**A Research Proposal Submitted to The Office Of RCSD**

**Adigrat University**

**College Of Engineering and Technology**

**Department Of Mechanical Engineering**

**Design and Development of Small-Scale Community-Based Solar-Powered Irrigation System to Enhance food security in Tigray Region as a Sustainable Solution for Postwar Rehabilitation: The Case of Agulae Irrigation Farm**

**Principal Investigator: Teklay Tesfay Hailu (Ass. Professor In Thermal Engineering)1**

**College of Engineering and Technology**

**Department: Mechanical Engineering**

**E-mail: teklush16@gmail.com**

**Phone No: +251 960334918**

**January, 2024 G.C**

Contents

[Executive summary of the project: 1](#_Toc186028846)

[1. Background and Justification 2](#_Toc186028847)

[2. Objectives Of the Project: 3](#_Toc186028848)

[2.1 General objective 3](#_Toc186028849)

[2.2 Specific Objectives: 3](#_Toc186028850)

[3. Statement of the Problem 4](#_Toc186028851)

[4. Review of Literature 5](#_Toc186028852)

[5. Methods and Materials: 7](#_Toc186028853)

[Site description 7](#_Toc186028854)

[Descripition of the project 8](#_Toc186028855)

[5.1. Methods 8](#_Toc186028856)

[5.2. Materials 9](#_Toc186028857)

[6. Scope of the project 10](#_Toc186028858)

[7. Expected output: 10](#_Toc186028859)

[8. Number of publishable articles expected and means of dissemination 11](#_Toc186028860)

[9. Significance and Beneficiaries 11](#_Toc186028861)

[9.1. Significance 11](#_Toc186028862)

[9.2. Beneficiaries 12](#_Toc186028863)

[10. Time schedule or Work Plan 12](#_Toc186028864)

[11. Duration 12](#_Toc186028865)

[12. References: 13](#_Toc186028866)

# **Executive summary of the project**:

*The Tigray Region, located in northern Ethiopia, boasts a rich agricultural history spanning thousands of years. Agriculture serves as the primary livelihood and economic foundation for much of the population, with crop production and livestock farming forming the backbone of the Tigrayan economy. Over 80% of rural residents are engaged in subsistence agriculture, relying on crop production for food security, animal feed, and nutrition. However, the Ethiopian agricultural sector is highly vulnerable to external shocks, including climate change and global price fluctuations. Climate change poses a significant threat to rain-fed agriculture, primarily due to declining rainfall patterns. This situation has prompted a shift toward irrigated agriculture, which offers farmers better access to water and can help meet crop water requirements. Despite its advantages, irrigated agriculture faces challenges, particularly concerning energy accessibility for water pumping. Traditional energy sources, such as fuel and electricity, are often costly, unreliable, and environmentally unsustainable. This reliance on fossil fuels and conventional methods presents significant barriers to effective irrigation. A viable solution lies in harnessing renewable energy, particularly solar power. Solar energy for irrigation has gained popularity due to its potential to provide a sustainable and consistent water supply in remote areas. Renewable energy technologies are advantageous because they are naturally replenished and considered environmentally sustainable. This project aims to design and develop a community-based solar-powered water pump system tailored to the specific needs of small-scale farmers. The expected outcome is the development of a solar-powered water pumping system that enhances irrigation practices, reducing dependence on fossil fuels. The total estimated budget for this study is €5,400, focusing on creating a sustainable solution for agricultural challenges in the Tigray Region.*

# Background and Justification

Tigray is a region found in northern part of Ethiopia. Prior to the war in Tigray, agriculture consisted of crop production and livestock farming was the backbone of the Tigray economy. More than 80% of the rural people in Tigray are primarily engaged in subsistence agriculture, and crop production which is one of the important production systems for food, feed and nutritional security (FAO Citation2021). The agricultural sector in Tigray has been showing an improvement because of significant progress in restoring of the degraded lands and improving its agricultural input use and water security. Growth in the agricultural sector remains highly important to maintaining overall growth of the region. According to Regional Gross Domestic Product (RGDP), the economy of Tigray registered an average growth rate of 8.1% during the last consecutive four years (2015 –2019) of GTP II implementation period (TSA, Tigray Statistical Agency, and Citation2021). The agriculture sector in particular had registered an annual growth rate of 4.0%. Among the agriculture sector, crop production activity contributed its greatest share (65%) to the agricultural GDP, which was followed by livestock and forestry by 32% and 3%, respectively. Meanwhile, the contribution of agriculture was 37% to the total real GDP.

