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"Energy-Water nexus in Saudi Arabia"

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Abbreviation

MED: Multi effect distillation (MED)

MSF: Mutli-stage flash (MSF),

RO: Reverse osmosis

Co2: Carbon dioxide

PPM: Parts per million

TDS: Total dissolved solids

SW: Sea water

BW: Brackish water

ED: Electrodialysis

VCD: Vapor Compression Distillation

PH: Potential hydrogen

EJ: Exajoule

KW: kilowatt

MW: Megawatts

PV: Photovoltaic

Figures and tables

Contents

1. Introduction

The demand for fresh water is growing increasingly due to the growth of the world population, increasing the use of water in food and other basic productions. The supply of fresh water on earth however is limited and many countries are already faced with extreme water shortages. Water desalination could be a potential solution to the issue of water shortages.

The need for more treatment plants for non-conventional water supplies is growing worldwide. Any water desalination techniques, which are deemed conventional technologies, have been built into effective and proven processes over the half century. of most established water desalination technologies, three are of special interest: Reverse osmosis (Ro), Mutli-stage flash (MSF), Multi effect distillation (MED). several recent process changes have been made to these techniques to maximize productivity and reduce energy usage per 1 cubic meter of water. (1)

That being said, owing to the high energy needs, the latest desalination approaches are known to be expensive. moreover, because of environmental emission and in terms of cost, they are very costly. In order to merge desalination plants with “green energy sources, several attempts have been made. Over the last few decades, a few tiny brackish and sea water desalination unties installed renewable energy sources. But because of small size, intermittency and insufficient supply of renewable energy, traditional energy sources remain much more preferred for desalination, and in terms of money. (2)(3)

Due to the effect of variety of factors such as the uniqueness of each event, form of feed water, energy supply applied during the desalination process ,the energy consumption per cubic meter of water varies from and to another .The energy consumption for the process of seawater desalination is often incorrectly portrayed, especially when compared to other technologies, since many deciding factors are not take into account .over the last 20 years, big developments have been made in water desalination technologies leading to less energy usage and the cost has been substantially reduced, Despite this the energy footprint of desalination remains high, not every country can afford it and substantial further changes are unlikely to be achieved in the immediate future.(2)(3)(4)

Desalination adds greatly to the overall availability of fresh water for most developed countries. The biggest concern is that desalination would be able to cope with the total need for fresh water in the coastal areas and desalination can be only considered for urban uses or also for commercial and agricultural purposes. The division of the market for alter into various objectives are very important, since it was not feasible to prevent the use of industrial water. This involves drinking water, bathing and cleaning; these are the demands of persons that are bound to be met. With wastewater treatment and water-saving technology, the use of water for industrial and agricultural uses will be limited to the possible limit. Therefore, it’s very interesting to think what we expect from desalination, do we go with it for any human need or simply for the fundamental ones

1.1. Aims and Objectives

The proposed project aims to investigate the energy consumption and CO2 emission of the water desalination plants in the Kingdom of Saudi Arabia. The second aim, is shifting to renewable energy for water desalination is economically beneficial? Another aim of the research is to increase the awareness of water scarcity and its relationship with climate change.

2. Global water resources

Water is the source of life and a vital requirement of human nature. The earth is covered by-around 70% of water. That being said, salt water from the seas with salinity up to 30000 parts per million in total dissolved solids (PPM TDS) is up to 97% of earth's water. Fresh water is just 3% of the world's water. A pool of fresh water has low dissolved salt levels and other Total dissolved compounds. Fresh water can define as water with less than 500ppm TDS according to the world health organization (WHO). Most fresh water is obtained from soil water bodies including wells or surface water like rivers, lakes and reservoirs. Currently 4600km3 per year is the global demand for water ,according to (unesco,1999) is it's expected to grow by about 10-12% every ten years 5060 km3 by 2050

Distribution of earth water is shown below:

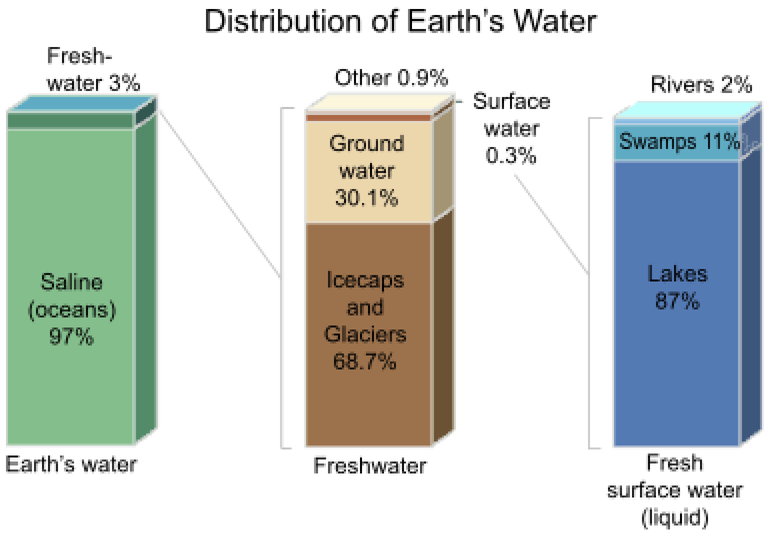


Figure 1

2.1. Water Shortage and Consumption

Many countries and regions lack sufficient fresh water consider their large water supplies. Interesting attention is paid to global water issues. Water depletion is primarily caused by the exponential development of the population. According to the World Bank, about 80 countries have water shortage affecting health and economy, and 40% of the world's population mostly in arid, rural area and islands do not have access to clean water. (6) According to the IDA (international desalination association), humans use only 20 litters of water per day in developing countries, for 200 litters in a day for developed countries for domestic use. While the industry sector consumers a lot of water, the biggest needs are for making good that we consume and wear. (9)

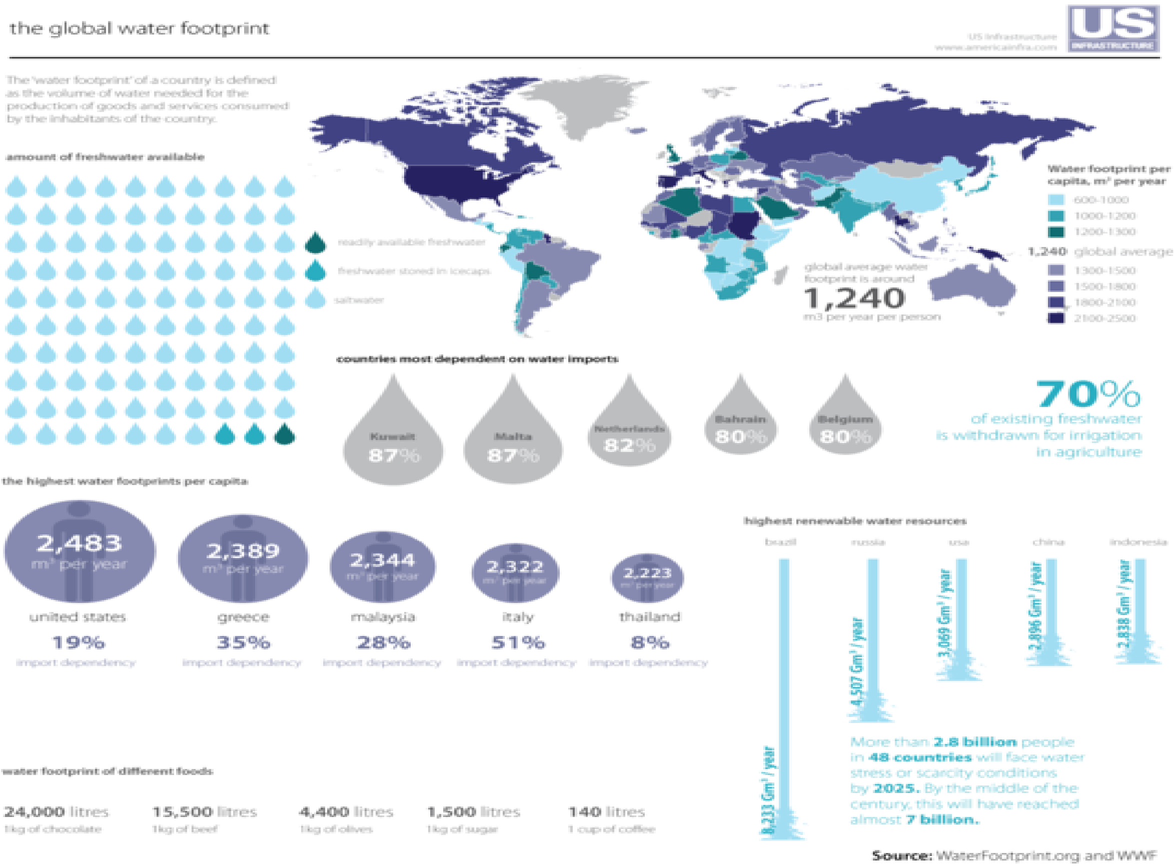


Figure 2

2.2. Water desalination

Either for human use or for the industrial and agricultural uses, salt water or brackish water in not suitable. Nonetheless, there is a significant deposit of sea water on earth, thus, they could have been a significant source of fresh water by extracting the salt from the virtually limitless seawater or brackish water. The desalination of water is a saline separation process; there are two type of feed water a source with a reduced concentration of dissolved salts and concentrated stream of brine and the other with high concentration of salts.

Since the supply of freshwater is limited, mankind should explore alternate water supplies in order to satisfy the need for water for a population that is continually increasing. Every year the human needs for municipal, manufacturing and agricultural operations are growing, water desalination from the enormous water supplies of the seas and oceans may be good solution to this issue. Even the countries that already do not face water problems may also be vulnerable in the immediate future to the issue of fresh water depletion, according to the world watch institute, more than two thirds of the world population will suffer water shortage by 2025 affecting virtually every country in the world. (7)(8)

2.3. Current desalination

Water supply is short and desalination is the prime source of water production the Middle east and in particular the GCC (gulf cooperation council) countries. Countries in the region are the main produces of water desalination in the world suck as Saudi Arabia and the United Arab Emirates. Saudi Arabia which generates 17% of the world's overall desalination capability is the largest producer of fresh water by desalination. Coming second by 12% is the United Arab Emirates, the rest of the GCC add up to 10% of the global desalination power. Together 39% of global desalination is provided in the GCC countries. (10)

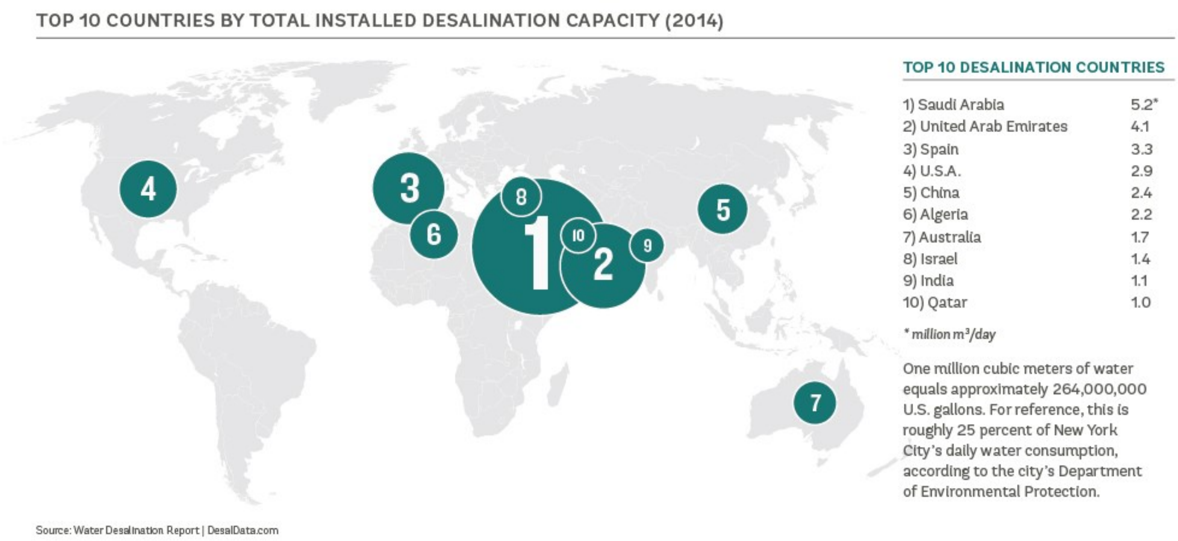


Figure 3

3. Determining the energy consumption

Various factors the influence the water desalination energy footprint was explored in the existing literatures. Any of them affect the energy footprint more significantly than others. The following consideration are: desalination capacity (small/medium/large), form of energy required (electrical or thermal energy), type of water (seawater or brackish), treatment (mechanical or chemical). the overall energy consumption of plants is determined by all these factors.

