FAHAD BIN SULTAN UNIVERSITY
COLLEGE OF ENGINEERING
DEPARTMENT OF RENEWABLE ENERGY ENGINEERING

Optimized and Energy Efficient Desalination Utilizing Renewable Energy Integration Project

Final Year Project I (REE 498) Report

Presented to

Department of Renewable Energy Engineering

Team Members:

No.	Student Name	Student ID
1.	Seham Abdullah Alqubali	202015041
2.	Lama Muhannah Alsaadoun	202015039
3.	Hamzah Muhannah Alsadoun	202011076

Project Advisors:

Dr. Faraz Rasheed Mir

Dr. Abdullah Alali

19/6/2025

ABSTRACT

The objective of this thesis is to enhance the efficiency and consumption of primary desalination technologies, including reverse osmosis, multi-effect distillation, and multi-flash distillation. The thesis explores the potential of renewable energy sources, including solar, wind, and geothermal energy, to power these desalination technologies. This objective is pursued by employing models and algorithms for optimization. The objective of the final year project is to identify the most effective integration that optimizes energy efficiency, enhances production, and reduces costs. The thesis will assess a pilot-scale system that integrates renewable energy sources with a desalination technology to evaluate energy efficiency and effectiveness. An in-depth analysis of the technology, economic factors, and environmental impacts associated with the system will be conducted to ascertain its feasibility and potential for large-scale implementation.

ACKNOWLEDGEMENT

We extend our deepest gratitude to our advisors, Dr. Faraz and Dr. Abdullah, for their invaluable support throughout this project. We are especially thankful to Dr. Faraz for his dedication and unwavering commitment from the very first day. His insightful feedback, continuous encouragement, and expertise have been instrumental in shaping our work.

STATEMENT

This is to confirm that the project titled Optimized and Energy Efficient Desalination Utilizing Renewable Energy Integration is an original work, and all the design, analysis, and related tasks have been accomplished by the group consisting of Lama Alsadoun, Hamzah Alsadoun, and Seham Alqubali, under the supervision of Dr. Faraz Mir and Dr. Abdullah Alali. Any assistance or contributions from others are properly acknowledged.

LIST OF ABBREVIATION

Abbreviation	Definition
BW	Brackish water
ED	Electrodialysis
FYP	Final year project
GHG	Greenhouse gas
GOR	Gain output ratio
MED	Multi-effect distillation
MSF	Multi-stage flash distillation
NF	Nanofiltration
PV	Photovoltaics
RE	Renewable energy
RES	Renewable Energy Sources
RO	Reverse osmosis
SW	Seawater
SWRO	Seawater reverse osmosis
TDS	Total dissolved solids
TRL	Technology readiness level
UN	United Nations
VC	Vapor compression

Units	Definition
Ah	Ampere-hour (battery capacity)
kg CO_2-eq	Kilograms of carbon dioxide equivalent
kWh	Kilowatt-hour (for energy consumption)
m^3	Cubic meters (for volume of water)
MW	Megawatt (for power levels)
°C	Degrees Celsius (for temperature)
ppm	Parts per million (for salinity levels)
US$/$m^3$	Cost per cubic meter
W/m^2	Watts per square meter (irradiance)

Table of Content

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Water is unquestionably the source of life on our planet and the driving force of human progress. As the world's population is growing and the pollution of existing natural water resources is increasing, water scarcity has increased significantly in recent years. The world population is expected to increase from 7.7 billion in 2017 to 9.4–10.2 billion by 2050, with two-thirds of the population residing in cities. At the same time, it is estimated that 50% of the countries on our planet could address water stress or water shortage by 2025, while by 2050, as much as 75% of the world's population could address water scarcity. Hence, the global scarcity of freshwater is a vital and serious humanitarian issue that has to be addressed. For this reason, most countries have been investigating alternatives to conventional water resources. Desalination is perceived as a viable and feasible solution to address this worldwide problem. In the desalination, the feed water is separated into two streams, the product stream (freshwater) and the by-product stream (brine). At the end of 2017, there were 19,372 desalination plants worldwide with a total desalination capacity of roughly 99.8 mil- lion m^3 /day. (Barcelo, 2019)

Potable water is very scarce in arid areas and the establishment of human habitats in such areas strongly hinge on how such water can be made available . Reverse osmosis (RO) has become the most commonly used and preferred desalination technology world-wide. With the rise in population and the increased demand for potable water there is a great need to come up with lasting solutions . Between 2008 and 2013 global desalination capacity grew Sea Water Reverse Osmosis Desalination: Energy and Economic Analysis by 57%. This movement is expected to continue for the following main reasons: population growth, traditional water resources are diminishing, and advances in membrane technology. Seawater desalination is a major contributor, with about 59% of global desalination capacity attributed to it. One of the major significant costs in the economics of desalination of water is energy costs, but the insufficiency of water is motivating the rapid growth and development of desalination facilities worldwide. Non-renewable conventional fossil fuels have been exploited as the main source of energy, but excessive emission of greenhouse gases, leading to global warming, has encouraged worldwide development and implementation of minimal energy use strategies and green energy supplies. Several advancements of RO technology have occurred recently and research continues to be carried out to improve this process. (Nucbe, 2019)

1.1 Background

Water and energy are inseparable sources which interchangeably affect each other. Producing fresh water by desalination requires energy which is conventionally supplied from fossil fuels. Similarly, water is required in the extraction and refining of fossil fuels. These processes, as well as burning fossil fuels to produce energy for desalination, have severe harmful impacts on the environment due to the greenhouse gas (GHG) emissions. By 2050, the worldwide emission from desalination processes is expected to reach 0.4 billion tons of CO2 equivalents per year. Therefore, the growing demand for clean water will not only cause a depletion of fossil fuels but also significant damage to our environment. Relying on fossil fuels as the main energy source for desalination also affects the process economics due to the rapid changes in the cost of fossil fuels. Thus using renewable energy sources for desalination is essential to provide a suitable supply of clean water to meet our future needs and reduce the harmful effects on the environment. ((R. Hashaikeh), 2020)

1.1.1 Problem Statement

The world is witnessing a water crisis that has raised great concern, as many people suffer from a lack of this essential resource, leading to significant environmental and economic impacts. In the year 2025, nearly two thirds of the world population will be subjected to water shortages, according to the United Nations. With climate change prominent, the relevant problem of searching for sustainable solutions is pressing (Water, 2024). Water technology has become a key solution to the problem of fresh water shortages around the world. Key technologies include reverse osmosis (RO), multi-stage instant distillation (MSF) and multi-effect distillation (MED). It is also known that RO is cost-effective in relation to energy expenditure compared to the other thermal processes, but the process still consumes a lot of energy and produces very large amounts of salt water, which results in environmental pollution. Such processes as MED and MSF, on the contrary, are fuel and energy intensive processes and are fossil fuel dependent thus adding to greenhouse gas emission as well. However, regarding high energy consumption, due to the very high costs of these methods, they have become one of the major challenges facing many developing countries. Desalination technologies utilizing renewable sources like solar, wind, and geothermal energy can represent a strategic perspective in minimizing the negative impact on the environment and the costs of clients while carrying out the functions. This study is also perfectly consistent with Saudi Vision 2030 by using sustainable strategies in energy provision, which leads to improving the Kingdom's global position, economic development, and environmental protection. This concludes that the thesis advances the Vision's agenda of enhancing modernization and protecting the climate by pursuing water security through the resourceful incorporation of renewable sources into desalination technologies. More research is needed on the integration process to ensure these sources are optimally integrated into desalination systems. The main purpose of this thesis is to address this gap in knowledge by developing optimization models and assessing the combination of renewable energy sources with desalination systems at Technology Readiness Levels (TRL) 5-6. At these levels, the focus is on verifying the individual elements of the system, as well as the joint work of the elements in a stand-alone system under conditions which model the operational atmosphere in order to test performance and track problems. It will be also the added analysis of techno-economics as well as environmental studies to determine the viability and expandability potential of such systems.

1.1.2 Objectives of the Study

1. Evaluate Desalination Technologies: The first objective is to analyze in-depth the performance with regard to energy consumption of diverse desalination technologies such as, reverse osmosis (RO), multi-effect distillation (MED), and multi-stage flash distillation (MSF). These quantitative methods will also rely on comparative analysis of various alternatives in order to identify the possible approach and appropriate model of system components and design criteria taking into account the prevailing situation. Furthermore, energy requirements, water quality aspects and environmental impact considerations will be analyzed thoroughly and based on facts.

2. Investigate Renewable Energy Option Integration: The second specific objective is to assess the potential of integrating renewable energies such as solar, wind and geothermal energy into desalination processes. This thesis will focus on the use of renewable energy to provide and enhance the sustainability and efficiency of water desalination systems, as well as its cost and impact on the environment. The results will provide practical insights into how feasible it is to use renewable energy for water production.

3. Formulation of the Optimization Model: The third targeted objective is to build optimization models that will be used to determine the most suitable arrangement and operating procedures for integrating renewable energy sources into desalination units. This thesis aims to address such issues as energy use, water generation within the econometric performance of the overall assimilation to optimize minimalist solutions.

4. Test at TRL 5-6: This focus centers around the simulation and evaluation of an integrated renewable energy-desalination system at Technology Readiness Levels (TRL) 5–6. At these levels, the technology undergoes testing in more realistic settings than the laboratory but remains within a controlled environment. This stage acts as a bridge that connects the proof-of-concept and operational deployment, enabling the possibility of the early identification of performance, energy usage, and integration problems under nearly actual conditions. Testing the system at TRL 5-6 allows for gaining confident insights into its functionality and efficiency. This phase ensures the collection of essential data for optimizing the model. It also contributes to the development and improvement of the system, making it ready for fieldwork.

5. Carry out Techno-Economic and Environmental Assessment: Lastly, the assessment will analyze techno-economic and environmental performance of the integrated systems as a whole. This assessment will determine whether this technology can be expanded, taking into account life cycle costs, environmental impacts and its usefulness, especially in areas suffering from water scarcity. The outcomes will assist the decision makers, the industry and the researchers working towards addressing the sustainable water challenges.

