Desalination of Brackish Water Using Renewable Energy

By

Mohammad Tasnimul Hasan

19121063

Mohammad Asadul Islam

18221029

Saad Bin Haider

18221009

Aseer Irtiza

19121036

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of
Bachelor of Science in Electrical & Electronic Engineering

Department of Electrical and Electronic Engineering
BRAC University
January, 2023

Desalination of Brackish Water Using Renewable Energy

Academic Technical Committee (ATC) panel Members

Dr. Md. Mosaddequr Rahman

PhD, Professor and Chairperson, Department of Electrical and Electronic Engineering, BRAC University

Mohaimenul Islam

Lecturer, Department of Electrical and Electronic Engineering, BRAC University

Aldrin Nippon Bobby

Lecturer, Department of Electrical and Electronic Engineering, BRAC University

Department of Electrical and Electronic Engineering

BRAC University
January, 2023

Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is our own original work while completing degree at BRAC University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, exceptwhere this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Mohammad Tasnimul Hasan 19121063	**Mohammad Asadul Islam** 18221029
Saad Bin Haider 18221009	**Aseer Irtiza** 19121036

Approval

The Final Year Design Project (FYDP) [Desalination of Brackish Water Using Renewable Energy] submitted by

1. Mohammad Tasnimul Hasan (19121063)
2. Mohammad Asadul Islam (18221029)
3. Saad Bin Haider (18221009)
4. Aseer Irtiza (19121036)

Of Fall, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical & Electronic Engineering on 15th December, 2022.

Examining Committee

Academic Technical Committee (ATC):
(Chair)

Dr. Md. Mosaddequr Rahman
PhD, Professor, Chairperson
Dept of EEE, BRAC University

Final Year Design Project
Coordination Committee:
(Chair)

Dr. Abu S.M. Mohsin
Associate Professor, Dept. of EEE
BRAC University

Departmental Chair:

Dr. Md. Mosaddequr Rahman
PhD, Professor, Chairperson
Dept of EEE, BRAC University

Ethics Statement

We found 14% plagiarism in our report which is below the plagiarism boundary limit 35%.

Abstract

The coastal people of Bangladesh have been victim of saline water. The water they get is badly impacting their health. High blood pressure, waterborne diseases, death of new born etc. are very common there. The water with high salinity is to blame here. Thus, purification that is up to the mark is needed. For better purification we need help of energy source as normal filtration is never enough there. On the other hand, Renewable energy is a savior in current energy crisis. In this project we intend to solve the problem of coastal area people with the help of renewable energy.

Keywords

Brackish Water; Desalination; PVRO; Renewable Energy; Reverse osmosis.

Acknowledgement

Words cannot express our gratitude to our supervisor, Dr. Md. Mosaddequr Rahman, Mohaimenul Islam, Aldrin Nippon Bobby whose co-operation made this project possible. Their guidance and advice carried us through all the phases of writing my report. Their dynamism, vision, sincerity and motivation deeply encouraged us.

We are extremely grateful to our parents for their love, support, encouragement and keen interest in my academic career. Furthermore, big thanks to our friends whose support made our academic life much easier.

Finally, praises and thanks to the God, the Almighty, for His showers of blessings throughout our project work to complete the project successfully.

Table of Contents

Declaration..ii

Approval iii

Ethics Statement…...iv

Abstract/ Executive Summary… v

Acknowledgement… .... **vi**

Table of contents… vii

List of Table.. .xi

List of Figures…... xi

List of Acronyms………………………………………………………………xiii

Chapter 1 Introduction.. **1**

1.1 Introduction………………………………………………………………,,. 1

1.2 Objectives, Requirements, Specification, and Constraints 4

1.3 Summary of the Proposed Project...11

1.4 Conclusion… 11

Chapter 2 Project Design Approach

2.1 Introduction…... 12

2.2 Identify Multiple Design Approaches.. 12

2.3 Describe Multiple Design Approach…..14

2.4 Analysis of Multiple Design Approaches 17

2.5 Conclusion… 20

Chapter 3 Use of Modern Engineering and IT Tools

3.1 Introduction 21

3.2 Select Appropriate Engineering and IT Tools… 21

3.3 Use of Modern Engineering and IT Tools… 24

3.4 Conclusion… 36

Chapter 4 Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction 27

4.2 Optimization of Multiple Design Approaches. 27

4.3 Identify Optimal Design Approach 32

4.4 Performance Evaluation of Developed Solution..34

4.5 Conclusion… 41

Chapter 5 Completion of Final Design and Validation

5.1 Introduction 42

5.2 Completion of Final Design 42

5.3 Evaluate the Solution to Meet Desired Need 43

5.4 Conclusion 53

Chapter 6 Impact Analysis and Project Sustainability

6.1 Introduction… 54

6.2 Assess the Impact of Solution 54

6.3 Evaluate the Sustainability 56

6.4 Conclusion 57

Chapter 7 Engineering Project Management

7.1 Introduction… 58

7.2 Define, Plan, and Manage Engineering Project… 58

7.3 Evaluate Project Progress… 58

7.4 Conclusion 61

Chapter 8 Economical Analysis

8.1 Introduction… 62

8.2 Economic Analysis 62

8.3 Cost Benefit Analysis 63

8.4 Evaluate Economic and Financial Aspects 66

8.5 Conclusion… 69

Chapter 9 Ethics and Professional Responsibilities

9.1 Introduction 70

9.2 Identify Ethical Issues and Professional Responsibility 70

9.3 Apply Ethical Issues and Professional Responsibility 71

9.4 Conclusion 73

Chapter 10 Conclusion and Future Work

10.1 Project Summary/Conclusion 74

10.2 Future Work 74

Chapter 11 Identification of Complex Engineering Problems and Activities

11.1 Identify the Attribute of Complex Engineering Problem (EP) 75

11.2 Provide Reasoning How the Project Address Selected Attribute (EP) 75

11.3 Identify the Attribute of Complex Engineering Activities (EA) 76

11.4 Provide Reasoning How the Project Address Selected Attribute (EA) 77

References 78

Appendix A 81

List of Tables

Table-1: Functional and Nonfunctional Requirements 5

Table-2: Specifications 6

Table-3: Applicable compliance, standards, and codes 10

Table-4: Analysis of Multiple Design Approaches 01 17

Table-5: Analysis of Multiple Design Approaches 02 18

Table-6: Analysis of Multiple Design Approaches 03 19

Table-7: Select Appropriate Engineering and IT Tools: Software Tools 22

Table-8: Comparison Between 3-D Modeling Software 23

Table-9: Comparison Between Simulation Software 23

Table-10: Comparison Between Energy Calculation Software 24

Table-11: Hardware Tools 24

Table-12: Identify optimal design approach 32

Table-13: Energy Usage Criteria in Different Time Domains 38

Table-14: Analysis of Solar Energy Production 47

Table-15: Water Filtration Data 51

Table-16: Water Quality Data 52

Table-17: Economic analysis 62

Table-18: Cost benefit analysis 64

Table-19: Budget 67

Table-20: Identify the attribute of complex engineering problem (EP) 75

Table-21: Identify the attribute of complex engineering activities (EA) 76

List of Figures

Figure-01: Pie-chart of better alternative solution of pure water problem survey in BRAC University 3

Figure-02: Pie-chart of satisfaction of RO filter water quality from survey in BRAC University 3

Figure-03: Block Diagram of a Solar Still 12
Figure-04: Block Diagram the Solar Humidification and Dehumidification System 13
Figure-05: Block Diagram of the Photovoltaic Reverse Osmosis System (PVRO) 14
Figure-06: Block Diagram of Solar Still 27
Figure-7: Block Diagram of Solar HDH System 28
Figure-8: Block Diagram of PVRO System 29
Figure-9: 3D model of a PVRO using Sketch Up 30
Figure-10: Solar Array Configuration 33
Figure-11: Time Duration for pump 33
Figure-12: Results & Graph 34
Figure-13: Monthly Report on Energy Production 35
Figure-14: Solar Panel Monitoring Circuit 36
Figure-15: Water Level Monitoring System 37
Figure-16: 3D model of a PVRO using Sketch Up 39
Figure-17: Water Pump 40
Figure-18: Pressure Vessel 40
Figure-19: Yearly Energy Production and Usage 42
Figure-20: User's Needs for Specified Load & Run-Time 43
Figure-21: Trial & Error Phase of Arduino Code and Water Sensor 44
Figure-22: Final Prototype of PVRO System 45
Figure-23: Diagram of impacts of new sources of safe drinking water 49
Figure-24: EEE 400P Gantt chart 52
Figure-25: EEE 400D Gantt chart 53
Figure-25: EEE 400C Gantt chart 53
Figure-27: Consent Form for Installing PVRO 62

List of Acronyms

USGS	United States Geological Survey
SLR	Sea Level Rise
WHO	World Health Organization
HDH	Humidification and Dehumidification
PVRO	Photo-Voltaic Reverse Osmosis
RO	Reverse Osmosis
TDS	Total Dissolved Solids
UV	Ultra Violet
GPIO	General Purpose Input/Output

Chapter 1

Introduction

1.1 Introduction

In the first chapter, we will discuss about the problem that we are going to solve along with the challenges. Moreover, the needs with appropriate stipulations, standards are also shown to gain a better idea of how we will achieve our goals.

1.1.1 Problem Statement

Finding pure water for drinking is becoming a challenge. Around the world about 1.2 billion people don't get pure water for drinking [1]. If we look at our country the problem is very critical in coastal areas. Especially in the south west districts. People in these areas are at risk of being exposed to seawater. It is predicted that mean sea level would rise from 4.5 to 23.0 cm by 2025, and from 6.5 to 44.0 cm by 2050. Previous research has regularly found greater salinity, as well as significant trace and hazardous substances, in groundwater samples from this location [2-8]. Although deep tube wells give a lower amount of saline water, the presence of sand renders it unfit for drinking [9]. Hoque (2009), estimated that nearly 30 million people in this region are unable to obtain potable water, and 15 million are already compelled to drink saline groundwater [10]. To ensure fresh water for the vast people living on the coastal area, solar energy can be a very sustainable method.

Diesel generators or grid electricity can be used for purification of water. However, diesel generators damage the environment and their fuel is costly. Grid power may be unavailable or too costly. In our country, PV cells are used abundantly to use solar energy. Moreover, it's becoming inexpensive day by day. In addition, Coastal areas do provide a decent amount of sunlight. So, we want to reach the demand of pure water in the coastal remote areas using solar energy in the most feasible method possible.

1.1.2 Background Study

Water is the soul of the Earth. According to USGS, about 71 percent of the Earth's surface is water-covered, and the oceans hold about 96.5 percent of all earth's water [11]. 60% of our human body is full of water. We humans cannot survive without using or drinking water. About 326 million cubic miles of water on the planet but various sources suggest that about 3% and some sources say only 1% of water is fresh. On a planet of 7.753 billion, it surely is not enough. Bangladesh is a land of rivers that ends at the Bay of Bengal. A large area of water that is part of an ocean or lake and partly surrounded by land is a bay. The surrounding lands of the Bay of Bengal are heavily affected b y salinity. In the southwest districts, people are mostly at risk of being exposed to seawater. Previous research has regularly found greater salinity, as well as significant trace and hazardous substances, in groundwater samples from this location [12]. Recent research shows that coastal 6 million people are suffering from high salinity (>5 ppt) and SLR will lead it to increase to 13.6 million in 2050 [13]. Hoque (2009), estimated that nearly 30 million people in this region are unable to obtain potable water, and 15 million are already compelled to drink saline groundwater [14]. Although deep tube wells give a lower amount of saline water, the presence of sand renders it nonfat for drinking [15]. Drinking water with too much salt has been related to a number of negative health impacts. The average concentration of salt in drinking water is 20 mg/L, which is regarded as an insignificant contribution to daily salt intake. Therefore, the WHO has a 200 mg/L aesthetic guideline value rather than a health-based limit [16]. However, numerous studies have linked a higher risk of hypertension to excessive salinity in drinking water [17, 18]. Additionally, connected to preeclampsia and pregnancy hypertension risk is drinking water saltiness. Additionally, investigations have linked the condition to infant mortality, cholera outbreaks, and cutaneous and diarrheal illnesses [19, 20]. The standard drinking water salinity in Bangladesh is 600 mg/L [21, 22]. Because of the high salinity that occurs naturally in coastal waters, locals are more susceptible to a variety of negative health impacts [23].

Negative health impacts can be avoided if we can provide a new and fresh source of water. In coastal areas, freshwater resources are not very much available. Thus, in search of freshwater people need to use transportation. Longer transport and storage times provide more opportunities for recontamination between the point of collection and the point of use, decreasing household water quality [24]. These unintended consequences could potentially worsen drinking water quality. Therefore, the solution to this problem must not only provide better water quality but also an easily accessible, portable system.

For purifying water of coastal areas Solar Distillation, Solar HDH or PVRO can be great alternatives. They are renewable energy and do not affect nature. But in order to come up with a feasible solution their effectiveness should be checked. In the case of solar distillation, it runs on a natural mechanism. Thus, simulation cannot be done and the same goes for solar HDH. We had learned how to calculate the amount of pure water we are getting and its flow rate. Our calculations and research show that Solar Distillation has the slowest water flow rate. PVRO can be the better option among them. It has better water quality; faster flow rate and the system can be modified in optimum ways. We had conducted a survey among the students and most of them had chosen PVRO as their preferred solution for this coastal area problem. Moreover, 65.7% have RO water filtration systems at their home. 40.6% are somewhat satisfied with the quality of water they are getting from it.

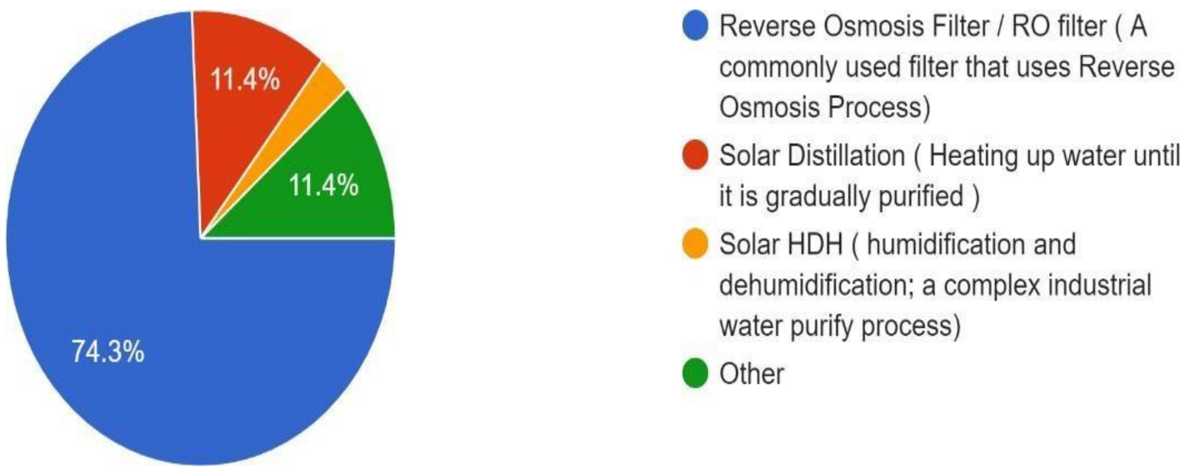


Figure-01: Pie-chart of better alternative solution of pure water problem survey in BRAC University

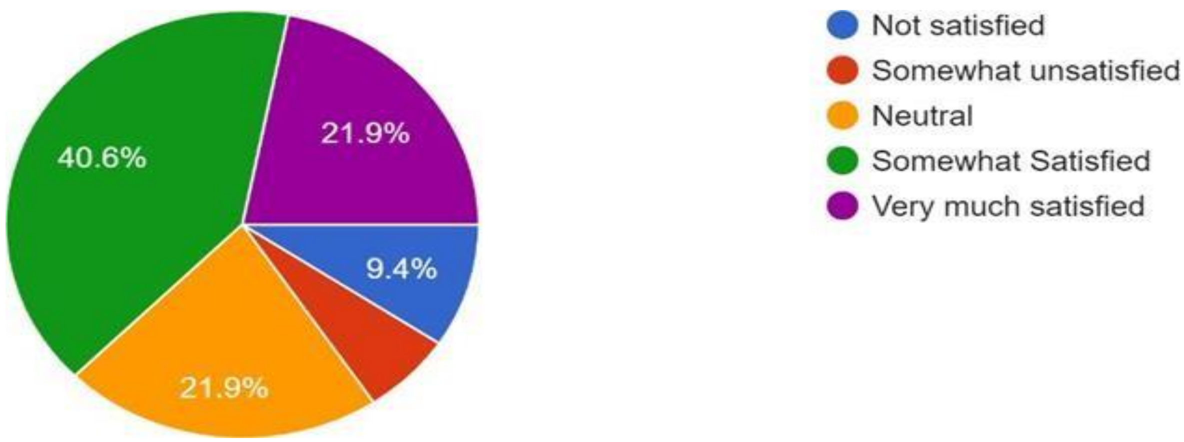


Figure-02: Pie-chart of satisfaction of RO filter water quality from survey in BRAC University m survey in BRAC University

1.1.3 Literature Gap

There has been lots of research on renewable energy and will increase in future too due to the current energy crisis. Additionally, access to pure water is also a challenge. For solving it with renewable energy lots of research has been done. We were able to find lots of approaches that are currently in use too. From the perspective of our country the approach is still somewhat new. The approach is yet to be applied with outcomes obtained in our country. The approaches we found based on our researches are all done abroad. So, it was uncertain whether it would be a feasible solution for our country. Besides, all the approaches contain not only electrical engineering knowledge but also some non-electrical engineering knowledge. Measuring water standard for instance, is a challenge. There are certainly lots of standards but which one and how to from perspective of our country is a big question. Furthermore, energy calculation, chemical components, amount of water to be obtained, coastal area sustainability of the project and the calculation of mechanical side of the project are some of the gaps we felt in our researches.

