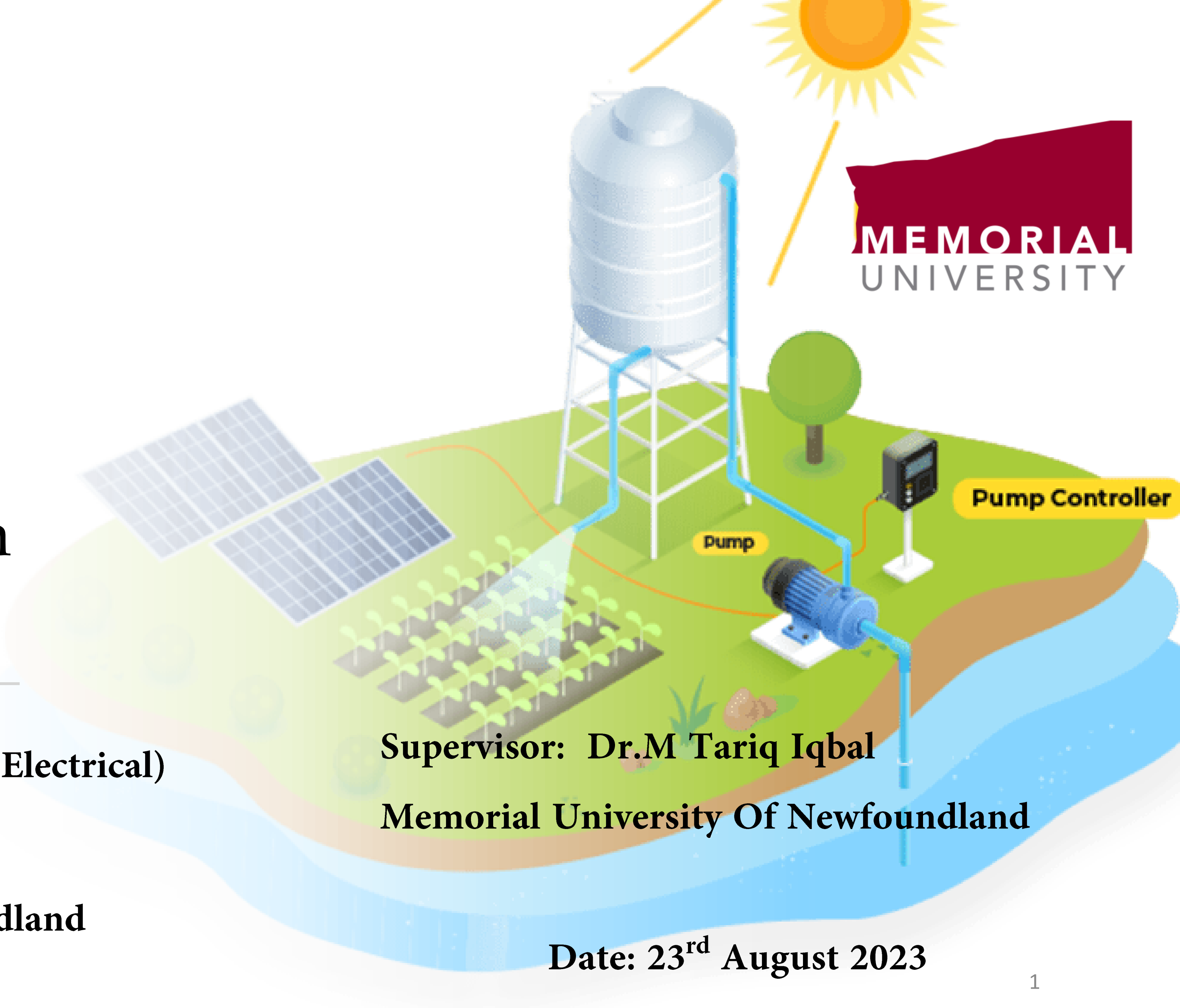
Remote Control And Monitoring of a Water Pumping System Using Cellular Network in Sukkur, Pakistan



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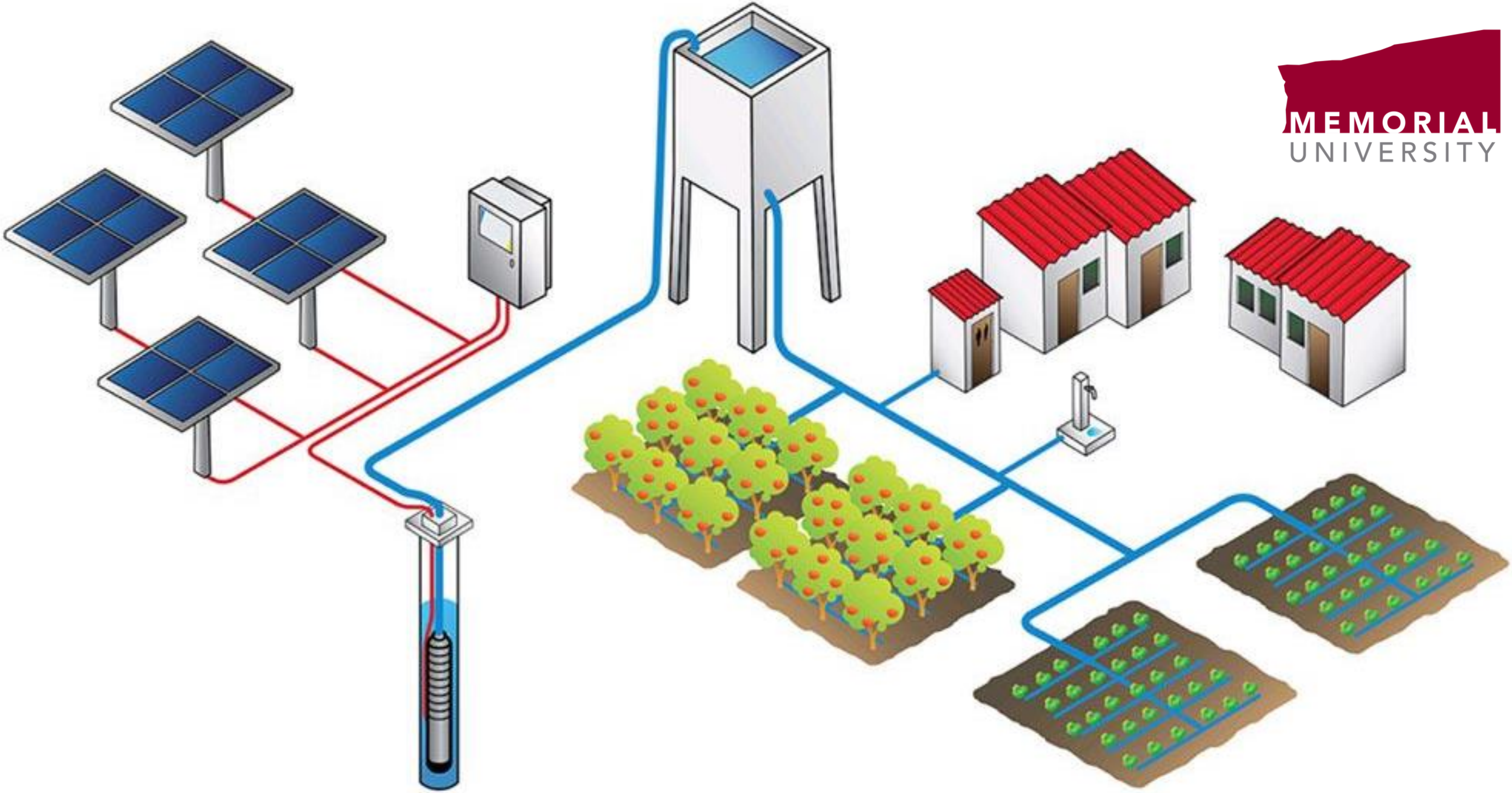
Date: 23rd August 2023

Outline of Presentation

- Introduction
- Need of this study
- Problem Statement & Research Objective
- Design of the Proposed System
- Control of the Proposed System
- Remote Data Acquisition System
- Conclusion & Future Work

Introduction

- DC voltage generated can be converted into AC voltage with the help of an inverter, or it can be stepped up or down using a boost or buck DC-DC converter
- In this study, the load is a water pump with a DC shunt motor, thus the load is DC, pumping water from a well or borehole as soon as exposed to sunlight
- Sometimes a two-stage DC-DC converter is used in high duty cycle applications
- The study will focus on an isolated PV solar water pumping system.



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Agricultural Importance of Water in Pakistan

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- Agriculture accounts for 22.2% of GDP and employs 42.3% of the workforce in Pakistan.
- Water availability dropped from 5000 m3 per capita in the 1950s to a projected 1000 m3 per capita by 2025.
- To overcome water shortage, water pumps have been installed. Initially, these were powered by fossil fuels, contributing to a circular debt of 1.2 trillion Pakistani rupees over five years.
- As a solution, the government is shifting its policies toward renewable alternative energy sources.

Pakistan's Renewable Energy Potential

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- Pakistan has an estimated renewable energy potential of 167.7 GW.
- The country has a significant solar potential with a capacity of up to 100,000 MW.
- The transition to renewable energy sources is advantageous due to the country's lack of fossil fuel resources.
- This shift can fuel water pumps, eliminating the need for reliance on fossil fuels.

Global Significance of Water Use

- Irrigated land generates about 40% of the world's food and fiber.
- Around 66% of the globally diverted freshwater and about 80% of the consumed freshwater are used for irrigation.
- Irrigated farmland has increased from 8 million hectares in 1800 to 270 million hectares in the early 21st century.
- However, this growth is expected to slow down significantly due to the costs and limited places for potential irrigation.

Stand-alone Water Pumping Systems

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- These systems, powered by solar, diesel, and wind, have been widely used for water supply in isolated off-grid locations.

- A PVWP system typically consists of a PV array, a power conditioning system, the pump, and the storage module.

- PVWP systems are very reliable, requiring less maintenance and repair, produce little noise and no greenhouse emissions.

Global Adoption of PVWP Systems

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More than 20,000 PV pumping systems were installed globally by the start of 2000.

Countries like Bangladesh and India have set ambitious goals for PVWP installations.

Despite a higher initial capital cost, PVWP systems prove more practical than Diesel Water Pumping (DWP) systems in terms of life cycle costs.

Problem Statement

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- Water scarcity is a significant challenge for agriculture; water pumps are currently used to alleviate this.
- These water pumps primarily operate on fossil fuels - a shift to renewable energy sources is advocated.
- Despite these advancements, a comprehensive analysis of Pakistan's water pumping infrastructure has been lacking.
- Our study aims to conduct a thorough assessment using advanced testing methods and telemetry-based pump monitoring.
- We seek to develop a remote-control system for these pumps, analyze efficiency trends, and understand economic implications of efficiency improvements.

