



Chemical Engineering Department-BIHE

Dissertation for Bachelor's Degree

**Investigation and feasibility study of renewable energy (solar,
wind energy) in order to supply electricity in the water
treatment industry in two regions of Iran**

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Acknowledgments

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Abstract

Today, in most parts of the world, especially in the Middle East, we face a severe shortage of fresh water, which is one of the primary human needs. Since freshwater resources are limited, desalinating water, such as brackish water and seawater, is more necessary than ever. In this article, we will review three types of water desalination methods. However, the remarkable thing about these methods is their electricity supply, which consumes much energy. Therefore, in this article, we discuss the feasibility and evaluation of the water treatment plant's electric energy supply by renewable energies (solar and wind) in two geographical regions of Iran. We carry out the necessary investigations from an economic and environmental point of view.

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Chapter 1

Introduction

1.1 Introduction:

There is a growing water shortage on Earth, a primary ingredient for life. Water shortages are expected to affect more people shortly. A part of this increase is due to population growth and a part to industrialization. Every 20 years, water consumption doubles. The availability of clean and fresh water is closely related to future peace and prosperity. In total, about 1.4 billion km³ of unmeasurable water on Earth, of which only 3% is fresh and accessible. The rest has been frozen in ice caps and glaciers, making it inaccessible. Approximately 77% of Earth's waters are stored underground, on the surface (lakes, swamps, rivers, etc.), in plants, and the atmosphere. Like fossil resources, these waters have accumulated over time and are nonrenewable. Rain is the only renewable natural source of fresh water; it occurs due to the global water cycle. The hydrological cycle of the world is illustrated in figure 1. Evaporation and transpiration from plants recycle much of the precipitation that falls on the Earth into the atmosphere. Approximately 26% of this cycle is devoted to human consumption. ¹

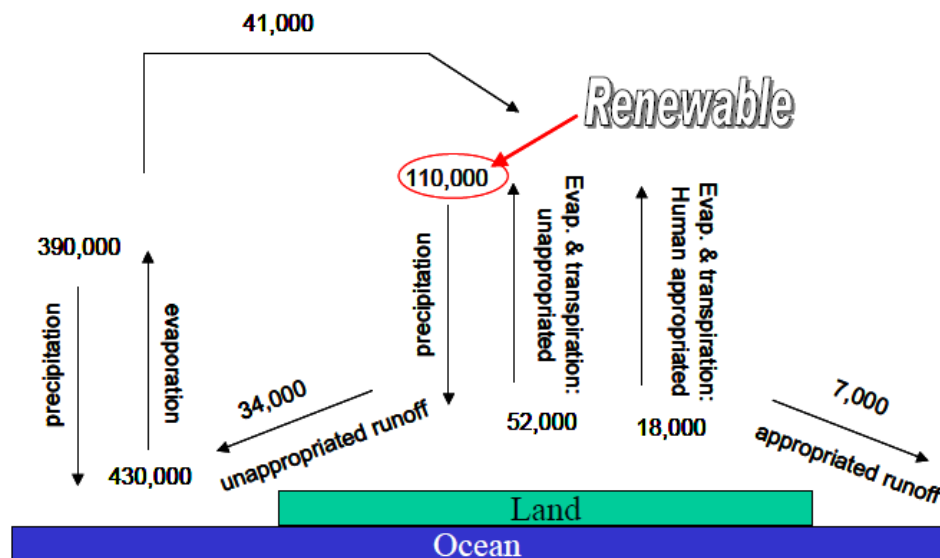


Figure 1 The global water cycle with estimates of flows and human appropriation. Units are km³/year.

A severe water deficit is observed in numerous thirsty and semi-arid regions. Since utmost of the water on Earth is salty, we need to purify it. For this purpose, there are different ways for desalination to purify saline water.²

Since Iran is located in a dry region, it is facing a deficit of fresh water, which is also included in the table from 2025.

Table 1 Distribution of renewable freshwater resources on a per capita basis

Country	Renewable Water (m ³ /year)				
	Total (km ³ /yr)	Per capita (2000)	Per capita (2025 low)	Per capita (2025 med.)	Per capita (2025 high)
Kuwait	0	0	0	0	0
United Arab Emirates	0	77	61	58	55
Saudi Arabia	2	118	63	59	56
Jordan	1	142	87	81	76
Libyan Arab Jamahiriya	1	151	107	100	95
Yemen	4	223	89	85	82
Oman	1	394	196	185	177
Tunisia	4	412	348	316	291
Israel	3	464	354	330	310
Algeria	14	472	361	335	313
Pakistan	255	1805	1063	1016	973
Iran (Islamic Republic of)	129	1827	1400	1293	1206
India	1908	1891	1511	1411	1323

Chapter 2

Basic Concepts

2.1 Water Quality Index:

An essential parameter of the water and wastewater quality index³:

Color of Water:

Water has a surface color that can be formed from the decomposition of organic matter and seepage through sewers. The main reason for the change in water color is water overuse, and the water level's lowering over time.

Taste of Water:

There can be different flavors in water. Flavors are generally classified into three categories: sweet, medium, and spicy. The taste of water is related to several factors, including decaying organic matter, living organisms, iron, etc. The presence of natural salts in water is responsible for its average taste. Sewage leakage, excessive pumping of underground water, disposal of residential waste, etc., are among the factors that change the taste of underground water.

Smell/ Odor of Water:

The smell of water is classified into three categories: no scent, mild smell, and pungent smell. The smell of water is usually due to sewage leakage in it.

Total Dissolved Solids (TDS):

Water can dissolve a wide range of minerals and inorganic solutes such as potassium, sodium, bicarbonates, chlorides, sulfates, etc. These minerals create an unwanted taste and dilute color in the appearance of water. Total solids dissolved (TDS) in drinking water originate in many ways, from sewage to industrial, municipal, etc. Therefore, the test is considered an indicator to determine the general quality of water.

Electrical Conductivity (EC):

Pure water is an excellent insulator, not a conductor of electric current—the electric conductivity of water increases as the ion concentration increases. The amount of solids dissolved in water determines its electrical conductivity. The ionic strength of a solution allows it to conduct a current that determines electrical conductivity (EC). According to WHO guidelines, a value of 400 $\mu\text{m}/\text{cm}$ is considered the maximum EC value.

pH of Water:

Hydrogen ion concentration in water determines the pH purity of water. This value varies from 0-14. The pH of water with a value of 7 is considered neutral. A pH of less than seven acidic makes the water toxic, and a pH of more than seven basic gives water a bitter taste. pH levels in water should range between 6.5 and 8.5 according to WHO standards.

Bicarbonates (HCO_3):

Water's bicarbonate concentration depends on pH and is typically less than 500 mg/lit in underground water. Almost all surface and underground water contain these alkaline compounds, which are affected by the alkalinity and hardness of the water. Weathering of rocks increases the level of bicarbonate in water. Magnesium and calcium bicarbonates are considered to be the major factors of water hardness because most bicarbonates are soluble in water. WHO does not recommend a certain amount of bicarbonate.

Chloride (Cl):

Chloride is mainly obtained from dissolved salt hydrochloric acids such as salt NaCl and NaCO_2 and is added through industrial waste, sewage, seawater, etc. It especially affects the metabolic activity of the human body and other physiological processes. In addition to damaging pipes and metal structures, the high chloride concentration also stunts plants' growth. According to WHO standards, chloride concentrations should not exceed 250 mg/lit.

Sulfate (SO_4):

Sulfate is mainly obtained from the dissolution of sulfuric acid salts and is present in almost all waters. The high sulfate concentration may be due to the oxidation of Pynte and drainage of the mine, etc. The sulfate concentration in natural water varies from several to several hundred milligrams per liter. This is even though it has no adverse effect on the health of the human body. WHO has named 250mg/lit as the highest usable limit of sulfate in drinking water.

Magnesium (Mg):

Magnesium is abundant in the Earth's crust and a natural water component. It is essential for living organisms and is found in minerals such as dolomite and magnesite. There are about 25 grams of

magnesium in the human body, 60% in bones and 40% in tissues and muscles. According to the WHO standard, magnesium in water should be 150 mg/lit.

Calcium (Ca):

Calcium is abundant in the Earth's crust and is very important to the physiology of human cells and bones. Around 97% of the calcium in the body is stored in bones and teeth. High calcium deficiency leads to diseases such as rickets, bone fractures, etc., and calcium excess leads to cardiovascular problems. As per WHO recommendations, the usable amount of drinking water is 75 mg/lit. An adult need 1000 mg/day to better function.

Hardness:

Hard water containing minerals is referred to as calcium carbonate. Hard water mainly contains calcium, and carbonates are the most dissolved ions in hard water. According to the WHO, the water hardness is roughly 500 mg/lit.

Sodium (Na):

There is a small amount of sodium in water. A sufficient amount of sodium in the human body prevents many diseases, such as kidney damage, high blood pressure, etc. In some countries, the amount of sodium in water is about 20 mg/lit; in others, the amount of sodium is more than 250 mg/lit. This is while the WHO standards have considered the amount of sodium in drinking water to be 200 mg/lit.

Potassium (K):

Potassium is an element that is highly reactive with water and is essential for the functioning of body organisms and protects the heart, blood pressure regulation, muscle contraction, etc. Therefore, it is present in all body tissues, even plant cells. The amount of potassium in the human body is between 110-140 grams. Potassium deficiency leads to depression, muscle weakness, etc. According to the WHO standards, the amount of potassium in drinking water is 12 mg/lit.

Nitrate (NO₃):

Nitrate is one of the most important diseases that cause water quality parameters, especially blue baby syndrome. Nitrogen sources include the nitrogen cycle, industrial waste, nitrogen fertilizers, etc. The WHO authorizes the maximum amount of nitrate in drinking water at 10 mg/lit.

COD:

Chemical oxygen demand (COD) in oxygen measurement is a sample susceptible to oxidation by a strong chemical oxidant. Oxygen requirement is determined by measuring the amount of oxygen consumed using titrimetric or photometric methods. The chemical oxygen demand test uses a strong chemical oxidant in an acid solution and heat to oxidize organic carbon to CO₂ and H₂O. This test is not affected by toxic substances. Furthermore, the test data are ready within 1-3 hours, making water quality assessment and process control faster.⁴ So, COD is the amount of dissolved oxygen that must be present in water to oxidize chemical substances such as oil. It is used to measure the short-term effect of wastewater on the oxygen level of receiving waters.⁵

TOC:

A total organic carbon test (TOC) oxidizes organic compounds to CO₂ and H₂O using heat, ultraviolet light, and a strong chemical oxidizer. Through infrared spectroscopy and conductivity coulometry (an electrochemical method), oxygen requirement can be indirectly determined by determining the amount of CO₂ produced. It takes a few minutes and several hours to process the obtained information.⁴ The TOC is generally measured in purified water to determine the level of organic molecules or pollutants. In order to ensure that the water used in a company's processes is pure enough, TOC is used as an analytical technique.⁶

BOD:

It shows aerobic waste treatment models and aquatic ecosystems among the three tests (COD, TOC, BOD) determining oxygen demand. The experiment involves microorganisms that consume organic compounds for food and oxygen simultaneously. BOD is a standard test for measuring oxygen consumption in a sample over five days. This test is limited in some applications, such as industrial wastewater, where heavy metal ions, cyanides, and other toxic substances are present. As a result, the experiment BOD becomes ineffective when toxic substances poison the microorganisms.⁴ An organic

matter's biochemical oxygen demand (BOD) determines how much oxygen is needed to remove it from water.⁷

TSS:

As a major pollutant, total suspended solids (TSS) contribute to reduced water quality, higher water treatment costs, reductions in fish resources, and degradation of water quality in general. Water quality can be controlled by predicting suspended sediments. TSS is important because it removes too much dissolved oxygen from the outlet water.⁴ Total suspended solids are the fine particles that remain suspended in water. As with turbidity, this property provides the actual particle weight for a given sample volume (usually mg/L).⁸

2.2 Methods of Desalination:

There are different methods for desalination, and here we discuss three of them.

2.2.1 RO-Pretreatment:

Ro pretreatment for seawater and brackish water:

RO pretreatment systems for seawater or saltwater are primarily designed to reduce water sedimentation in the RO membrane system. Membrane sedimentation is more likely to occur in seawater and brackish water. Surface water sources are generally used for RO seawater, while underground sources are usually used for RO brackish water.⁹

Sand filtration:

Sand filtration is usually used for the pretreatment of seawater in desalination plants.¹⁰ When the water passes through the sand bed, the suspended particles in the water, whose diameter is about 50μ , such as mud and paint, are separated, which in this case causes the water to become thick and clear. However, it does not dissolve the salts and chemicals in the water; a carbon filter should be used.¹¹

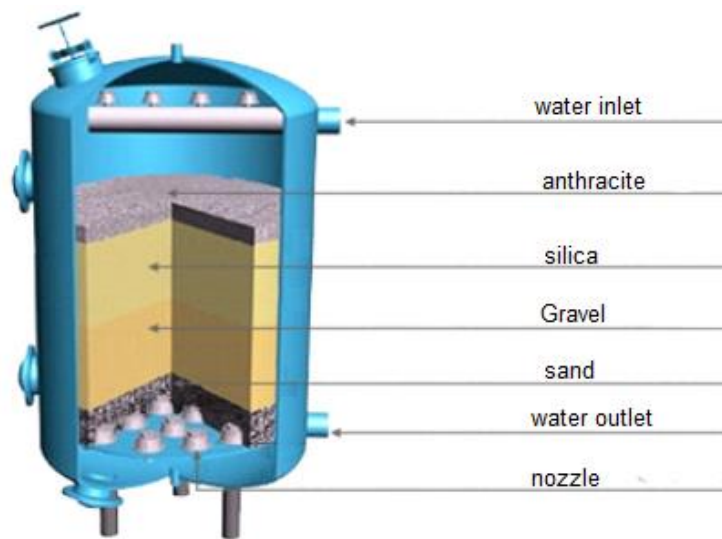


Figure 2 Sand filter components.

Carbon filtration:

Activated carbon (AC) includes a wide variety of processed amorphous carbon-based materials with high porosity. Peat coal, wood, synthetic polymer, etc., are often used as raw materials for producing activated carbon. The preparation process includes the carbonization of carbon raw materials and the activation of the carbon product. Carbonization occurs in the absence of air by pyrolysis without the addition of chemical agents or by heating. Granular activated carbon (GAC) is used to adsorb various pollutants in a wide range of applications in water and wastewater treatment. ¹²It can be used in methods RO and IXR, which helps to better purify water in terms of color, odor, and chlorine by removing organic compounds and residual disinfectants in water. The life of the carbon filter depends on the amount of water that enters it. Water passes over the carbon and fills the holes on the carbon surface, and the carbon becomes saturated; in this case, it must be replaced. ^{13,14}



Figure 3 Activated Carbon Filtration.

Conventional Pretreatment:

Conventional pretreatment typically involves the addition of acid, coagulant, disinfectant, media filtration, and granular media filtration. By reducing the pH of the feed water (between 5-7), calcium

carbonate becomes soluble and deposits in many feed waters. Sulfuric acid is the most common acid to reduce pH in feed water. Adding sulfuric acid can cause sulfate precipitation, so hydrochloric acid is used instead. Water particles and colloidal substances usually have a negative charge since they have similar charges and repel each other. In addition to neutralizing similar charges, coagulants allow suspended solids to group into flocs (large groups of loosely bound particles). Thus, coagulants are usually small molecules with a positive charge. Most inorganic coagulants are iron or aluminum salts, such as iron chloride or aluminum sulfate. While organic coagulants are usually cationic polymers (Dimethyldiallylammonium chloride or poly amines) with low molecular weight ($<500,000\text{Da}$), aluminum is usually not used in pretreatment coagulation before membrane filtration due to the possibility of damaging the membrane system.