1.1.3 Significance of the Research

The significance of the research lies in two aspects. Firstly, it innovatively integrates renewable energy to power desalination technologies. Secondly, it aligns with local goals and the Saudi Vision 2030, which promotes sustainability practices and a circular carbon economy. Finally, it aligns with NEOM's ambitious goals to build a fully sustainable and renewable energy city

2. LITERATURE REVIEW

2.1 Overview of Desalination Technologies

Sea water desalination is a process that separates saline water into two major components, the low dissolved salts concentration water stream (fresh or potable water) and the high dissolved salts concentration water, using several generally high energy and cost mechanisms. Reverse Osmosis (RO) is currently the most widely used technology owing to its continuous improvement in membrane technology and energy consumption rates, thereby increasing the throughput and efficiency of the technology. These improvements have led to a dramatic reduction of both the capital and the operational costs. Studies on reduction of energy consumption in desalination have been one of the major priorities in recent years and the results have been very significant. The incorporation of energy recovery devices has also led to major benefits in technology as some of the energy is recycled for productive use. Research and development of energy and cost-effective desalination technologies is an ongoing process as sources of fresh water continue to diminish at an alarming rate while at the same time the population growth is increasing dramatically. In this regard, RO has become the most viable technology in desalination. This paper seeks to analyze the effects of energy and costs of RO desalination technology. (Nucbe, 2019)

2.1.1 Reverse Osmosis

The most commonly used membrane-based technology for desalting saline water is the pressure-driven reverse osmosis (RO). In the RO, hydraulic pressure is applied to the compartment of higher salt concentration, forcing water molecules to move through a semipermeable membrane into the compartment of lower salt concentration. The applied pressure gradient has to overcome the difference in osmotic pressure between the feed brine (Πf) and the permeate liquid (Πp). The result is that the solute (concentrated brine) is retained on the pressurized side of the membrane, while the pure solvent (freshwater) allowed to cross on the other side. A typical schematic diagram of RO is presented in Figure 1. (Barcelo, 2019)

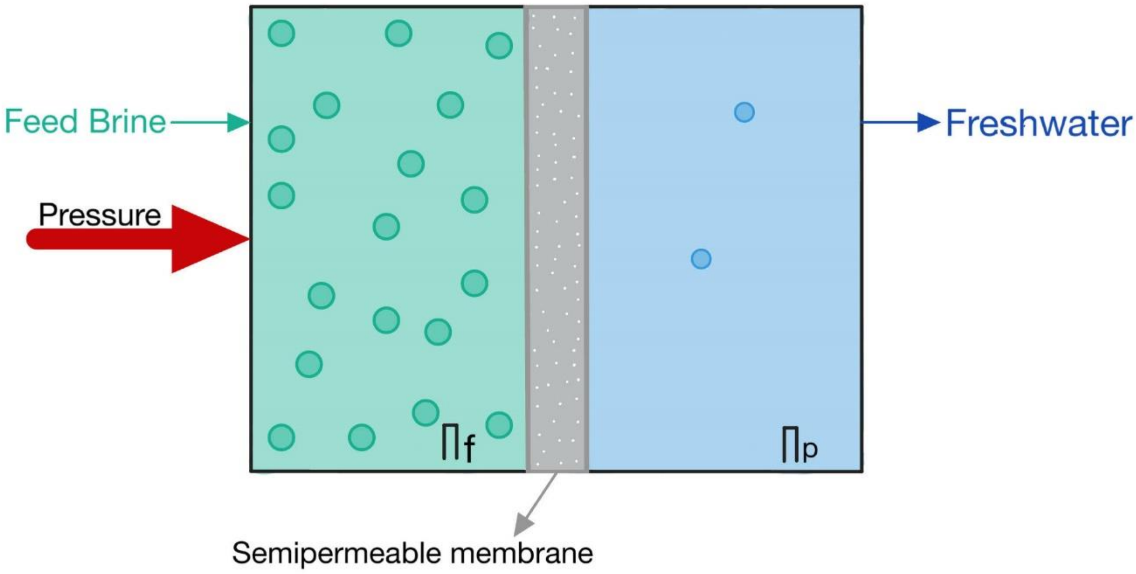

Figure 1 Typical schematic diagram of RO

2.1.2 Multi-Effect Distillation & Multi-Stage Flash Distillation

Multi-Stage Flash distillation (MSF) and Multi-Effect Distillation (MED) are the leading thermal-based desalination technologies. Al though these commercial technologies are originally developed for BW/SW desalination, they could be appropriate for brine treatment after material upgrades. In the MSF, the feed brine is preheated utilizing condensing vapors from the flash units and conclusively reaches a maximum temperature (up to 110–120 °C) with an external heat source, the brine heater. The hot feed brine is transferred through successively lower vapor pressure (and temperature) flash units in which a portion of the feed solution is evaporated and condensed in the feed preheat exchangers. Thus, the condensed water vapor is the freshwater whereas the concentrated brine is the liquid that exits from the final flash unit in the series. The MED technology is similar to the MSF, except that (i) vapor condensation occurs in heat exchange with the liquid in the subsequent distillation effect and (ii) the maximum temperature is up to 70–75 °C. A typical schematic diagrams of MSF and MED are illustrated in Figure 2 and Figure 3, respectively. (Barcelo, 2019)

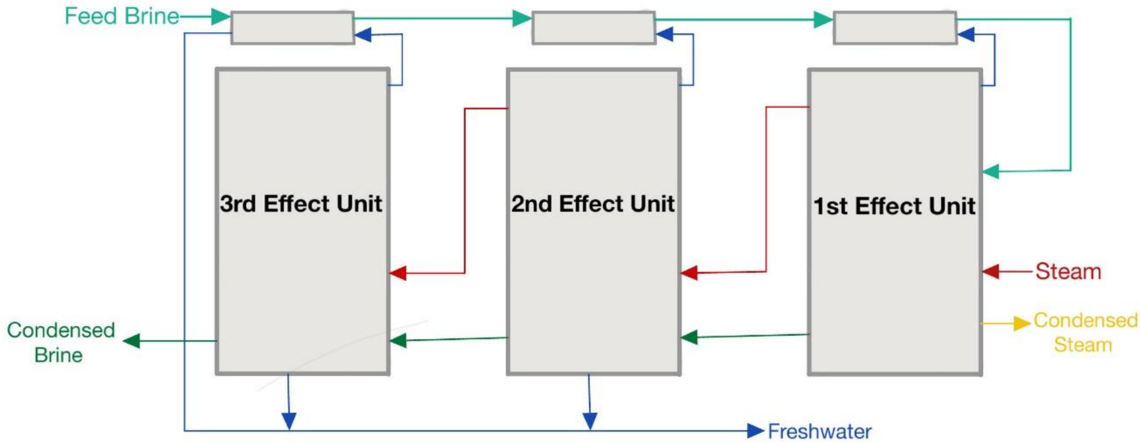

Figure 2 Typical schematic diagrams of MSF

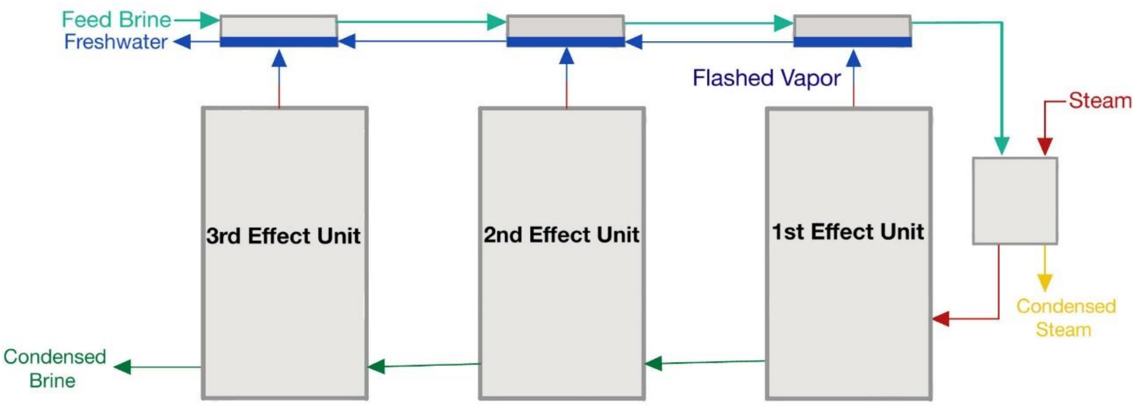

Figure 3 Typical schematics diagram of MED

2.2 Performance Metrics of Desalination Technologies

Gain Output Ratio (GOR) is a term extensively used to describe the efficiency of a distillation process. It is defined by the energy required to convert 1 kg of water into water vapor (latent heat). The authors also studied the impact of temperature drop across the effects on GOR and energy in a process with 8 effects. Their results showed that increasing the temperature drop across the effect leads to increased specific heat consumption and lower GOR. Amongst the different arrangements, parallel feed gives the best performance, which is why it is the most common one in Figure 4 and Figure 5. ((R. Hashaikeh), 2020)

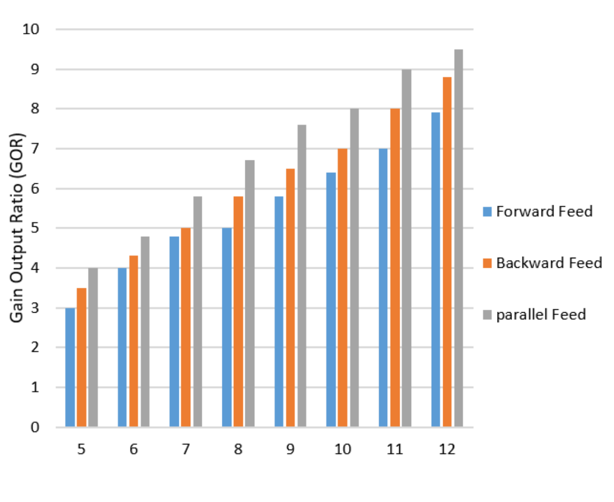

Figure 4 Gain output Ratio (GOR) ((R. Hashaikeh), 2020)

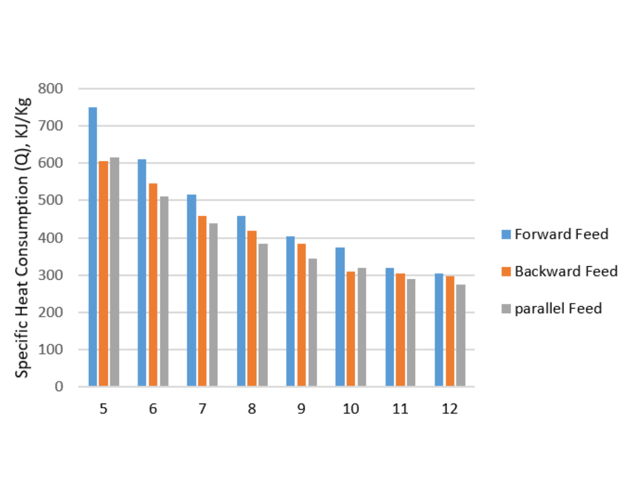

Figure 5 Specific Heat Consumption (Q), KJ/Kg ((R. Hashaikeh), 2020)

Energy efficiency evolution of reverse osmosis desalination has recently replaced thermal desalination technologies in many parts of the world due to their lower energy requirements. High-pressure pumps and energy recovery devices are crucial for improving RO efficiency in Table 1 and Table 2. ((R. Hashaikeh), 2020)

Table 1 Evolution in specific energy reduction for thermal and RO technologies in Spain. ((R. Hashaikeh), 2020)

Year	DesalinationTechnology	KW-h/m^3
1970	MSF	22
1980	MSF	18
1985	VC	15
1988	RO	13
1990	RO	8.5
1994	RO	6.2
1996	RO	5.3
1998	RO	4.8
1999	RO	4.5
2000	RO	4.0
2001	RO	3.7
2005	RO	3.5
2009	RO	3.0
		RO<3.0

Table 2 Required energy for producing 1 m^3 of drinking water from different water sources. ((R. Hashaikeh), 2020)

