ASSESSMENT OF PRACTICAL IMPLEMENTATION CHALLENGES OF SOLAR-POWERED RURAL WATER SUPPLY SYSTEMS: THE CASE OF BOLOSO SORE WOREDA IN WOLAYITA ZONE, ETHIOPIA

A Thesis Submitted to the Department of Water Resource Engineering and Management, School of Civil Engineering and Architecture

By

Melaku Tafesse

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Water Resource Engineering (Specialisation in Water Supply and Environmental Engineering)

Office of Graduate Studies

Adama Science and Technology University

March 2025

Adama, Ethiopia

ASSESSMENT OF PRACTICAL IMPLEMENTATION CHALLENGES OF SOLAR-POWERED RURAL WATER SUPPLY SYSTEMS: THE CASE OF BOLOSO SORE WOREDA IN WOLAYITA ZONE, ETHIOPIA

A Thesis Submitted to the Department of Water Resource Engineering and Management, School of Civil Engineering and Architecture

By

Melaku Tafesse

Advisor: Yemane G. Asfaha (PhD)

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Water Resource Engineering (Specialisation in Water Supply and Environmental Engineering)

Office of Graduate Studies

Adama Science and Technology University

March 2025

Adama, Ethiopia

DECLARATION

I hereby declare that this Master thesis entitled "**Assessment of Practical Implementation Challenges of Solar Powered Rural Water Supply Systems: The Case of Boloso Sore Woreda in Wolayita Zone, Ethiopia**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Assessment of Practical Implementation Challenges of Solar Powered Rural Water Supply Systems: The Case of Boloso Sore Woreda in Wolayita Zone, Ethiopia**" prepared under my guidance by **Melaku Tafesse** submitted in partial fulfilment of the requirement for the Degree of Master's in Water Resource Engineering (Specialisation in Water Supply and Environmental Engineering). Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Yemane G. Asfaha (PhD)	______________	______________
Major Advisor	Signature	Date

APPROVAL PAGE OF M.Sc. THESIS

I, the advisor of the thesis entitled "**Assessment of Practical Implementation Challenges of Solar Powered Rural Water Supply Systems: The Case of Boloso Sore Woreda in Wolayita Zone, Ethiopia**" and developed by **Melaku Tafesse**, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Yemane G. Asfaha (PhD)	____________	____________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by **Melaku Tafesse** have read and evaluated the thesis entitled "Assessment of Practical Implementation Challenges of Solar Powered Rural Water Supply Systems: The Case of Boloso Sore Woreda in Wolayita Zone, Ethiopia" and examined the candidate during the open defence. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Water Resource Engineering (Specialisation in Water Supply and Environmental Engineering).

____________	____________	____________
Chairperson	Signature	Date
____________	____________	____________
Internal Examiner	Signature	Date
____________	____________	____________
External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

____________	____________	____________
Department Head	Signature	Date
____________	____________	____________
School Dean	Signature	Date
____________	____________	____________
Office of Postgraduate Studies, Dean	Signature	Date

ACKNOWLEDGMENT

I give all thanks and credit to my Lord, to whom I owe everything.

I want to extend special thanks to my advisor, Dr. Yemane G. Asfaha, for the continued guidance and support during the thesis work. I should appreciate the Department of Water Resource Engineering of Adama Science and Technology University for allowing me to pursue my MSc in Water Supply and Environmental Engineering. My appreciation will extend to those who supported me during the data collection process; thank you.

I would also like to thank my brother, Fitsum Tafesse, for the instrumental wake-up calls throughout the tiresome study and thesis work. Finally, I want to thank my wife, Tewedaj Shewaye, for all the encouragement. Last but not least, I want to express my gratitude to my daughters, Yoadan, who is two years old, and Naomi, who is only two months old. Your smiles have been healing and have given me extra energy during this challenging period.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

CMP	Community Managed project
CSA	Central Statistical Agency
FGD	Focus group discussion
GIS	Geographical Information Systems
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
HH	Household
JMP	Joint Monitoring Programme
KIIs	Key Informant Interviews
Lpcd	Liter per capita per day
MDG	Millennium Development Goal
MIS	Information Management System
NGO	Non-Governmental Organization
NWI	National WASH Inventory
O&M	Operations and Management
PV	Photo Voltaic
RHS	Rectangular Hollow Section
SDGs	Sustainable Development Goals
SPRWSS	Solar Powered Rural Water Supply Systems
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WMP	Woreda Managed Project
WSPs	Water Service Providers

ABSTRACT

Many nations, including Ethiopia, seek to promote, advocate for, and mainstream the use of solar energy in rural water supply projects for communities and institutions. Although solar energy is being promoted as a replacement for diesel-driven systems, identifying bottlenecks in solar-powered water supply systems has not been emphasized. Therefore, this research study aimed to evaluate the main practical challenges of implementing solar-powered water supply systems in Boloso Sore Woreda, Ethiopia. The study employed a mixed-method approach, combining quantitative and qualitative data collection and analysis techniques. The research data were collected via review of design documents, a structured household questionnaire, and triangulated with focus group discussion, key informant interview, and physical observation. As a result, it was identified that practical implementation challenges were encountered in Boloso Sore Woreda SPRWSS. The technical challenges included inadequate design and poor construction quality, system malfunctions, and inadequate service reservoir capacity. On the other hand, the financial challenges were due to the high initial investment, the need for regular operation and maintenance, and the community's unwillingness to pay for water. Moreover, the operation and maintenance challenges arose from a lack of technical expertise, limited access to spare parts, and unclear roles and responsibilities of the committees. Additionally, a study of community satisfaction regarding the project revealed mixed perceptions among residents. While some expressed pride and happiness, others reported dissatisfaction with the performance of the water management committees and the system's overall management. Overall, this study provides valuable insights and recommendations to build the capacity, skills of technical experts involved in implementing, operating, and maintaining solar-powered water supply systems in the region and across the country. In addition, it recommended to carefully select construction materails, avail solar spare parts in the local market with reasonable price, subsizide the expesive solar components required for maintenance. Furthermore, it recommended the replication of such kind of research in other regions with different context and encourages more research aimed at devising an optimum water tariff setting and community contribution to enhance the financial sustainability of SPRWSS.

CHAPTER ONE

INTRODUCTION

1.1. Background and Justification

Water is one of the most critical resources, and without it, life could be challenging. Water is, therefore, essential for a sustainable way of life. Water is necessary for both domestic (drinking, cooking, cleaning, etc.) and productive uses in households. Health and productivity significantly improve when people have access to enough clean, safe water. The United Nations proclaimed access to clean water and sanitation to be a fundamental human right. It is necessary to achieve numerous human rights, such as those pertaining to survival, education, and living standards. As per a report (WHO UNICEF JMP, 2022), drinking water interventions significantly reduced the risk of childhood diarrhea. Compared with an unimproved source, providing water supply on premises with higher water quality reduced diarrhea by 52%. Water treated at the point of use through filtration, solar treatment, or chlorination reduced diarrhea by up to 50% compared with untreated water from an unimproved source (WHO UNICEF JMP, 2022, 2023). When someone cannot get safe water for any reason, these rights are restricted to some degree.

Apart from the Health benefits, access to reliable water sources can spur socio-economic development in rural areas. With a stable water supply, communities have reported improved agricultural productivity, as farmers can adequately irrigate their crops and livestock. Additionally, the availability of clean water facilitates the establishment of businesses, such as small-scale water treatment enterprises or vegetable gardens, creating new economic opportunities for local communities. Traditional water collection methods frequently fall on women and girls, leaving them with limited time for other activities, such as education or income-generating work. Solar-powered rural water supply systems have alleviated this burden by reducing the time and effort required to access water, for they benefit from increased access to water, as it enables them to engage in more productive activities and pursue educational opportunities.

A report (WHO UNICEF JMP, 2022) confirmed that investment in drinking water systems in the last 20 years has led to a reasonable increase in improving access. Access to safely managed drinking water services was possible for two billion people worldwide. Compared to 62% (3.8 billion) in 2000, 74% (5.8 billion) of the world's population used safely managed drinking water in 2020. Even with the advancements, there are still 2 billion people who do not have access to safely managed water in 2020 due to significant regional differences (WHO UNICEF JMP, 2023). The 2030 SDG targets are far from being achieved by the world. For instance, by 2030, just 37% of people in sub-Saharan Africa will have access to safely managed drinking water. Various challenges hindering the provision of drinking water in Africa have been extensively documented. According to the African Ministers' Council on Water (AMCOW, 2018), key challenges include limited financial resources, inadequate infrastructure, population growth, climate change, and inadequate institutional capacity for operation and maintenance. These challenges aggravate the existing disparities in water supply, particularly affecting marginalized and rural communities.

The Joint Monitoring Programme (JMP) data shows that between 2015 and 2020, there was a rise in the number of Ethiopians who use basic drinking water services from 42 million to 57 million (or from 42% to 50% of the population, or by 1.5 percentage increase every year (WHO UNICEF JMP, 2021). Ethiopia also experienced the fastest decline in surface water dependency of any African nation during this time, going from 12 million to 5 million people. One of the critical reasons for the progress is the Ethiopian ONEWASH National Programme, which serves as a model of acceleration through government leadership and cooperation across ministries and sector stakeholders.

Access to clean water is severely hampered in rural areas of developing nations, frequently due to poor infrastructure or restricted access to energy. This problem is being addressed by solar-powered water pumping systems, which provide an affordable and environmentally friendly substitute for conventional diesel-powered pumps. In addition, solar systems have been advocated as a climate-resilient and sustainable energy option for rural water supply projects in Ethiopia.

Different research studies have been conducted focusing on evaluating the feasibility of solar energy for rural water supply in Ethiopia, the solar energy potential of Ethiopia, and its current utilization for different purposes, such as electricity and rural water supply (Girma et al., 2015; Kabade et al., 2013). The research conducted so far concluded that Ethiopia has abundant solar energy to harness and that solar-powered water supply systems are feasible compared to diesel-driven water supply systems.

However, limited research has been conducted to evaluate the practical challenges encountered after implementing solar-powered water supply systems in Ethiopia. Moreover, as per the knowledge of the authors, no research study has been done on solar-powered water supply systems in the study areas. This confirms that there is a considerable knowledge gap around the challenges encountered while implementing solar-powered water supply systems. Apart from advocating for the use of solar energy for water supply systems in Ethiopia, all stakeholders should work on identifying what went well and what didn't so far in applying the technology. Therefore, a detailed study of the practical challenges of implementing solar-powered water supply systems with a scientific research approach will fill the knowledge gap, which is the aim of this study.

1.2. Statement of the problem

The sustainability of rural water supply (RWS) projects and the benefits they yield are currently among the industry's top concerns. This concern is well-founded; each year, millions of dollars are invested in project implementation by both national governments and international donor agencies, and despite increasing efforts to address the issue, many still fail to sustain the flow of benefits over the 15- or even 20-year project lifetimes that are intended. While systematic studies on this issue are scarce, many practitioners estimate that a sizable portion of rural water supply systems in developing countries may be rendered completely inoperable or abandoned at any given time (Sara et al., 2018).

Ethiopia has made remarkable progress in water and sanitation over the MDG period and continuing on the SDG phase despite all the challenges. The water supply coverage of Ethiopia for 2018 at national level as per GTP-II standard is generated by the MIS as 47%, 57%, and 49%, for rural, urban and total respectively as their orders (FDRE Water Development Commission, 2019). The GTP-II standard for rural water supply states 25l/p/d at 500m radius and 30 minutes round trip water collection time. Beker & Kansal, (2024) showed that the national, rural and urban water supply coverage reached 50% (19.2 million), 41% (52.5 million), and 84% (71.7 million) of water provided from basic water services in 2020, respectively. The progress has been mainly due to the establishment of a Government-led WASH coordination mechanism (ONE WASH program) involving the Ministry of Water, Health, Education and Finance and Economic Development, and development partners (Wilson et al., 2018).

The functionality of rural drinking water supply systems remains a challenge, especially as infrastructure stock grows. The second National WASH Inventory, last conducted in 2019, reported that 19 percent of schemes were non-functional at the time of inventory due to various reasons (FDRE Water Development Commission, 2019) . Discontinuity of supply and unpredictable breakdowns interrupt access, jeopardizing the health benefits associated with continuous access. The recent drought raised concerns about the resilience of systems, with very high rates of hand-dug wells running dry in particular, and raised the question of whether progress in extending access to basic services has masked a problem with their underlying vulnerability (World Bank Group, 2018).

The cost of using solar power to pump water from boreholes has fallen dramatically in recent years, so it is increasingly being used to get water to people. However, as with any technology, if solar pumping is badly implemented or poorly managed, it will not be sustainable (WaterAid, 2021). A number of factors, including reduced costs, reliable technology, a booming private sector, high solar radiation in vast areas of Africa and Asia, and environmental concerns, among others, have been pivotal in bringing about this renewed interest in solar photovoltaic (PV) solutions in the relief sector. Solar PV pumping is not a panacea despite its numerous advantages, and careful contextual analysis beyond technical considerations should be carried out before its adoption (W. Kiprono & Ibáñez Llario, 2020). It is not realistic to expect rural communities to be able to manage solar-powered systems without crafting an appropriate management model that considers factors like community willingness and ability (WaterAid, 2021).

According to recent research, many nations, including Ethiopia, seek to promote, advocate for, and mainstream the use of solar energy in rural water supply projects for communities and institutions (Mwangi et al., 2018). Girma et al. (2015) concluded that the solar photovoltaic water pumping system is more economical and feasible than the diesel one. According to the study, abundant solar radiation and enough underground water sources in Ethiopia can be combined to make clean drinking water available to rural communities. The study employed a mixed approach: PVsyst 5.56 software was used to study the feasibility of solar photovoltaic water pumping systems in the selected sites, and a life cycle cost analysis method was also applied to compare solar PV and diesel pumping systems economically. Despite studying the feasibility of solar-powered water supply systems, the research has limitations in showing the challenges encountered while implementing the technology. Therefore, a scientific research study is required to identify those challenges to bridge the knowledge gap and bring solutions to challenges faced in such projects.

Boloso Sore is one of the woredas with limited water supply coverage, still standing at 49.6% as of 2020 (Gizachew et al., 2020), and with 30% non-functionality rate as of 2023. Stakeholders like World Vision Ethiopia have begun implementing solar-powered water supply systems in Woreda with the ambition of enhancing the water supply coverage. It is confirmed that no research was done before focused on SPRWSS in the area and SPRWSS interventions are very limited so far. Therefore, it is noted that there is limited knowledge of the factors that have contributed to the limited adoption of solar energy as a solution to water pumping. The practical implementation of such systems faces several significant challenges that need to be assessed and addressed for effective adoption. Therefore, this research focuses on assessing the practical implementation challenges of solar-powered rural water supply systems in the case of Boloso Sore Woreda in the Wolayita Zone.

1.3. Research Questions

The following research questions were devised to enable the study to come up with proper answers and solutions to the objectives set.

1. What specific technical challenges arise when implementing solar-driven water supply systems in Boloso Sore Woreda?
2. What specific financial challenges arise when implementing solar-driven water supply systems in Boloso Sore Woreda?
3. How does the community perceive and the level of user satisfaction with solar-driven water supply systems in Boloso Sore Woreda?
4. Are there operation & maintenance challenges in implementing the solar-powered water supply system in the study area?

1.4. Research Objectives

1.4.1. General Objective

The general objective of this research work was to assess the major practical implementation challenges faced by solar-powered water supply systems in Boloso Sore Woreda. The research focused on identifying the key barriers and factors influencing the successful implementation of these systems.

1.4.2. Specific Objectives

- Identify the technical challenges encountered while implementing a solar-powered water supply system in the study area.

- Assess the financial challenges/constraints impacting the implementation of solar-powered water supply systems in the study area.
- Assess the operation & maintenance challenges in the implementation of solar-powered water supply systems in the study area.
- Assess the community perception and user satisfaction with solar-powered water supply systems in the study area.

1.5. Significance of the study

The study outcome resulted in a detailed identification of challenges encountered in implementing solar-powered water supply systems in Boloso Sore Woreda. The study findings are significant and can complement the planning, management, operation, and maintenance aspects of rural water supply powered by solar energy. Thus, this research will contribute to a better understanding of problems and factors related to practical solar water supply system implementation. The recommendations generated from this research provide valuable insights for stakeholders involved in implementing, operating, and maintaining solar-powered water supply systems in the region and across the country. Moreover, the results are beneficial to the concerned sectors involved in this field in revising and sustaining the project.

1.6. Delimitation Scope

This study focused on assessing the practical implementation challenges of solar-powered water supply systems constructed in 14 kebeles of Boloso Sore Woreda, and where there is no solar-powered water supply system, it will not be part of the study. In addition, the quality of water is not checked in the laboratory as the research aimed to get the perceived quality of water from the user community.

CHAPTER TWO

LITERATURE REVIEW

2.1. Overview of a solar-powered water supply system

According to a research (Shrey Verma et al., 2020) Many renewable energy sources can be used to pump water, but solar energy has gained popularity because it is accessible everywhere, even in remote areas, and reduces reliance on diesel and the grid to power the pump. Solar energy is clean and abundant, as evidenced by the direct correlation between availability and water demand, and photovoltaic panels directly convert sunlight into useful electrical energy that powers the water pump either directly or through an inverter. Over the past few years, scientists have been working to create more efficient solar PV water pumps. Since gasoline and diesel engines demand costly fuel and over time pollute the air and create noise in clean residential areas. SPRWSS have a number of advantages over typical pumping systems. Because SPRWSS are environment friendly and don't require extra fuel to operate. It has the power to transform rural areas through socioeconomic development in addition to water provision. Since they don't have to travel far to fetch water, women and children have more time for higher education.

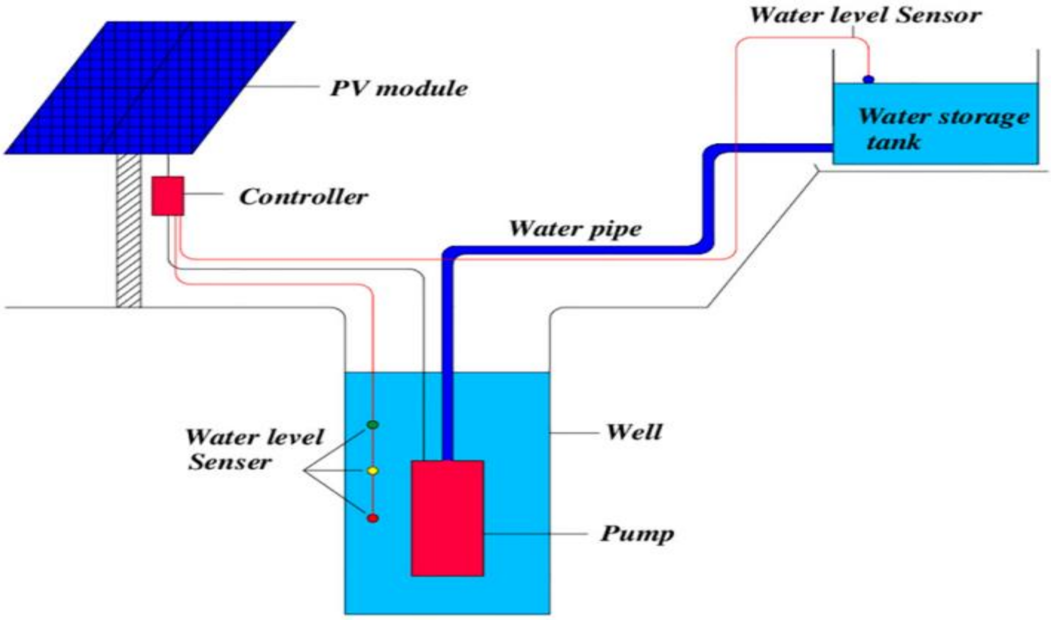


Figure 1. *A sample representation of a SPRWSS (Shrey Verma et al., 2020)*

Due to their independence and lack of reliance on other energy sources like diesel and grid power, solar-powered rural water pumping systems, or SPRWSS, have become more and more popular as power outages in rural and isolated locations have increased. Although there are other designs for creating the SPRWSS, PV panel-powered water pumping is typically employed, as shown in **Figure 1**, which consists of a solar power conversion system linked with a power conditioning unit, a hydraulic water pump, and a storage tank. PV panels plus a tracking system for increased efficiency make up a solar power conversion system, which collects solar energy and transforms it into electrical energy. The inverter must convert the output energy to AC in order to power the pump because the generated energy is primarily in DC but the pump is primarily available in AC. A water pump can be placed on the ground level or submerged in the water. In order to benefit from gravity flow, it pumps water from the reservoir to the tank that is positioned at a certain height. The head of the pump is the height differential between the tank and the water reservoir level. This head is a crucial factor to consider when choosing a pump to retrieve water from a reservoir. The primary goal of recent SPWPS research has been to boost the system's efficiency.

2.2. Solar Energy Potential of Ethiopia

Ethiopia, located very close to the equator between 30 and 150 N, receives abundant solar energy potential that can be harnessed and used in thermal and electrical energy. The average solar radiation is around 5.2 kWh/m2, which is more or less uniform. The value varies seasonally from a minimum of 4.55 kWh/m2 in July to a maximum of 5.55 kWh/m2 in February and March. With location, the radiation varies more widely between 4.25 kWh/m2 in extreme western lowlands and 6.25 kWh/m2 in the northern part of the country (Bekele Mulatu et al., 2023a; Hailu & Kumsa, 2020).

The government of Ethiopia, in collaboration with the Chinese government, prepared a solar and wind master plan for the whole country, which can be very useful in identifying the gross amount and distribution condition of wind and solar energy resources, construction conditions, cost, and other limiting factors of wind and solar power generation projects(MoWE, 2013). Based on the analysis of this master plan, Ethiopia has an annual total solar energy reserve of 2.199 million TWh/annum as shown in **Figure 2**.