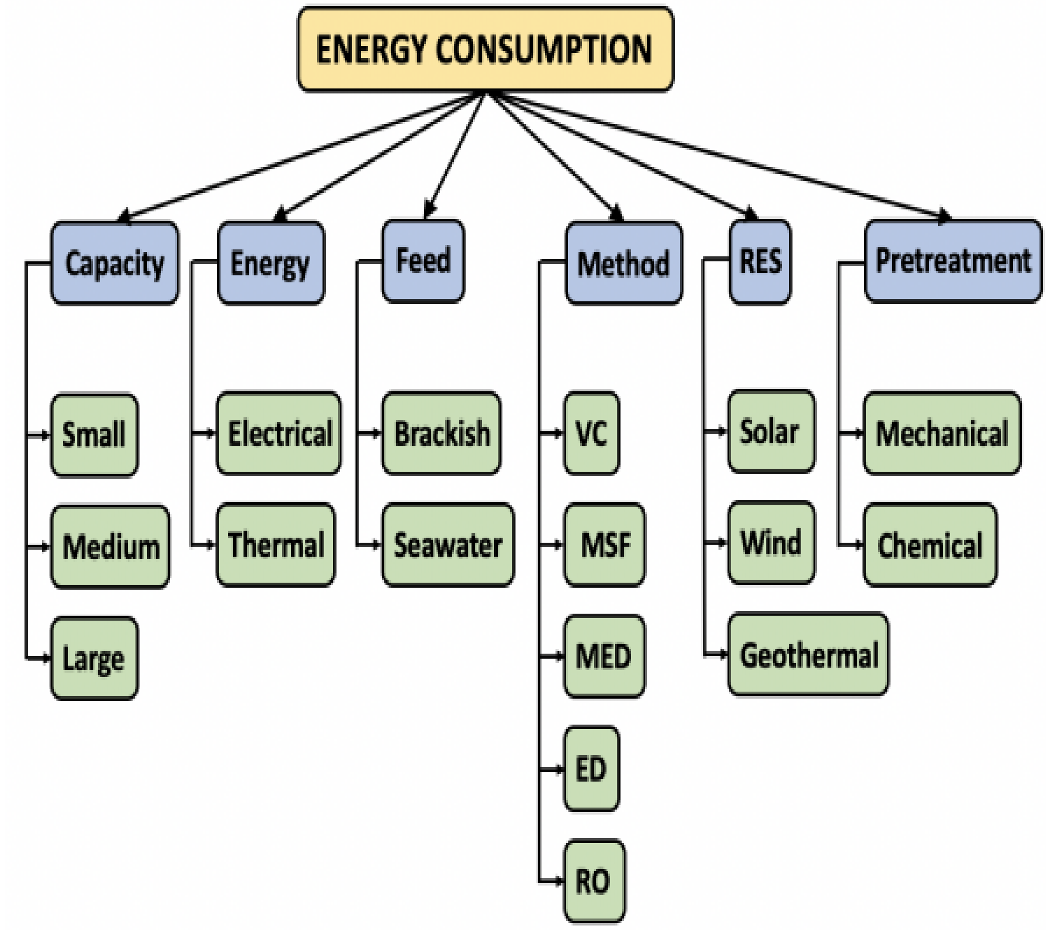


Figure 4

3.1. Capacity

The capacity of the desalination plant has a big effect on electricity use and desalination costs. With expanded capability of desalinating factory, it is more cost-effective. The size of desalination plants may well be classified into three groups independent of desalination technology: Small, medium, large. Each of these technologies has a different set with its three dimensions. Saudi Arabia's massive desalination facilities, which can generate more than half a million-meter cube per day, primarily use large scale thermal desalination methods. (2)(51)

Capacity (m3/day)		Desalination technology					
		SW RO	BW RO	MSF	MED	VC	ED
	Small	<1000	<1000	<23 000	12 000 - 55 000	1000 - 1200	<1000
	Medium	1000 - 5000, 12 000 - 60 000	5000 - 60 000	55 000 - 90 000	55 000 - 90 000	3000	1000 - 60 000
	Large	>60 000 - 320 000	>60 000 - 320 000	>90 000 - 528 000	>90 000	>3000	>60 000 - 145 000

Table 1

3.2. Type of energy

The processes of desalination involve various type of energy: thermal or electrical. Electricity is used in all steps involved in membrane technologies no thermal energy is needed. For the generation of high pressure, forcing water into the membrane, energy is needed for RO plants. Regarding the ED technologies, electricity is important to make a difference in electric potential for production. In order to break seawater from salts, thermal technologies need both electrical and thermal power. MSF and MED use thermal energy as primary source and electricity as secondary source to the drives the water in the pumps. The vast amounts of fuel needed to vaporize the saltwater in thermal methods are more costly than membrane thermal approaches. There is various way to generate electricity such from: coal, oil, gas, renewable energy and nuclear power. Thermal energy can be generated from fossil-fuel-fired boilers, power-plants waste heat and renewable energy. Saudi Arabia mainly use oil as a method to generate energy for the desalination plants. (68)

3.3. PRE-TREATMENT

Water pre-treatment is another determinant of the overall desalination system's energy use. This is especially important for RO, but it is also crucially relevant for other distillation processes. Standard pre-treatment is based on the mechanical treatment of screen and filters for eliminating waste and other unwanted substances, the other treatment is by using chemicals like chlorination, flocculant dosing and dosing for scaling prevention, in this stage electrical energy is needed. the power consumption of the pre-treatment is around 15%-20% of the total power of the desalination process. (4)

3.4. Desalination technologies

Thermal (distillation) process

As the name describe, the thermal process is when the sea water is heated to a level that it starts to vaporize to separate it from the salt. The important factor is that the producers of thermal distillation is too costly for sea water desalination, they can be sub-divided in 3 groups.

Multi-Stage Flash Distillation (MSF)

This method includes the use of distillation in many (Multi-stage) chambers, the method, each successive step of the plant, operators at increasingly lower pressures. Feeding water would then be boiled under high pressure and taken into the first flash chamber, where the pressure is removed causing the water to boil more quickly, which lead to rapid evaporation or flashing, this flashing of the section continues for each stage of the cycle, due to the extreme pressure of each stage is lower than in the previous stage. The vapor created by flashing converts to fresh water by condensing the heat exchanger tuber that pass through each point. The tubers are cooled by the incoming water supply; typically, just a limited amount of feed water is converted to vapor and filtered. The benefit of using multi-stage flash distillation includes the performance of the treated water containing less than 10mg/l of tds.

The salinity of the feed water should not have a direct effect on MSF's operation or costs.it may be paired with other methods for example the use of thermal energy from the power generating plant. In addition, some of the drawback of using multi-stage flash distillation includes construction and operating costs along with high degree of technological expertise. The Average throughput is low; therefore, more feed water is utilized to ensure the same quantity of produced water. Scaling and degradation are major issues, since the evaporator elements are exposed to feed water. (11)(12)(13)

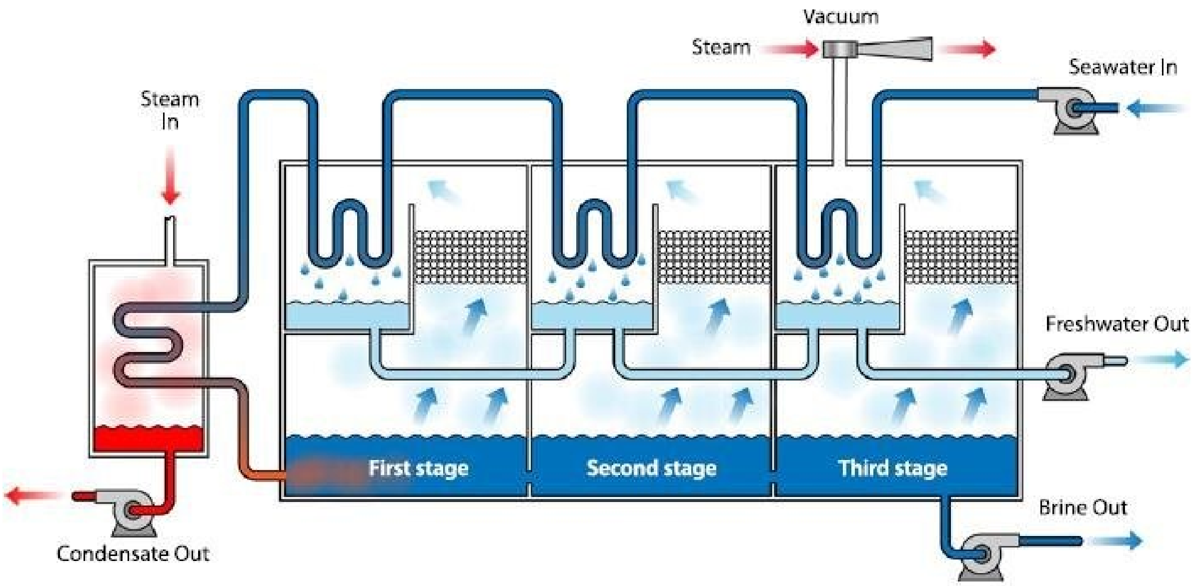


Figure 5

Multi-Effect Distillation (MED)

Multi-effects evaporation (MED), also referred to as multiple effects distillation (MED), is a desalination process which was first designed and implemented in the 1950s.It was a promising effort in the sector of desalination technology however lost traction and was substitute by MSF due to the issue with the doubling of heat transfer tubes. It is not now commonly used but it has gained popularity due to the improved thermal efficiency than MSF. In MED the vapor of each phase is diluted in the next subsequent stage, giving up the heat to create further evaporation. Seawater is then pumped over these heated tubes to evaporate the water. This vapor is then transmitted, the distillery must not enter the primary distillate stream in order to prevent the boiler chemicals from being combined with the pure distillate. At the base of each impact the salt is gathered, which either circulates or transported from the framework. Each stage is successively lowered to improve output. In a lower temperature plant, the top boiling temperature will be as low as 55c, minimizing degradation and scaling, allowing limited waste heat to be used. MED can be configured in many ways be heat transfer vertical climbing fill, upward vertical fill, horizontal tube fill and therefore by brine flow direction, compared to vapor flow according to the form of heat transfer surface. The key advantage of multi –effect distillation (MED) is the improved thermal efficiency compared to MSF. When waste heat is used for the distillation process, it can run at low running costs. this procedure can be used with less consistency feed water than reverse osmosis (RO). the key drawback of this process are the high running costs when waste heat is not sufficient for distillation and the output of the corrosion and size. (15)(14)