It includes materials such as sand, anthracite, pumice, garnet, and often a combination of materials is used in layers in the filter bed to use different effective sizes of materials. The treatment beds can be open to the atmosphere, and gravity is used to create the permeate flow, or the filters can be closed to the atmosphere and pressurized. Although it is more expensive and energetic, media filtration is much more common in RO pretreatment, and it can reduce the SDI of feed water by two times. Media filtration can be sensitive to changes in feed water. Cartridge filtration is the last stage of RO pretreatment. The filter cartridge is usually $1\text{--}10\text{ }\mu\text{m}$. Moreover, the final stage of payment is removing larger particles that, through media filtration, have passed and acted. Suspended particles of more than $5\text{--}10\text{ }\mu\text{m}$ can be used to remove the RO concentrate channel contamination. As a result, filter cartridges are an essential step before RO.

Antiscalants, mainly as RO pretreatment for systems of saltwater, are used. Usually, after granular filtration, before or after cartridge filtration are selected as doses. A specific antiscalant depends on the composition of the feed water. Optimizing the type and dose of antiscalant is as important as optimizing the coagulant. High doses usually do not reduce salt deposits, and the presence of certain deposits can alter the effectiveness of a particular antiscalant. If the concentration of certain sediments is too high, antiscalants is not recommended.

Disinfection is achieved by adding a strong oxidizer such as ozone, chlorine, chloramine, or potassium permanganate. The oxidant is usually dosed in high concentration to use the remaining disinfectants through the rest of the pretreatment system and prevent biological growth. If chlorine is used as a disinfectant, activated carbon (usually present in the filter) or sodium bisulfite is used at the end of the

pretreatment system to remove chlorine (chemical reduction). Sodium bisulfite is cheaper and is used for large desalination plants. Most RO membranes Available in the market are aromatic polyamides that are very sensitive to chlorine. If they are exposed to chlorine for a long time, they cause membrane deterioration and a decrease in salt excretion. Other oxidants can be used for disinfection, such as ozone, but they cause the formation of bromate, which is carcinogenic. All disinfection processes cause the formation of disinfection by-products, which are toxic oxidation products formed from the reaction between disinfectants and organic and inorganic water components.

2.2.2 Reverse Osmosis (RO):

RO is currently the most reliable state-of-the-art seawater and brackish water desalination technique. It has been used as an alternative source for producing clean water to minimize desalination-associated costs. Based on the input-processing quality, RO processes can be grouped into brackish water RO plants (BWRO), where the salinity is 500 mg/L to 10,000 mg/L, and seawater RO plants (SWRO), where the salinity is around 30,000 mg/L. BWRO is further sub-grouped into low salinity BRWO that process feed water between 500 and 2500 mg/L and high salinity BRWO plants that process water with salinity between 2500 and 10,000 mg/L. Currently, around 50% of the global desalinated water is produced using RO. The efficiency of RO depends on several factors, including the operational parameters, the employed membrane, and the feed water characteristics.

The physical phenomenon of osmosis has been known to humanity for many years. Osmosis, in simplest terms, can be defined as a natural process in which water molecules spontaneously move from a solution of low solute concentration (low osmotic pressure) to a solution of high solute concentration (high osmotic pressure) across a semipermeable membrane (Figure 4a). The semipermeable membrane rejects the solutes and only allows water molecules to pass through. The osmosis process continues until an osmotic equilibrium is reached, where the chemical potentials

across the membrane become equal (Figure 4b). The flow of water molecules can be stopped or reversed by applying external pressure on the solution of higher concentration (feed solution). Suppose the applied pressure difference is greater in magnitude than the osmotic pressure difference across the membrane. In that case, water molecules are forced to flow in a direction opposite to that of the natural osmosis phenomenon. In such a case, the process occurring is known as RO and is depicted in (Figure 4c).¹⁵

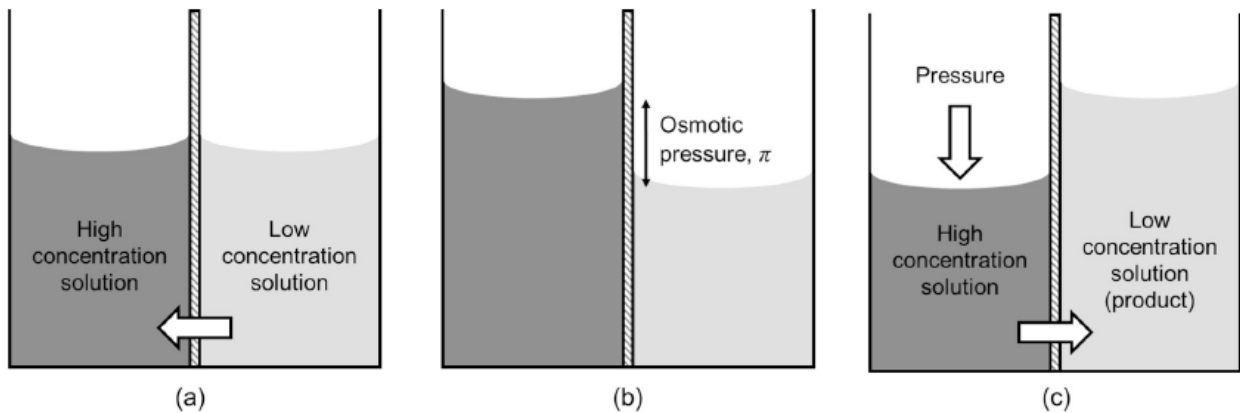


Figure 4 Schematic of (a) osmosis (b) osmotic equilibrium (c) RO.

In a continuous RO process, the feed water stream splits into two streams, as shown in (Figure5). The first stream consists of water molecules that have permeated through the membrane. This stream of low solute concentration is called permeate or product water. The second stream consists of a decreased amount of water molecules and the rejected solutes. This stream is of higher solute concentration compared to the feed and is termed brine, concentrate, or reject. Recovery or conversion of an RO process is defined as the volume fraction of feed water that is recovered as permeate or product water.¹⁵

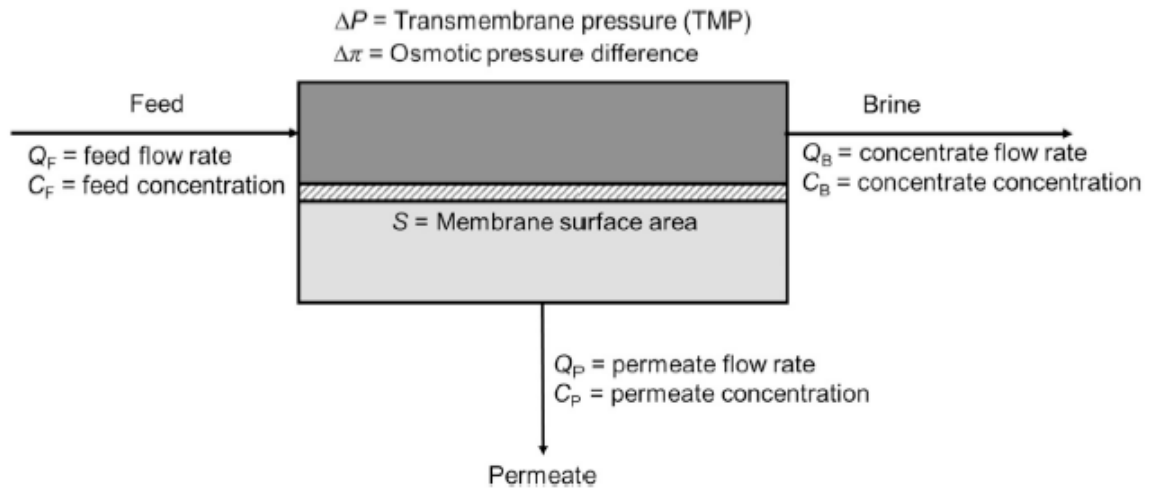


Figure 5 Schematic of a continuous RO system.

Reverse osmosis (RO) is a membrane separation process that recovers water from a saline solution pressurized to a point greater than the osmotic pressure of the solution (Figure 6). The membrane filters out the salt ions from the pressurized solution, allowing only the water to pass. RO post-treatment includes removing dissolved gasses (CO_2), stabilizing the pH via adding Ca or Na salts, and pressurizing the saline water, which accounts for most of the energy consumed by RO. Since the osmotic pressure, and hence the pressure required to perform the separation, is directly related to the salt concentration, RO is often the method of choice for brackish water, where only low to intermediate pressures are required. The operating pressure for brackish water systems ranges from 15 – 25 bar, and for seawater systems, from 54 to 80 bar (the osmotic pressure of seawater is about 25 bar). Since the pressure required to recover additional water increases as the brine stream is concentrated, the water recovery rate of RO systems tends to be low. A typical recovery value for a seawater RO system is only 40%.

RO membranes are sensitive to pH, oxidizers, a wide range of organics, algae, bacteria, and of course, particulates and other foulants. Therefore, pretreatment of the feed water is an important consideration and can significantly impact the cost of RO, especially since all the feed water, even the 60% that will eventually be discharged, must be pretreated before being passed to the membrane.¹⁶

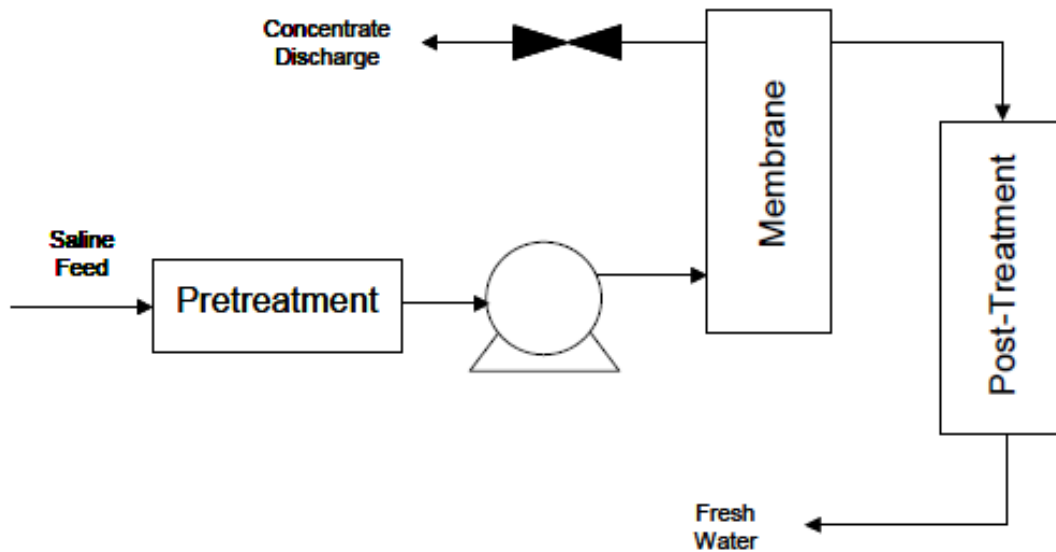


Figure 6 Block diagram of reverse osmosis operations – optional pressure recovery devices not depicted.

2.2.3 Membrane Distillation:

Membrane distillation is a non-temperature membrane process that uses thermal energy to deliver the vapor phase of the volatile molecules in the flow (mainly water) and compress the penetrated vapor on the cold side. The driving force on MD is the minor pressure difference between each side of the membrane pores—the temperature difference results in the vapor pressure difference across the membrane. Due to the hydrophobic nature of the membrane, only vapor can pass through the membrane, and the liquid solution is not distilled.¹⁷

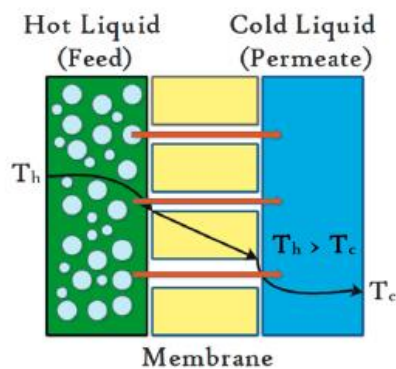


Figure 7 Schematic diagram of the MD process.

(Figure 7) shows that volatile steam molecules in the hot feed that evaporate at the common liquid/vapor interface can cross the membrane pores. On the other hand, the liquid feed is prevented from transmitting through the membrane's pores. This phenomenon is mainly because of the hydrophobic nature of the MD membrane and its surface tension. Therefore, it is important to note that dry pores should not be soaked by a liquid feed that is directly in contact with the hydrophobic membrane.¹⁸

In theory, influence! It can reach 100 % of non-volatile components. In addition, energy efficiency! (In terms of carbon emissions) can be significantly improved if low-grade loss or solar energy is available. MD transportation mechanism It can be described in four stages; 1- The heat is transmitted from the mass solution to the membrane surface by the heat transfer of the border layer. 2-The liquid evaporates in the hot membrane feeding interface. 3- The steam passes through the membrane pores by the temperature gradient. 4- The steam is dense by the cooling liquid or cooling plates.¹⁹

MD process Initially, it was thought to be a separate process that could act with the minimum external energy requirement and the least capital and land for the plant. The equipment needed for the MD process is much smaller, which means saving the actual situation, and the working temperature is much lower, as the process does not need to be heated above the weld temperature. These benefits lead to less environmental heat loss through the equipment surface. Feed temperature in MD Typically, it is between 35-85 ° C. The main advantages of membrane processes are 1- Low energy consumption, 2- Available operating conditions, 3- Simple maintenance 4- High construction compactness among various desalination technologies. MD, compared with RO, has high potential. MD can be accompanied by solar energy to produce drinking water in arid regions. MD is widely used in industrial wastewater treatment and desalination, sea and saline water.²⁰

Table 2 A comprehensive overview of the positive and negative points of the MD process.

Advantages	Disadvantages
Low operating temperature (the process liquid is not essentially heated up to the boiling temperatures)	Lower permeate flux compared to other commercialized separation processes, such as RO.
Lower hydrostatic pressure required compare to pressure-driven membrane separation processes such as reverse osmosis (RO).	
High rejection (99–100%) for macromolecules, non-volatile compounds (colloids, salts), and inorganic ions. In fact, 100% separation happens, theoretically.	High susceptibility of permeate flux to temperature and concentration polarization effects, partial or total pore wetting, and membrane scaling and fouling.
Lower requirements on the mechanical properties of the membrane.	
Larger pore size and less chemical interaction between process solution and membrane lead to less fouling.	High heat loss (by conduction) and energy consumption
Alternative low-grade energy sources like waste heat, solar energy, and geometrical heat can be utilized.	Pore wetting risk
The possibility to combine with some other separation processes in order to build an integrated separating system, like an RO unit or ultrafiltration	Unclear economic and energy costs for different MD applications and configurations, just when waste heat is available MD becomes cost competitive.
An efficient method to eliminate heavy metals and organic from wastewater.	
It is an effective and safe process to remove radioactive waste.	The lack of commercially available MD modulus manufactured for large-scale applications and high-performance membrane.
MD is able to work with a saturated solution or high solute concentration in a liquid stream	
Fewer vapor spaces needed in comparison with common distillation process so MD can be used at a smaller scale.	Having less producers of MD technology
Reduced sensibility to concentration polarization.	
High concentration polarization or osmotic pressure does not limit performance.	
Having low cost and less sophisticated installation and construction (because of lower operating temperature and pressure), leads to a full level of automation.	Limitations of MD permeate flux, due to a further mass transfer resistance caused by trapped air through the membrane
Being less sensitive to membrane pollution or concentration polarization and without a pretreatment stage.	