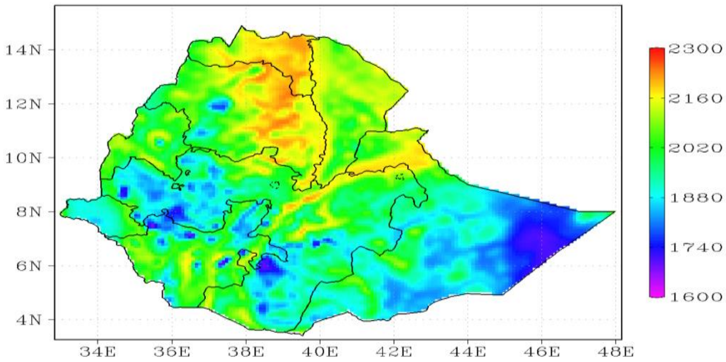


Figure 2. Distribution of average annual total solar radiation in kWh/(m^2.a), (MoWE, 2013)

2.3. Utilization of solar power in Ethiopia

Solar energy can be effectively utilized for rural water supply in Ethiopia. The utilization is not limited to water supply only but can be utilized for more than one purpose, as stated below (Bekele Mulatu et al., 2023a):

Solar-powered water pumps: Solar-powered water pumps can be installed in rural areas to extract water from wells or other water sources. These pumps are an efficient and sustainable alternative to traditional diesel or electric pumps. They can be powered by solar panels installed nearby, providing a reliable and clean source of energy for water extraction.

Solar water heating systems: Solar water heating systems can be used to provide warm water for domestic use in rural areas. These systems use solar collectors to absorb sunlight and heat water, which can be used for bathing, washing clothes, and other household tasks. Solar water heating systems are cost-effective and environmentally friendly compared to conventional electric or gas water heaters.

Solar-powered water treatment systems: In areas with poor water quality, solar-powered water treatment systems can be implemented. These systems use solar energy to power water purification processes such as filtration, disinfection, desalination, and Advanced oxidation processes. Solar-powered water treatment systems can improve water quality, making it safe for drinking and irrigation.

Solar-powered water distribution systems: Solar energy can be used to power water distribution systems in rural areas. This can involve the installation of solar-powered water storage tanks and pumping stations, which can distribute water to different households or communities. These systems can help overcome the challenges of water scarcity and lack of infrastructure in remote areas.

Solar-powered community water centers: Solar energy can also be used to establish rural community water centers. These centers can provide the local population with clean drinking water, sanitation facilities, and other water-related services. Solar energy can power the water treatment and distribution systems at these centers, ensuring a sustainable and reliable source of water supply.

Solar photovoltaic (SPV) water pumping systems are among the best technologies that utilize solar energy to pump water from deep-well underground water sources and to provide clean drinking water worldwide. Ethiopia has abundant solar radiation and enough underground water sources that can be combined to make clean drinking water accessible to rural communities.

Ethiopia has abundant solar energy resources for off-grid photovoltaic (PV) systems for the rural population. Girma et al. (2015) indicated that due to the high fuel oil prices, even larger photovoltaic systems are very competitive with diesel generators and village power supply. The PV water pumping systems may be the most cost-effective option in locations with no existing power grid lines. When properly sized and installed, PV water pumps are very reliable and require little maintenance.

2.4. Solar Energy application and status in Ethiopia

The first photovoltaic (PV) systems were erected in Ethiopia in the mid-1980s for school and rural home lighting (Bekele Mulatu et al., 2023b). The biggest of these was a 10.5kWp system that was put in place in Central Ethiopia in 1985 and powered 300 rural families via the hamlet's microgrid. In 1989, the system was upgraded to 30kWp to power the grain mill and village water pump. Ethiopia is thought to be now using 5.3MWp of PV in total. With 87% of all installations going toward off-grid telecom systems, mostly for mobile and landline network stations, PV is currently the most widely used application. PV systems are often utilized for water pumping in social institutions like schools and health stations. In rural areas, some 30,000 residential customers are also powered by photovoltaics.

Ethiopia has substantial solar energy resources. However, less than 1% of the potential has been exploited so far (Hailu & Kumsa, 2020). According to the recent data collected by the energy information administration and development follow-up core process, the total energy generated from solar photovoltaics within the last six years is more than 35 MWh, more than the installed capacity by 6MW. Solar water heating systems with a total energy generation of 299 MWh and ten water pumps with a pumping capacity of 10 kW have been installed in different parts of the country by governmental and non-governmental organizations (Bekele Mulatu et al., 2023b).

2.5. Past studies of solar energy in Ethiopia

Most of the studies conducted so far focus on the solar energy potential of Ethiopia, the feasibility of solar power usage for rural water supply compared to other sources like diesel, and solar energy application for different purposes like electrification (Bekele Mulatu et al., 2023a; Hailu & Kumsa, 2020). There are limited studies on the challenges of implementing solar-powered water supply systems. Therefore, the main interest of this research study will be identification of practical implementation challenges of solar-powered rural water supply systems in Boloso Sore Woreda**.**

Girma et al. (2015) studied the life cycle cost analysis of pumping water using solar power versus diesel systems. They concluded that the solar photovoltaic water pumping system is more economical and feasible than the diesel one. According to the study, abundant solar radiation and enough underground water sources in Ethiopia can be combined to make clean drinking water available to rural communities. The study employed a mixed approach. PVsyst 5.56 software was used to study the feasibility of solar photovoltaic water pumping systems in the selected sites. A life cycle cost analysis method was also applied to economically compare solar PV and the diesel pumping system. The results of this study encourage the use of the PV system for drinking water supply in remote areas of the country.

Two studies by Benti et al. 2022 and Hailu & Kumsa 2020 concluded that Ethiopia has enormous solar energy potential that can be utilized for different purposes like water pumping, electrification and heating. Hailu & Kumsa (2020) have studied Ethiopia's renewable energy potential and current state. The study employed a mixed approach of document analysis and literature review. As per this specific study, despite abundant solar energy resources available in the country, only about 14 MW of solar PV have been used for telecom service, lighting, powering water pumps in rural areas, and water heating in major cities. It also studied the opportunities as Ethiopia has launched the first tender to build, own, and operate three 100 MW solar PV projects, and ENEL Green Power (EGP) was selected as the preferred bidder for one of the projects located near Metehara. The challenges/limitations identified by the study are Unevenly distribution of solar energy utilization and the underutilization of it compared with th potential. The study showed that only about 14 MW of solar PV have been implemented limited or only used for telecom service, lighting, powering water pumps in rural areas, and water heating in major cities.

Benti et al. (2022) studied solar energy's potential as a power generation and financial feasibility for selected locations in rural areas of Ethiopia. Ethiopian annual solar radiation ranges from 1730kWh/m2 in Chencha city to 2481kWh/m2 in Asaita city. The annual PV energy was found to be 1686.579 kWh, 5059.95 kWh, and 83832 kWh, respectively. The study identified challenges and limitations as low investment in solar energy, limited promotion to government actors, and the need for high capital.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area Description

The Southern Nations, Nationalities, and Peoples' Region (SNNPRS) of Ethiopia includes Boloso Sore, one of the woredas in the Wolayita Zone, where the study was conducted. Boloso Sore shares borders with Sodo Zuria and Damot Sore on the south; Boloso Bombe on the west; Kembata Tembaro Zone on the northeast; Hadiya Zone on the northeast; Damot Pulasa on the east; and Damot Gale on the southeast. Areka is home to the administrative center. Boloso Bombe and Damot Sore woredas were formerly part of the Woreda; however, in 1999 E.C., both woredas were split off from Boloso Sore.

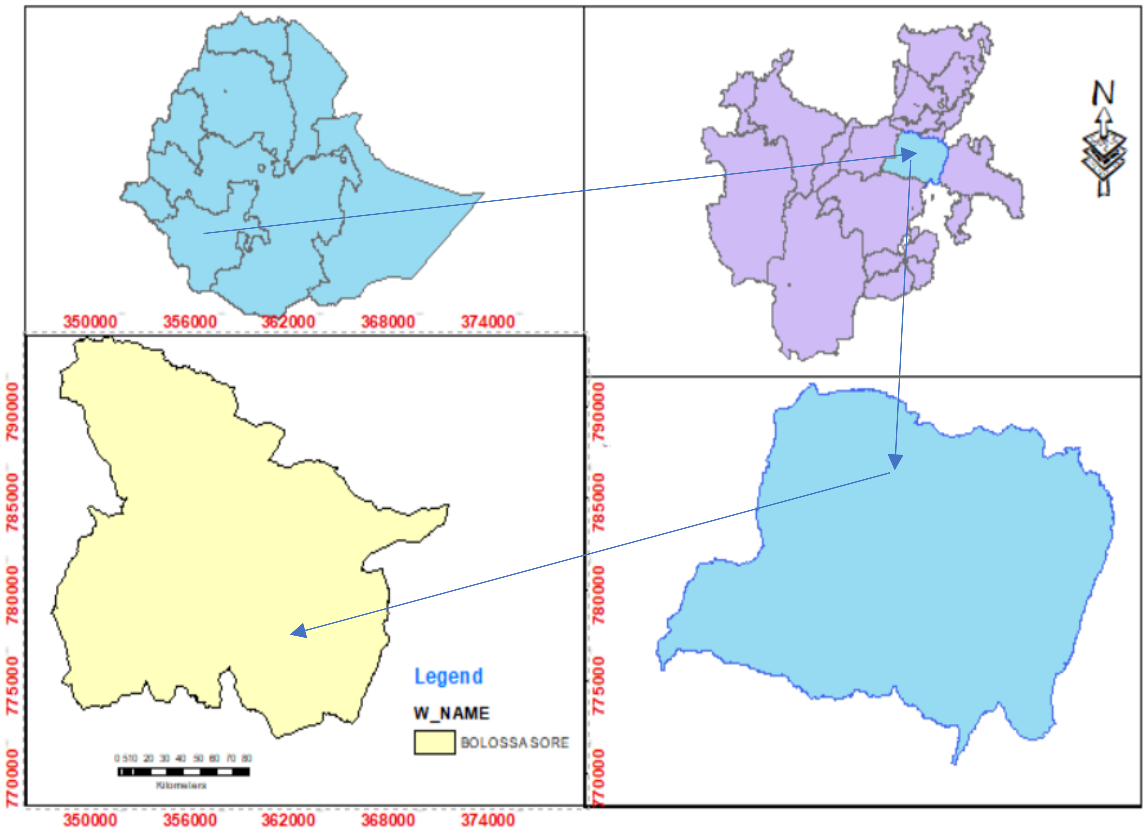


Figure 3. Map of the study area

The Woreda is situated between latitudes 6005'0” and 7011’0 “N and longitudes 3700’0” and 37050’0 “E as shown in **Figure 3**. The Soddo Hosanna road leads to Areka, the Woreda’s capital. The Woreda has a total area of around 273.26 km^2. With a population of 219,649, it is administratively divided into 27 rural & 6 urban kebeles, located 155 kilometers to the west of Hosanna Town and 29 kilometers north of Soddo. The Woreda has a total area of around 273.26 km^2. Its 219,649 inhabitants are spread throughout 33 kebeles for administrative purposes.

3.2. Research Design

A mixed method was used, combining quantitative and qualitative data collection and analysis techniques. Additionally, both primary and secondary data analyses were undertaken to answer the research questions.

3.2.1. Sample Size and Sampling Technique

As per the data from the Woreda water office, the non-functionality rate of water supply schemes stands at 30%, which is very alarming. There are around 41 solar-powered water supply schemes in Bolososore Woreda out of the 286 existing water supply schemes. The sample will only consider the population benefiting from solar-driven water supply systems. Out of the total 33 kebeles in the Woreda, only 14 kebeles are reached with solar-driven water supply systems, and the sample size is calculated from these kebele populations. The total number of households getting water from solar-powered water schemes in the 14 kebeles is 3635. The research covered a representative sample size of 392 using a standard equation by Yamane (1967). Simple random sampling techniques will be used to select study households in the Woreda.

$$n = \frac{N}{1+N(\mathrm{e}^{\wedge}2)} \qquad \text{Yamane equation}$$

N stands for sample size, N stands for total population and e stands for margin of error, 5%.

3.2.2. Sampling quantitative study

To meet the requirements and objectives of the research, non-random purposive sampling techniques were used for selecting purposively selected sampling units with which seven solar-powered rural water supply systems (three functional, four non-functional) and simple random sampling techniques for the selection of the ultimate sampling units in which each household and communities have an equal chance of being selected for the sample considered.

3.2.3. Sampling qualitative study

Qualitative data was collected through Key-informant interviews (**Appendix 3**), focus group discussions (***Appendix 4***), desk reviews, and direct observation of solar-driven Water Supply facilities to complement the quantitative information (**Appendix 5**). Purposive sampling techniques were used to select the sample population to gather relevant qualitative data.

Key Informants Interviews (KII): The KII was critical in getting in-depth qualitative information on the key issues under this assessment, which were found to be crucial methods to answer the key research questions one to four. The source for such data is selected from key community members, institutions like water federation, and stakeholders working on solar-driven water schemes, including staff and relevant government partners. In total, ten KII were conducted.

Focus Group Discussions (FGDs): The FGDs helped ascertain information obtained from KIIs and showed the group dynamicity on the issue under assessment/study. The FGDs were conducted by experienced facilitators who were assisted by a note-taker (**Appendix 19**). All three FGDs, with 36 participants in total, were tape-recorded with consent from each participant (**Appendix *2***). Semi-structured FGD guides were used to facilitate the FGDs.

Desk/Document Review: The solar-powered water supply project-related documents in the woreda/Zone/Region/Federal level, historical profiles, and other secondary data and information to substantiate the quantitative data obtained from the field at different stages of the assessment process were reviewed.

Direct observation (DOs): An inventory was performed to assess the status of community-level solar-driven water supply facilities/ constructed through the sample area (**Appendix 18**).

3.3. Data Collection

The design document of the project was collected from the implementing agency and the Woreda Water Office. The document has been critically reviewed to confirm whether standard water supply design procedures are followed or not to inform the technical soundness of the project. In addition, key informant interview has been conducted with water supply Engineers and technicians from government and implementing NGO in order to figure out the key technical gaps using a semi structured KII guide (**Appendix 3**).

The data collection tool proposed for quantitative assessment was mobile-based face-to-face personal interviewing using the Kobo toolbox. The interviewer reads questions to the respondent from a mobile phone screen preloaded with the questionnaire via the Kobo toolbox. The respondent's answers are immediately entered into the device, which avoids the need for manual re-keying of the data. This enables each interviewer to run a set of consistency checks during the interview to resolve anomalies with the respondent. A structured household assessment questionnaire was prepared for the quantitative survey (**Appendix *2***). The instrument was meant to capture data to answer the objectives of the assessment and research questions stated in the section of this proposal. The assessment questionnaire was prepared in English and, upon review by the research advisor and approval, was translated into the local language in the study area.

Semi-structured and open-ended key informant interview guides and FGD guides were developed in English and later translated into the local languages of the study area. The final approved KII and FGD guides were pretested before use for the study. In addition, a standard observation checklist was prepared and used to guide direct observation of solar-powered water supply facilities.

3.4. Data Analysis

The review of the project design document is aimed at identification of technical gaps that could impact the practical implementation of SPRWSS and it is triangulated with the findings of the KII. Accordingly, analysis was done focusing on the key technical aspects that could have negative impact on the continued functionality of the schemes like the capacity of solar pumps, reservoir and water demand analysis to check the balance with the water supply or production.

The collected data is analyzed to identify the practical implementation challenges these systems face, such as technical, financial, operational, management, and social factors, including user perception & satisfaction. The challenges are analyzed and evaluated to identify the key factors that impact the sustainable implementation of solar-powered rural water supply systems.

The quantitative data collection was mobile-based and personal interviews. Thus, the data collection and entry are accomplished simultaneously, accurately, and on time. The data was transferred (exported) into SPSS, and the data analysis was performed using this software. Before the analysis, further data check-ups were made including data cleaning by checking missing values, removing duplicates, detect outliers and consistent data coding. The second data analysis phase was a major statistical data analysis process to calculate percentages and averages, tabulate by sample stratifications, assess causal determinants, etc.

Qualitative data analysis involved thematic coding of the transcribed and translated in-depth interviews and focus group discussions. Data was analyzed and compiled using a thematic approach by conducting an ongoing content analysis of the transcripts. Then, the identified challenges were classified into technical, financial, social, and institutional dimensions.

3.5. Ethical Consideration

Survey participant's safety and security are paramount and guide all research decisions. Thus, when conducting the intended evaluation, the researcher ensured that the potential benefits to the respondents were greater than the risks involved. Moreover, the following standard ethical considerations were made during the whole research process:

- ✓ Before conducting the assessment, the necessary communications about the study's overall purpose and appovals were made with woreda /community-level administrative bodies as shown in **Appendix *20***.
- ✓ The study participants were given complete information as to the objective of the study and their benefits/risks, and they participated in the study only after their consent was given.
- ✓ Information gathering and documentation were done in a manner that presents the least risk to respondents, is methodologically sound, and builds on current experiences and good practice.
- ✓ The confidentiality of individuals and the information they reveal is always protected.
- ✓ Every participant in the study obtained informed consent, as shown in ***Appendix 2***.
- ✓ The information collected is anonymous, and no identification, such as names, identification numbers, etc. All the information and data collected were accumulated, organized, stored, analyzed, and retrieved, guaranteeing confidentiality. Information is interpreted as group data and not as individual data.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Demographic Characteristics of the Respondents

Information on the socio-demographic characteristics of the households provides a context for the population's living conditions. The mean age of the respondents is 35 years, which shows that the majority of the population is young. The average family size was 5 as per the data collected.

The results shown on **Figure 4** below revealed that 58% of the respondents were female, and 42% were male. Additionally, 80%, 9%, 9%, 1%, and 1% of respondents were spouses, daughters, sons, relatives, and housemaids, respectively.

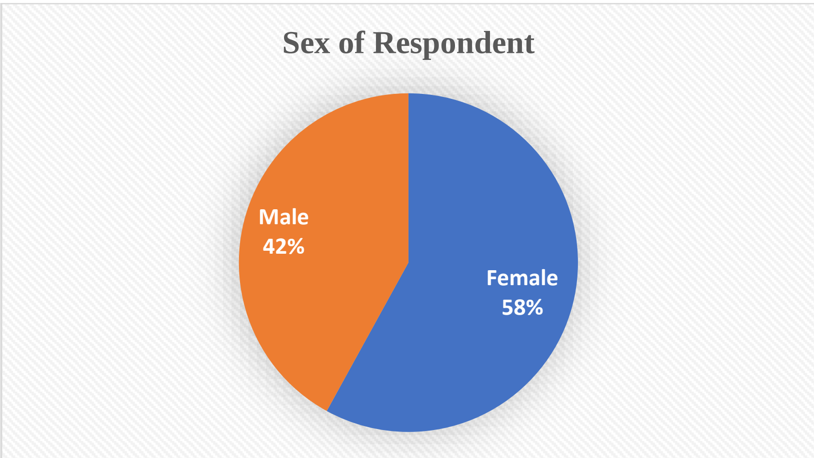


Figure 4. *Sex of respondent*

The respondent's position in the household shows 49% are wives, 31% are husbands, 18% are sons/daughters, and the remaining 2% are others, including relatives (**Appendix 6**). Looking at the marital status of the respondents, 76% are married, 20% are single, 3% are widowed, and 1% are divorced.

Moreover, the education level was assessed as a core aspect of the demography, as shown in **Appendix 7**. About a quarter of the respondents (26%) were illiterate (can't read and write), and 6% of the respondents could read and write only. Whereas 37% of the respondents go until primary school as their highest level of education completed, 23% attended from Grade 9-12, and the remaining 8% are above grade 12, including TVET and University graduates.

4.2. Technical Challenges

4.2.1. Assess the design and construction quality

The design document of the solar-powered water supply schemes was reviewed to see whether the expected standard procedures had been followed. Thus, the design document missed assessing the available solar radiation(World Vision Ethiopia, 2019), which is mandatory before selecting the solar panels that will generate the required energy from the available radiation in the area under study. It is strongly recommended by international design guidelines (Water Mission, 2021) and the national level standards (MoWIE) to determine the active sunlight hours during the day on which the design of electromechanical components should be based on. Moreover, the project implementation is not as per the design document; for instance, it was proposed to use a plastic service reservoir supported by RHS steel structure, but practically, the plastic service reservoir is not supported by a steel structure. The questionable part of the design is that it puts the same size pump, reservoir, and other basic components for the different sites, which raises concerns about the credibility of the assumptions considered while preparing the study document. Each system has its own characteristics and basic components, like a pump, reservoir, riser pipe, and pressure line. However, the type and capacity required for different sites should be separately addressed based on the specific details of the site.

To be more specific, the solar submersible pump capacity design was explicitly checked on the discharge, total dynamic head, and pipe material used. The total dynamic head and the safe yield from the well are the major inputs used to determine the capacity of the submersible pump for each site. The design document shows that the SQ Flex model 2.5-2 pump model was selected and installed at all sites. The specified pump model has the capacity to deliver water at 120 m maximum head with 1.4 KW power. Based on the physical observation, one scheme at Ocha Village of Dubo Kebele has eight solar panels, giving a total power of 11.2KW, and the remaining schemes under assessment have four solar panels, giving a total power of 5.6KW per scheme.

The table below (**Table 1**) details the designed power and identifies whether the calculated head and pump capacity are correctly sized. According to the analysis, out of the seven, three pumps are sized correctly, found in Boyna Kare, Mante and Ocha Villages; the remaining four are undersized.