1.1.4 Relevance to current and future Industry

Renewable energy is the future. So, certainly it is quite relevant to current and future industry. As discussed earlier, there has been lots of researches done earlier and the approaches are already in use. Fossil fuels are becoming costly and people are in need of alternative energy for the industries. Renewable energy will provide the solution. In our country, lots of houses are using renewable energy. The same energy can be used for providing water for the family and thus the renewable energy will provide all sort of energy demand. The people of our coastal area are habituated with brackish water. As a result, suffering from lots of disease; child mortality rate is becoming a concern. Our country has a vast coastal area. The Bay of Bengal provides an abundance of brackish water. We can use such huge amount of brackish water through industrial water plants based on renewable energy. Such plants can provide pure waters in coastal area houses. This will lessen their hassle of transportation and disease rate. Countries in middle-east, USA, European countries are already providing such solution where the water treatment plants are based on renewable energies. They are very feasible solution and thus in amidst of such energy crisis we expect our approach should do very well and grow larger in our country.

1.2 Objectives, Requirements, Specifications and constraints

1.2.1 Objectives

- To access adequate clean water in the rural coastal area.
- To prevent waterborne diseases.
- To make an easily portable and usable system.
- To construct a technically and economically feasible system.
- Further upgrade and make plans for our vast coastal area.

1.2.2 Functional and Nonfunctional Requirements

Sub-systems	**Ratings**
RO system	Operational pressure: 65 PSI Temperature: 77℃ Max. input TDS: 500 ppm
Photovoltaic solar panel	Power: 250 W No. of cells: 60 pcs
Feed water pump	Power: 2 HP - 1.5 KW
Water tank	Capacity: 100 Liter
RO pre-filter	Maximum Water Flow: 75 gpm Carbon and sediment filter : 1500 gl
Pipe	Diameter: 13.3 mm
Submersible pump	Power: 2 HP Water lifting capacity: 15 to 50 m Maximum discharge flow: 100 to 500 LPM Discharge outlet size: 1 to 2 inch
battery	Supply voltage: 26V

1.2.3 Specifications

Sub-system	Components	Model	Specification	Comments
Energy Source	Photovoltaic Solar Panel	Ce ISO TUV UL Certificates Byd 12V 300W Solar Panel Camping.	Solar Cell: Poly 156 × 165 mm Power: 250 watts No. of cells: 60 pcs Rating: IP67 waterproof.	Ten 250 watts solar panels supply 2500watts of electricity to our water purifier per day.
Water Storage	Water Tank	Gazi House Hold Tanks 100 Liter.	Size: approx. 500 × 500 × 650 mm Weight: 18.08 Kg Capacity: 100 L	100L of purified water is stored in this tank.
Water Purifier	RO UV Water Purifier.	Puricom CP-3+UV Wall Mount 4 Stages UV Water Purifier	Filter system: (UV) Filter stage: 4 stages UV Housing: Stainless Steel 304 Grade UV Lamp: Philips/ TUV 6W; G6 T5/ Made in Poland Operation pressure: 15-85 PSI	Under the standard water quality and flow, the filter is capable of killing or restraining 99.9% of bacteria and virus effectively under UV lamps
Water filter pipe	Food Graded Pipe	(1⁄4) 6mm 10 feet pipe	Grade: Food-graded pipe Size: (1) 6 mm	Flows water through pipe from one filtration process to another filtration process.
Electricity transmitter	Electric Wires	Water Purifier Wire Harness	Insulated material: PVC Current rating: maximum 30 Amp	Electric wires are needed to connect solar power with filter for

			Voltage rating: 12-48 VDC Working temp: -10-60*C Material: Copper	supplying power to the system, RO booster pump with booster pump DC adapter, high-pressure and low-pressure switch with tank and booster pump etc
Automatic Water Level Detector	Sensors	MD-L100E	Power supply:12-28V Output: 4~20mA/RS485 Rating: IP68 waterproof design Quality: Anti-electromagnetic interference design to ensure signal stability.	Measures liquid level or water depth based on the principle of hydrostatic pressure.
Energy Storage	Battery	N50Z Battery of Globatt Ace	Type: Lead-acid battery Output Voltage: 12V Output Current: 60A Storage Backup: Up to 20 hours	It works as energy storage. It stores unused energy from solar. At night when solar can’t supply electric power that time this battery will supply its stored energy. This battery is rechargeable
Water pressure supplier	Feed Water Pump	100 GPD	Operating Voltage: 24 VDC Rated Current: 1.8 Amp 100% QC Passed Certification: RoHS	Increase the pressure of reverse osmosis process feed water. RO process

				demands a certain amount of pressure to filter properly otherwise the filter would simply work as blockages to the water supply.
Power supplier	AC-DC Adapter	3-24V 72W Speed Control Volt AC/DC Adjustable Power Adapter Supply Display	Output current: 5A real Power:48W Efficiency: 95% Total cable length: 200cm Input: AC100-240V 50/60Hz Output: DC 3-24V adjustable high-quality components	AC-DC SMPS 24V 2A power supply for RO water purifier.

1.2.4 Technical and Non-technical consideration and constraint

Technical Consideration

- System must be sustainable enough for the coastal weather.
- Filtration must be good enough for not only proper desalination but also germs not easy to kill.
- Water quality monitoring should be ensured for expected outcome.

Non-Technical Consideration

- Bangladesh’s coastal area is full of natural calamities.
- Building an easy-to-understand system considering their literacy.

Constraints:

- Insufficiency of solar radiation: Possible solution: Add solar tracker (sensor) and energy storage with the solar system to increase the sufficiency of our solar radiation.

- Maintenance cost of the system: Possible solution: An energy recovery system can be added which will save a good amount of energy of our system. So, Sufficiency will increase and cost will reduce as well.

- Natural disasters of coastal areas: Possible solution: We must build a system that is not so fragile for the coastal area considering the natural disasters. Stronger build quality and additional shielding might be helpful for that.

1.2.5 Applicable compliance, standards, and codes

Applicable compliance

Standards and Codes

Sub-system Name	**Standard**
Solar Modules	SREDA determined solar modules standard - IEC 61215:2016, 60904- 1:2013, 60904-2:2013 and 60904-9:2013
Membrane Filtration	ISO 20468-5:2021
Reverse Osmosis	NSF/ANSI Standard 58/ASSE 1086
Feed Water pH	6-9
Feed Water Pressure	>300 PSI
Feed Water Temperature	20-45 C
Total Alkalinity	125/L

1.3 Summary of the Proposed Project

The proposed project intends to improve the coastal people's life. Our project is based on renewable energy. Currently, the country is facing energy crisis. Renewable energy can become the savior in such situation. The developed countries are already depending on renewable energy for all kind of purposes. We are expecting to improve the situation by inspiring such renewable energy-based project. The project has two parts. One is energy source and the other part is water purifying system. For energy source, we are looking for renewable energy source as discussed and the purifying system must be capable of desalinating water. Additionally, the water we are getting should maintain appropriate standards of pH, TDS etc. Moreover, we must ensure that the project is feasible enough for the coastal area environment and people. For the betterment of people and ease of access portability of the system will be also in consideration. Furthermore, the constraints, applicable compliance, standards, and codes will be maintained. Though there are some literature gaps existing, the proposed project is significantly promising to industry. Therefore, we are looking forward to accomplish it and aid people.

1.4 Conclusion

It is high time we made such a system that is capable of supplying pure drinking water on a continuous basis in the coastal area of our country. According to our survey, most of the people are using RO (Reverse Osmosis) water purification systems as water purifier and a higher number of people are satisfied with RO water purifier performance. So, we have decided to use RO water purification systems for our project to desalinate brackish water. In addition, frequent load-shedding is hampering the continuous electricity supply to RO water purifiers in the coastal area. To address this issue, we are using photo-voltaic solar cells to supply power to our system which not only solves electricity shortage but also saves non-renewable energy. So, our RO water purifier with a solar system is capable of providing adequate clean water in the rural coastal area which will reduce waterborne diseases, solution of electricity shortage, and offers an environmentally friendly system. However, there are some limitations in our system like insufficiency of solar radiation, and high maintenance costs but adding a solar tracker and energy recovery tools to our system can be a good solution for these constraints. Lastly, component specifications and requirements have been set by following the national standards and codes to make a government certified Water purification system.

Chapter 2

Project Design Approach

2.1 Introduction

To fulfill our objectives, we have proposed three approaches. The approaches are quite different from each other though they serve same goals maintaining high standard and quality.

2.2 Identify Multiple Design Approaches

<u>Approach-01: Solar Still</u>

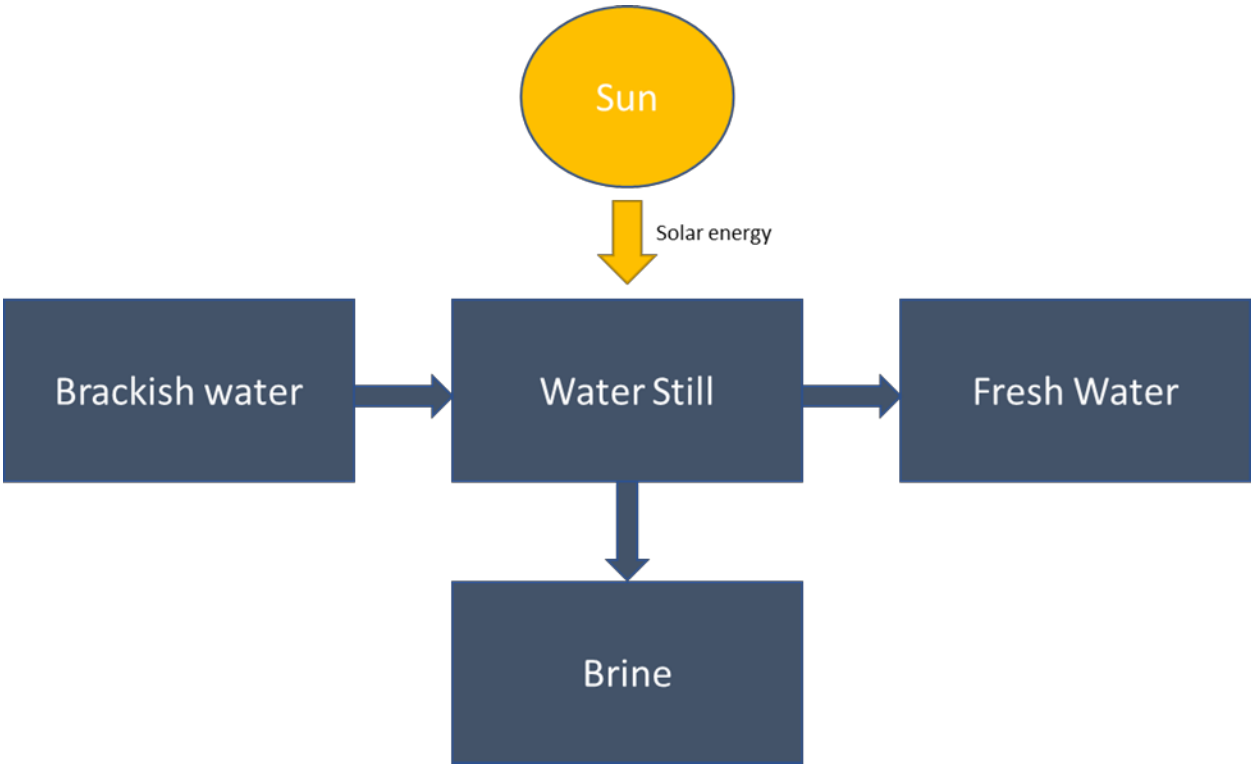


Figure-03: Block Diagram of a Solar Still

Approach-02: Solar Humidification and Dehumidification System

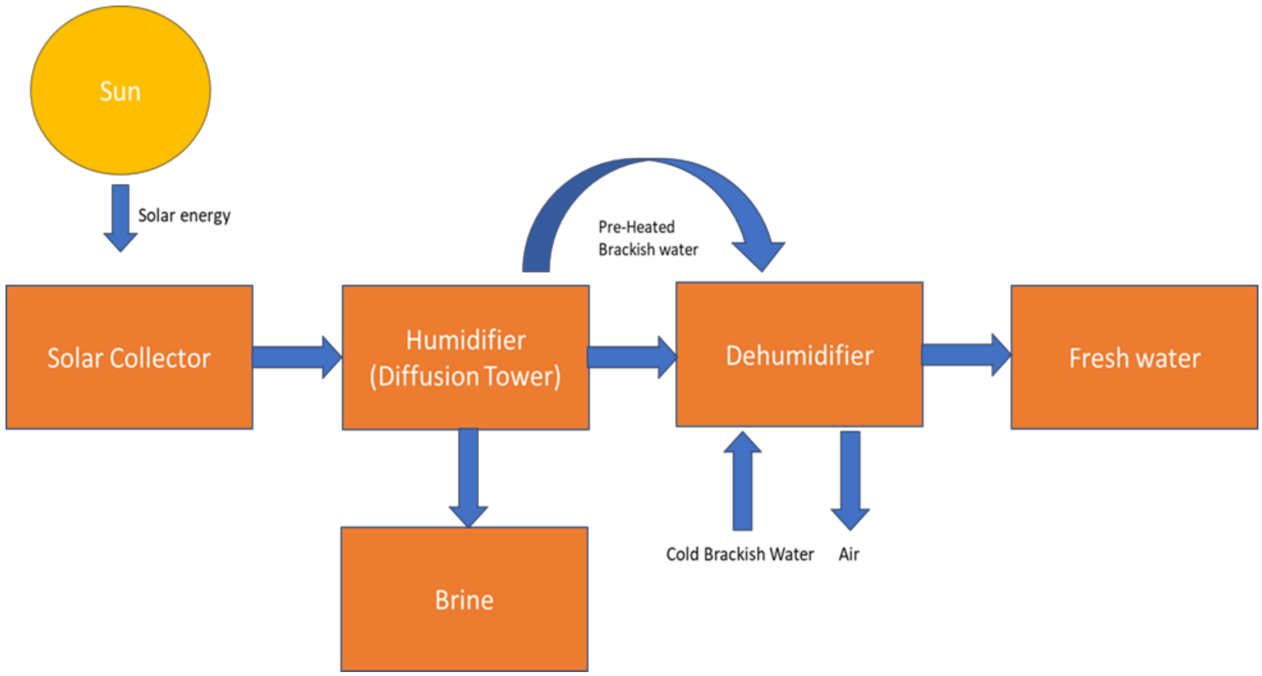


Figure-04: Block Diagram the Solar Humidification and Dehumidification System

Approach-03: PVRO System

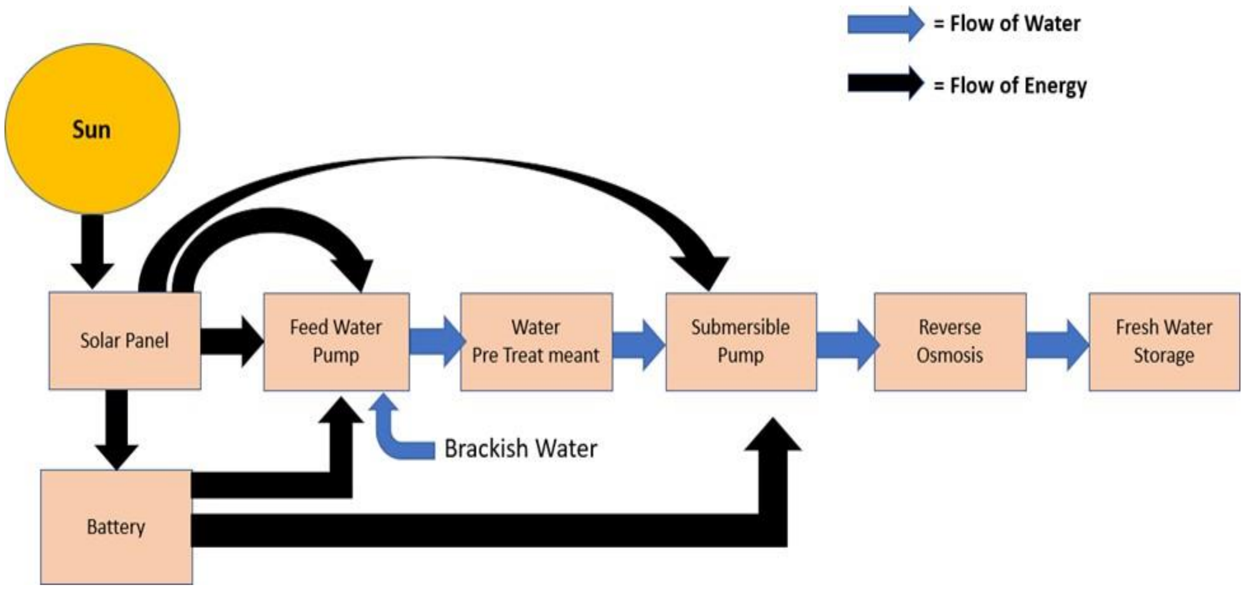


Figure-05: Block Diagram of the Photovoltaic Reverse Osmosis System (PVRO)

2.3 Describe multiple design approach

First Design:

This is still a huge basin-type system used to supply fresh water from brackish feed water. To partially fill the basin, water is poured into the still. The glass cover allows sun energy to enter the still, where it is primarily absorbed by the blackened base. To improve the absorption of sun rays, this inside surface is blackened. The water begins to heat up, increasing the moisture content of the air trapped between the water's surface and the glass cover. The evaporated heated water vapor from the basin condenses on the interior of the glass lid. The salts and bacteria that were in the original water are left behind during this process. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle. There are some pros and cons of this process. Condensed water drips down the slanted glass lid and into an internal collection trough before exiting into a storage bottle.

Pros:

- There is no moving part that’s why it is reliable and maintenance free.
- Neutral pH is claimed (like rain water), not like the neutral pH steamed.
- Low ecosystem.

Cons:

- ➢ Low production capacity and not enough for filling up the needs of drinking water for an average family per day.
- ➢ The large area of tilted glass cover might attract the insects.
- ➢ Solar distillers do not claim to kill bacteria and also do not breakdown the harmful chemicals.
- ➢ Most time-consuming process.

Second Design

A thermal water desalination technique is the solar humidification-dehumidification process (HDH). It is based on the condensation of humid air produced by the evaporation of seawater or brackish water, often at ambient pressure. Compared to the Solar Still Approach, this process simulates the natural water cycle over a significantly shorter period of time. But this is a complex process to purify water and it is more of an industrial process. This system is not a portable system for day- to-day use.