Water Source	Energy (kWh/m^3)
Surface water (lake or river)	0.37
Groundwater	0.48
Wastewater treatment	0.62-0.87
Wastewater reuse	1.0-2.5
Seawater	2.58-8.5

2.2.1 Energy Consumption in Desalination

Energy is a critical factor for socio-economic development and is also an important need in industrial growth, as is quality water. Water and energy are two inseparable commodities that govern the lives of humanity and promote civilization. Usage of renewable energy sources has been implemented in recent years but renewable sources have proven to have their own inherent disadvantages, including technological shortcomings and capital intensive installation costs. Energy source and energy efficiency needs to be considered in designing desalination systems as well as renewable sources and sustainability, therefore having in place the related infrastructure required to integrate advanced desalination solutions is important. The amount of energy (thermal and/or electrical) needed for a desalination plant depends on the technology used. Table 3 shows the typical values required for the production of 1 m^3 of water exclusive of the water transport. ((R. Hashaikeh), 2020)

Table 3 Typical energy requirements for different desalination techniques. ((R. Hashaikeh), 2020)

Process	Thermal Energy (kWh/m^3)	Electrical Energy (kWh/m^3)	Comments
MFS	12	3.5	Feed steam >100° C
MED	6	1.5	Can operate at < 70° C
RO	-	4-7	-
Note MSF-Multi-stage flash distillation; MED-Multi-effect distillation			

The only form of energy required in the RO process is electrical energy. A number of factors affect the energy consumption of the RO unit. One major factor is the salinity of feed water and the recovery rate of the system. Feed water with high-salinity requires a higher amount of energy owing to higher osmotic pressure. Osmotic pressure is associated with the concentration of total dissolved solids (TDS) of the feed water. RO units vary in size from very small units with a capacity of 0.1 m^3/day to very large units with a capacity of 395 000m^3/day. The average energy consumption reported ranges from 3.7 kWh/m^3 to 8 kWh/m^3. The consumption may surpass 15 kWh/m^3 for very small unit sizes. Several aspects such as process design, energy recovery system, waste water disposal system, quality of desalinated water, and the type of membrane, affect energy consumption. The leading factors in minimization of energy usage in RO desalination processes can be categorized as follows: enhanced system design, energy recovery, high efficiency pumping, innovative technologies, and advanced membrane materials. Figure 6 shows the various components of an RO system and their respective energy usage. ((R. Hashaikeh), 2020)

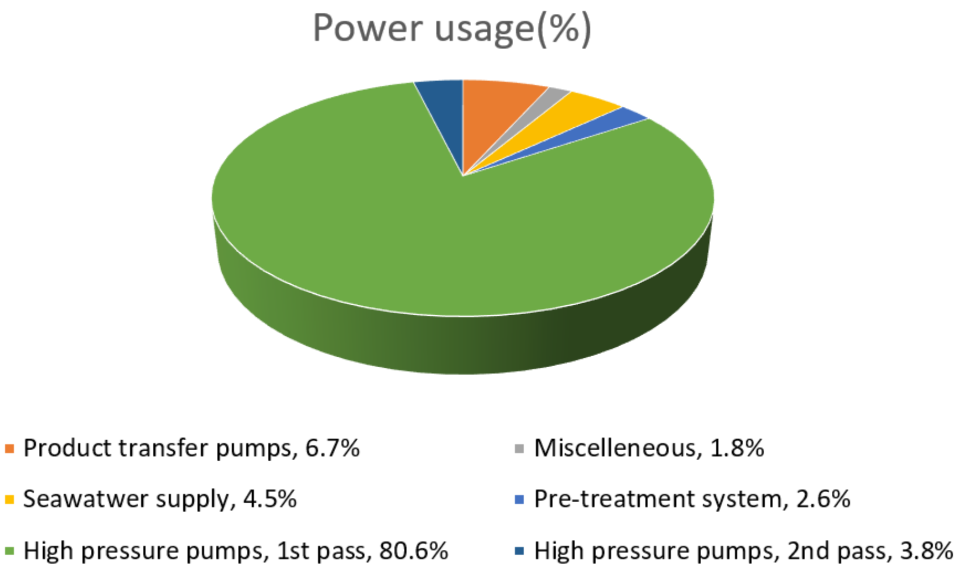

Figure 6 Different components and their power usage in a RO. ((R. Hashaikeh), 2020)

2.3 Renewable Energy Sources for Desalination

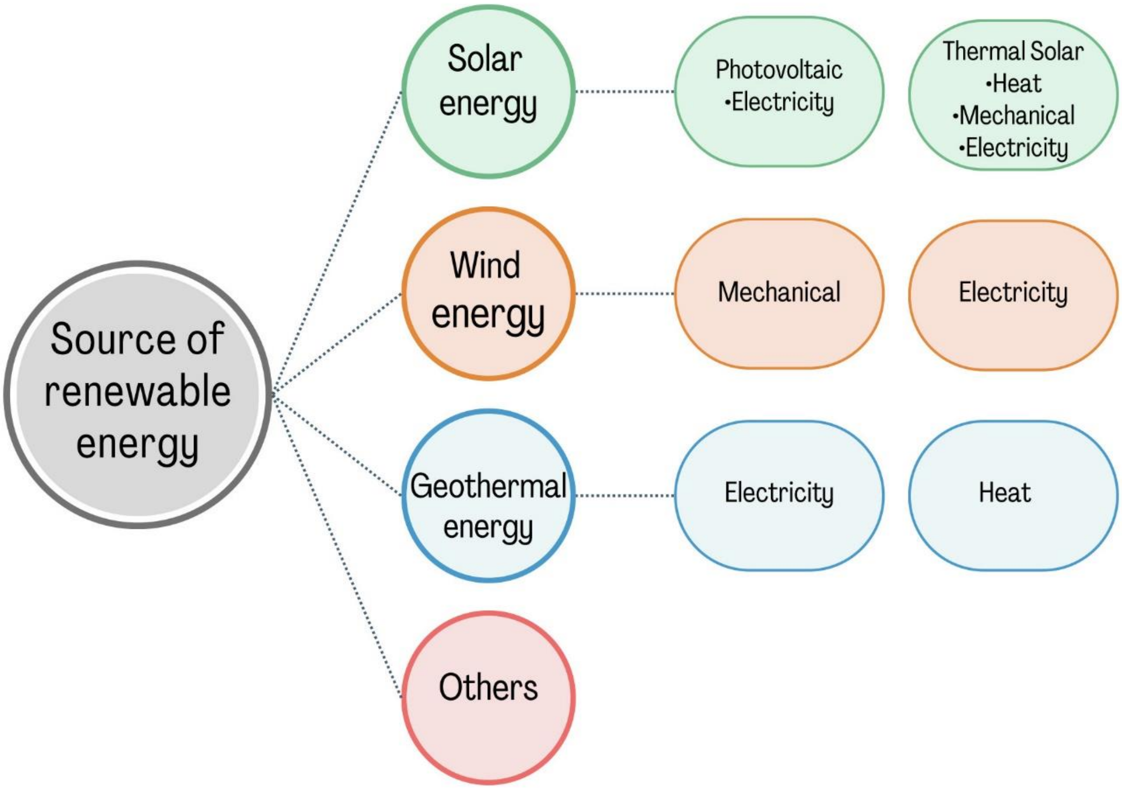

Figure 7 Types of renewable energy sources for desalination technologies. ((R. Hashaikeh), 2020)

2.3.1 Solar Photovoltaics

Solar PV powered RO units have reported to have better socio-economic benefits compared to those powered by diesel . The efficiency of the RO unit powered by solar PV depends upon the efficiency of all its individual components. For example, a small-scale solar PV-powered reverse osmosis desalination plant in Jeddah, Saudi Arabia, was developed with a capacity of 1.2 gallons/min, sufficient to fulfil the drinking water demands of about 250 residents. ((R. Hashaikeh), 2020)

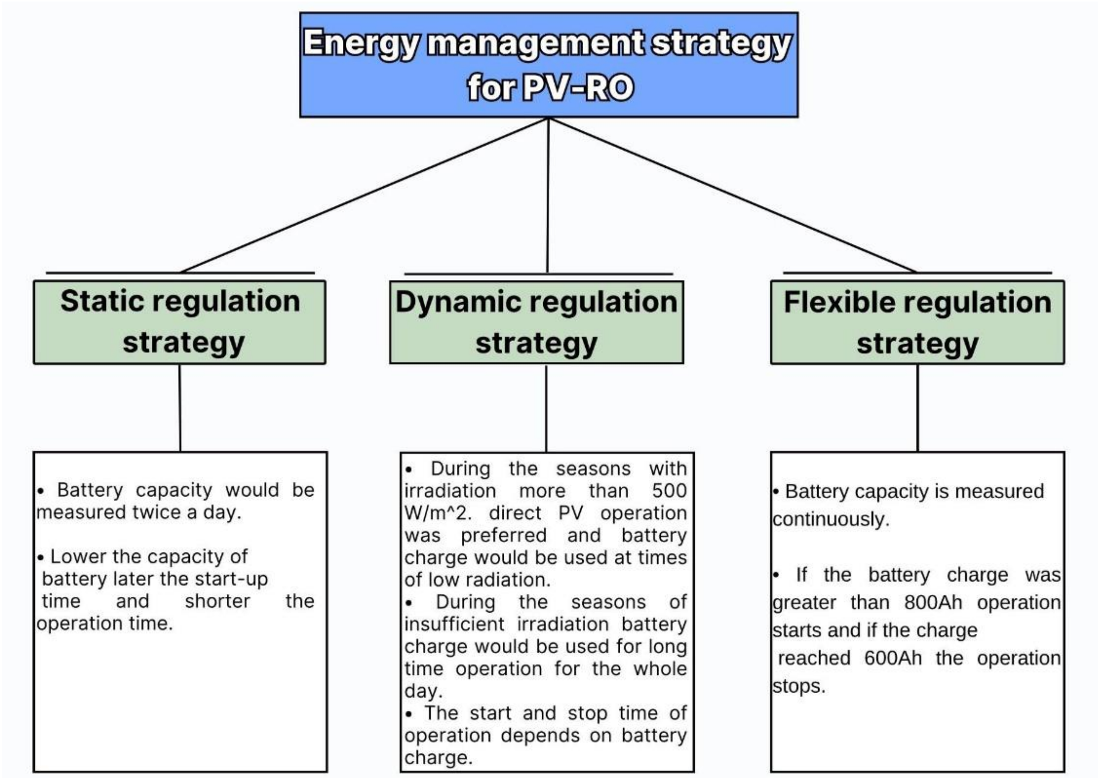

Figure 8 Energy management strategy for so solar PV-RO. ((R. Hashaikeh), 2020)