Table 1. Assessment of total dynamic head and pump capacity

Name of site	Safe Yield	Total Dynamic Head		Pump capacity in kW	
		Designed	Calculated	Designed	Calculated
Achura Mazegaj	2	80.84m	134.28m	2.44	3.8
Achura No 2	2	80.5m	136.51m	2.43	3.8
Ocha Village Dubo Kebele	1.5	99.39	100.42	2.25	2.1
Mante Village Dubo Kebele	1.5	75.98	75.31	1.86	1.6
Boyna Kare Village Sh/Homba Kebele	2	67.25	74.19	2.03	2.1
Gasho Basa Village Wormuma Kebele	1.7	80.29	99.08	2.06	2.4
Dijala Village Wormuma Kebele	2	77.19	106.08	2.33	3.0

Ocha village in Dubo Kebele has eight solar panels installed, each with a capacity of 1.4 KW at 120meter head, and with a pump capacity of around 2.2 KW, which is found proper, being almost equal with the calculated 2.1 KW capacity and the same is true for Mante Village in Dubo Kebele and Boyna Kare Village in Shuye Homba Kebele, as the pump capacity deisgned is found correct compared with the calculated capacity. The two villages in Wormuma Kebele, Gasho Basa, and Dijala have undersize pumps compared with the calculated pump capacity shown on the table. The remaining two systems in Achura Kebele have similar scenario with the above villages in Wormuma Kebele, as the designed pump capacity was found undersize compared with the calculated pump capacity.

The submersible pump installed is the same in each site as the implementing agency opted to install the same size pump at all sites despite the different characteristics like total dynamic head and well yield, to mention the major factors that could affect the selection of the electrotechnical components. This has been identified as a major technical gap resulting from the limited skill and experience of experts involved in the design stage as a practical implementation challenge encountered in the solar-powered rural water supply systems in Boloso Sore Woreda. The finding goes in line with the national standards and other research reports (Mwangi et al., 2018; Water Mission, 2021), highlighting the importance of a comprehensive design, proper sizing, use of high-quality components, and providing skilled technical support, focusing mainly on building the skill of local level technical experts.

Moreover, frequent damage to the HDPE riser pipe was reported by 50% of the KII participants. The review of the design document showed that HDPE PN10 used for the riser pipe in all seven SPRWSS under study. In order to identify the possible reason of damage, the total dynamic head was calculated by taking the required measurements during the physical observation of each scheme (Table 1). Accordingly, the two villages in Achura Kebele have higher TDH than designed surpusing the allowable pressure of installed PN10 HDPE riser pipe. It is the same for Dijala Village where the TDH was calculated at 106.08m and it is found above the maximum allowable head of the installed PN10 riser pipe, which is around 100m or maximum pressure of 10 bar. Therefore, it can be concluded that the inadequate design of the riser pipe with PN10 resulted in frequent damage of the pipe and non-functionality of the scheme for longer.

Furthermore, 85% of the focus group discussion and key informant interview participants revealed that the seat of the plastic reservoirs is not smooth enough where gravel and steel bars are left open, exposing the base of the plastic reservoir to be damaged within a short period after construction. This showed poor construction quality due to a lack of professional construction follow-up and a material selection gap. In addition, the size of the elevated storage reservoir was initially designed to be 10 m^3, and due to damage to the storage tankers, some users replaced them with 1 m^3, two in number, which puts the quantity of water to be stored under a question mark. The long time spent fetching water on each site and the adjustment of programs to fill the reservoir are good evidence that the discrepancy between what has been planned/designed and installed resulted in the provision of less water to the user community.

4.2.2. Assess system functionality and causes of malfunction

As per the field-level assessment and physical observations, four out of seven schemes were found to be non-functional during the visit. The detailed findings on each specific scheme are presented in the table (**Table 6**).

The results in **Figure 5** reveal respondents' feedback for the major causes of mal-functionality/breakdown across the study area. Accordingly, 38% of the respondents confirmed that a leaking reservoir is the major cause of the non-functionality of solar-powered water supply systems specific to the four schemes that are not functional. The findings from the focus group discussion and key informant interview showed the same result for almost all participants of FGD & KII, who reiterated their big concern about the quality of the water storage tanker installed under the project.

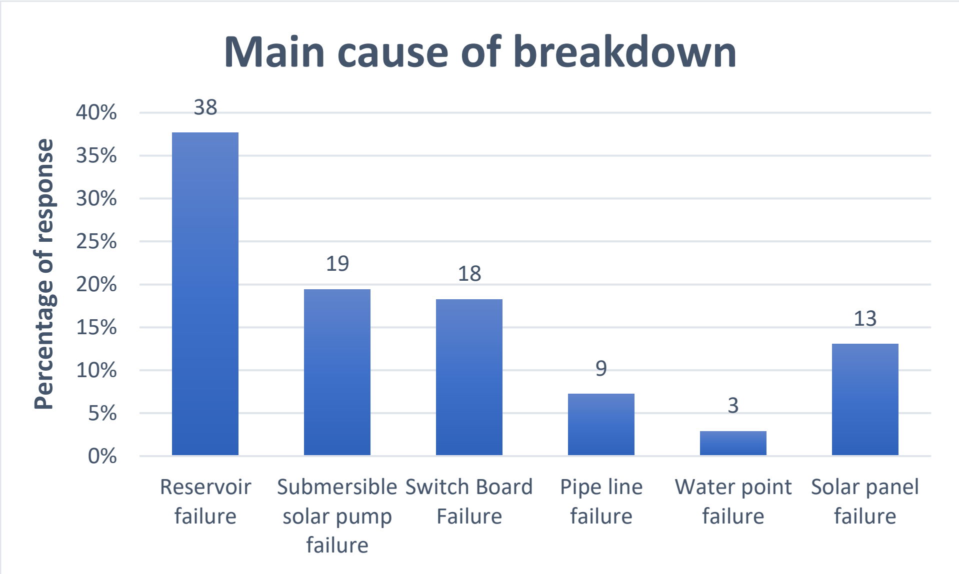


Figure 5. *Main causes of scheme breakdown*

It is followed by submersible pump, switchboard, solar panel, pipeline, and water point failures at 19%, 18%, 13%, 9%, and 3%, respectively. One of the key informant interviews shared their insight that *"the solar pumps are getting damaged due to the undersized HDPE riser pipes used on the pressure line for HDPE PN10 pipes were used as the pressure main, and the majority of them are bursting, notwithstanding the water pressure, which could be a major cause for the submersible pumps getting damaged easily"*.

When respondents were asked the question 'What is the problem with your solar-powered water supply system?' on both functional and non-functional, 78 out of 345 respondents reflected that it takes longer to get water, and 73 cited broken pipes and leaking reservoirs as the major problems. Additionally, 42 of the respondents reflected that the tariff is not affordable, 34 mentioned the theft of system components, and 23 reflected other reasons, followed by 30 respondents on each reported submersible pump and switchboard failure, respectively. Malfunctioning solar panels, reduced quantity of water, and poor quality of water were given as the problems of the systems by 26, 5, and 4 respondents, respectively. These findings reflect the details of the main problems shown in **Figure 5** above.

Therefore, based on the findings shown in **Figure 5** and **Table 6** it can be concluded that the longer time required to collect water resulted from the combined effect of broken pipes, leaking reservoir, reduced quantity of water from the source due to malfunctioning solar panels that are shaded by trees.

In analyzing the time it takes to collect water from various water points in **Appendix 8**, it is indicated that 50% of the respondents took more than 30 minutes. For 28% of respondents, it took more than one hour, while 15% reported taking exactly 30 minutes. Only 7% of respondents were able to collect water in less than 30 minutes. The leaking reservoir became the major problem in most of the schemes, and the majority of respondents confirmed it took longer to get water, which shows the big impact of the leaking reservoirs resulting in the loss of water from the reservoir that the user community could utilize if proper quality storage tank with quality finishing of elevated tanker seat is ensured from the very beginning.

One of the assessment findings in **Table 6** indicated that 26 out of 345 respondents identified malfunctioning solar panels as a challenge. However, the issue was not related to technical problems; instead, it was caused by a cluster of trees located very close to the solar panels, which shaded them and blocked sunlight (**Appendix 14**). Almost all of the solar panels were found dirty during the physical observation as shown on the pictures (**Appendix 15**). Moreover, none of the operators have a routine cleaning schedule in place.

Similarly, physical observation on selected solar panel sites showed that six out of the seven solar panel sites are extremely shaded by long trees. The focus group discussions (FGD) and key informant interviews (KII) revealed a common observation: the lifespan of the trees at these sites exceeded the duration of the project. This indicated that the trees had never been trimmed, even after the project was completed and it reduces the sunlight exposure like the cloudy days in the rainy season. The finding goes in line with one study which showed the limitations and challenges, such as cloudy days and summertime minimizing the solar energy captured (Girma et al., 2015).

Moreover, one technical challenge in implementing solar-powered rural water supply systems in Boloso Sore Woreda is the limited technical expertise at all levels who can design and install the schemes with the required standard. The lack of technical expertise has forced the local government and user community to seek technical support from the implementing agency, which had already left the area after completing the project work. Poor workmanship and limited capacity resulted in the damage of schemes in Wormuma kebele Gasho Basa village, where the solar submersible pump fell into the well while the woreda technician was taking it out for inspection. As a result, the village community has not received water from the scheme for the past two years. This situation highlights the significant technical challenges and limitations encountered while implementing solar-powered rural water supply systems in Boloso Sore Woreda.

During the rainy season, sunlight is intermittent, limiting the solar system's capacity to generate enough water for the community, which presents another technical challenge faced in the area. In addition to the cloudy days, trees around the solar panels block the sunlight from striking the panels, reducing the quantity of water pumped from the well into the elevated storage tankers.

Furthermore, the respondents in Dijala village of Wormuma Kebele confirmed that the HDPE riser pipe was repeatedly damaged, and the woreda technician fixed it by cutting the damaged part. However, the length of the riser pipe became too short and got out of the required depth from the well. The respondents also reported that the submersible solar pump failed after that, and some parts of the pump were stolen during check-ups. These could lead to the conclusion that the submersible solar pump was burnt while dry pumping as the riser pipe is too short to get inside the well deep enough for the pump to function properly.

4.2.3. Service Reservoir

Designing the capacity of a service reservoir is important for a solar-powered water pumping system in order to prevent water shortages caused by fluctuations in water demand (affected by conditions like cloudy weather or peak sunlight). The ultimate objective is to maintain a constant flow of water at all times. The reservoir capacity should be one-third of the maximum daily demand (m^3/day) as per the national standard design guidelines. Relevant data were taken from the study document prepared by the implementing agency, and the accuracy of the reservoir size determined was checked.

Based on the long water collection time reported, calculating water deficit was found critical to cross check whether the water supply meets the water demand in each scheme as shown on below table.

Table 2. *Water Deficit calculation on each scheme*

Kebele	**Village**	**Water Supply (m3/day)**	**Water Demand (m3/day)**	**Water Deficit**
Achura	Mazegaj	16.2	19.93	-3.73
Achura	Kutr 2	16.2	25.35	-9.15
Dubo	Ocha	21.6	14.48	7.13
Dubo	Mante	21.6	10.85	10.75
Shuye Homba	Boyna Kare	16.2	19.93	-3.73
Wormuma	Gasho Basa	18.36	12.68	5.69
Wormuma	Dijala	36	12.68	23.33

It should be noted that the water supply or production is calculated based on the data provided on the design document of the project. The design document shows well yield ranging from 1.5l/sec to 2l/sec. In addition, GTP-II standard of 25l/p/d was considered while calculating the water demand. It is found that three schemes out of seven have a water deficit, namely; Mazegaj, Kutr 2 and Boyna Kare villages and the remaining four schemes have good balance. Furthermore, 10 m^3 storage reservoir was installed as shown on the design document as well as the actual physical observation. When compared with the water demand per day, all the reservoirs are inadequately sized forcing frequent operation of the SPRWSS. The inadequate sizing of the storage tankers and the water deficit imply that the pumps are forced to operate more frequently within a given day. This inturn affected the performance of the pump and the wells due to overpumping compromising the recharge rate of the well.

As shown on above table, all reservoir sizes under use were found to be undersized for the calculated maximum day demand of the users. There might be two reasons behind this: one could be a reduction of the reservoir size to go in line with the available water/yield of the wells, and the other reason might be focused on financial availability. In both ways, the community demand for water was not met, as evidenced by the longer time it took to get water. However, there is another contradiction to consider: the existing reservoirs took longer to fill, raising questions about the reliability of the yield estimates. These estimates were not verified through pump tests at all sites, and the figures used were based solely on expert estimates made during the well development process. Therefore, it can be concluded that there were technical challenges related to proper reservoir design that can be taken as a result of the limited technical capacity to undergo professional design and study for project implementation.

Upon closer examination of the issue, it appears that the design could be enhanced by storing water from multiple wells in a larger storage tank. This approach could save costs and ensure a sufficient water supply for the communities involved. Additionally, this technical solution aligns with the recommendations of the National One WASH Program, which suggests a multi-village water supply system as a cost-effective solution. According to the physical observations, it is recommended that storage should be optimized according to the shallow wells yield. By doing so, water flow can be optimized to technical feasibility by pumping out as much water as can be sustainably abstracted. The physical observation confirmed all seven water supply schemes (100%), and water point operators reported delaying water collection times in the morning or closing as early as 1 pm to facilitate water pumping into the tanks. This practice often led to long wait times at the water point, especially as 55% of consumers interviewed collected water in the morning. The root cause of this issue was limited pumping during low-demand periods due to storage limitations, leading to rapid water depletion in the tanks during peak-demand times, necessitating replenishment in the late afternoon or early morning.

In addition to the proper design of the service reservoirs, two reservoirs were totally collapsed. The remaining five were leaking water, as shown in **Appendix 17**, causing a water loss that, in turn, affected the quantity of water the community could get from the water supply system. Similarly, one reservoir in Ocha village of Dubo Kebele was totally damaged, and the communities were forced to replace it with two plastic reservoirs of 1 m^3 each, putting the total storage at 2 m^3, implying a loss of 8 m^3 in the quantity of water stored for distribution. Therefore, the water stored in the two replaced reservoirs gets empty within an hour, and it needs another three hours to fill before the community expects water to fetch from the water points. Additionally, all seven systems have inadequate storage for a one-day household demand. It is worth noting that longer water collection time was mentioned as a leading problem in all sites which directly relates to the available/storage capacity. The submersible pumps were reported to malfunction by 19% of respondents, and this could be due to the frequent starting and stopping of the pumps due to inadequate storage capacity. The same has been flagged on the national level operation and maintenance guidelines, which state that frequent pump starting and stopping causes overloading,hereby reducing the life of the equipment (Ministry of Water, 2018).

4.3. Financial Challenges

4.3.1. Payment modality for water use

According to the assessment, two financial management approaches have been applied so far in Boloso Sore Woreda: pay as you fetch and monthly contribution. Monthly contribution, as the name indicates, involves households' contribution by paying a fixed amount of money on a monthly basis regardless of the quantity of water they consume. It was applied to all solar schemes across the woreda from the beginning by fixing the amount per household. The pay-as-you-fetch payment refers to the user community paying an agreed amount of money for each jerrycan of 20 liters every time they fetch water from the water points. The exact amount of money per 20-liter jerrycan is fixed upon discussion with the entire community.

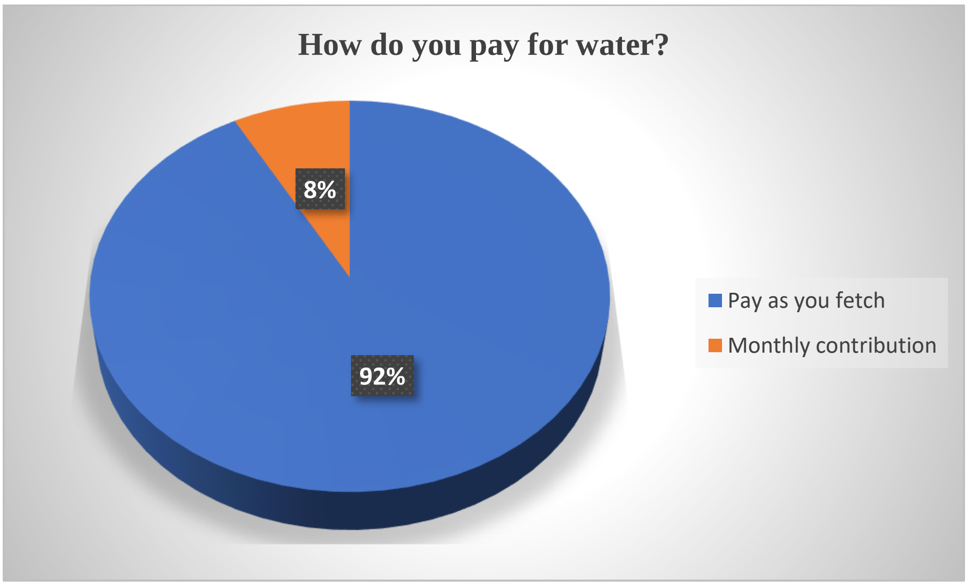


Figure 6. *Water fee payment modality*

The respondents to the questionnaire 'How do you pay for water?' all respondents confirmed the monthly contribution was being applied to all schemes at the beginning of the project. After observing the limited funds raised through the first approach, the majority of users switched to the second option. Specifically, 92% of respondents indicated that they were using the 'pay as you fetch' method, while the remaining 8% opted for the monthly contribution method, as illustrated in **Figure 6**, which displays the results for each option. Therefore, it can be concluded that the community is willing to accept and change the water fee payment modality based on the challenges encountered.

4.3.2. Water tariff setting

It is crucial that the community, through WASHCOs, collect enough user fees to ensure the system's financial viability because fixing a significant solar-powered system malfunction could be expensive (compared to manual pumps, for example). This cost was decided by the community WASH Committees after consulting with the user community in the specific village, as 100% of study respondents replied.

The community started a hot discussion among themselves and consulted the Woreda water office for technical guidance on how to solve the financial limitations resulting from the monthly contribution modality. After this, they decided to use the pay-as-you-fetch modality, where they sold 20-liter jerrycans for an agreed amount of money in each community. However, some communities are applying the monthly contribution approach in the woreda. The cost per a 20Liter Jerrycan ranged from 1-2 Ethiopian Birr.

The mean value for those paying using the monthly contribution is 16.03 Birr per household, and for those using the pay-as-you-fetch modality, it is 2.88 Birr per 20-liter jerrycan. The average/mean value resulting from the questionnaire 'How much do you spend on water per month overall?' is 111.43 Birr. Considering the additional convenience and time savings offered by the solar-powered systems, most water users felt these costs to be reasonable.

To further assess the payment for water, the community was asked whether they were willing to pay for water in the future per **Figure 7** below. As a result, 51% responded yes only per bucket of water & during breakdowns, 19% reported yes only per bucket, 2% reflected yes only when asked for breakdowns, and 28% of the respondents reported No as they are not willing to pay in the future for water use which is quite a large number of users.

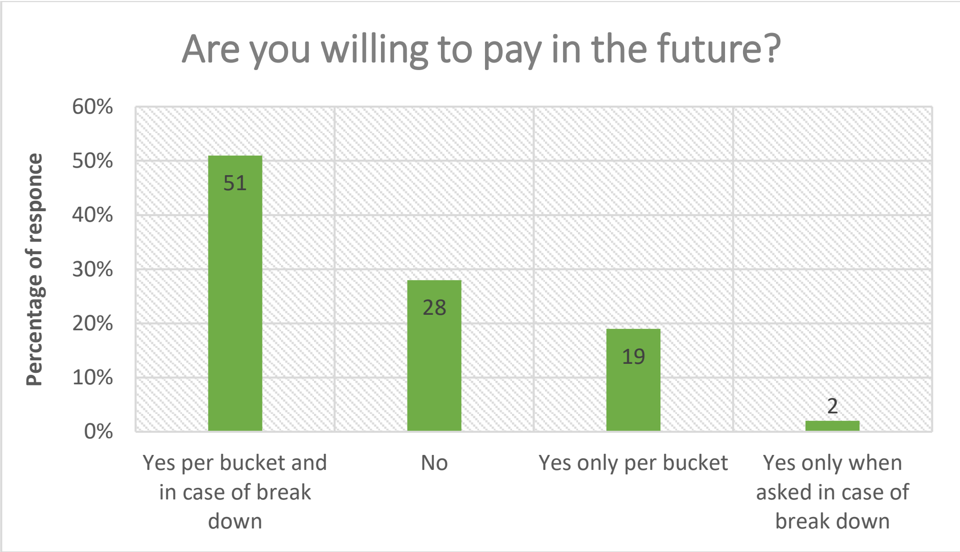


Figure 7. *Willingness to pay water fee*

Those not willing to pay in the future were asked why, and the reasons for not paying for water are shown in **Appendix 9**. Out of the 28% of respondents unwilling to pay in the future, their reason for not paying reads 18% responded they don't have enough money to pay, and 7% responded that other water sources are available. The remaining 3% responded the government and NGOs should pay, not the user community. The response shows that there are a large number of communities that have financial limitations/poor, but this was not the only reason for not paying water fees as there are still users who preferred to go to other water sources to get water instead of paying here and there are other users that believed the water should be provided on free basis. Eventhough, the majority of those unwilling to pay mentioned they don't have enough money to pay for water, 67% of respondents have a mobile phone, expending 152 birr on average per month on it, more than the average expenditure on water, which stands at 114 birr. This leads to the conclusion that the belief that water should be free of charge outweighs the entire community despite some poor community members finding it unaffordable to pay.