Research Objectives

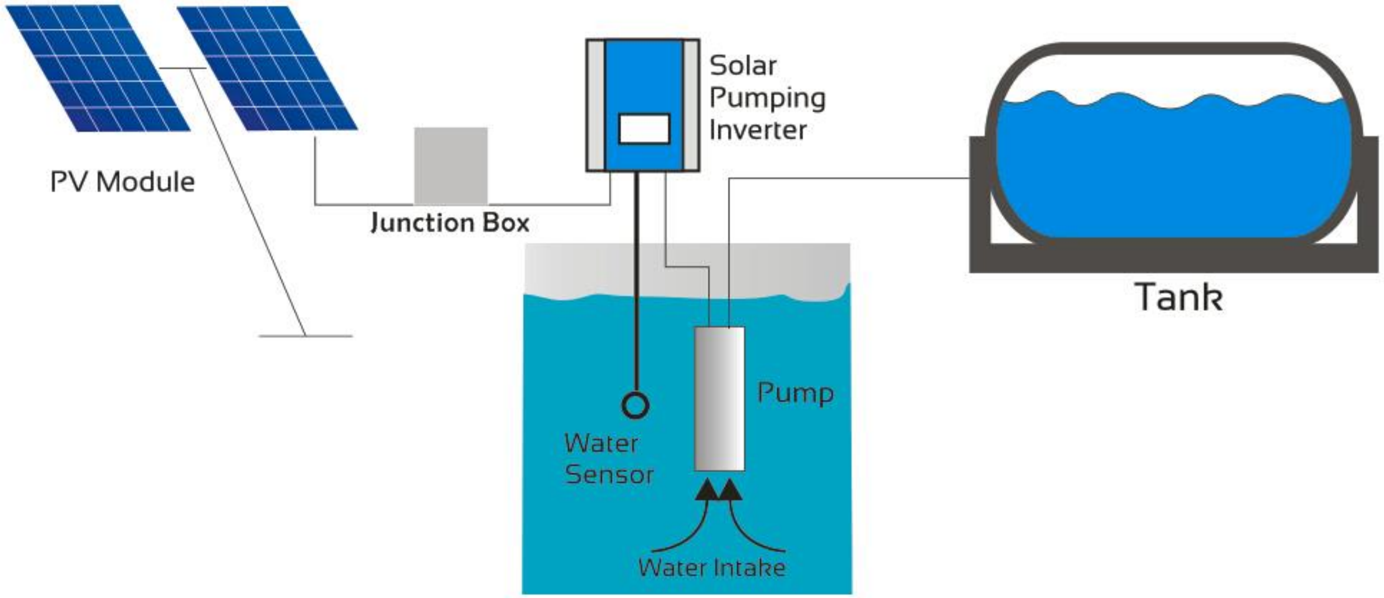
- To understand the working principles of solar water pumps and their relevance to the agricultural sector in Pakistan.
- To design a solar water pumping system for Sukkur, Pakistan, considering site selection, calculation of load for the water pump, and system configuration.
- Effective design and simulation of the solar water pumping system.
- To control the PV water pumping system using microcontroller technology and various other hardware components.
- To develop a data logging system for the PV water pumping system.
- To build a remote data acquisition system for the Photovoltaic Water Pumping System
- To establish a reliable system for data communication and management, and to analyze the results and outcomes.

System Design

- The solar water pumping system consists of four main components:

- PV panels
- Energy storage system (battery bank)
- DC to AC power converter
- Water pump

System Design



Site Selection

The chosen location for the project is a 20-acre farm in the Saleh Pat Tehsil of the Sukkur District, Pakistan, close to the city of Sukkur (GPS coordinates 27.481784, 69.051130).

The region is populated with date palm plants spaced twenty feet apart in all directions.

Around one thousand plants are at various stages of development on the farm.

Site Selection

Load Calculation

- Water required by date palm tree: $287\ L/day$
- Water required by 1000 date palm trees: $287\ m^3/day$
- Flow Rate for 24 hours: $11.958\ m^3/h$

Considering optimal solar insolation per day is $6-8\ hours$, a higher flow rate is required:

- Increased Flow Rate = $11.958\ m^3/h \times 4\ =\ 47.8\ m^3/h$
- Water Depth = $100\ feet$ = $30.48\ m$
- Total Dynamic Head = $35\ m$

Load Calculation

- Hydraulic power of the water pump (P_h) is calculated as:

$$P_h = \frac{\rho \times g \times h \times Q}{3600} = 4557.5\ W$$

where ρ = density of water
g = gravitational acceleration
h = dynamic head
Q = water flow

Load Calculation

- Assuming motor efficiency (η) as 80%:

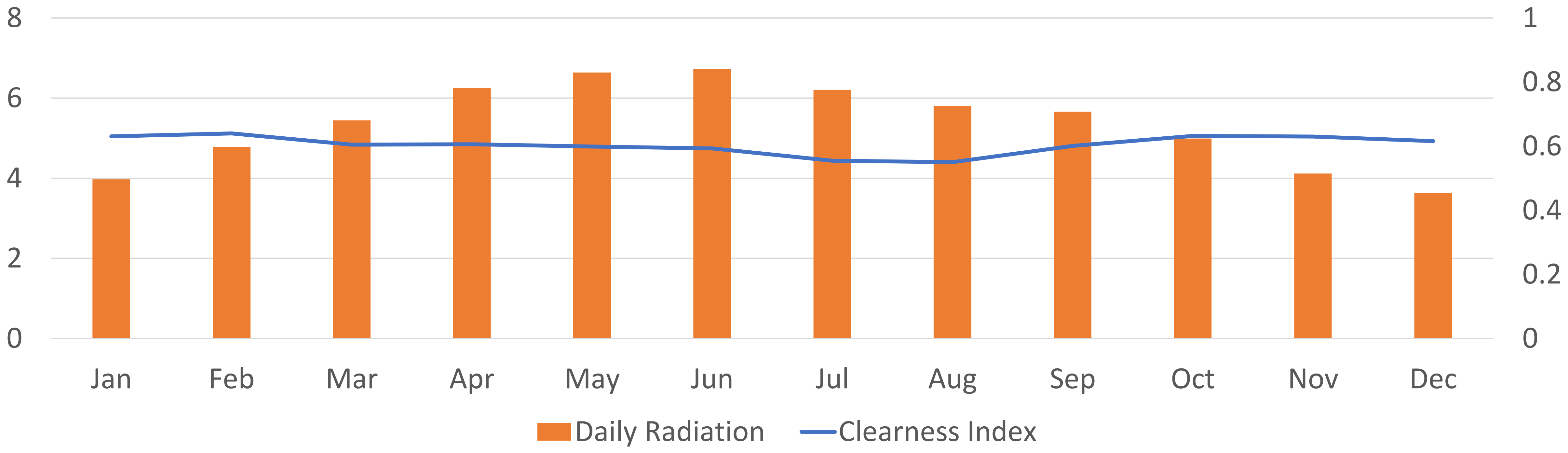
$$Motor\ Power\ (P_m) = P_h/\eta = 4557.5/0.8 = 5696.82\ W$$

- Assuming pump efficiency as 50%:

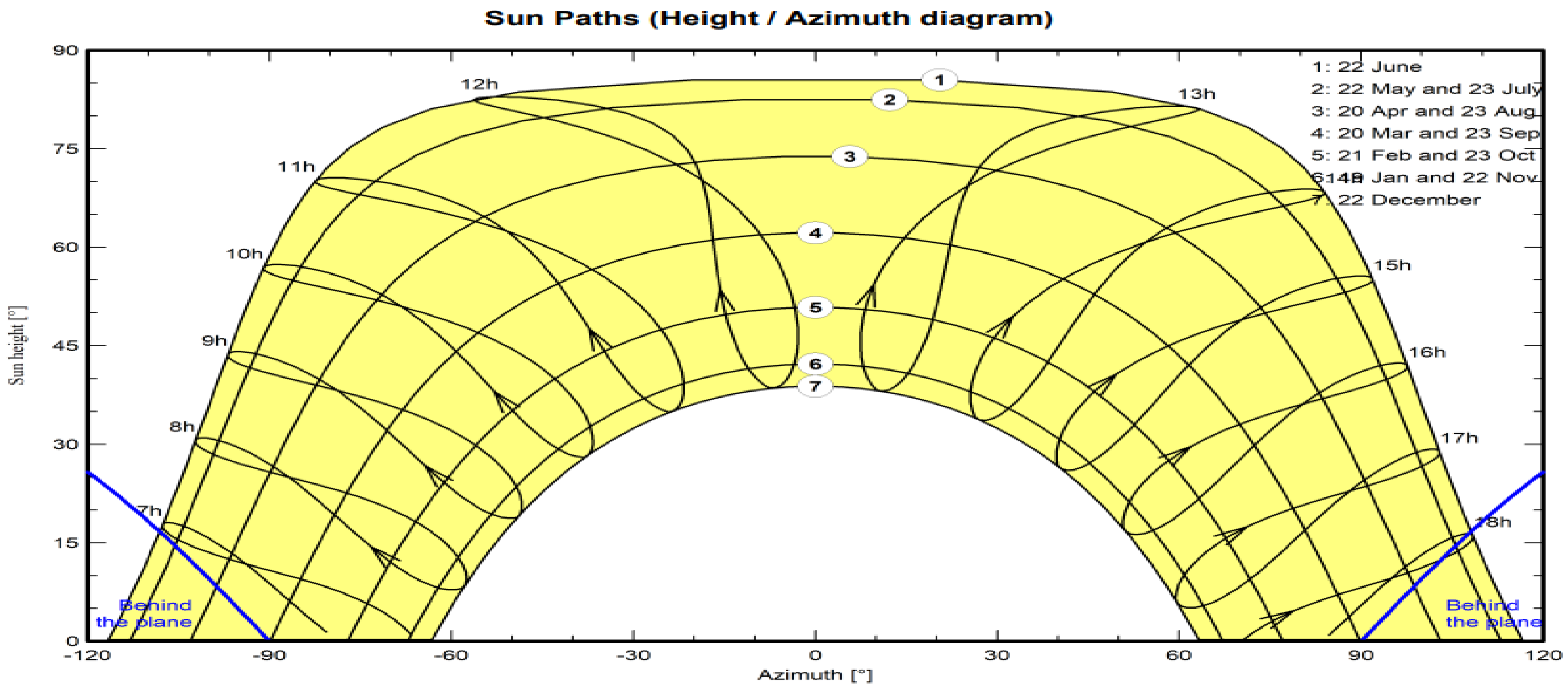
$$Required\ Power\ (P) = 5696.82/0.5 = 11.394\ kW$$

- Converting to horsepower, the required pump is estimated to be 15.27 hp.