Pros:

- ➢ Best fit for industrial purposes.
- ➢ Pollution-free green energy

Cons:

- ➢ Very large and static model.
- ➢ Complex and time-consuming

Third Design

The RO technology is based on the properties of semi-permeable membranes which can separate water from a saline solution. First of all, we will use a feed water pump to draw groundwater. Then, the water goes through the pre-treatment process by which the large particles will be filtrated. After completing the first stage of purification with the help of a high-pressure pump the water will enter the reverse osmosis system. Under the standard water quality and flow, the filter is capable of killing or restraining 99.9% of bacteria and virus effectively under UV lamps. Then the purified will be stored in a water storage tank. RO can be applied to different types of water: seawater as well as brackish water, with the equivalent objectives depending on the pressure applied to the membrane. First of all, with the help of solar, we get the required energy for our system. The energy we got from solar is used for purifying water using a reverse osmosis system also there is a battery used to store energy. The stored energy will be used during gloomy weather or insufficient solar radiation. After that, the energy obtained from the PV panel is used by the feed water pump to draw the saline water. Then the saline water will flow through the pre-treatment process to complete the first stage of water purification. Afterward, during the pre-treatment process, the water will run down through the reverse osmosis system. In a reverse osmosis system, there are various stages to purify the water. After completing the reverse osmosis water purification. The purified water will be stored in a tank as day-to-day drinking water for an average family.

Pros:

- Easily portable.
- More reliable water purification system.
- Less time consuming.
- Efficiency and accuracy of the purification is very impressive.

Cons:

- Maintenance cost is a bit high.
- Solar dependency.

2.4 Analysis of Multiple Design Approaches

Approach-01: Solar still

Sustainability Criteria / Functional Parameters	Environmental (25)	Technical (25)	Economical (25)	Social (25)	Total (100)
Water Collection & Distribution	25	0	10	15	50
Water Pre-treatment	20	5	20	15	60
Storage Water Tank	20	0	20	15	55
Energy Capture	25	0	10	10	45
Energy Recovery System	0	0	0	0	0
Water Post-treatment	20	5	10	10	45
Osmosis Membrane	0	0	0	0	0
Energy Storage	0	0	0	0	0

Reverse Osmosis	0	0	0	0	0
Brine Management	20	10	10	10	50
Safety	15	5	5	10	30

Approach-02: Solar HDH System

Sustainability Criteria / Functional Parameters	Environmental (25)	Technical (25)	Economical (25)	Social (25)	Total (100)
Water Collection & Distribution	20	25	15	10	70
Water Pre-treatment	25	25	15	10	75
Storage Water Tank	20	20	15	15	60
Energy Capture	25	25	10	10	70
Energy Recovery System	15	20	10	10	55
Water Post-treatment	25	25	20	15	85

Osmosis Membrane	10	25	15	15	65
Energy Storage	15	25	15	15	70
Reverse Osmosis	0	0	10	10	20
Brine Management	25	25	15	15	80
Safety	25	20	20	15	80

Approach-03: PVRO System

Sustainability Criteria / Functional Parameters	Environmental (25)	Technical (25)	Economical (25)	Social (25)	Total (100)
Water Collection & Distribution	25	25	20	25	95
Water Pre-treatment	25	20	20	20	85
Storage Water Tank	20	20	20	20	80
Energy Capture	25	25	15	20	85

Energy Recovery System	15	20	15	15	65
Water Post-treatment	20	20	20	15	75
Osmosis Membrane	25	20	20	25	90
Energy Storage	15	25	20	20	80
Reverse Osmosis	25	25	25	25	100
Brine Management	20	15	15	15	65
Safety	25	25	20	20	90

2.5 Conclusion

After analyzing all three approaches from the weighted matrixes, it can be clearly seen that the Approach 3 is more suitable for our project. It has more scores in most of the functional parameters making it a sustainable choice in terms of feasibility.

Chapter 3

Use of Modern Engineering and IT Tools

3.1 Introduction

Modern Engineering tools are must for a project. The tools can not only design but also simulate, validate, calculate etc. Therefore, we had used modern engineering tools to make this project more efficient and up to the standard.

3.2 Select Appropriate Engineering and IT Tools

3.2.1 Software Tools

Objective	**Selected tools**
3D Modeling	Sketch-UP
Simulation (Circuit Simulation)	Proteus
Simulation (Energy Simulation)	PVSYST

Table 7: Different software tools is selected for different objective.

As a part of modern engineering and IT tools to build our design, we have used some software. We have built the 3D design of our system using Sketch Up 3D Modeling Software. Also, to simulate our system we have used Proteus Design Suite software and PVSYST simulation. Sketch up is a well-known 3D modeling application that lets us build both 2D and 3D models. It is a program used for a wide range of 3D modeling projects. On the other hand, using Proteus we have built the two-dimensional circuit design similarly PVSYST simulation is used for analyzing solar energy.

3-D modeling Software:

We have compared the other 3D modeling software for our design and choose SKETCHUP to build our design. Here is a comparative analysis of 3D modeling software.

Software	**Template**	**Library Tools**	**Animation**	**Third-party Integration**	**Collaboration of Tools**
Sketch-Up	✓	✓	✓	✓	✓
Blender	✓	×	✓	×	×
Adobe Aero	✓	×	×	✓	×

Table 8: Comparison between different 3-D modeling software.

From the above comparative analysis, it’s visible that sketch is a more user-friendly software for 3D design. Though doing animation is not possible in sketching up which is not needed for our project. That's why we choose Sketch Up as our 3D modeling software.

Simulation Software:

A comparison between some popular simulation software is shown below-

Simulation Software	2D Features	Interact Simulation	Library Materials
PROTEUS	✓	✓	✓
MATLAB	✓	×	✓
PSPICE	✓	×	✓

Table 9: Comparison between different simulation software.

All the simulation software features are quite similar to each other. One of the unique features of Proteus simulation is we can interact with the running simulation by using switches. We have chosen Proteus for our simulation because PROTEUS simulation is less complex to operate.

Energy Calculation Software:

To calculate the energy requirement for electrical components of our system a comparative analysis has shown below-

Software	Accurate Area Selection	Live Result Display	Economic Evaluation
PVSYST	✓	✓	✓
HOMER PRO	✓	×	✓
MATLAB	×	×	×

Table 10: Comparison between different software capable of energy calculation.

The above comparison highlights that PVSYST can precisely select the area, display live results also show the economic evaluation for energy calculation. Whereas HOMER PRO and MATLAB cannot show live results for energy requirements.

3.2.2 Hardware Tools

Objective	Selected tools
Energy source	Solar power
RO filtration System	Hi pure RO Filter
Water pump & Adapter	Diaphragm pump & Hi pure adapter
Connection & Structure	Pipes, wires, wooden box
Storage	Water Storage Tank
Sensors	pH sensors, sonar sensor, TDS sensor, temperature sensor

Table 11: Different hardware tools selected for different purpose.

3.3 Use of modern engineering and IT tools

3.3.1 Proteus

It is a circuit designing software used for the simulation, design, and drawing of electronic circuits. With the use of this software, we can draw schematics, PCB layout, and code and even simulate the schematic. We have used Proteus to examine whether the sensors are working according to their task. Such as water level sensors, timer sensors, measuring the depth of the water in the tank, and automated switching of the pump. Advantages of using PROTEUS for design simulation:

- Can interact with the running simulation, using switches.
- Wide range of components in its library.

- Design a schematic with the use of thousands of parts.
- Integration with popular tool chains.

3.3.2 Arduino IDE

Integrated Development Environment, or Arduino IDE, is a program that was officially released by Arduino.cc and is primarily used for authoring, compiling, and uploading code to virtually all Arduino modules and boards. Because it is an official Arduino program, code compilation is far too simple. Several Arduino modules are available, including the Uno, Mega, Leonardo, Micro, and many others. On the board of each of them is a microcontroller that is actually programmed and takes data in the form of code. There are a number of I/O pins on the Arduino development board, which houses the Microchip ATmega328P microcontroller, to connect expansion boards, sensor modules, or other digital or analog devices. It has a Clock, CPU, Interrupts, Timers, RAM, ROM and GPIOs that can all perform many tasks at once. A multitude of sensors, modules, shields, and communication methods can all be used with Arduino. We will use Arduino UNO to collect sensor data at predetermined intervals.

3.3.3 Sketch Up

SKETCHUP can visualize the design of the mind's eye. With the help of sketch up, we can picture the exact design. The advantage of using sketches up is-

- It's easy to draw a design because it works as an extension of hand design.
- Adjust to life-like as SKETCHUP is an intuitive and simple 3d drawing tool.
- Allows rendering in an array of styles and a variety of designs to choose from.

3.3.4 PVSYST

It is an energy modeling tool that helps in analyzing how much solar energy can be harvested into electrical energy from a particular site. To run our system, we will use solar panels to generate electrical power. To calculate the required amount of energy we will get from the solar panels we have used PVSYST. Advantages of using PVSYST:

- All three main types of PV systems can be designed and simulated in PVSYST.
- Prominent feature to quickly design a PV power system and calculate hourly, monthly, and yearly energy production demand.
- Extensive modules of PV modules and inverters, seem to be more responsive than others.

3.4 Conclusion

We implemented modern engineering tools based on our knowledge, flexibility and ease of use. The tools are up to the standard and hopefully provided us with expected result.

Chapter 4

Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

Here, the optimal solution among the three suggested approaches has been selected for the project. Although the three designs operate in distinct ways, they both achieve the same outcome. Specifications, requirements, cost and standard have been considered for all the three approaches to elaborately analyze all the approaches. In addition, feedback from the consumers has been considered and a weighted matrix for the optimal design selections has been done. Next, some software simulations and analysis have been done for the validation. Finally, based on the results of all the analysis we have selected the best approaches.

4.2 Optimization of multiple design approaches

For the multiple design approach, the team chose three different design alternatives which are

“Solar Still”, “Solar HDH System” and “PVRO System’. For optimization process “Solar Still” full mechanical system without solar panel mounting and “Solar HDH System” is fully industrialized water treatment plant. For this block diagram analysis will be discussed.

4.2.1 Solar Still

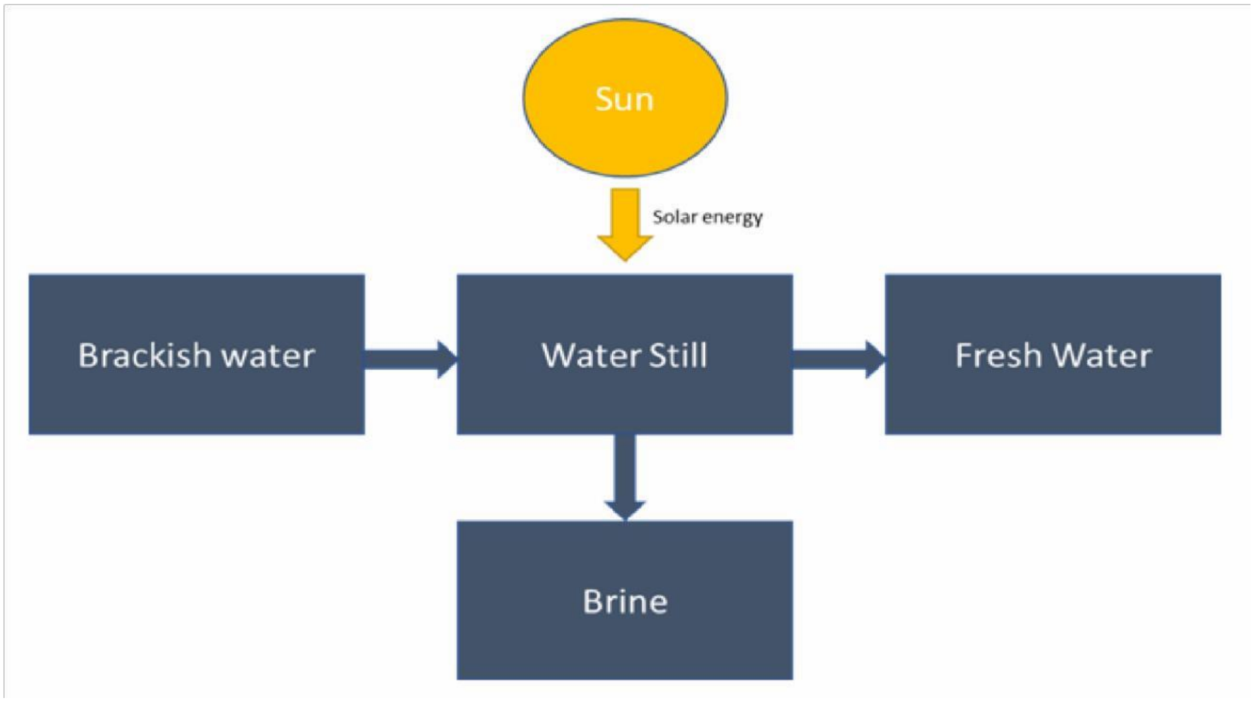


Figure-06: Block Diagram of Solar Still

This enormous basin-style still uses brackish feed water to produce fresh water for consumption. The still is filled with cleaning water until the basin is halfway full. Solar radiation can enter the still through the glass top, but is primarily absorbed by the base's blackened surface. A substance that has been blackened is used on this internal surface to increase sunlight absorption. As the water warms up, the amount of moisture in the air that is trapped between the water's surface and the glass lid rises. The glass cover's inside becomes condensed with the heated water vapor that had been evaporating from the basin. The original water's minerals and microorganisms are not removed throughout this process. Condensed water drips down the inclined glass lid, collecting in an internal collection trough and draining into a storage bottle.

4.2.2 Solar HDH System:

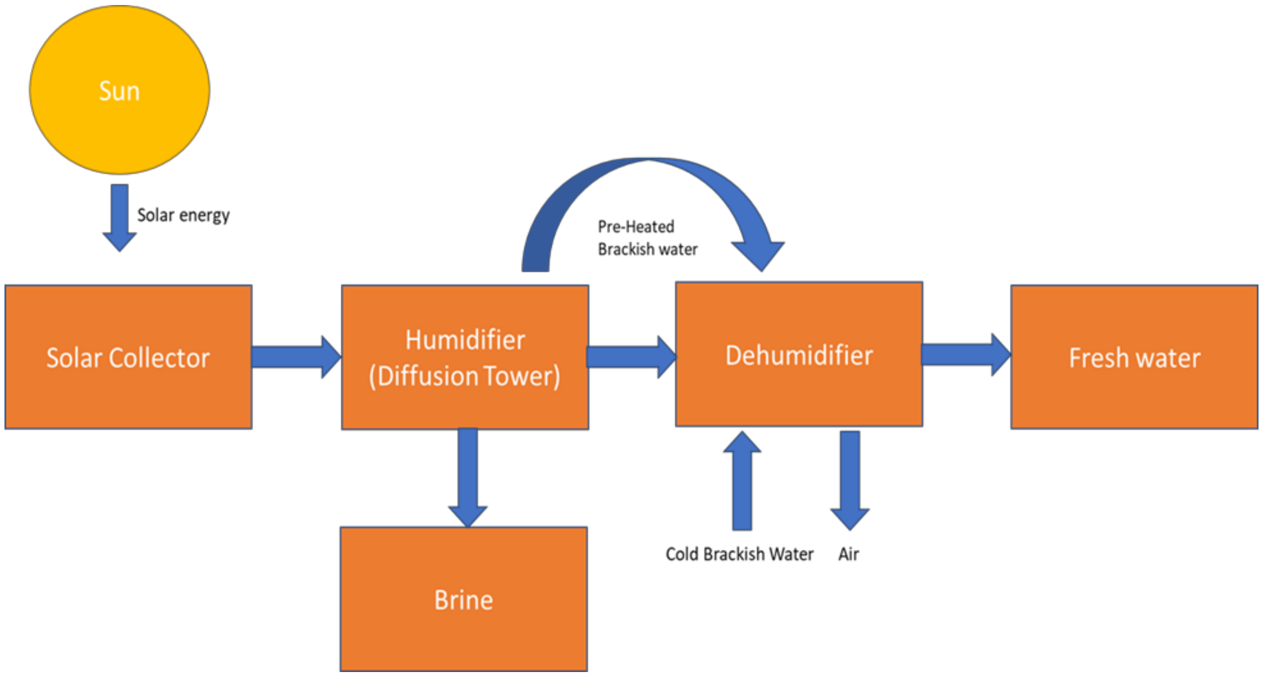


Figure-07: Block Diagram of Solar HDH System.

The solar humidification–dehumidification method (HDH) is a thermal water desalination method. It is based on the evaporation of seawater or brackish water and subsequent condensation of the generated humid air, mostly at ambient pressure. This process mimics the natural water cycle, but over a much shorter time frame compare to Solar Still Process. But this is a complex process to purify water and it is more of an industrial process. This system is not a portable system for day-to-day use.

4.2.3 PVRO System

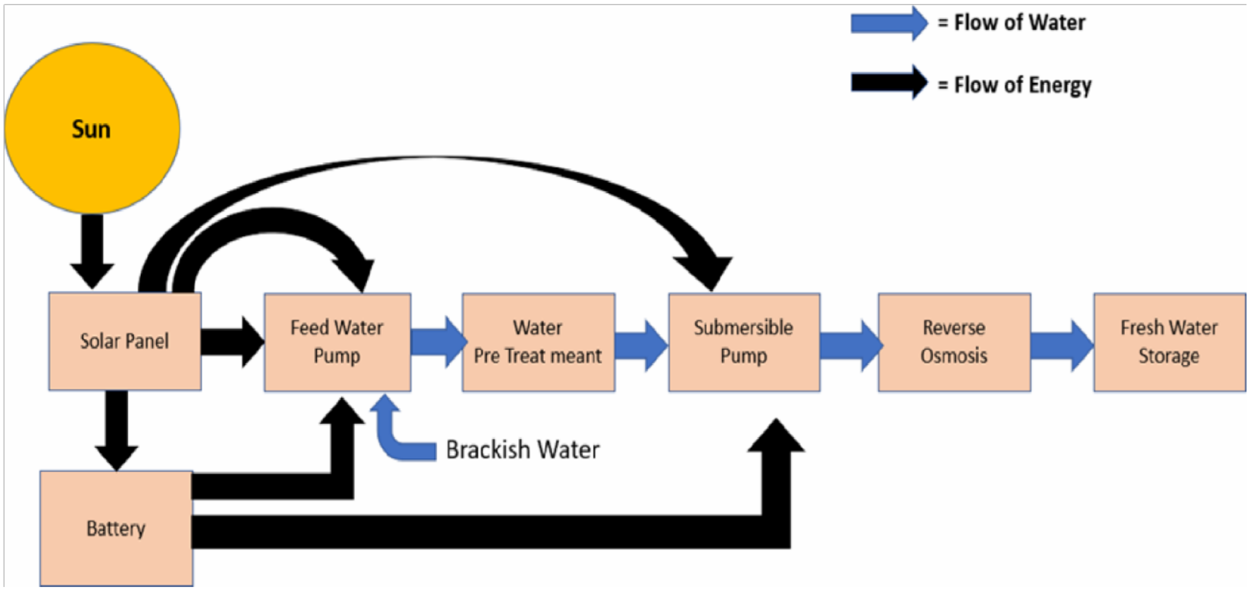


Figure-08: Block Diagram of the Photovoltaic Reverse Osmosis System (PVRO)

The RO technology is based on the properties of semi-permeable membranes which can separate water from a saline solution. First of all, we will use a feed water pump to draw groundwater. Then, the water goes through the pre-treatment process by which the large particles will be filtrated. After completing the first stage of purification with the help of a high-pressure pump the water will enter the reverse osmosis system. Under the standard water quality and flow, the filter is capable of killing or restraining 99.9% of bacteria and virus effectively under UV lamps. Then the purified will be stored in a water storage tank. RO can be applied to different types of water: seawater as well as brackish water, with the equivalent objectives depending on the pressure applied to the membrane.