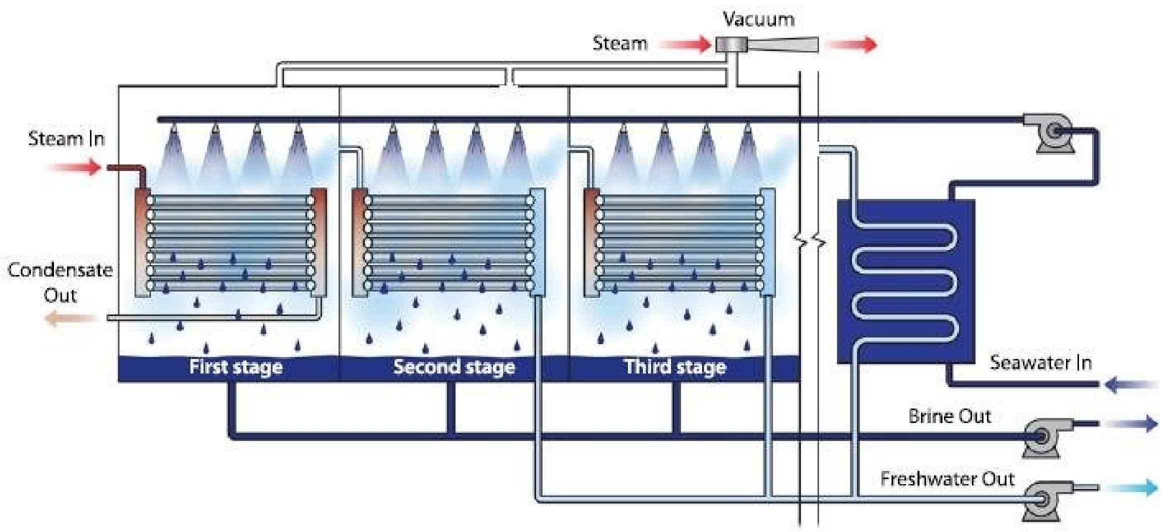
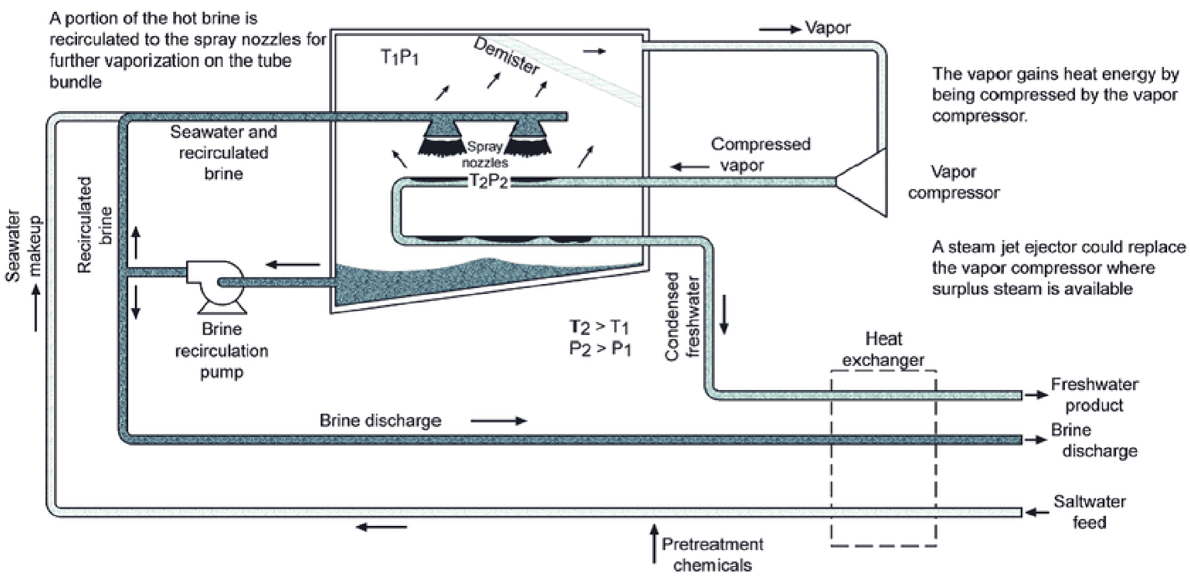


Figure 6

Vapor Compression Distillation

The method of vapor compression (VCD) is either used in conjunction with or by itself other process suck as the MED. Instead of the direct heat exchange generated in a boiler for the heat to evaporate water, vapored waster is used in a variety of configurations vapor compression (VC) units are developed. the heat produced is a by mechanical compressor. The VC units' potentials are limited and mostly used in hotels resorts and industries. (16)



Membrane Technologies

In membrane process, a two –phase membrane enable's one or more components to be transferred readily over the other parts, a pressure gradient, temperature gradient or electrical potential gradient can be the driving force for transportation. Divided into two different groups, membrane technologies are Reversal Osmosis (RO)/Electrodialysis Osmosis (ED)

Reverse osmosis (RO)

Reverse osmosis (Ro) is a method for membrane isolation where the water is segregated from the salt dissolved by the water-permeable membrane. A Differential pressure produced between pressure feed water and commodity water at near-atmospheric pressure promotes the liquid flows through the membrane the presence of the pressurized feed water. The remainder of the feed water starts as brine though the pressurized side of the reactor. No Shift in heating or steps happens. Initial pressure of the feed water is the main energy requirement. The working pressure for brackish water is 15-25 bar and 54-80 for sea water. Reverse osmosis does not only extract suspended substance from the brine but also organic, colloidal and certain microorganisms.RO is usually used for salt concentration between 100 and 10000ppm in brackish water. In certain reverse osmosis (RO) operations, low pressure membranes have lowered pressure requirements by up to 50%, reverse osmosis (Ro) effectiveness will without doubt be increasing and cost will be reduced by increasing membranes. A wide range of flow rates can be used from a few litters of brackish water to 7.5x105l/day and for sea water 4.0x105l/day. If applicable, additional modules will expand the systems capability at a later date. Chemicals are not commonly used for cleaning for cleaning purposes.RO membranes on the other hand, are pricey and have a 2-5 year; of cycle. if the facility uses sea water, the operation during stormy weather will interrupted. this can induce particle re-suspension, which raises the number of suspended solids in the water and allows pre-treatment of feed water so as to extract particles to survive longer in membranes.RO membranes are susceptible to PH, oxidizing agents and number of foulants organic bacteria .the pre-treatment of feed water is crucial and can have a considerable impact on the cost of RO, especially all feed water including 60% which will be eventually released ,need to be pre-treated before it is passed on the membrane. (17)(16)(13)

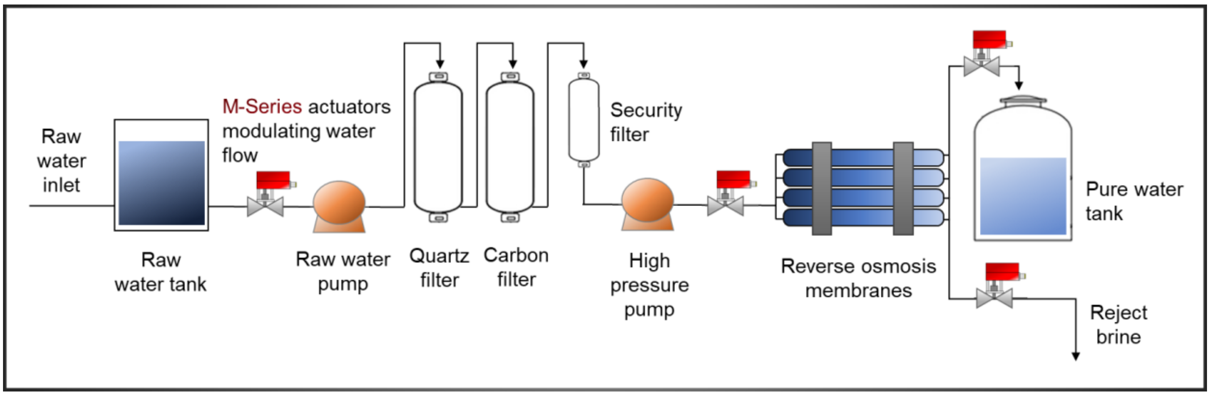


Figure 7

Electrodialysis (ED)

Electrodialysis (ED) is a membrane mechanism powered by voltage, an electrical energy is used to transfer salts across a membrane that leaves fresh water as product water. (Ed) was launched commercially in the 1960.while Ed was initially developed as a seawater treatment process approximately 10 years prior to reverse osmosis (RO), it was usually used for the process desalination of brackish water.

The general rules of ED are:

-The bulk of salts dissolved into water are ions, either loaded positively (Cations) or loaded negatively (anions)

-Because poles repel one another and draw different poles, the irons move to the opposite electric charging electrodes

-suitable membrane may be designed for either anion or cation selective

In a saline solution, dissolved ions such as sodium(+) and chloride(-) migrate through the membranes chosen to the opposite electrodes that allow for the passage of cations or anions (not both).membranes are typically arranged in an alternative patter with anion-selective Diaphragm and a cation- selective diaphragm .the salt content of the during this process the water channel is condensed when the electrodes from compressed solutions.in the spaces between the alternating membranes ,condensed and diluted solution are formed which are called cells, bound by two membranes .ED units consists of several hundred electrode-connected ensuring a continuous stream of desalinated water and a continuous stream of brine from the stack. (16)(18)

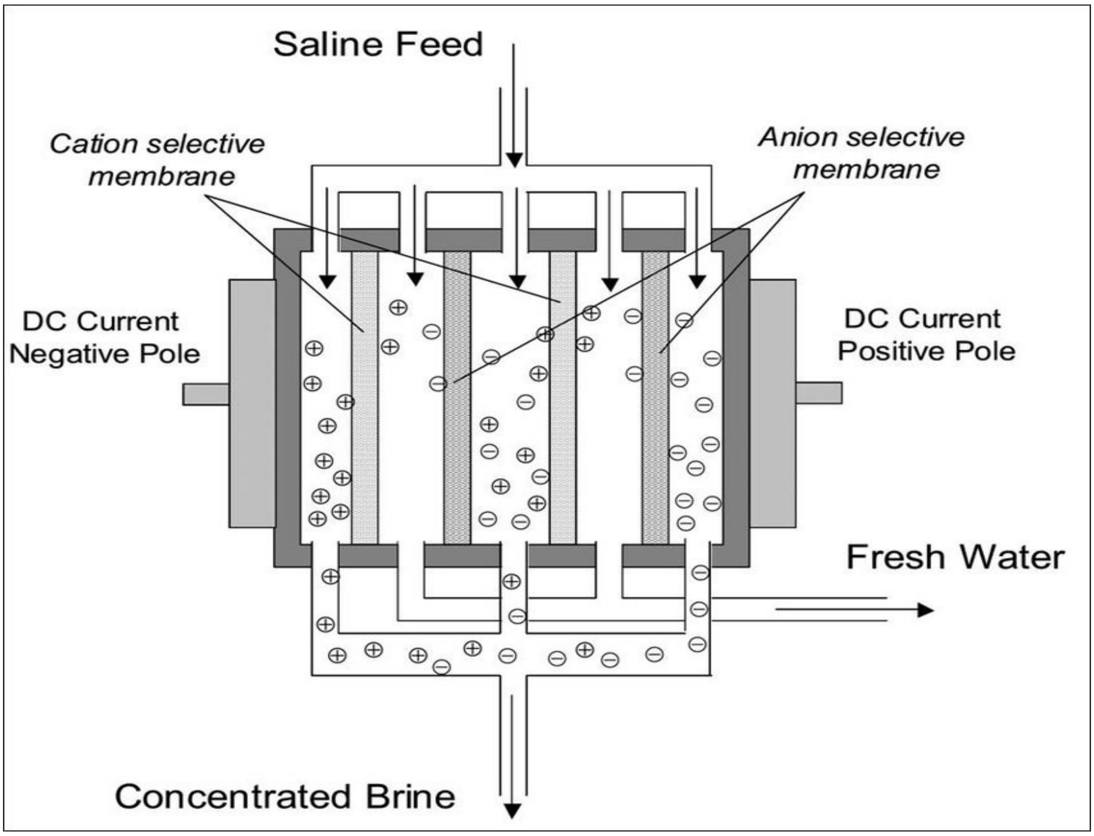


Figure 8

4. Desalination issues

Desalination has emerged as a sustainable alterative to many remote communities worldwide for the problem if a secured water source over the year, this method has made some strides making it economically and technically a possible process. Al though the importance of desalination provides to the human race with critical water supply, there have been multiple environmental impacts. In connection with each step-in desalination stations from feed water to brine disposal.