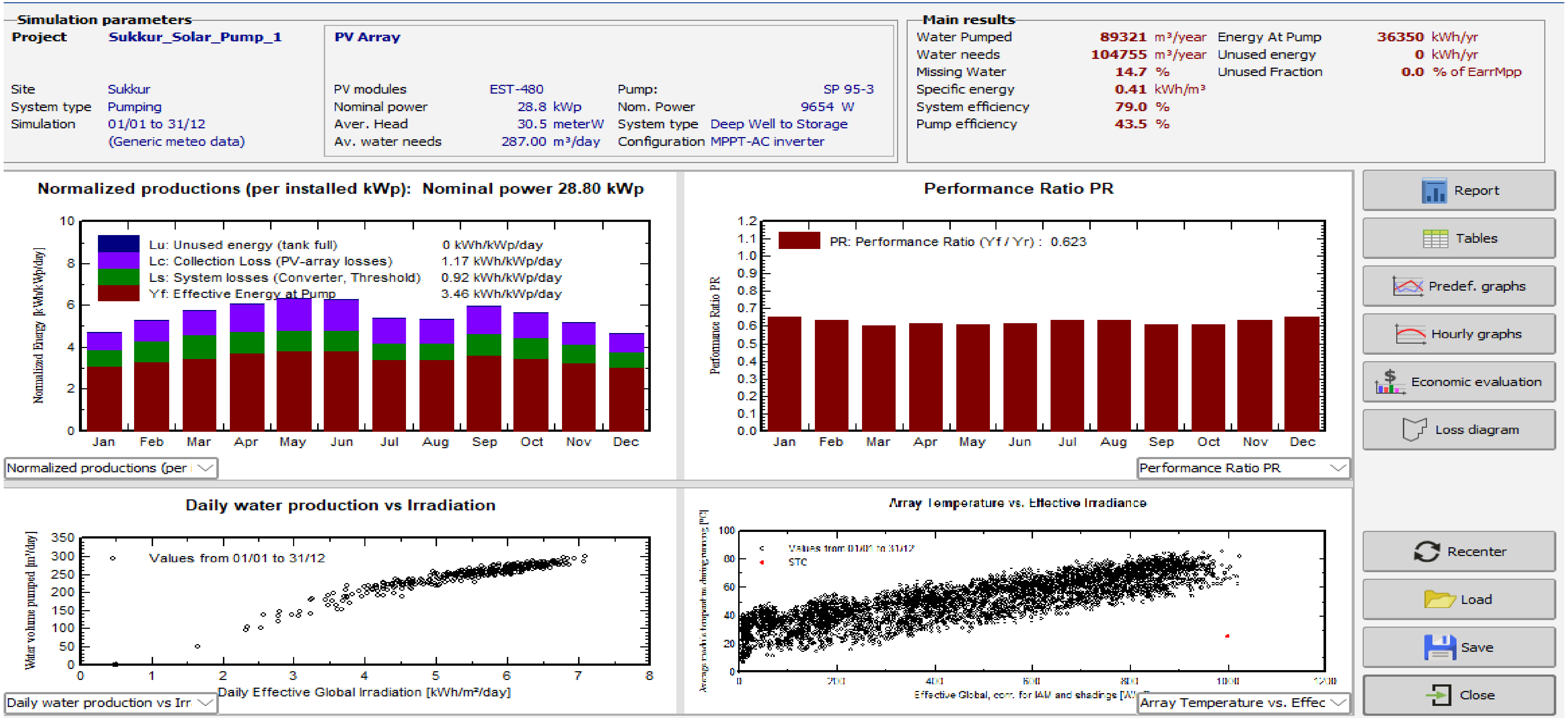
Irradiance and Clearance Index of Site



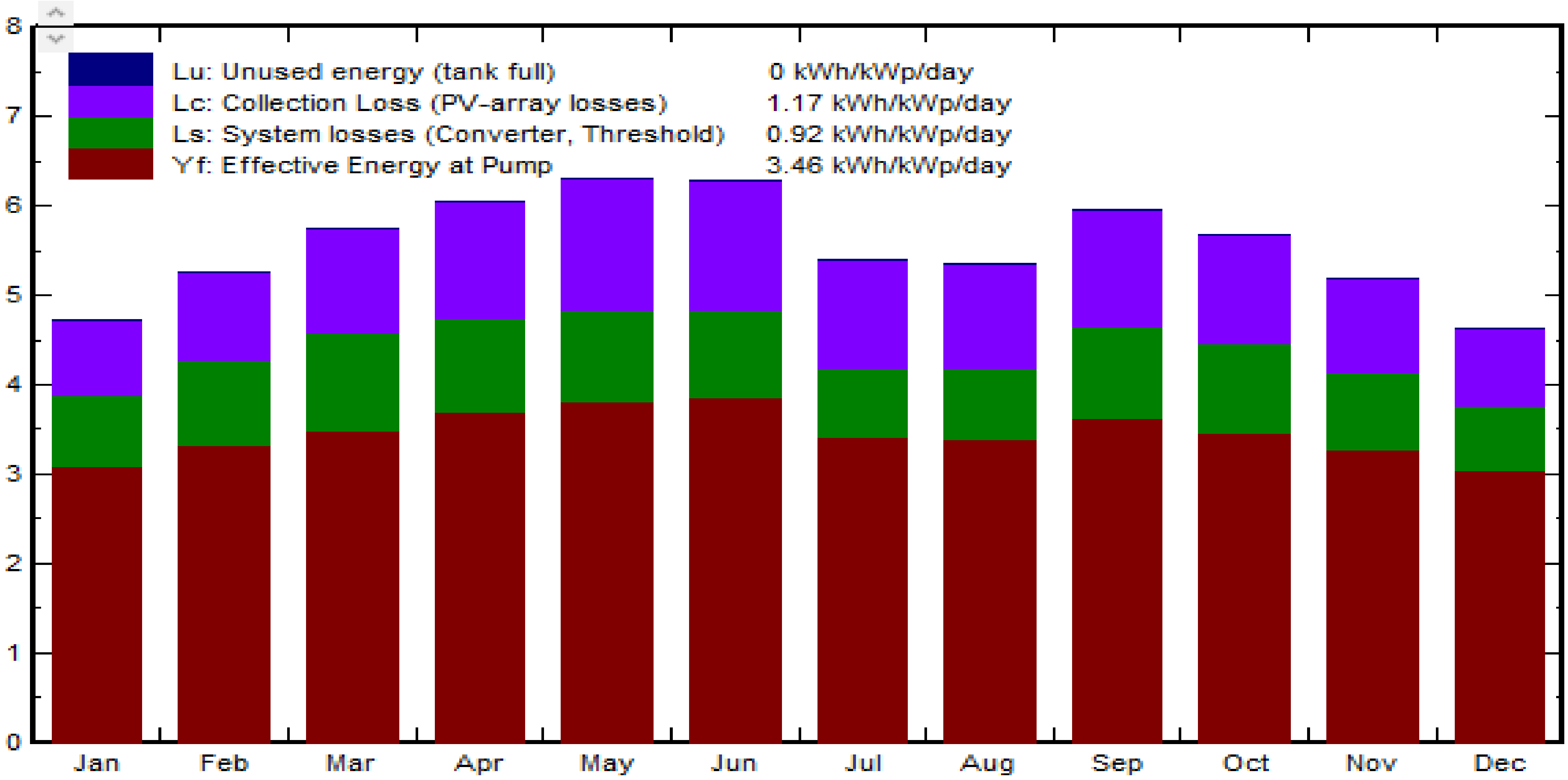
Sun Horizon line at the Site



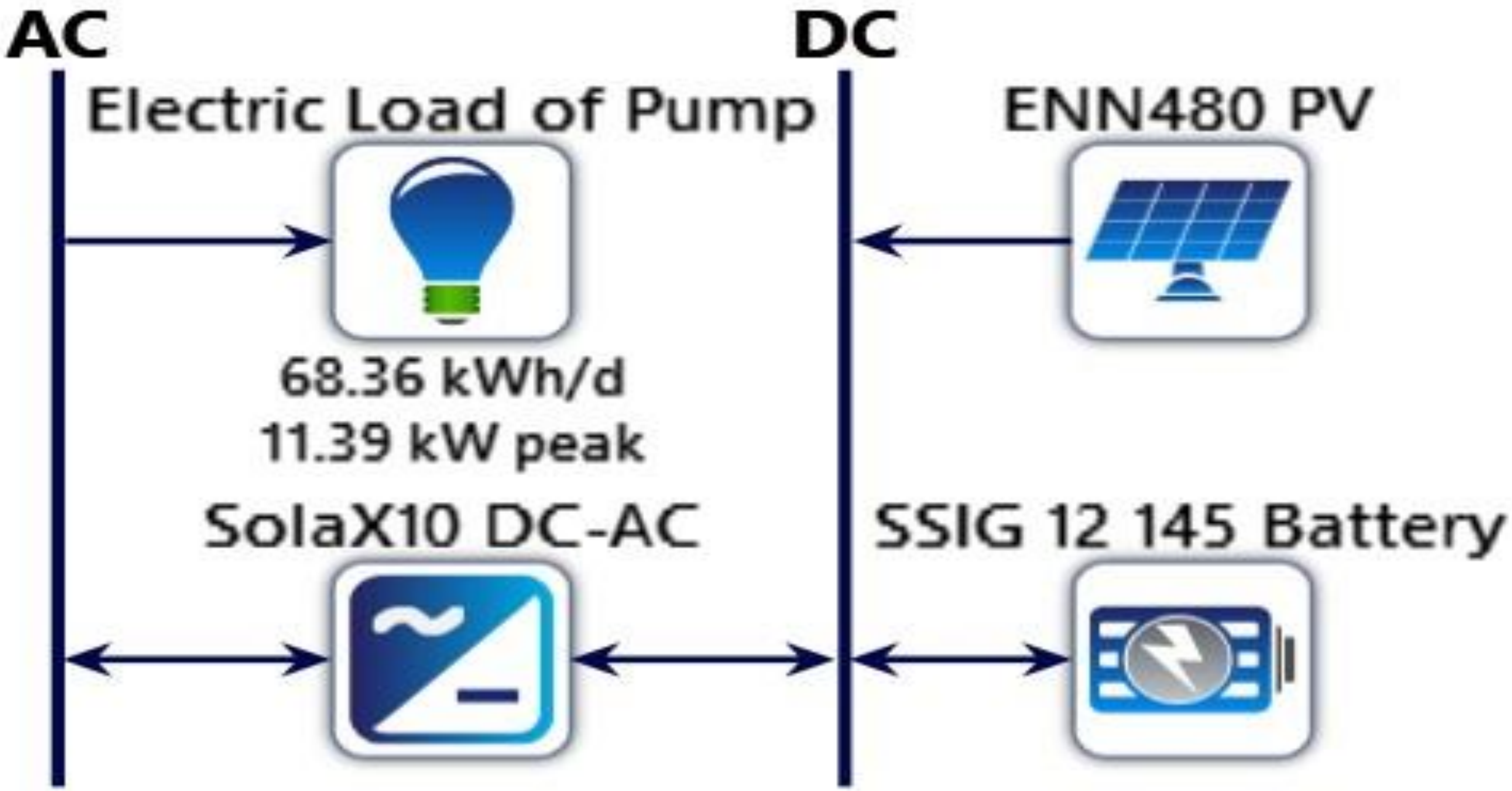
PVSyst Design & Result



PVSyst Design & Result



HOMER Design & Result



HOMER Design & Result

System Architecture:
ENN Solar Energy480EST-480 (29.9 kW)
Trojan SSIG 12 145 Battery (3.00 strings)
SolaX X3-hybrid10 DC-AC (17.6 kW)
HOMER Cycle Charging

Total NPC:	$29,133.95
Levelized COE:	$0.09033
Operating Cost:	$820.40

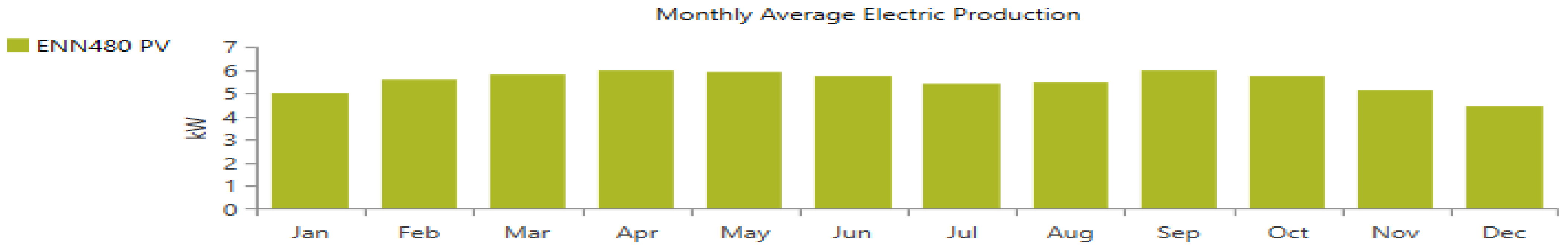
ENN Solar Energy480EST-480 | SolaX X3-hybrid10 DC-AC | Emissions
Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Trojan SSIG 12 145 Battery