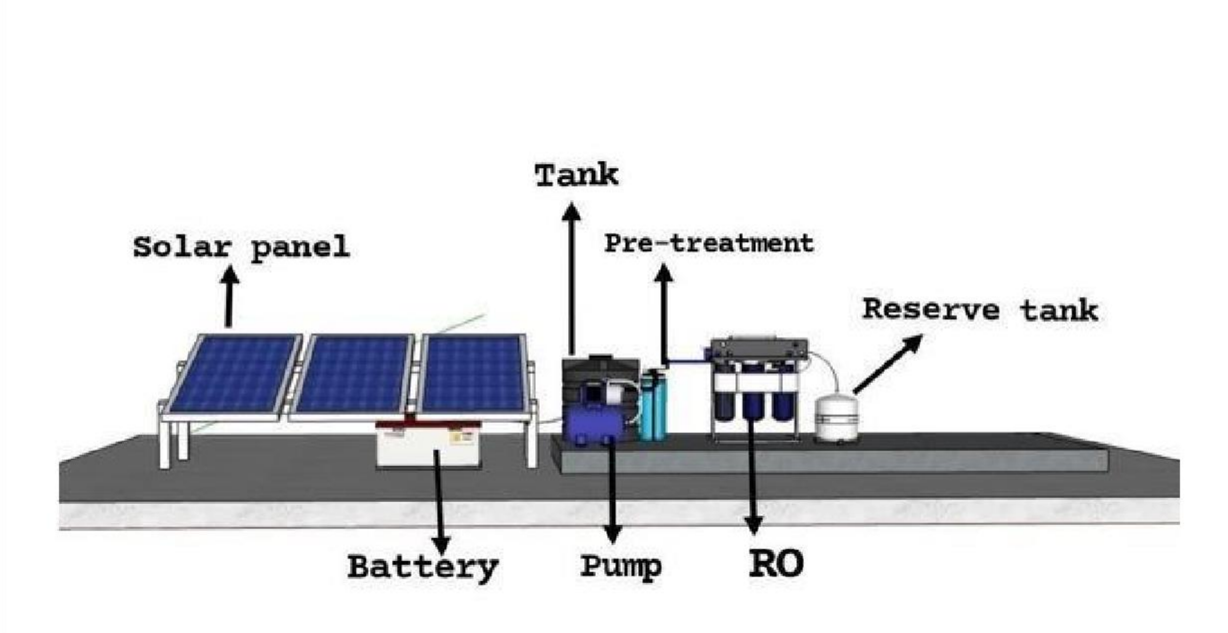


Figure -9: 3D model of a PVRO using Sketch Up

We have designed the PVRO system using Sketch Up 3D modeling software. All the components that we have used for our systems such as Solar panels, batteries, motor pumps, prefiltration systems, reverse osmosis systems, pipes (to carry water), and water storage have been designed with the help of SKETCHUP. First of all, with the help of solar, we get the required energy for our system. The energy we got from solar is used for purifying water using a reverse osmosis system also there is a battery used to store energy. The stored energy will be used during gloomy weather or insufficient solar radiation. After that, the energy obtained from the PV panel is used by the feed water pump to draw the saline water. Then the saline water will flow through the pre-treatment process to complete the first stage of water purification. Afterward, during the pre-treatment process, the water will run down through the reverse osmosis system. In a reverse osmosis system, there are various stages to purify the water. After completing the reverse osmosis water purification. The purified water will be stored in a tank as day-to-day drinking water for an average family.

4.3 Identify optimal design approach

	Multiple Design Approaches						
Selection Criteria	Solar Still		Solar HDH		PVRO System		Weighted value
	Rating	Score	Rating	Score	Rating	Score	
Efficiency	2	0.4	3	0.6	4	0.8	20%
Accuracy	2	0.5	3	0.75	5	1.25	25%
Time Consumption	1	0.15	3	0.45	4	0.75	15%
Implementation And portability	3	0.3	1	0.1	5	0.5	10%
Maintenance	4	0.6	3	0.45	2	0.3	15%
Durability	3	0.3	4	0.4	4	0.4	10%
Handling ease	5	0.25	3	0.15	4	0.2	5%

Table 12: Weighted matrix for multiple design approach

In terms of choosing optimum design solution some vital criteria was under consideration, which are Efficiency, Accuracy, Time Consumption, Implementation, Maintenance, Durability and Handling Ease. On the right of the table weighted value of these criteria is mentioned for three different systems. In the weighted value most important parts are Accuracy and Efficiency. As this system is related to human health by providing pure drinking water, so proper water quality should be maintained with all the value of pH, Dissolved Solids, Clearance, etc. Otherwise if this system fails to handle efficiency and accuracy then the water will not be fully pure and health hazard may occur. After that Time Consumption and Maintenance are two another key factor in this project. As this system will provide water for human, it has to provide water anytime of the day to avoid dehydration for users. On the other hand, if maintenance cost is very high and frequent maintenance is required that it will not sustain for a long period of time. Lastly Implementation, Durability and Handling also measured.

From the above table it is very clear that “PVRO System” has the highest rating in terms of Efficiency, Accuracy, Time Consumption and Implementation. But for other three different category it is not the best choice but the rating is very promising. “PVRO System” has the highest value in terms of Accuracy and Efficiency which two are the most important part of the design study. Then in terms of Time and Implementation, “PVRO System” is also best fit for user’s needs. But in terms of maintenance “PVRO System” is a bit costly but “Solar Still” and “Solar HDH System” are less costly than that and also for Durability and handling purpose.

4.4 Performance Evaluation of Developed Solution

In our project, we use three types of design approaches which include Solar still, Solar humidification and dehumidification system, and lastly Solar Reverse Osmosis system for desalination of water. For the solar energy production calculation of the RO system, we use PVSYST where we got our all-over energy needs for the whole system which includes energy calculation for the feed water pump to run the water flow into the system and stored energy of the battery. From the PROTEUS simulation software model, we also got a circuit simulation of the sonar sensor which is used for water level detection and controlling of the motor.

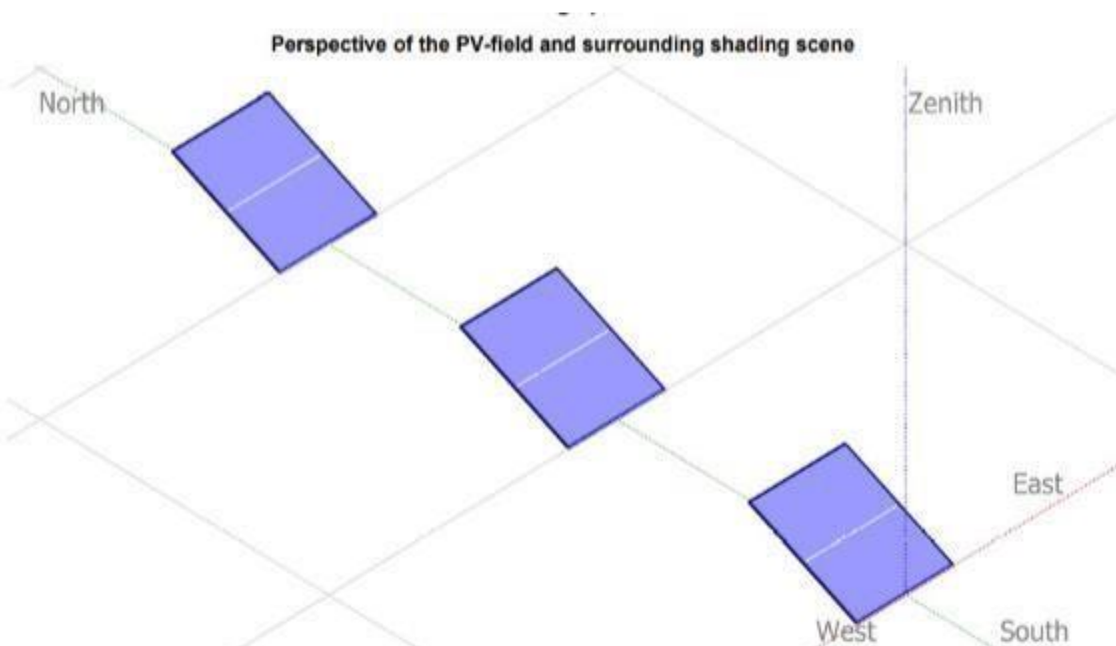


Figure-10: Solar Array Configuration

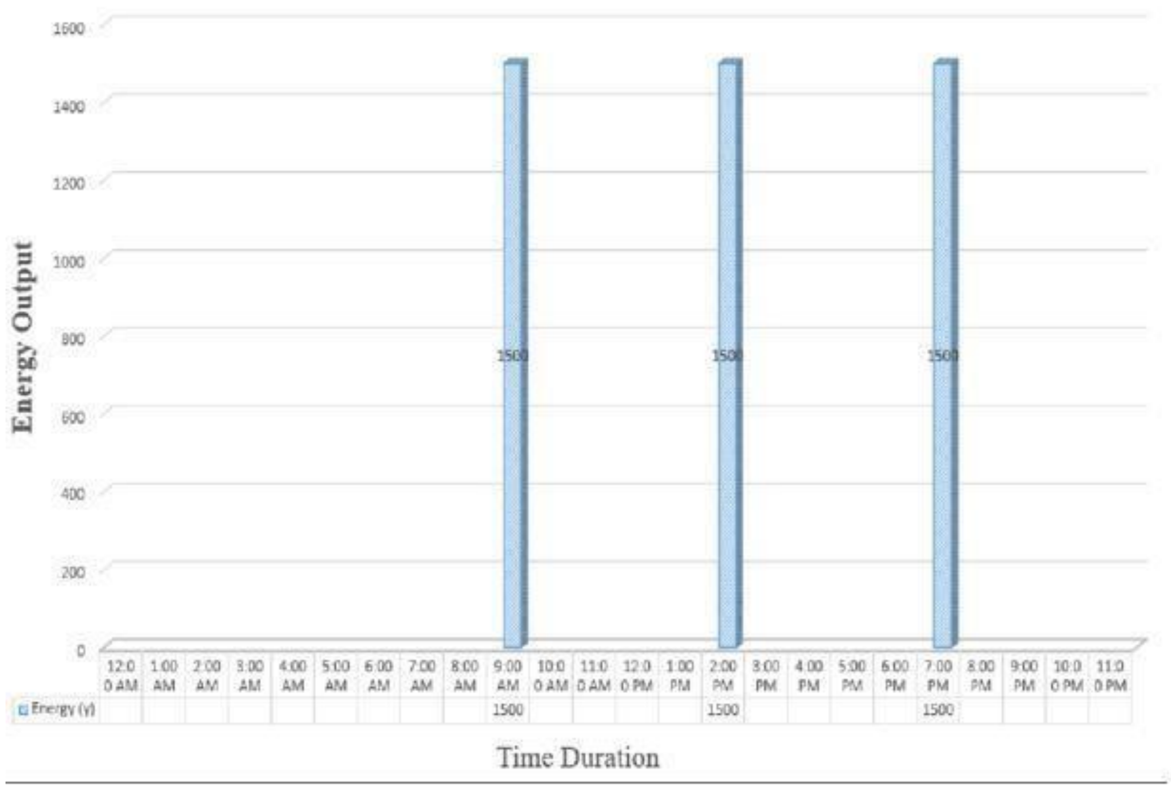


Figure-11: Time Duration for pump

4.4.1 Selected Solar Panel Parameters for PVSYST Simulation

- Panel Tilt and Azimuth angles are 23 Degree and 0 degrees.
- No of sheds is 3 units with sheds spacing 5m.
- Configuration criteria are Monofacial panels with 250 Wp 60 cells and 6 units of PV modules are used.
- Battery module is Li-Ion, 26V 180 Ah

4.4.2 Simulation Result Analysis

- For water flow, a feed water pump is used which has a rating of 1.5 kW and will be running for 3 hours/day with a time interval of 4 hours in between them.
- So, for the required energy from the user the end for water the r pump is 1.5 KW× 3 hours/day = 4.5 KW/day. So for 30 days a month, the energy demand is 135.7 kW and for 31 days a month, it is 140.2 KW.
- Consider for May. The total energy stored from PV is 182.2 kW and the energy supplied to the user is 140.2 KW. So daily the system gets 140.2/31 = 4.5 kW which is enough for our system's power supply. Also, extra power, 182.2 - 140.2 = 35.12 KW will be stored in the battery for future use in bad weather conditions.

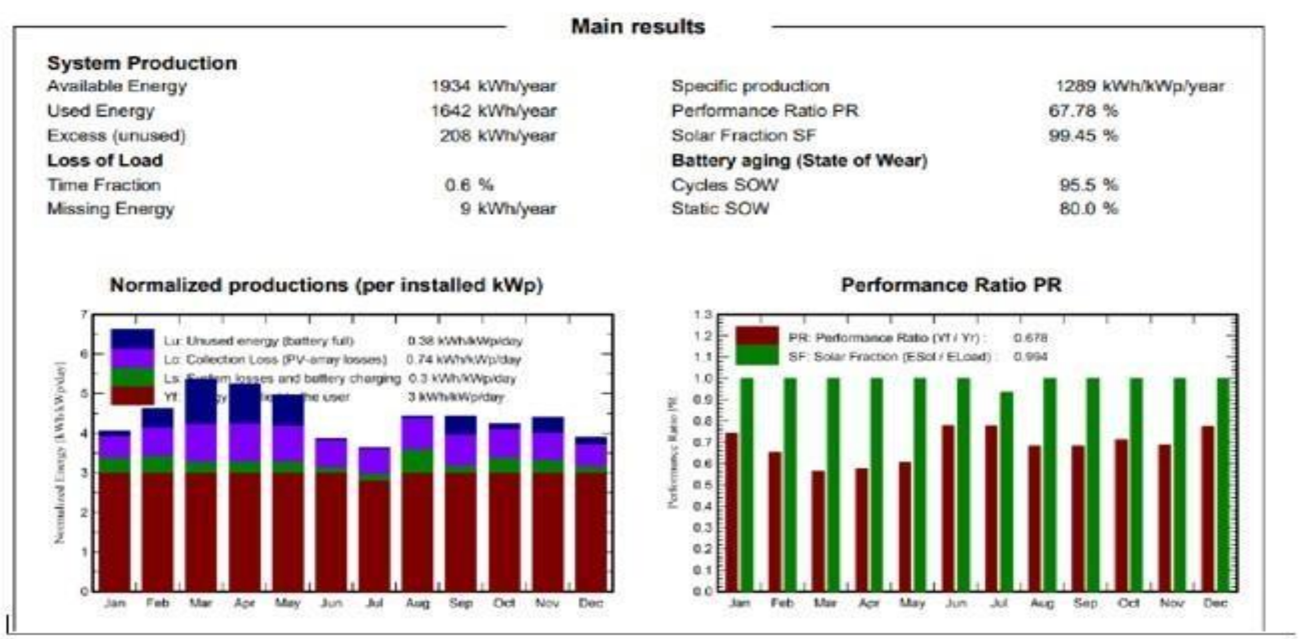


Figure-12: Results & Graphs

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	103.3	119.9	156.6	5.56	0.000	140.2	140.2	1.000
February	112.0	123.5	158.0	19.44	0.000	126.7	126.7	1.000
March	153.8	158.6	199.5	52.11	0.000	140.2	140.2	1.000
April	156.9	149.6	187.1	44.60	0.000	135.7	135.7	1.000
May	163.5	145.8	182.2	35.12	0.000	140.2	140.2	1.000
June	125.7	109.5	135.7	1.05	0.000	135.7	135.7	1.000
July	120.5	105.6	131.5	0.01	9.118	131.1	140.2	0.935
August	141.9	129.6	161.3	1.44	0.000	140.2	140.2	1.000
September	128.0	125.7	156.5	19.68	0.000	135.7	135.7	1.000
October	118.2	125.0	155.9	5.21	0.000	140.2	140.2	1.000
November	108.2	125.9	160.2	16.26	0.000	135.7	135.7	1.000
December	97.4	115.1	149.4	7.85	0.000	140.2	140.2	1.000
Year	1529.4	1533.8	1934.0	208.30	9.118	1642.1	1651.3	0.994

Legends

GlobHor	Global horizontal irradiation
GlobEff	Effective Global, corr. for IAM and shadings
E_Avail	Available Solar Energy
EUnused	Unused energy (battery full)
E_Miss	Missing energy
E_User	Energy supplied to the user
E_Load	Energy need of the user (Load)
SolFrac	Solar fraction (EUsed / ELoad)

Figure-13: Monthly Report on Energy Production

4.4.3 Table for Energy Usage Criteria in Different Time Domains

Energy Usage Criteria	Energy Output (Solar) (kW)	Energy Demand (user) (kW)
Hourly	1.5	1.5
Daily	4.5	4.5
Monthly (Average)	161.17	137.58
Yearly (Average)	1934	1642

Table 13: Energy Usage Criteria in Different Time Domains

For the Solar Still model, we cannot use any model-based simulation process as its whole process is not included any electrical or mechanical part so there is no need to calculate energy production or water flow calculation as this process will be ongoing all day whenever sunlight is available. When sunlight penetrates the glass, it will vaporize the water and after it hit the glass it will again condensate and water will be collected slowly.