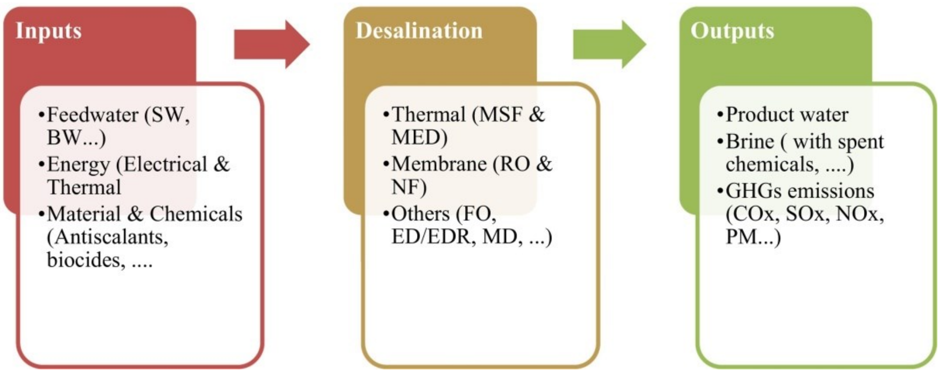


Figure 9

Feed water Intake

Desalinations plants could well receive water from different sources, but the most common option is open sea water intakes. The open use of aquatic organisms may lose intakes if they crash with the intake stream or are drawn into the plant with the water source, Initial disturbance caused by the construction of the intake and pipe structure is the re-suspension of the water column sediment, nutrients or pollutants, the structures can influence the exchange of water and transport of sediment after installation, act as the artificial reeds for organisms or shipping routes or other marine uses may be interfered with. (19)

Brine disposal

Desalination brine is both a qualitative and a quantitative substantial waste stream. The ratio of brine to feeder for SWRO can range from 1-2 and 5-8 for thermal process, which has a major impact on the marine environment at the discharge point (20). Harmful effects on the marine ecosystem may occur especially when discharges of high waste water coincide with ecosystem sensitivity, the effect on marine environment depends on the physical-chemical properties if the disposal stream ,major effects from the brine disposal can be increase of water temperature, and the load of chemical used during the pre-treatment suck as biocide ,disinfection by-products, aluminium sulphate and ferric chloride. (22)(21)(23)

Energy consumption and GHG emission

Energy is needed to drive a thermal or electrical desalination process. The sources of both forms of energy are generally the same i.e., fossil fuel such as petrol, gas and coal which are currently the world's main source of energy. The conventional power generated from 900 twh results to 31gt carbon. (24)

Emissions the desalination industry exacerbates air pollution by NOx and SO2 emissions due to its high energy consumption. NOx emissions are decreasing due to the technological advancements and So2 emission rise or fall according to the use of petroleum rather than natural gas. Furthermore, after the oil sector in the GCC countries, the water sector in the second largest co2 emitter and is a big contributor to climate change, the consumption of fossil fuel in desalination plants will continue as new desalination capacity becomes operational with rising water demand. (25)

5. Kingdom water shortage

The kingdom of Saudi Arabia (KSA), which occupies an area of 2.25 million square kilometres, it is an arid and water-deficit country with insufficient fresh water sources.it lack rivers or permanent water sources. KSA is one of the driest regions on the planet, marked by poor rainfall and high evaporation rates. KSA has under gone remarkable economic growth in the past four decades due to the discovery of fossil fuel deposits, resulting in high living standards for its people has steadily seen an increase in population and mass migration to urban areas in search of better opportunities. These trends also put extraordinary pressure on the scarce water supply of the country and increased demand. In order to satisfy the need of its people, the country's scarce clean natural water supplies have ben massively over-exploited. Aquifers are the country's only supply of fresh water. The average daily per capital water usage in Saudi Arabia has increased since 2009, when it averaged 227l/day and increased steadily to reach 270l/day in 2016 the third highest in the world. (26)

The kingdom began its very ambitious agricultural program in the 1980s in order to fulfil the nutritional demand and recognize self-sufficiency. The goals were accomplished successfully and the kingdom enjoyed self –sufficiency in many food crops and became the sixth largest exporter of wheat at the costs of its water supplies. Over the past few decades, Massive groundwater depletion from non- renewable aquifers has contributed to significant reduction in ground water levels and decline in ground water quality. The unhealthy culture of water usage in Saudi Arabia was created through practices such as liberal water use, reckless water source management, unregulated population growth and irresponsible agriculture policies. As well as low recharge rates; the kingdom has a small supply of non-renewable groundwater. Despite the very small renewable water supplies in Saudi Arabia, the KSA utilizes about 7 billion cubic meter of water a day, 60% of which is desalinated, 40% if this falls from municipal desalination stations and 20% percent from private sector managed stations. (27)

The kingdom's water industry is currently facing a variety of challenges endangers water and food safety, security, overall growth of carbon incentives and water derations, deplete oil supplies. The cost of clean water has added up a tension on the desalination plants and water treatment plants. (28)

5.1. Water Resources in the Kingdom

Kingdom is vulnerable to temperature fluctuations, low annual precipitation, no natural perennial flow and small ground water supply in a semi-arid climate. The KSA high rates of evaporation and an average perception of less than 100mm, reducing the sources and supplies of water. The kingdom is split into three classes of water supply. Surface water, renewable and non-renewable ground water and non-traditional water sources include desalinated and treated waste water. (29)

Surface Water

Surface water supplies 10%, mostly from the west and southwest areas of the kingdom. Not often but intensely: intermittent flash floods and random rainfall produce surface water. Water is processed in barracks and also used for drinking purpose, obtained by rain fall (surface water). During rainstorms that happen in the coastal areas and southwest highlands, the dams trap surface water rushing. Flash floods from November to April refuel the surface water. Initiatives such as constructing new dams and establishing a rainwater harvester (RWH) projects were taken by the kingdom. The biggest volume of rainfall (about 60%) is located in the southwest part of the kingdom. According to experts, new and current pipeline will receive, store and transport this water into other areas of the country.

The rainfall volume and time depend on the rainfall pattern and distribution which differ temporarily and spatially. An approximate of 0.6 billion m3 was obtained by the 260 irrigation dams in 2013 from intermittent flash floods. The 302 dams stored approximately 1,4billion cubic meters in 2015.in 2016 449 dams were used for storage, retention, refill and regulating flash flows. The national water strategy (2016) states that overall available water supplies from dams are roughly 1.6 billion cubic meters a year according to recent figures. There are currently 535 operating dams in the kingdom, with more than 2 billion cubic meters of storage and more dams being constructed to improve water quality and consumable water supplies. (29)(30)

Groundwater Resources

Two outlets provide freshwater. The first source is non-renewable soil water from deep, renewable soil water from shallow alluvial aquifers.40% of the supply in the kingdom comes from ground water sources. Over 80-90% of domestic water is provided by groundwater drained from local aquifers. The groundwater is deposited with a minimum annual charge in many aquifers in Saudi Arabia. The total storage capacity in the Arab peninsula is estimated at 80,000 km3 and in Saudi Arabia it is estimated to be approximately around 2.259 billion cubic meters. (31)(32)

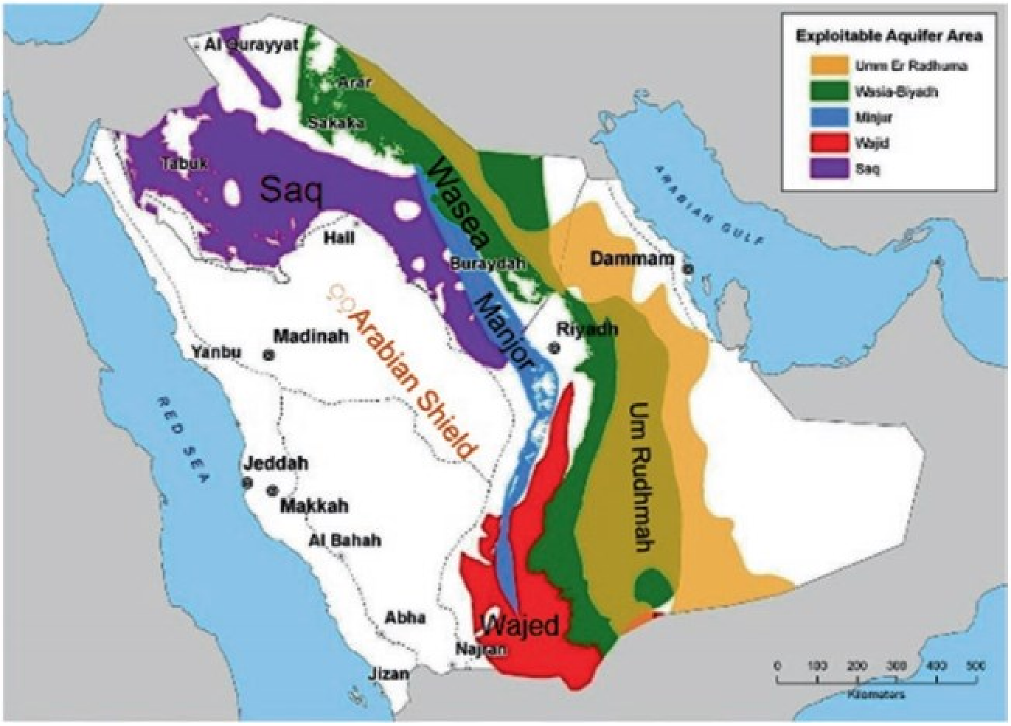


Figure 10

Desalination Plants

Desalination water supplies 50% of the drinking water from 35 desalination plants. Of the overall fresh water supplies, desalinated water ranged from 7-9% from 2010-2017. Without rivers and other lasting water bodies, due to the increasingly depleting underground water supplies, desalination water plants appear to be one of the safest, relevant and most suitable strategic options for making fresh water accessible and meeting increasing domestic water demand in the kingdom. The KSA is the world's leading supplier of desalinated water and currently supplies around one-fifth of global supply. The KSA administration treats sea desalination as the strategic alternative to mitigate water shortages and resolve the country's increasing domestic demand for water. 35 desalination plants are available in the kingdom located on the east and west coast of the kingdom. Recent figures show that the gross desalination capacity in 2019 amounted to 1883.6 million m3. The saline water conversion corporation (SWCC) has expanded its output capacity from approximately 200 million cubic meters per year in 1980 to approximately 1.18billion cubic meter in 2016 and 1.2billion in 2017.there are 2500miles of desalination piper all over the kingdom in order to make water accessible to the consumers. Electricity and water production is rising by 8% annually. Desalinated water use rises by about 14% annually. This doubles the increase in overall use of domestic water and 6 times the growth rate of the population. It is double the average worldwide and it consumer much more water than countries with bigger sources of water.in the next decade the kingdom will double its ability to desalinate. High energy input is needed in the desalination process. In order to operate desalination plants, over half of the domestic oil is required and current demand rates imply that it will hit 50% by 2030

Furthermore, high costs and energy consumption associated with the desalination process have affected the kingdom's capacity to desalinate, its water supply therefore depends on a stable oil supply, with the main issue established, and desalination is concluded to be extremely costly and not feasible for the long term.it accounts for 10-20% of energy consumption.

