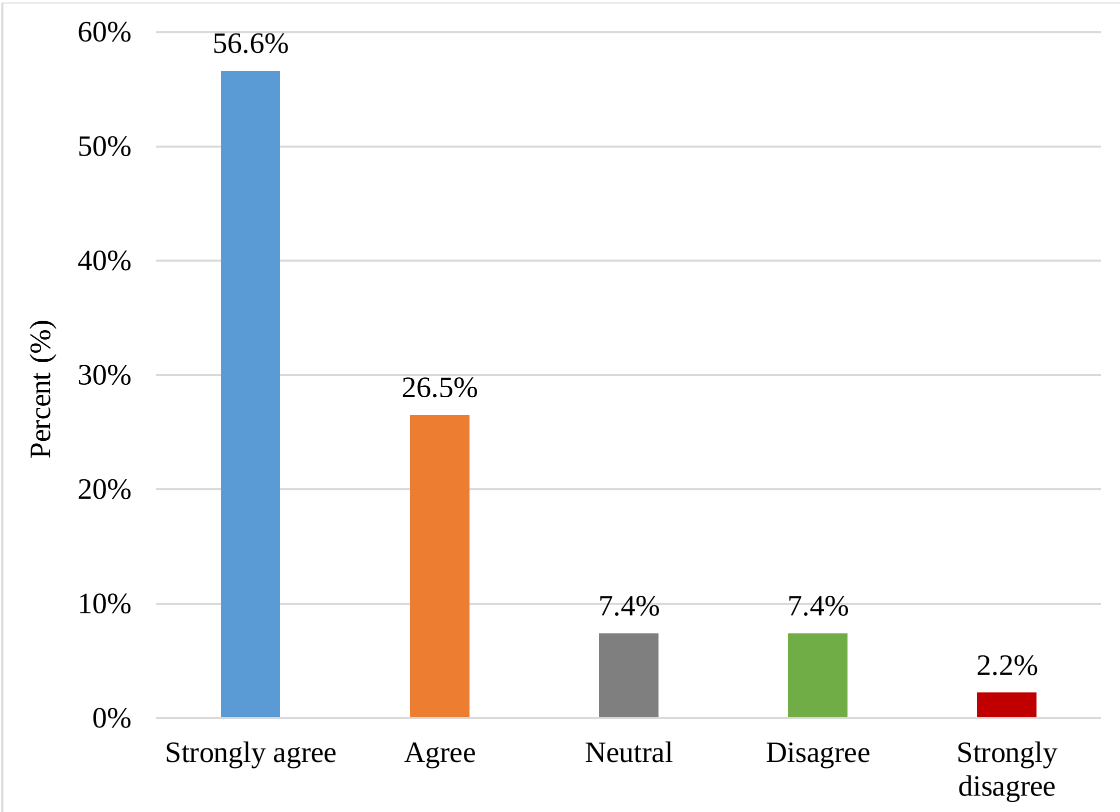


Figure 4.11 Security situation improved after MHP installation

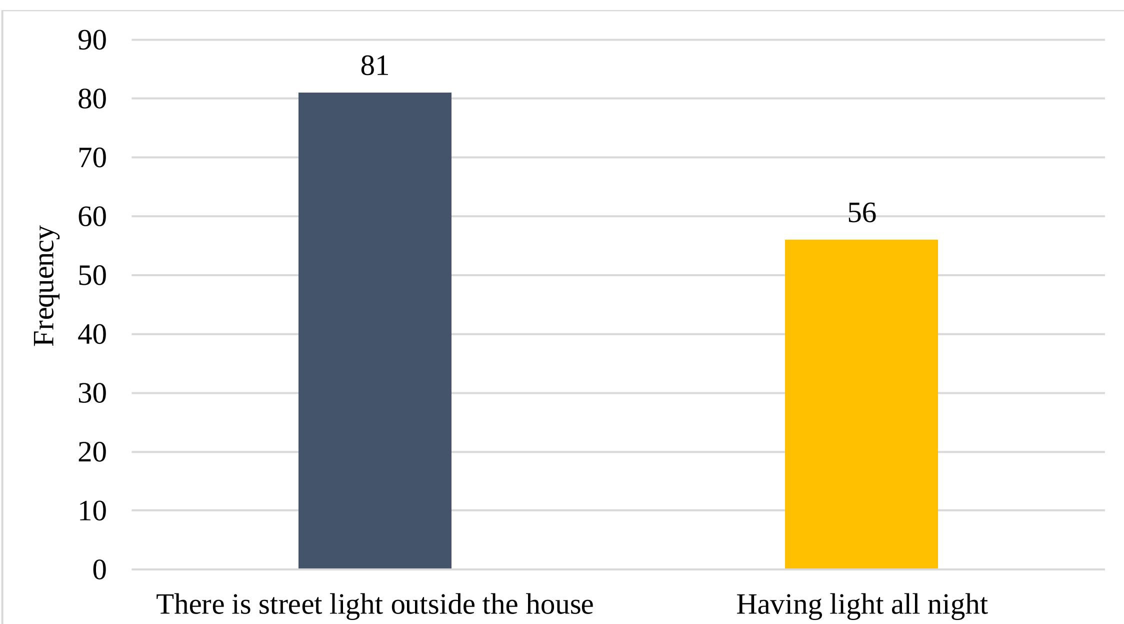


Figure 4.12 Reason for improvement in the security situation

4.9. Access to Information and Communication Technologies

77.2% of the respondents agree that access to information has increased after MHP electrification[16]. The ownership of information and communication technologies (ICTs) before and after micro hydro electrification is compared in **Figure 4.14** below that before electrification only 66.90% of the respondents had radio and after electrification 88.20% of the respondents have radio. The major change has been observed in ownership of the TV. Before electrification only 2.20% of the respondents had TV but after electrification ownership of TV has drastically increased. Almost 60% of the respondents owns a TV after electrification. There has also been improvement in the ownership of mobile phone. After electrification 94.10% of respondents at least owns one mobile phone. Few respondents also owns a computer after electrification. So access to information and communication technologies has improved after electrification. This has been evident from a study conducted in Bajaur agency where after installation of solar system the ownership of ICTs increased. Ownership of mobile phones and TV increased greatly [27], [28].