Lastly, Solar HDH System, as it is a whole industrial process and is used in massive water desalination and water treatment plant, so solar energy calculation and other water flow rate calculations cannot be possible for this system. Because this system includes huge mechanical and electrical processes, so we cannot implement the system into our reachable sources.

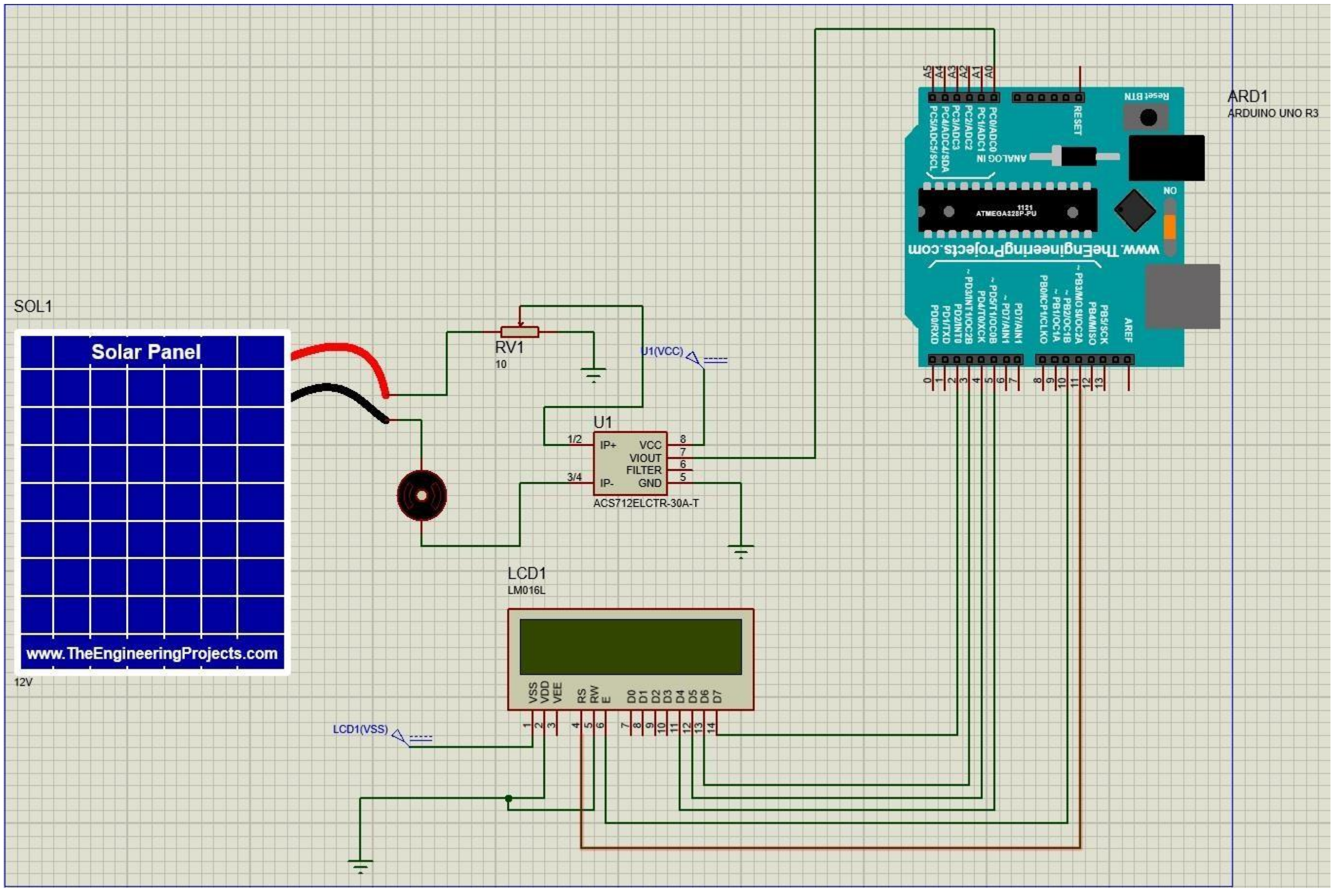


Figure-14: Solar Panel Monitoring Circuit

This Circuit simulation is for Solar Energy Monitoring Device. The device can measure how much solar energy the system is getting every day from the sun by showing accurate value in the display channel and it can also control how much energy the system needs to operate and how much energy will be stored in the battery.

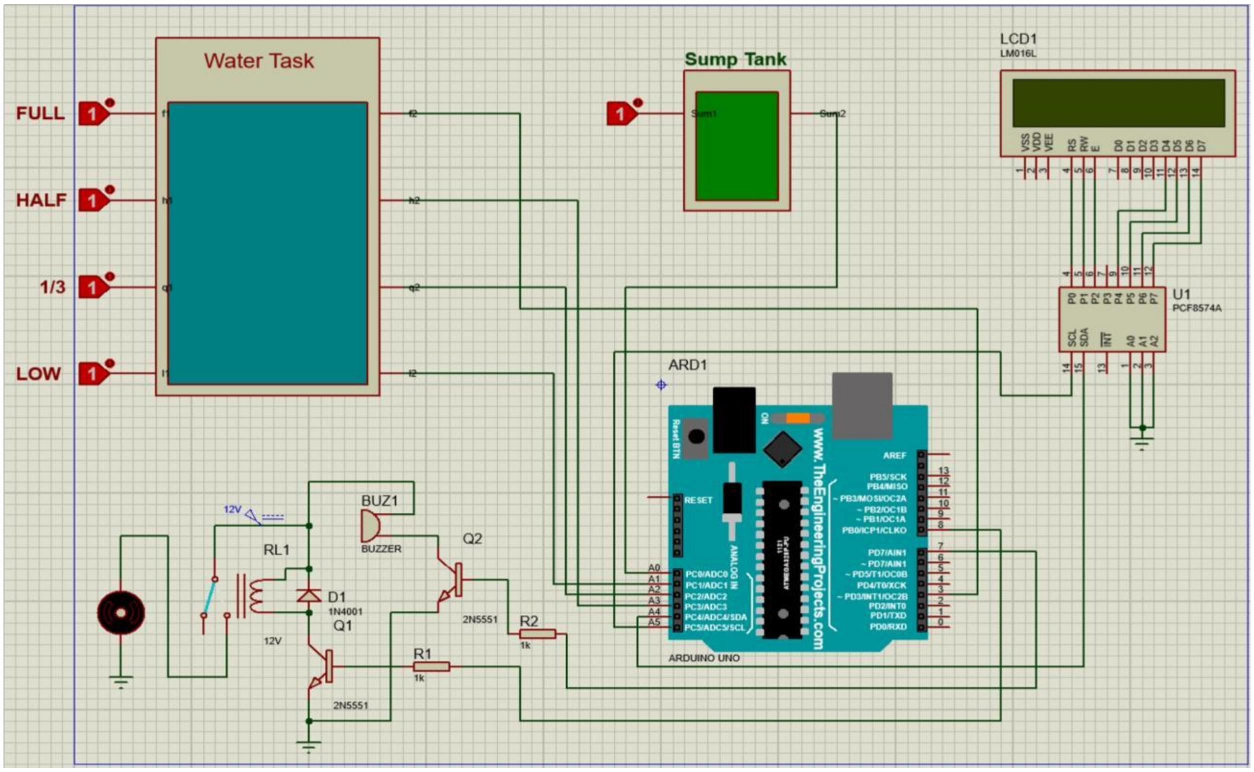


Figure-15: Water Level Monitoring System

Here this simulation circuit represents Water Level Control Circuit inside of the tank. As the system is fully automated by various circuits and control panel, this part only responsible for water level control, when the water will flow to the tank, how much water level to start over the water pump to supply water through the tank. First the Arduino circuit measure the water level inside of the tank by identifying with SONAR Sensor. Then accordingly pump will get the command to flow the water into tank from the Arduino circuit until the water level reach to full level indication. As soon as the level of water becomes full inside of the tank, Arduino immediately pass the command stop to the pump to reduce water loss.

4.5 Conclusion

Optimization of multiple design approaches is really important to find out the best approaches. For this reason, we thoroughly analyze all the suggested approaches by comparing Specifications, requirements and budget. To validate more, software simulations have been done. Finally, after taking consideration of the user's feedback and all the analysis, approach 3- Photovoltaic RO System has been selected as the best approach.

Chapter 5

Completion of Final Design and Validation

5.1 Introduction

In this chapter, it is discussed about the completion process of the final design project and how does the validation process occur. After completing all the previous calculation with the help of simulated result and background theory from various paper and research materials, we sum up all the data from the theory with the real-life parameters to get the ultimate solution which is final design of our prototype water filter. To match with the final data with our prototype result we have ran our projects multiple times from energy monitoring to filtration process and lastly measure the water quality to evaluate the result.

5.2 Completion of Final Design

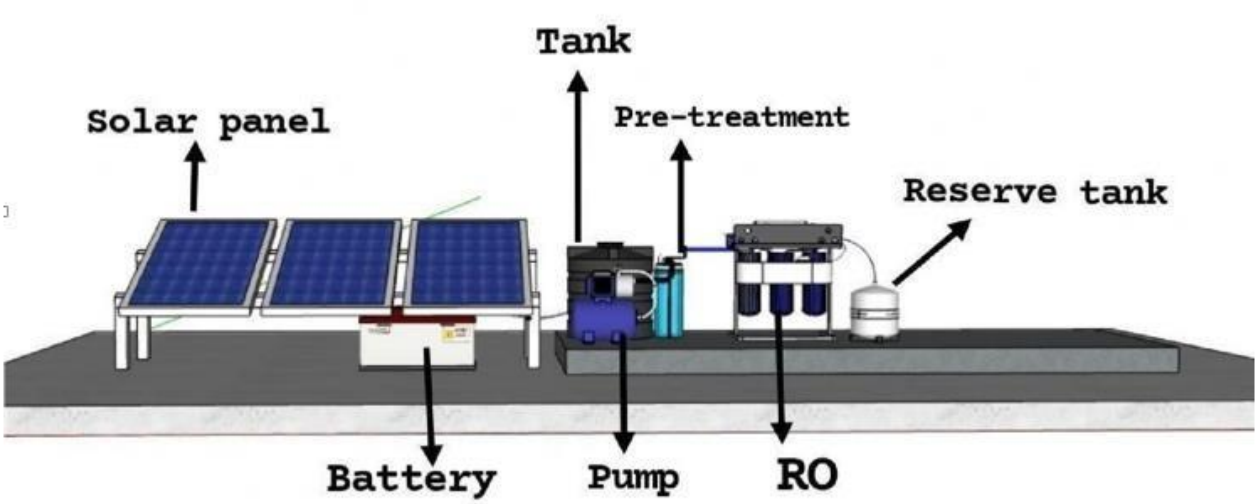


Figure-16: 3D model of a PVRO using Sketch Up

We have designed the PVRO system using Sketch Up 3D modeling software. All the components that we have used for our systems such as Solar panels, batteries, motor pumps, prefiltration systems, reverse osmosis systems, pipes (to carry water), and water storage have been designed with the help of SKETCHUP. First of all, with the help of solar, we get the required energy for our system. The energy we got from solar is used for purifying water using a reverse osmosis system also there is a battery used to store energy. The stored energy will be used during gloomy weather or insufficient solar radiation. After that, the energy obtained from the PV panel is used by the feed water pump to draw the saline water. Then the saline water will flow through the pre-treatment process to complete the first stage of water purification. Afterward, during the pre-treatment process, the water will run down through the reverse osmosis system. In a reverse osmosis system, there are various stages to purify the water. After completing the reverse osmosis water purification. The purified water will be stored in a tank as day-to-day drinking water for an average family.

5.3 Evaluate the solution to meet desired need

At first the proposed prototype of water filter is being assessed through various theory and calculation from different paper and selected 3 major alternative design approach for the prototype. First one is “Solar Still”, then second one “PVRO System” also known as “Photovoltaic Reverse Osmosis System”, and the third one is “Solar HDH System” also known for “Solar Humidification and Dehumidification System”. As for final prototype “PVRO System” is selected by considering different design and efficiency criteria. For design and implementation part first the team took an on field survey of the actual system where it is located. In the site visit, the team took all the data from real life machine.

The team first took data from solar panel such as power output of solar panel, how many hours it took to charge the battery inside the system, how many watts of power is used for running the whole system, what is the battery voltages and ampere-hour of the battery. Then the team looked for the water pump which is one of the vital component of the system. Moreover, the team took the measurement of pipe and the size of the water storage. Also other components like water vessels, power adapter, external and internal pump. One of the major important part to look out was how much the pump needed to fill out the storage water tank with the help of battery power and how much was the flow rate of water in terms of pipe's diameter. Finally when all the data is taken the team proceed to simulation process, as it is important to calculate solar power output to meet up the demand of the scaled down prototype.

Figure -17: Water Pump

Figure -18: Pressure Vessel

Second part of the design part was simulation part, where the team simulated the whole system part by part in terms of energy calculation using "PVSYST", water pump pressure and water flow rate calculation background theory, then electrical sensor mounting evaluation using "PROTEUS" and also lastly Arduino based program part which will run the entire system with trigger and logic. Firstly, in "PVSYST" software team calculated whole energy demand through various load of the proposed prototype. The main goal of this simulation is that to run whole system it was needed to scale down the project into small prototype. In the site the water plant was for 10 storage building where 10 big family is currently living. So it was important to calculate how much time is needed to fill out the whole storage water tank which is 3000L. From our calculation it took 29 minutes in real life. So the team calculated how much is needed for full solar power to charge the battery up to full capacity. So all the real parameters and data were given into the experiment module inside the “PVSYST” software where team also defined standard time duration for the entire system to run on full capacity.

After the simulation result the team got the data set for monthly solar power output which will charge the battery and will run the system entirely for 3 hours from charged battery with real life water pump parameters. Here for the energy and load calculation it is considered only water pump because in the proposed design only water pump needed electric power supply and the rest of the components will take power from the micro-controller as the team were focusing the system to be fully automated. From the simulation process and data set, whole team got the energy requirements for the system and with the help theoretical knowledge water flow is also calculated to get the prefer model for the RO system as it is main portion of the system.

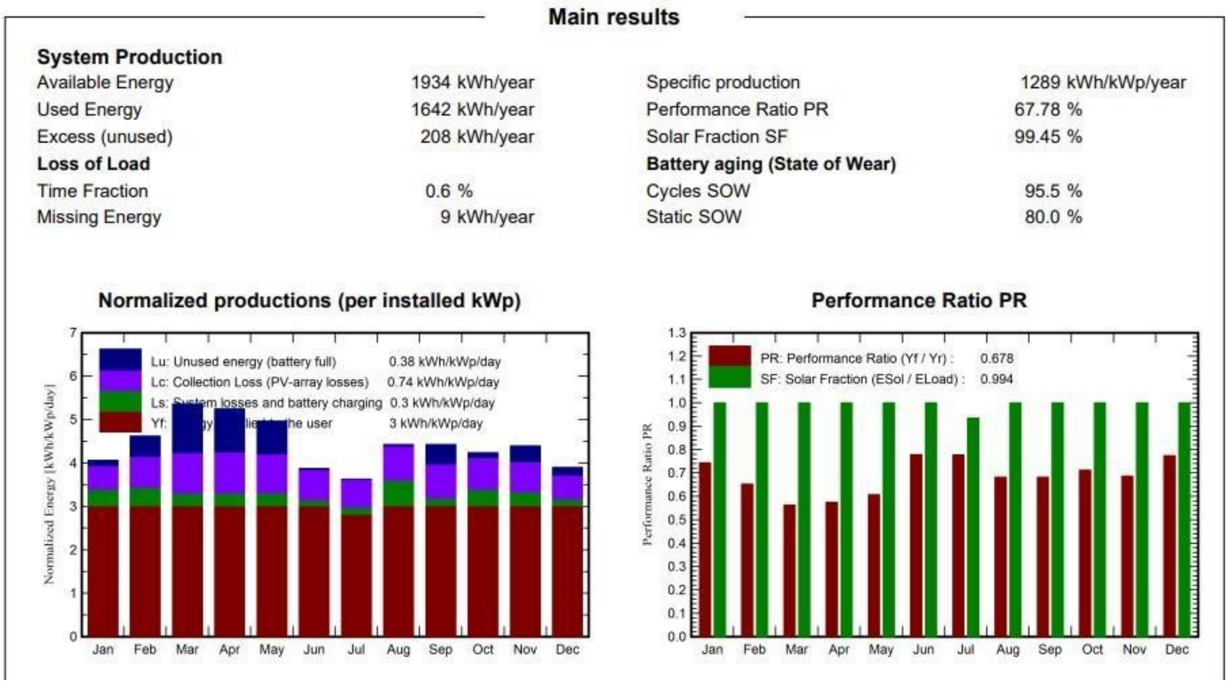


Figure-19: Yearly Energy Production and Usage.

5.3.1 Result Analysis of Solar Energy Production

- For water flow, a feed water pump is used which has rating of 1.5 kw which will be running for 3 hours/day with a time interval of 4 hours in between them.

- So for the required energy from user end for water pump is 1.5 kw×3 hours/day = 4.5 kw/day. So for 30 days month energy demand is 135.7 kw and for 31 days month it is 140.2 kw.

- Consider for May. The total energy stored from PV is 182.2 kw and energy supplied to the user is 140.2 kw. So daily the system gets 140.2/31 = 4.5 kw which is enough for our system's power supply. Also extra power 182.2 - 140.2 = 35.12 kw will be stored in the battery for future use for bad weather condition.

Energy Usage Criteria	**Energy Output (Solar) (kw)**	**Energy Demand (user) (kw)**
Hourly	1.5	1.5
Daily	4.5	4.5
Monthly (avg)	161.17	137.58
Yearly (avg)	1934	1642

Table 14: Solar energy production analysis.