Production	kWh/yr
ENN Solar Energy480EST-480	48,271
Total	48,271

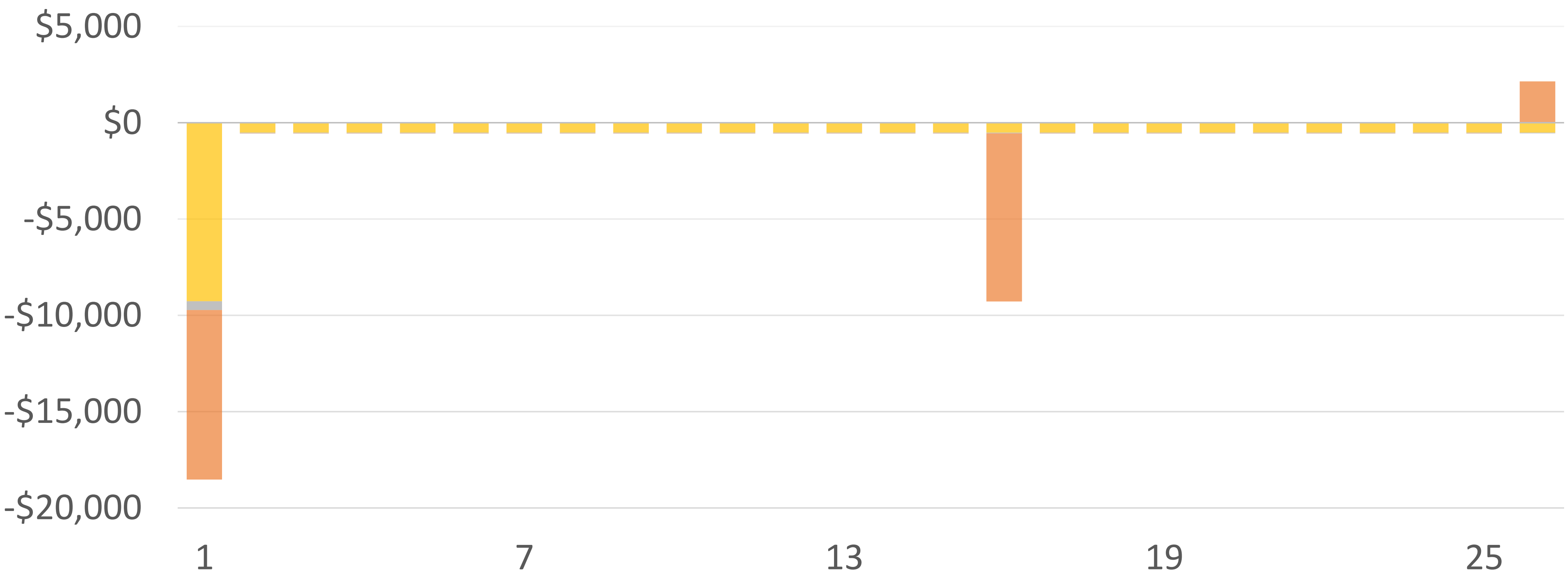
Consumption	kWh/yr	%
AC Primary Load	24,948	100
DC Primary Load	0	0
Total	24,948	100

Quantity	kWh/yr	%
Excess Electricity	21,916	45.4
Unmet Electric Load	4.95	0.0198
Capacity Shortage	24.7	0.0989

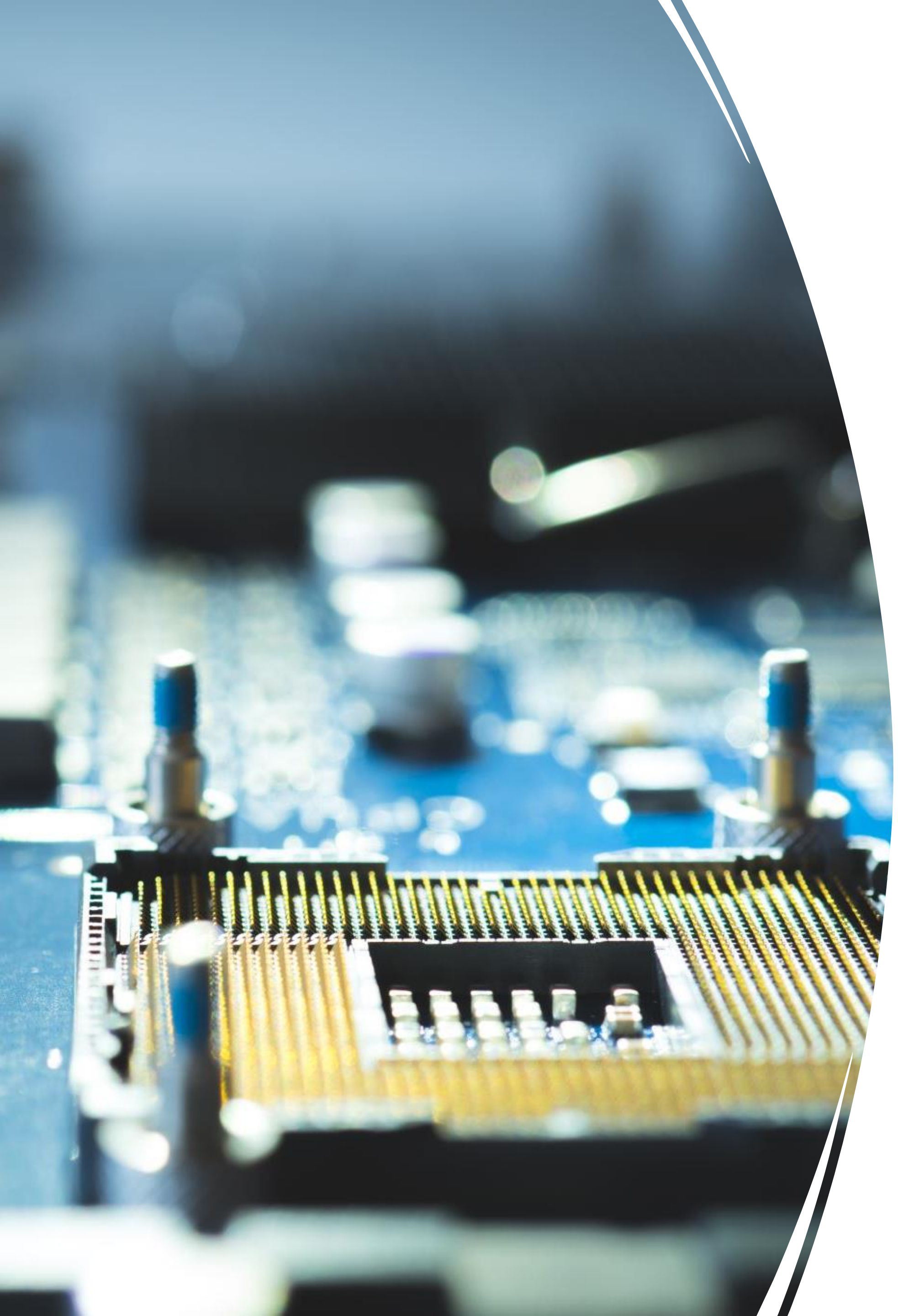
Quantity	Value
Renewable Fraction	100
Max. Renew. Penetration	254