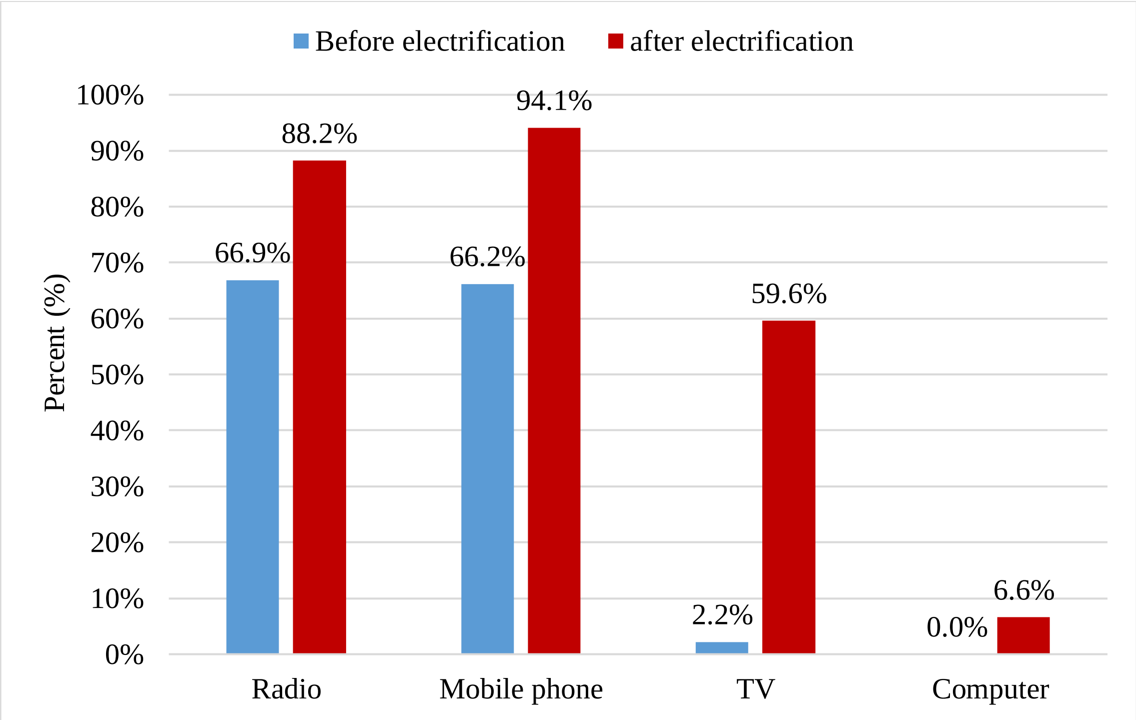


Figure 4.13 Access to information and communication technologies

4.10. Satisfaction with MHP

The respondents were asked about whether they are satisfied with the electricity provided by MHP. 86.8% of the participants were satisfied with the electric power supplied by MHP as depicted in the **Figure 4.15**. This has also been suggested by[29].

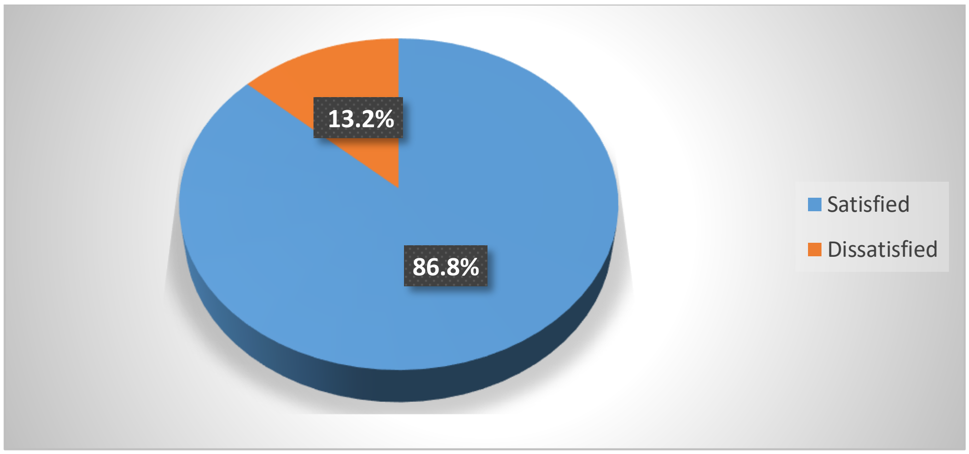


Figure 4.14 Satisfaction with electricity from MHP

Summary

This chapter has summarized and discussed the results. The chapter starts with demography of the respondents. Then it discusses the type of energy sources used for lighting and cooking by the respondents before and after electrification. The chapter also reveal that MHP had a positive impact on education.It increases the study hour of the children. The chapter also reveal benefits of MHP in terms of respondent's health. There was a significant reduction in various diseases after MHP installation.The mos reduction was seen in the eye infection after MHP according to the respondents. MHP also had positive impacts on income of the respondents as discussed in the chapter. 64.7% of the respondets reported increase in the income after MHP electrification.Security situations were also improved after MHP installation.The major reason stated for improved security was having light all light.Respondents access to information also increased after electrification.By asking the respondents about ownerships of ICTs before and after.The major improvement was seen in the ownership of TV. Overall majority of the respondents were satisfied with services provided by MHP.

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CHAPTER 5

Conclusions and Future Recommendations

5.1. Conclusions

As a primary data gathering instrument, this study used a Questionnaire survey. The main aim of this research was to determine the socioeconomic impact of micro hydroelectricity. The research was carried out in the village of Lalko (Swat). A total of 136 respondents took part in the survey. This study used a simple random sample strategy as its sampling method. SPSS software was used to examine the data. Tables and graphs were used to present the findings.