However, in 2020, these combined with a plague of desert locusts the impact of the COVID-19 pandemic and national-level pressures including macro-economic difficulties affected the growth in agricultural production. Besides, at the beginning of November, 2020, The Ethiopian government declared armed conflict in Tigray, involving the Ethiopian national defense force (ENDF) and its ally’s formal and informal military factions of the Amhara region, the Eritrean defense force (EDF) and Somali soldiers (Annys et al., Citation2021; World Peace Foundation, Citation2021). Several international and national reports confirmed that many farms, agricultural offices, farm institutions in rural areas were destroyed, crops burned down and looted, farm equipment and irrigational structures destroyed, and livestock were looted and/or slaughtered (BoARD, (Bureau of agriculture and rural development), Citation2021; Annys et al., Citation2021). Moreover, due to lack of rainfall water on the region has had a severe impact on the region's agricultural sector, leading to a decline in agricultural productivity and food security.

Currently most Irrigation systems use diesel-generated power for Water pumping. Diesel and petrol-based pumps have many problems, such as inflated costs, transportation, global warming, noise and fumes can disturb livestock [2]. Solar-powered water pumps offer a sustainable and renewable energy solution by harnessing solar power for water pumping. This project seeks to leverage solar energy to create an accessible and community-driven irrigation system for small-scale farmers. Hence, Solar Poweredwater pumping system can be implemented to minimize the dependency on fossil-based power generation. Therefore, this research project focuses on design and development of a community-based solar-powered water pump system for small-scale irrigation.

# Objectives Of the Project:

## **2.1 General objective**

Design and development of small-scale community-based solar-powered irrigation system to enhance food security as a sustainable solution for postwar rehabilitation:

## **Specific Objectives**:

The specific objectives of this research are the following:

1. Design and modeling essential components of solar powered small scale irrigation systems (i.e Solar Panels, mounting structure for PV a pump controller and power, DC water pump and distribution system (Pipe Sizing), Storage tank for irrigation system, Evaluating the performance, efficiency, and sustainability of the solar-powered water pump system
2. Developing and analyzing the performance and efficiency of the solar-powered irrigation systems in terms of water utilization, energy consumption
3. Analyzing the economic viability and cost-effectiveness of solar-powered irrigation systems compared to conventional irrigation methods
4. Identifying potential challenges and barriers to the adoption and implementation of solar-powered irrigation systems

## Statement of the Problem

Due to the combined with a plague of desert locusts the impact of the COVID-19 pandemic and national-level pressures including macro-economic difficulties affected the growth in agricultural production. Besides, at the beginning of November, 2020, The Ethiopian government declared armed conflict in Tigray, involving the devastating two year long war. Several international and national reports confirmed that many farms, agricultural offices, farm institutions in rural areas were destroyed, crops burned down and looted, farm equipment and irrigational structures destroyed, and livestock were looted and/or slaughtered. Moreover, due to lack of rainfall on region has had a severe impact on the region's agricultural sector, leading to a decline in agricultural productivity, food security, crop failure, and livestock losses.

This has resulted in widespread food insecurity, with many households facing limited access to food. Famine conditions have been reported in different zones and weredas of the region leading to and increased vulnerability malnutrition and other health impacts as a community, livelihood disruption, displacement and migration, and all in all the region reduced agricultural productivity.

Addressing the impacts of war, drought and famine requires a comprehensive approach. Now days there are a number of alternatives power sources such as diesel, petrol, wind, hydro and solar energies to drive pumps for irrigation systems. Our community is using diesel and petrol as a power sources for their irrigation. However, the cost of these fuels is inflating from time to time due to instabilities and insecurities also they are environmental pollutants. More over due to the combined with a plague of desert locusts the impact of the COVID-19 and a two year of catastrophic war the economic capacity of the society are highly affected.

To overcome the above stated problems it is the only way to use improved and cost effective technologies for sustainable agricultural practices. Hence, renewable energy technologies are the most promising substitute for conventional energy sources since renewable energy sources are naturally replenished on a human timescale and they are considered as sustainable energy sources. To ensure long-term food security sustainable development by designing Solar-Powered Irrigation systems for enhancing food security in addition to that it is environmentally friendly. Therefore, this research project focuses on design and development of a community-based solar-powered water pump system for small-scale irrigation.