In most of the schemes assessed, communities would frequently provide free or much cheaper water to the most impoverished, but much depended on the user community's willingness, awareness, and financial capacity under consideration. Provisions were not being made in many localities. However, 55% of the user community responded that the water fee is affordable, whereas the remaining 45% disagreed with the water fee. This makes the SPRWSS under assessment financially unsustainable, at least partially, and it disagrees with the national guidelines (Ministry of Water, 2016). When further questioned about the users unwillingness to pay in the future, 18% responded they don't have enough money to pay, which translates to an equivalent number of populations in each village unable to pay water fees, regardless of the cost, according to the WASHCOs and households surveyed. When this happened, it was found that some of WASHCOs/communities offered in-kind aid to needy individuals. In actuality, the low-income, with 5% of communities and 44% of them, were forced to use other (unimproved) water sources. In conclusion, the SPRWSS in Boloso Sore Woreda has an affordability issue and couldn't meet the water demand of the poorest community as opposed to the Ethiopian water resource management policy that considers water as a resource with both economic and social value.

Two contradicting findings were observed regarding how the low-income users within the community are provided water. One of the WASHCO members in Achura Kebele confirmed the following during a focus group discussion:

"There are very low-income people in our community for whom water was provided on a free basis. However, the woreda trained us to collect water tariffs, and we stopped providing water to those people as the water could only be provided with an equivalent tariff. These people are fetching water from unprotected sources because they don't have the money to pay for it".

Whereas the other WASHCOs in Dubo Kebele responded in the other way as below:

"The poorest of the poor in our village are allowed to use the water on a free basis as they don't have income/money to pay for it."

4.3.3. Overall financial management

In most villages, it was identified that WASH Committees are responsible for collecting user fees and keeping them in a common user account at omo-microfinance at the woreda level. However, the user fees were not being collected on those schemes that did not give service or became non-functional. After checking the scheme's age, the money available in the group account was minimal. In all situations, users were not given payment log books and receipts.

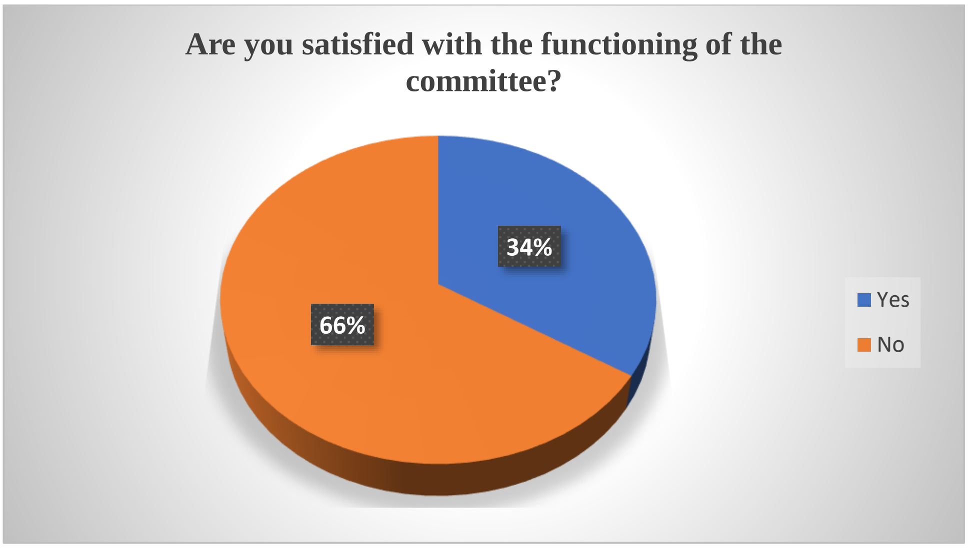


Figure 8. *Community satisfaction with WASHO performance*

Furthermore, 66% of respondents were not satisfied with the functioning of the water management committee, and the other 34% were satisfied with the functioning of the committee per **Figure 8** above. Those who were not satisfied with the water management committee were asked why they were not satisfied. Thus, focusing on the results relevant to this section, 68 out of 228 respondents reflected that the committee doesn't use revenue well, and 29 respondents reported the committee charged too much for water, as shown in **Figure 9**. This leads to the conclusion that there is a financial management challenge for the committee doesn't use the revenue well and charges too much. The results for the remaining respondents, 131 in number from those not satisfied, are incorporated under section 4.4.6.

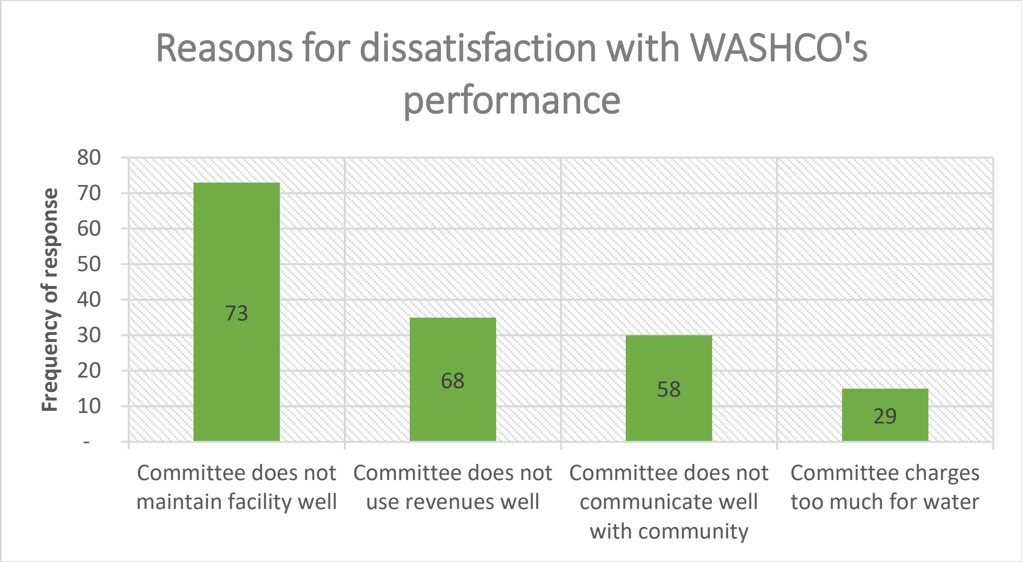


Figure 9. *Reasons for dissatisfaction with WASHCO's performance*

Also, 86% of respondents confirmed that technical, administrative, and financial records are kept, and 14% confirmed records were not kept at all. Looking at whether the records were shared with the user community, 43% of respondents reported yes but less than every year, 23% reflected yes at least every year, 15% reported yes twice a year, and 5% of respondents confirmed the records were not shared to the community. Hence, it can be concluded that there are gaps in the keeping and sharing of financial and administrative records to the user community, reflecting the overall challenge of financial management.

Furthermore, respondents were asked about their expectations of the roles and responsibilities of the water management committee, as shown in **Appendix 10**. As a result, 132 respondents from 345 reflected that the committee should consult with the user community more often, 110 responded that the committee should help more effectively in case of breakdown, and 103 reflected that the committee should ensure there are enough water points.

For the question, 'What do you do when you have problems with your solar-powered water supply?, 124 out of 345 respondents reported they would help make decisions, 112 reported they know who to talk to, 105 reflected they contribute money, and other four reported they play no role. A further question was asked, 'When you have problems with your water supply, who is the best to go to?' for which 46% of the respondents confirmed they preferred an NGO or implementing partner, 25% preferred the woreda water office, 11% preferred the water committee, 12% reported no one and 6% reflected they don't know as shown in **Appendix 11**.

As witnessed during the focus group discussion, the community started being curious when they observed some households fetching unlimited quantities of water in the name of social events and yet paying the same amount of money they used to pay. As time went on, the collected money was found to be less, and the community could not maintain their schemes when needed, resulting in the schemes' non-functionality for a longer period than expected as seen in the table below (**Table *3***). The available savings amount at Boyna Kare village of Shuye Homba Kebele was found to be 2250 Birr for the WASHCOs, and the user community decided to continue with the monthly contribution. In addition, they stopped water fee collection after the damage to the switchboard. The first critical financial challenge under solar-powered systems is the huge initial investment as stipulated during the key informant interviews. One key informant from the implementing agency said:

"It is only in Ethiopia that solar panels & related spare parts remain expensive as opposed to the relatively declining cost of solar panels across the world in the eye of diverse product types creating positive competition among manufacturers."

While implementing Boloso Sore SPRWSS, the implementing agency first encountered financial challenges due to the lengthy importation from abroad, customs clearance, and quality inspection processes.

The focus group discussion and the key informant interviews revealed the devastating truth that there was a major bottleneck on the financial aspect while assessing the financial challenges. It is a narrative that says water from the solar system should be free of charge, like the sunlight. Those not willing to pay in the future for water use from solar-powered water supply systems mentioned that water is a free gift from God and that they must not be asked to pay for its use. It came from the unmannered advocacy for the use of solar energy for rural water supply systems. Specifically SPRWSS are considered to have zero operation and running costs compared with diesel-run water supply systems, which created the negative notion that water from solar-powered systems comes free of charge for the user community.

Table 3. Water fee-saving status per scheme at the time of study

Name of Kebele	Name of Village	Account Number	Available saving-Birr	Remark
Achura	Mazegaj	37386	75, 000	NF
Achura	Kutr 2	37059	35, 000	F
Dubo	Ocha	38037	2, 066	F
Dubo	Mante	38358	29, 000	F
Shuye Homba	Boyna Kare	36947	2250	NF
Wormuma	Gasho Basa	37288	2100	NF
Wormuma	Dijala	37036	10750	NF

The above table (***Table 3***) shows the actual saving amount as of the study time where the non-functional schemes confirmed they were not collecting water fees. Furthermore, ***Table 4*** shows the estimated cost for annual operation and maintenance. The next one (***Table 5***) shows the estimated annual saving amount from each scheme to aid our analysis of the financial stability of SPRWSS.

Table 4. Annual operation and maintenance cost estimation per scheme

Cost item	Estimated cost (Birr)	Details of cost
Personnel cost	60,000	Salary for care taker, technician, guard
Spare part for maintenance	85,000	Spare part for pump, pipe line
Solar panel maintenance	15,000	Cleaner cost, minor maintenance cost
Transportation	10,000	Cost to cover transportation during maintenance including for Woreda expert
Community training	8,000	Training cost for WASHCOs, users
Insurance	4,000	Insurance of equipment for damage, theft
Miscellaneous costs	3,000	Unforeseen and other operational costs
Total O & M costs	185, 000 Birr	

Table 5. Annual saving estimated from water fee

Name of scheme	Users paying with monthly contribution	Users paying with pay as you fetch	Saving in Birr, monthly contribution	Saving in Birr, pay as you fetch	Total saving
Achura	9	106	1080	381,600	382,680
Achura	4	51	480	183,600	184,080
Dubo	4	44	480	158,400	158,880
Dubo	4	52	480	187,200	187,680
Shuye Homba	5	60	600	216,000	216,600
Wormuma	4	44	480	158,400	158,880
Wormuma	3	34	360	122,400	122,760

Moreover, the annual finance required for operation and maintenance was estimated based on field experience and expert advise. According to ***Table 4*** above, the annual operation and maintenance cost is estimated at 185,000 Birr. When compared with the possible saving from water fee collection (***Table 5***), four schemes out of seven are believed to save below the estimated annual finance required for operation and maintenance. Hence, the annual saving being less than the cost to be incurred, the four schemes are not financially in good shape to cover their operation and maintenance costs. This leads to the conclusion that the SPRWSS in Boloso Sore have faced financial challenges to ensure the scheme are giving service in the long run. The annual saving estimated on the table here might not exactly reflect the actual saving and it solely is absed on the finding of the this specific study on users willingness to pay.

4.4. Operation and Maintenance Challenges

The term "operation" in this particular thesis work refers only to the day-to-day management, oversight, and control of a solar-powered rural water delivery system with the possibility of additional remote monitoring. The term ‘maintenance’ in this thesis work refers to several key activities to ensure the solar-powered rural water supply system operates efficiently and reliably.

4.4.1. Functionality of schemes

According to the respondents, the mean value of the number of days the solar-powered rural water supply system was non-functional was more than 186 days, which is more than half a year. The maximum was 762 days, and the minimum was one week. The respondents were asked how many days it usually takes to repair the systems, and the below chart (**Figure 10**) shows the response. Around 43% responded that it took more than one month, 40% responded that it took two weeks, and 17% responded that it took one week to repair the breakdowns. The difference in the time required to repair breakdowns reflected that there are minor breakdowns like fittings that need days to fix and major breakdowns on electromechanical components requiring more than a month.

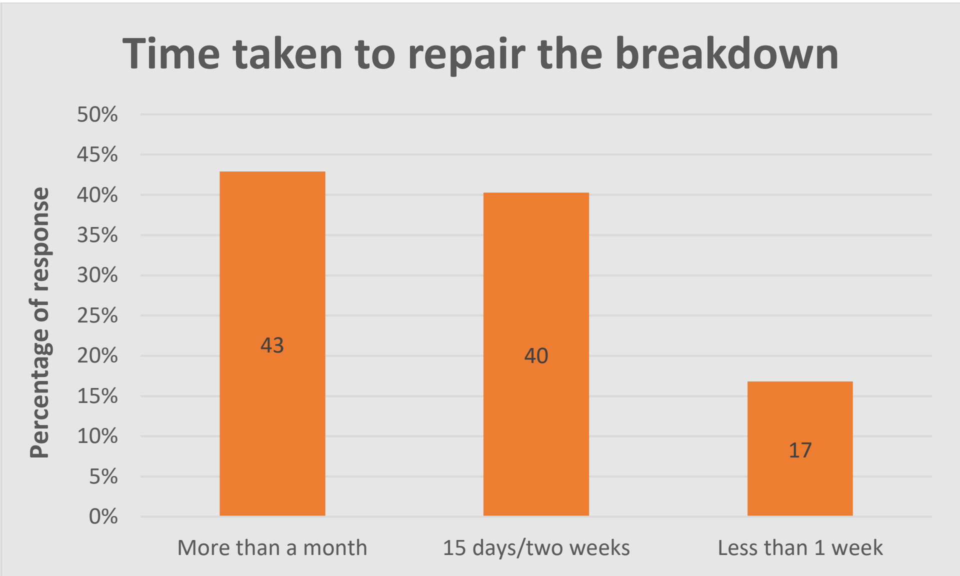


Figure 10. *Duration to repair breakdowns*

4.4.2. Major causes of system breakdown

The results in **Figure 5** showed that 38% of the respondents confirmed that leaking reservoirs are the major cause of the non-functionality of solar-powered water supply systems specific to the four schemes not functional. It is followed by submersible pump, switchboard, solar panel, pipeline, and water point failures at 19%, 18%, 13%, 9%, and 3%, respectively. This leads to the conclusion that the major causes of the non-functionality of solar-powered rural water supply systems in Boloso Sore Woreda do not specifically come from the technology itself. Rather, it results from the non-solar components like the storage tankers, pipelines, and water points in the majority of sites visited. However, the solar components like the switchboard, submersible pump, and solar panels took a reasonable portion of the reasons for the system breakdown even though they came due to limited preventive maintenance, shading from trees, and damage from unauthorized people.

The focus group discussion and key informant interview showed the same result for almost all participants of FGD & KII, who reiterated their big concern about the quality of the water storage tanker installed under the project. The leaking reservoir being a major bottleneck has not been reflected in previous studies, though the other causes of breakdown, like the pump and switchboard, were found to be major causes similar to this specific study finding. The poor construction material selection during the system design stands out as a big gap regarding the leaking reservoir in Boloso Sore Woreda, as it has not been a big issue in previous studies and projects.

4.4.3. Water supply system breakdown and repair

According to the respondents, the mean value of the number of days the solar-powered rural water supply system was non-functional was more than 186 days, which is more than half a year. The results on the number of days required for repairs showed more than 17 days are needed for repairs.

Even comparatively minor problems could result in a large amount of system downtime when systems malfunction, as reservoir leakage could be considered a minor problem given its availability in the local market. The minimum time to fix the breakdowns is one week, and the maximum is one month. As witnessed during the focus group discussion and key informant interview, repairs related to fitting and pipeline were managed within days. This partially goes in line with a previous study finding (UNICEF Ethiopia 2014), as the average number of days to fix repairs was reported to be three days. Because of inadequate spare parts supply chains and a shortage of locally competent personnel to perform repairs, a single fault can sometimes cause an entire system to remain inoperable for weeks, even years, as witnessed in Gasho Basa village of Wormuma Kebele, where the system stayed more than two years without repairs.

If the breakdown is related to pumps, switchboards, and related major components, the repairs typically required the transportation of specialized technicians from Addis Ababa, expected to take weeks due to the great demand for their services, but it didn’t work out for Boloso Sore Woreda and has left the user community without water. The findings demonstrate the urgent need for better supply management for spare parts and local capacity creation.

4.4.4. Capacity of technical experts and & preventive maintenance

As confirmed by household survey respondents, focus group discussions, and key informant interviews, the lack of properly trained technical experts is one of the major challenges posing difficulty to operating and maintaining the solar-powered rural water supply systems in Boloso Sore Woreda. In addition, the number of technical experts at the woreda level is very limited because only one expert took training organized by the implementing agency, and the other expert accompanying him didn’t take any kind of technical training. This was confirmed during focus group discussions as they mentioned that the number of experts is very minimal compared with the total number of schemes in the woreda, leading to frequent breakdowns and resulting in the non-functionality of the schemes for longer than expected.

Enhancing the technical skills of employees at all levels was crucial. It was discovered that a limited number of skilled specialists were heavily relied upon, frequently requiring lengthy travel times to reach communities. Due to the strong demand for their services, minor repairs that could be completed quickly and cheaply at the local level continue to be costly.

For example, Shuye Homba and Wormuma Kebeles, where WASHCOs paid per diems of woreda technicians for a check-up of system failure and fixing it, took almost all the savings of the schemes. They even go beyond the woreda, seeking support from zonal & regional experts as well as looking for a connection to the Addis Ababa market in search of major components for replacement like solar pump, switchboard, etc. On the one hand, they paid every penny per perdiems, and the other issue is the limited capacity/skill/number of government technicians and unavailability of the spare parts in the local market, even in Addis Ababa. The worst part is there are only two experts at the Woreda level, with one having hands-on experience repairing SPWSS & the second one having very limited knowledge skills to manage SPWSS, as the technician himself witnessed during KII.

The design document of the implementing agency and solar pump manufacturer confirmed that the solar pump has a life span of 15 years and will not get problems before the first 5 years of service. The operation and maintenance manual prepared by MoWIE states the same: "The submersible pump is manufactured to a very high specification and will operate on a daily basis without problem for at least 5 years, probably many more”. However, the pumps in Boloso Sore Woreda showed signs of problems from the early service years, which could be caused by the lack of operation and maintenance plan. Preventive maintenance is key to ensuring the SPRWSS is safe and providing long service. None of the WASHCOs, the Woreda water office, or the water federation have a plan in place for operation and maintenance. As one technician confirmed during KII, they usually visit pumps and other key parts of the schemes when the community or the WASHCO requests them to do so, mainly when it stops giving service due to an unidentified problem.

Moreover, all of the solar-powered systems under this specific study were manually operated, meaning they were turned on and off as needed. Compared to systems with automatic controls, these systems were found to malfunction more frequently. Because a pump operator was required to supervise the system's daily operation, which allowed for human mistakes, manually operated systems also resulted in higher operating expenses. In one case at Shuye Homba Kebele, an unauthorized person entered the scheme compound, insisting on fixing the problem on the switchboard, and ended up damaging the whole system as it had misconnected wires and burned the switchboard. In addition, a storage tank was seen visibly overflowing at Dubo Kebele as the pump operator was not available to switch off the system, leading to water wastage and safety concerns. These findings confirm that the system is manually operated as one challenge and clearly show the need to look for a better option than the manually operated system as the automatic system performs better, as shown on different solar-powered rural water supply systems and other research findings support it (UNICEF, 2016).

In conclusion, the limited skill and number of technical experts, together with the lack of preventive maintenance, have posed a major challenge to the operation and maintenance of solar-powered rural water supply systems in Boloso Sore Woreda.

4.4.5. Access to spare parts

The lack of spare parts has been mentioned as a major challenge to fix breakdowns by all focus group participants. In addition, the key informant interviews showed that there is no single marketplace to get spare parts in the vicinity of the woreda. They even said that the WASH Committees and Woreda water office experts tried to search for spare parts like the switchboards and submersible pump but couldn’t get them. Moreover, the lack of spare parts has forced the schemes to stay non-functional for a longer period, up to more than two years, in Wormuma kebele.

Furthermore, the submersible pump fell due to poor workmanship, manifesting the multifaceted challenges encountered while implementing solar-powered rural water supply systems in Boloso Sore Woreda. One key informant from the implementing agency said: *"We faced challenges in importing solar panels, pumps, and accessories from abroad due to the lengthy customs clearance and quality inspection processes. Additionally, there is a shortage of spare parts and accessories, which are often expensive when available" (KII, Implementing agency/World Vision Ethiopia).*

4.4.6. Role and responsibility for maintenance

The question 'Who is responsible for maintenance during breakdowns?' was raised to the respondent user community. As a result, 59% of respondents said the district water office, 31% said water committees, and 10% said the user community is responsible for the maintenance, as shown in **Figure 11**. The response would not vary from one respondent to the other if clear document were provided from the beginning on the roles and responsibilities for maintenance. In addition, some members withdrew from the WASHCO and the replaced members were not provided with the information, creating awareness gap among members. On top of this, the lack of clear roles and responsibilities resulted in the lack of preventive maintenance schedules leading to failure of critical system components.