In an MD regular system, thermal and electrical energy are needed. To supply hot flow, saline solution or water/wastewater must be heated by 40–80 °C to re-circulate cold and hot flows or create a vacuum or gas flow sweeping. On the penetration side of the electrical energy is needed. So the energy source must supply electricity to run the MD process. One of the processes of the MD process is it can be accompanied by a renewable energy source to improve overall efficiency. Different renewable

energies such as solar, geothermal, and wind can be done with the MD process. MD Process is Mainly used for desalination. However, recycling water from sewage flows is one of the most promising MD applications for the future. A suitable technology to eliminate other impurities. While purifying all kinds of sewage and salt water, It's ability to compete with current technologies like RO and heat-based water technologies is still limited due to the lack of experimental data on the trial scale and specific membranes and modules. Another major challenge against MD There is to be applied to wastewater treatment. Wastewater flows are typically a dinner for many chemicals that can potentially lead to the deposition of the membrane surface and soak the membrane pores. This is because the precipitation of these elders on the membrane surface can dispel the membrane and lead to the pores and thus decrease the flux. That is why there is limited work on wastewater treatment using MD Compared with desalination.

2.2.4 ION Exchange Resins:

The term ion exchange resin (IXR) refers to various organic compounds that take ions from the solution and release other ions from the resin into the solution for chemical reactions with dissolved ions. Acidic resins, also called cationic resins, are designed to absorb positive ions (Ca^{2+} , Na^{2+} , Mg^{2+} , K^{+} , Mn^{2+} , Fe^{3+} , ...) and release H^{+} ions. As a result, the hardness of water decreases, and its acidity increases, because pH increases with a higher concentration of H^{+} ions. Basics resins absorb negative ions such as Cl^{-} , NO_3^{2-} , SO_4^{2-} , SiO_2^{-} , CO_3^{2-} and release OH^{-} ions.²¹

In water purification, the goal is usually either to soften the water or to remove all minerals. Water is softened by using a resin containing Na^{+} cations. But it absorbs Ca^{2+} , and Mg^{2+} releases Na^{+} , creating softer water. If the water needs complete mineral removal, it passes through a resin containing H^{+} (which replaces all cations) and then through a second resin containing OH^{-} (which replaces all anions). Then the H^{+} and OH^{-} react and produce more water.

This process has disadvantages; in some waters that contain organic substances or Fe^{3+} ions, it can contaminate the resin.²² Among its other problems is the destruction of the anion exchanger by oxygen in surface water under hot regeneration conditions and the creation of divalent metal ions in the cation exchangers, which requires a pre-softening stage. These additional steps make the approach

uneconomical. Its advantages include the long life of resin and cheap maintenance. Also, this method is suitable for the selective removal of organic and inorganic ions that may cause membrane fouling.²³

In (Figure 8), Brine water first flows through weak acid resin and strong acid resin; after this stage the acidity of the water increases. Degassing is required because the bicarbonates in the water react with the H^+ ions to produce carbon dioxide. After this step, the water flows through the weak base resin and the strong base resin, reducing the acidity of the water. An amphoteric resin (combination of acid and base) is usually added to complete the removal of ions. During the normal process, the resins are gradually saturated by ionic solids. Hence, regeneration is needed periodically to recover the resins. Acidic solutions (H_2SO_4 , HCl) are used for acid resins, and alkaline solutions (NH_4 , OH , $NaOH$) are used for basic resins.

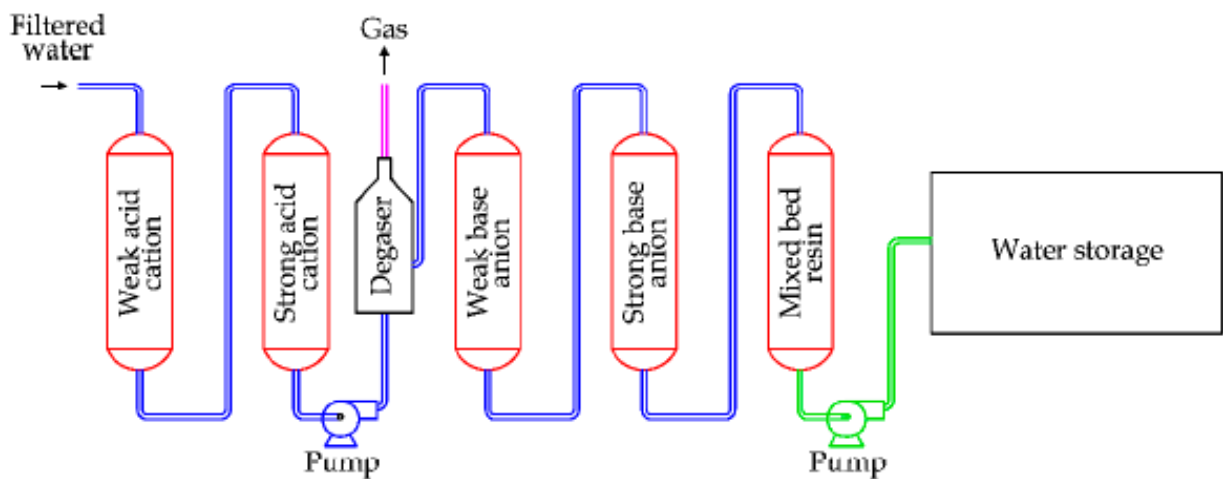


Figure 8 A schema of an Ion-Exchange Resin desalination plant.

Chapter 3

Renewable Energy for Desalination

In today's era, there are many reasons to use refined renewable energies for water purification:

- There is an increasing demand for water worldwide.
- Fuel costs for electricity and energy production such as oil, gas, and coal are increasing, which are limited resources.
- The need for small systems to work in remote and deprived areas that often do not have electricity networks.
- Climate changes: extensive melting of ice and snow, increase in the average global sea level.

Renewable energies, especially solar and wind energy, can reduce carbon emissions and have been more favorable from an economic point of view, and this article deals with these two energies.

3.1 Solar:

Solar energy refers to both electrical and thermal energy that is harnessed from the sun. Solar thermal energy can be harnessed passively where no moving parts are required, such as in a solar building design, or actively harnessed for a wide range of applications, including domestic hot water, and heating through solar thermal collectors. Direct current (DC) of electricity can be produced directly through sunlight using photovoltaic cells. In this article, we will focus more on the photovoltaic effect.²⁴

Since water treatment is a very energy-intensive process, it requires high-tonnage power plants that are powered by conventional fuels. Using water purification techniques based on renewable energies, among which solar energy is the most promising. Because access to salt water usually coincides with the abundance of solar resources in dry areas.

Solar thermal desalination systems are usually classified into two main categories, direct and indirect systems:

3.1.1 Direct Solar Desalination:

In this system, both evaporation and condensation are done in one device. It is mostly used for domestic applications or small communities with less than 200 m³/day freshwater needs. Fixed solar devices that undergo direct desalination can separate fresh water using a greenhouse technique. They act as traps for solar radiation to pass through the covered enclosure to evaporate water. Then the water vapor condenses and forms fresh water droplets that exit through certain channels. In (Figure 9), it can be seen that the solar radiation heats the liquid panels and creates a greenhouse effect inside the chamber, increasing the saline water's temperature. This phenomenon causes the surface water to evaporate, and the water vapor reaches the panels, becoming drinking water. Using this cycle, you can get 3-4 lit/day/m² fresh water. Due to low production and reduction of operating costs, this system is of great importance. The main cost of fresh water production is mainly related to the capital cost of building and maintaining the plant. The pumping cost is also considered in case of transferring water to another place. Since the performance of solar devices can be affected by many factors such as ambient temperature and salt water, slope, wind speed, thermal insulation, and salt concentration, caution should be taken when installing solar devices to prevent the overall loss of system efficiency.

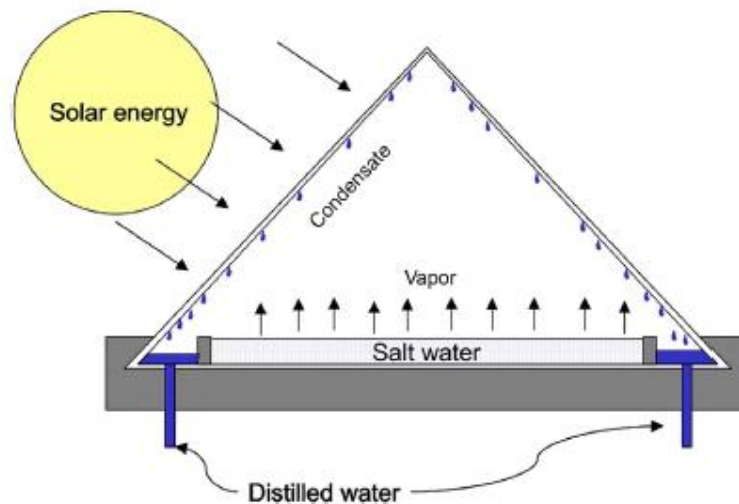


Figure 9 A solar still desalination unit.

3.1.2 Indirect Solar Desalination:

In these systems, the plant consists of two sub-assemblies: the desalination section and the solar collection device, usually solar collectors or solar ponds. These systems are used on a large scale. And there are different types of collectors such as discharge tubes, heat pipes, flat plates, and solar concentrators can be combined with thermal desalination processes. Solar pond systems are large solar collectors with high energy storage capacity, where solar energy trapped in the stored brine is circulated as a heating medium in the desalination process unit. These systems are the most convenient and cheapest option for heat storage, which are very suitable for desalination plants. The salt residue from desalination can be used as a salt source to create a density gradient. Solar ponds are uniquely able to absorb and store solar thermal energy on cloudy days, which is more effective than other methods. A typical solar pond has 3 separate zones; this system with three convective zones is shown in (Figure 10). The low density of brackish water plays the role of absorbing and transferring energy. The second zone with an average amount of salt water and called the non-convective zone (NCZ) from heat exit to UCZ prevents and thus maintains the temperature for the lower areas at a higher level. The bottom zone (LCZ) is the bottom convective zone that acts as a heat storage zone with uniform salt density.

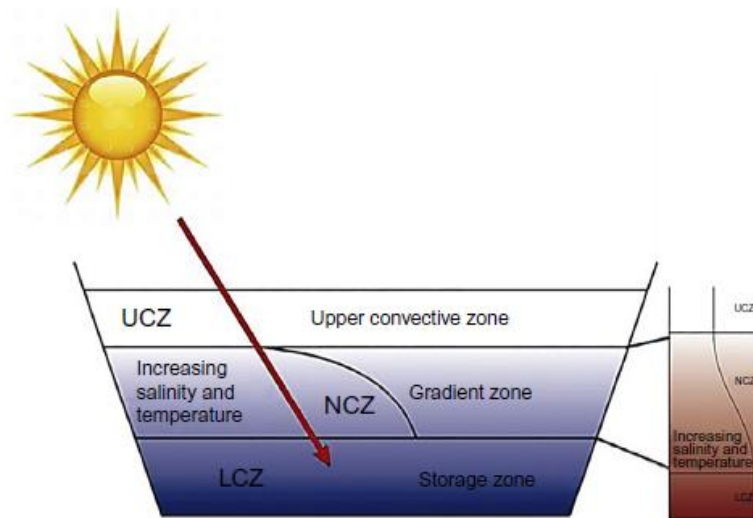


Figure 10 A solar pond system along with its convective zones.

3.1.3 Solar PV:

As a mature technology, solar photovoltaic (PV) systems are semiconductor devices that convert sunlight into DC electricity through electron transfer. The energy conversion process is mainly done in two steps. The production of electron-hole pairs through the absorption of light in semiconductor materials, and after that, the separation of the electron to the negative terminal and the hole to the positive terminal is done by the structure of the device to supply electricity. In order to produce a larger amount of electrical energy, solar cells may be arranged in series and have several modules connected to form an array. Solar-PV systems offer several advantages, including simple design, long operation life, high reliability, and no additional pollution during energy supply. Currently, there are three generations of PV cells: The first generation: is crystalline silicon (c-Si). Second generation: Amorphous silicon thin film (TF); And the third generation: is Nano PV. Today, the most common material used for PV cells is crystalline silicon. The overall efficiency of a PV system is strongly dependent on the temperature of the cells, such that the efficiency decreases as the operating temperature increases. In addition, the main components of a solar-PV system are a PV panel, charge controller, battery pack, DC/AC inverter, DC/DC converter, and DC shunt. This equipment must be added to a PV module to power a desalination plant. In order to increase this energy, a flat PV system can be used, and as a result, the absorption of solar energy increases due to tracking the path of the sun. Based on how solar-PV systems are connected to an electrical load, these systems are generally categorized as stand-alone and functionally interactive systems. In the second case, the system relies on the availability of sunlight, which requires connecting the system to the power grid through a power conditioning unit that may be a high-quality inverter. Standalone PV systems are stand-alone systems that provide DC or AC electrical loads, making them suitable for isolated users who are off the grid.²⁵

3.2 PV-RO:

A plan of this system is shown in (Figure 11). The feasibility of this system depends not only on the change in solar radiation but also on the type of source water used and the size of the system. However, widespread use of PV-RO on a large and small scale is still limited due to high energy costs, which should be considered by improving the energy efficiency of the PV-RO systems. Specific energy consumption (SEC) for experimental desalination PV-RO systems is between 101-163Kwh/m³ depending on the size of the system, use of batteries, power source (seawater or salt water), pretreatment and energy recovery devices (ERD) type; it is different if any. Researchers of a simple

yet innovative concept to improve the performance of PV and RO by taking thermal energy from and using it to heat the feed water and reduce the PV temperature of the module simultaneously and increase in PV temperature and feed temperature of RO they introduced. They found that energy consumption can be reduced by 28% due to the effect of temperature on the PV modules and efficiency RO reduced. The feed water temperature increases the membrane flux by up to 3%. Electrical efficiency PV has the opposite relationship with temperature so the higher the temperature, the less favorable it is. For PV cells for crystalline silicon, the efficiency drop is 0.2-0.5 for the degree of temperature increase. They could increase the water output by up to 20% in the systems. Immediately after that, they adjusted the membrane morphology to increase the permeation flux and found that combining heat transfers from PV to RO feed and improving water friendliness reduces energy costs by about 40%. When using such techniques for plant design, possible adverse effects, heating of the feed water, should be considered. Warmer water often exacerbates biofouling because it causes bacteria to grow on the surface of the membrane. In addition, along with the water's permeability, the feed's temperature becomes hotter. Also, it increases the permeability of salt, and as a result, the quality of the permeate decreases.²⁶

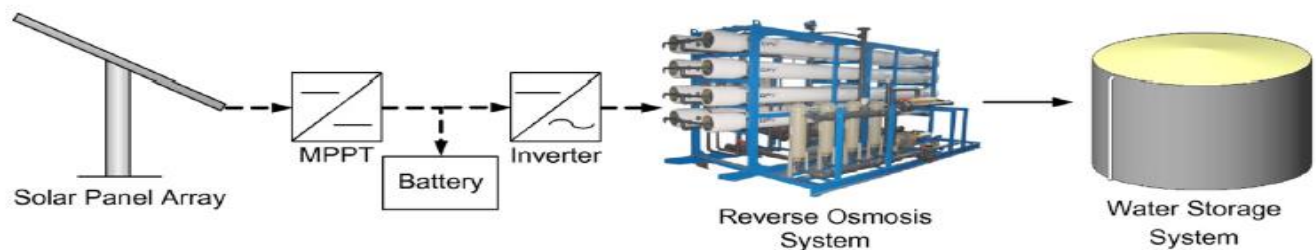


Figure 11 A schematic of PV operated RO system which includes an RO system, a water storage system, and a solar panel array equipped with a maximum power point.