2.3.2 Wind Power

Wind energy has emerged as a valuable sustainable energy resource since the first inception of wind turbines in the 1970s. With wind turbines being commercially available, desalination using wind energy has become a promising technology, especially at places where there is a high availability of the resource. Huge development in this sector was observed from 2004 to 2015, whereby the installed wind energy capacity increased by almost 9 times. Mostly, wind-powered desalination systems are on a small scale. Isolated regions, such as islands, are a potential site for wind energy to power SW desalination plants. Such systems have the advantage of reduced water cost due to negligible water transport costs. Fresh water production cost from stand-alone units have been reported to be in the range from \$1.35–\$6.7 per m^3, compared to \$1.0 per m^3 for RO. The water cost is directly related to the efficiency of the wind turbines, which in turn generate the electricity. Theoretically reported maximum aerodynamic conversion efficiency for such wind turbines is reported to be 59%. With improved blades, efficiency as high as 45% have been achieved. Improved blade materials and efficient power storage systems can provide further improvements. For example, it was reported that about 40% decrease in blade weight can decrease capital cost by 20–25%. performed a theoretical economic analysis of a wind farm with five wind turbines of 2 MW each. Results showed that in a region of northern Algeria, wind energy could successfully power a SWRO desalination plant. ((R. Hashaikeh), 2020)

2.3.3 Geothermal Energy

Energy generation from on-shore high-enthalpy geothermal resources (>150°C) has become a mature technology over the past decades. One of the first studies on geothermal-based desalination was reported in 1976 by Awerbuch et al. Geothermal reservoirs can be used to generate heat and electricity from their steam and hot water, thus, making it a potential RE source for both thermal and membrane desalination processes. One major advantage of geothermal energy is that there is no need for thermal storage, and thus can supply quite stable energy output compared to the other RE sources such as the solar and wind. ((R. Hashaikeh), 2020)

A relatively constant ground temperature is encountered below a certain depth, and thus geothermal reservoirs below 100 m can be used to power desalination plants. Geothermal energy can provide both electricity and thermal energy. This makes it easier to couple with almost all the existing desalination technologies, both thermal and membrane-based. Huge energy savings through geothermal heating are reported, which otherwise not possible through other RE sources, as shown in Figure 9. Various projects have been implemented all over the world , which showed that a geothermal source having temperatures between 80 and 100°C, is enough to produce fresh water at a cost of 2 US\$/m^3. Geothermal has potential to power small-scale, middle-scale and large-scale desalination plants, with the present largest one having a productivity of about a million m^3/day. ((R. Hashaikeh), 2020)

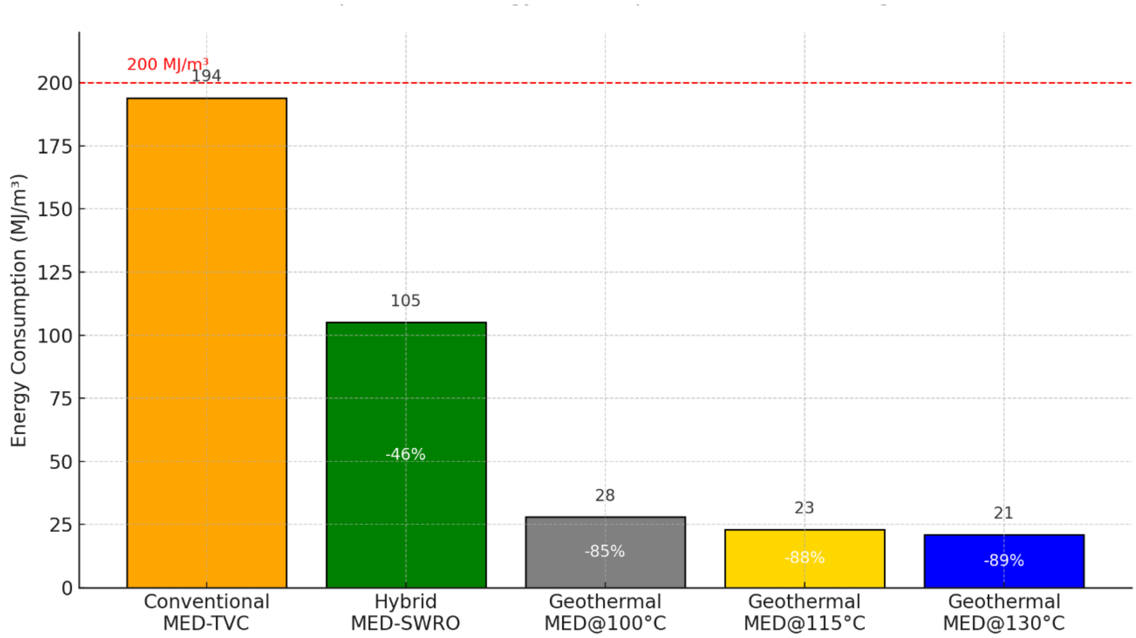

Figure 9 Potential energy savings on using geothermal-assisted MED at different source temperature. ((R. Hashaikeh), 2020)

2.4 Integration of Renewable Energy with Desalination

Renewable energy sources, such as the solar, wind, and geothermal energies, will hopefully bring about environmental sustainability, water security, and energy sustainability. Not every RE is applicable for all desalination technologies, while some are more suited for small-scale units rather than large plants. In addition, it depends upon several factors including energy accessibility, cost considerations, infrastructure, and government regulations.

By far, solar energy is the most widely used RE source for desalination, and hence has been used to power several existing desalination technologies such as MSF, VC, RO, ED, and NF. Solar energy can either be used as solar thermal energy to drive turbines, or can be harnessed directly as electricity. The most frequent combination is PV with RO. Apart from solar PV, solar collectors are also gaining considerable attention, with a thermal efficiency between 60% and 75%. The selection of using either direct solar energy or converting it to electricity for desalination depends upon the compatibility with the selected desalination process. ((R. Hashaikeh), 2020)

Solar Thermal Energy: The solar thermal process includes a solar collector, which is utilized for the absorption of solar radiation. The collected solar energy is converted to heat energy and then conveyed to fluid passing in the absorber. Such heat energy can be employed directly to operate thermal desalination or indirectly to operate membrane systems by the conversion of heat energy to both electrical and mechanical energy. Despite enhancement in the application of solar energy and improvement in its design for application with the water desalination systems, still, they are not practical for large-scale freshwater production. Moreover, the application of solar thermal-driven desalination is restricted to areas with significant exposure to sunlight and requirement for a huge area for operation. A great deal of investigations is focused on improving high-quality substances for effective conversion of sunlight to thermal energy. Regardless of such attempts, still, a shortcoming of how these material-dependent technologies can improve the total performance of solar thermal-driven desalination is obvious. Effective condensation and the recovery of latent heat from condensation are still challenges that must be addressed to render the solar thermal-based desalination process from techno-economic aspects feasible. (A.shokn, 2022)

Photovoltaic Solar Energy: By converting sunlight to electrical energy using an instrument with photovoltaic effects a solar photovoltaic energy system is fabricated. The photovoltaic effect is the indication of voltage variation due to light radiation on efficiently designed electrodes with a liquid or solid between them. Photovoltaic technology has turned into a promising option because of its increased lifetime, and reduction in operating and capital costs. However, challenges like fouling of photovoltaic panels reduce process performance and limit their energy. Moreover, usually, photovoltaic systems are applied in regions with significant solar radiation which increases their efficiency but simultaneously is challenging because of the requirement for the cooling process. Also, weathering and dust, reliance on climatic fluctuations, wind speed, and amount of humidity especially in hot areas are some of the conspicuous challenges which definitely affected energy loss. According to the intermittent nature of solar radiation, batteries are typically utilized to save energy in the photovoltaic system. The application of photovoltaic energy in the desalination process has been focused significantly on the RO because it demands electrical energy to operate and is the most superior desalination technology. The major purposes of most studies on integrated RO and photovoltaic are to explore the modifications for economic feasibility and flexibility to decrease location limitations. Hybridization of RO and photovoltaic with other RES eliminates both RO and photovoltaic limitations. (A.shokn, 2022)

Wind Energy: The application of the kinetic energy of air movement by employing a wind turbine and changing this kinetic energy to mechanical and then electrical energy. Wind energy is relatively inexpensive and significantly eco-friendly. Intermittent nature is regarded as the main restriction of wind energy, which as a result influences the regular energy generation because wind speed constantly is changing. More- over, wind energy is mainly available in remote areas, especially on coastlines. In order to alleviate the aforesaid challenge, its incorporation with a storage system, grid, or combination with other RES has been recommended and conducted (Lai et al., 2016). For example, because solar energy is only available during the day and wind speed is higher at night, to increase their synergistic effect, their hybridization is suggested. Wind energy is frequently utilized to drive RO systems. Ac-cording to the techno-economic studies of Tomaszewska et al. (2020) for wind application in RO plants, the cost for the production of drinkable water varies from 2962 to 6457 $\$/m^3$. The techno-economic feasibility of MVC and wind-based RO was explored by Forstmeier et al. (2007), whereas Jin et al. (2017) studied the effects of wind intermittency on the RO and recommended three solutions including the application of energy storage, integrated energy systems, and regulating RO capacity with a temporary energy supply. Rosales-Asensio et al. (2019) studied the economic analysis of a RO process operated by wind energy over the traditional energy sources utilizing the levelized cost of freshwater as the major factor and concludes that the wind-based RO process demonstrates a lower levelized cost for the freshwater production. The wind-driven desalination systems introduced until now which are not connected to a traditional grid are individual microgrids. These microgrids have not been designed to deal with large-scale desalination plants and limited explorations concerning their large-scale conduction were performed. A significant percentage of these microgrids have needed the integration of energy storage structures, predominantly batteries. Nevertheless, it is worth mentioning that the application of batteries is not a cost-effective option hence it is better to explore other stable energy sources like geothermal energy for the large-scale operation of desalination plants. (A.shokn, 2022)

Geothermal Energy: The heat that is derived from beneath the earth, in the type of either steam or hot water or a combination of them. Geothermal energy is classified into temperatures below 150°C or low temperatures and temperatures higher than 150°C or high temperatures. Generally, geothermal wells with a depth of 100 m can be safely utilized for the desalination process. Geothermal energy is a highly stable and eco-friendly RES. It offers regular heat flux, which renders it a remarkably reliable energy source. As a result, in the application of geothermal energy to desalination plants, the requirement for heat storage facilities is precluded. Typically, geothermal energy shows economic feasibility over solar energy sources. As a result, in regions with the availability of enough geothermal energy, this energy source can be highly beneficial, under the condition that by techno-economic evaluation its validity is confirmed. Moreover, since its operating costs are fairly low and also do not rely on weather fluctuations, its viability is ensured. However, the main restriction is the significant cost of power plants and the limited location for their activity. The geothermal plant is highly practical for thermal desalination operations because it offers a direct provision of heat energy. In other words, geothermal energy sources with temperatures varying from 80 to 100°C are available in large quantities over the world which is preferable for the MED process because it requires lower ranges of temperature for operation. Moreover, it can be converted to electrical and mechanical energy for application in membrane desalination operations. For example, in RO, mechanical energy is utilized in the pressure pump, which produces the required pressure to propel the feedwater towards the membrane. The low-temperature feedwater has a higher viscosity which requires higher pressure for the RO operations and, as a result, demands higher energy usage. Operating RO with a temperature tolerance varying from 20 to 35°C, geothermal waters with a proper salinity and temperature can be used as feed to generate freshwater. In this way, the required mechanical energy to pump cold water during the winter to some extent alleviated. Regardless of the two aforesaid methods, other techniques are available in which hot water is directed from the ground towards the circulation of energy-producing turbines and then goes to the MED plants. In this way, geothermal energy can be applied effectively to the operation of desalination plants, especially in areas with hyper-saline waters. In addition, not only geothermal energy can be utilized for operating desalination plants but also it can be properly treated if it has an acceptable amount of chemical components. Then this treated water can be utilized for crop irrigation or even serve as drinking water. Significant quantities of energy can be saved by geothermal heating compared with other RES. (A.shokn, 2022)