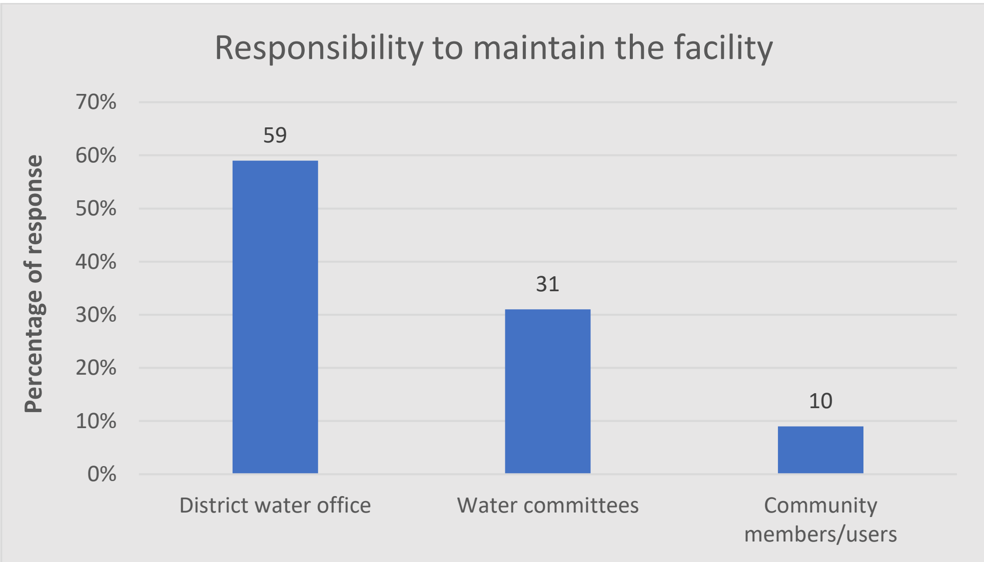


Figure 11. *Responsibility for maintaining the SPRWSS*

Additionally, respondents were asked whether there is a water management committee for solar-powered rural water supply systems in the woreda. And 344 respondents out of 345 responded yes, confirming each scheme has a water management committee, and only 1 responded no to the question. In line with this, 54% of respondents confirmed that the Woreda Water Office selected the water management committees, whereas 38% confirmed the entire community selected the committee, as shown in **Appendix 12**. The remaining 8% confirmed the kebele leaders made the selection. Therefore, it can be concluded that the selection was mainly made by the government body, whereas the community had limited opportunity to select. It contradicts the focus group discussion and key informant interview findings as both confirmed that the committee selection is merly done by the user community, except for some KII participants expressing their concern about the committee selection. The community believed the selection was made mainly to include relatives and friends of those working in the Woreda Water office. This resulted in role confusion and underperformance of the WASH committees and created disappointment in the user community.

The performance of water management committees was assessed by asking the respondents whether the water management committee carried out the expected roles per **Figure 12** below. The result revealed that about 75% of the respondents confirmed some of them, 13% confirmed that they didn't carry out their roles, and 12% reported yes, the committee fulfilled their roles as expected. Those who reflected some clarified that some members within the WASHCO showed poor performance, resulting in the below-expected performance of the WASHCO as a group. It can be concluded that those WASHCOs that didn't carry out their roles are the ones selected by the Woreda Water office, not the community, and role confusion also played a key part here.

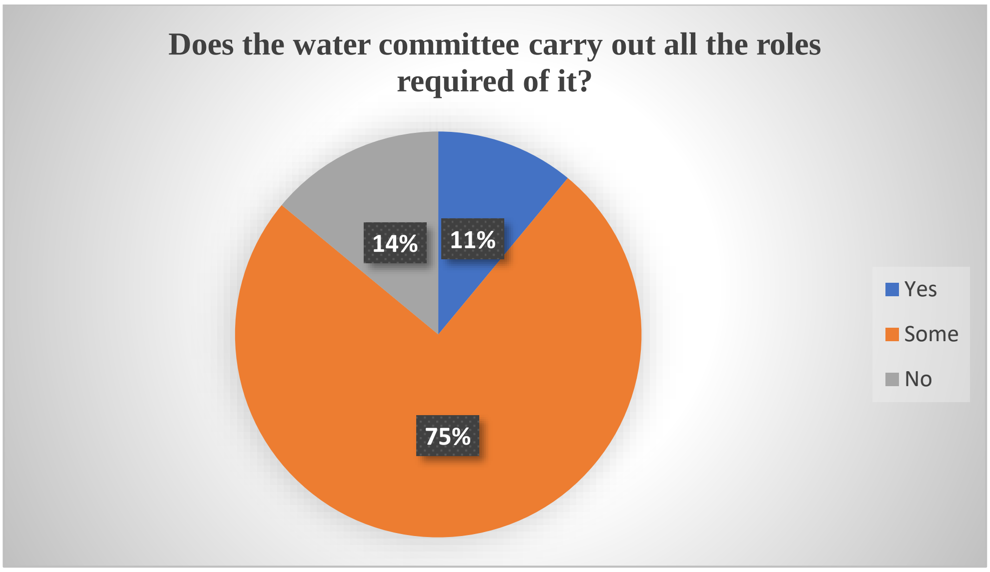


Figure 12. *Respondent's reflection on the management role by the WASHCO*

Meanwhile, 66% of respondents were not satisfied with the functioning of the water management committee, as shown in **Figure 8**, and were asked why they were not satisfied. Accordingly, 73 out of 228 respondents reported the committee doesn't maintain the facility well, and 58 reflected the committee doesn't communicate well with the community. This is a confirmation that the communication gap might have resulted from the poor performance on the maintenance of the facilities by the committee and could even have been intentional to hide some cheating, as some of the communities reported.

Furthermore, 14% of respondents confirmed that technical, administrative, and financial records were not kept at all. Even those who kept the records didn't usually share it, as confirmed by 5% of respondents, and when they do, it is done after so long, like after a year. The above finding confirms that the majority of the WASHCOs are not fulfilling their responsibilities. It is due to this that the user community asked for greater openness about the administration, collection, and distribution of user fees. However, it is equally important to mention that some of the WASH Committees that had bank accounts and were able to produce and demonstrate their available funds.

On the other hand, respondents expressed their expectations about the roles and responsibilities of the water management committee. The users reflection showed that the committee should consult with the user community more often, help more effectively in case of breakdown, and ensure there are enough water points. Participants of FGD in Dijala Village of Wormuma kebele reported that they had a saving of 10,750 Birr by the time the interview underwent (**Table *3***) and knew that they needed around 16, 000 Birr to buy the damaged HDPE riser pipe. However, the Woreda Water Office and water management committee didn't take the initiative to take the lead in collecting the remaining/missing amount of money, which is quite small compared to what was saved already. This leads to the conclusion that there is a communication gap, some areas lack support during breakdowns, and some areas are still without water points. Hence, the gaps identified here confirm the unclear roles and responsibilities for maintaining and managing the facilities.

Despite the confusion of roles and responsibilities on the management committee side, the user community seems to have a better understanding and willingness to play its part. For instance, the user community was asked the question, 'What do you do when you have problems with your solar-powered water supply? Surprisingly, more than 66% of respondents reported they would like to help make decisions and contribute money. This is an additional confirmation that the community lacked the proper support and accountability body for the management of the facilities. The underperformance of the WASHCOs and the Woreda Water office forced the user community to look for support from the implementing agency/NGOs, as confirmed by 46% of the respondents. Even 6% of respondents reported that they didn't know whom to look after for support, and the same percentage of respondents reflected that they expected no one to support them. It is worth mentioning that the guards on the non-functional schemes were not getting paid as the WASHCO couldn't collect money from the community. This might be one reason why the schemes were getting damaged frequently, like the water points reservoir and theft of some components like fencing became more common.

4.5. Community Perception and User Satisfaction

4.5.1. Community water source and perception

The community members were asked about their drinking water source during dry and wet seasons. According to the interviewees, 90% of them currently get their water from solar-powered shallow wells during the dry season, and 78% of them get it during the wet season. This shows around a 12% reduction in users from solar-powered shallow wells during the wet season, which the community clarified that the solar system gives less discharge due to more cloudy days, and the springs will give more discharge. Therefore, more beneficiaries are attracted towards the spring capping during the wet season, which is clearly noticed with the increased percentage of spring capping users by around 11%. It shows that the majority of the community relies on solar-powered shallow wells as a main source of drinking water as long as they get a reasonable quantity of water from them.

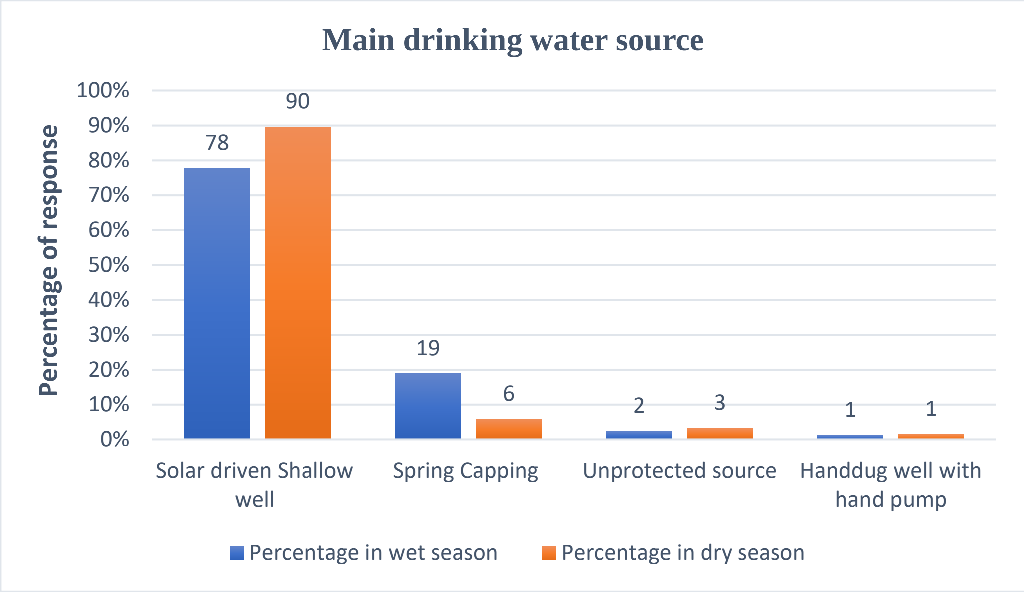


Figure 13. *Source of drinking water in the study area*

The results from **Figure 13** above revealed that 19% are getting water from spring capping during the wet season, and only 6% are from spring capping during the dry season, whereas 2% in the wet and 3% in the dry season are reverting to unprotected sources like rivers and streams. Those reverting to unprotected sources, almost similar in number in both seasons, are mainly the poorest community members who can't afford the water fee and are devoid of the opportunity to get free or discounted fees, as elaborated in detail in the user perception and satisfaction section. These can be considered a major human right to water and sanitation violation. It is vital that social safety nets are provided, both in the public and private context, to ensure the poorest are not excluded from accessing new innovative water supply systems.

4.5.2. User satisfaction with the solar-powered water supply schemes

The communities were asked about what they felt about solar-powered water supply systems. As a result, 22% of respondents replied that they feel proud, 66% feel happy, 5% feel indifferent, and 7% feel angry, as shown in **Figure 14**. The overall finding with 88% of respondents shows a positive feeling, those feeling happy and proud with their solar-powered water supply system.

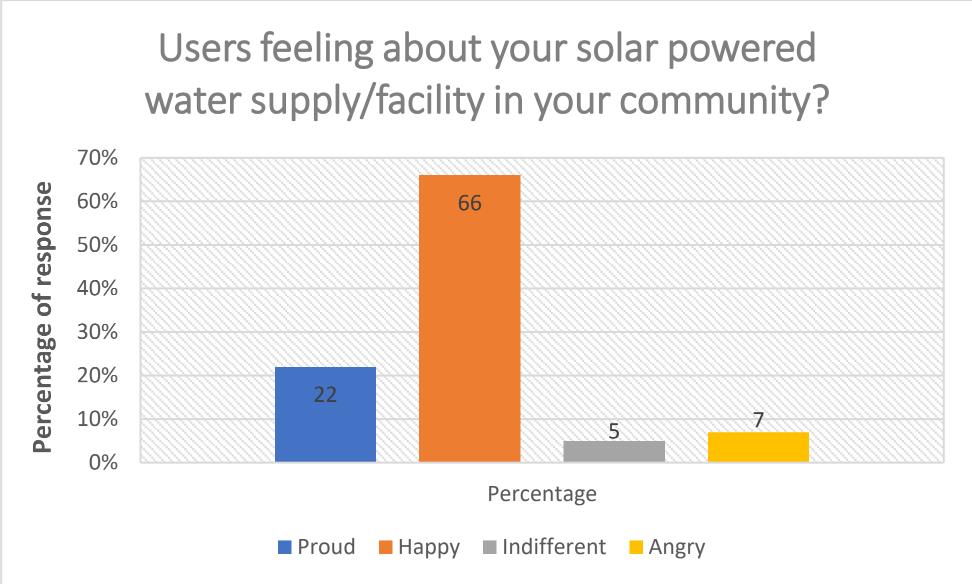


Figure 14. *Users feeling about their SPRWSS*

Despite the positive feelings from a large proportion of respondents, there are still those respondents who feel indifferent and angry, which triggers the idea that there are reasons behind the negative feelings. It can be traced by looking at the community's main problems while using water from the solar-powered water supply systems in Boloso Sore Woreda. The table below (**Table 6**) captured the findings about perceived problems with solar-powered rural water supply systems.

Table 6. *Perceived problems with the SPRWSS*

What is the problem with your solar-powered water supply?	Frequency
Takes longer to get/fetch water	78
Broken pipes, leaking reservoir (water supply components)	73
Tarif is not affordable	42
Theft of solar panels or other parts	34
Other	23
Failure of solar pump	30
Switchboard/control failure	30
Malfunctioning solar panels	26
Reduced quantity/dry source	5
Poor quality of the water	4

To further elaborate and assess user satisfaction, the satisfaction of users per the water service, such as time taken to collect water, quality, and quantity of water, were assessed.

Regarding the time taken to collect water (round trip), around 269 out of 345 respondents reported that they need 30 minutes to one hour, which shows they are investing much time to get water from the solar-powered schemes, and that is well beyond the national standard of below 30 minutes collection time within 0.5km radius per GTP-II. The reasons behind it, per the finding from FGD and KII, include the longer time taken to fill the storage tankers due to long trees shading the solar panels & leaking reservoirs, apart from the other major technical, financial, and management bottlenecks. The more time it takes to get water from the solar-powered schemes, the more frustrated users will decide to return to unprotected or other optional water sources in the area.

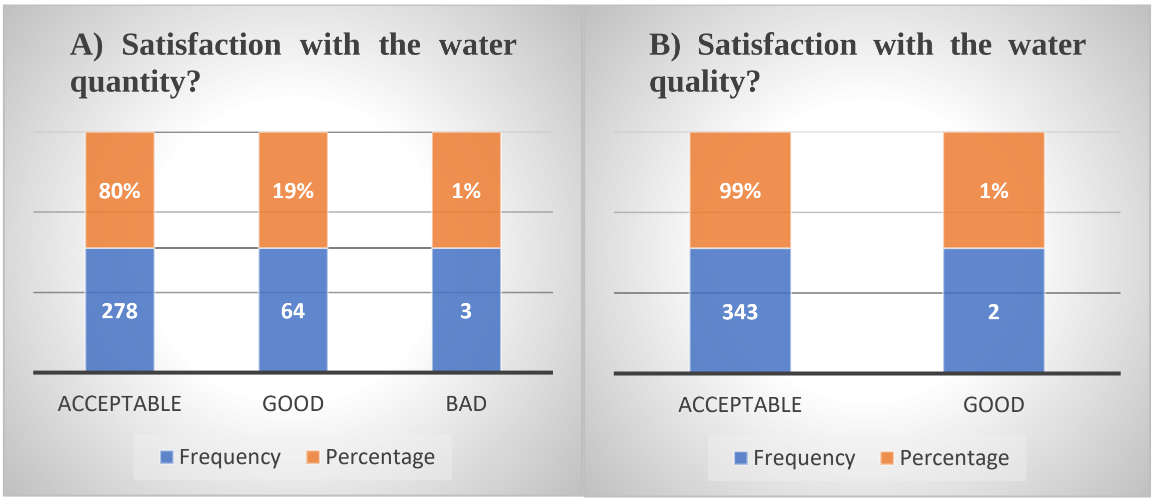


Figure 15. *User satisfaction with the quality and quantity of water*

User satisfaction with the water quality is very positive, as shown in **Figure 15**, in which 100% of respondents reported the quality is good and acceptable. There were some concerns about the color of the water from the schemes, as some participants of the FGD described the water quality as poor. The findings from the focus group discussion and key informant interviews in Shuye Homba Kebele have shown the same water quality problem: the water gets turbid during the rainy season from flooding.

As seen in **Appendix 13**, 44% of respondents said they are getting more than 25 liters per person per day, while the other 56% are getting less than 25 liters, which is far less than the national standard. This confirms that most respondents are getting less than the expected quantity of water per the national standard shown on GTP-II. Although most respondents are getting less than the required quantity of water, 99% are satisfied with what they get from the schemes per **Figure 15**. Even though most of the respondents have water quantity below the national standard, they enjoy every drop of water. This happened because the majority did not have an awareness of the national standard. Moreover, they faced difficulties before the implementation of the solar-powered water supply systems in the area.

4.5.3. User satisfaction with overall management

The assessment showed that there is a water management committee, usually known as 'WASHCO,' responsible for managing the operation and maintenance of the solar-powered rural water supply systems in Boloso Sore Woreda. User satisfaction was assessed by comparing the performance of the WASHCOs in each village.

According to the assessment, only 12% of respondents believe that the WASHCOs carried out their role properly. Still, the majority doubted their performance, with 75% of the respondents confirming some of the WASHCOs performed well and 13% confirming that they didn't carry out their roles.

In agreement with the above paragraph, where the majority of users questioned WASHCO's performance, the majority of respondents, 66%, were not satisfied with the functioning of the water management committee, and 34% were satisfied with the functioning of the committee. The reasons for the larger proportion of users getting dissatisfied were mentioned by the user community as follows: (1) the committee doesn't maintain the facility well, (2) the committee doesn't use revenue well, (3) the committee doesn't communicate well with the community and the committee charged too much for water. This shows a clear relation between user satisfaction and water scheme management committee performance.

The user community highlighted the importance of community involvement and ownership in the management of SPWSS and also noted challenges in this regard. There were instances of misunderstandings and mistrust between the community and the implementing agency regarding the responsibility for addressing the technical issues and maintaining the system. The community expressed a strong desire to take ownership of the SPWSS and contribute to its sustainability. Still, they felt they needed more support and resources from the government and implementing agencies. The following quotations are considered to reflect the true feelings of the community.

"We consider the water from the SPWSS like 'YES' water, the famous bottled water in Ethiopia." (Ocha Village Dubo Kebele FGD).

“The community is aware of the benefits of SPWSS, and they have a very positive feeling towards the SPWSS because they understand fuel costs are not affordable, and the sunlight is free of charge, so they appreciate the technology by itself.” (Achura Kebele FGD).

“The community feels ownership of the SPWSS and took the scheme as their own asset for which they are looking after the components of the system.” (Dubo Ocha FGD)

It is found important to rank the challenges based on the impact and significance of each challenge towards continued functioning of the SPRWSS. To rank the challenges identified, they are categorized based on their significance and impact on the implementation of solar-powered rural water supply systems (source: https://doi.org/10.1007/s40899-021-00526-8). The challenges can be grouped into three main categories: technical, financial, operational and maintenance challenges.

In order to rank the identified challenges, they are categorized based on their significance and impact on the practical implementation of SPRWSS. Each of the challenge are evaluated with their significance based on frequency and severity of issues mentioned under the findings of the study from section 4.2 to 4.5. The ranking of the challenges is based on the combined score on each of the criteria shown below and the significance was based on the combined score.

Impact on system functionality: How much does the challenge affect the overall performance and reliability of the SPRWSS.

Sustainability: Does the challenge hinder the long-term viability of the systems?

User Satisfaction: How does the challenge affect the community’s perception and satisfaction with the system?

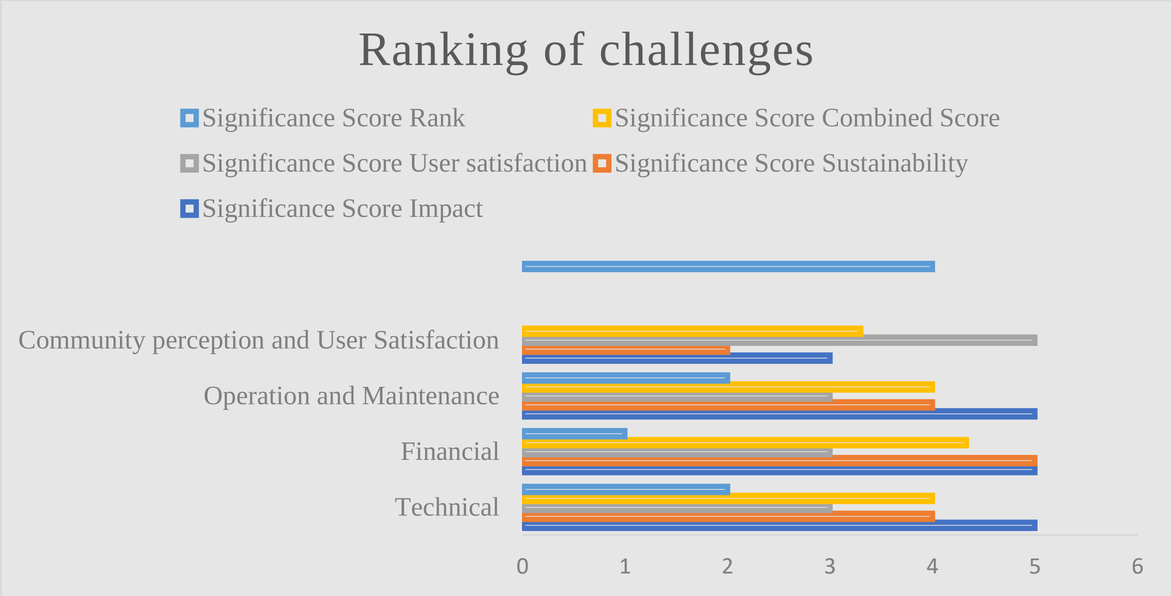


Figure 16*. Ranking of identified challenges*

The analysis of the challenges identified in the result and discussion is shown on **Error! Reference source not found.** above, reflecting their significance and impact. The finding from the table indicate that financial challenges are the most significant, followed by technical, operation, maintenance, and user satisfaction. According to the ranking, financial challenges should be prioritized together with technical, operation and maintenance challenges as the score are very similar implying the interconnected nature of the challenges around SPRWSS. Specific recommendations on how to address the prioritized challenges are presented on section 5.2.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The study revealed significant technical challenges in implementing SPRWSS in Boloso Sore Woreda, as critical study/design aspects like solar radiation study were missed. Additionally, a standardized approach was adopted for pump and reservoir sizes across varying sites, which are inherently different. Only 43% of the pump installations met the required specifications, with the remaining systems undersized, particularly in Achura Kebele, where required pump power calculated to be 3.8 kW, but installations were limited to 2.4 kW. Moreover, four out of seven schemes under study were non-functional, with 38% of respondents citing the leaking reservoirs as the major reason, in addition to poor design, construction quality, and inadequate service reservoir capacity. In addition, three schemes have HDPE riser pipes with PN10 where the required was found to be more than 10 bar resulting in frequent damage of the pipes. On top of this, three scheme have a water deficit and all seven schemes have inadequate storage tanker compared with the water demand leading to overpumping of wells which is damaging the pumps and the well. Furthermore, six out of seven solar sites were surrounded by long trees that hindered the sunlight from reaching the solar panels, reducing the quantity of water pumped from the well into the elevated storage tankers. Therefore, it can be concluded that technical challenges are encountered while implementing solar-powered rural water supply systems in Boloso Sore Woreda.