## Review of Literature

In this section review papers related to design and development of community -based solar powered water pump for small scale irrigationwere discussed below.

The work indicated in entitled as “Design And Analysis Of Solar Powered Water Pumping System” [3].The Paper presents Solar powered water pumping system is one of the options, because it has less maintenance (no moving parts), easy to install, and, environmentally friendship via lifetimes and economically feasible after installation. MATLAB was used for modeling and simulation of Buck converter, Inverter, PV Cell, PV Array and HOMER software was used for PV water pumping economic cost analysis.

The work indicated in entitled as “Design and Simulation of Solar Powered Water Pumping System for Irrigation Purpose in Kaduna, Nigeria” [4]. The Paper presents designed and simulated a solar powered water pumping system for irrigation purposes. A hectare of pepper plantation was adopted as a case study in Kaduna, Nigeria. The study was carried out using a software package called PVSYST version 5.5. The result of the study predicted a pumping efficiency of 65.8%.

The work indicated in entitled as “The Current Irrigation Potential And Irrigated Land In Ethiopia: A Review”[5]. The Paper presents A review of recent studies on irrigation water potential and irrigated land in Ethiopia was conducted from the historical point of view up to the present and the future. This review discusses Ethiopian current irrigation potential, water resources and irrigated land current and its contributions to the national economy, challenges and opportunities, and future development perspectives. Ethiopia is noted for having abundant surface and groundwater resources, earning it the nickname "the water tower of East Africa."

The work indicated in entitled as “Factors on Community Investment-Based Small Scale Irrigation Development in Indonesia”[6]. The Paper presents Community-based investment for small-scale irrigation (CISI) was one of the opportunities to increase food production, mainly rice, to support food security at household and national levels. Social capital played a crucial role in small irrigation management allowing all water distribution with appropriate criteria, amount and time for all farmers within the irrigation network."

According to the researcher the CISI financial feasibility was strongly determined by benefits derived from the irrigation construction such as planted rice acreage increase. The CISI benefits were determined by community’s ability to perform maintenance investment.

The work indicated in entitled as “Optimal Solar Water Pumping System for Small Scale Irrigation : A Case Study on Economical Sizing for Dangila Area of Ethiopia“[7]. the paper presents, the optimization of the PV pumping system for irrigation is possible when for a certain optimal policy of irrigation water distribution i.e. for corresponding values of hydraulic energy, the certain nominal power of PV generator is found, which could meet all demands in the best possible way, throughout the entire observed period. On the other hand, irrigation power requirements tend to coincide with the seasonal incoming solar radiation. Therefore, it is a time to shift to solar energy utilization for the sustainable growth. Furthermore, it is reliable that as water demand increase solar power also increases.

The work indicated in entitled as “Experimental validation of autonomous PV-based water pumping system optimum sizing [8].“ the paper presents has been proved analytically and experiment tally that a proper designed PV-based electricity generator in collaboration with an appropriate energy storage device not only has the capability to cover the electricity needs of remote consumers but also contributes to water pumping in order to meet additional water management needs.

The work indicated in entitled as “Design of Jigessa Small Scale Irrigation in Dara Woreda, Southern Ethiopia”[9]. The paper presents design of small-scale irrigation in Dara Wereda by assessing irrigation agronomy, analyzing hydrological condition of the area and designing different engineering structures like the headwork structure, main canal, cross drainage structure, etc. and also analyzing the stability of the structure which already designed. The structure they designed in this project will resist the 50-year return period peak flood.

The work indicated in entitled as “Designing and Developing Solar Energy Powered Water Pump for Small Scale Irrigation” [9].The paper presents a solar energy powered water pump is designed for a small-scale irrigation system replacing the conventional system which makes use of natural fuels that are exhaustible and non-friendly to the environment. A solar water pump is designed and experimented and satisfied results are obtained.

**Research Gap**

Most of the work done on PV water pumping system as discussed in the above section were focused on feasibility, Design and Simulation and optimization, but few of them worked on the design and development of solar-powered irrigation systems and none even on the community-based aspect of it, therefore, it is found important to present a design and development on community -based solar powered water pump for small scale irrigation the case of agulae district in Tigray region. Therefore, this research focuses on, design, development, installation and field test of solar powered water pump for the small-scale irrigation in the community-based approach emphasizes the involvement of local communities in the installation, operation, and maintenance of solar irrigation systems.