The study's findings suggest that MHP installation has a favorable impact on rural people's lives. It has improved the rural household's socioeconomic status. The findings reveal that having access to electricity has good consequences in terms of education, health, lighting expenditure, access to information and communication technologies, security, and income. After electricity, MHP assisted children in increasing their study hours. Access to information and communication technologies was also boosted as a result of having electricity. After the MHP was installed, the number of people who owned information and communication technologies rose. Households also reported changes in their health after the MHP was installed. Following the installation of the MHP, there was a considerable reduction in health-related concerns. Following the installation of the MHP, respondents said they were more aware of health issues. The consumption of kerosene and candles was also significantly reduced. After the MHP was installed, the majority of the responders ceased using these harmful fuels. Access to electricity also resulted in huge savings on candles and kerosene. In terms of income, there were also positive effects observed. However, there was no discernible influence on income-generating activities. Prior to and after the installation of the MHP, respondents used fuel wood as their major source of cooking. As a result, MHP had little to no effect on the decrease of fuel wood

5.2. Future Recommendations

More research is needed to have a better grasp of the socioeconomic and environmental effects of these MHP projects on Pakistani rural communities. Future research should focus on the environmental impact of these projects. Another essential facet of MHP is its environmental consequence, which will have significant policy conclusions in terms of extending MHP in the face of global climate change.

APPENDIX-A

QUESTIONNAIRE

QUESTIONNAIRE ON RESARCH ENTITLED

“Socio-Economic Impacts of Micro Hydropower (MHP) Electrification on the Rural Community of Pakistan: A Case Study of Village Lalkoo (Swat) 150 KW MHP Plant’’

Note: Dear respondent, I am a master’s degree student at NUST USPCAS-E, Islamabad. The information provided through this questionnaire will be used solely for academic purpose and will be treated with utmost confidentiality. Kindly spare some of your valuable time to answer these questions by ticking one of the alternatives given. Thank you for your time and cooperation.

Section 1: RESPONDENT DEMOGRAPHIC INFORMATION

1) Gender of respondent

   a) ☐ Male b) ☐ Female

2) Age of respondent

   a) ☐ <20 b) ☐ 20-30 c) ☐ 31-41 d) ☐ 42-52 e) ☐ > 52

3) Respondent marital status

   a) ☐ Married b) ☐ Unmarried

4) Household size

   a) ☐ 2 -3 b) ☐ 4-5 c) ☐ 6-7 d) ☐ 7 plus

5) What is your occupation?

a) ☐ Farmer

b) ☐ Business

c) ☐ Shopkeeper

d) ☐ Government servant

e) ☐ Daily wager

f) ☐ Unemployed

e) ☐ Housewife

h) ☐ Other (specify) ________________

6) Number of male childern in your household_____________

7) Number of female childern in your household___________

8) Number of elderly males in your household_____________

9) Number of elderly females in your household____________

Section 2: CONSUMPTION OF ENERGY SOURCES

10) What type of energy source do you use for lighting?

Energy sources	Consumption Before MHP a) Yes b) No	Consumption after MHP a) Yes b) No	Monthly expenditure in PKR before electrification a) 0-200 b) 200-400 c) 400-600 d) 600-800 e) 800-1000 f) >1000	Monthly expenditure in PKR after electrification a) 0-200 b) 200-400 c) 400-600 d) 600-800 e) 800-1000 f) >1000
MHP				

Grid electricity				
Generators				
SHS				
Charcoal				
Kerosene				
Emergency lights				
Candles				
Fuel wood				
Dung				
Crop waste				
Others (specify)__				

11) What type of energy sources do you use for cooking?

Energy sources	Consumption Before MHP	Consumption After MHP	Monthly expenditure in PAK Rupees before electrification	Monthly expenditure in PAK Rupees after electrification
	a) Yes b) No	a) Yes b) No	a) 0-200 b) 200-400 c) 400-600 d) 600-800 e) 800-1000 f) >1000	a) 0-200 b) 200-400 c) 400-600 d) 600-800 e) 800-1000 f) >1000

Kerosene				
Dung cakes				
Fire wood				
Charcoal				
Crop waste				
Electricity				
Others				

12) What do you use electricity mainly for? **(Select all that applies).**

a) ☐ Lighting
b) ☐ TV
c) ☐ Charging
d) ☐ Computer
e) ☐ Fan
f) ☐ Shop
g) ☐ Other (specify) ________________