Cash flow over the period of 25 years

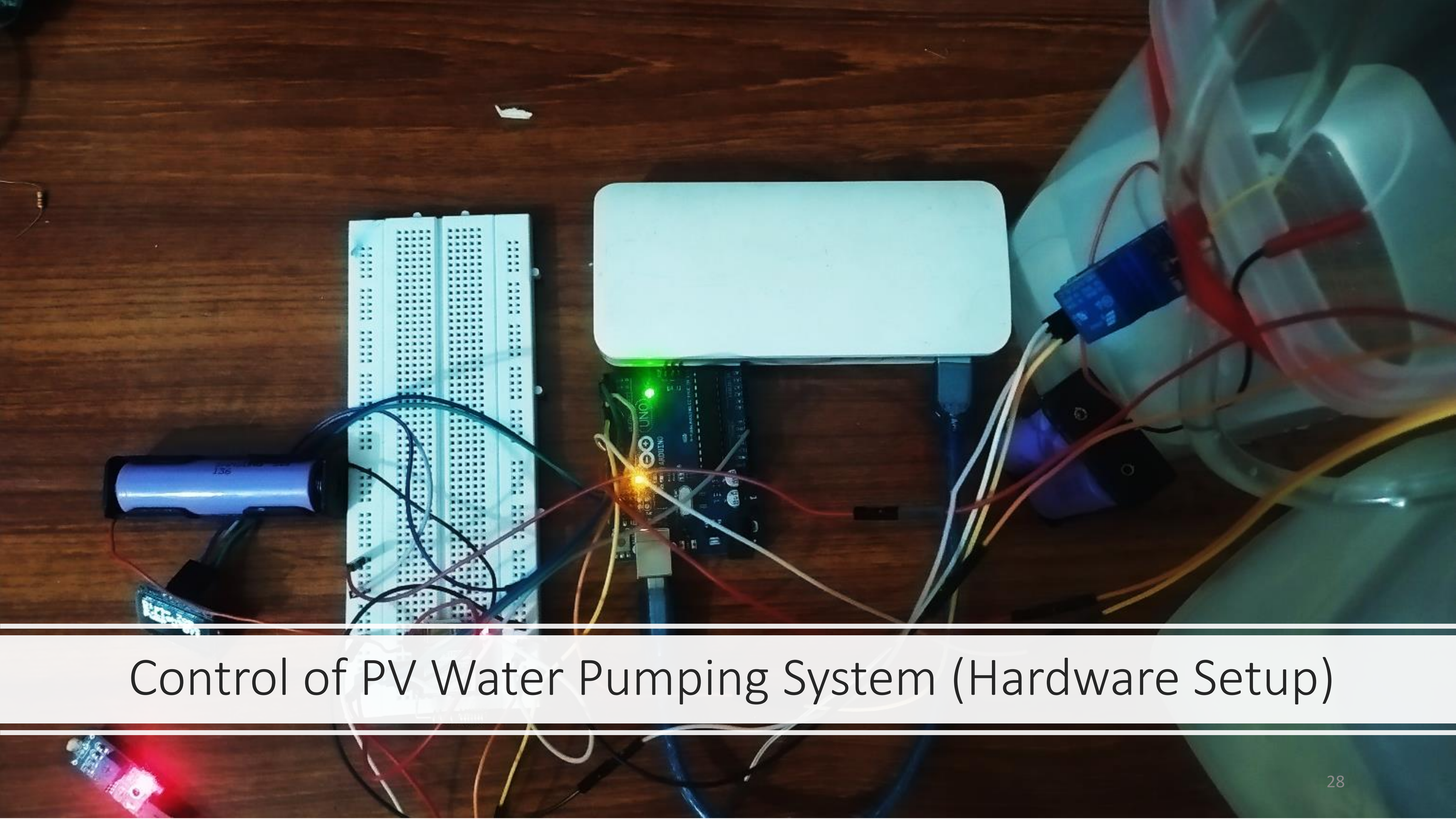


Control of the Proposed System



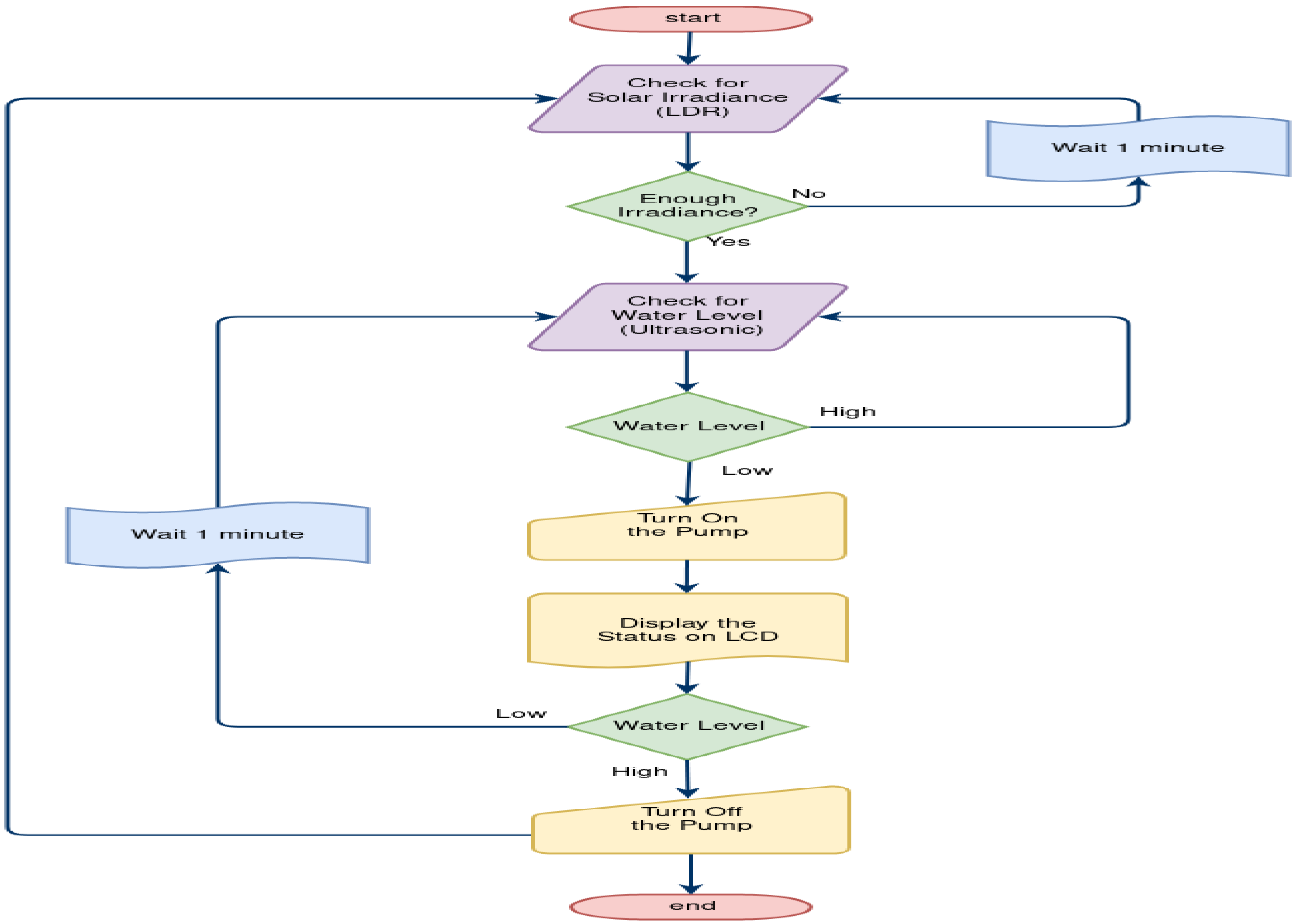
Control of PV Water Pumping System

- Arduino UNO R3
- 128 x 64 OLED for local display
- 220 Ω and 4.7 kΩ Resistors
- Ultrasonic Distance Sensor for water level measurement
- Photoresistor to measure solar irradiance.
- Motor for the pump
- Single Pole Double Throw (SPDT) Relay for motor control
- 18650 Li-ion Battery Cells for backup
- Sim800l GSM Module for 2G network connectivity



Control of PV Water Pumping System (Hardware Setup)

Flowchart of the Control Strategy

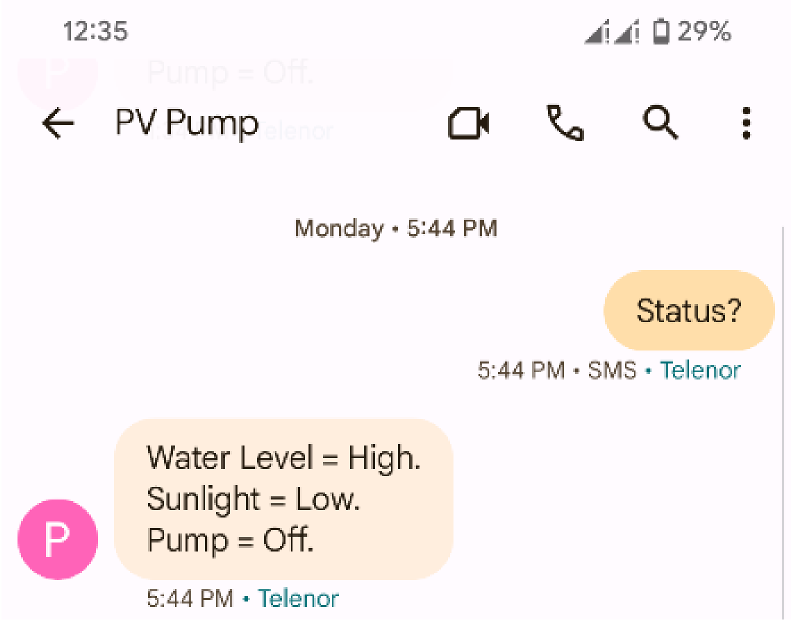


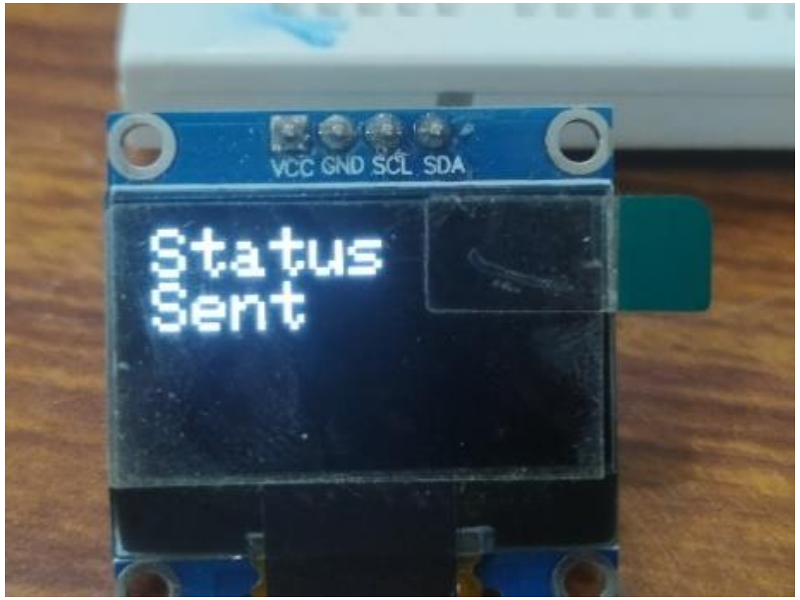
Data Logging

Sr. No	Pump Status	Water Level (cm)	Solar Irradiance
1	OFF	21	LOW
2	ON	18	HIGH
3	ON	15	HIGH
4	ON	12	HIGH
5	ON	9	HIGH
6	ON	7	HIGH
7	OFF	7	LOW
8	ON	5	HIGH
9	OFF	5	LOW
10	OFF	5	LOW
11	ON	21	HIGH
12	ON	18	HIGH

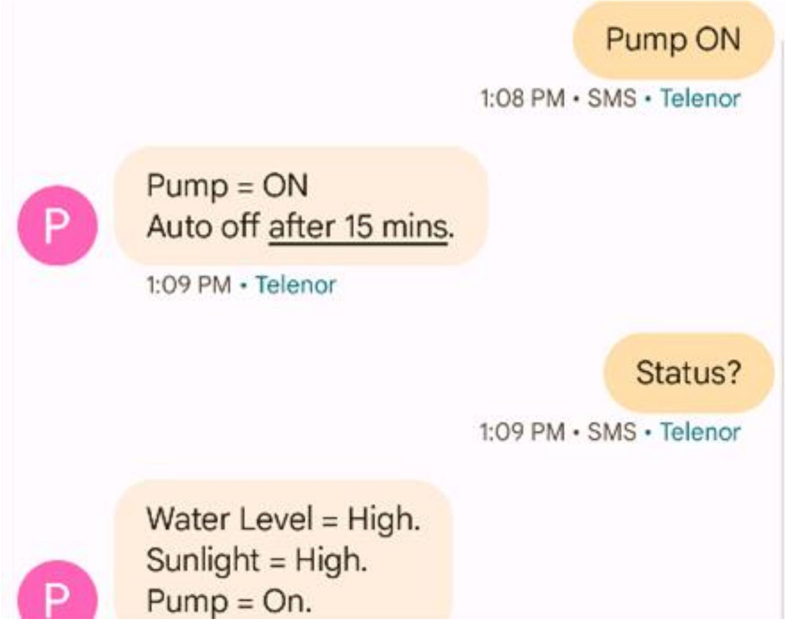
Data Logging

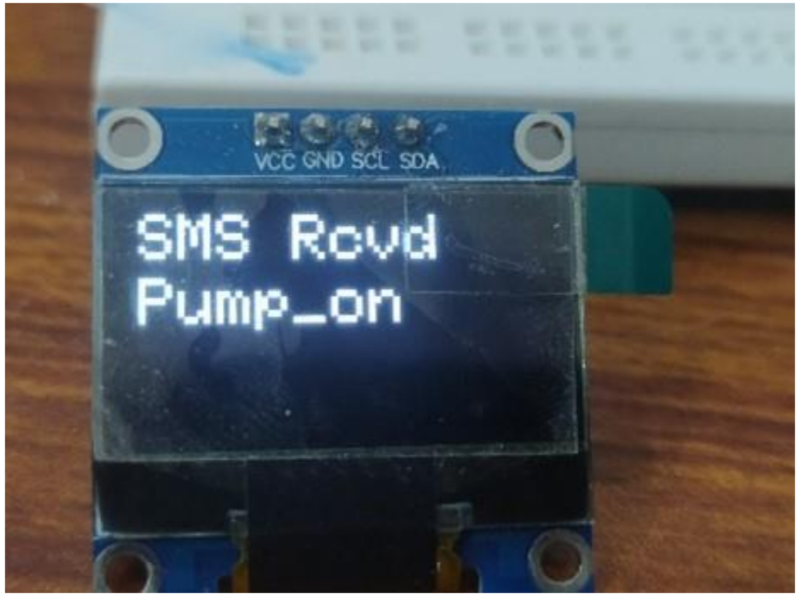
Sr. No	Pump Status	Water Level (cm)	Solar Irradiance
13	ON	15	HIGH
14	ON	12	HIGH
15	ON	9	HIGH
16	ON	7	HIGH
17	OFF	7	LOW
18	OFF	7	LOW
19	ON	5	HIGH
20	OFF	5	LOW
21	OFF	5	LOW
22	ON	21	HIGH
23	ON	18	HIGH
24	ON	15	HIGH