The feed pressure of RO systems is usually between 6-8 MPa for seawater applications and 0.6-3 MPa for saltwater applications. RO efficiency and recovery ratio are greatly influenced by the characteristics of the membrane used, feed water salinity, feed pressure, feed flow rate, etc. Well-established energy recovery devices in RO plants significantly contributed to high energy efficiency. Process. Much work and research have been done on solar-powered RO desalination systems. When combined with solar energy, RO can be driven by electrical power generated by photovoltaic (PV) cells, thermal power plants, or mechanical power converted from thermal energy by the thermodynamic cycle. In a PV-powered RO system (Figure 12), the PV and RO subsystems operate

independently. Since both of them are commercialized technologies, the technical feasibility of the PV-RO plant is not an issue compared to its economic feasibility and reliability. Since the 1980s, many small-scale or pilot-scale PV-RO seawater/brackish water desalination plants have been constructed and investigated.²⁷

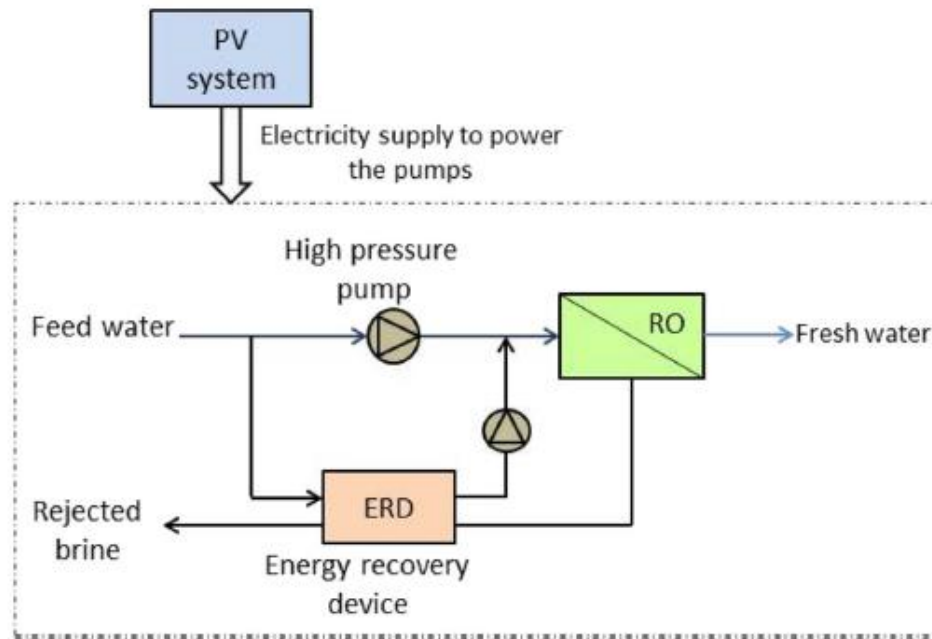


Figure 12 Schematic diagram of PV-driven RO system.

3.3 Wind:

The sun's uneven heating of the Earth causes the poles to receive less energy than the energy received at the equator. In addition, land can warm and cool faster than the ocean. Wind energy is usually harvested through windmills to produce mechanical energy or wind turbines to produce electrical energy.²⁸

3.3.1 Wind energy tech integrated with desalination system:

Wind energy can be fully used to generate electricity. A wind turbine's electrical or mechanical power can be used to run desalination plants. Wind-powered desalination systems are one of the most common renewable desalination plants. Combining desalination with wind energy has the least impact on the environment, which includes a 75% reduction. Therefore, wind energy is a very suitable option in areas with high wind potential where desalination is also required.

Wind farms and desalination are two different technologies that can be integrated into different ways. The energy required for desalination is still a very important factor in system costs. Wind energy can supply desalination plants directly or indirectly through 4 types of energy: 1- Electricity, 2- Thermal energy, 3- Gravitational potential energy, and 4- Kinematic power (shaft power). Electricity is the most common energy used as an interface between wind energy and the desalination process. For the intermittent characteristic of wind power, the supporting facilities such as the battery, water tank, and flywheel system may be integrated into the system until the wind speed exceeds the required value or cannot reach it; the energy is stored or released.

RO is one of the most efficient desalination technologies that require about 3-10 kWh of electrical energy per cubic meter of freshwater produced from seawater.²⁹ Low operating cost, high efficiency, and the availability of wind energy in some areas, especially coastal areas, make wind turbines a successful choice for supplying energy to the RO power plant.³⁰ In (Figure 13), shows that the electricity generation system of RO power plant by wind is around 19%, and the PV-RO system is around 32%.

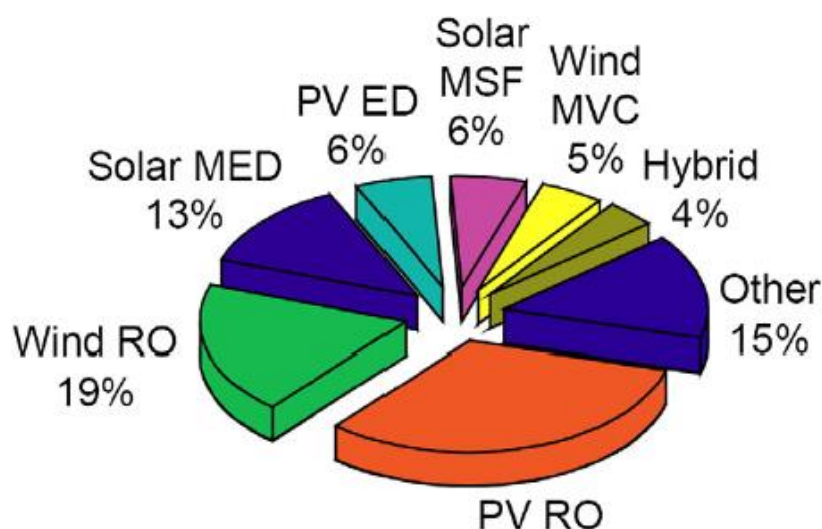


Figure 13 Breakdown of renewable energy-powered desalination system technologies.

Chapter 4

Simulation and Methodology for Solar and Wind Desalination plants in Iran

We investigated to design and evaluate the power supply system of the water treatment plant with renewable energies (solar and wind) based on Iran's climatic conditions. We chose two geographical areas that were suitable in terms of solar radiation and wind. We chose Chabahar port for our plant, which is suitable for solar radiation, and using its environmental information and the TDS of Oman sea water, which is about 36,000ppm, we evaluated and calculated the solar panels. Our other chosen place is the city of Manjil, which is very suitable for wind. There, we calculated the number of turbines and their feasibility using environmental information and the TDS of Manjil's Dam water, which is around 1,800ppm.

4.1 Physical conditions of the places:

4.1.1 Location of the solar desalination plant:

Chabahar is one of the southeastern cities of Sistan and Baluchistan province and the only ocean port in the country, located on the coast of the Oman Sea and the Indian Ocean. Chabahar, with an area of about 17,155 km, is in the extreme southeast of Iran. This port, with an area of more than 11 km², is located at 7 m above sea level. The proximity of the Chabahar free zone to the sea, the proximity to the orbit of the Cancer Center, and being in the path of the monsoon winds of the Indian subcontinent and tropical fronts have made it have water and Moderate tropical weather with relative humidity.³¹

4.1.2 Photovoltaic Power Potential:

I chose this area to use solar energy, and the Photovoltaic power potential was estimated at 5.2 kWh/m² per day according to the solar resources map.³²

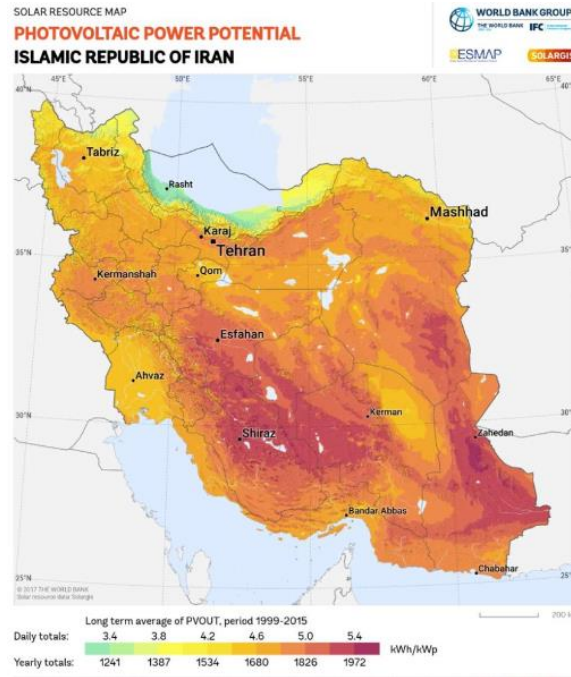


Figure 14 Photovoltaic Power Potential.

η solar panels = 17%

$$\text{For each } m^2 \text{ of Solar Panel (daily)} = 5.2 * \frac{17}{100} = 0.844 \text{ kWh}/m^2$$

4.1.3 Methodology:

Oman sea water was chosen as the water for desalination, and since the purpose of this project is to check the energy required for water purification through renewable energies, I obtained the necessary pressure for the pump by using the Wave Software (water application value engine an innovative new modeling software program that integrates three leading technologies into one comprehensive platform ultrafiltration, reverses osmosis, and ion exchange resins)³³. To calculate the pump pressure in this software, it is necessary to add a series of important parameters, where I only entered the TDS, which was about 36,000 mg/lit.³⁴ And I considered its SDI (Silt Density Index) to be less than 2.5. During my conversations with different companies, they considered the type of membranes for seawater to be SW30HRLE-400. And since each sea membrane is about 15 m³, I calculated the number of membranes and pressure vessels, and finally, the pump pressure was calculated for me for three volumetric flow rates. All the reports on this software are attached, and thus the energy I calculated and finally calculated the required area for using solar panels. I calculated this energy estimate for three different volumetric flow rates as follows:

Sunmodule®

Photovoltaic Module Specifications	
Model name	SW130 Poly/R6A
Cell Type	Polycrystalline Silicon
Maximum power rating(Pmax)	130W
Maximum power voltage (Vmpp)	17.7V
Maximum power current (Impp)	7.38A
Open circuit voltage (Voc)	21.9V
Short circuit current (Isc)	7.65A
Weight	11.8Kg
Dimensions (mm)	1508*680*34
Quantity of panels in each line	4 (parallel)
DC Voltage	34V
DC Current	4*8A
AC connection of system	1 phase
Photovoltaic Power	2080W

Unit Price: 7.150.000 IRR

Solar Battery 12-120

Voltage:	12 V
Nominal capacity:	100Ah
Rules of Reference:	IEC 60896 parte 21 e 22 DIN 40742 DIN 43539 T5 V. UL 1989 / CEI IEC 61427 EUROBAT "Long Life" (>12 years)
Negative Pole:	2
Weight:	32.0 Kg

Unit Price: 5.200.000 IRR

So the area of each solar panel is:

$$A = 1.508 * 0.68 = 1.02544 \text{ m}^2$$

Since sea water is being treated, SW-30HRLE400 is used. According to the datasheet, if this membrane, the active area is 37 m².

Product Specifications

Product	Part number	Active area ft ² (m ²)	Maximum operating pressure psig (bar)	Permeate flow rate gpd (m ³ /d)	Stabilized boron rejection %	Minimum salt rejection %	Stabilized salt rejection %
SW30HR LE-400	217822	400 (37)	1,200 (83)	7,500 (28)	92	99.65	99.80

For treating seawater with SDI<2.5, the RO system operates satisfactorily when the flux is 15-19 lit/(m²*h).

Feed Source	Seawater			
	With DuPont UF + B-free	Well or Open Intake with Ultrafiltration	Open Intake with generic membrane filtration or advanced conventional pretreatment	Open Intake with generic conventional pretreatment
Design Flux Range, gfd (lmh)	10 - 12 (17 - 21)	9 - 11 (15 - 19)	8 - 10 (14 - 17)	7 - 10 (12 - 17)

Figure 15 Design guidelines for 8-inch FilmTec™ Elements in water treatment.

The number of membrane elements is calculated below:

$$N_E = \frac{\dot{v}}{f * A}$$

For 100 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{100 \frac{m^3}{d} * \frac{1000 \text{ lit}}{1 m^3} * \frac{1 d}{24 h}}{(15 - 19) \frac{\text{lit}}{m^2 * h} * 37 m^2} = 5.9 - 7.5 \approx 6$$

The 6-element pressure vessel is chosen.

$$N_v = \frac{6}{6} = 1$$

TDS of water and Water type (Sea water with SDI<2.5) are the inputs of WAVE software. Design temperature, pH, and recovery of the system are 25°C, 7.9 and 50 %, respectively.

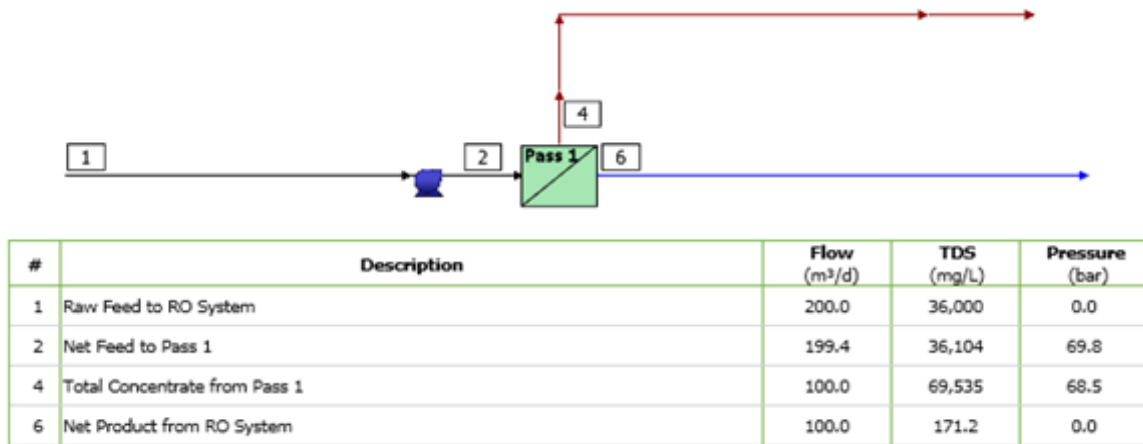


Figure 16 RO System Flow for volumetric 100 m³/day.

Table 3 RO Flow for volumetric 100 m³/day

Stage	Element	Recovery (%)	Feed Flow (m ³ /d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m ³ /d)	Perm Flow (m ³ /d)	Perm TDS (mg/L)
1	1	14.0	199.4	69.5	36,103	171.6	27.9	79.90
1	2	13.4	171.6	69.2	41,707	148.7	23.0	109.1
1	3	12.2	148.7	69.0	47,821	130.7	18.2	152.9
1	4	10.5	130.7	68.9	54,077	117.0	13.7	219.5
1	5	8.6	117.0	68.7	60,014	107.1	10.0	320.6
1	6	6.7	107.1	68.6	65,234	100.0	7.14	471.8

Maximum element recovery for seawater with SDI<2.5 (beach well) is 15%. Therefore, the design is optimum.