Since in recent years, solar energy in Ethiopia has emerged as one of the cleanest, environmentally friendly, and reliable sources of energy. Energy is one of the main inputs of agriculture, especially for small scale irrigation, is becoming a focus in the agricultural water management agenda of the country Ethiopia. In this respect, Solar Powered Irrigation Systems are promoted widely in Ethiopia as the alternative to diesel-run pumps which is widely used by farmers in Ethiopia for sustainable development. Therefore, the focus of this project is to design and develop a solar-powered water pump system that can cater to the irrigation requirements of small-scale farming in the target community.

## **Methods and Materials**:

Site description

Agula is a town located in northern Ethiopia. Located in the Debubawi (Southern) Zone of the Tigray Region, it lies about 32 km northeast of Mekelle, just east of the Mekelle - Addis Ababa highway (Ethiopian Highway) and 25 km north of Qwiha. It has a latitude and longitude of (13°41′30″N39°35′30″E) with an elevation of 1930 meters above sea level**.** This district is characterized by abundant water potential and ample solar radiation, making it an ideal region for agricultural activities. However, the majority of farmers in Agula-e district currently rely on diesel-powered water pumps for irrigation purposes. In order to address the environmental and economic challenges associated with diesel pumps, there is a strong need to replace them with solar-powered water pumps in this study area. The introduction of solar-powered water pumps holds tremendous potential for the farmers in Agulae district.

Descripition of the project

The project titled "Design and development of Community-Based Solar Powered Water Pump for Small Scale Irrigation"for enhancing agricultural productivity in Tigray region aims to address the need for sustainable and efficient irrigation practices in rural communities. The focus of this project is to design and develop a solar-powered water pump system that can cater to the irrigation requirements of small-scale farming in the target community. The project recognizes the importance of irrigation for small-scale farmers who often face challenges in accessing reliable and affordable water sources. By utilizing solar energy, a clean and renewable resource, the project seeks to provide an environmentally friendly and cost-effective solution to meet the irrigation needs of these farmers. The design and development process of the community-based solar-powered water pump will involve extensive research and analysis of the local conditions and requirements. Factors such as the water demand of the crops, the availability of solar radiation, and the specific needs and limitations of the community will be considered in the design phase. The project will also focus on developing a system that is easy to operate and maintain, ensuring that it can be effectively utilized by the community members.

## **Methods**

To achieve the above specific objectives, the following procedure will be used:

* **Literature Review**: Conduct an extensive review of existing literature and studies related to solar-powered irrigation systems, postwar rehabilitation, and agricultural development in the agula irrigation farm. This step helps establish a theoretical foundation and identify knowledge gaps in the field.
* **Data Collection**: Gather primary and secondary data relevant to the research objectives. This includes collecting data on the, solar energy potential, and socio-economic conditions in the site. Primary data can be collected through surveys, interviews, and field observations, while secondary data will be obtained from governmental reports, research papers, and databases.
* **Design Considerations**: Analyze the specific design considerations for solar-powered irrigation systems in the agula site. This involves assessing factors such as available sunlight, water sources, crop water requirements, topography, and local farming practices. Consult with experts, stakeholders, and local communities to gather insights and ensure the relevance and appropriateness of the system design.
* **System Design**: Develop conceptual designs for solar-powered irrigation systems based on the identified design considerations. This includes selecting appropriate solar panels, pumps, storage systems, and irrigation methods suitable for the Tigray Region. By considering factors such as system capacity, efficiency, and cost-effectiveness.
* **Performance Analysis**: Implement pilot projects or conduct simulations to assess the performance of solar-powered irrigation systems. Monitor and evaluate parameters such as water delivery efficiency, energy consumption, crop yield, and economic viability. Compare the performance of solar-powered systems with conventional irrigation methods to determine their potential benefits and limitations using simulations.
* **Economic and Environmental Analysis**: Conduct an economic analysis to assess the financial feasibility and cost-effectiveness for implementing solar-powered irrigation systems Consider factors such as capital costs, operation and maintenance expenses, and potential income generation. Additionally, evaluate the environmental impact of these systems, including reductions in greenhouse gas emissions and water conservation.
* **Stakeholder Engagement**: Engage with local farmers, community members, policymakers, and other stakeholders throughout the research process. Seek their input, feedback, and perspectives to ensure the relevance, acceptance, and sustainability of the proposed solar-powered irrigation systems.