5.3.2 Water Flow Rate Calculation

- Ability to purify water is 420 mL/minute
- Then converted to (420 $\times$ 60 = 25,200 mL/hour)
- Again converted to (25,200/3800 = 6.6 gallon/hour)
- So finally (6.6 $\times$ 24 = 159 gallons per day means 800 litre/day

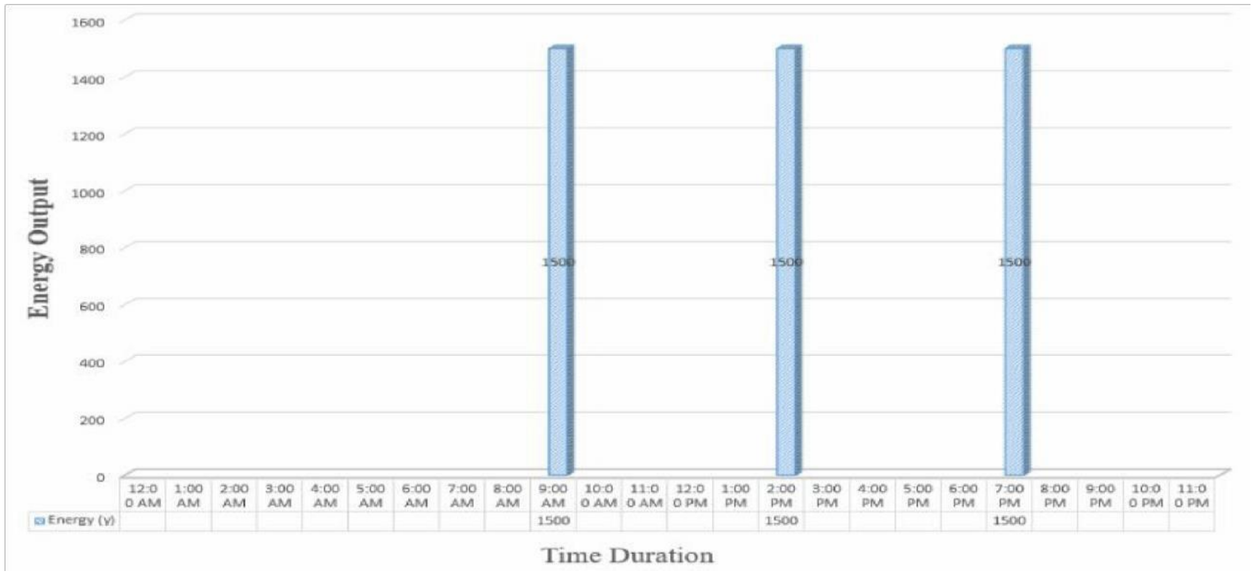


Figure-20: User’s Needs for Specified Load & Run-Time

For the last part was done for sensor optimization. In this part the members of the team first analysis that if they want to run the system without any interruption from human it had to be automated. So first they try to find what types of sensors can be useful in this regard. After analysing all sorts of sensors, the decision has been made for sensor part. In the final prototype of the proposed design first and foremost is that water level sensor is needed to detect the water level so that pump can be turned on for more water filtration and after it is done than pump needs to be stop at the right time so that no water will be wasted. As it was hard for taking look inside the storage tank, the team had to design their own sensor mounting procedure and own parameters for sensor to work out. But firstly sensor should be tested properly so they run various simulated result to clarify actual data from the software. In this case “PROTEUS” is used for sensor simulation. In “PROTEUS” both water level sensor and sonar sensor is tested but for the main prototype sonar sensor is used mainly as it was giving more accurate data. Moreover Arduino micro-controller was also tested and had to write different code for multiple command.

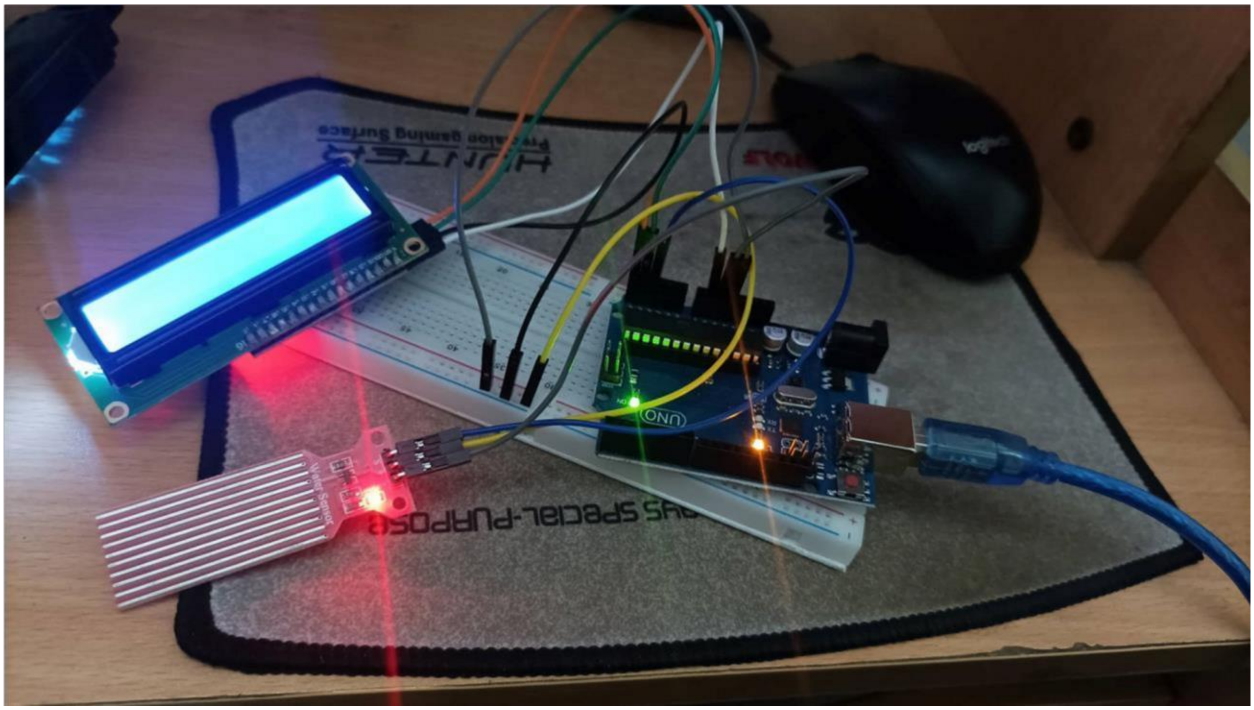


Figure-21: Trial & Error Phase of Arduino Code and Water Sensor

For the final prototype system, other sensors are also used to measure the quality of water according to BSTI standard. For quality check “pH Sensor”, “TDS Sensor”, “Temperature Sensor” are used. There was also another code for relay switching as it is expected that whenever water goes down to below 50% of our storage tank “SONAR Sensor” will detect the level and send data to “Arduino” so that it can trigger the “Relay Switch” to turn on both the pump (external & internal pump) which will allow to flow the water through “RO System”. After that the “SONAR Sensor” detect the water level to 90%, it will automatically turn off both the motor with “Arduino”.

Figure-22: Final Prototype of PVRO System

After getting all the simulated result and real life data, the final prototype is ready to observe. At first the solar panels are capable of generating 40W power (each 20W panel) and with the help of solar power it can charge the whole battery in 15 hours. The battery rating for our system is 12V9Ah and used 2 batteries as we are using 2 sets of 12V-1.2A water pump to run the system.

There is also charge controller connected in between battery and solar panel. Then both pump and battery is connected with a relay and other end of the relay is connected with Arduino through bread board. For the whole sensor connection a bread board is used for the base for all the wiring connection.

Finally all the different part of the components were connected properly to make the whole system fulfill. In the RO System all pipe inside the filter were properly cut to fit in every connection and also sensors and Arduino were connected through bread board connection. Furthermore, the connection of each every part of the components were cross check multiple times if there is short circuit or leakage in the system design. After all the procedure the system started to run full throttle and the team took all the data carefully to compare with desire need from user's end.

5.3.3 Water Filtration Data

Steps of Procedure	Processing Time
Pre-Filtration	2 minutes
Reverse Osmosis Process	6 minutes
Water Pump Pressure	75 psi
Water Flow Rate	400 mL liters per minute

Table 15: Water filtration data

5.3.4 Water Quality Data

Sensor Type	Results
pH Sensor	Acidic (6.5)
Temperature Sensor	23.5-24.5 C
TDS Sensor	50-150
Sonar Sensor	Trigger at 50% & stop at 90% water level

Table 16: Water quality data.

So this was our data collection from the system run time. The values are measured for several times to minimize the errors and all the data were taken in real time scenario with all the part of the system running. These result analysis table set represent all the data acquired from the prototype. As this design is made for small family the water flow rate we got from the result is 400 mL per minute which is very close to standard water flow rate. For the system pre-filtration process took 2 minutes and it is ensured when water through wastage pipe got running. Then after 6 minutes whole filtration process were done and the water level of storage water tank began to rise. From the rated water flow rate, the pump pressure was also measured which 75 psi.

Besides for measuring water quality pH sensor and TDS sensor is used. From the resultant water the reading of the pH was 6.5 which is very slightly acidic. From BSTI standard for pure water the range of pH is from 5.5 to 7.5. So the value is for pure water. To evaluate the system's accuracy brine solution is used and from the sensor the reading was 3.5 which is very acidic. So after filtration process the pH went up to 6.5, so process is accurate. For TDS the value was around 50-150 range for pure water. This TDS is used for measuring total dissolved solid in the water. After using salt water, the value of the TDS was 10,000 mg/L/. So after filtration the value were sometimes 75 or 120 as we measured for different types of salt water. Lastly for the temperature sensor, it was sometimes showing the value of room temperature as the test case was in room so the value was from 25 degree C to 26 degree C.

5.4 Conclusion

In the end, after all calculated result together, it is applied on the system mounting process. From Solar to RO system and also sensor part each and every set of connection and electrical wirings were properly connected and the system ran smoothly. But the team also faced difficulties in sensor coding and mounting and also faced discharge issue of the battery. Some parts of filter such as water pump also got defected. To maintain all the parameters, it is carefully organized in terms of debugging and connection. At the very end, the final design prototype ran perfectly with all the data collection and also not much different from the actual water plant. All parameters including energy production from solar to charging the batteries, from water level indicate to turn on or off the motors at the same time and also the measurement of the water quality. Besides given data is the reflection of the entire system which is perfect for small family providing the supply of pure drinking water.

Chapter 6

Impact Analysis and Project Sustainability

6.1 Introduction

Whether a product will be well-received by stakeholders and the general public is a constant source of worry. This is dependent on the product's feasibility and effectiveness on water purification utilizing renewable energy. To preserve the needs of the stakeholders while prioritizing other elements like societal, health, safety, environment, culture, and effect optimization, many considerations needed to be addressed.

6.2 Assess the impact of solution

For Bangladesh lack of safe drinking water has been an acute problem. Safely managed water services are accessible to only 12% of the population [13]. Moreover, Coastal people of southwest Bangladesh are forced to drink unsafe saline water. In the five coastal districts (Satkhira, Khulna, Bagerhat, Pirojpur, and Barguna) people are forced to drink unsafe saline water because of a higher degree of spatial variability of salinity in both shallows and deeper aquifers [13]. So, a desalination method like PVRO system with renewable energy will have a huge impact.

First of all, our PVRO system will provide safest water in the coastal area. So, people when starts getting pure safe water, it will impact their culture. Previously, they were using unsafe, saline water but when they will come to know about water with better taste and quality it will change their habit. Every householder would want to have one of their own.

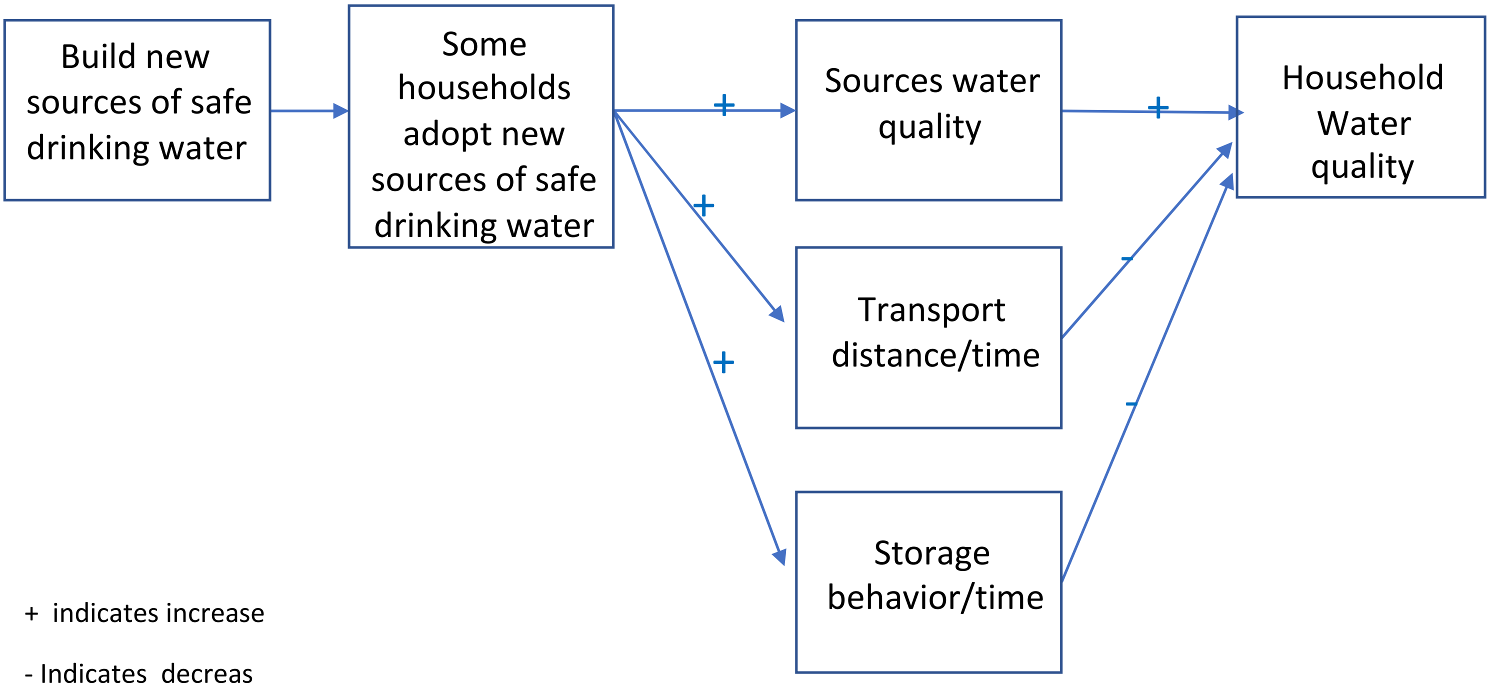


Figure-23: Diagram of impacts of new sources of safe drinking water [24]

Next, our water purification system fully run with green energy (photovoltaic solar system). So, PVRO system will have a great impact to the coastal society. Mass use of our project will ensure a green society. Moreover, people will be more willing to use pure water.

Thirdly, it will have a good impact on people's health. Coastal people commonly suffer from diseases like typhoid, cholera, dysentery, Diarrhea, etc. These waterborne disease rates will be lessened. Moreover, the child mortality rate will be lessened. In the coastal region, pregnant women are greatly affected by unsafe water. One of the common problems, hypertension should decrease which causes maternal death and stillbirth.

Need to be mention that our PVRO system demand regular maintenance. So, users have to maintain our system in a regular basic otherwise it might cause chemical contamination. Consequently, people will again suffer from waterborne diseases.

For all the reasons stated above Safe drinking water obviously will have a positive impact on people's safety. A safer family, safer society resulting in a safer region. Additionally, when natural disasters occur water salinity increases due to the Bay of Bengal. During those crisis times, food and pure water become rare. However, our project will provide them with safe water at those times. Ensuring their safety of themselves by themselves.

For our project, there is not much legal impact. One concerning matter is copying our project design/ idea. In order to prevent such things, legal actions might be needed. Another thing to consider will be if our project fails and produces unhealthy water resulting in health issues. As a result, we might have to face legal action. So, we intend to ensure that such a blunder does not occur.

6.3 Evaluate the sustainability

In terms of both environmental and economic aspects, this project seeks to be sustainable. Our project is mainly built for people who live in coastal areas. Not only is it difficult to find clean drinking water in coastal areas, but the continuous supply of electricity is frequently disrupted. To prevent the scarcity of pure drinking water in those areas, a portable water purification system using renewable energy can solve the problem to a great extent. So, we used a reverse osmosis filtration system, which will be powered through solar. Also, we used a battery to store energy and supply the necessary energy to the reverse osmosis purification system when the weather seems gloomy or the required amount of energy cannot be acquired through solar radiation. Even the filtration system can be used at night with the help of a battery. To observe the water quality parameters such as TDS, pH, and temperature, quite a few microcontroller sensors were used. As a result, anyone can check the water quality. Subsequently, relays and switch sensors are also used for automatic on and off.

Along with this, two motors are used to generate water continuously for the reverse osmosis filtration system when the switch is on. Also, we added an additional pre-treatment stage to our system to filter out the large particles of saline water that might cause damage to the reverse osmosis system. As a result, the maintenance cost of the system can be reduced. As we are using solar energy to run our system, it will make our project more eco-friendly and budget-friendly.

6.4 Conclusion

Since consumer opinion can vary, the process of developing something is unpredictable. The people who reside in coastal areas will be benefited by this project. Our reverse osmosis system can purify water without power, utilizing solar energy. Eventually, assist people in obtaining clean drinking water at a suitable rate. Furthermore, this initiative is sustainable in terms of its impact on the environment, culture, ethics, and economy.

Chapter-07

Engineering Project Management

7.1 Introduction

Project management can be defined as an important feature of defining the plan, process, goal, and deliverables of the project. To make a project successful, defining the project scope and maintain and update the project timeline on a regular basis is pretty important. Moreover, evaluating the resources and project plan is also needed. Lastly, we have a contingency plan for the project in case any emergency arises.

7.2 Define, plan and manage engineering project

Engineering Project means the work assignment to be carried out by all pieces of equipment combined for a specified, pre-determined worksite. A goal needs to be set according to the requirements of the project. Now in order to reach the goal strong plans are needed and followed by the group members.

Our final year design project has been divided into three parts: topic selection, simulation and prototype implementation. We have made different plans for performing these stages. We have made different gantt chart where each and every stage have been scheduled through performing some specific procedures. These charts represent the time management of each stage for developing the project. We revise the Gantt chart when any unwanted issue arises or some changes in the plan.