The cost per unit of water supply was found to be fairly high, attributable to high pumping water transport cost from the coast to the kingdoms center. The kingdom currently operates 3 types of water desalination technologies: Multi-stage flash, reverse osmosis and multiple distillations. The Multi-stage flash plants accounts for 62% of the existing overall production capacity in the kingdom. The minister of environment, water and agricultures reported that nine new water desalination plants operating with advanced techniques would be built on the red sea coast in 2019-2020 to improve the water service quality. Ras AL-Khair industrial city has the world's largest desalination plant 75 km north-west of Jubail at a cost of 7.2b$.the plant has a capacity of 1.025million cbm of desalinated water and 2600mw of electricity per day. Rabigh on the red sea near taiff was another giant desalination plant installed with a capacity of 600000 cubic meters per day in 2018. The capital, Riyadh fulfills the majority of its water needs from desalinated water pumped 467 km into the city from the Arabian Gulf. (33)(34)(35)

Desalination Plants

Desalination water supplies 50% of the drinking water from 35 desalination plants. Of the overall fresh water supplies, desalinated water ranged from 7-9% from 2010-2017. Without rivers and other lasting water bodies, due to the increasingly depleting underground water supplies, desalination water plants appear to be one of the safest, relevant and most suitable strategic options for making fresh water accessible and meeting increasing domestic water demand in the kingdom. The KSA is the world's leading supplier of desalinated water and currently supplies around one-fifth of global supply. The KSA administration treats sea desalination as the strategic alternative to mitigate water shortages and resolve the country's increasing domestic demand for water. 35 desalination plants are available in the kingdom located on the east and west coast of the kingdom. Recent figures show that the gross desalination capacity in 2019 amounted to 1883.6 million m3. The saline water conversion corporation (SWCC) has expanded its output capacity from approximately 200 million cubic meters per year in 1980 to approximately 1.18billion cubic meter in 2016 and 1.2billion in 2017.there are 2500miles of desalination piper all over the kingdom in order to make water accessible to the consumers. Electricity and water production is rising by 8% annually. Desalinated water use rises by about 14% annually. This doubles the increase in overall use of domestic water and 6 times the growth rate of the population. It is double the average worldwide and it consumer much more water than countries with bigger sources of water.in the next decade the kingdom will double its ability to desalinate. High energy input is needed in the desalination process. In order to operate desalination plants, over half of the domestic oil is required and current demand rates imply that it will hit 50% by 2030

Furthermore, high costs and energy consumption associated with the desalination process have affected the kingdom's capacity to desalinate, its water supply therefore depends on a stable oil supply, with the main issue established, and desalination is concluded to be extremely costly and not feasible for the long term.it accounts for 10-20% of energy consumption.

The cost per unit of water supply was found to be fairly high, attributable to high pumping water transport cost from the coast to the kingdoms center. The kingdom currently operates 3 types of water desalination technologies: Multi-stage flash, reverse osmosis and multiple distillations. The Multi-stage flash plants accounts for 62% of the existing overall production capacity in the kingdom. The minister of environment, water and agricultures reported that nine new water desalination plants operating with advanced techniques would be built on the red sea coast in 2019-2020 to improve the water service quality. Ras AL-Khair industrial city has the world's largest desalination plant 75 km north-west of Jubail at a cost of 7.2b$.the plant has a capacity of 1.025million cbm of desalinated water and 2600mw of electricity per day. Rabigh on the red sea near taiff was another giant desalination plant installed with a capacity of 600000 cubic meters per day in 2018. The capital, Riyadh fulfills the majority of its water needs from desalinated water pumped 467 km into the city from the Arabian Gulf. (33)(34)(35)

	Cubic meter/year			
Plants	**2016**	**2017**	**2018**	**2019**
Ras al khair	306150899	381152734	383961826	378014121
Jubail	358240820	431618438	440885029	462203586
Khobar	131997765	166863167	181502583	177844201
kfaji	7915940	7012375	21713234	21848144
jeddah	199709870	196785920	201577838	170641280
shubaiba	172162034	204220456	250199635	269837371
Yanbu	143429552	175946182	257346729	340863955

shuqaiq	31966704	34271383	35579483	32433796
Small Deslnations	25389760	26379345	30344643	32433796

Table 2

6. Analysing the Energy Consumption, GHG Emission

CO-Generation:

A co-generation plant for electricity and desalination uses the same supply of energy, which is also known as a dual plant. In Saudi Arabia this concept has been applicable to many plants that can be used alongside power stations, the heat-power steam from the power supply of thermal desalination units (MSF/MED). While the advantages of this type of plant is the sharing of the plant's equipment for example the intake of seawater and auxiliary systems, reduction of the energy costs and the energy demand for the transportation from the grid to desalination plants.

Due to the fact that the increase in energy prices and demand has effects on country's economies and the global climate change, Saudi Arabia's continue to use high energy desalination treatments to fulfil their water requirements. This is attributed mostly to the dwindling inventory of freshwater and the fast-growing population. This chapter addresses energy use and GHG emission use in seawater desalination plants in Saudi Arabia for water supply. The data behind the analysis were gathered from 2016-2019 of the 35 plants in Saudi Arabia. Relevant equivalent energy per meter of water generated was computed in kilowatt hours (KWH/m3)

The need for desalination energy depends on various factors such as regeneration, pre-treatment configuration, type of technology MED, MSF and SWRO, pump and engine efficiency, type and energy recovery system installation, the surrounding environments. The demand for energy depends also on the requirement of the product water. For instance, the use of a second boron removal SWRO pass would raise energy requirements for the desalination processes. With advanced facilities, (pressure exchangers, frequency pumps, low-pressure membranes) modern SWRO plants can reach a basic energy demand of 2.5 KWH/m3 and total energy demand of 3.5 kwh/m3, In less optimal conditions, actual energy demand could be higher. For instance, the basic energy demand estimated of a feed water salinity of 40000 ppm and 20 c with the overall recovery of 41% is approximately 3.8 kWh/m3 fitted with the most effective method of energy recovery, for pre-treatment, waste water and sludge treatment a further 0.2-0.8 kwh/m3 is essential (depending on the feed water quality, management buildings and labs, post-treatment and water pumping leading to overall energy consumption of approximately 3-4. Kwh/m3.

Specific data reported from (73) from two SWRO plants located at separate locations. A first SWRO single pass plant (salinity= 35000 ppm) consumes total energy (including pre-treatments and posttreatments) at 3.8 KWH/m, while the second SWRO double-pass plant absorbs 4,25 KWH/m (salinity= 39000ppm). The Spanish national hydrological plant needs a total of 4 KWH/m3 overall energy worth on the basis that the plant are fitted with the most advanced technology, which is comparable for other major SWRO projects in the world to the energy demands recorded. Older or smaller SWRO plants could use up to 7 KWH/m3 without a power generation. The relatively higher energy use in the storage and delivery of water using conventional means should be taken into account, in addition to the overall process demand. The electricity demand for local surface water treatments usually ranges from 0.2 to 0.4 KWH/m3, in contrast to a specific energy requirement in favourable conditions on a new SWRO plants with 3,5 KWH/m3, this resulted in the best case with an improvement in the relative desalination of 3.1 to 3.3 KWH/m3. The relative increase of a local desalination plant will be much lower at areas where water is conveyed over long distances.

For MSF distillation plants with operating temperature's up to 120 c, the output of one meter of water requires approximately 250-330 MJ of thermal energy and 3-5 KWh of electrical energy, for MED plants operating under 70 c, i45 to 390 mj of thermal and 1.5 to 2.5 kwh of electricity per cubic meter of water are needed. While the thermal distillation processes take more energy than SWRO, in middle east countries they continue to be the first option for political, technological and economic reasons including difficulty conditions of feed water for SWRO plants and low-cost electricity supply. The area is dominated by dual-use co-generation systems, which combine MSF or MED distillation with energy generation. Since MSF and MED are capable of using low and waste heat, the overall energy consumption of distillation cannot be easily compared to SWRO.

During comparison lifetime evaluations of various desalination systems, it was determined that, whether they are running with a traditional boiler, the environmental effect of SWRO was one order of magnitude lower than the impact of thermal processes, but comparable whereby the thermal processes are powered entirely by waste heat. MED was found to be more effective than MSF and more efficient than RO in one assessment, assuming wate heat is used. (68)

GHG Emission

The key environmental and public health concerns about desalinisation are the emission of atmospheric contaminants, mainly GHGs (CO_2), acid rain gas (NO_x, SO_2) and fine particulate matter. As both electricity and thermal energy used for desalination of sea water is generated usually from fossil energy sources. Emissions can arise directly from the process where fossil fuel is used for heat supply by steam in power and water cogeneration plants for thermal desalination or indirectly where electricity is extracted from the for the desalination of water. The type of fuel, the performance of the electricity produces for the desalination plant and of the installed exhaust purification equipment are the main factors to be considered for the GHGs and air pollutant emissions. CO_2, since it depends primarily on the carbon content of petrol, can be forecasted with a high measure of certainty. For order to take into account all possible climate change gasses resulting from fossil fuel burning (sulphur hexafluoride, hydrofluorocarbons, perfluorocarbons, nitrous oxide and methane) any emission of pollutant gases can be interpreted as CO_2 equivalents. The energy mix of respective grid must also be taken into consideration as the power is taken from the grid. The following calculations will be made for CO_2 emissions in SWRO plants, according to a special energy demand of 4 KWH/m3, the Gold coast deslination project in Queensland, Australia essmisons were calculated by using a grids average value of 1.16 kg of co2-e per kWh. A grid average value of 1.31 kg CO_2-e per kWh applies to the Victorian SWRO plant in Melbourne. In contrast, the CO_2-e emissions in the case of Queensland, 4.6 kg/m3 and 5.2 kg/m3 for the case of Melbourne, are assumed to be 4 kWh/m3 energy requirement for the SWRO operation. Emissions would be greater if water transport, site planning and CO_2 emissions correlated with material and chemicals use were not included in the estimate. The examples listed all quantify the electricity emissions from the that is based on the pollution factor of the grid. A SWRO or any deslantion plant may also be situated nearby to an existing power plant that provides direct power in order to prevent transmission losses. For example in Ashkelon, the SWRO system is supplied to the desalination plant with a capcity of 330.000 m3/day(3.6 kWh/m3) through a natural gas-fired power plant locally the supplies 50 m2 electricity . (71) (72)

Energy Calculation

Saudi Arabia Desalinations plants from which data was gathered employing 3 technologies for the current analysis: RO, MED, MSF. Thermal energy was converted to electricity for the analysis

In the current research, the energy intake of seawater desalination plants is calculated to provide one cubic meter of desalinated water, these plants use three forms of desalination technology, as discussed above. The average energy consumption is as a ratio of total electricity consumed (kWh) to total water production (m3). For MSF and MED, both the thermal energy and the actually absorbed electricity must be taken into consideration, by measuring the relevant equivalent work, the energy equivalent of thermal energy was calculated for MSF and MED plants in (kWh).