## Materials

The design and development of solar-powered irrigation systems involve various tools and materials. Here are some key components and materials commonly used:

* **Solar Panels**: High-quality solar panels are essential for capturing sunlight and converting it into electrical energy. The panels should have a sufficient capacity to meet the irrigation system's power requirements.
* **Mounting Structures**: These structures are used to securely install and position the solar panels. They can be made of aluminum, steel, or other sturdy materials to withstand weather conditions.
* **Pump**s: Efficient water pumps are necessary to transport water from the source, such as a well or a reservoir, to the irrigation system. The type of pump required depends on factors like the required flow rate, head, and the distance the water needs to be pumped.
* **Pipes and Fittings**: PVC (polyvinyl chloride) or HDPE (high-density polyethylene) pipes and corresponding fittings are typically used for water distribution within the irrigation system. These materials are durable, corrosion-resistant, and easy to install.
* **Support Structures**: Depending on the specific design and layout, structures like poles, frames, or trellises may be required to support the piping, wiring, and shading elements of the system.
* **Monitoring and Control System**: A monitoring and control system can be implemented to track the system's performance, manage water schedules. It is important to note that the selection of specific tools and materials may vary based on factors such as the scale of the system, local availability, budget constraints, and specific project requirements. Consulting with experts in the field or engaging with suppliers specializing in solar-powered irrigation systems can help in identifying the most suitable tools and materials for the project.

## Scope of the project

The scope of this project includes the following:

* Design and analyze of community-based solar-powered water pump system.
* Feasibility assessment, including economic, social, and environmental considerations.
* Dissemination of research findings through academic publications and workshops to foster knowledge sharing

## **Expected output**:

The expected outputs of this research project are as follows:

* **Performance Evaluation**: The research is expected to provide a comprehensive assessment of the performance of solar-powered irrigation systems. This includes evaluating parameters such as water utilization efficiency, energy consumption, crop yield, and economic viability. The results would help determine the effectiveness of solar-powered irrigation systems in enhancing agricultural productivity.
* **Improved Water Management**: The research may highlight the potential of solar-powered irrigation systems to improve water management. By analyzing water delivery efficiency and irrigation scheduling, the study may show how these systems can optimize water use, reduce water waste, and enhance overall water resource management.
* **Sustainability Assessment**: The research is expected to provide insights into the sustainability aspects of solar-powered irrigation systems. This includes evaluating their environmental impact, energy efficiency, and potential contributions to sustainable agricultural practices. The results may indicate the potential reduction in greenhouse gas emissions, decreased reliance on fossil fuels, and improved resilience to climate change.
* **Economic Viability**: The research may assess the economic feasibility and viability of implementing solar-powered irrigation systems in the Tigray Region. The results could demonstrate the potential cost-effectiveness of these systems, including factors such as capital costs, operation and maintenance expenses, and potential income generation. This information would be valuable for policymakers and stakeholders in making informed decisions regarding system implementation.

## Number of publishable articles expected and means of dissemination

* The research project aims to publish a minimum of two articles in reputable peer-reviewed journals. The articles will cover different aspects of the research, such as system design, performance analysis, and socio-economic impact.
* **Means of dissemination**:

The research findings will be disseminated through various channels to reach the target including farmers, policymakers, researchers, and development organizations.

The dissemination activities will include:

* Publication of research papers in peer-reviewed journals.
* Presentation of findings at national and international conferences and workshops.

## Significance and Beneficiaries

## Significance

The proposed project holds several significant outcomes, including:

* Increased access to reliable and sustainable water sources for small-scale irrigation, leading to improved agricultural productivity and food security.
* Reduced operational costs and environmental impact by utilizing solar energy as a clean and renewable power source.
* Empowerment of local communities through participatory decision-making, knowledge sharing, and ownership of the irrigation system.
* Enhanced economic development and livelihood opportunities for small-scale farmers.
* Contribution to climate change mitigation and adaptation through the adoption of sustainable technologies.

## Beneficiaries

The primary beneficiaries of this project are:

* Farmers: The community-based solar-powered water pump system will directly benefit farmers by providing them with affordable and reliable irrigation, enhancing their agricultural productivity and income.
* Local communities dependent on agriculture, who will benefit from increased agricultural productivity, improved food security, and economic growth.
* The local government and relevant stakeholders, who can utilize this technology to support sustainable agriculture and rural development initiatives.