13) What would be the major problems to your household if electricity supply failed for sustained period? **(Select all that applies)**

a) ☐ Children's study affected
b) ☐ Discomfort due to no fan during summer
c) ☐ Affect TV viewing
d) ☐ Disturbance in sleeping at night during summer
e) ☐ Unnecessary delay in dinner
f) ☐ Other(specify) _______________

14) How has an electricity connection affected your daily life?

a) ☐ Significantly   b) ☐ Marginally   c) ☐ No change

Section 3: EDUCATION

15) Total number of children enrolled in school from your household____

16) What were the number of study hours at home (average per day) before MHP electrification?

a) ☐ <1 hour   b) ☐ 1-2 hours   c) ☐ 3-4 hours   d) ☐ >4 hours

17) What are the number of study hours at home (average per day) after MHP electrification?

a) ☐ <1 hour   b) ☐ 1-2 hours   c) ☐ 3-4 hours   d) ☐ >4 hours

18) Having electricity is important for children's education

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

19) Children can study more hours after MHP electrification

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

20) Television has hampered the study time of children after MHP electrification

a) ☐ Strongly disagree

b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

Section 4: HEALTH

21) Health related issues has decreased after MHP electrification

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

22) Incidence of disease/ health problems in your household after MHP electrification has

Diseases	**a) Increased**	**b) Decreased**	**c) No Change**	**d) No Disease**
Eye infection				
Respiratory				
Cough				
Headache				
Back problem				
Others (specify)_____				

23) Number of visits to a health clinic in the last 12 months_______________

24) Would you agree that health care services has improved due MHP electrification?

a) ☐ Strongly disagree

b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

25) Has your awareness or knowledge regarding health issues increased after MHP electrification?

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

26) If agreed to Q25, what could be the reason for change? **(Select all that applies)**

a) ☐ Internet
b) ☐ Newspaper
c) ☐ TV
d) ☐ Social media
e) ☐ Friends/acquaintances
f) ☐ Others (specify) ________________

27) Access to information has increased after MHP electrification

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

28) Which of the following information and communication appliances do you own?

Appliances	Before MHP electrification a) Yes b) No	After MHP electrification a) Yes b) No
Radio		
Mobile phone		
TV		
Computer		
Other_____________		

Section 5 Economic Impact

29) Energy expenses decreased after MHP electrification

a) ☐ Agree

b) ☐ Disagree

30) Has your income increased after MHP installation?

a) ☐ Agree

b) ☐ Disagree

	Before MHP	After MHP
31) How much do you earn in a month?	a) ☐ <20,000 b) ☐ 20,000-30,000 c) ☐ 30,001,40,001 d) ☐ >40,001	a) ☐ <20,000 b) ☐ 20,000-30,000 c) ☐ 30,001,40,001 d) ☐ >40,001

	Before MHP	After MHP
32) Is/was there income generating activity in your household		
	☐ Yes ☐ No	☐ Yes ☐ No
	Before MHP	After MHP
33) If yes, then what activity	a) ☐ Sewing cloth b) ☐ Making Handicraft c) ☐ Carpenter d) ☐ Weaving e) ☐ Other(specify)__	a) ☐ Sewing cloth b) ☐ Making Handicraft c) ☐ Carpenter d) ☐ Weaving e) ☐ Other (specify)__

Section 6: SECURITY

34) Would you agree that security has improved due to MHP electrification?

a) ☐ Strongly disagree
b) ☐ Disagree
c) ☐ Neutral
d) ☐ Agree
e) ☐ Strongly agree

35) If agree with Q34, what is/are the reasons **(Select all that applies)**

a) ☐ Having light all night in the house
b) ☐ Theft and robbery become difficult
c) ☐ There is street light outside the house

d) ☐ Other(specify) _______________

Section 7: SATISFACTION WITH THE PROJECT

36) Are you satisfied with the electricity provided by MHP project?

a) ☐ Satisfied b) ☐ Dissatisfied

37) What is your saying on present electricity tariff?

a) ☐ Affordable b) ☐ Unaffordable

38) Time duration of electricity availability in hours______

THANK YOU FOR YOUR COOPERATION