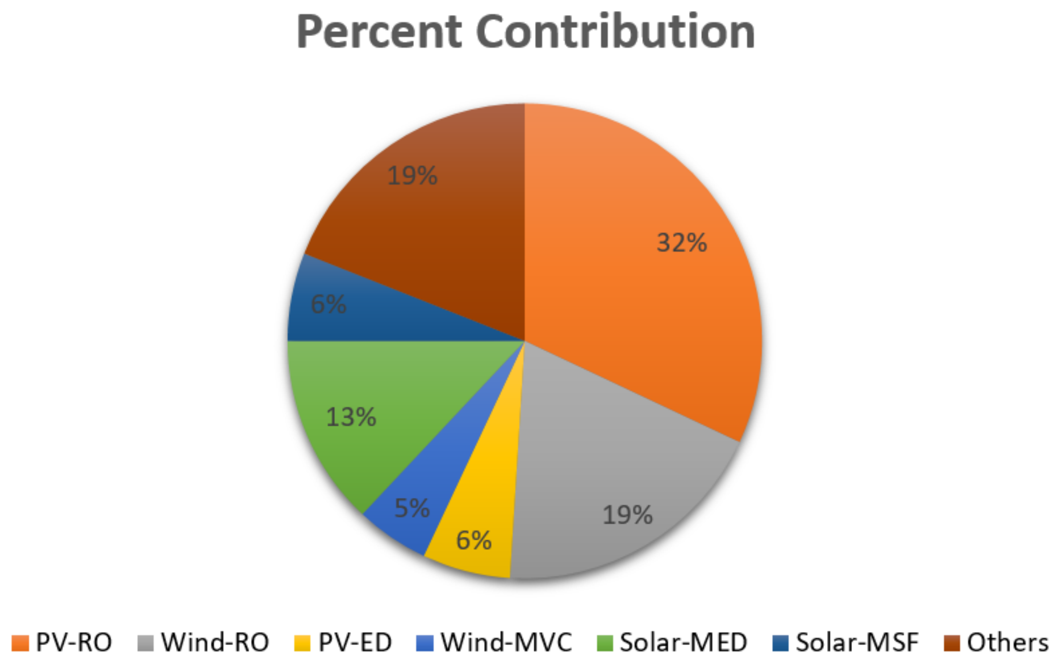

Figure 10 Current condition of solar energy combined with various desalination technologies. (A.shokn, 2022)

2.4.1 Conclusion and Future Plan

The global demand for fresh water is increasing rapidly due to population growth, climate change, and production. Consequently, The development of sustainable and effective desalination technologies is imperative. Conventional desalination technologies, such as reverse osmosis (RO), membrane distillation (MD), and multi-effect distillation (MED), are energy-intensive, with consumption ranging from 2.5 to 8 kWh/m^3. These technologies also have significant environmental impacts. To address these challenges, there is an imperative to integrate renewable energy sources, such as solar, wind, and geothermal energy, as an energy source. The FYP1 also reviews the fundamentals of these technologies, including their operational mechanisms, performance metrics, and energy requirements. The analysis indicates that reverse osmosis is the most widely used technology, primarily due to its comparatively efficient energy consumption in contrast to other thermal technologies, such as MSF and MED. Furthermore, FYP1 delves into performance metrics such as the gain output ratio (GOR) and specific energy consumption to assess the efficiency of these technologies. The evaluation will entail the measurement of water flow rate per unit area, with a target improvement of 15 to 20% in GOR. Additionally, FYP1 discusses the integration of diverse renewable energy technologies, including wind, solar, and geothermal, into desalination processes. The FYP1 provides a foundation for methodological and experimental work, wherein a pilot-scale desalination model will be designed. This model will be integrated with conventional energy sources and subsequently with renewable energy to evaluate its performance, energy efficiency, and water flow rate. Moreover, a comprehensive techno-economic and environmental assessment of the integrated system will be conducted to evaluate its viability and potential for large-scale deployment.

3 METHODOLOGY

Overview:

The proposed system is a Reverse Osmosis (RO) desalination unit designed to convert seawater into drinkable water. It follows a structured process involving intake and pre-treatment, reverse osmosis processing, and post-treatment with storage to ensure high-quality potable water. Each stage is designed to optimize efficiency and maximize water recovery while minimizing waste.

3.1 Description of the pilot setup / system

The pilot setup designed for this project is a membrane-based seawater desalination system, primarily utilizing reverse osmosis (RO). Seawater is first pumped from the seawater storage tank to the pre-filtration unit using a medium-pressure electric pump. The pre-filtration stage consists of three sequential filters: a Sediment Filter, followed by a Pre-Carbon Filter, and finally a Post-Carbon Filter. This step is intended to remove suspended particles, chlorine, and other impurities that may harm the RO membrane.

After pre-treatment, the partially filtered water is collected in a feed tank which supplies water to the high-pressure pump (HPP). The HPP pressurizes the feedwater and directs it into the RO membrane unit, where the separation process takes place. The RO system has two outputs:

- The permeate (filtered water) is directed to a mineralization (alkaline) filter to enhance water quality before being stored as drinkable water.
- The reject stream (brine) is discharged into a wastewater (brine) tank.

To increase the system's sustainability, the pumps are powered using solar energy harnessed from photovoltaic (PV) solar panels installed as part of the setup.

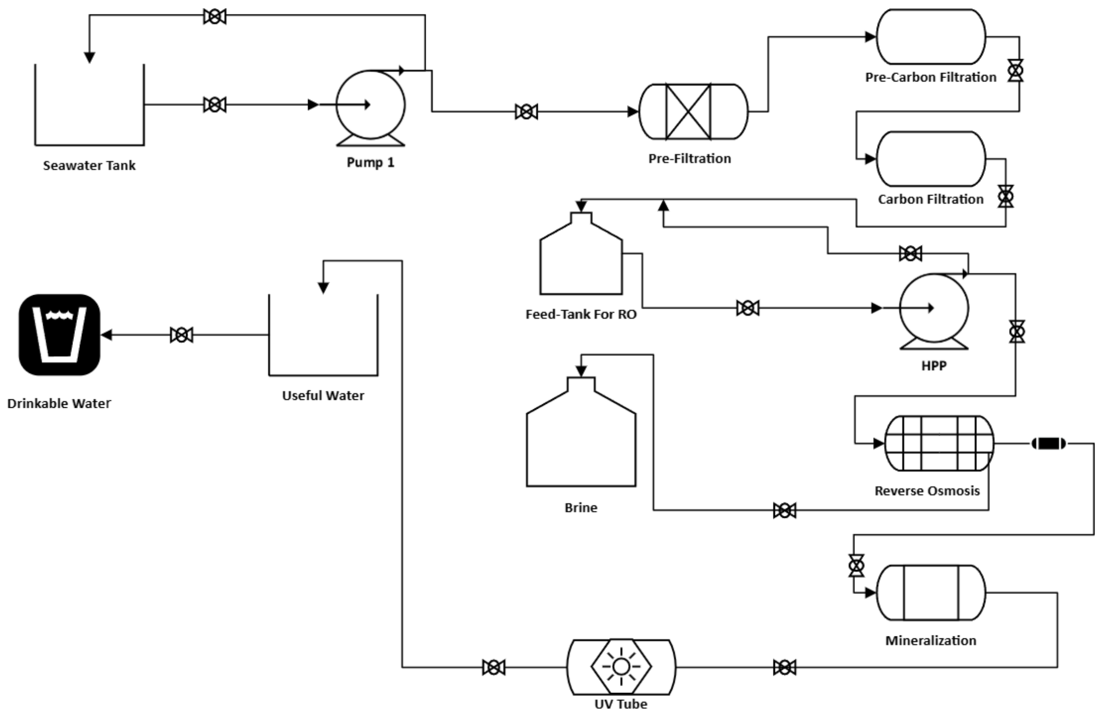

Figure 11 System Schematic and Flow Diagram

3.1.1 Materials used

Table 4 Materials Used (Membrane) (Pump (both medium and high pressure))

Component	Brand / Model	Function	Max Flow	Max Pressure
Sediment Filter	AquaDart – Diamond	Removes suspended solids (sand, rust, silt)	1.0 GPM	1.25 PSI
Pre-Carbon Filter	AquaDart – Diamond	Removes chlorine, VOCs, organics	1.0 GPM	1.25 PSI
Post-Carbon Filter	AquaDart – Diamond	Polishing stage, improves taste	1.0 GPM	1.25 PSI
Alkaline (Mineralization) Filter	M-PURE	Increases pH, adds minerals	100 L/h	5 bar
Reverse Osmosis (RO) Membrane	Likely Vontron 75 GPD	Salt rejection (up to 97–98%)	75 GPD (284 L/day)	60–100 PSI
Medium-Pressure Electric Pump	Generic	Transfers seawater through pre-filtration	3–5 L/min	6 bar
High-Pressure Pump (HPP)	Generic	Pressurizes feed water into RO membrane	1.5–2 L/min	10–11 bar
Seawater Feed Tank	HDPE	Stores raw seawater	—	—
RO Feed Tank	HDPE	Stores pre-filtered water	—	—
RO Feed Tank	HDPE	Collects concentrated brine	—	—
Potable Water Tank	HDPE	Stores desalinated water	—	—
Pressure Gauge	Analog Type	Monitors system pressure	—	0–25 bar
PVC/Plastic Hosing[i]	Generic	Connects pumps, filters, and tanks	—	8–12 bar

3.1.3 Experimental Results

Table 5 Experimental Results

Parameter	Experiment 1	Experiment 2	Experiment 3
Experiment No.	**1**	**2**	**3**
Water Source	Seawater	Seawater	Tap Water
Membrane Type (ppm)	1000	3500	3500
Feedwater Volume (L)	3	3	3
Runtime (min)	7	7	7
Flow Rate (L/min)	0.43	0.43	0.43
Energy Consumed (Wh)	0.91	0.91	0.91
TDS Feed (ppm)	4999	4999	450
TDS Permeate (ppm)	370	250	23
Salt Rejection (%)	92.6	95.0	94.7
Recovery Rate (%)	90	95	60

3.1.4 Experimental Procedure

Once all required materials and components were gathered, the system assembly began by individually testing the functionality of each pump. After confirming the pumps were operational, the plastic hosing was measured, cut, and connected to the valves and filters as per the system design.

Subsequently, the pumps were connected to the filtration system, and the entire setup was tested initially using tap water to ensure proper flow, pressure, and filtration. After successful trial runs, a tank was filled with seawater, and the system was operated under real conditions. During this phase, performance parameters such as flow rate, pressure, and output water quality were observed and recorded.