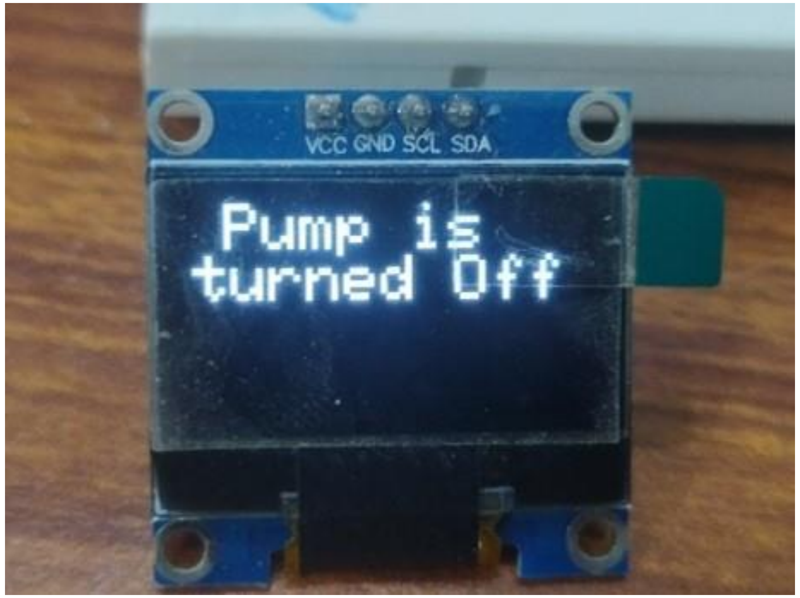


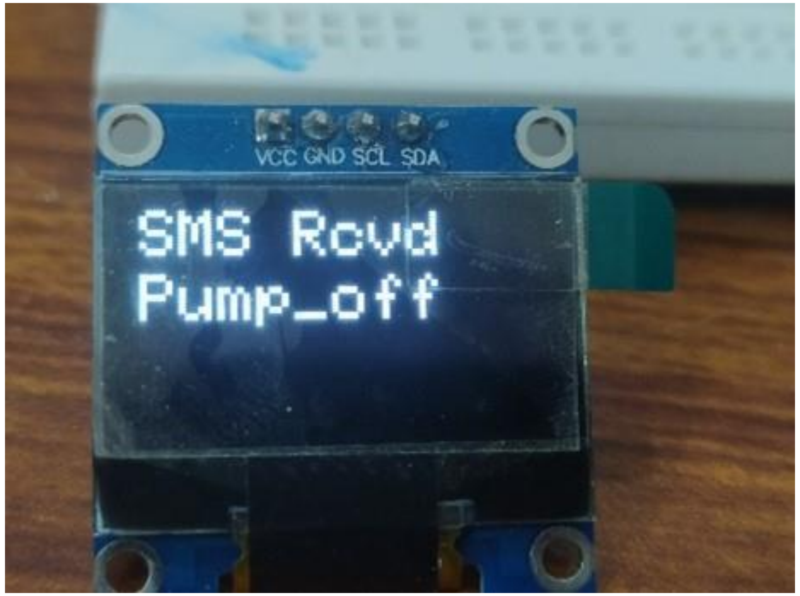
User Controlled Setup (Status Query)





User Controlled Setup (On Query)



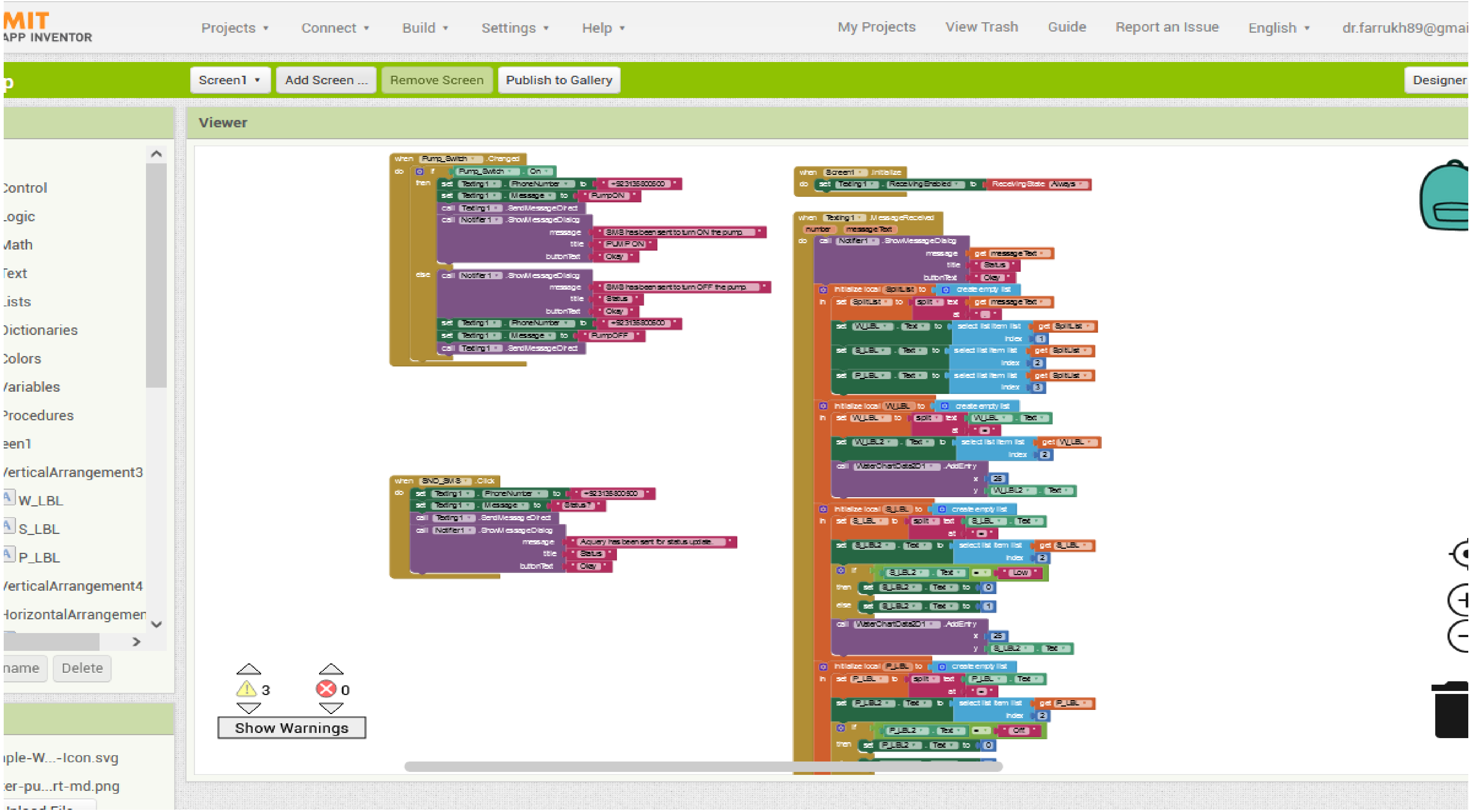


User Controlled Setup (Off Query)

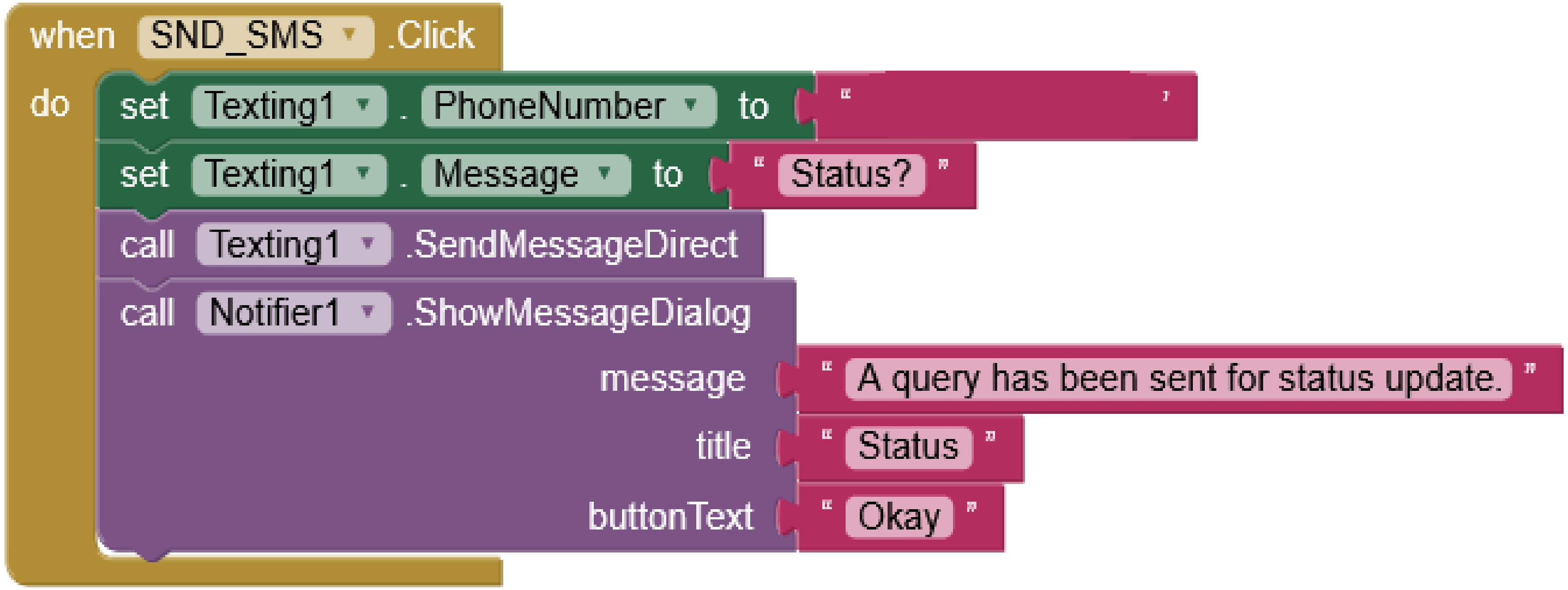
Remote Data Acquisition System

- The setup includes a solar-based water pumping system, facilitated by advanced hardware and software configurations.
- The system is controlled by an Arduino Uno microcontroller with a GSM module.
- Raspberry Pi 2 acts as a server and cloud storage unit for the system, providing efficient data management and accessibility.
- A user-friendly app, developed using MIT App Inventor platform, allows easy monitoring and control of the system.
- These components work in synergy, enabling effective remote data acquisition and control of the solar-based water pumping system.