The energy consumption of seat water desalination plants in the kingdom of Saudi Arabia can be calculate using balance equation along with the specific energy consumption (SEC) and the capacity of the plants in KHW/m3 desalinated water, the energy consumption of all desalination processes involved in this study (RO, MED and MSF) are converted to the form of electricity, kWh/m according to (36)

$$\mathbf{ECa = \sum SECi \times Ci \times 365 \times Pa}$$

ECa = annual energy consumption of the plant, kWh/y

SECi = specific energy consumption of seawater desalination plants with process i

Ci = capacity of the desalination plants with process i, m3/d

Pa = the availability of the plant

The specific energy consumption of each technology is (MSF 15.5 kwh/m3), (MED 7.5 kwh/m3), (RO 3 kwh/m3 (37)

CO2 calculation

During the production of one cubic meter of fresh water, the carbon foot prints of the desalination plants are estimated to be around 2.716 kg co2 (MSF), 1.164 kg co2 (MED), 2.238 kg co2 (RO) (37)

Results

	Water production(m3/y)	Energy consumption
2016		KhW
RO	285023051.89	855069155.7
MSF	1078483719.31	16716497649
MED	11425392.00	85690440
Total	1374932163.20	17657257245

2017		
RO	296811193.84	890433581.5
MSF	1314200101.42	20370101572
MED	13238704.74	99290285.55
Total	1624250000.00	21359825439

2018		
RO	341437021.16	1024311063
MSF	1446445254.66	22419901447
MED	18612885.11	139596638.3
Total	1806495160.93	23583809149

2019		
RO	336569376.65	1009708130
MSF	1533273689.48	23765742187
MED	16277183.87	122078879
Total	1886120250.00	24897529196

Table 3

Technolgy	Foot print (kg co2)	Emission(t co2)
2016		
RO	2.238	637882
MSF	2.716	2929162
MED	1.164	13299
2017		
RO	2.238	664263
MSF	2.716	3569367
MED	1.164	15410
2018		
RO	2.238	764136
MSF	2.716	3928545
MED	1.164	21665
2019		
RO	2.238	753242
MSF	2.716	4164371
MED	1.164	18947

Table 4

A worst-case scenario for desalination processes energy requirement and air pollutant emissions is Saudi Arabia which depend heavily on desalinated Seawater from co-generation plants. As mentioned above it depends heavily to produce 90% of the national water supply and heavy crude oils are almost entirely set for the energy demand needed. Being the largest country for seawater desalination capacity, in 2016 they produced **1374932163.20m3** with a energy consumption of 17657257 khw needed which resulted in the emission of **3580343.**

These numbers keep on increasing largely due to the increasing demand of the fast-growing populations, in 2019 the energy consumption of RO 1009708 khw for 336569376.6 m3 which caused a factor of co2 emission of 753242 t, MSF had emission of 4164371 for the energy consumption of 23765742 khw and MED generated 16277183.87 m3 of desalinated water with energy demand of 122079 khw which resulted in co2 emission of 18947 t.

7. Renewable energy

Globally, populations rely on drinking water desalination. Remote areas in developed countries and small islands also have no access to drinking water or a proper power grid. in addition, desalination plants need a low emission energy supply which is simultaneously inexpensive to reduce their environmental effects. In order to address both problems, alternative sources such as photovoltaic and thermal energy sources, wind or geothermal energy should be used so it can be cost-effective for the locally available renewable resources. This approach will lead to significant greenhouse gas cutting because the global desalination capability currently exceeds 70 million m3/day.

Furthermore, given the projected decrease in the costs of clean energy technologies, this would become more desirable in rural, populations-sparing regions with inadequate fresh water, power transmission and distribution facilities. Renewable desalination now accounts for less than 1% of desalination capability in the world. Most current desalination plants based on RO (62%) led by MSF and MED are based on green energy. Photovoltaic solar used in 43% of the current RE desalination plant then solar thermal and wind energy are the dominance green energy source for water desalination. (74)

In this chapter the theory of how the Renewable energy can be coupled with the desalination technologies and analysing the cost of the conventional energy and renewable energy cost in 2012, Saudi Arabia ranked 6th in the world among the 10 best source of renewable energy positions in the world. In addition, the national policies in the coming decades are targeted at promoting the use of green energies. Variety of proposals and programs have recently been introduced to switch from the use of fossil fuel to renewable sources of energy. In order to raise awareness of the need for green energy promotion in Saudi Arabia, the issue of inefficient use of fossil fuels is growing, both nuclear and solar energy will be the utilization.

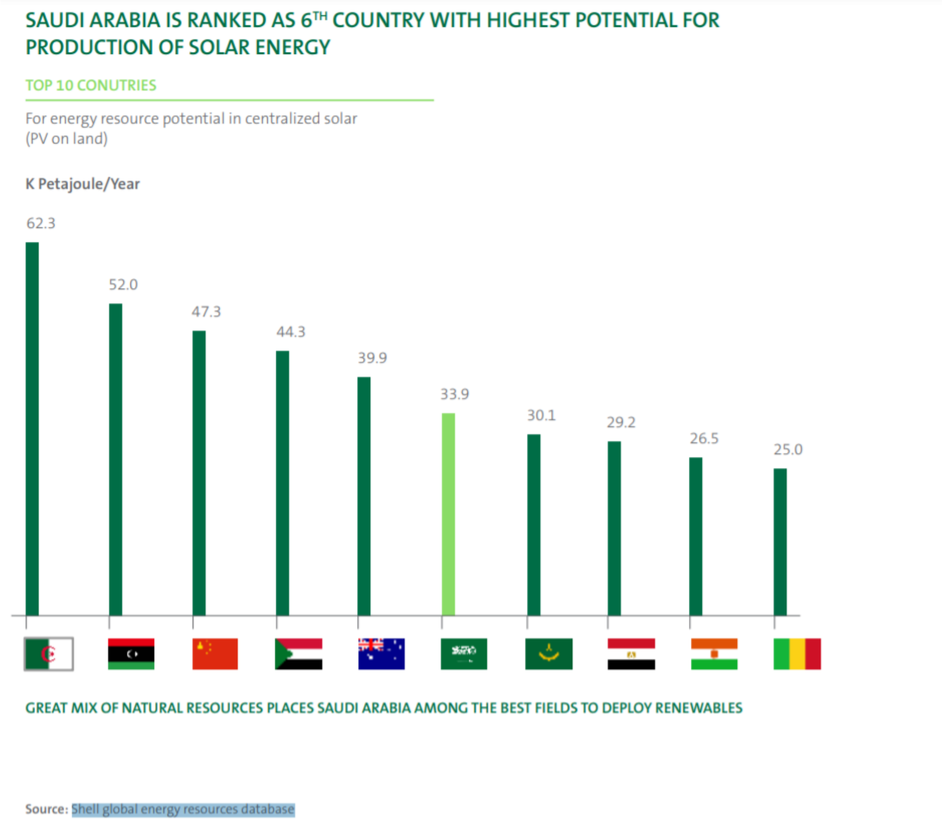


Figure 11

7.1. Renewable energy sources

Solar

The cumulative global solar radiation on the planet is over 7,500 times the annual world primary energy consumption of 450 EJ. The annual solar radiation to the earth's atmosphere, about 3400000 EJ exceeds all know supplies of non-renewable energy. The kingdom has tremendous potential to take advantage of solar energy, as it has sufficient factors like clear skies, the country's geography and vast unused landscape. with the reduction in its dependency on fossil fuel, the KSA has ranked sixth in solar energy potential generation in the world. Saudi Arabia is therefore strongly designed to produce solar energy with empty desert ranges, taking advantage of over 3000 hour a year of sunshine. On Farasan island, the first solar power plant with 500 KW static tilt photovoltaics was installed in 2011,though more than half of the electricity is supplied using crude oil .solar energy deployment has risen in Saudi Arabia since 1960, with photovoltaic cell prices continuing to decline .With the substitution of a same capital provided by renewable solar energy, the KSA electricity production potential was reduced by 77gw in 2016 (said 2019).In the city of al-Khafaji on of the biggest solar plants with a capacity of 3.5MW was built. (38)(39)(40)(41)(42)(43)(44)

Effective application of solar energy is still not advancing dramatically in Saudi Arabia primarily because of a variety of challenges:

- The broad supply of oil, its dominance as a source and its comparatively low cost to solar energy
- The sand impact they can minimize solar energy in some section by 10-20%

Governmental subsides are available for the production of oil and electricity and comparable subsides are not available for renewable energy programs which such subsides are required

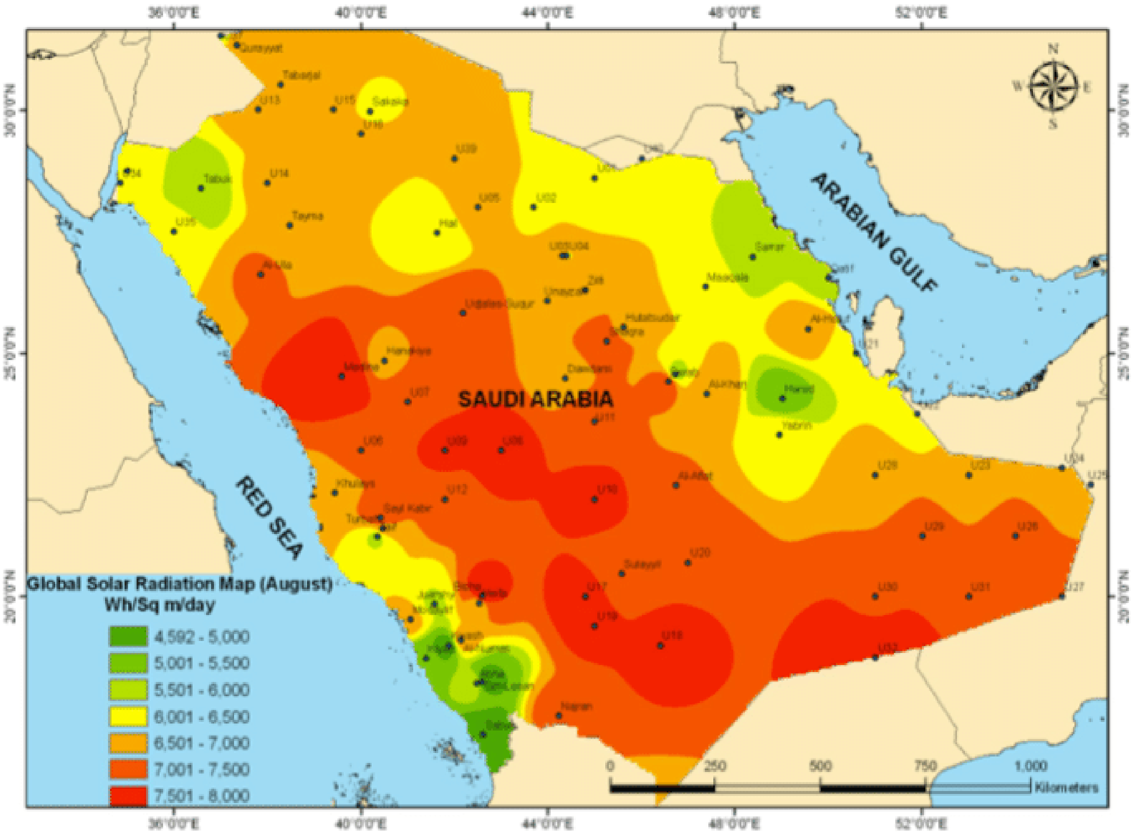


Figure 12

Wind

The atmospheres environmental influence is driven by changes in temperatures under sunlight on the plant's surfaces. Wind energy is used for water or power generations, although it involves a large network to provide a substantial amount of electricity, the kingdom has two wide windy areas on the Arabian gulf and the red sea costal area. In those areas, the average annual wind rate reaches 9 knots (16.7 km/h) and varies from around 14 to 22km/h to 16 to 19 km/h across the Arabia gulf and red sea. Wind speed data in Saudi Arabia are available from multiple sources: king Fahd university of petroleum and minerals and Saudi Aramco. the best areas in the Arabian gulf near Dhahran have been also illustrated. In a further analysis, Dhulum and Arar were possible sites of off-grid, remote wind turbine and were demonstrated to partially allow the two coasts cites of Yanbu and Dharan to use grid connected wind turbines. wind power plants can provide power much faster than any other normal source. Wind power in Saudi Arabia has been a significant source of clean energy.to estimate the feasibility of the use of wind power at grid location and at power plants attempts have been made to use 1-10 kw small turbine along with model water pumps from goulds 45j in order to generate wind and pump water energy for remote areas that are not connect to local power grid in Arar ,Rawdat ben hubs and Juaymah rejion .(45)(46)(47)(48)