Financial challenges identified revealed that four out of seven schemes have saved below the expected saving required to ensure the smooth operation of the SPRWSS. Furthermore, 68 of 228 respondents reflected the committee doesn’t use revenue well, and 29 respondents reported the committee charged too much for water. The huge initial investment was mentioned, coupled with the bureaucratic processes while importing the different parts of the solar system, which are the major financial barriers for the implementing partner. The community and local government face financial challenges from the lack of options to access finance, leaving them with no mechanism to support them in kind or cash to repair the scheme breakdown. The demand for regular operation and maintenance was expensive and considered a challenge for the community and local government. Surprisingly, some community members believe they should get water free of charge as solar energy and water are natural, making it very difficult to collect the tariff from every user. The monthly contribution tariff model, with a fixed monthly contribution per household, was criticized for being unfair & inefficient due to disproportionate water usage for social gatherings. Therefore, it can be concluded that financial challenges are encountered while implementing solar-powered rural water supply systems in Boloso Sore Woreda.

The assessment showed that system downtime was, on average, 186 days, and the repairs took more than 17 days. The leading cause of failures was identified as leaking reservoirs, accounting for 38% of breakdowns, primarily due to poor construction materials rather than solar technology issues. The capacity for maintenance is severely limited, as only two partially trained technical experts serve the entire woreda, leading to inadequate local responses to breakdown incidents. This shortage is exacerbated by a lack of access to spare parts, evidenced by accounts of certain schemes remaining inoperative for over two years. Furthermore, 66% of respondents expressed dissatisfaction with the WASHCO's performance, often attributed to unclear roles and poor communication with the community. Some of the non-functional schemes mentioned lack of finance/money as a challenge to cover the operation and maintenance costs. Hence, it can be concluded that operation and maintenance challenges are encountered while implementing solar-powered rural water supply systems in Boloso Sore Woreda.

The community's perception and user satisfaction were mixed, with 88% of respondents expressing pride and happiness. In contrast, 12% reported feeling angry & indifferent mainly due to poor performance of the water management committees/on maintenance of breakdowns and long water collection times. Approximately 78% of respondents require over 30 minutes to collect water, exceeding national standards. Water quality is rated positively by 100% of respondents, with minor concerns noted regarding turbidity during rainy seasons. But 56% of respondents reported to receive less than the nationally recommended 25 liters per person per day.

In conclusion, the identified challenges were ranked in a way that shows their significance. Accordingly, financia challenges have the highest score of 4.33 and with the highest significance followed by technical, operation, and maintenance challenges with scores of 4. Overall, the study concluded that solar-powered rural water supply systems in Boloso Sore Woreda faced several challenges, including technical, financial, operational, and maintenance issues and limited community acceptance at the initial stage. Given the complex nature of the challenges encountered, the solution needs to come up with a multifaceted approach that could address the overall challenges to ensure the smooth implementation of solar-powered rural water supply systems in the woreda.

5.2. Recommendations

It became clear from the conclusion that solar-powered rural water supply systems, such as Boloso Sore Woreda, can be a viable option to provide a reliable drinking water supply for the rural community. Despite the viability of solar-powered water supply systems in rural areas like Boloso Sore Woreda, it is found that there are major challenges while implementing solar-powered rural water supply systems in Boloso Sore Woreda, including technical challenges, financial challenges, and operation and maintenance challenges.

To avert and address the challenges identified, the below recommendations are provided:

- Building expert technical skills and capacity from regional to woreda level government water office. This can also be done in collaboration with nearby universities like Wolayita Sodo or TVET College in Areka Town. This collaboration could help capacitate and get hands-on practical knowledge on how to design, install, operate, and maintain solar-powered rural water supply systems, including those in Boloso Sore Woreda. On top of this, government and implementing agencies should create a thorough understanding & awareness about the technology within the user community so that the community will have enough awareness about the benefits of solar power and shall protect it from damage, cut trees from around the solar panels that are blocking the sunlight from the panels and be advocates for the adoption of the technology in rural areas. Proper selection and use of high-quality construction materials accompanied by strong follow-up during the construction phase is recommended to avoid the use of poor-quality water storage tankers and limited finishing works on the construction of the elevated tankers/seats observed during the study.
- The assessment findings highlighted the significant benefits of the solar-powered water supply systems in Boloso Sore Woreda and the various technical, operational, socio-economic, and financial challenges that the community has faced in sustaining these systems. The discussions also revealed the community's strong desire to take ownership of the SPWSS and contribute to its long-term sustainability, but they also emphasized the need for greater support and resources from the government and implementing agencies to address the identified challenges. Therefore, conducting

frequent dialogue with the user community is recommended to help identify issues properly and give community-driven solutions based on their say. It is equally important to provide technical support and financial assistance to fill the gaps observed.

- Lack of spare parts and the expensive price were major challenges in the operation and maintenance of SPRWSS in Boloso Sore Woreda. Therefore, it is recommended that solar equipment and materials should be made available in the local market for a smooth, practical implementation of solar-powered rural water supply systems. The price of critical components like the submersible pump and switchboard should be reasonable/affordable to the user community. The government and other concerned agencies can do this by establishing local business owners that can sell spare parts required for the maintenance of solar-powered rural water supply systems. In addition, it is recommended to establish a regular maintenance schedule & routine inspection, strongly working on preventive maintenance to ensure the scheme is properly functioning by adapting from national operation and maintenance guidelines for SPRWSS. The local level experts responsible for operation and maintenance must be trained properly and provided with the necessary standard maintenance toolkits.
- The study has found that lack of access to finance to fund the repair of system breakdowns posed a practical financial challenge to the community and the local government. In the short term, establishing an emergency/contingency maintenance fund is recommended to leverage small contributions from the user community and the local government. For the long term, the government should collaborate with implementing agencies and the private sector to provide financial assistance to the rural community in Boloso Sore Woreda for purchasing expensive components.
- The study has helped identify the major implementation challenges of SPRWSS in Boloso Sore Woreda. It is recommended that the research be replicated in other rural areas of Ethiopia where SPRWSS is being implemented. One can also refer to the findings and the recommendations before implementing a new SPRWSS to understand the possible challenges and take context-based lessons from it. Additionally, more research needs to be done on the identification of the efficiency of existing/installed SPRWSS in different weather conditions. Further research works are recommended, specifically on optional and acceptable water tariff models with optimal user contributions.

References

Bekele Mulatu, A., Ayall Negash, W., & Teshome, M. (2023a). The Status of Solar Energy Utilization and Development in Ethiopia. *American Journal of Applied Scientific Research*. https://doi.org/10.11648/j.ajasr.20230903.13

Bekele Mulatu, A., Ayall Negash, W., & Teshome, M. (2023b). The Status of Solar Energy Utilization and Development in Ethiopia. *American Journal of Applied Scientific Research*. https://doi.org/10.11648/j.ajasr.20230903.13

Beker, B. A., & Kansal, M. L. (2024). Complexities of the urban drinking water systems in Ethiopia and possible interventions for sustainability. *Environment, Development and Sustainability, 26*(2), 4629–4659. https://doi.org/10.1007/s10668-022-02901-7

Benti, N. E., Aneseyee, A. B., Asfaw, A. A., Geffe, C. A., Tiruye, G. A., & Mekonnen, Y. S. (2022). Estimation of global solar radiation using sunshine-based models in Ethiopia. *Cogent Engineering, 9*(1). https://doi.org/10.1080/23311916.2022.2114200

FDRE Water Development Commission. (2019). Federal Democratic Republic of Ethiopia Water Development Commission Draft Report on National WaSH Inventory-II & MIS.

Girma, M., Assefa, A., & Molinas, M. (2015). Feasibility study of a solar photovoltaic water pumping system for rural Ethiopia. AIMS Environmental Science, 2(3), 697–717. https://doi.org/10.3934/environsci.2015.3.697

Gizachew, M., Admasie, A., Wegi, C., & Assefa, E. (2020). Bacteriological Contamination of Drinking Water Supply from Protected Water Sources to Point of Use and Water Handling Practices among Beneficiary Households of Boloso Sore Woreda, Wolaita Zone, Ethiopia. International Journal of Microbiology, 2020. https://doi.org/10.1155/2020/5340202

Hailu, A. D., & Kumsa, D. K. (2020). Ethiopia renewable energy potentials and current state. In AIMS Energy (Vol. 9, Issue 1, pp. 1–14). AIMS Press. https://doi.org/10.3934/ENERGY.2021001

Kabade, A., Rajoriya, A., & Chaubey, U. C. (2013). Solar Pump Application in Rural Water Supply-A Case Study from Ethiopia. In International Journal of Energy Engineering (IJEE (Vol. 3, Issue 5).

Ministry of Water, Irrigation, and Energy (2016). The Federal Democratic Republic of Ethiopia Ministry Of Water Irrigation and Electricity Demewoz Consultancy Rural Piped System Water Supply Operation and Maintenance Management Part B: Module A-Session B A Trainer's Manual for Community Based Financial Management for Rural Piped System.

Ministry of Water, Irrigation, and Energy (2018). Volume-I Technical Operation and Maintenance Requirements For Rural Piped System.

MoWE. (2013). Ethiopia's Renewable Energy Power Potential and Development Opportunities.

Mwangi, M., Gichangi, B., Kinuthia, B., Samo-Project Manager, J., Githu-Project Director, I., & Executive Summary v. (2018). Evaluation of the Sustainability of Solar Powered Water Supply Systems in Kenya Acknowledgement. www.solarzzy.comwww.eedadvisory.com

Sara Travis Katz, J., Sara, J., Katz, T., Lee Washington, K., Manou Savina, A., Vera, R., Quiton Daza, J., Nuñez, M., Brand, T., Maber, S., Brown, G., Pollard, R., Khan, S., Rehan, R., Minatullah, K., Narathius, A., & Lidonde, R. (2018). UNDP-World Bank Water and Sanitation Program Making Rural Water Supply Sustainable: UNDP-World Bank Water and Sanitation Program Making Rural Water Supply Sustainable: Report on the Impact of Project Rules.

UNICEF. (2016). Scaling up Solar Powered Water Supply Systems: a review of experiences 2 I.

WaterAid. (2021). Technology brief: Appropriate technologies for sustainable and inclusive water and sanitation services.

Water Mission. (2021). Design and Installation Guide Solar Powered Water Systems.

WHO UNICEF JMP. (2021). Five Years into the SDGs Progress on Household Drinking Water, Sanitation and Hygiene WHO/UNICEF Joint Monitoring Programme for Water Supply, Saniation and Hygiene. http://apps.who.int/bookorders.

WHO UNICEF JMP. (2022). State of the World's Drinking Water : An Urgent Call to Action to Accelerate Progress on Ensuring Safe Drinking Water for All.

WHO UNICEF JMP. (2023). Progress on Household Drinking Water, Sanitation and Hygiene 2000-2022 Special Focus on Gender WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. https://washdata.org

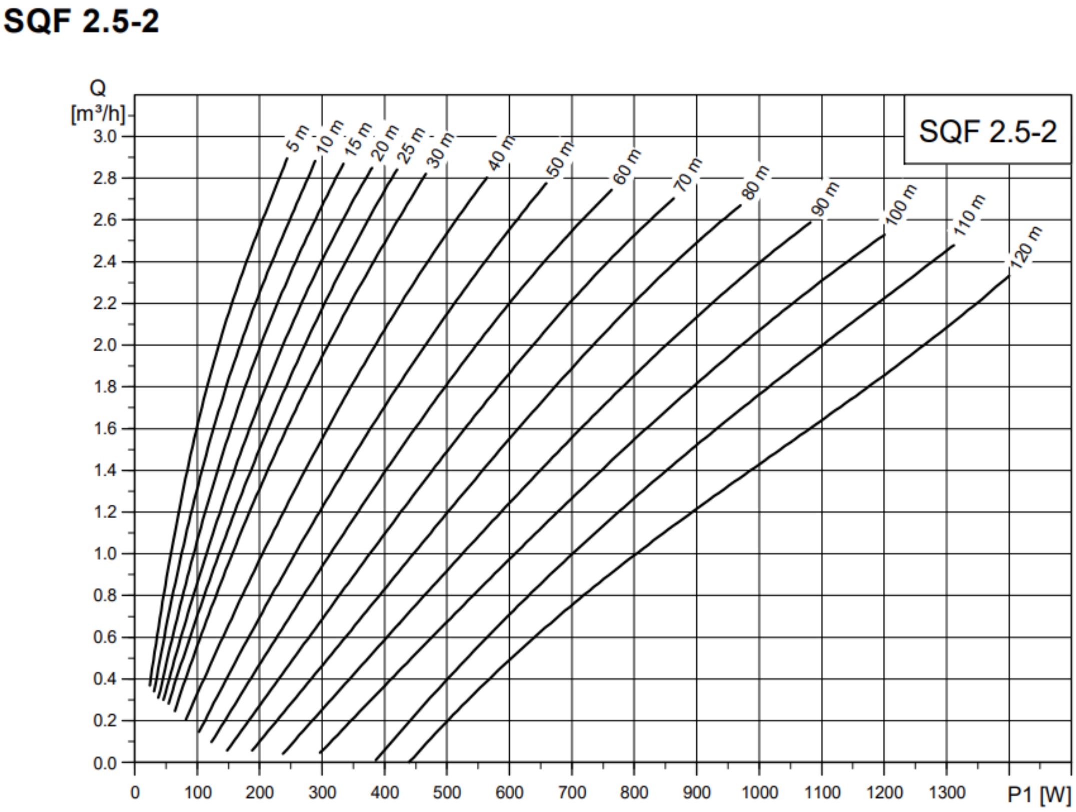
Wilson, R., Faris, K., & Getaneh, A. (2018). ONE WASH National Program 2 Federal Democratic Republic of Ethiopia ONE WASH National Program (OWNP) A Multi-Sectoral Swap Review of Phase I Final ONE WASH National Program (OWNP) A Multi-Sectoral SWAP Consultants.

W. Kiprono, A., & Ibáñez Llario, A. (2020). Solar Pumping for Water Supply. In *Solar Pumping for Water Supply*. Practical Action Publishing. https://doi.org/10.3362/9781780447810

World Bank Group. (2018). Maintaining the Momentum while Addressing Service Quality and Equity A Diagnostic of Water Supply, Sanitation, Hygiene, and Poverty in Ethiopia.

World Vision Ethiopia. (2019). CIFF SCH/STH Transmission Break Program SQ-FLEX Solar Powered Water Supply Scheme Feasibility Federal Democratic Republic of Ethiopia South Nations Nationalities and People Regional State Wolaita Zone Water, Mine and Energy Department CIFF FUNDED STH/SCH Transmission Break Program Boloso Sore Woreda SQ-FLEX Solar Powered Rural Water Supply Project Study and Design Report.

LIST OF APPENDICES



Appendix 1. Performance Curve of SQ Flex 2.5-2 Submersible Pump

Appendix 2. Household Questionnaire in Amharic

አባሪ 1፡ የቤተሰብ ዳሰሳ መጠይቅ መግቢያ ስሜ መላኩ ታፈሰ እባላለሁ በቦሎሶ ሶሬ ወረዳ (ወላይታ ዞን) ደቡብ ኢትዮጵያ ክልል በፀሃይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓት ተግባራዊ ተግዳሮቶች ግምገማ በሚል ርዕስ ለማደረገዉ ጥናታዊ ፅሁፍ መረጃ መሰብሰብ እፈልጋለሁ። የፍቃድ ቅፅ፡ ቀደም ብዬ እንደገለጽኩት የ MSc ተሲስን እየሰራሁ ነው እና የመረጃ አሰባሰብ ለጥናት ዓላማዬ ብቻ በፀሀይ ሃይል የሚሰሩ የውሃ አቅርቦት ስርዓቶች ላይ ያተኮረ ነው። ከቤተሰብዎ/የቤተሰቡን ራስ የመንከባከብ ኃላፊነት ካለው ከቤተሰብዎ ውስጥ ካለው ሰው ጋር መነጋገር እፈልጋለሁ። በዚህ ቃለ መጠይቅ የምሰበስበው መረጃ ሙሉ በሙሉ ሚስጥራዊ ይሆናል። እንዲሁም፣ የሁሉም ቃለመጠይቆች ውጤቶች ሲጣመሩ፣ ከተሰበሰበው መረጃ ጋር የተወሰኑ ግለሰቦችን አልለይም። ያቀረቡት መረጃ የMSc ጥናቴን እንድፈጽም ይረዳኛል፣ በፀሀይ ሃይል የሚሰራ የውሃ አቅርቦት ስርዓትን ስንተገብር ያሚያጋጥሙንን ተግዳሮቶች በተሻለ ለመረዳት ይረዳኛል። (እባክዎ ምላሽ ሰጪው ያደረጉትን ውሳኔ የሚገልጸውን ምድብ ምልክት ያድርጉ) ። በቃለመጠይቁ ለመሳተፍ ፈቃደኝነት 1. ፈቃደኛ ነኝ 2. ፈቃደኛ አይደሉም

ክፍል 1፡ የጥያቄ መግለጫ

አይ.	ጥያቄ	መግለጫ ካታጎሪዎች
1.1	ወረዳ	ቦሎሶ ሶሬ
1.2	የቀበሌ ስም	____________
1.3	የመንደር ስም	____________
1.4	የጠያቂ ኮድ	____________
1.5	የተጠያቂ ኮድ	
1.6	የቃለ መጠይቅ ቀን	
1.7	የቃለ መጠይቅ ጊዜ	መጀመሪያ: ___________ መጨረሻ:_________

ክፍል 2; ምላሽ ሰጪው ሶሺዮ-ዲሞግራፊክ መግለጫ

አይ.	**ጥያቄ**	**ኮድ ማድረጊያ ምድቦች**	**ዝለል**
2.1	የምላሽ ሰጪው ጾታ?	ሴት .... 1 ወንድ 2	
2.2	ምላሽ ሰጪው ማነው?	የትዳር ጓደኛ... 1 ሴት ልጅ ....2 ወንድ ልጅ... 3 ዘመድ.....4 የቤት ሰራተኛ...5 ሌላ ___6	
2.3	ምላሽ ሰጪዎች በቤተሰብ ውስጥ ያላቸዉ ቦታ?	የቤተሰብ አስተዳዳሪ-ሚስት_______1 የቤተሰብ አስተዳዳሪ-ባል_______2 የቤተሰብ አስተዳዳሪ ሴት/ወንድ ልጅ_______3 ሌላ (ይግለጹ)_______4	
2.4	ስንት አመትህ/ሽ ነው?	.... (በተጠናቀቁ ዓመት)	
2.5	ትምህርት	ማንበብና መጻፍ አይችልም _______1	

		ማንበብና መጻፍ ይችላል _______2 1-6 ከ1-6ኛ ክፍል_______3 7-8 ከ7-8ኛ ክፍል_______4 9-10 ከ9-10ኛ ክፍል_____5 11-12 ከ11-12ኛ ክፍል_______6 ከ12ኛ ክፍል በላይ_____7	
2.6	የተጠሪ የአሁኑ የትዳር ሁኔታ	ያላገባ_______1 ያገባ_______2 የተፋታ_______3 ባል የሞተባት________4	
2.7	ሃይማኖት	ሙስሊም______1 ኦርቶዶክስ______2 ፕሮቴስታንት______3 ካቶሊክ______4 ባህላዊ______5	
2.8	በዚህ ቤተሰብ ውስጥ ምን ያህል ሰዎች በቋሚነት ይኖራሉ?	_____________________ ቁጥሩን ይፃፉ	