7.3 Evaluate project progress

As mentioned in the previous section, to evaluate the project, distinct plans have been made for all three semesters. Some of those major plans are shown briefly bellow-

7.3.1 Topic Selection and Multiple design approaches

Firstly, lots of research has been done among the group members to find out some topics for the project. After gathering some topics, we proposed them to our ATC panel members so that they can give feedback on them and select a topic for the project. If none of the topics is selected then again, we choose some new topics and showed them to the panel members. After selecting the topic our next step is to research deeply on that topic and find out some approaches which have the same end result but in a different way. We choose three approaches that are capable of providing pure drinking water by using renewable sources. Those are-

1. Solar Still
2. Solar Humidification-Dehumidification Desalination System
3. Photovoltaic Reverse Osmosis Desalination System (PVRO)

7.3.2 Finding Optimal Design Solution Through Software Simulation

To find the best design approach among the suggested three approaches, several software simulations have been done for detailed analysis and data. We have used Proteus software for motor and pump connection analysis, PVsyst software for solar performance analysis, and lastly SketchUp for 3D design modeling. After all the analysis we have come to the conclusion that 3rd approach offers better output among all the approaches.

7.3.3 Prototype Construction for the Main Approach

We have breakdown our prototype construction among the group mates into three parts-

1. Solar to battery connection.
2. RO filter connection.
3. Water quality check with sensors.

Lastly, we have equally divided the chapters among the group mates to complete our final reports.

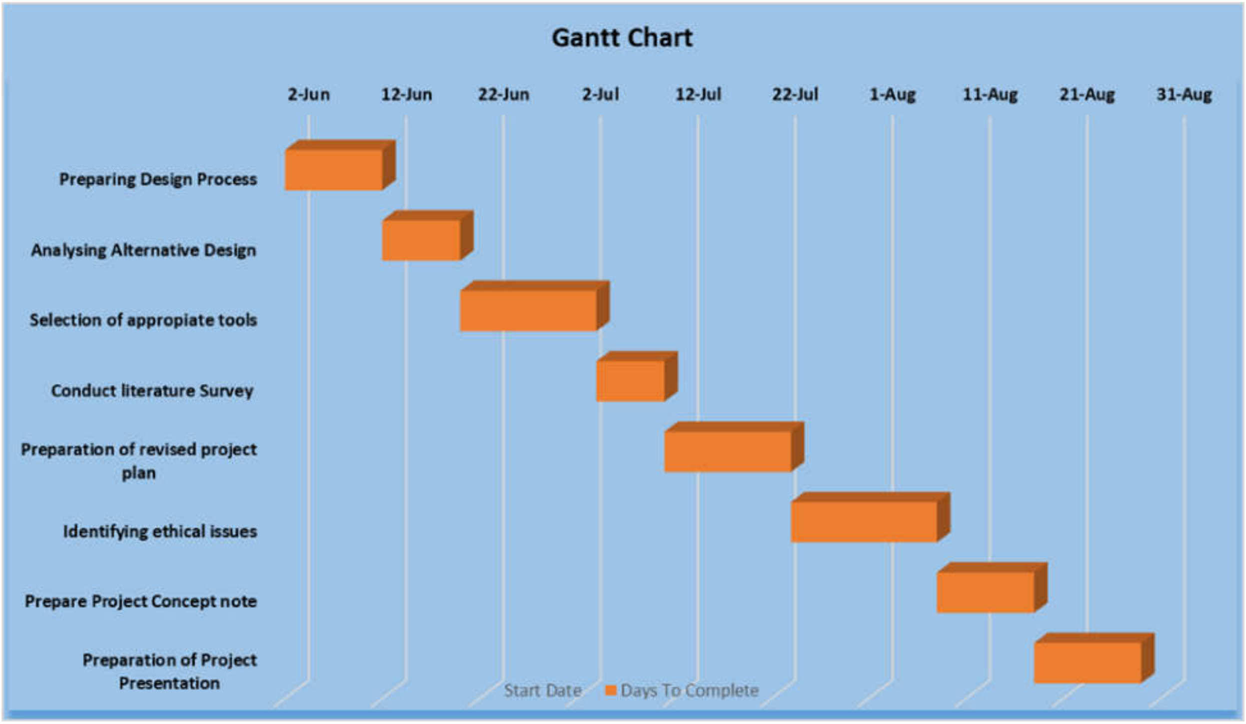


Figure-24: EEE 400P gantt chart

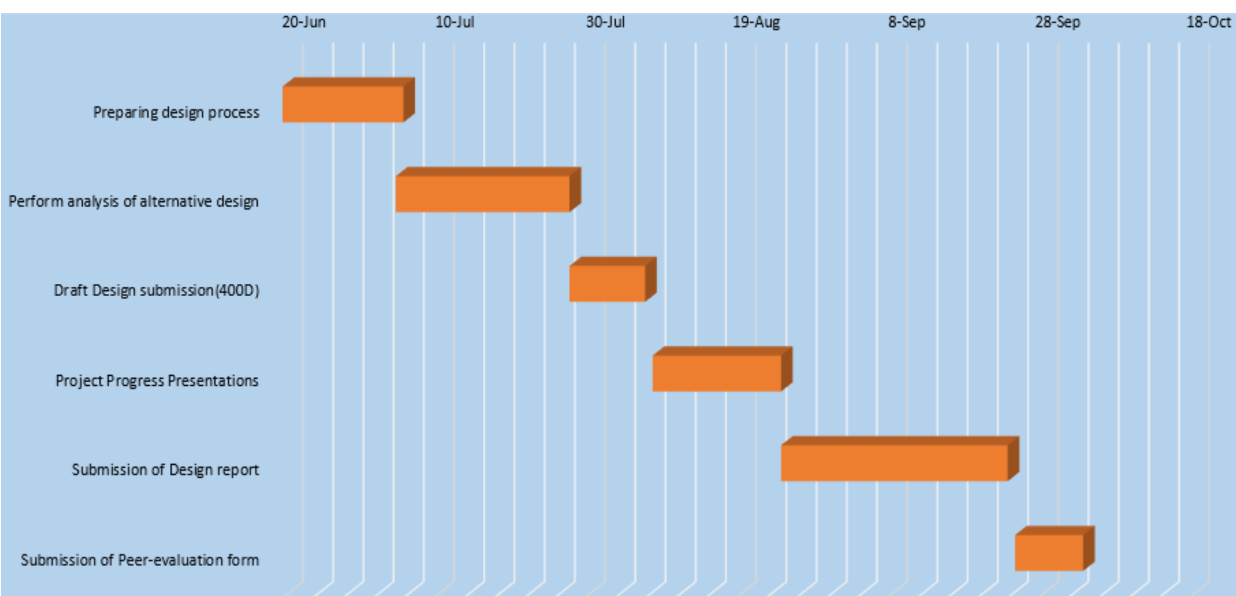


Figure-25: EEE 400D gantt chart

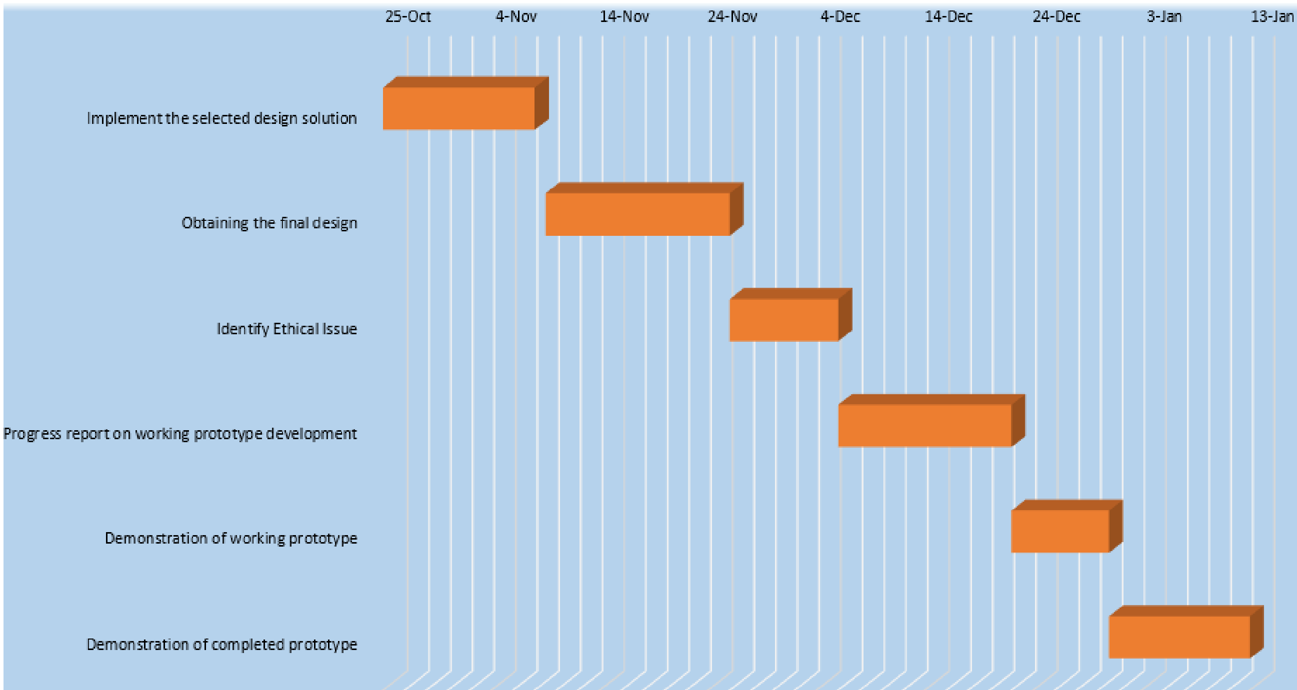


Figure-26: EEE 400C gantt chart

7.4 Conclusion

To complete all the tasks of the project in the allocated time, group members' participation is really significant. Also, having track of the work completed is necessary. To do that, we maintain a log book where we regularly updated our weekly progress. Through this project management procedure, we organize our project framework.

Chapter 08

Economical Analysis

8.1 Introduction

A project is feasible enough if it is economically well managed. Economic aspects give us a view of how much profitable a project is. So, it is important to understand the economic perspective for a project. It is discussed in this chapter

8.2 Economic analysis

Component	**Quantity**	**Price (Taka)**
30watt mono solar panel	×2	2700
BT-12M 7.5A 12V Lead acid battery	×4	3200
Sediment filter	×1	50
Carbon filter	×1	250
Activated carbon	×1	250
Test filter	×1	500
Mineral filter	×1	800
RO membrane	×1	2000
UV filter + Set up	×1	3000
Housing	×4	4000
Booster pump + Adapter	×2	5200
Pressure meter	×1	600
Sonnet bulb	×1	800

High pressure + Low pressure switch	×1	1000
Frame	×1	2000
Food Graded filter pipe + fittings	×12-15	1000-1200
Arduino uno	×1	850
HC-SR04 sonar sensor	×1	70
Carbon water level sensor	×1	50
TMP-10 digital water level sensor	×1	80
830-Point breadboard	×1	85
Jumper wire	×2 sets	100
1602 LCD display	×1	160
3.7-6V motor	×1	70
9V battery + cap	×1	60
12V relay	×2	40
Switch	×4	25
5mm LED	×10	10

8.3 Cost benefit analysis

A cost benefit analysis is the method of contrasting the estimated costs and benefits related with a project decision to predict weather it makes sense from a business point of view. This analysis offers a reliable, quantifiable guidance for making decisions to the future of the system. Not necessarily the project has to be cost effective, effectiveness, performance and longevity of the system matters the most. So, whenever selecting the best design approaches, one must ensure the sustainability and performance of the components. In addition, components should be both affordable and effective. So, before selecting the best design approach, a comparison among the major components of all the approaches should be considered-

Approach 1 core component analysis-

Components	Price (TK)	Strength	Weakness
Glass cover	1500	1. Light refractive	1. Easily breakable. 2. Non-portable.
Water basin	8000	1. Long lasting	1. Costly 2. Large area required
Absorber plate	3000	1. Easily repairable	1. Frequent reinstall issue. 2. Slow processing time.
Insulation	800	1. Cost effective	1. Poor longevity
Distillate trough channel	2000	1. High longevity	1. Complex maintenance. 2. Quickly damaged.

Table 18 : Core component analysis for design 1.

Approach 2 core component analysis-

Components	Price (TK)	Strength	Weakness
Solar panel	13500	1. Renewable energy 2. Good longevity 3. Low maintenance cost	1. Costly 2. Low efficiency

Centrifugal water pump	10000	1. Durable 2. Fast processing time	1. Expensive. 2. Heavy weight
Humidifier chamber	3000	1. Long lasting 2. Easy maintenance.	1. Slow processing unit.
Dehumidifier chamber	4500	1. Long lasting 2. Easy maintenance.	1. Slow processing unit.
Pure water storage	1500	1, Durable	1. Large area required 2. immobile

Table 19: Core component analysis for design 2.

Approach 3 core component analysis-

Components	Price (TK)	Strength	Weakness
Solar panel	1800	1. Renewable energy 2. Good longevity 3. Low maintenance cost	1. Costly 2. Low efficiency
Battery	1700	1. Rechargeable 2. Portable	1. Poor longevity 2.Non-enviromental friendly
Feed water pump	2000	1. Light weight 2. High efficiency 3. Repairable	1. Quickly damaged

RO water purifier	10000	1. Ensure 100% pure water 2. Customizable 3. Highly efficient	1. Higher amount of waste water 2. Frequent maintenance needed
Sensors	4000	1. Make system automated 2. Low cost 3, Ensure water quality	1. Delicate 2. Complex connection system

Table 20: Core component analysis for design 3

After analyzing all the three tables we can say that approach 3 is more cost beneficial for the consumers than the approach 1 and 2.

8.4 Evaluate economic and financial aspects

Before building up a system, one must consider how much economically viable and sustainable the system is for the consumers. So, it is necessary to conduct a financial review to check whether the system will be cost effective and efficient for the users. So, analyzing cost, threat and return value is important for the designers. As a result, we choose approach 3 which is more beneficial in both economic and financial aspect in accordance with fulfilling the demands of the consumers. At first, we made a details budget list to analyze cost of the prototype-

Budget:

Component	Quantity	Price (Taka)
30watt mono solar panel	×2	2700
BT-12M 7.5A 12V Lead acid battery	×4	3200
Sediment filter	×1	50
Carbon filter	×1	250
Activated carbon	×1	250
Test filter	×1	500
Mineral filter	×1	800
RO membrane	×1	2000
UV filter + Set up	×1	3000
Housing	×4	4000
Booster pump + Adapter	×2	5200
Pressure meter	×1	600
Sonnet bulb	×1	800
High pressure + Low pressure switch	×1	1000
Frame	×1	2000
Food Graded filter pipe + fittings	×12-15	1000-1200

Arduino uno	×1	850
HC-SR04 sonar sensor	×1	70
Carbon water level sensor	×1	50
TMP-10 digital water level sensor	×1	80
830-Point breadboard	×1	85
Jumper wire	×2 sets	100
1602 LCD display	×1	160
3.7-6V motor	×1	70
9V battery + cap	×1	60
12V relay	×2	40
Switch	×4	25
5mm LED	×10	10
	Total	23000

8.4.1 Time value of investment in capital

As our prototype is fully automated and portable, users have the advantages of saving time and physical energy. So, consumers should consider the time value of our prototype. This time and energy savings have impact on the economy of the consumer after long term usage of our prototype.

8.4.2 Payback period

As we are using renewable energy for electricity supply, so consumers can save a little amount of electricity bill in everyday usages. Here a rough estimation of saving shown below-

We know,

1 kWh/hour = 1 unit = 6.20 tk (In Bangladesh)

When our 40watt solar panel efficiency is at maximum, the solar will produce an estimated maximum generation 0.0337 kWh/hour at a clear day.

So, per day electricity bill savings is = (6.2×0.0337×24) = 5.01 tk/day

So, the approximate payback period = (20000÷5.01)/365days = 10.94 years

So, the calculation highlights that consumer will get return their money in minimum 11 years.

8.5 Conclusion

It is understandable that optimum design gives the best solution theoretically and economically. However, in near future changes can be brough to make it a more profitable project. It is expected that in plant level it will be a feasible project.

Chapter 9

Ethics and Professional Responsibilities

9.1 Introduction

To create a long-term and beneficial engineering project for people, it is critical to address the project's ethical and professional duties. Understanding the social, environmental, and economic effects of our endeavor can be helped by focusing on these ethical and professional duties. In order to build a project with goodwill in mind from a social and moral standpoint, we might use our ethical considerations as a guide. However, our obligations as professionals will direct us to correctly demonstrate our engineering abilities when designing our project.