The permeate flow TDS is 171.6 mg/lit, which is suitable for drinking water. The pressure of high-pressure pump is 69.8 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 200 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 1.15 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 1.15 \div 0.7 = 1.65 \text{ kW}$$

High-Pressure Pump:

$$P = 69.8 \text{ bar} + 2 \text{ bar (pressure drop)} = 71.8 \text{ bar} = 7180 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 7180 \text{ kPa} * 200 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 16.62 \text{ kW}$$

$\eta_{\text{pump}} = 70\%$

$$Q = 16.62 \div 0.7 = 23.74 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 23.74 + 1.65 = 25.39 \text{ kW}$$

Area of Solar Panel PV:

$$PV\text{Area} = \frac{Q * 24\text{hr}}{\text{Power Potential}}$$

$$PV\text{Area} = \frac{25.39 \text{ kW} * 24\text{hr}}{0.884 \frac{\text{kWh}}{\text{m}^2}} = 689.41 \text{ m}^2$$

$$\text{number of Solar Panel} = \frac{689.41}{1.02544} = 672$$

For 1000 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{1000 \frac{\text{m}^3}{\text{d}} * \frac{1000 \text{ lit}}{1 \text{ m}^3} * \frac{1 \text{ d}}{24 \text{ h}}}{(15 - 19) \frac{\text{lit}}{\text{m}^2 * \text{h}} * 37 \text{ m}^2} = 59 - 75 \approx 67$$

The 6-element pressure vessel is chosen.

$$N_v = \frac{67}{6} = 11$$

TDS of water and Water type (Sea water with SDI<2.5) are the inputs of WAVE software. Design temperature, pH, and recovery of the system are 25°C, 7.9 and 50 %, respectively.

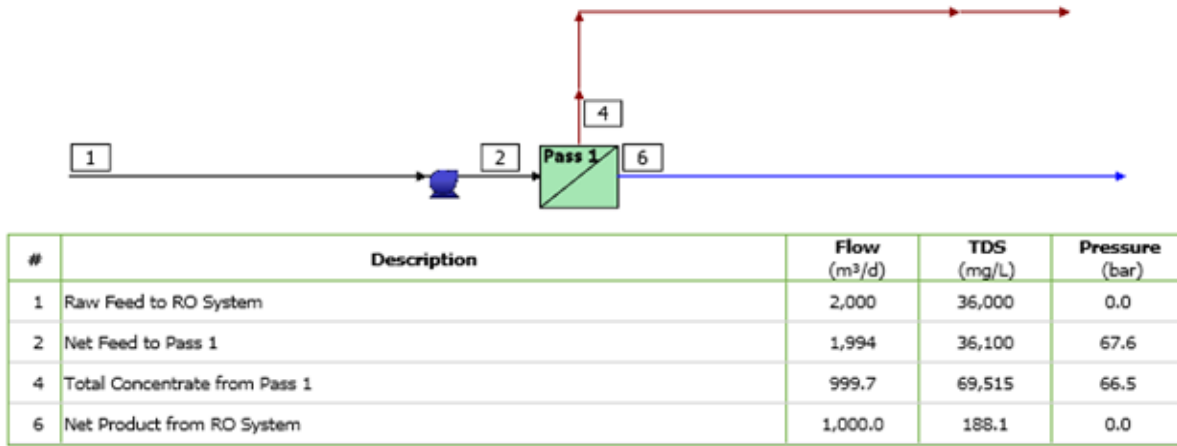


Figure 17 RO System Flow for volumetric 1000 m³/day.

Table 4 RO Flow for volumetric 1000 m³/day

Stage	Element	Recovery (%)	Feed Flow (m³/d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m³/d)	Perm Flow (m³/d)	Perm TDS (mg/L)
1	1	14.6	181.3	67.3	36,100	155.0	26.4	84.67
1	2	13.8	155.0	67.1	41,960	133.8	21.3	118.1
1	3	12.3	133.8	66.9	48,293	117.5	16.4	169.4
1	4	10.3	117.5	66.8	54,651	105.4	12.1	249.0
1	5	8.2	105.4	66.7	60,520	96.9	8.62	371.5
1	6	6.2	96.9	66.6	65,520	90.9	6.01	556.2

Maximum element recovery for seawater with SDI<2.5 (beach well) is 15%. Therefore, the design is optimum.

The permeate flow TDS is 171.6 mg/lit, which is suitable for drinking water. The pressure of the high-pressure pump is 67.6 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 2000 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 11.5 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 11.5 \div 0.7 = 16.5 \text{ kW}$$

High-Pressure Pump:

$$P = 67.6 \text{ bar} + 2 \text{ bar (pressure drop)} = 69.6 \text{ bar} = 6960 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 6960 \text{ kPa} * 2000 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 161.11 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 161.11 \div 0.7 = 230.15 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 230.15 + 16.5 = 246.65 \text{ kW}$$

Area of Solar Panel PV:

$$PV\text{Area} = \frac{Q * 24\text{hr}}{\text{Power Potential}}$$

$$PV \text{ area} = \frac{246.65 \text{ kW} * 24\text{hr}}{0.884 \frac{\text{kWh}}{\text{m}^2}} = 6696.61 \text{ m}^2$$

$$\text{Number of Solar Panel} = \frac{6696.38}{1.02544} = 6530$$

For 5000 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{5000 \frac{m^3}{d} * \frac{1000 \text{ lit}}{1 m^3} * \frac{1 d}{24 h}}{(15 - 19) \frac{\text{lit}}{m^2 * h} * 37 m^2} = [296 - 375] \approx 336$$

The 6-element pressure vessel is chosen.

$$N_v = \frac{336}{6} \approx 56$$

TDS of water and Water type (Sea water with SDI<2.5) are the inputs of WAVE software. Design temperature, pH, and recovery of the system are 25°C, 7.9 and 50 %, respectively.

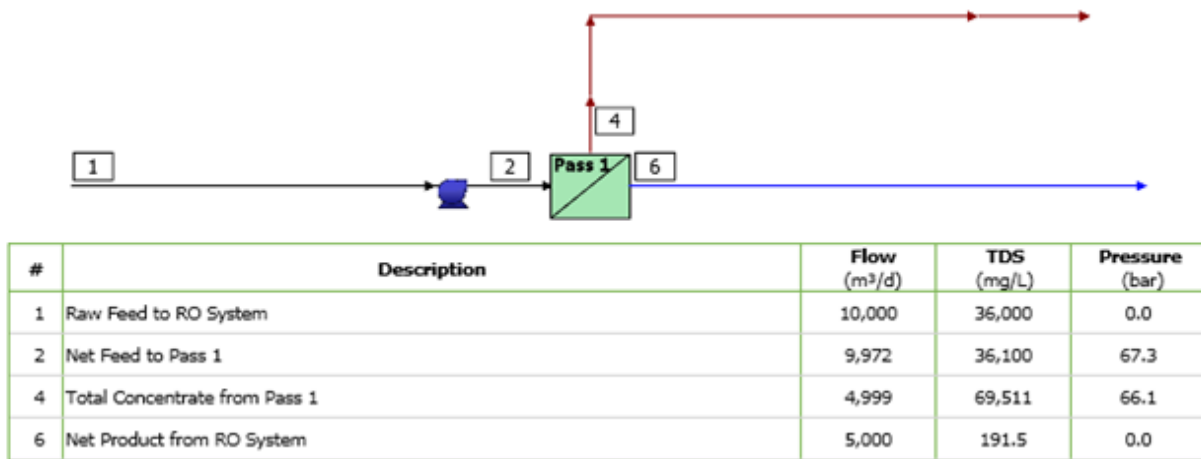


Figure 18 RO System Flow for volumetric 5000 m³/day.

Table 5 RO Flow for volumetric 100 m³/day

Stage	Element	Recovery (%)	Feed Flow (m ³ /d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m ³ /d)	Perm Flow (m ³ /d)	Perm TDS (mg/L)
1	1	14.7	178.1	67.0	36,099	152.1	26.1	85.59
1	2	13.8	152.1	66.7	42,010	131.2	21.0	119.9
1	3	12.3	131.2	66.6	48,387	115.1	16.1	172.8
1	4	10.3	115.1	66.4	54,763	103.4	11.8	255.1
1	5	8.1	103.4	66.3	60,617	95.0	8.37	382.2
1	6	6.1	95.0	66.2	65,574	89.3	5.81	574.2

Maximum element recovery for seawater with SDI<2.5 (beach well) is 15%. Therefore, the design is optimum.

The permeate flow TDS is 191.5 mg/lit, which is suitable for drinking water. The pressure of the high-pressure pump is 67.3 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 10000 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 57.9 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 57.9 \div 0.7 = 82.71 \text{ kW}$$

High-Pressure Pump:

$$P = 67.3 \text{ bar} + 2 \text{ bar (pressure drop)} = 69.3 \text{ bar} = 6930 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 6930 \text{ kPa} * 10000 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 802.08 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 802.08 \div 0.7 = 1145.83 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 82.71 \text{ k} + 1145.83 \text{ kW} = 1228.54 \text{ kW}$$

Area of Solar Panel PV:

$$PV \text{ Area} = \frac{Q * 24 \text{ hr}}{\text{Power Potential}}$$

$$PV\ Area = \frac{1228.54\ kW * 24hr}{0.884 \frac{kWh}{m^2}} = 33354.02\ m^2$$

$$Number\ of\ Solar\ Panel = \frac{33354.02}{1.02544} = 32527$$

4.1.4 Location of the Wind Desalination Plant:

Manjil city is located in Rudbar city in Gilan province. Manjil's wind is one of the famous factors of this city. The reason for Manjil's winds is the intersection of the semi-arid climate with the humid Caspian climate in the East region, which causes quasi-Mediterranean characteristics in Manjil. There is a wind power plant installed in this city, and the average wind speed in Manjil is 6 m³/s. I used the V-47 660 kW model, which is installed in this power plant.³⁵

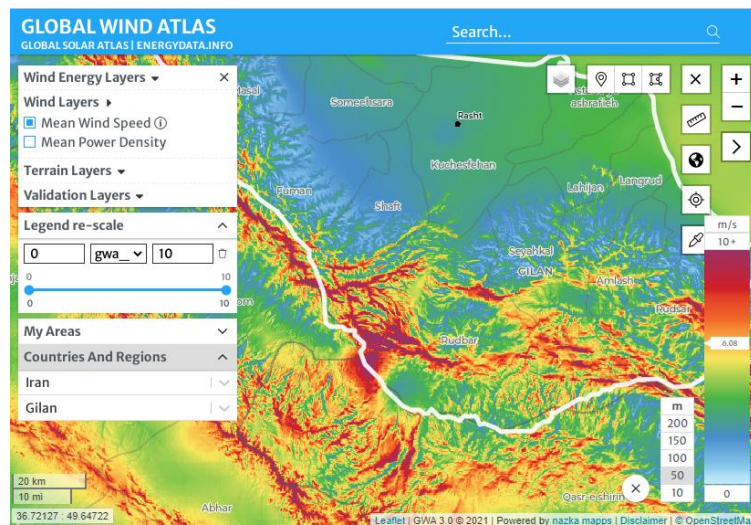


Figure 19 Global Wind Atlas.

4.1.5 Methodology:

Therefore, I chose the Manjil Dam as a source for desalination, and to check the necessary energy, I obtained the required pump pressure from the Wave software; to calculate the pump pressure in this software, it is necessary to add a series of important parameters, where I only entered the TDS, which was about 1,800 mg/lit. And I considered its SDI (Silt Density Index) to be less than 2.5. During my conversations with different companies, they considered the type of membranes for

seawater to be BW30-400. And since each sea membrane is about 19 m^3 , I calculated the number of membranes and pressure vessels, and finally, the pump pressure was calculated for me. All the reports on this software are attached, and thus the energy I calculated and finally calculated the required area for the use of wind turbines. I calculated this energy estimate for three different volumetric flow rates as follows:

$$Q_{\text{turbine}} = 0.5 * \rho_{\text{air}} * u^3$$

$$Q_{\text{turbine}} = 0.5 * 1.27 \frac{\text{kg}}{\text{m}^3} * \left(6 \frac{\text{m}}{\text{s}}\right)^3 = 137.16 \frac{\text{W}}{\text{m}^2} = 0.13716 \frac{\text{kW}}{\text{m}^2}$$

$\eta_{\text{turbine}} = 30\%$

$$Q_{\text{turbine}} = 0.13716 * 0.3 = 0.04 \frac{\text{kW}}{\text{m}^2}$$

Since surface water is being treated, BW30-400 is used. According to the datasheet of this membrane, the active area is 37 m^2 .

FilmTec™ Element	Active area ft ² (m ²)	Feed spacer thickness (mil)	Permeate flow	Stabilized salt rejection (%)	Minimum salt rejection (%)
			rate gpd (m ³ /d)		
BW30-400	400 (37)	28	10,500 (40)	99.5	99.0

For treating surfacewater with $\text{SDI} < 2.5$, the RO system operates satisfactorily when the flux is 27-34 $\text{lit}/(\text{m}^2 \cdot \text{h})$.

Feed Source	Surface Water			
	With DuPont UF + B-free	Ultrafiltration	Generic membrane filtration or advanced conventional pretreatment	Generic conventional pretreatment
Design Flux Range, gfd (lmh)	17 ~ 21 (29 ~ 36)	16 ~ 20 (27 ~ 34)	13 ~ 17 (22 ~ 29)	12 ~ 16 (20 ~ 27)

Figure 20 Design guidelines for 8-inch FilmTec™ Elements in water treatment.

The number of membrane elements is calculated below:

$$N_E = \frac{\dot{v}}{f * A}$$

For 100 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{100 \frac{m^3}{d} * \frac{1000 \text{ lit}}{1 m^3} * \frac{1 d}{24 h}}{(27 - 34) \frac{\text{lit}}{m^2 * h} * 37 m^2} = [3.3 - 4.17] \approx 4$$

The 4-element pressure vessel is chosen.

$$N_v = \frac{4}{4} = 1$$

TDS of water and Water type (surface water with SDI<2.5) are the inputs of WAVE software.

Design temperature, pH, and system recovery are 25°C, 7.9 and 55 %, respectively.

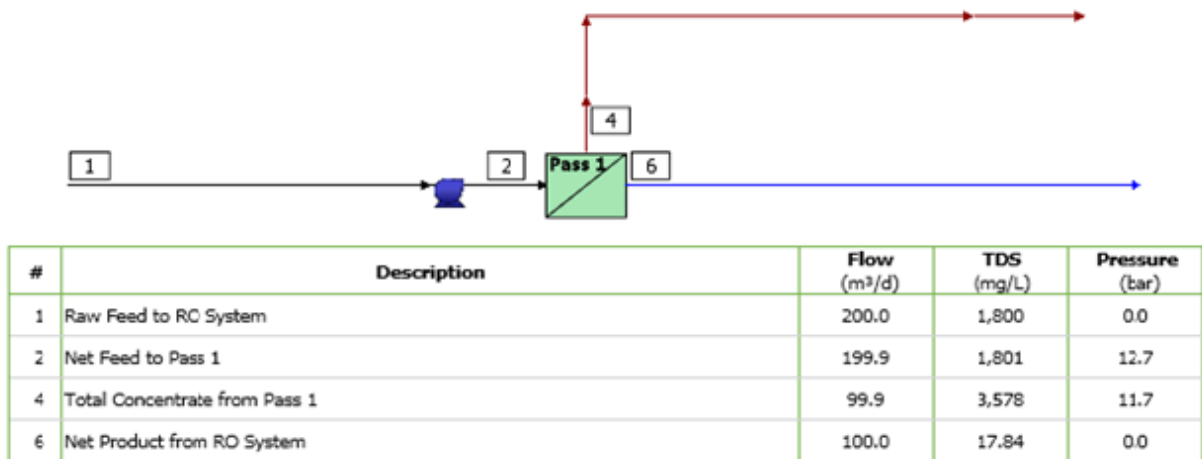


Figure 21 RO System Flow for volumetric 100 m³/day.