ክፍል 3: የቤት ውስጥ የውሃ አቅርቦት

አይ.	ጥያቄ	ኮድ ማድረጊያ ምድቦች	ዝለል
3.1	በደረቅ/በበጋ ወቅት የመጠጥ ውሃ ምንጫችሁ ምንድነው?	1. በፀሀይ ሃይል የሚሰሩ መለስተኛ ጉድጓድ/ቄል ውሃ 2. በፀሀይ ሃይል የሚሰሩ የጥልቅ ጉድጓድ/ቄል ውሃ 3. በእጅፓምፕ ሚሰራ በእጅ የተቆፈረ ጉድጓድ ውሃ 4. የእጅፓምፕ የሌለዉ በእጅ የተቆፈረ ጉድጓድ ውሃ 5. የጎለበተ ምንጭ 6. የጣሪያ ውሃ ያልተጠበቁ ምንጮች	
3.2	በክረምት ወቅት የመጠጥ ውሃ ምንጫችሁ ምንድነው?	1. በፀሀይ ሃይል የሚሰሩ መለስተኛ ጉድጓድ/ቄል ውሃ 2. በፀሀይ ሃይል የሚሰሩ የጥልቅ ጉድጓድ/ቄል ውሃ 3. በእጅፓምፕ ሚሰራ በእጅ የተቆፈረ ጉድጓድ ውሃ 4. የእጅፓምፕ የሌለዉ በእጅ የተቆፈረ ጉድጓድ ውሃ 5. የጎለበተ ምንጭ 6. የጣሪያ ውሃ ያልተጠበቁ ምንጮች	
3.3	ንጹህ የውኃ ምንጭ ትጠቀማለህ?	1. አዎ 2. አይ 3. ሌሎች	
3.4	የውኃ ተቋሙ ቢጋን ጨምሮ ዓመቱን ሙሉ የውሃ አገልግሎት ይሰጣል ወይ?	1. አዎ 2. አይ 3. ሌሎች	

3.5	ባለፈው ዓመት ውስጥ የውኃ ተቋሙ ለምን ያህል ቀናት የማይሰራ ነበር?	-----------------	
3.6	የውኃ ተቋሙ የተበላሸበት የመጨረሻ ጊዜ መቼ ነበር?	1. 1 ሳምንት ያነሰ ጊዜ 2. 2 ሳምንት 3. 1-3 ወር 4. 3-6 ወር 5. ከ6 ወር በላይ ተበላሽቶ አያዉቅም	
3.7	ብልሽት በሚፈጠርበት ጊዜ የውኃ ተቋሙን ለመጠገን በመደበኛነት ምን ያህል ጊዜ ይወስዳል?	1. ከ3 ቀን በታች 2. 3 ቀን 3. ከ1 ቀን በታች 4. ተበላሽቶ አያዉቅም አላዉቅም	
3.8	በውኃ ተቋሙ ብልሽት ወቅት ቤተሰቦች ለጥገናው አስተዋፅዖ እንዲያደርጉ ተጠይቀዋል?	1. አዎ አይ	
3.9	አዎ ከሆነ፣ በኢትዮጵያ ብር/ሳንቲም ለአንድ ቤተሰብ ምን ያህል ገንዘብ?	1. ከ5ብር ያነሰ 2. 5-15 ብር 3. 15-20 ብር 4. ከ20ብር በላይ	
3.10	የውሃ ተቋሙን የመጠገን ኃላፊነት ያለው ማነው? (ብዙውን ጊዜ የተቋሙን ጥገና ለሚያደርግ አንዱን ምልክት ያድርጉበት)	1. ወረዳ ዉኃ ጽ/ቤት 2. ዉኃ ኮሚቴ 3. ዉኃ ተጠቃሚ/ማህበረሰብ 4. የአከባቢ መሪዎች 5. የግል ድርጅት ሌላ	
3.11	ብልሽት ከተፈጠረ ዋናው ምክንያት ምንድን ነው?	1. ሶላርፓሌል ስርቆት 2. ሶላርፓሌል ብልሽት 3. የፓምፕ ብልሽት 4. የፓይፕ መሰበር 5. የዉኃ ሮቶ ብልሽት 6. የጉድጋድ ዉኃ መድረቅ 7. አላዉቅም	
3.12	የወቅቶች መዛባት ከሆነ ምንጩ ለምን ያህል ጊዜ/ቀን ደርቋል?	________________	
3.13	በውሃ ብዛት/መጠን ረክተዋል?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው 3. መጥፎ/ያነሰ ነዉ	
3.14	የመጠጥ ውሃዎን ቀለም እንዴት ይገልጹታል?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው 3. መጥፎ/ያነሰ ነዉ	
3.15	የመጠጥ ውሃዎን ጣዕም እንዴት ይገልጹታል?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው 3. መጥፎ/ያነሰ ነዉ	
3.16	የመጠጥ ውሃዎን ሽታ እንዴት ይገልጹታል?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው 3. መጥፎ/ያነሰ ነዉ	
3.17	የውሃው ጥራት ምን ያህል ነው?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው	

		3. መጥፎ/ያነሰ ነዉ	
3.18	ውሃ ለመቅዳት በጠፋው ጊዜ ረክተዋል?	1. ጥሩ ነዉ 2. አጥጋቢ ነዉ/ተቀባይነት አለው 3. መጥፎ/ያነሰ ነዉ	
3.19	ቤተሰብዎ በበጋ/ደረቅ ወቅት በአማካይ በቀን ስንት ሌትር/ባልዲ ውሃ ይጠቀማሉ?	1. ከ25 ሌትር ያነሰ 2. ከ25 ሌትር በላይ 3. ምንም	
3.20	በበጋ/ደረቅ ወቅት ከተቋሙ ባለው የውሃ መጠን ረክተዋል?	1. አዎ 2. አይ	
3.21	በክረምት ወቅት ከተቋሙ ባለው የውሃ መጠን ረክተዋል?	1. አዎ 2. አይ	
3.22	በበጋ/ደረቅ ወቅት ከተቋሙ ውሃ ለመቅዳት ምን ያህል ጊዜ ያጠፋሉ (የደርሶ መልስ ጉዞ)	1. ከ1ሰዓት በላይ 2. ከ30 ደቂቃ በላይ 3. 30 ደቂቃ 4. 30 ደቂቃ በታች	
3.23	ባለፈው አንድ ሳምንት ውስጥ ውሃ ለመቅዳት ረጅሙ ጊዜ ስንት ነበር? (በደቂቃዎች ውስጥ)	___________________	
3.24	ባለፈው አንድ ሳምንት ውስጥ ውሃ ለመቅዳት አጭሩ ጊዜ ስንት ነበር? (በደቂቃዎች ውስጥ)	___________________	
3.25	ውሃ ለመቅዳት ወረፋ አለ?	1. አዎ አለ 2. የለም 3. አልፎ አልፎ	
3.26	ከተቋሙ ለሚያገኙት ውሃ ይከፍላሉ?	1. አዎ እከፍላለዉ 2. አልከፍልም	
3.27	ለውሃ እንዴት ይከፍላሉ?	1. በቀዳሁ ቁጥር 2. በየወሩ	
3.28	ለአንድ ባልዲ ውሃ ወይም ወርሃዊ መዋጮ በኢትብር ምን ያህል ይከፍላሉ?	___________________	
3.29	በኢትብር በወር ምን ያህል ለውሃ ታወጣለህ/ሽ?	___________________	
3.30	የውሃ ታሪፍ ተመጣጣኝ ሆኖ አግኝተሃል?	1. አይደለም 2. አዎ ተመጣጣኝ ነዉ	
3.31	አዎ ከሆነ ለምን?	___________________	
3.32	አይ ከሆነ ምን ያህል ለመክፈል ይፈልጉ ነበር (በኢትብር)	___________________	
3.33	ወደፊት ለመክፈል ፈቃደኛ ነህ/ሽ?	1. አዎ በቀዳሁት ባልዲ መጠን 2. አዎ ብልሽት ኖሮ ስጠየቅ ብቻ 3. አዎ በቀዳሁት ባልዲ ልክ እና ብልሽት ሲኖር 4. ፈቃደኛ አይደለሁም	
3.34	ለምን አይሆንም?	1. ሌላ የዉሃ አማራጭ አለ 2. ሌላ አካል መክፈል አለበት 3. ገንዘብ የለኝም	
3.35	የእርስዎ ቤተሰብ ሞባይል ስልክ አለው?	1. አዎ አለኝ 2. የለኝም	
3.36	በየወሩ ለሞባይል ጥሪ ካርዶች ምን ያህል ያወጣሉ (በኢትብር)?	___________________	
3.37	በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ስርዓት የውሃ አስተዳደር ኮሚቴ መኖሩን ያውቃሉ?	1. አዎ አቃለዉ 2. አላዉቅም	

3.38	በፀሐይ ኃይል የሚሠራ የውኃ አቅርቦት ሥርዓት የውኃ አስተዳደር ኮሚቴን የመረጠው ማን ነው?	1. ኤንጂኦ/የፕሮጀክቱ ፈጻሚ 2. ሁሉም ማህበረሰብ 3. የቀበሌ መሪዎች 4. ወረዳ ዉኃ ጽ/ቤት 5. አላዉቅም	
3.39	የቴክኒክ፣ የአስተዳደር እና የፋይናንስ መዝገቦች መያዙን ያውቃሉ?	1. አዎ ይያዛሉ 2. አይያዙም 3. አላዉቅም	
3.40	የቴክኒክ፣ የአስተዳደር እና የፋይናንስ መዛግብት ከማህበረሰቡ ጋር ይጋራሉ?	1. አዎ በዓመት ሁለቴ 2. በየዓመቱ 3. አዎ ከዓመት በላይ 4. አይጋሩም	
3.41	የውሃ ኮሚቴው የሚፈለጉትን ተግባራት በሙሉ ያከናውናል?	1. አዎ 2. አይወጡም 3. የተወሰኑት ብቻ 4. አላዉቅም	
3.42	በኮሚቴው አሠራር ረክተዋል?	1. አዎ 2. አልረካዉም 3. አላዉቅም	
3.43	ካልሆነ ለምን አይሆንም?	1. ኮሚቴዉ በሚገባ አያናግረንም 2. ኮሚቴዉ እላፊ የዉኃ ክፍያ ያስከፍላል 3. ኮሚቴዉ የዉኃ ተቋሙን በተገቢ አልያዘዉም 4. ኮሚቴዉ ገቢዉን በሚገባ አልተጠቀመም	
3.44	በእርስዎ አስተያየት በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት አስተዳደሪ/ኃላፊዎች ከሆኑ ሰዎች ምን ይጠብቃሉ?	1. ከዉኃ ተጠቃሚ ጋር በየግዜዉ መምከር 2. በቂ የዉኃ ቦኖ እንዲኖር ማድረግ 3. ብልሽት ሲኖር ተገቢ/አፋጣኝ እርምጃ መዉሰድ/እገዛ ማረግ 4. አላዉቅም	
3.45	በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ተቋማቱ ላይ ችግር ሲያጋጥም ምን ያደርጋሉ?	1. ምንም 2. ዉሳኔዎች ላይ እሳተፋለዉ 3. ከማን ጋር መምከር እንዳለብኝ አዉቃለዉ 4. አላዉቅም	
3.46	በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ተቋሙ ያለበት ችግር ምንድነው?	1. የማይሰራ ሶላር ፓኔል 2. ሶላር ፓኔል ስርቆት 3. የኃይል መቆጣጠሪያ ብልሽት 4. የዉኃ ተቋሙ የተለያዩ ክፍሎች ብልሽት 5. ሶላር ፓምፕ ብልሽት 6. ዉኃ ለመቅዳት ረዥም ሰዓት ይወስዳል 7. የዉኃ ክፍያ/ታሪፍ ተመጣጣኝ አይደለም 8. የዉኃ ጥራት ጉድለት 9. የዉኃ ምንጭ መድረቅ/ማነስ 10. የዉኃ ተጠቃሚ ማነዉ እና በምን ምክንያት 11. ሌላ 12. ምንም	
3.47	በውሃ አቅርቦትዎ ላይ ችግሮች ሲያጋጥሙዎት ወደ ማን መሄድ ይሻላል?	1. ማንም ጋር አልሄድም 2. ኤንጂኦ/የፕሮጀክቱ ፈጻሚ 3. የቀበሌ መሪዎች 4. የዉኃ ኮሚቴ 5. የወረዳ ዉኃ ጽ/ቤት 6. አላዉቅም	

3.48	በእርስዎ አስተያየት በፀሃይ ሃይል የሚሰራው የውሃ ተቋም ቢበላሽ ማን መክፈል አለበት?	1. መንግስት/ኤንጂኦ 2. የዉኃ ኮሚቴ፥ኃላፊነቱ ሰለሆነ 3. እኔ መክፈል አለብኝ 4. አላዉቅም	
3.49	በማህበረሰብዎ ውስጥ ስላለው በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት/ተቋማት ምን ይሰማዎታል?	1. እኮራለዉ 2. ደስተኛ ነኝ 3. ምንም አያሳስበኝም 4. ያናድደኛል 6. ያሳስበኛል 7. አላዉቅም	

Appendix 3. Key Informant Interview Guide in Amharic

አባሪ 3፡ የቁልፍ መረጃ ሰጭ ቃለ መጠይቅ የሀሳብ ማሰባሰቢያ መሳሪያ/መመሪያ

ሀ. ስም: ____

ለ. የስራ ድርሻ: ____

ሐ. ሚሰሩበትመ/ቤት: ____

መ. በፀሃይ ሃይል ሚሰሩ የዉኃ ተቓማት ላይ ያሎት አጠቃላይ የስራ ልምድ:____________________

በፀሃይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓት የተግዳሮት ዳሰሳ

1. በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓትን ተግባራዊ ለማድረግ ዋና ዋና ተግዳሮቶች ምን ምን ናቸው?
2. በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓትን ተግባራዊ ለማድረግ ቴክኒካል ተግዳሮቶች አጋጥመውዎታል? አዎ ከሆነ፣ ምንድናቸው?
3. በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓትን ተግባራዊ ለማድረግ የፋይናንስ ተግዳሮቶች አጋጥመውዎታል? አዎ ከሆነ፣ ምንድናቸው?
4. በፀሀይ የሚመራውን የውሃ አቅርቦት ስርዓት በመተግበር እና በመንከባከብ ረገድ ተግዳሮቶች አሉ ወይ? አዎ ከሆነ፣ ምንድናቸው?
5. በስርዓቱ ውስጥ ብልሽቶች ወይም ብልሽቶች ምን ያህል ጊዜ ያጋጥሙዎታል?
6. በተደጋጋሚ ጥገና ወይም መተካት የሚያስፈልጋቸው የስርዓቱ ልዩ ክፍሎች አሉ?
7. ከስርዓቶቹ ዲዛይን ወይም ተግባራዊነት ጋር የተያያዙ ልዩ ጉዳዮችን ለይተው ማወቅ ይችላሉ?
8. የስርዓቶቹን ቅልጥፍና እና ውጤታማነት የሚነኩ ተደጋጋሚ ችግሮች አሉ?
9. እነዚህ ተግዳሮቶች የውኃ አቅርቦት ስርዓቶችን አጠቃላይ ተግባራዊነት እና ዘላቂነት እንዴት ይጎዳሉ?
10. የስርአቱ አጠቃላይ አፈፃፀም ለህብረተሰቡ የውሃ አቅርቦት ምን ያህል ረክተዋል? ማህበረሰቡ በፀሃይ የሚነዱ ስርዓቶችን የሚቀበል/የሚደግፍ ይመስላችኋል? አዎ/አይ ከሆነ ለምን?

ተጨማሪ ጥያቄዎች

- በወረዳው በፀሃይ ሃይል የሚሰሩ የገጠር ውሃ አቅርቦት ስርዓት አፈፃፀሙ እንዴት ይገመገማል?
- የስርዓቶቹን አፈጻጸም ለመገምገም የሚያገለግሉ ልዩ አመልካቾች አሉ?
- በስርዓቶቹ ላይ ፍተሻ እና ጥገና ምን ያህል ጊዜ ይከናወናሉ?
- ጉዳዮችን በፍጥነት የሚዘግብበት እና የሚፈታበት ሥርዓት አለ?
- በፀሀይ ሃይል የሚሰራ የውሃ አቅርቦት ስርዓት ካለ ችግሮችን ለመፍታት የስልጠና እና የአቅም ግንባታ ስራዎች አሉ?
- በቴክኒሻኖች እና ኦፕሬተሮች መካከል መስተካከል ያለባቸው ልዩ ክህሎቶች ወይም የእውቀት ክፍተቶች አሉ?
- በስርአቱ ውስጥ የተሳተፉትን ሰራተኞች ቴክኒካል እውቀት ለማሳደግ የስልጠና ፕሮግራሞቹን እንዴት ማሻሻል ይቻላል?

ሙያዊ የምፍትሄ ሃሳቦች ተቀበል

- በወረዳው በፀሃይ ሃይል የሚሰራውን የገጠር ውሃ አቅርቦት ስርዓት ዋና ዋና ተግዳሮቶችን ለመፍታት ከርስዎ ልምድ በመነሳት ዋና ዋና ምክሮች ምንድናቸው?
- የውሃ አቅርቦት ስርዓት ማህበረሰቡን ተቀባይነት፣ ተሳትፎ እና ባለቤትነትን እንዴት ያረጋግጣሉ?

- ከዚህ በፊት የተጠቀሱትን መሰናክሎች/ተግዳሮቶች ለማሸነፍ የተተገበሩ ምርጥ ተሞክሮዎች ወይም የተሳካላቸው ጣልቃገብነቶች አሉ?
- በረጅም ጊዜ ውስጥ የስርዓቶቹን ዘላቂነት እና ተግባራዊነት ለማረጋገጥ የሚያስፈልጉት ወሳኝ እርምጃዎች ምን ምን ናቸው?

ማጠቃለያ

- በርዕሱ ላይ ማንኛውም ተጨማሪ አስተያየቶች ወይም ግንዛቤዎች

ለጊዜዎ እና ጠቃሚ ግብአትዎ በጣም እናመሰግናለን።

የመረጃ ሰጪው አድራሻ:
የመረጃ ሰጭው ፊርማ፡
የቃለ መጠይቁ ቀን:

Appendix 4. Focus Group Discussion Guide in Amharic

አባሪ 4፡ የትኩረት ቡድን ውይይት ከውሃ አስተዳደር ኮሚቴ ጋር
ወረዳ: ______________________
ቀበሌ: ____________________
የቡድን ውይይት አስተባባሪ: __________________
ማሰታወሻ ያዠ: ___________________
ቀን: ___________________________

መግቢያ
ወደዚህ የትኩረት ቡድን የውይይት ክፍለ ጊዜ እንኳን በደህና መጡ እና ለግዜዎ እና ለግብአትዎ እናመሰግናለን። የትኩረት ቡድን ውይይቱ ዓላማ በኢትዮጵያ ቦሎሶ ሶሬ ወረዳ በፀሀይ ሃይል የሚሰራ የገጠር ውሃ አቅርቦት ስርዓት ተግባራዊ የትግበራ ተግዳሮቶችን ለመገምገም ነው። እባክዎን ውይይቱ ለ1 ሰአት ያህል የሚቆይ እና አስተያየታችሁ ሚስጥራዊ ነው እና በኢትዮጵያ በፀሀይ ሃይል የሚሰሩ የውሃ አቅርቦት ስርዓቶችን በተለያዩ ክልሎች ለማሻሻል ጥቅም ላይ ይውላል።

በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ስርዓት ተግባራዊ የትግበራ ተግዳሮቶች

1. በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ሲስተሞች ያጋጠሙዎትን አወንታዊ ተሞክሮዎች ወይም ጥቅሞች ማካፈል ይችላሉ?
2. በፀሐይ ኃይል የሚሠሩ የውኃ አቅርቦት ሥርዓቶችን ተግባራዊነት ላይ ተጽዕኖ ያደረጉ ቴክኒካዊ ጉዳዮች አሉ?
3. በፀሃይ ሃይል የሚሰራ የውሃ አቅርቦት ሲስተሙ ያጋጠሙዎት አንዳንድ ተግዳሮቶች ምንድን ናቸው?
4. በፀሃይ ሃይል የሚሰሩ የውሃ አቅርቦት ስርዓቶች የጥገና ችግሮች አጋጥመውዎት ያውቃሉ? ከሆነ እባክዎን ይግለጹ።
5. በፀሓይ ኃይል የሚሠራ የውኃ አቅርቦት ሥርዓት ውሃን በተከታታይ በማቅረብ ረገድ ምን ያህል አስተማማኝ ነው?
6. በፀሐይ ኃይል የሚሠሩ የውኃ አቅርቦት ሥርዓቶች ሥራ ላይ ተጽዕኖ ያሳደረባቸው ማህበራዊና ኢኮኖሚያዊ ችግሮች ምንድን ናቸው?
7. በፀሐይ ኃይል የሚሠሩ የውኃ አቅርቦት ሥርዓቶች ዘላቂነት ላይ ተጽዕኖ ያደረጉ የፋይናንስ ችግሮች አሉ?
8. በፀሃይ ሃይል የሚሰሩ የውሃ አቅርቦት ስርዓቶችን በማስተዳደር ላይ የማህበረሰብ ተሳትፎ ወይም ተሳትፎ ተግዳሮቶች ነበሩ ወይ?
9. በፀሃይ ሃይል የሚሰሩ የውሃ አቅርቦት ስርዓቶች አፈፃፀም እንዴት ሊሻሻል ይችላል ብለው ያስባሉ
10. በቦሎሶ ሶሬ ወረዳ በፀሃይ ሃይል የሚሰራው የውሃ አቅርቦት ስርዓት የሚያጋጥሙትን ተግዳሮቶች ለመፍታት ምን ድጋፍ ወይም ግብዓት ያስፈልጋል ብለው ያስባሉ?

ስለ ጊዜዎ እና ደግ ትብብርዎ በድጋሚ እናመሰግናለን!