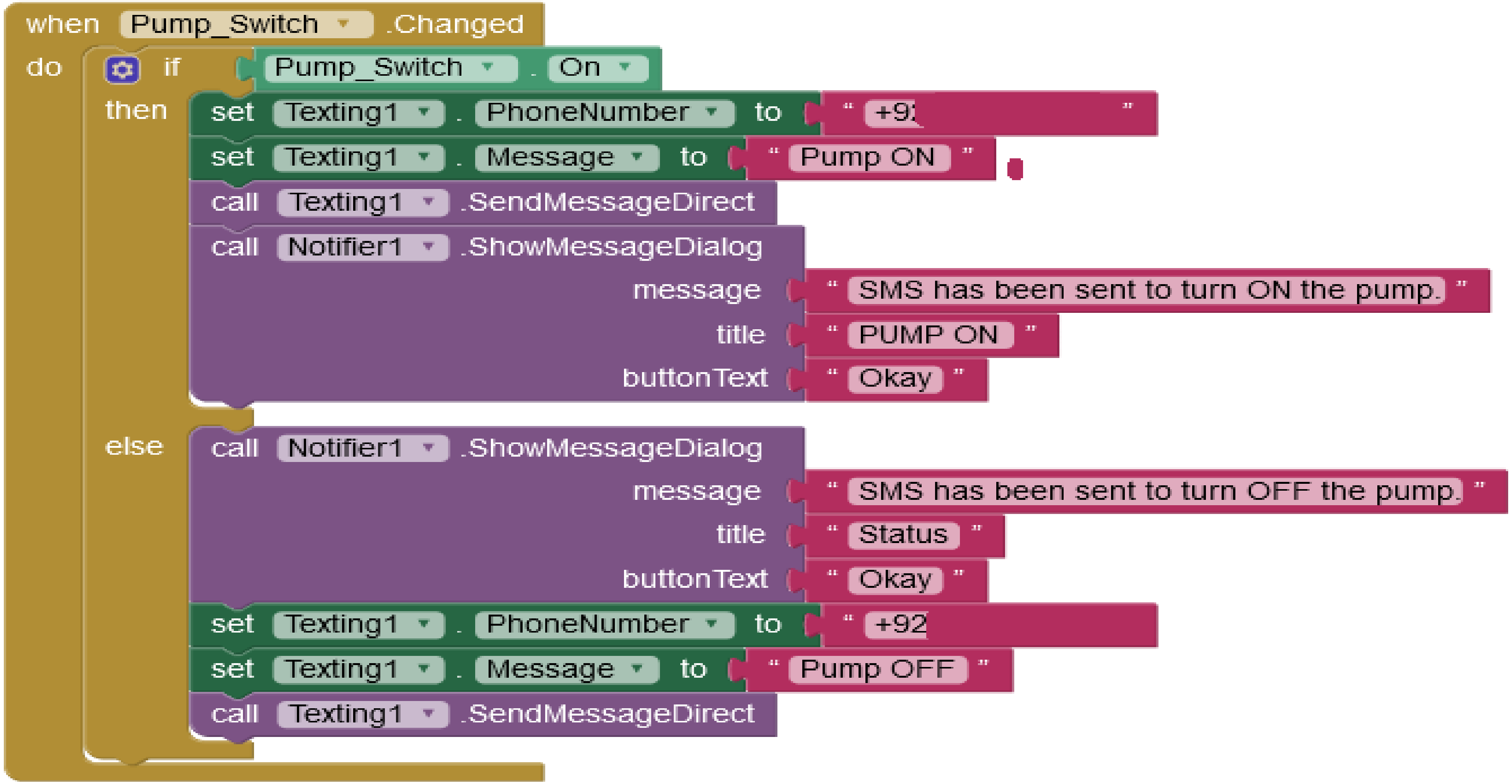
MIT App Inventor



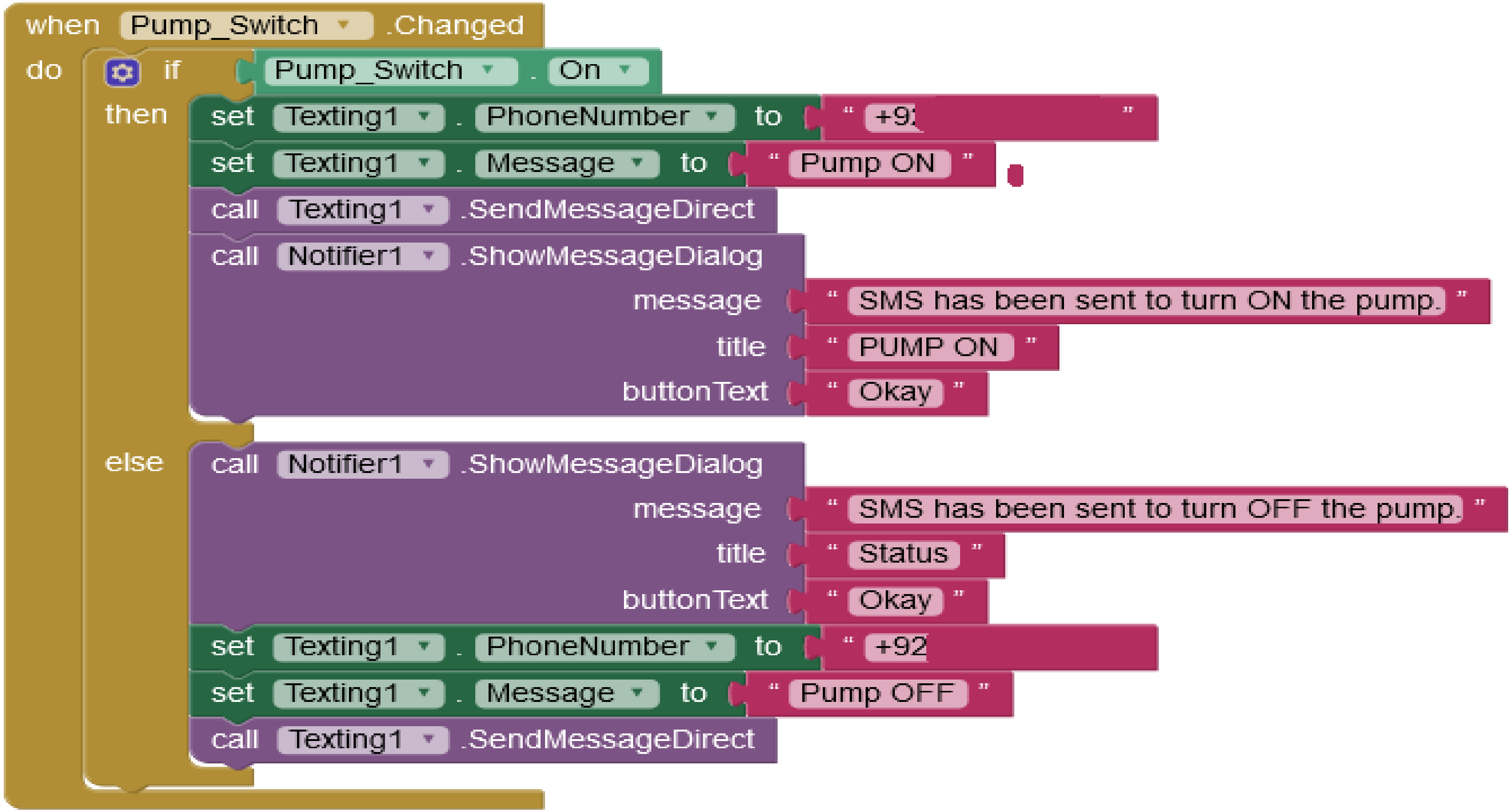
MIT App Inventor (Status Query)



MIT App Inventor (Status Query)

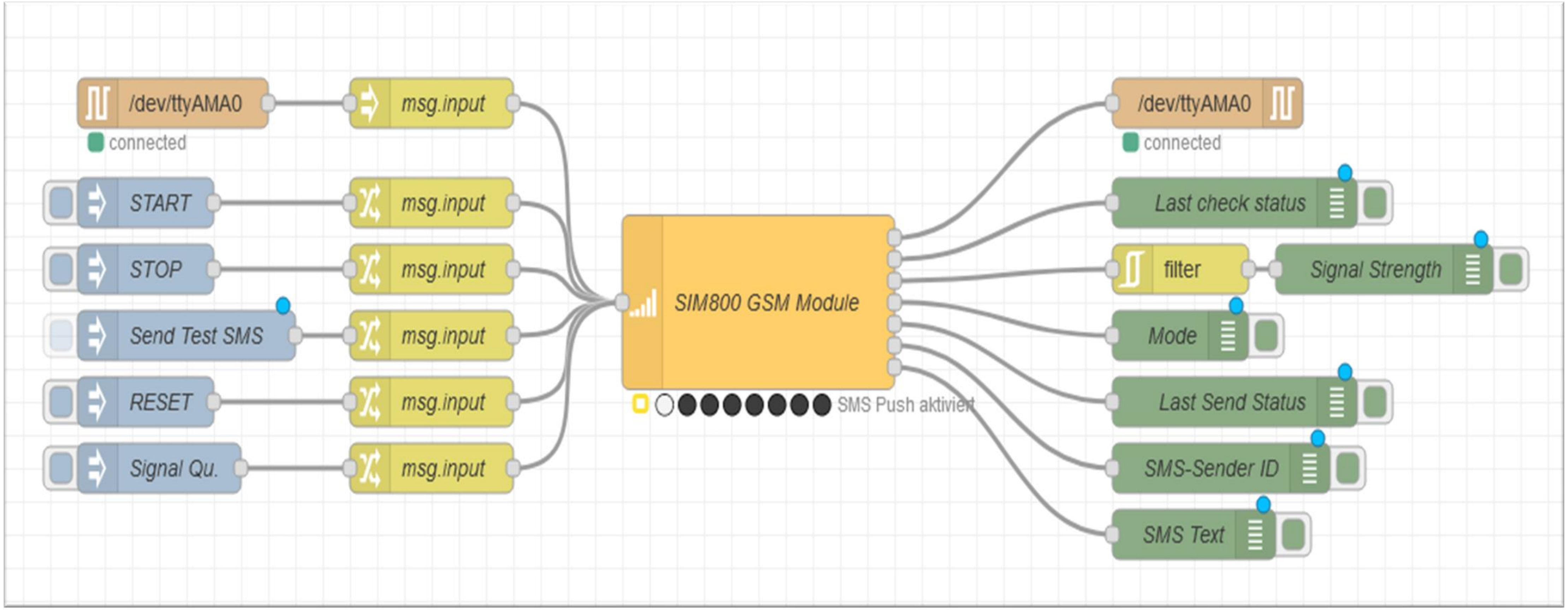


MIT App Inventor (ON & OFF Query)



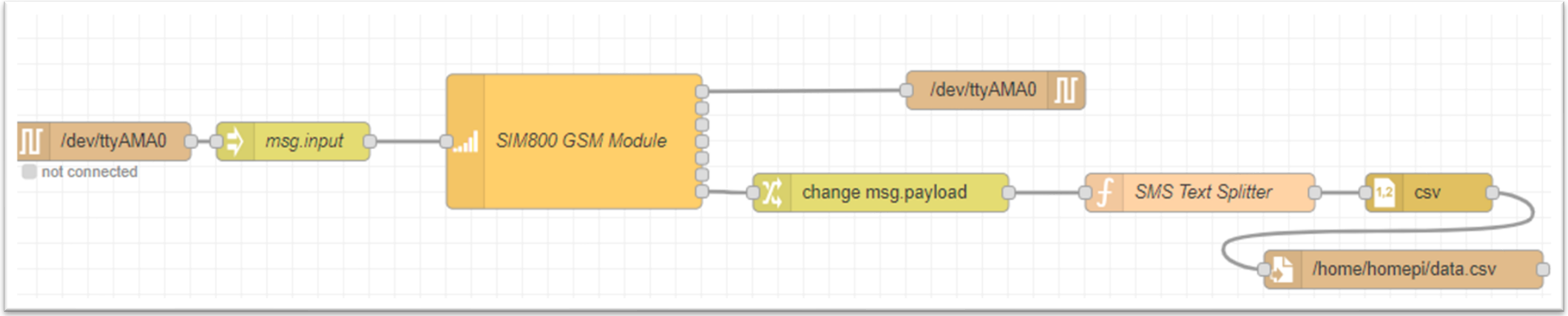
MIT App Inventor (Application Design)