Renewable integration: (will be discussed once renewable energy is integrated)

3.2 Evaluation of Desalination Technologies/Best case study

Reverse Osmosis (RO) technology was chosen for several reasons, the most important of which are:

1- Its high efficiency in removing impurities and salts: RO systems have proven their effectiveness in removing a very large amount of salts and impurities, which enhances their effectiveness in converting seawater into drinking water.

2- Relatively low operating cost: Despite its high initial cost, the maintenance and operating cost is considered lower compared to some other technologies such as multi-stage distillation (MSF).

3- Ease of maintenance and operation: Although RO requires periodic maintenance, it is not complicated compared to other systems.

4- Low environmental impact: Due to its integration with renewable energy such as solar energy, which reduces carbon emissions and makes the water desalination process more sustainable.

3.2.1 Energy Consumption Analysis

The desalination system consists of two pumps, each with a power consumption of 58 watts. Therefore, the total power consumption for the pumps is:

$$\text{Total Power Consumption} = 2 \times 58\ \text{W} = 116\ \text{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(\mathbf{i})$$

Solar energy generation fluctuates throughout the day and across different seasons. To accurately model the system's performance, solar irradiance data will be used to simulate energy production over different time periods.

3.2.2 Solar Energy Generation

The energy generated by the solar panels is given by the equation:

$$P_{solar}(t) = A \cdot G(t) \cdot \eta_{solar} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(\mathbf{ii})$$

This model accounts for variations in solar power generation throughout the day and across seasons.

3.3 Wind Energy Generation

The power generated by the wind turbines is modeled by:

$$\text{Pwind}(t) = 1.2 \cdot \rho \cdot A\ \text{wind} \cdot v(t)^3 \cdot Cp \text{ ....}(\textbf{iii})$$

This equation models the wind power based on local wind conditions.

3.3.1 Hybrid Energy System Model

The hybrid system combines solar and wind energy to meet the system's total energy demand. The total power from both sources is:

$$\text{Ptotal}(t) = \text{Psolar}(t) + \text{Pwind}(t) \text{ ....}(\textbf{iv})$$

The system must ensure that energy generation satisfies the total energy demand at any given time:

$$\text{Ptotal}(t) \geq \text{Ptotal demand}(t) \text{ ....}(\textbf{v})$$

Where Ptotal demand(t) Ptotal demand(t) represents the system's energy consumption at time tt.

3.3.2 Optimization Model

The optimization model aims to minimize the energy mismatch between supply and demand, ensuring the system operates with maximum efficiency. The objective is to minimize the difference between the energy generated and consumed, using the following function:

$$\text{Min} \sum_T |\ \text{Ptotal}(t) - \text{Ptotal demand}(t)\ | \text{ ....}(\textbf{vi})$$

This optimization process will focus on determining the most efficient configuration of solar panels and wind turbines while considering constraints such as resource availability and system capacity. Optimization techniques will be employed to achieve an ideal balance between energy generation and consumption, ensuring sustainable system operation.

3.4 Performance Evaluation Equations

To accurately assess the performance of the desalination system, key performance indicators were calculated using the following equations. These metrics provide insights into the system's energy efficiency and water recovery under different operational conditions. The equations were applied to all experimental trials throughout this chapter

- Permeate-to-Energy Ratio (mL/Wh):

Permeate to Energy Ratio = Volume of produced water (L) / Energy consumed (Wh) .... (**vii**)

- Recovery Percentage (%):

Recovery (%) = Permeate volume / Permeate volume + Brine volume ....(**viii**)

- Salt Rejection

Salt Rejection (%) = (Permeate conductivity / Feed conductivity – 1) ....(**ix**)

4 Results and Discussion

Raw Data

The following table presents the raw data collected from a series of desalination experiments using different water sources (tap and seawater) under two operational cases. The impact of high-pressure pump settings (HHP) on water production efficiency was investigated. For each trial, the volume of permeate and brine was measured, along with the run time and calculated flow rate. Electrical energy consumption was estimated based on pump specifications.

Table 6 Results for Each Condition

	Case 1				
	Permeate (TDS, ppm)	Brine (TDS, ppm)	Energy (Wh)	Flow Rate (mL/min)	Run Time (min)
Tap Water	332	381	0.875	47.4	7
Seawater First Trial	720	^999	0.875	102.9	7
Seawater Final Trial	550	0	0.875	78.6	7
Pump 1 (bar)	7 to 8				
HHP (bar)	7 to 8				

	Case 2				
	Permeate (TDS, ppm)	Brine (TDS, ppm)	Energy (Wh)	Flow Rate (mL/min)	Run Time (min)
Tap Water	532	320	2.51	76	7
Seawater First Trial	720	877	2.51	102.9	7
Seawater Final Trial	932	0	2.51	133.1	7
Pump 1 (bar)	11				
HHP (bar)	10 to 11				

Table 5 presents a comparison between two operational models for a water desalination system using different water sources, including tap water and seawater. The results show that Model 2, which operated under higher pressure using a more powerful high-pressure pump, achieved better performance in terms of water flow rate and permeate volume. However, this improvement came with a higher energy consumption of 2.51 Wh, compared to 0.875 Wh in Model 1. Tap water appeared to be easier to process due to its lower TDS levels, but it resulted in lower flow rates compared to seawater in some instances. Additionally, the differences between the first and final trials in each model indicate system stabilization and improved performance over time. Overall, the data highlights the significant impact of pump pressure on the efficiency of the desalination process, where higher pressure leads to better productivity at the cost of increased energy usage.

Data Processing & Graphs

The graph illustrates the permeate-to-energy ratio (ml/Wh) for different water sources under two operational cases. In Model 1, the system demonstrated significantly higher energy efficiency, particularly during the first seawater trial, reaching 822.9 ml/Wh. Even the final seawater trial and tap water in Model 1 maintained relatively high ratios of 628.6 and 379.4 ml/Wh, respectively. In contrast, Model 2 showed a noticeable drop in efficiency across all water types, with the highest ratio being only 371.7 ml/Wh. This decline is directly related to the increased energy consumption observed in Model 2. The comparison highlights how pump selection and system pressure settings can greatly influence the energy efficiency of the desalination process.

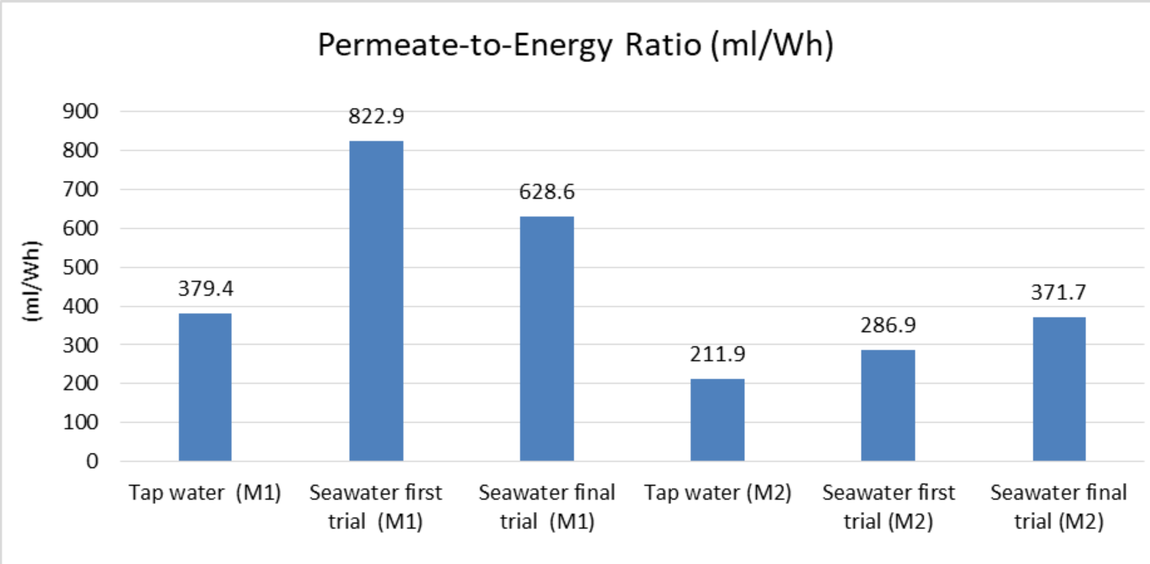

Figure 12 Permeate-to-Energy Ratio (ml/Wh)

The recovery percentage was highest in Model 2 with tap water, indicating efficient water recovery. For seawater cases, recovery was around 42–45%, which aligns with expected performance in small-scale RO systems.

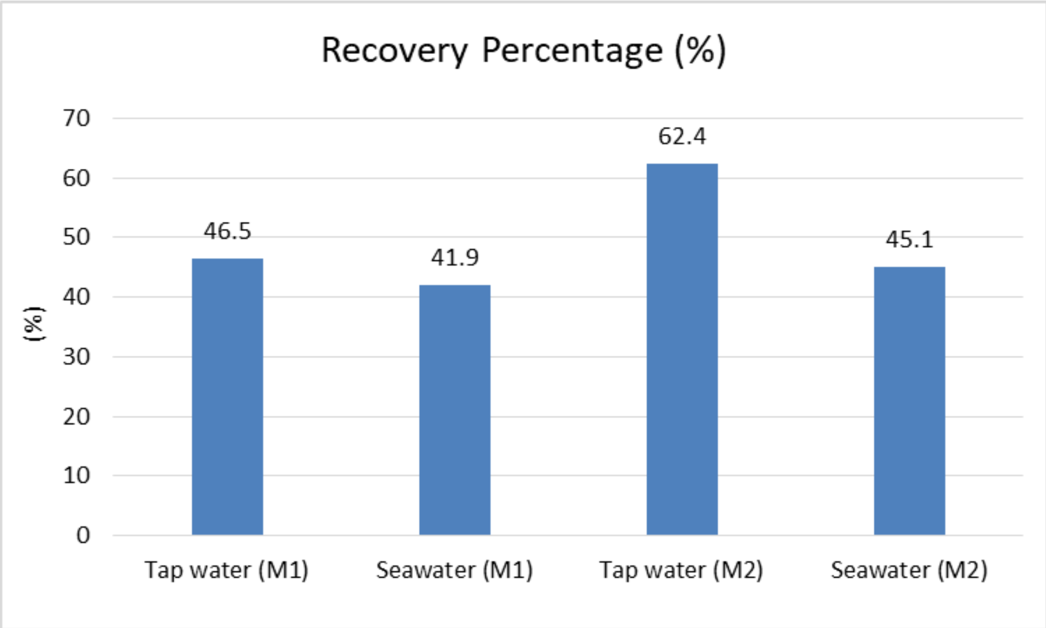

Figure 13 Recovery Percentage (%)

Despite the limitations, the results show that our custom-built system can produce a reasonable amount of permeate water with relatively low energy consumption, especially when optimized. This makes it promising for small-scale or off-grid desalination applications powered by renewable energy sources like solar or wind.