Table 6 RO Flow for volumetric 100 m³/day

Stage	Element	Recovery (%)	Feed Flow (m ³ /d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m ³ /d)	Perm Flow (m ³ /d)	Perm TDS (mg/L)
1	1	13.6	199.9	12.4	1,801	172.8	27.1	12.71
1	2	14.9	172.8	12.1	2,081	147.0	25.8	15.40
1	3	16.6	147.0	11.9	2,443	122.6	24.4	19.22
1	4	18.5	122.6	11.8	2,923	99.9	22.7	25.27

Maximum element recovery for surface water with SDI<2.5 (beach well) is 19%. Therefore, the design is optimum.

The permeate flow TDS is 17.84 mg/lit. The pressure of the high-pressure pump is 12.7 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 200 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 1.15 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 1.15 \div 0.7 = 1.65 \text{ kW}$$

High-Pressure Pump:

$$P = 12.7 \text{ bar} + 2 \text{ bar (pressure drop)} = 14.7 \text{ bar} = 1470 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 1470 \text{ kPa} * 200 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 3.40 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 3.40 \div 0.7 = 4.86 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 4.86 + 1.65 = 6.51 \text{ kW}$$

Power of Turbine:

$$Q_{\text{turbine}} = 0.5 * \rho_{\text{air}} * u^3$$

$$Q_{\text{turbine}} = 0.5 * 1.27 \frac{\text{kg}}{\text{m}^3} * \left(6 \frac{\text{m}}{\text{s}}\right)^3 = 137.16 \frac{\text{W}}{\text{m}^2} = 0.13716 \frac{\text{kW}}{\text{m}^2}$$

$\eta_{\text{turbine}} = 30\%$

$$Q_{\text{turbine}} = 0.13716 * 0.3 = 0.04 \frac{\text{kW}}{\text{m}^2}$$

Swept Area of Wind Turbine:

$$\text{Total Area} = \frac{Q_{\text{pump}}}{Q_{\text{turbine}}} = \frac{4.86 \text{ kW}}{0.04 \frac{\text{kW}}{\text{m}^2}} = 121.5 \text{ m}^2$$

$$\text{Number of Turbine} = \frac{\text{Total Area}}{\text{Swept Area Turbine}} = \frac{121.5 \text{ m}^2}{1735 \text{ m}^2} = 0.07 \approx 1$$

For 1000 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{1000 \frac{\text{m}^3}{\text{d}} * \frac{1000 \text{ lit}}{1 \text{ m}^3} * \frac{1 \text{ d}}{24 \text{ h}}}{(27 - 34) \frac{\text{lit}}{\text{m}^2 * \text{h}} * 37 \text{ m}^2} = [33 - 42] \approx 42$$

The 6-element pressure vessel is chosen.

$$N_v = \frac{42}{6} = 7$$

To increase the recovery, the 2-stage configuration is applied. Five modules are placed in stage 1, and 2 are placed in stage 2.

TDS of water and Water type (surface water with $SDI < 2.5$) are the inputs of WAVE software. Design temperature, pH, and system recovery are 25°C , 7.9 and 75 %, respectively.

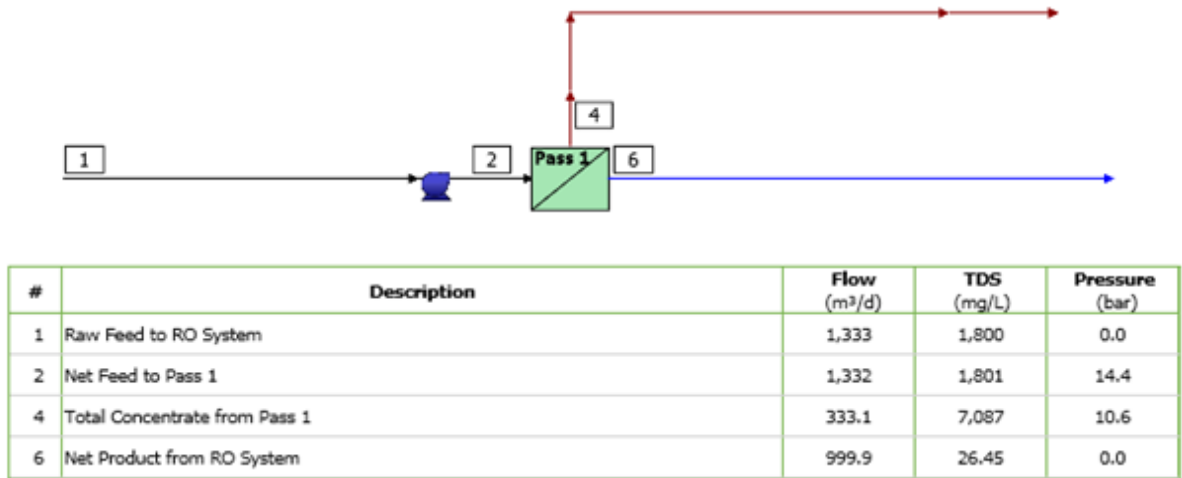


Figure 22 RO System Flow for volumetric 1000 m³/day.

Table 7 RO Flow for volumetric 1000 m³/day

Stage	Element	Recovery (%)	Feed Flow (m³/d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m³/d)	Perm Flow (m³/d)	Perm TDS (mg/L)
1	1	11.3	266.5	14.0	1,801	236.3	30.2	11.20
1	2	12.2	236.3	13.7	2,029	207.6	28.8	13.16
1	3	13.2	207.6	13.4	2,307	180.2	27.4	15.66
1	4	14.4	180.2	13.1	2,655	154.2	26.0	19.24
1	5	15.9	154.2	12.9	3,098	129.7	24.5	24.32
1	6	17.5	129.7	12.7	3,675	107.0	22.7	31.85
2	1	7.8	267.5	12.4	4,446	246.7	20.9	37.44
2	2	7.8	246.7	12.0	4,817	227.5	19.2	44.26
2	3	7.7	227.5	11.7	5,217	210.0	17.6	52.56
2	4	7.6	210.0	11.4	5,646	194.0	16.0	62.67
2	5	7.5	194.0	11.1	6,102	179.6	14.5	75.03
2	6	7.2	179.6	10.8	6,584	166.6	13.0	90.20

Maximum element recovery for surface water with $SDI < 2.5$ (beach well) is 19%. Therefore, the design is optimum.

The permeate flow TDS is 26.45 mg/lit. The pressure of the high-pressure pump is 14.4 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 1333 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 7.71 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 7.71 \div 0.7 = 11.02 \text{ kW}$$

High-Pressure Pump:

$$P = 14.4 \text{ bar} + 2 \text{ bar (pressure drop)} = 16.4 \text{ bar} = 1640 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 1640 \text{ kPa} * 1333 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 25.30 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 25.0 \div 0.7 = 36.14 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 36.14 + 11.02 = 47.16 \text{ kW}$$

Power of Turbine:

$$Q_{\text{turbine}} = 0.5 * \rho_{\text{air}} * u^3$$

$$Q_{\text{turbine}} = 0.5 * 1.27 \frac{\text{kg}}{\text{m}^3} * \left(6 \frac{\text{m}}{\text{s}}\right)^3 = 137.16 \frac{\text{W}}{\text{m}^2} = 0.13716 \frac{\text{kW}}{\text{m}^2}$$

$$\eta_{\text{turbine}} = 30\%$$

$$Q_{\text{turbine}} = 0.13716 * 0.3 = 0.04 \frac{\text{kW}}{\text{m}^2}$$

Swept Area of Wind Turbine:

$$Total\ Area = \frac{Q_{pump}}{Q_{turbine}} = \frac{47.16\ kW}{0.04\ \frac{kW}{m^2}} = 1179\ m^2$$

$$Number\ of\ Turbine = \frac{Total\ Area}{Swept\ Area\ Turbine} = \frac{1179\ m^2}{1735\ m^2} = 0.67 \approx 1$$

For 5000 m³/day:

$$N_E = \frac{\dot{v}}{f * A} = \frac{5000\ \frac{m^3}{d} * \frac{1000\ lit}{1\ m^3} * \frac{1\ d}{24\ h}}{(27 - 34)\ \frac{lit}{m^2 * h} * 37\ m^2} = [166 - 209] \approx 192$$

The 6-element pressure vessel is chosen.

$$N_v = \frac{192}{6} = 32$$

To increase the recovery, the 2-stage configuration is applied. Twenty modules are placed in stage 1, and 12 modules are placed in stage 2.

TDS of water and Water type (surface water with SDI<2.5) are the inputs of WAVE software.

Design temperature, pH, and system recovery are 25°C, 7.9 and 75 %, respectively.

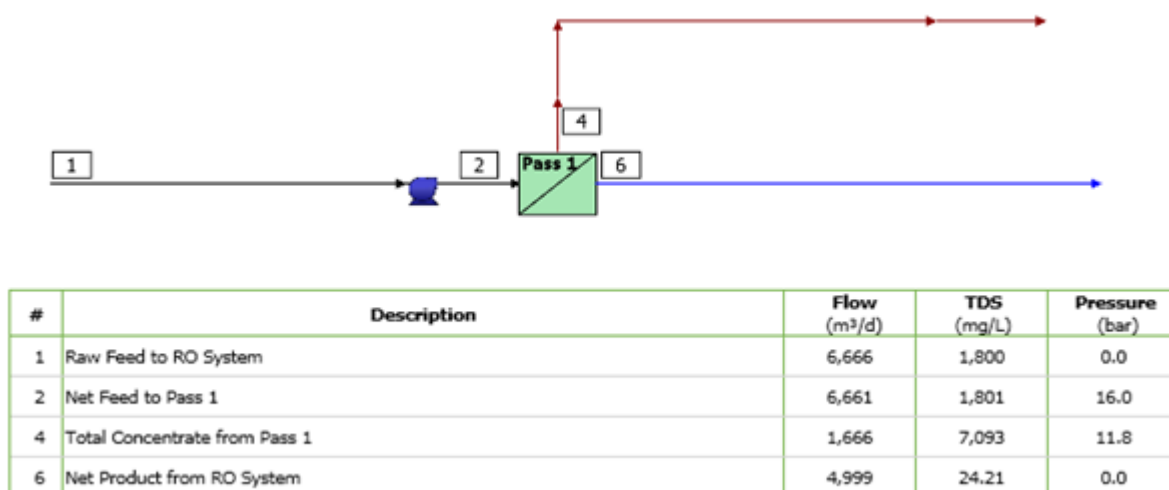


Figure 23 RO System Flow for volumetric 5000 m³/day.

Table 8 RO Flow for volumetric 5000 m³/day

Stage	Element	Recovery (%)	Feed Flow (m ³ /d)	Feed Press (bar)	Feed TDS (mg/L)	Conc Flow (m ³ /d)	Perm Flow (m ³ /d)	Perm TDS (mg/L)
1	1	10.0	333.1	15.7	1,801	299.7	33.4	10.02
1	2	10.6	299.7	15.2	2,000	267.9	31.8	11.61
1	3	11.3	267.9	14.7	2,236	237.5	30.4	13.52
1	4	12.2	237.5	14.3	2,519	208.6	29.0	16.04
1	5	13.3	208.6	14.0	2,866	180.9	27.6	19.43
1	6	14.5	180.9	13.8	3,299	154.7	26.2	24.04
2	1	9.4	257.9	13.4	3,852	233.7	24.1	28.59
2	2	9.6	233.7	13.0	4,245	211.3	22.4	34.15
2	3	9.8	211.3	12.7	4,689	190.6	20.7	41.12
2	4	10.0	190.6	12.4	5,191	171.7	19.0	49.99
2	5	10.1	171.7	12.2	5,757	154.4	17.3	61.39
2	6	10.1	154.4	12.0	6,390	138.8	15.6	76.22

Maximum element recovery for surface water with SDI<2.5 (beach well) is 19%. Therefore, the design is optimum.

The permeate flow TDS is 24.21 mg/lit. The pressure of the high-pressure pump is 16 bar.

Raw Water Pump:

$$P = 5 \text{ bar} = 500 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 500 \text{ kPa} * 6666 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 38.57 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 38.57 \div 0.7 = 55.10 \text{ kW}$$

High-Pressure Pump:

$$P = 16 \text{ bar} + 2 \text{ bar (pressure drop)} = 18 \text{ bar} = 1800 \text{ kPa}$$

$$Q = P * \dot{v}$$

$$Q = 1800 \text{ kPa} * 6666 \frac{\text{m}^3}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{3600 \text{ s}} = 138.87 \text{ kW}$$

$$\eta_{\text{pump}} = 70\%$$

$$Q = 138.87 \div 0.7 = 198.39 \text{ kW}$$

Total Consumed Power:

$$Q_{\text{Total}} = 198.39 + 38.57 = 236.96 \text{ kW}$$

Power of Turbine:

$$Q_{\text{turbine}} = 0.5 * \rho_{\text{air}} * u^3$$

$$Q_{\text{turbine}} = 0.5 * 1.27 \frac{\text{kg}}{\text{m}^3} * \left(6 \frac{\text{m}}{\text{s}}\right)^3 = 137.16 \frac{\text{W}}{\text{m}^2} = 0.13716 \frac{\text{kW}}{\text{m}^2}$$

$$\eta_{\text{turbine}} = 30\%$$

$$Q_{\text{turbine}} = 0.13716 * 0.3 = 0.04 \frac{\text{kW}}{\text{m}^2}$$

Swept Area of Wind Turbine:

$$Total\ Area = \frac{Q_{pump}}{Q_{turbine}} = \frac{236.96\ kW}{0.04\ \frac{kW}{m^2}} = 5924\ m^2$$

$$Number\ of\ Turbine = \frac{Total\ Area}{Swept\ Area\ Turbine} = \frac{5924\ m^2}{1735\ m^2} = 3.41 \approx 4$$

Chapter 5

Economic Analysis

5.1 CECPI and Currency Conversion:

CECPI (2011)	587.7
CECPI (2022)	797.6
1 \$ (2011)	15,000 Rial
1 \$ (2022)	317,020 Rial

5.2 Unit Price of Solar Panel:

$$7,150,000 \text{ Rial} * \frac{1\$}{15,000 \text{ Rial}} = 476.66\$$$

$$476.66\$ * 797.6 = 380184.02$$

$$\text{Price in 2022} = 380184.02 \div 587.7 = 646.90151\$$$

$$\text{Each Solar Panel Price in Iran (2022)} = 646.90151\$ * 317,020 \text{ Rial} = 205,080,716 \text{ Rial}$$

5.3 Unit Price of Battery:

$$5,200,000 \text{ Rial} * \frac{1\$}{15,000 \text{ Rial}} = 346.66 \$$$

$$346.66 * 797.6 = 276496$$

$$\text{Price in 2022} = 276496 \div 587.7 = 470.4714 \$$$

$$\text{Each Battery price in Iran (2022)} = 470.4714\$ * 317,020 \text{ Rial} = 149,148,829.3 \text{ Rial}$$

5.4.a. Economic Analysis for 100 m³/day Case:

Purchased Cost of Equipment:

All Solar Panel Price:

$$672 * 205,080,716 = 138,000,000,000 \text{ Rial}$$

All Batteries:

$$627 * 149,148,829.3 = 100,000,000,000 \text{ Rial}$$

Total Price:

$$138,000,000,000 \text{ Rial} + 100,000,000,000 \text{ Rial} = 2.38152 * 10^{11} \text{ Rial}$$

$$2.38 * 10^{11} \text{ Rial} * \frac{1\$}{317,020 \text{ Rial}} = 751220.6 \$$$

Installation Cost:

The global capacity weighted-average total installed cost for solar photovoltaic projects commissioned in 2019 was 995 USD/kW³⁶;

$$Q_{High \ pressure} = 16.62 \div 0.7 = 23.74 \text{ kw}$$

$$Q_{Raw \ Water} = 1.15 \div 0.7 = 1.65 \text{ kw}$$

$$Q_{Total} = 11.60 + 0.81 = 18.27 \text{ kW}$$

$$18.27 \text{ kW} * 995 \frac{USD}{kW} = 18179.02 \text{ USD}$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$751220.6 \$ + 18179.02 \$ = 769399.6 \$$$

Cost of Land:

$$1,000 \text{ m}^2 * \frac{5,000,000 \text{ Rial}}{1 \text{ m}^2} * \frac{1 \$}{317,020 \text{ Rial}} = 15771.88 \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$769399.6 \$ + 15771.88 \$ = 785171.48 \$$$

The Operating Cost of the Plant:**Cost of Employees:**

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: $4 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 21197.40 \$$

Salary of financial analysts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of electrical, civil, mechanical, and energy engineers: $4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 26496.68 \$$

Salary of logistics experts: $1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$

Salary of environmental experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of health and safety experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$785171.48 * 0.1 = 78517.148 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\textit{Total Operating Cost} = 72423.12\$ + 78517.148 \$ = 150940.26 \$$$

Total Income:

The cost of power for 12 hours a day is the money that will be saved by employing solar PV panels as the equipment for power generation.