NODE-Red

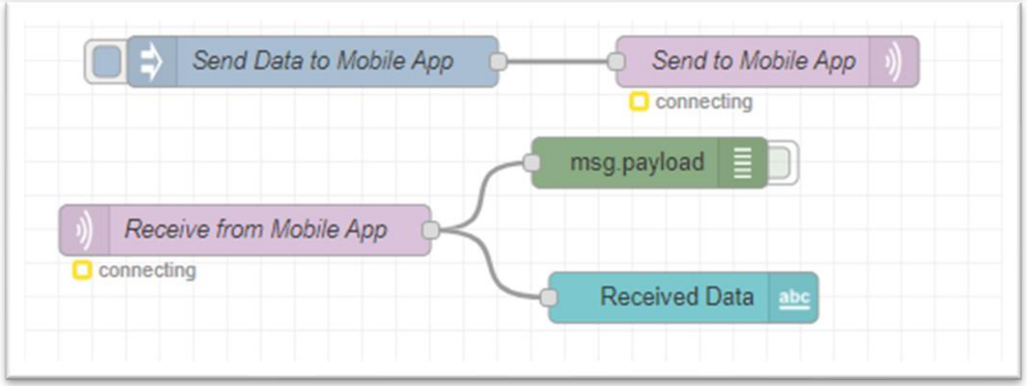


/dev/ttyAMA0
connected
msg.input
START
msg.input
STOP
msg.input
Send Test SMS
msg.input
RESET
msg.input
Signal Qu.
msg.input
SIM800 GSM Module
SMS Push aktiviert
/dev/ttyAMA0
connected
Last check status
filter
Signal Strength
Mode
Last Send Status
SMS-Sender ID
SMS Text

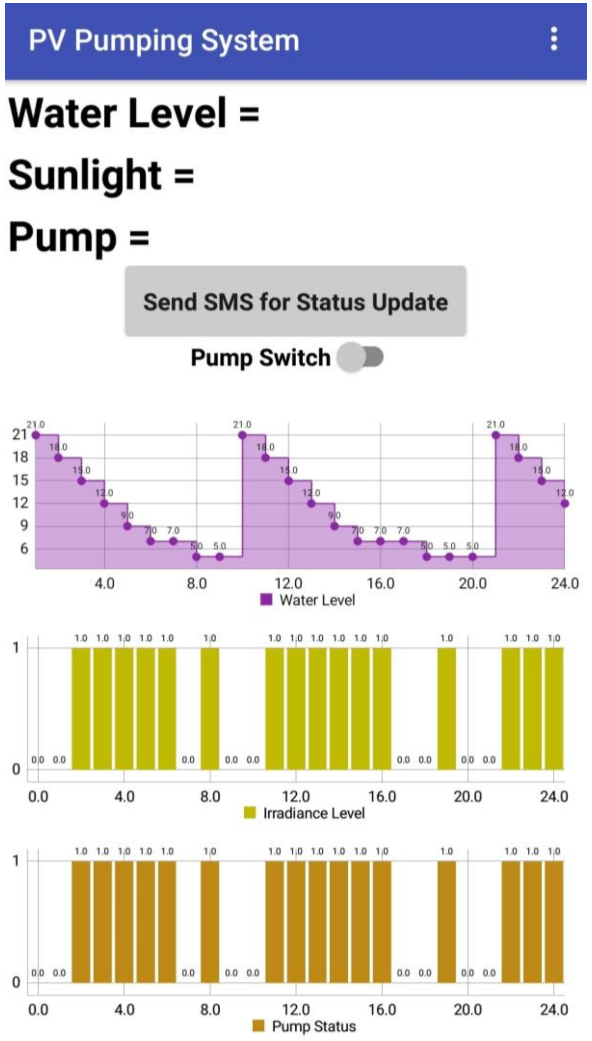
NODE-Red


/dev/ttyAMA0
not connected
msg.input
SIM800 GSM Module
/dev/ttyAMA0
change msg.payload
SMS Text Splitter
csv
/home/homepi/data.csv

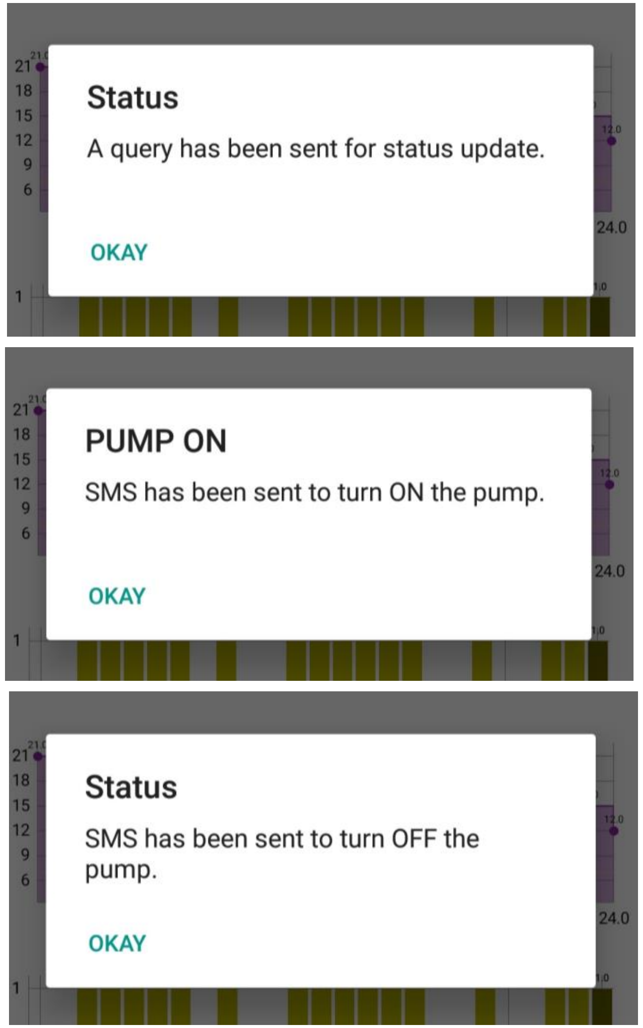

timestamp
/home/homepi/data.csv
Data Parser
csv
debug 2


Send Data to Mobile App
Send to Mobile App
connecting
msg.payload
Receive from Mobile App
connecting
Received Data

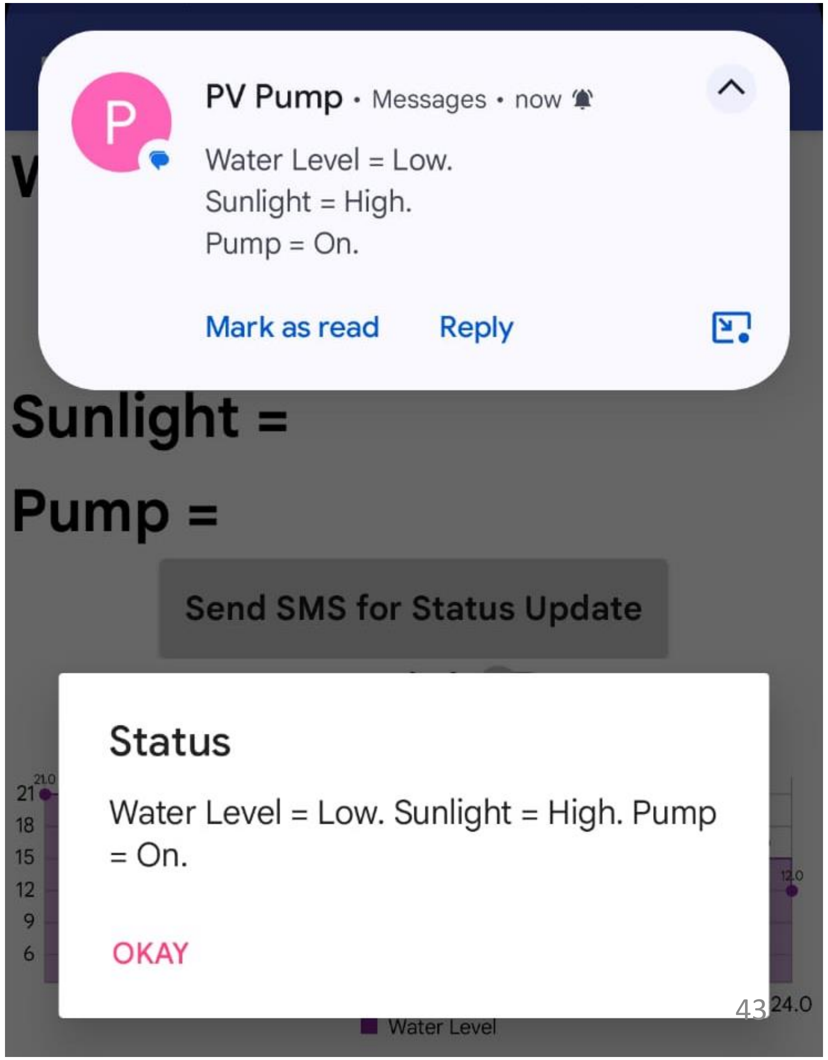
Results



PV Pumping System
Water Level =
Sunlight =
Pump =
Send SMS for Status Update
Pump Switch
Water Level
Irradiance Level
Pump Status



Status
A query has been sent for status update.
OKAY
PUMP ON
SMS has been sent to turn ON the pump.
OKAY
Status
SMS has been sent to turn OFF the pump.
OKAY



PV Pump • Messages • now
Water Level = Low.
Sunlight = High.
Pump = On.
Mark as read
Reply
Sunlight =
Pump =
Send SMS for Status Update
Status
Water Level = Low. Sunlight = High. Pump = On.
OKAY
Water Level

Conclusion

- The thesis explored and realized a solar-powered water pumping system, specifically designed to aid irrigation in areas like Sukkur, Pakistan, where access to surface water is limited.
- Main achievement: Designing and implementing a sustainable, cost-effective water pump system utilizing solar power, thus minimizing dependence on non-renewable resources.
- The implemented system incorporates intelligent monitoring and control mechanisms, enhancing efficiency and convenience for the user.
- This system enables real-time data logging and monitoring of critical operational parameters such as solar irradiance, water level, and pump status.

Future Work

- Predictive Analytics and Machine Learning: Enhancing system intelligence by predicting usage trends and environmental conditions for optimized pump operation.
- Scalability: Extending the system's design to accommodate larger water pumping requirements and multiple pump configurations.
- Integration of IoT: Implementing IoT technologies for better remote monitoring and control.
- Energy Storage: Investigating advanced battery technologies or other energy storage methods to optimize efficiency, reduce costs, and prolong system life.
- Robustness and Reliability: Increasing system resilience through advanced control algorithms and fault detection mechanisms.
- Environmental Impact Assessment: Assessing potential effects on local ecosystems to ensure long-term ecological sustainability as system implementation expands.

Publication

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- O. Ahmed and M. Tariq Iqbal, "Design of Solar Power Water Pumping System for Irrigation in City of Sukkur," Jordan Journal of Electrical Engineering, vol. 8, no. 2. ScopeMed, p. 195, 2022. doi: 10.5455/jjee.204-1644676329.
- O. Ahmed and M. Tariq Iqbal, "Remote Data Acquisition System for Photovoltaic Water Pumping System in Sukkur, Pakistan," European Journal of Electrical Engineering and Computer Science,
- O. Ahmed and M. Tariq Iqbal, "Remote Monitoring, Control and Data Visualization for a Solar Water Pumping System," European Journal of Electrical Engineering and Computer Science, vol. 10, no. 2.
- Omair Ahmed and M. Tariq Iqbal, Design of a Solar Water Pumping System for Sukkur, presented at the 32st Annual IEEE NECEC conference St. John's, November 19th, 2021.

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- ❖ My Wife, Family and Friends

Thank You

For Your Attention!

Any Questions