Appendix 5. Observation checklist on solar-powered rural water supply system components, Boloso Sore Woreda

1. Sanitary inspection on Boreholes/water points

A. Location of the boreholes	Yes	No
1. Is there a latrine within 30m of the borehole?		
2. Is there a manure pit or a rubbish dump within 30 m of the borehole?		
3. Is there an animal enclosure within 30 m of the borehole?		
4. Are there any chemicals (petrol, waste oil, solvent) on or around the water point (within 50m)?		
5. Is the borehole in an area liable to flooding?		
B. State of the concrete headwall of the borehole and of the drainage around the borehole		
6. Can the concrete headwall of the borehole be flooded (is the borehole area liable to flooding)?		
7. Are the screw nuts fixing the plate of the borehole headwall missing or not well tightened?		
8. Is there any way in which water could get from the concrete floor into the borehole (due to cracks in the concrete, etc.)?		
9. There is no concrete floor or the concrete floor is less than 1m wide all around the borehole?		
10. Are there cracks or breakages in the concrete floor around the borehole?		
11. Is there any stagnant water or a possibility for water to pool around the borehole?		
12. Are there leaks on the piping on the borehole headwall?		
C. State of the pipe network and the water tank		
13. Are there the pipes leaking? (noticeable by wet patches on the network path)		
14. Are there leaks on the special parts (valves, etc.)?		
Total Result from 14 (The higher the number of “Yes”, the higher is the sanitary risk for the water point.)		

2. Condition of the solar generator

	Yes	No
1. Is there grass growing under the solar panels?		
2. Does water pool around the solar panels allowing grass to grow?		
3. Are the solar panels dirty (dusty)?		
4. Are the solar panels cleaned with a dry or dirty cloth / dirty water / or with caustic products?		
5. Are the solar panels covered / shaded at any moment during the day (by trees, houses, etc.)?		
6. Is any solar panel broken or damaged?		
7. Is the enclosure of the panels damaged? Permitting access of animals/unauthorized persons to the panel's enclosure		
8. Is the entry gate unlocked or nonexistent?		
9. Are the solar panels stand foundations sinking into the ground (causing the panels stand to shift → risk of panel breakage)?		
10. Are the electrical wires connection boxes not waterproof or opened?		
11. Are there wires hanging lose and are not held in place?		
12. Are any wires cut?		
13. Are there wires connections outside of connection boxes?		

3. Condition of the water tank, the public stand-pipes and other water drawing points.

	Yes	No
1. Are there leaks on the water tank?		
2. Are there leaks in the pipe system (drive pipes, delivery pipes, evacuation pipe, overflow system)?		
3. Are there valves (under the water tank) that can't be turned easily or can't be turned at all?		
4. Is the stand pipe platform broken or cracked?		
5. Are there any taps broken?		
6. Are there any leaking taps?		
7. Are there leakages on the aerial pipe (steel zinc-coated pipe)?		
8. Is there stagnant water around the stand pipe or around any other water drawing point?		
9. Do any stand pipes or water-drawing points have blocked soak-away pits (and the water overflowing)?		

4. **Condition of the valves and valves chambers.**

	Yes	No
1. Are the valves covered by soil and buried?		
2. Are the valves concrete inspection chambers damaged?		
3. Are the covers slabs of the inspection chambers broken?		
4. Are there any valves that can't be turned easily or can't be turned at all?		

5. **Water quality and quantity.**

	Yes	No
1. Is the water turbid? (not clear)		
2. Does the water have an unusual smell?		
3. Does the water have an abnormal taste?		
4. Has the average quantity of water delivered daily diminished since the last monitoring visit?		

6. **Users behaviour**

	Yes	No
1. Are the taps badly handled?		
2. Is there water wastage (e.g.: water overflowing from containers)?		
3. Is there damage to the infrastructures (the public stand pipes for example)?		
4. Are containers generally dirty?		
5. Are the containers generally uncovered (or not having a mean to close them)?		

7. **Capacity to monitor and maintain the water point.**

	Yes	**No**
1. Is there a guard for the solar generator?		
2. Is there a guard house near to the solar generator for the guard?		
3. Is there a person in charge of daily cleaning/inspecting the solar panels?		
4. Is the person in charge of cleaning/inspecting the solar panels well trained?		
5. Is there a manager at each stand pipe?		
6. Is there a person in charge of monitoring the state of the water network (water tank, valves, taps, pipes, etc.)?		
7. Is there a periodic recording of the water meter both at the pump and at each of the stand-pipes?		
8. Is there a water system maintenance programme and is it in use?		
9. Is there a chart to monitor any repairs on the equipment (solar generator, inverter, water tank, valves, etc.)?		
10. Is there money available for repairs (what is the exact amount) and is it kept in a secure place?		
11. Does the village know which technical skills are needed and who to contact (name of structure, telephone number, etc.) if there is a breakdown on the water system?		

Additional points on management:

If there is a maintenance schedule for the water supply system, describe it:

What is the system of obtaining the spare parts?

What is the actual amount of money available (in a bank) for the water supply system maintenance and repairs?

What was the original agreed annual amount that the community would contribute to make sure enough money is set aside for maintenance and repairs?

Is the amount being collected enough to meet this target?

Water Point Management: Monitoring Checklist

1. Existence and functioning of the management body

	Yes	No
1. Are there persons in charge of the water-point management?		
2. Does the water point management committee have rules and regulations?		
3. Does the management committee meet periodically (and how often) to assess the water-point management and to take decisions?		

2. Equity

	Yes	No
1. Are there water-point access rules: who can access, how and when?		
2. Were the water point access rules developed in a participative manner with all the community structures?		
3. Are the water-point access rules applied?		
4. No rule is contested by the users?		
5. Is the management team composed of representatives of all the different user groups?		
6. Are there sanctions against those who do not pay their water charge?		

3. Good governance

	Yes	No
1. Is there a periodic election of the water point management team?		
2. Is there clear information available on the expenses incurred by the committee on behalf of the community water supply?		
3. Does the management committee make regular financial report to the community?		
4. Are reporting documents (financial and narrative) available?		
5. Are there clear/agreed processes for expense authorization and execution?		
6. Is the money collected in a secure place?		

4. Capacity to manage

	Yes	No
1. Does the water point committee know the approximate prices of the water point equipment spare parts?		
2. Is there an annual budget with an allowance for depreciation of the spare parts and daily management expenses?		
3. Has the committee clearly identified how they will mobilize funds for the water point maintenance and repairs?		
4. Is there a periodic maintenance programme for the water-point? (describe it)		
5. Has the money collection plan been followed? Who does not pay his/her water bill?		
6. Does the water point committee know qualified repairers in their area?		
7. Are the financial and narrative reports existent and well kept?		

5. Efficiency of the management

	Yes	No
1. Does the water point breakdown frequently?		
2. Are the breakdowns repaired after a long time?		
3. Is the water point in a poor condition (pump in a bad condition, cracks on the concrete floor, etc.)?		
4. The money in the bank is less than what was planned and agreed and is not enough for the expected maintenance &		

Precision on the efficiency of the water point management

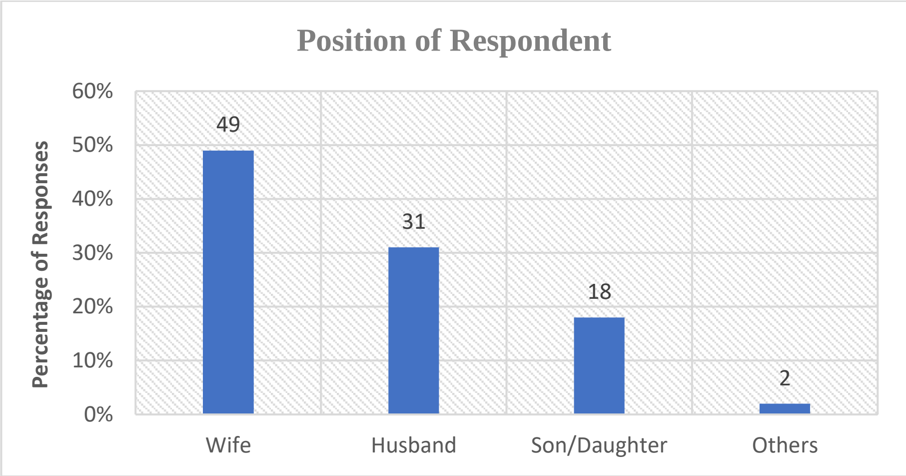
How many times the pump has broken down since the last monitoring?

What have been the natures of the failures and how much time it has taken to repair the pump (to have it functional again) for each case?

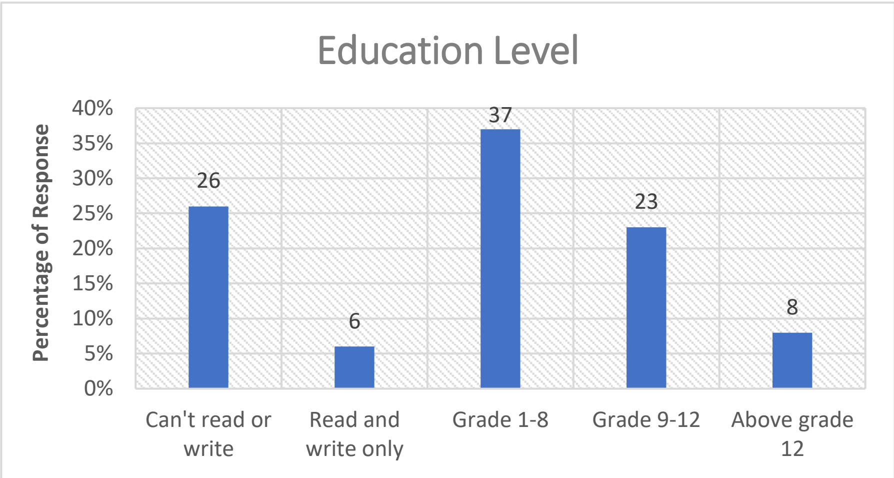
What is the actual amount of money available (in a bank) for the water point maintenance and repairs?

What was the original agreed annual amount that the community would contribute to assure enough money is set aside for maintenance and repairs?

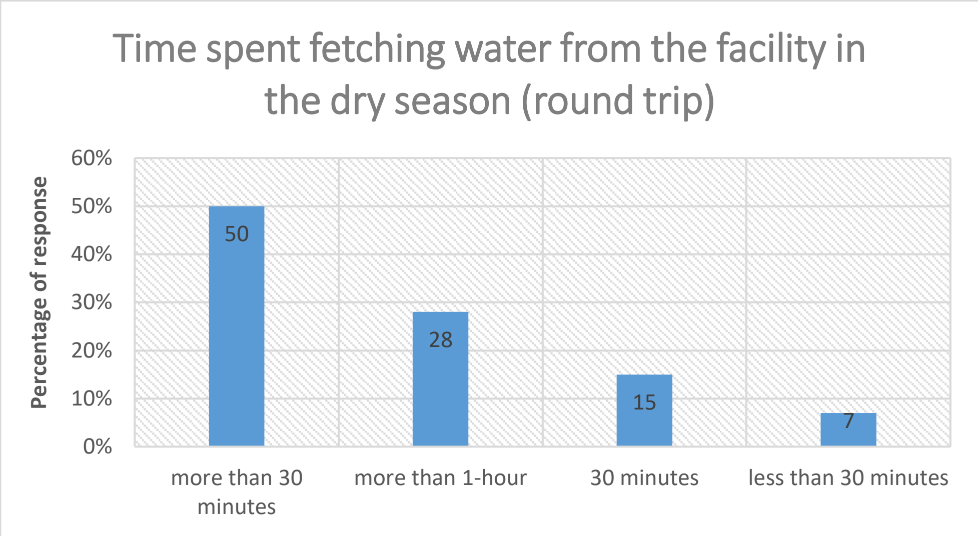
Is the amount being collected enough to meet this target?



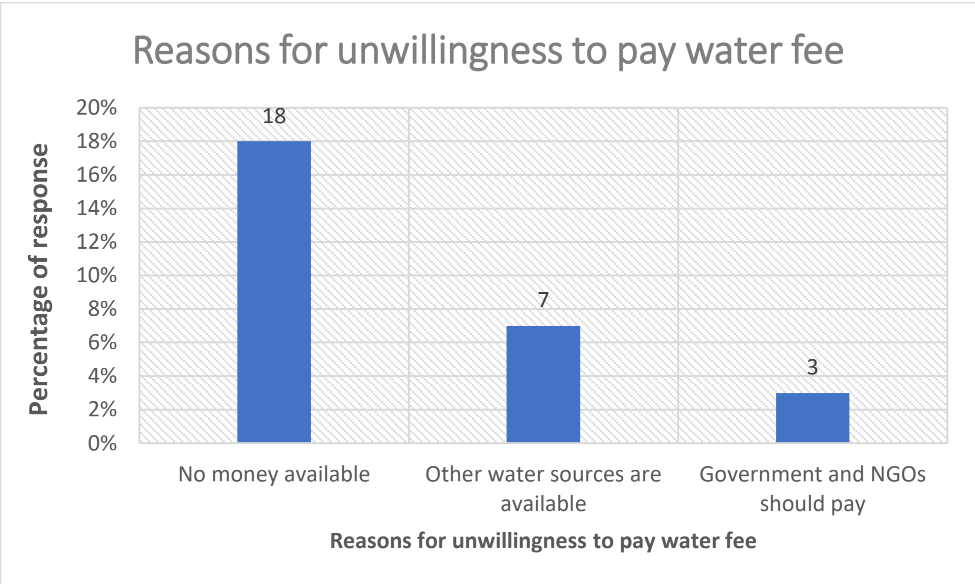
Appendix 6. *Position of respondent in the household*



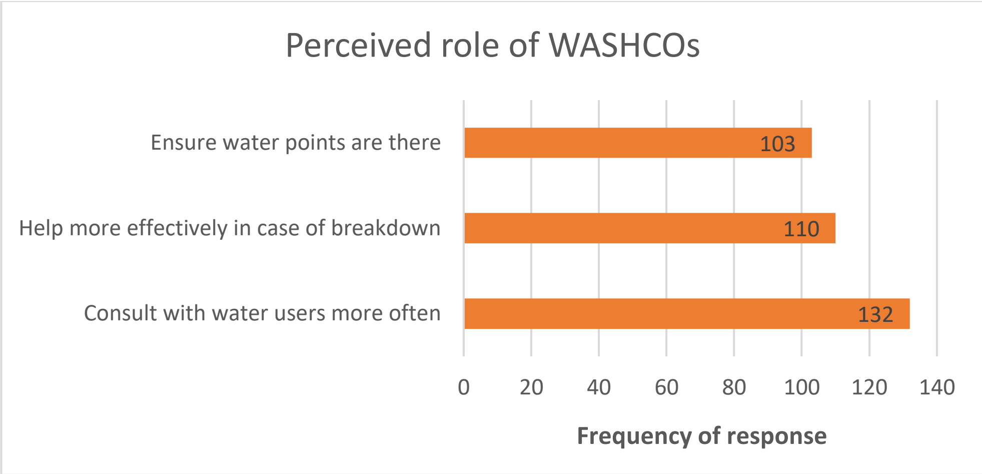
Appendix 7. *Education level of respondent*



Appendix 8. *Time spent fetching water in the dry season*

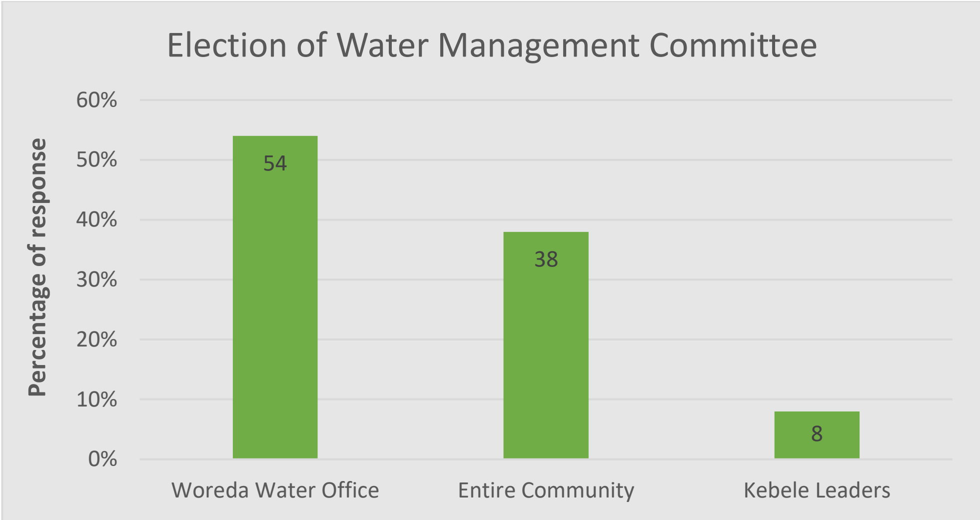


Appendix 9. *Reasons for unwillingness to pay water fee*

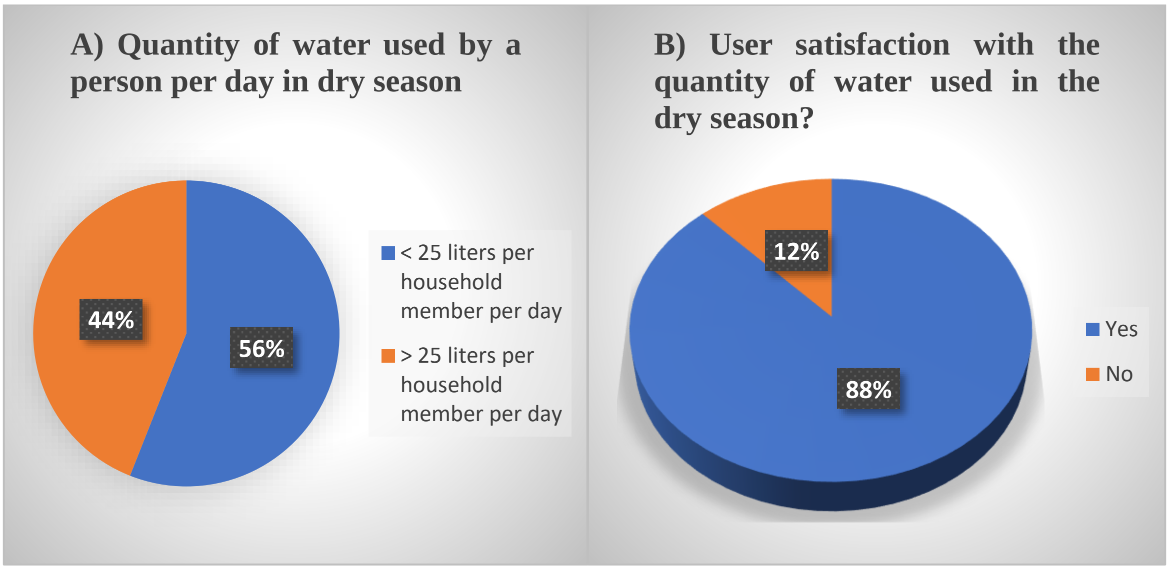


Appendix 10. *Perceived role of WASHCOs*

Appendix 11. *Community preference to solve their scheme problem*



Appendix 12. *Reflection on the election of WASHCO members*



Appendix 13. *Quantity of water used in dry season and satisfaction of users*

Appendix 14. *Solar panels shaded under long trees in Dubo and Achura Kebeles*

Appendix 15. *A solar panel full of dirt in Dijala Village, Wormuma Kebele*

Appendix 16. *A large number of people waiting at water points in Mante Village*

Appendix 17. *Reservoir leakage problem in Mante Village, Dubo Kebele*

Appendix 18. *Damaged water point fencing in Boyna Kare Village*

Appendix 19. *Focus group discussion underway in Dijala Village*

Appendix 20. Consent letter from Boloso Sore Woreda

South Ethiopia R/S/Wolaita Zone
Boloso Sore Woreda
Water Mine & Energy Office

ቀን: 27/02/2016

ቁጥር: 30/9/16

የቦሎሶ ሶሬ ወረዳ ውሃ መስኖ ማዕድንና ኢነርጂ ልማት ጽ/ቤት

<u>አረካ</u>

ጉዳይ: <u>በቦሎሶ ሶሬ ወረዳ በፀሐይ ኃይል የሚንቀሳቀሱ የገጠር ውሃ አቅርቦት ሥርዓት ተግባራዊ ተግዳሮቶች ግምገማ በሚል ርዕስ ለኤም.ኤስ.ሲ. ተሲስ የመረጃ አሰባሰብ ሥነ ምግባራዊ ማረጋገጫ ፈቃድ</u>

መላኩ ታፈሰ የተባለ ተማሪ በአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ በተፃፈ መደበኛ የድጋፍ ደብዳቤበ MSc ተሲስ ስራው ላይ መረጃ እንዲሰበስብ እንዲፈቀድለት ጠይቆናል። በደብዳቤው ላይ እንደተገለጸው፣የመረጃ አሰባሰቡ አስፈላጊ የሆኑ የስነ-ሕዝብ እና ሌሎች ሁለተኛ ደረጃ መረጃዎችን ማሰባሰብን፣ የመጀመሪያ ደረጃ መረጃዎችን ከቤተሰብ መሰብሰብን ያካትታል።

የቦሎሶ ሶሬ ወረዳ ውሃ መስኖ ማዕድንና ኢነርጂ ልማት ጽ/ቤት የስነ ምግባር ክሊራንስ ያጸደቅን ሲሆን መላኩ ታፈሰ በፀሀይ ሃይል በሚሰሩ የመጠጥ ዉኃተቓማት 14 ቀበሌዎች ጥናት/መረጃ እንዲሰበስብ ፍቃድ ሰጥተናል።

ምንተስኖት ጮሎ

የቦሎሶ ሶሬ ወረዳ ውሃ መስኖ ማዕድንና ኢነርጂ ልማት ጽ/ቤት ኃላፊ

<u>ግልባጭ</u>:

-ለቦሎሶ ሶሬ ወረዳ አስተዳደር ጽ/ቤት

-ለቦሎሶ ሶሬ ወረዳ ውሃ መስኖ ማዕድንና ኢነርጂ ልማት ጽ/ቤት

-ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