Cost of Power:

$$(for\ one\ day)Q_{High\ pressure} = 16.62 \div 0.7 = 23.74\ kW * 12\ hr = 199.44\ kWhr$$

$$(for\ a\ year) = Q = 199.44\ kWhr * 365 = 72797.22\ kWhr$$

$$72797.22 * 0.011\$ = 800.7694\ \$$$

$$Total\ Income = Cost\ of\ Power - Total\ Operating\ Cost$$

$$Total\ Income = 800.7694\ \$ - 150940.26\ \$ = -150139\ \$$$

5.5.a. Economic Analysis for 1000 m³/day Case:

All Solar Panel Price:

$$6530 * 205,080,716 = 1.34 * 10^{12} Rial$$

All Batteries:

$$6530 * 149,148,829.3 = 9.74 * 10^{11} Rial$$

Total Price:

$$1.34 * 10^{12} Rial + 9.74 * 10^{11} Rial = 2.31 * 10^{12} Rial$$

$$2.31 * 10^{12} Rial * \frac{1\$}{317,020 Rial} = 7296983 \$$$

Installation Cost:

The global capacity weighted-average total installed cost for solar photovoltaic projects commissioned in 2019 was 995 USD/kW;

$$Q_{High\ pressure} = 161.11 \div 0.7 = 230.15\ kW$$

$$Q_{Raw\ Water} = 11.5 \div 0.7 = 16.5\ kW$$

$$Q_{Total} = 230.15 + 16.5 = 177.61\ kW$$

$$6350.01\ kW * 995 \frac{USD}{kW} = 176723.1\ USD$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$7296983\ \$ + 176723.1\ \$ = 7473706\ \$$$

Cost of Land:

$$12,000\ m^2 * \frac{5,000,000\ Rial}{1\ m^2} * \frac{1\ \$}{317,020\ Rial} = 189262.50\ \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$7473706\ \$ + 189262.50\ \$ = 7662969\ \$$$

The Operating Cost of the Plant:**Cost of Employees:**

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: $4 * 120\ million\ Rial *$

$$\frac{1\ \$}{317,020\ Rial} * 14 = 21197.40\ \$$$

$$\text{Salary of financial analysts: } 1 * 120\ million\ Rial * \frac{1\ \$}{317,020\ Rial} * 14 = 5299.28\ \$$$

Salary of electrical, civil, mechanical, and energy engineers: $4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 26496.68 \$$

Salary of logistics experts: $1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$

Salary of environmental experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of health and safety experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$7662969 * 0.1 = 766296.9 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\textit{Total Operating Cost} = 72423.12 \$ + 766296.9 \$ = 838720.02 \$$$

Total Income:

The cost of power for 12 hours a day is the money that will be saved by employing solar PV panels as the equipment for power generation.

Cost of Power:

$$(\text{for one day})Q_{\text{High pressure}} = 161.11 \div 0.7 = 230.15 \text{ kW} * 12 \text{ hr} = 1933.33 \text{ kWhr}$$

$$(\text{for a year}) = Q = 1933.33 \text{ kWhr} * 365 = 705666.7 \text{ kWhr}$$

$$705666.7 * 0.011\$ = 7762.33 \$$$

$$\textit{Total Income} = \textit{Cost of Power} - \textit{Total Operating Cost}$$

$$\textit{Total Income} = 7762.33 \$ - 838720.02 \$ = -830957 \$$$

5.6.a. Economic Analysis for 5000 m³/day Case:

All Solar Panel Price:

$$32527 * 205,080,716 = 6.67 * 10^{12} \text{ Rial}$$

All Batteries:

$$32527 * 149,148,829.3 = 4.85 * 10^{12} \text{ Rial}$$

Total Price:

$$6.67 * 10^{12} \text{ Rial} + 4.85 * 10^{12} \text{ Rial} = 1.15 * 10^{13} \text{ Rial}$$

$$1.15 * 10^{13} \text{ Rial} * \frac{1\$}{317,020 \text{ Rial}} = 36344385 \$$$

Installation Cost:

The global capacity weighted-average total installed cost for solar photovoltaic projects commissioned in 2019 was 995 USD/kW;

$$Q_{High\ pressure} = 802.08 \div 0.7 = 1145.83 \text{ kW}$$

$$Q_{Raw\ Water} = 57.9 \div 0.7 = 82.71 \text{ kW}$$

$$Q_{Total} = 1145.83 + 82.71 = 884.79 \text{ kW}$$

$$884.79 \text{ kW} * 995 \frac{USD}{kW} = 880369.4 \text{ USD}$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$36344385 \$ + 880369.4 \$ = 37224754 \$$$

Cost of Land:

$$700,000 \text{ m}^2 * \frac{5,000,000 \text{ Rial}}{1 \text{ m}^2} * \frac{1 \$}{317,020 \text{ Rial}} = 1104031.3 \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$37224754 \$ + 1104031.3 \$ = 38328785 \$$$

The Operating Cost of the Plant:**Cost of Employees:**

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: $4 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 21197.40 \$$

Salary of financial analysts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of electrical, civil, mechanical, and energy engineers: $4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 26496.68 \$$

Salary of logistics experts: $1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$

Salary of environmental experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of health and safety experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$38328785 * 0.1 = 3832878.5 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\textit{Total Operating Cost} = 72423.12 \$ + 3832878.5 \$ = 3905301.62 \$$$

Total Income:

The cost of power for 12 hours a day is the money that will be saved by employing solar PV panels as the equipment for power generation.

Cost of Power:

$$(\textit{for one day})Q_{\textit{High pressure}} = 802.08 \div 0.7 = 1145.83 \textit{ kW}$$

$$* 12 \textit{ hr} = 9625 \textit{ kWhr}$$

$$(\textit{for a year}) = Q = 9625 \textit{ kWhr} * 365 = 3513125 \textit{ kWhr}$$

$$3513125 * 0.011\$ = 38644.375 \$$$

$$\textit{Total Income} = \textit{Cost of Power} - \textit{Total Operating Cost}$$

$$\textit{Total Income} = 38644.375 \$ - 3905301.62 \$ = -3866657.245 \$$$

The purpose of economic analysis is to show the profitability of the plant over the life of the case. Such an analysis should include the capital costs (purchase and installation of equipment, land clearing, construction of buildings and service facilities, etc.) that are required during the construction of the plant (fixed costs) and operating costs (purchase of raw materials, personnel salaries, water and electricity, taxes, etc.) that are incurred annually (variable costs). Therefore, in

this analysis, we must consider the future value of our initial investment and also determine the annual costs over the life of the plant proportionately.

Economic analysis is the main factor in determining whether a new process will be built or not.

For all three plants, I have considered 15 years of life and 10 years of depreciation.

For doing economic analysis, we had to sum our investment, sales, and income together. The total investment (IT) that we need to get the plant going is referred to as capital investment IT.

$$IT = IF + IW + IL$$

Where IF is the fixed capital cost, IW is the working capital (spending in the first year of operation includes initial raw materials, salaries, parts, etc. and it is equal to 15% of IF), and IL is the cost of the land.

Annual sales: The annual sales are calculated by summing the product of the production rate of each product, R_i , multiplied by its price, C_i .

$$AS = R_i * C_i$$

Annual total expenses: The annual total expenses, ATE, can be calculated as the sum of the annual direct manufacturing cost, ADME, the annual indirect manufacturing expenses, AIME, and the annual general expenses, AGE.

$$ATE = ADME + AIME + AGE$$

In this analysis 'A' represents the annual flow of money, \$/year.

The annual cash income, ACI, of a plant is equal to the annual sales, AS, minus annual total expenses, ATE.

$$ACI = AS - ATE$$

The government removes annual income taxes, AIT, leaving the annual net cash income, ANCI.

$$ANCI = ACI - AIT$$

The annual income taxes are calculated by subtracting the annual depreciation, AD, and the government annual incentives, AI, from the annual cash income, ACI, multiplied by the taxation rate, t , which is usually around 35 %.

$$AIT = (ACI - AD - AI) * t^{37}$$

yr	I _F	I _W	A _S	A _{TE}	A _{CI} =A _S -A _{TE} -I _W	A _D =I _F /10	A _I	A _{IT} =0.35*(A _{CI} -A _D -A _I)	A _{NCI} =A _{CI} -A _{IT}	CumA _{NCI}
0										0
1	785171.48		0	0	-785171.48			0	-785171.48	-785171.48
2	0	117776	800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-792499.17
3	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-799826.86
4	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-807154.55
5	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-814482.23
6	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-821809.92
7	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-829137.61
8	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-836465.3
9	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-843792.99
10	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-851120.68
11	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-858448.37
12	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-865776.05
13	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-873103.74
14	0		800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-880431.43
15	0	-1E+05	800.7694	54352.6	-53551.8314	78517.15	0	-46224.14279	-7327.68861	-887759.12

Figure 24 Cumulative Net Cash Income for 100 m³/day

yr	I _F	I _W	A _S	A _{TE}	A _{CI} =A _S -A _{TE} -I _W	A _D =I _F /10	A _I	A _{IT} =0.35*(A _{CI} -A _D -A _I)	A _{NCI} =A _{CI} -A _{IT}	CumA _{NCI}
0										0
1	7662969		0	0	-7662969			0	-7662969	-7662969
2	0	1E+06	7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7693282.9
3	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7723596.7
4	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7753910.6
5	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7784224.5
6	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7814538.3
7	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7844852.2
8	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7875166.1
9	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7905479.9
10	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7935793.8
11	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7966107.6
12	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-7996421.5
13	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-8026735.4
14	0		7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-8057049.2
15	0	-1E+06	7762.33	467020	-459258.122	766296.9	0	-428944.2577	-30313.8643	-8087363.1

Figure 25 Cumulative Net Cash Income for 1000 m³/day

yr	I _F	I _W	A _S	A _{TE}	A _{CI} =A _S -A _{TE} -I _W	A _D =I _F /10	A _I	A _{IT} =0.35*(A _{CI} -A _D -A _I)	A _{NCI} =A _{CI} -A _{IT}	CumA _{NCI}
0										0
1	38328785		0	0	-38328785			0	-38328785	-38328785
2	0	6E+06	38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-39458237
3	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-40587689
4	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-41717142
5	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-42846594
6	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-43976046
7	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-45105498
8	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-46234950
9	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-47364403
10	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-48493855
11	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-49623307
12	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-50752759
13	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-51882212
14	0		38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-53011664
15	0	-6E+06	38644.38	3840121	-3801476.44	3832879	0	-2672024.228	-1129452.21	-54141116

Figure 26 Cumulative Net Cash Income for 5000 m³/day

Finally, I calculated the bank profits of 10%, 16%, and 17%, which shows that we will not have any profit in this project and our capital will not return.

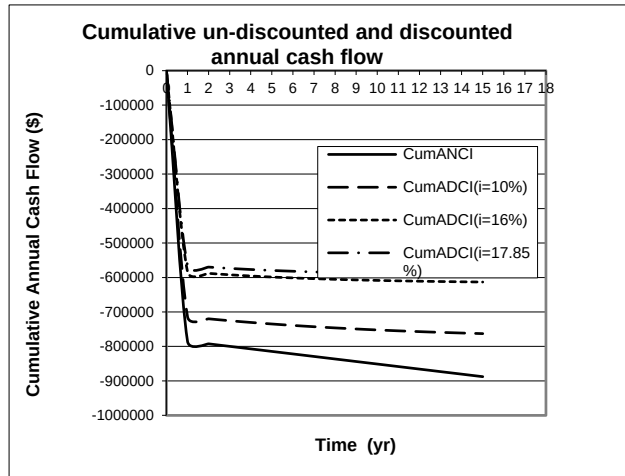


Figure 27 Interest for 100 m³/day

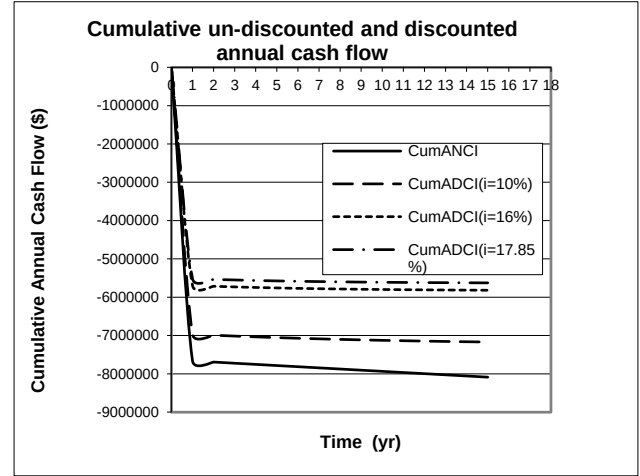


Figure 28 Interest for 1000 m³/day

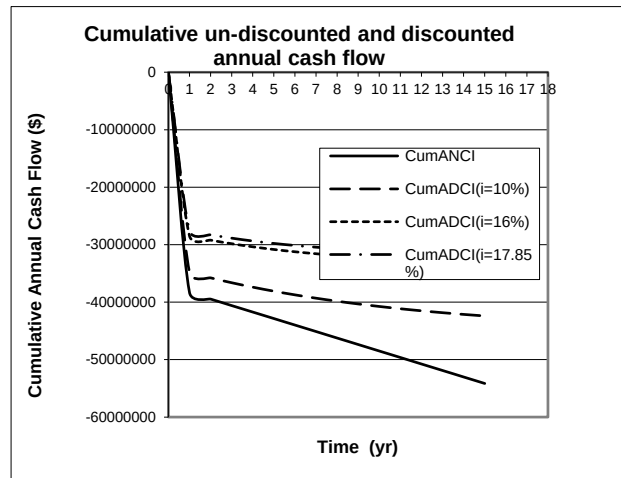


Figure 29 Interest for 5000 m³/day

5.7.b Economic Analysis for 100 m³/day Case:

Purchased Cost:

Each Wind Turbine (V-47 660 kW) price³⁸: 145,000€ = 145,000\$

Wind Turbine price:

$$1 * 145,000\$ = 145,000 \$$$

On 20 September 2022: 1\$= 317,020 Rial

$$145,000 \$ * 317,020 R = 4.59679 * 10^{10} \text{ Rial}$$

Installation Cost:

20% of the purchased cost is considered as the installation cost:

$$145,000 \$ * 0.2 = 29,000 \$$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$145,000 \$ + 29,000 \$ = 174,000 \$$$

Cost of Land:

$$100 \text{ m}^2 * \frac{5,000,000 \text{ Rial}}{1 \text{ m}^2} * \frac{1 \$}{317,020 \text{ Rial}} = 1577.18 \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$174000 \$ + 1577.18 \$ = 175577.18 \$$$

The Operating Cost of the Plant:

Cost of Employees:

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: 4 * 120 *million Rial* *

$$\frac{1 \$}{317,020 \text{ Rial}} * 14 = 21197.40 \$$$

$$\text{Salary of financial analysts: } 1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$$

$$\text{Salary of electrical, civil, mechanical, and energy engineers: } 4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 26496.68 \$$$

$$\text{Salary of logistics experts: } 1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$$

$$\text{Salary of environmental experts: } 1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$$

$$\text{Salary of health and safety experts: } 1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$175577.18 * 0.1 = 17557.718 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\text{Total Operating Cost} = 72423.12 \$ + 17557.718 \$ = 89980.838 \$$$

Total Income:

The cost of power for 24 hours a day is the money that will be saved by employing wind turbines as the equipment for power generation.