Membrane Performance and Experimental Results Discussion

In the first experiment, a membrane with a maximum salt tolerance (TDS) of 1000 (ppm) was used, and the experiment was conducted on seawater with a salinity of 4999 ppm. However, the membrane's performance was insufficient to effectively remove salts, as satisfactory reductions in salt concentration were not achieved. Based on this result, the membrane was replaced with another one that can tolerate up to 3500 ppm, since a high-pressure pump suitable for seawater salinity was not available. New experiments were then conducted to more accurately assess performance and achieve higher desalination efficiency.

The following table shows the values of the new membrane and its performance details in these experiments.

Table 7 Membrane Performance Results

Water Type	TDS level In (ppm)	TDS For Brine (ppm)	TDS For Permeate (ppm)	Flow rate (L/min)	Energy (Wh)	Permeate to Brine Ratio (%)
Tap Water	450	650	23	0.43	0.91	60
Seawater First Trial	4999	4999	250	0.43	0.91	10
Seawater Final Trial	4999	4999	370	0.43	0.91	5
Pressure (bar)	11					
Run Time (min)	7					

In the first experiment, using the membrane with lower tolerance, the salt removal was insufficient. However, with the new membrane, the salt concentration in the produced water decreased from 4999 ppm to 250 ppm in the first trial. Further optimization improved the system's performance, achieving a concentration of 370 ppm and a recovery rate of 5%, reflecting a significant increase in efficiency.

Experimental Results: Permeate-to-Energy and Recovery Rate

The following figures present the experimental results comparing system performance using tap water and seawater. Two key performance indicators were evaluated: permeate-to-energy ratio and recovery percentage.

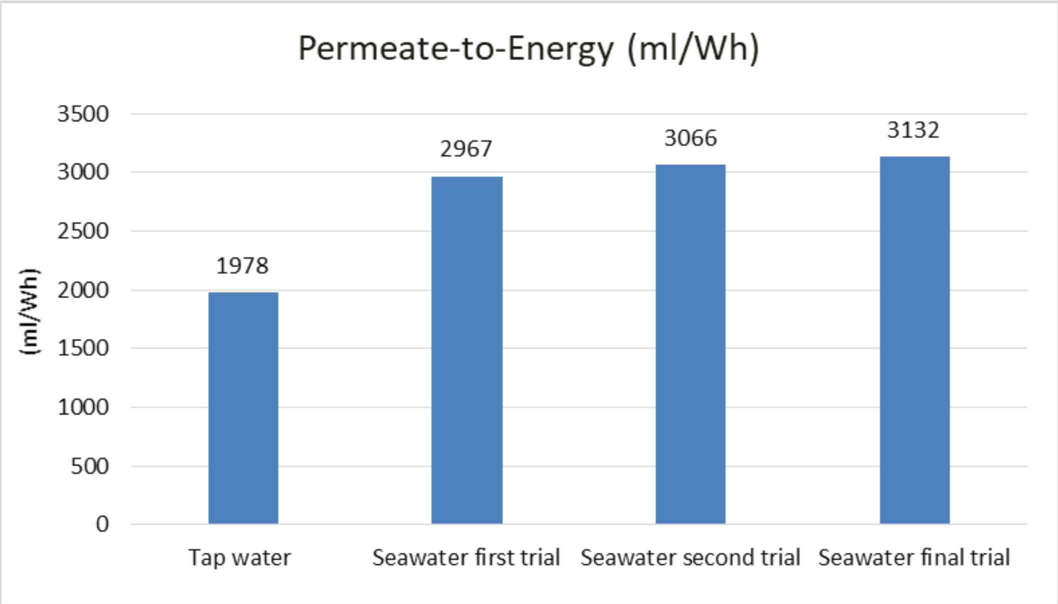

Figure 14 Permeate to Energy (ml/Wh)

The figure provides a comparative overview of the system's energy efficiency when treating different water sources. Tap water recorded the lowest permeate-to-energy ratio at 1978 mL/Wh, while the seawater trials showed noticeable improvements, reaching 2967 mL/Wh in the first trial, 3066 mL/Wh in an additional trial, and 3131.9 mL/Wh in the final trial. This upward trend suggests enhanced membrane performance and greater energy efficiency over time, potentially due to more stable operating conditions or improved membrane adaptation during repeated use.

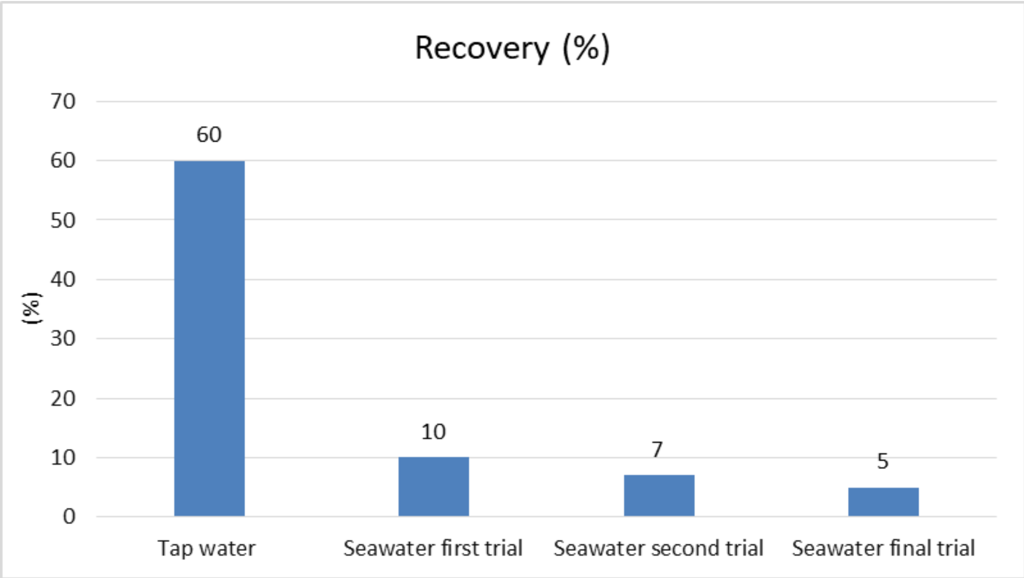

Figure 15 Recovery Rate Comparison

The figure provides a comparative overview of the recovery performance between tap water and seawater trials. As shown, the tap water trial achieved a recovery rate of 60%, while the seawater trials demonstrated significantly lower recovery rates of 10%, 7%, and 5%, respectively. This decrease in recovery for seawater may be attributed to higher salinity, membrane limitations, or increased fouling, despite improvements in permeate quality and energy efficiency.

Effect of Pressure on Recovery

Operating pressure plays a crucial role in determining the recovery rate in membrane-based desalination systems. As pressure increases, the driving force across the membrane is enhanced, facilitating greater water permeation and consequently improving recovery. A clear positive correlation between pressure and recovery was observed under the operating conditions of this experiment.

The system operated at an approximate pressure of 11 bar, which was the maximum output of the available medium-performance pump. Due to budget and sourcing constraints, higher-capacity pumps could not be obtained. Nevertheless, the selected pump was sufficient to demonstrate the relationship between pressure and recovery.

Although actual measurements were only conducted at 11 bar, an approximate graph was included to illustrate the general trend of how increasing pressure affects recovery. The values shown in the graph are approximate estimates for illustrative purposes and reflect the widely recognized trend that increasing pressure gradually leads to higher recovery rates in membrane desalination systems.

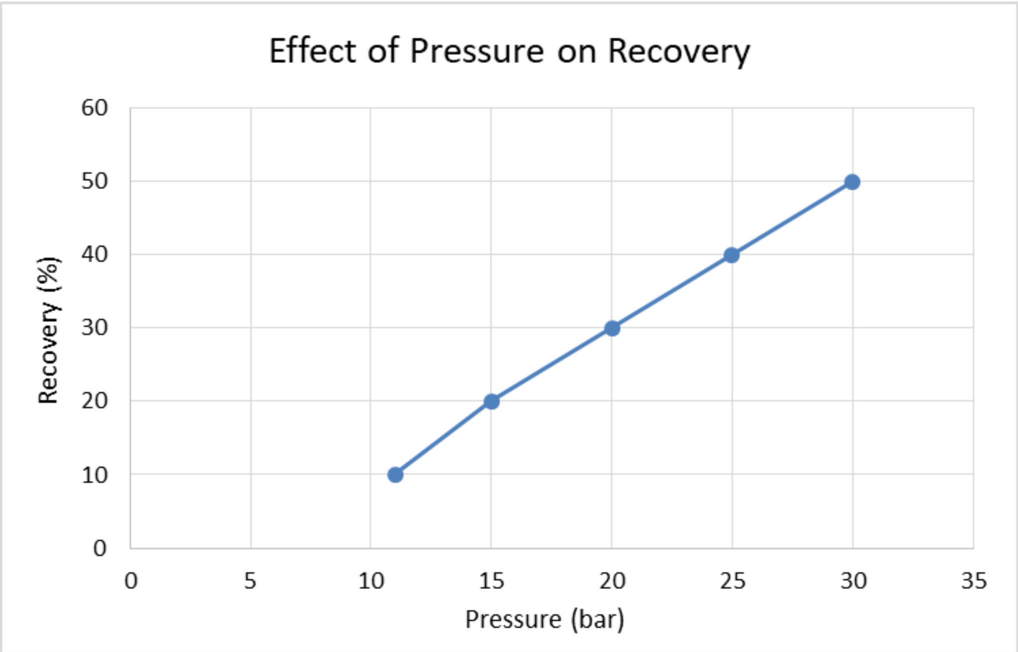

Figure 16 Effect of pressure on recovery rate in RO process (illustrative data). Adapted from (Kate McMordie Stoughton, 2013).

To assess the membrane’s effectiveness in removing dissolved salts, the salt rejection percentage was calculated for each water type based on the feed and permeate TDS values. This metric reflects the system’s ability to produce high-quality water under varying salinity conditions.

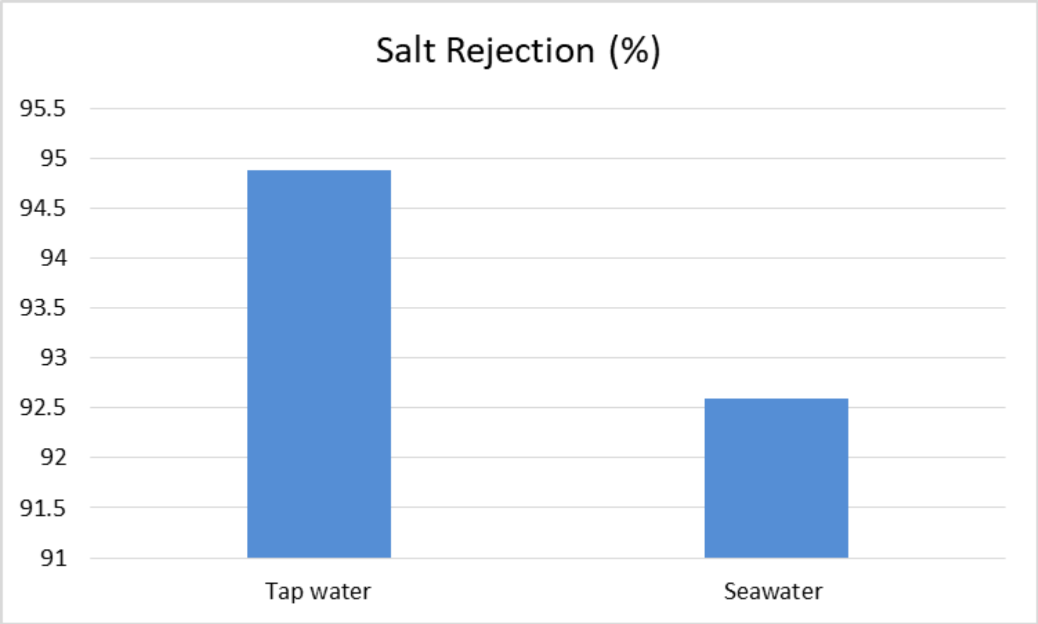

Figure 17 Salt Rejection Comparison

As illustrated in the figure, tap water achieved a salt rejection of approximately 94.89%, while the final seawater trial showed a slightly lower rejection of 92.60%. This decline may indicate a reduction in membrane performance due to factors such as fouling, partial clogging, or operational stress over time.