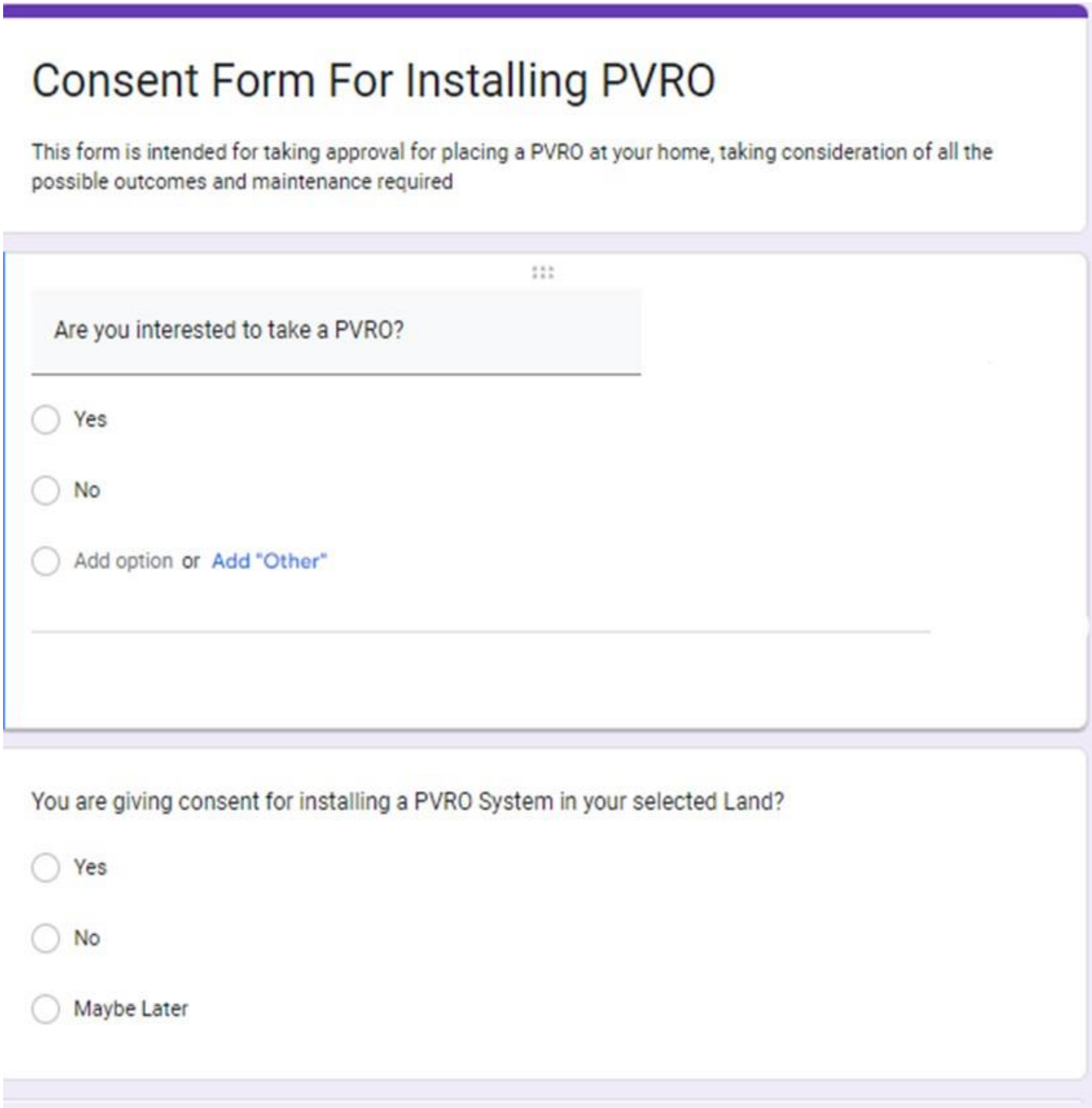
9.2 Identify ethical issues and professional responsibility

There are several things we have taken into consideration that are connected to ethics. First of all, we will advertise our filtration process to the users so that they can trust our product. That is why we will publish a consent paper regarding the PVRO system where users can learn how our device works. They will understand that we are using the safest technology (RO system) and also, they will get the best after services from us. Secondly, if we need a trial for our system, we will have all the necessary ethical considerations. We are considering taking permission from BSTI for our purifier. We will go to ICDDRB (International Centre for Diarrheal Disease Research, Bangladesh) which is an authorized drinking water testing center. Moreover, we will maintain the BSTI (Bangladesh Standards and Testing Institution) standard in the trial version so that our system can supply pure drinking water.

As an engineer, we have some professional responsibilities to the users as well as to society. By considering the best health safety to society, we are using the best water purification technology RO system which provides the safest drinking water. In addition, we are intruding solar system with our purification system which is green energy and environmentally friendly. In conclusion, our system will be safe for the human body as well as for society.

9.3 Apply ethical issues and professional responsibility

A consent form will be provided for those interested in taking installing PVRO at their home-


Consent Form For Installing PVRO

This form is intended for taking approval for placing a PVRO at your home, taking consideration of all the possible outcomes and maintenance required

Are you interested to take a PVRO?

- Yes
- No
- Add option or Add "Other"

You are giving consent for installing a PVRO System in your selected Land?

- Yes
- No
- Maybe Later

Figure-27: Consent Form for Installing PVRO you are aware that after installing the system it is filled (holding tank to full pressure), discharged once to a trickle, and then started using as normal from then on?

- ◯ Yes
- ◯ No

You are aware that the filters needs to be cleaned on a regular basis and if any contamination occurs for germs in the filter we are not to blame?

- ◯ Yes
- ◯ No. I want to be informed

I am aware of what the system comes with and after reading the consent form **I am giving my approval**

- ◯ Yes
- ◯ No
- ◯ Maybe Later I would like to contact for further inquiry

Figure-27: Consent Form for Installing PVRO

We will be doing a survey with people's opinions about the PVRO System, such as if they trust the system whether it can purify water properly, how they can feel safe, and if they are interested to install the PVRO in their home.

9.4 Conclusion

The main goal of this project is to create a renewable energy-powered water purification system that will benefit locals in coastal areas. To ensure that our project is trustworthy for users and sustainable to maintain, it becomes necessary to uphold all ethical and professional obligations when building it. People will be more inclined to use our system if we can earn their trust by carrying out these obligations.

Chapter 10

Conclusion and Future Work

10.1 Project summary

In this FYDP-400D, we have built a whole scenario of our project through data collected from site visits to set up a simulation in various software. From those softwares, we have calculated all the necessary values that we need to make our prototype and successfully install it in real life. This whole project depends on various parameters and calculations such as energy production, the water flow of the RO system, and Circuit simulation of water level indicator. So those softwares were helpful to improvise our optimum design throughout the whole semester. Furthermore, we have adjusted our new project plan for the upcoming FYDP-400C.

10.2 Future work

Like every other project our project also has some scopes of improvements that can be done in future. We would like to address some of them below -

Additional stages of purifier: Our optimum solution is based on RO system and pre filtration making it 5 stages of purifications. If we add more stages for germs and microbes that cannot be killed by those 5 stages the system should benefit the stakeholders more.

Automated Movement: Like a line following bot follows its path, same can be done to the system for a more automated and user-friendly system.

Brine Management: Coastal area is full of salt water. The ample amount of salt we get after purification can be managed smartly. If we build the system on larger plant level, the plant can provide economic benefits through the bi-product, salt.

Energy Recovery system: With help of power electronics, the energy part of the system can be improved. For instance, solar tracker can be added for better energy management. Moreover, the energy recovery system should recover sufficient energy for the time when solar energy is short.

Chapter 11

Identification of Complex Engineering Problems and Activities

11.1 Identify the attribute of complex engineering problem (EP)

	Attributes	**Put tick (√) as appropriate**
P1	Depth of knowledge required	☑
P2	Range of conflicting requirements	
P3	Depth of analysis required	☑
P4	Familiarity of issues	☑
P5	Extent of applicable codes	☑
P6	Extent of stakeholder involvement and needs	☑
P7	Interdependence	☑

11.2: Provide reasoning how the project address selected attribute (EP):

- P1- This project required various knowledge about sensors, circuits, DC pumps and chemical reaction.
- P3- The analysis behind the project wide in range and various analogy tools are used to analysis any effect.
- P4- Various range of issues are also present there.

- P5- Project has to maintain all international and domestic standard codes.
- P6- Stakeholder's involvement is necessary because investment is needed.
- P7- The system is also interdependence in terms of energy, pump and purification

11.3 Identify the attribute of complex engineering activities (EA):

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	☑
A2	Level of interaction	☑
A3	Innovation	
A4	Consequences for society and the environment	☑
A5	Familiarity	☑

11.4 Provide reasoning how the project address selected attribute (EA):

- A1- Wide range of resources is available in online journals and also in field works.
- A2- Various levels of interaction is also present for the project.
- A4- Project has great impact in terms of health security and also green technology.
- A5- The project is very familiar in various country and also in Bangladesh

References

1. World Health Organization and UNICEF, Meeting the MDG drinking water and sanitation target, 2006, http://www.who.1

2. Bahar, M.M.; Reza, M.S. Hydrochemical characteristics and quality assessment of shallow groundwater in a coastal area of Southwest Bangladesh. Environ. Earth Sci. 2010, 61, 1065–1073.

3. Islam, A.R.M.T.; Siddiqua, M.T.; Zahid, A.; Tasnim, S.S.; Rahman, M.M. Drinking appraisal of coastal groundwater in Bangladesh: An approach of multi-hazards towards water security and health safety. Chemosphere 2020, 255, 126933

4. Islam, M.R.; Das, N.G.; Barua, P.; Hossain, M.B.; Venkatramanan, S.; Chung, S.Y. Environmental assessment of water and soil contamination in Rajakhali Canal of Karnaphuli River (Bangladesh) impacted by anthropogenic influences: A preliminary case study. Appl. Water Sci. 2017, 7, 997–1010.

5. Naus, F.L.; Schot, P.; Ahmed, K.M.; Griffioen, J. Influence of landscape features on the large variation of shallow groundwater salinity in southwestern Bangladesh. J. Hydrol. X 2019, 5, 100043.

6. Rahman, M.A.; Hashem, M.A. Arsenic, iron and chloride in drinking water at primary school, Satkhira, Bangladesh. Phys. Chem. Earth, Parts A/B/C 2019, 109, 49–58.

7. Rakib, M.A.; Sasaki, J.; Matsuda, H.; Fukunaga, M. Severe salinity contamination in drinking water and associated human health hazards increase migration risk in the southwestern coastal part of Bangladesh. J. Environ. Manag. 2019, 240, 238–248.

8. Saha, R.; Dey, N.C.; Rahman, S.; Galagedara, L.; Bhattacharya, P. Exploring suitable sites for installing safe drinking water wells in coastal Bangladesh. Groundw. Sustain. Dev. 2018, 7, 91–100.

9. M.F. 1996. Coastal water supply in Bangladesh.In: J. Pickford, et al. (Eds.), Reaching the unreached: Challenges for the 21st century. Proceedings of 22nd Water, Engineering and Development Centre (WEDC) International Conference. pp. 165-168, New Delhi, India

10. Hoque, M.R. Access to Safe Drinking Water in Rural Bangladesh: Water Governance by DPHE 2009; BRAC University: Dhaka, Bangladesh, 2009

11. https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-thereearth#:~:text=About%2071%20percent%20of%20the,in%20you%20and%20your%2 0dog.

12. Hossain, M., Chowdhury, M., Jahan, S., Zzaman, R. and Islam, S., 2021. Drinking Water Insecurity in Southwest Coastal Bangladesh: How Far to SDG 6.1?. Water, 13(24), p.3571.

13. Hossain, M. and Majumder, A., 2018. Impact of climate change on agricultural production and food security: a review on coastal regions of Bangladesh. International Journal of Agricultural Research, Innovation and Technology, 8(1), pp.62-69.

14. Hoque, M.R. Access to Safe Drinking Water in Rural Bangladesh: Water Governance by DPHE 2009; BRAC University: Dhaka, Bangladesh, 2009

15. M.F. 1996. Coastal water supply in Bangladesh.In: J. Pickford, et al. (Eds.), Reaching the unreached: Challenges for the 21st century. Proceedings of 22nd Water, Engineering and Centre (WEDC) International Conference. pp. 165-168, New Delhi, India.

16. World Health Organization. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum; WHO: Geneva, Switzerland, 2017.

17. Talukder, M.R.; Rutherford, S.; Huang, C.; Phung, D.; Islam, M.Z.; Chu, C. Drinking water salinity and risk of hypertension: A systematic review and meta-analysis. Arch. Environ. Occup Health 2017, 72, 126–138.

18. Al Nahian, M.; Ahmed, A.; Lazar, A.N.; Hutton, C.W.; Salehin, M.; Streatfield, P.K. Drinking water salinity associated health crisis in coastal Bangladesh. *Elementa Sci. Anthrop.* **2018**

19. Grant, S.L.; Tamason, C.C.; Hoque, B.A.; Jensen, P.K. Drinking cholera: Salinity levels and palatability of drinking water in coastal Bangladesh. *Trop Med. Int. Health* **2015**, *20*, 455–461.

20. Dasgupta, S.; Huq, M.; Wheeler, D. Drinking Water Salinity and Infant Mortality in Coastal Bangladesh. Water Econ. Policy 2016, 2.

21. Benneyworth, L.; Gilligan, J.; Ayers, J.C.; Goodbred, S.; George, G.; Carrico, A.; Karim, M.R.; Akter, F.; Fry, D.; Donato, K.; et al. Drinking water insecurity: Water quality and access in coastal south-western Bangladesh. Int. J. Environ. Health Res. 2016, 26, 508–524.

22. Akter, T.; Jhohura, F.T.; Akter, F.; Chowdhury, T.R.; Mistry, S.K.; Dey, D.; Barua, M.K.; Islam, M.A.; Rahman, M. Water Quality Index for measuring drinking water quality in rural Bangladesh: A cross-sectional study. J.Health Popul. Nutr. 2016, 35, 4.

23. Chakraborty, R., Khan, K., Dibaba, D., Khan, M., Ahmed, A. and Islam, M., 2019. Health Implications of Drinking Water Salinity in Coastal Areas of Bangladesh. International Journal of Environmental Research and Public Health, 16(19), p.3746.

24. Cocciolo, S., Ghisolfi, S., Habib, M., Rashid, S. and Tompsett, A., 2021. Do Community Water Sources Provide Safe Drinking Water? Evidence from a Randomized Experiment in Rural Bangladesh. The World Bank Economic Review, 35(4), pp.969-998.

Appendix

Codes for Sensors

```
#include <EEPROM.h>

#include <OneWire.h>

#include <Arduino.h>

#include <DallasTemperature.h>

#include <SoftwareSerial.h>

#include "GravityTDS.h"


unsigned long sendDataPrevMillis = 0;


// For pH Sensor

const int pH_analogInPin = A0;

int pH_sensorValue = 0;

unsigned long int pH_avgValue;

float b;

int buf[10], temp;



// For TDS sensor

#define TdsSensorPin A1 // TDS Pin to A1
```

```
GravityTDS gravityTds;

// For Turbidity sensor
#define turbidPin A2 // Turbidity Pin to A2

float pH;
float temp;
float tdsValue;
float turbidity;

void setup() {
  // (Arduino - PC) Serial Communication
  Serial.begin(9600);

  pinMode(turbidPin, INPUT);

  gravityTds.setPin(TdsSensorPin);
  gravityTds.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
  gravityTds.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
  gravityTds.begin();  //initialization

  sensors.begin();
```

```
}

void loop() {
  read_pH();
  read_tds();
  read_turbidity();

  delay(500);
}

void read_pH() {
  temp = 25;
  for(int i=0; i<10; i++) {
    buf[i] = analogRead(pH_analogInPin);
    delay(10);
  }
  for(int i=0; i<9; i++) {
    for(int j=i+1; j<10; j++) {
      if(buf[i] > buf[j]) {
        temp = buf[i];
        buf[i] = buf[j];
        buf[j] = temp;
```

```
      }
    }
  }
  pH_avgValue = 0;
  for(int i=2; i<8; i++) pH_avgValue += buf[i];
  float pHVol = (float) pH_avgValue * 5.0/1024/6;
  pH = -5.25 * pHVol + 20.6625;
}

void read_tds() {
  gravityTds.setTemperature(temp);  // set the temperature and execute temperature compensation
  gravityTds.update();  //sample and calculate
  tdsValue = gravityTds.getTdsValue();  // then get the value
}

void read_turbidity() {
  turbidity = analogRead(turbidPin);}
```

FYDP (P) Spring 2022 Summary of Team Log Book/ Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
26.02.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1. Need to finalize topic	Everyone	Research for topic
3.3.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Topic finalized and approval needed Discuss EP and EA checklists.	Everyone	Topic approved
11.3.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1.Research 2. multiple approaches 3. impact	Task 1 = Aseer Task 2 = Saad Task 3= Asad	Research needed
18.3.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Concept note & slide presentation for progress	Everyone	N/A

25.3.22	1.Saad 2.Aseer 3.Asad 4.tasnimul	Multiple design approaches analyze	Approach 1 = Asad Approach 2= Tasnimul Approach 3= Aseer	N/A
3.4.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Defining the standard codes preparing proposal note	Task 1= asad , aseer Task 2= saad tasnimul	N/A
11.4.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Prepare slides for presentation Update draft of project proposal	Task 1= asad , aseer Task 2= saad tasnimul	Update needed
18.4.22	1.Saad 2.Asad 3. tasnimul	Finalizing all the updates in the proposal and slides	ALL	Need to work on block diagrams

FYDP (D) summer 2022 Summary of Team Log Book/ Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
3.06.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1. Need to fix a time for meeting 2. research on softwares	Everyone	N/A
10.6.22	1.Saad 2.Asad 3. tasnimul	Work on 3d designing	Everyone	Choose energy calculation software
12.6.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	A site visit	Everyone	Calculation needed for prototype
18.6.22	1.Saad 2.Aseer	1. design the best approach	Task 1 = Aseer Asad	N/A

	3.Asad 4. tasnimul	2. calculate for prototype	Task 2 = Saad tasnimul	
25.6.22	1.Saad 3.Asad 4. tasnimul	1. Progress presentation slide making 2. 3d design 3. simulation	Task 1 = Asad Task 2= Tasnimul Task 3= Aseer	3d design can be improved
12.7.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1. update design 2. simulate and calculate	Task 1= asad , aseer Task 2= saad tasnimul	N/A
21.7.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1. Work on report 2. update block diagrams 3. 3d video	Task 1= asad , aseer Task 2= saad Task 3=tasnimul	Update needed
29.7.22	**1.Saad** **2.Asad** **3. tasnimul**	**Work on updating report**	**ALL**	**Need to work on block diagrams**

7.8.22	**1.Saad** **2.Aseer** **3.Asad** **4. tasnimul**	**Work on calculation and budget** **And finalize slide and report**	**ALL**	**N/A**
15.8.22	**1.Saad** **2.Aseer** **3.Asad** **4. tasnimul**	**After update mail to ATC panel**	**ALL**	**N/A**

FYDP (C) Fall 2022 Summary of Team Log Book/ Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
28.09.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1.fix a time and date for meeting 2. search for required materials	Everyone	N/A
5.10.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1.Finalize required materials 2. Meet the ICEPE deadline	Everyone	Budget and materials are approved
12.10.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1. Start building the prototype 2. work sub system by sub system	Everyone	N/A
19.10.22	1.Saad 2.Aseer	1.Start preparing	Everyone	Correction needed

	3.Asad 4. tasnimul	progess slides 2. check circuit simulatins		
26.10.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Update about prototype and progress slides	All	N/A
5.11.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	1.Modification on design . 2.Improve circuit part	Task 1= asad , aseer Task 2= saad tasnimul	N/A
12.11.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Check functionality of prototype	All	System is ok
19.11.22	1.Saad 2.Asad 3. tasnimul	Start working on final report	ALL	Update needed

30.11.22	**1.Saad** **2.Aseer** **3.Asad** **4. tasnimul**	**Connecting solar panel to the ssytem**	**Tasnimul** **Asad** **Aseer**	**N/A**
7.12.22	1.Saad 2.Aseer 3.Asad 4. tasnimul	Start preparing slides and finalzing draft report	All	Update needed
15.22.22	.Saad 2.Aseer 3.Asad 4. tasnimul	Make necessary updates in the report and mail to ATC	All	N/A