Station	Latitude	Longitude	Altitude (m)
Riyadh	24.7	46.7	620.0
Gassim	26.18	43.58	648
Arar	30.54	43.29	542
Aljouf	29.56	40.12	562
Dhulom	22.11	42.07	1117
Guriat	31.4	37.4	504
Jeddah (western coast)	21.7	39.2	17
Haql (western coast)	26.25	34.93	36
Yanbu (western coast)	42.07	38.03	6
Jezan (western coast)	16.52	42.35	5
Dhahran (eastern coast)	26.3	50.2	17
Nejran (south)	17.6	44.4	1212

Table 5

7.2. Renewable energy desalination

There is a growing interest worldwide in green energy desalination systems, over the last few years, more than 130 RED plants have been opened. Apart from hydropower and biomass energy, the major sources of renewable energy sources are solar, wind, wave, geothermal and tidal energy. hydropower and biomass energy are not appropriate for desalination because they demand water supplies that are which Saudi Arabia lacks. The most effective source of renewable energy to be combined with desalination technology is solar energy, since it can provide the heat and electricity necessary by all desalination processes .key technologies for solar processing are photovoltaic (PV), linear Fresnel , Parabolic through and central receiver. The most prospective solar power is CSP it can create high temperatures (500-1000c) used to generate gas or steam turbine steam. Around 70% of renewable plants run by solar energy. RO and ED desalination systems are often paired with wind energy because they require electricity rather than heat. RO and ED desalination systems are often paired with wind power because they require electricity rather than heat. Combining desalination plant with renewable energy is either directly connected or supplemented with electricity in the electricity grid to eliminate the intermittence of renewable energy. (49)(50)(51)(52)

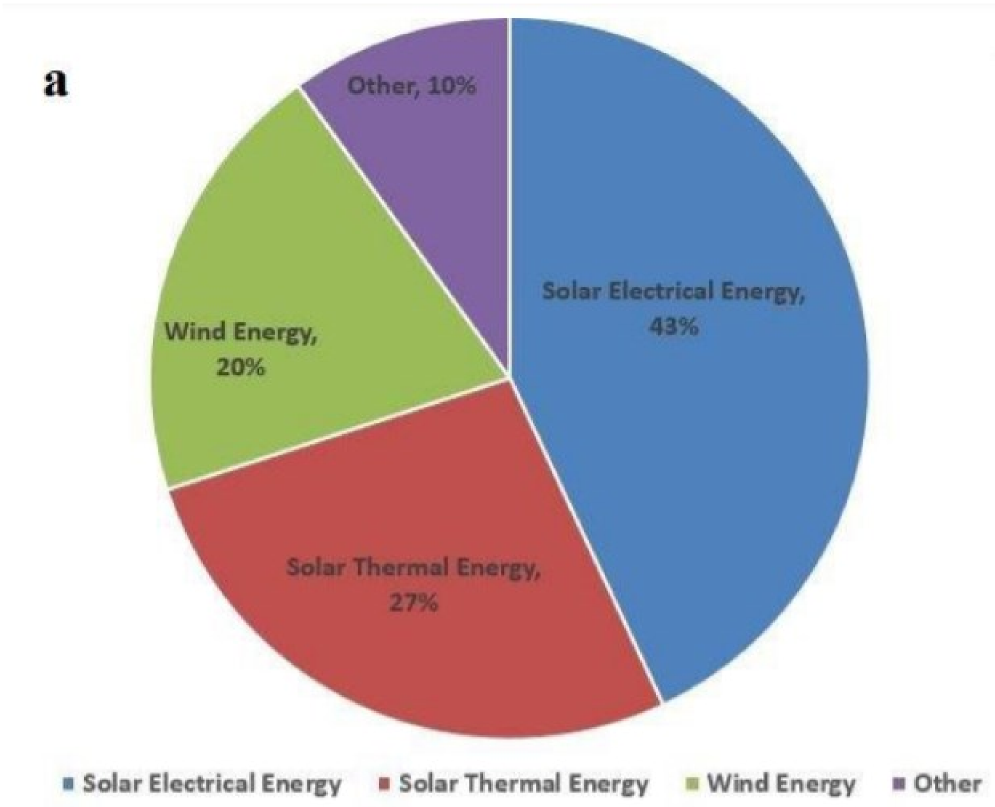


Figure 12

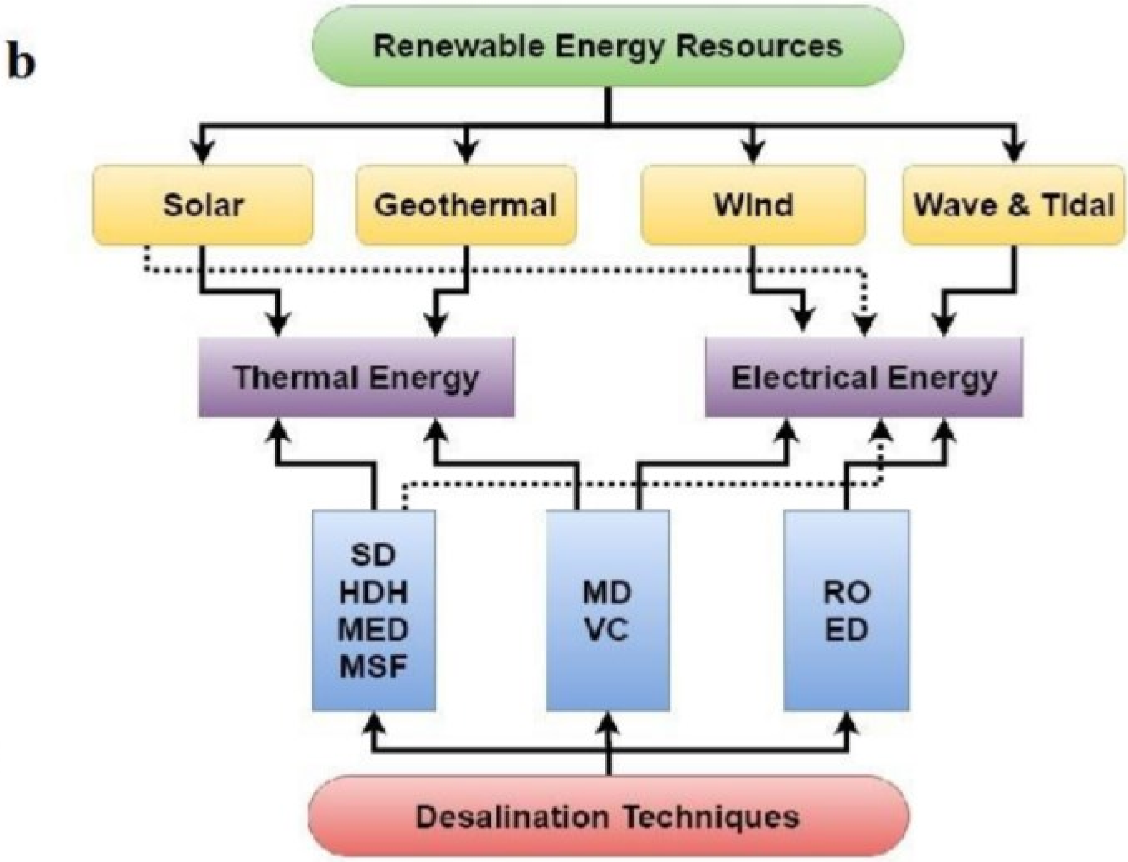


Figure 13

Desalination plant name	Location	Desalination technology	Capacity (m^3/d)	Renewable energy source
Kimolos	Greece	MED	200	Geothermal
Keio University	Japan	MED	100	Solar collectors
PSA	Spain	MED	72	Concentrating solar power (CSP)
Ydriada	Greece	RO	80	Wind turbine
Morocco	Morocco	RO	12-24	Photovoltaics (PV)
Oyster	Scotland	RO	n.a.	Wave energy

Figure 14

Water desalination using solar power energy

Water desalination using solar power has a lengthy energy. The first recorded use of solar still was in the sixteenth century and in 1872, the Swedish engineer, Carlos Wilson, installed a massive solar energy plant to provide drinking water in mining region in chile. Solar desalination is a useful approach for manufacturing fresh water, especially in remote and sunny regions. It will add significantly to the provision of fresh water to communities with a clean, free, and environmentally sustainable energy sources. The desalination processes with solar power are usually categorized into two groups direct and indirect systems. (53)

Direct system

The direct system is where the process of heat recovery and desalination normally exist on the same unit. The solar basin also reflects its simplest use, and acts as a funnel for solar radiation through a translucent shell.