## Time schedule or Work Plan

* The general work plan of the research study is as shown below and this will only be effective when the proposal gets approval and funded.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ACTIVITIES** | **Quarter 1** | | | | **Quarter 2** | | | | **Quarter 3** | | | | **Quarter 4** | | | |
| 1 | 2 | 3 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Proposal Writing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2. Literature Review |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3. Data Collection |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4. Component Design |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5. Material Preparation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6. Component Manufacturing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7. Assembling and Testing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 8. Rearrangement |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 9. Documentation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 10. Final Report Submission |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## **Duration**

**December,2024 to December ,2026 G.C**

**Budget**

The total budget for this study is estimated to be **euro 5400**. The detailed cost breakdown is tabulated below.**Material cost**

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Percentage | Cost (Euros) | Details |
| Solar Panels | 40% | 2160 | 4-6 high-efficiency panels (e.g., 300W each) for power generation. |
| Inverter | 10% | 540 | 1-2 kW inverter to convert DC to AC power for the pump. |
| Irrigation Pump | 20% | 1080 | Submersible or surface pump (0.5-1.5 HP) for water extraction. |
| Battery Storage | 15% | 810 | 2-4 deep-cycle batteries (e.g., 12V, 100Ah) for energy storage. |
| Mounting Structure | 5% | 270 | Aluminum or steel racks for mounting solar panels. |
| Charge Controller | 2% | 108 | 20-30A MPPT charge controller for energy regulation. |
| Piping and Fittings | 3% | 162 | PVC or HDPE pipes, connectors, and valves for water distribution. |
| Tanker | 3% | 162 | To store water |
| Controllers and Sensors | 2% | 108 | Timers, moisture sensors, and flow meters for automation. |
| Wiring and Electrical | 2% | 108 | Cables, connectors, and switches for electrical connections. |
| Installation and Labor | 5% | 270 | Professional installation services for the system. |
| Miscellaneous/Contingency | 3% | 162 | Tools, transportation, and unforeseen expenses. |
| **Total** | **100%** | **5400** |  |

## **References**:

[1] G. People, “Solar Irrigation Market Analysis In Ethiopia.”

[2] S. Goel, S. Goel, P. Mohapatra, And R. K. Pati, “International Journal Of Power System Operation And Energy Management Solar Application For Transfer Of Technology - A Case Of Solar Pump Solar Application For Transfer Of Technology - A Case Of Solar Pump,” Vol. 2, No. 1, 2013, Doi: 10.47893/Ijpsoem.2013.1051.

[3] P. Palanivel, H. Alemayehu, R. Selvarasu, B. Chandramouli, And A. Science, “Design And Analysis Of Solar Powered Water Pumping System,” Vol. 11, No. 9, Pp. 92–100, 2020, Doi: 10.34218/Ijeet.11.9.2020.009.

[4] R. Bhattacharjee, P. Pavithra, S. Venkatesh, C. Mohan, M. Sudarshan, And S. L. K. Kanth, “Design And Simulation Of Small Scale Solar Pv System For Department Staff Room Of An Educational Institute,” Vol. 12, No. 5, Pp. 45–49, 2022, Doi: 10.9790/9622-1205014549.

[5] B. M. Mekonen, D. B. Gelagle, And M. F. Moges, “The Current Irrigation Potential And Irrigated Land In Ethiopia : A Review,” Vol. 5, No. 1, Pp. 274–281, 2022.

[6] W. Nusa, R. N. Suhaeti, A. Saleh, And A. Abbas, “Faktor-Faktor Dalam Pengembangan Irigasi Kecil Berbasis Investasi Masyarakat Di Indonesia : Kasus Nusa Tenggara Barat Factors On Community Investment-Based Small Scale Irrigation Development In Indonesia :,” No. 2014, 2015.

[7] M. Zegeye, V. S. Ramakrishnan, And M. Premalatha, “Optimal Solar Water Pumping System For Small Scale Irrigation : A Case Study On Economical Sizing For Dangila Area Of Ethiopia,” No. 7, Pp. 1–5, 2017.

[8] J. K. Kaldellis, G. C. Spyropoulos, K. A. Kavadias, And I. P. Koronaki, “Experimental Validation Of Autonomous Pv-Based Water Pumping System Optimum Sizing,” *Renew. Energy*, Vol. 34, No. 4, Pp. 1106–1113, 2009, Doi: 10.1016/J.Renene.2008.06.021.

[9] M. U. Hailemariam Doko1, Ermias Birhane1, “Design Of Jigessa Small Scale Irrigation In,” Pp. 1–13, 2016, Doi: 10.4236/Oalib.1102563.