To further illustrate the effectiveness of the membrane in salt removal, the following figure presents a comparison between the feed and permeate TDS levels for both tap water and seawater trials. This visual representation highlights the significant reduction in salinity achieved through the membrane process.

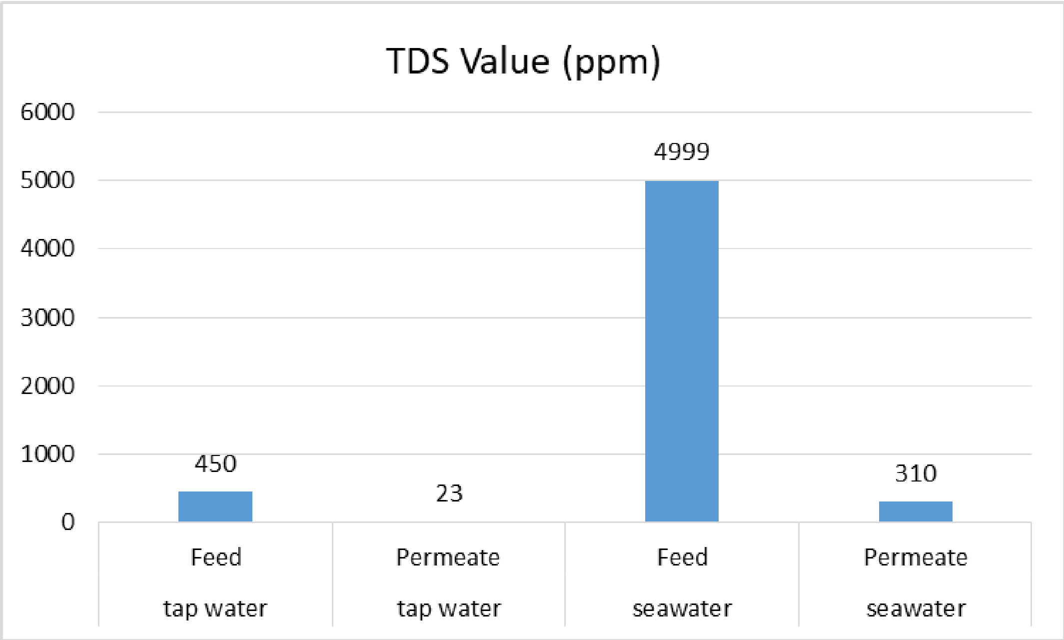

Figure 18 TDS Comparison: Tap and seawater

As shown in the figure, the membrane successfully reduced the salinity of tap water from 450 ppm to 23 ppm, and seawater from 4999 ppm to an average of 310 ppm. The considerable drop in TDS levels in both cases demonstrates the membrane's ability to maintain high rejection efficiency, even under varying salinity conditions. This reduction confirms the system's suitability for treating both low and high salinity sources.

Key Findings

During the experimental phase, the system faced several technical challenges that affected its overall efficiency. Initially, a membrane with a maximum salt tolerance of 1000 ppm was used. However, when tested with seawater containing a salinity of 4999 ppm, The membrane was unable to effectively remove salts because the applied pressure was too low, resulting in high salinity in the produced water and a significant drop in system performance. It was later determined that the main issue was salt buildup inside the membrane, which caused clogging, hindered water recovery, and reduced energy efficiency.

To address this problem, the membrane was replaced with another one that could tolerate up to 3500 ppm. Although this rating was still lower than the salinity of the seawater used, the system's performance improved noticeably. In the first trial using the new membrane, the TDS of the produced water was approximately 250 ppm. However, after extended operation, the concentration increased to 370 ppm, likely due to salt buildup and filter clogging during continuous use. During this phase, the recovery rate was around 10%. Improvements were also observed in energy efficiency and flow stability, due to reduced fouling and better membrane compatibility with the high-salinity feedwater.

When comparing both membranes, the second clearly outperformed the first in terms of salt rejection, recovery rate, and operational stability. The first membrane proved unsuitable for seawater treatment, leading to weak performance and a higher risk of clogging and failure.

One of the most critical factors influencing system performance was the pump. In the initial trials, a medium-performance pump was used due to resource constraints, which limited the operating pressure and, consequently, the system's overall efficiency. After replacing the membrane, it became clear that the pump's ability to provide sufficient pressure played a key role in improving water flow and recovery. Higher pressure resulted in increased water permeation through the membrane, leading to better flow rates and recovery percentages. However, the current pump's limitations prevented the system from reaching its full potential. Therefore, upgrading to a high-pressure pump is expected to have a direct and significant impact on water quality, flow rate, and overall system performance.

5 Conclusions and Recommendations

In this phase of the project, we successfully designed, built, and tested a small-scale seawater desalination system using reverse osmosis technology. The system was powered by solar energy and later tested with a combination of solar and wind to explore renewable integration. Through several trials, we evaluated the performance of the system in terms of salt rejection, energy consumption, and water recovery.

Although the first membrane used could not handle high salinity levels, replacing it with a better-suited membrane significantly improved the results. The system achieved a salt rejection of up to 95% and a permeate TDS as low as 250 ppm. We also noticed that pressure had a major impact on the efficiency of the system, and higher pressure led to better recovery rates and cleaner water.

While there were some challenges with equipment availability and system pressure, the results showed that renewable-powered desalination can work efficiently on a small scale. In the next phase, we aim to improve energy modeling, explore hybrid energy setups, and further optimize system components to enhance both efficiency and sustainability.

It is recommended to upgrade the current high-pressure pump to a model capable of delivering at least 19 to 20 bar, ensuring sufficient pressure for optimal membrane performance and improved salt rejection.

Future experiments should utilize a seawater-grade RO membrane with a TDS tolerance exceeding 5000 ppm, better aligning with the feedwater salinity and enhancing system efficiency.

Additional trials under variable solar and wind conditions are necessary to assess the reliability and stability of the system when powered by different renewable sources.

The pre-treatment process should be optimized to reduce the risk of membrane fouling and prolong the lifespan of the system components.

Long-term operational trials are recommended to evaluate the durability, maintenance requirements, and cost-effectiveness of the system under realistic environmental and operational scenarios.

6. Conclusion and Future Plan

Building upon the findings from this phase, the next stage of the project will focus on system optimization and validation under realistic and prolonged operating conditions. The plan includes:

Integration of an upgraded high-pressure pump to enable operations at pressures above 19 to 20 bar, ensuring better desalination efficiency.

Implementation of a seawater-grade RO membrane with higher salt rejection capabilities suited for the target feedwater salinity.

Development of a hybrid renewable energy setup, combining solar and wind power, with real-time monitoring of energy production and system performance.

Optimization of system configuration, including flow rate balancing, recovery rate improvements, and enhanced brine management strategies.

Comprehensive techno-economic and environmental assessment of the optimized system to determine its scalability and potential for deployment in remote or off-grid location

7. References

(R. Hashaikeh), (. H. (2020, June 8). Energy for desalination: A state-of-the-art review. *Desalination*, p. 44.

A.shokn. (2022, Aug 10). A sustainable approach in water desalination with the integration of renewable energy sources: Environmental engineering challenges . *Environmental Advances*, p. 19.

Barcelo, D. (2019, May 25). Desalination brine disposal methods and treatment technologies - A review. *Science os Total Enviroment*, p. 693.

Kate McMordie Stoughton, X. D. (2013, November). Reverse Osmosis Optimization. *U.S. Department of Energy – Federal Energy Management Program (FEMP)*.

Nucbe, R. &. (2019, December 12). SEA WATER REVERSE OSMOSIS DESALENATION: ENERGY AND ECONOMIC ANALYSIS. *International Journal of Mechanical Engineering and Technology (IJMET),* p. 731.

Water, U. (2024, Mar 22). Water Scarcity Overview Adressing Global Challenges .

8. Annex A: Materials and Specifications

Component	Type/Specification	Use/Placement	Index	Reference/Link
Sediment Filter	5 Micron, Polypropylene	First stage filtration	F1	—
Pre-Carbon Filter	Activated Carbon, 10" Cartridge	Removes chlorine and organics	F2	—
Post-Carbon Filter	Activated Carbon, 10" Cartridge	Improves taste and odor	F3	—
Alkaline Filter	Mineral Cartridge	Re-mineralization & pH balance	F4	—
RO Membrane	Vontron ULP1812-75, Max TDS: 2000 ppm	Main desalination unit	F5	(Membrane)
Medium-Pressure Pump	6 bar, 220V	Pre-filtration circulation	P1	(Pump (both medium and high pressure))
High-Pressure Pump	10–11 bar, 220V	Feeds RO membrane	P2	(Pump (both medium and high pressure))
Seawater Feed Tank	Plastic, ~50 L (pilot scale)	Initial seawater input	T1	—
RO Feed Tank	Plastic, ~30 L	Holds pre-filtered water	T2	—
Brine Tank	Plastic, ~20 L	Collects waste water	T3	—
Potable Water Tank	Plastic, ~20 L	Stores filtered water	T4	—
Pressure Gauge	Analog, 0–25 bar	Before RO membrane	G1	—
Hosing	PVC/Plastic, 0.5–0.75 inch, 8–12 bar	Connects system elements	C1	—
Valves & Connectors	PVC fittings	Flow control and sealing	C2	—
Mounts & Screws	Plastic/Metal	Assembly support	C3	—
Solar Panel	24V DC Output	Power supply	R1	—
Charge Controller	Compatible with 24V solar	Regulates charging	R2	—
Battery	12V, Rechargeable	Stores solar energy	R3	—

Final Year Project Team Contacts

Hamzah Alsadoun

HamzahAlsadoun@gmail.com | +966507640463 | LinkedIn: https://www.linkedin.com/in/hamzah-alsadoun

Seham Abdullah Alqubali

seham.alqubali@gmail.com | +966599468005 | LinkedIn: https://www.linkedin.com/in/seham-alqubali-b40b59216

Lama Alsaadoun

Lamalsadoun@gmail.com | +966538645689 | LinkedIn: https://www.linkedin.com/in/lama-alsaadoun-2092a7207