Cost of Power:

$$(\text{for one day})Q_{\text{High pressure}} = 3.40 \div 0.7 = 4.86 \text{ kW} * 24 \text{ hr} = 116.64 \text{ kWhr}$$

$$(\text{for a year}) = Q = 116.64 \text{ kWhr} * 365 = 42573.6 \text{ kWhr}$$

$$42573.6 * 0.011\$ = 468.30 \$$$

$$\text{Total Income} = \text{Cost of Power} - \text{Total Operating Cost}$$

$$\text{Total Income} = 468.30 \$ - 89980.838 \$ = -89512.538 \$$$

5.8.b Economic Analysis for 1000 m³/day Case:

Purchased Cost:

Each Wind Turbine (V-47 660 kW) price: 145,000€ = 145,000\$

On 20 September 2022: 1\$ = 317,020 Rial

$$145,000 \$ * 317,020 R = 4.59679 * 10^{10} \text{ Rial}$$

Installation Cost:

20% of the purchased cost is considered as the installation cost:

$$145,000 \$ * 0.2 = 29,000 \$$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$145,000 \$ + 29,000 \$ = 174,000 \$$$

Cost of Land:

$$2,000 \text{ m}^2 * \frac{5,000,000 \text{ Rial}}{1 \text{ m}^2} * \frac{1 \$}{317,020 \text{ Rial}} = 31543.75 \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$174000 \$ + 31543.75 \$ = 205543.75 \$$$

The Operating Cost of the Plant:

Cost of Employees:

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: $4 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 21197.40 \$$

Salary of financial analysts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of electrical, civil, mechanical, and energy engineers: $4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 26496.68 \$$

Salary of logistics experts: $1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$

Salary of environmental experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of health and safety experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$205543.75 * 0.1 = 20554.375 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\textit{Total Operating Cost} = 72423.12 \$ + 20554.375 \$ = 92977.49 \$$$

Total Income:

The cost of power for 24 hours a day is the money that will be saved by employing wind turbines as the equipment for power generation.

Cost of Power:

$$(\textit{for one day})Q_{\textit{High pressure}} = 25.0 \div 0.7 = 36.14 \text{ kW} * 24 \text{ hr} = 867.36 \text{ kWhr}$$

$$(\textit{for a year}) = Q = 867.36 \text{ kWhr} * 365 = 316586.4 \text{ kWhr}$$

$$316586.4 * 0.011\$ = 3482.45 \$$$

$$Total\ Income = Cost\ of\ Power - Total\ Operating\ Cost$$

$$Total\ Income = 3482.45 \$ - 92977.49 \$ = -89495.04 \$$$

5.9.b Economic Analysis for 5000 m³/day Case:

Purchased Cost:

Each Wind Turbine (V-47 660 kW) price: 145,000 € = 145,000 \$

Wind Turbine price:

$$4 * 145,000\$ = 580,000 \$$$

On 20 September 2022: 1\$= 317,020 Rial

$$580,000 \$ * 317,020 R = 1.83 * 10^{11} Rial$$

Installation Cost:

20% of the purchased cost is considered as the installation cost:

$$145,000 \$ * 4 * 0.2 = 116,000 \$$$

Capital Cost of Equipment:

Purchased Cost + Installation Cost

$$580,000 \$ + 116,000 \$ = 696,000 \$$$

Cost of Land:

$$12,000\ m^2 * \frac{5,000,000\ Rial}{1\ m^2} * \frac{1\ \$}{317,020\ Rial} = 189262.50 \$$$

Capital Cost of Plant:

Capital Cost of Equipment + Cost of Land

$$696,000 \$ + 189262.50 \$ = 885262.5 \$$$

The Operating Cost of the Plant:

Here, I considered one year equal to 14 months; in this way, 1 month for rewards for each year + 1 month of holidays for each year.

Salary of legal, energy, regulation, real estate, and taxation experts: $4 * 120 \text{ million Rial} *$

$$\frac{1 \$}{317,020 \text{ Rial}} * 14 = 21197.40 \$$$

Salary of financial analysts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of electrical, civil, mechanical, and energy engineers: $4 * 150 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} *$

$$14 = 26496.68 \$$$

Salary of logistics experts: $1 * 200 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 8831.2 \$$

Salary of environmental experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Salary of health and safety experts: $1 * 120 \text{ million Rial} * \frac{1 \$}{317,020 \text{ Rial}} * 14 = 5299.28 \$$

Total salary: 72423.12 \$

Cost of Maintenance and Repairs:

10% of the capital cost is considered the cost of maintenance and repairs.

$$885262.5 * 0.1 = 88526.25 \$$$

Total Operating Cost= *Total salary* + Cost of Maintenance and Repairs

$$\textit{Total Operating Cost} = 72423.12 \$ + 88526.25 \$ = 160949.37 \$$$

Total Income:

The cost of power for 24 hours a day is the money that will be saved by employing wind turbines as the equipment for power generation.

Cost of Power:

$$(for\ one\ day)Q_{High\ pressure} = 138.87 \div 0.7 = 198.39\ kW * 24\ hr = 4761.36\ kWhr$$

$$(for\ a\ year) = Q = 4761.36\ kWhr * 365 = 1737896.4\ kWhr$$

$$1737896.4 * 0.011\$ = 19116.86\ \$$$

$$Total\ Income = Cost\ of\ Power - Total\ Operating\ Cost$$

$$Total\ Income = 19116.86\ \$ - 160949.37\ \$ = -141832.51\ \$$$

The purpose of economic analysis is to show the profitability of the plant over the life of the case. Such an analysis should include the capital costs (purchase and installation of equipment, land clearing, construction of buildings and service facilities, etc.) that are required during the construction of the plant (fixed costs) and operating costs (purchase of raw materials, personnel salaries, water and electricity, taxes, etc.) that are incurred annually (variable costs). Therefore, in this analysis, we must consider the future value of our initial investment and also determine the annual costs over the life of the plant proportionately.

Economic analysis is the main factor in determining whether a new process will be built or not.

For all three plants, I have considered 15 years of life and 10 years of depreciation.

For doing economic analysis, we had to sum our investment, sales, and income together. The total investment (IT) that we need to get the plant going is referred to as capital investment IT.

$$IT = IF + IW + IL$$

Where IF is the fixed capital cost, IW is the working capital (spending in the first year of operation includes initial raw materials, salaries, parts, etc. and it is equal to 15% of IF), and IL is the cost of the land.

Annual sales: The annual sales are calculated by summing the product of the production rate of each product, R_i , multiplied by its price, C_i .

$$AS = R_i * C_i$$

Annual total expenses: The annual total expenses, ATE, can be calculated as the sum of the annual direct manufacturing cost, ADME, the annual indirect manufacturing expenses, AIME, and the annual general expenses, AGE.

$$ATE = ADME + AIME + AGE$$

In this analysis 'A' represents the annual flow of money, \$/year.

The annual cash income, ACI, of a plant is equal to the annual sales, AS, minus annual total expenses, ATE.

$$ACI = AS - ATE$$

The government removes annual income taxes, AIT, leaving the annual net cash income, ANCI.

$$ANCI = ACI - AIT$$

The annual income taxes are calculated by subtracting the annual depreciation, AD, and the government annual incentives, AI, from the annual cash income, ACI, multiplied by the taxation rate, t , which is usually around 35 %.

$$AIT = (ACI - AD - AI) * t$$

yr	I_F	I_W	A_S	A_{TE}	$A_{CI}=A_S-A_{TE}-I_W$	$A_D=I_F/10$	A_I	$A_{IT}=0.35*(A_{CI}-A_D-A_I)$	$A_{NCI}=A_{CI}-A_{IT}$	Cum A_{NCI}
0										0
1	175577.18		0	0	-175577.18			0	-175577.18	-175577.18
2	0	26337	468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-185247.6
3	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-194918.03
4	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-204588.45
5	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-214258.87
6	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-223929.3
7	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-233599.72
8	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-243270.14
9	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-252940.57
10	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-262610.99
11	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-272281.41
12	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-281951.84
13	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-291622.26
14	0		468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-301292.68
15	0	-26337	468.3	24800	-24331.73	17557.72	0	-14661.3068	-9670.4232	-310963.1

Figure 30 Cumulative Net Cash Income for 100 m³/day

yr	I _F	I _W	A _S	A _{TE}	A _{CI} =A _S -A _{TE} I _W	A _O =I _F /10	A _I	A _{IT} =0.35*(A _{CI} -A _O -A _I)	A _{NCI} =A _{CI} -A _{IT}	CumA _{NCI}
0										0
1	205543.75		0	0	-205543.75			0	-205543.75	-205543.75
2	0	30832	3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-214153.97
3	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-222764.2
4	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-231374.42
5	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-239984.64
6	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-248594.86
7	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-257205.09
8	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-265815.31
9	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-274425.53
10	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-283035.76
11	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-291645.98
12	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-300256.2
13	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-308866.42
14	0		3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-317476.65
15	0	-30832	3482.45	27796.7	-24314.237	20554.38	0	-15704.0142	-8610.2228	-326086.87

Figure 31 Cumulative Net Cash Income for 1000 m³/day

yr	I _F	I _W	A _S	A _{TE}	A _{CI} =A _S -A _{TE} I _W	A _O =I _F /10	A _I	A _{IT} =0.35*(A _{CI} -A _O -A _I)	A _{NCI} =A _{CI} -A _{IT}	CumA _{NCI}
0										0
1	885262.5		0	0	-885262.5			0	-885262.5	-885262.5
2	0	132789	19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-904101.92
3	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-922941.34
4	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-941780.76
5	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-960620.18
6	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-979459.59
7	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-998299.01
8	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1017138.4
9	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1035977.9
10	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1054817.3
11	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1073656.7
12	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1092496.1
13	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1111335.5
14	0		19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1130174.9
15	0	-1E+05	19116.86	95768.6	-76651.702	88526.25	0	-57812.2832	-18839.4188	-1149014.4

Figure 32 Cumulative Net Cash Income for 5000 m³/day

Finally, I calculated the bank profits of 10%, 16%, and 17%, which shows that we will not have any profit in this project and our capital will not return.

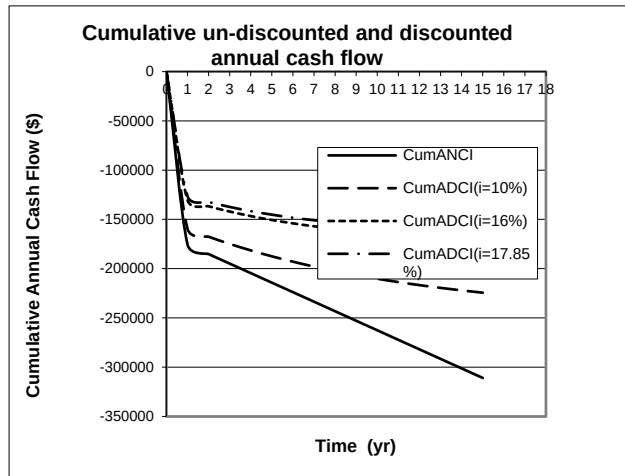


Figure 34 Interest for 100 m³/day

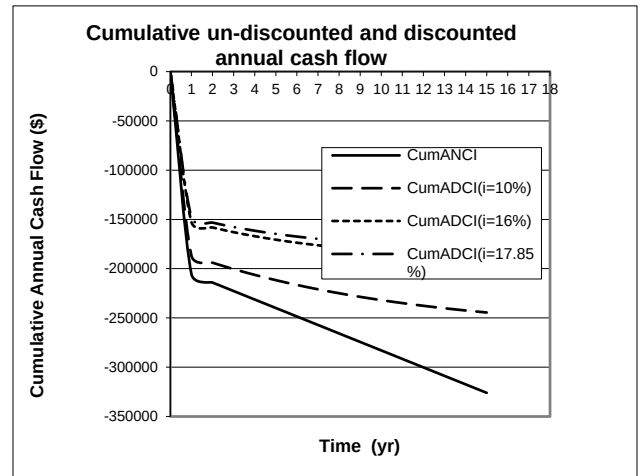


Figure 33 Interest for 1000 m³/day

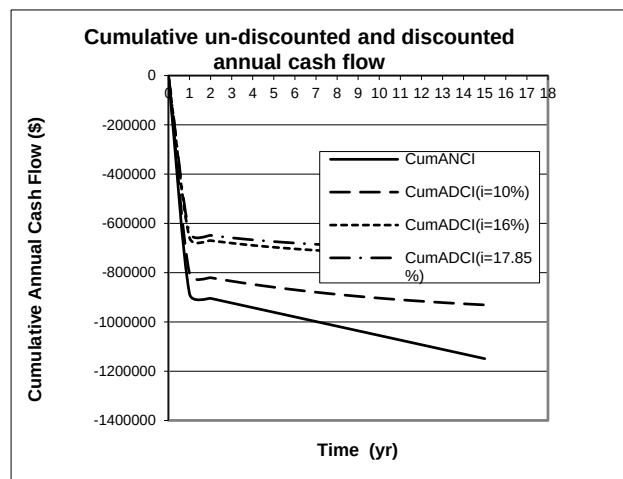


Figure 35 Interest for 5000 m³/day

Chapter 6

Conclusion and Recommendation

6.1 Conclusion

In this article, three methods of water purification (RO, MD, IXR) were investigated; the RO method is more suitable than other methods. We examined the RO method using renewable energies (solar and wind) in the following. Finally, the feasibility and evaluation of two geographical regions of Iran where we had the necessary electricity supply system for water purification with solar and wind energy, and we came to the conclusion that we, as a researcher, to supply power for such a system for water purification In Iran, which is based on reality, it is not economically appropriate to set up such a system; Because the price of fossil fuel and electricity in Iran is very low and the use of renewable energies is not economically justified. But the hidden layers of this theory are that fossil fuels have environmental pollution and will also run out one day. Therefore, it is necessary to have plans for replacement from now on.

6.2 Recommendation

1. Investigation and feasibility study of another renewable energy (Geothermal, Biomass, Biofuel) to supply electricity in the water treatment industry.
2. Using solar thermal energy to supply electricity in industries.
3. Production and use of biogas from sewage sludge.

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