Solar still

The solar panels are used to create a much smaller hydrological cycle by the direct use of sunlight, the theory of solar stills construction and operation is basic, solar energy passes into the system through a transparent pane of glass or aplastic panel and heats the salt water container. Typically, the basin is black for optimal energy absorption, heated water vaporizes and then condenses on the colder panel of glass. The condensed droplets run through the panels to be processed for use. Solar stills are usually less than 50 percent effective i.e they use less than 50 percent of incident radiation. The general rule of thumb is that about 1 m2 of soil water can contain just 4 litters of freshwater per day. As a result, its necessary to use cheaper building material to reduce the capital costs. (54)(55)

Pros and cons of solar panels: solar panel technology also need a big solar collecting area so it's not viable for big development, especially in the vicinity of a city with a scarce, costly land. Compared to other systems, comparable installation costs appear to be significantly higher. They are also prone to weather damage. The cost of labour for routine maintenance is likely to be large to deter scale formation and restoration of vapor leakage and panel glass loss. It can, however, be economically feasible for households and local communities to generate small communities, particularly if solar power and lost cost labour is plentiful. (55)

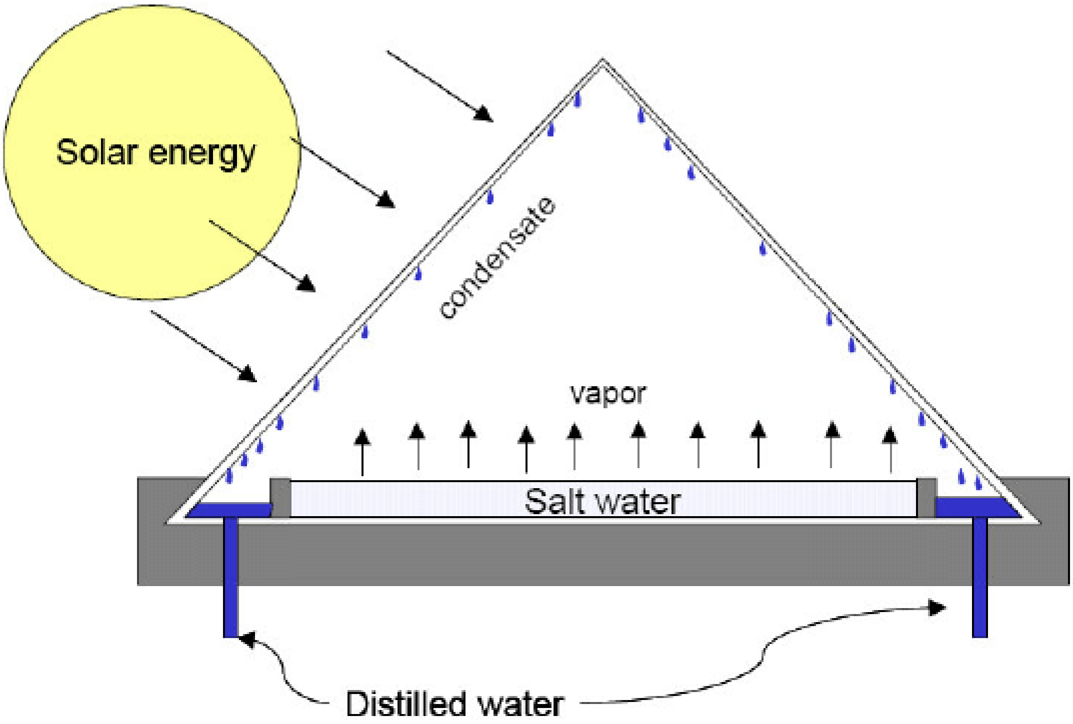


Figure 15

Indirect system

The plant is divided into two subunits, a solar collector and a desalination unit. The solar collect can be a flat plate, evacuated tube and can be connected to any previously mentioned forms of distillery units using the evaporation/condensation concept like MSF,MED to allow thermal desalination-with the use of solar power. Solar energy collectors can be categorized according to the temperature range measured in the collector. When the temperature is <100c its considered low ,100-150c range its medium and >150c is considered high. (56)

Solar thermal driven desalination

The idea of using solar concentrations to control MSF processes is to produce water vapor by heating sea water with solar energy. After heating comes in to a low pressure chamber, which induce a rapid decreases in pressure and blasts water to vapor. This method is constantly replicated in a variety of champers in which the pressure at various levels is minimized water vapor is condensed in a set of heat exchangers to create fresh water. MSF desalination processes distillate manufacturing rate mainly depends on the temperature of the saline, the number of phases, feed water salinity and brine heat resistance.

The output of plant distillate can be improved by increasing the temperature difference between heating water discharged and seawater inlet. Solar multi-stage flash desalination distillate output may be increased with water as solar collector heat transfer fluid and by increasing the thermal storage tank capacity

For MED the distillation mechanism is carried out in a variety of vessels collectively combined with concentrated with solar energy. In the concentrated solar collector area the thermal fluid is heated and then moved to the impact vessels to heat sprayed salt water, a pre heated sea water, normally sprayed on bundle of tubes in which the heat fluid flows, would be added at the top of the effect in order to create a dropping film. The temperature of the thermal fluid is greater than that of the salty water. At the dropping film, water vapor is produced and the guided towards the next effect in which its latent condensation heat is released to the salt water input to create distillation water. (57)

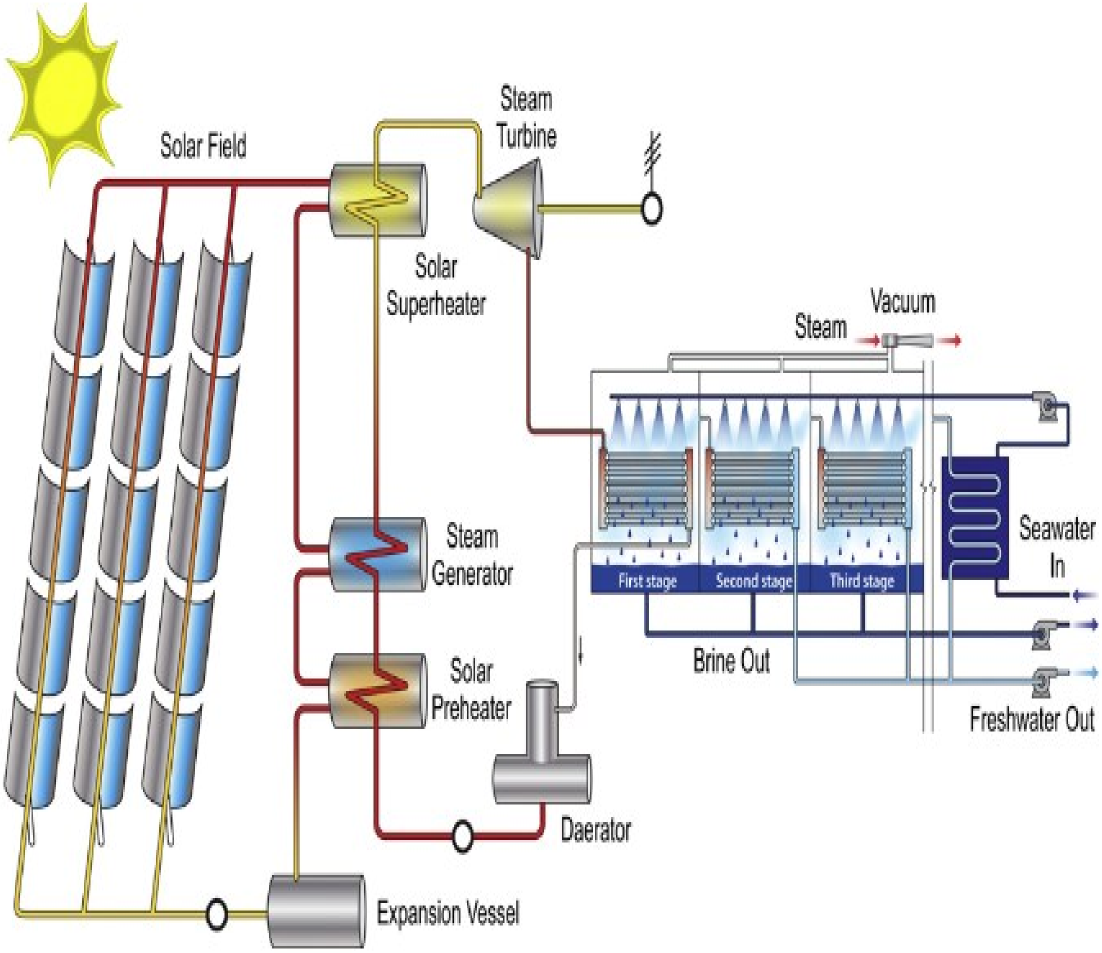


Figure 16

RO powered through PV

The viability of photovoltaic RO systems as a valid desalination solution in remote areas has been demonstrated, high costs for now the biggest concern of these developments. PV-RO demo systems were basically a regular RO system configured for fuel power supply, but then they were powered by PV cells. Due to weak efficiencies both with regular RO systems and in batteries, the solution appears to demand a very large PV array for a production process, the cost of water from suck devices appears to be very high with wide PV frames and routine battery replacement (58)

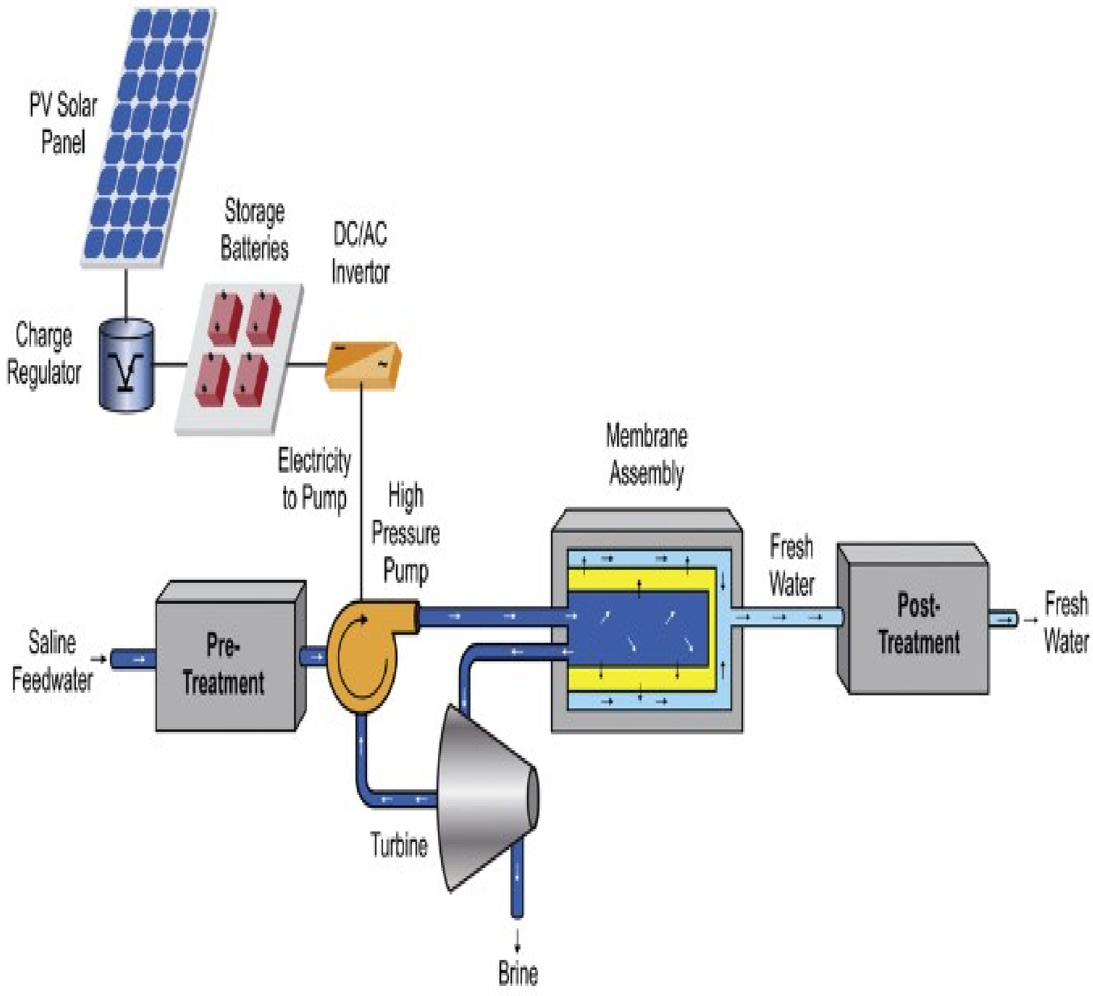


Figure 18

Desalination powered by wind

Wind turbines transform air flow to mechanical power storage or power generators to generate electricity. VAWT are powered by lift powers in all existing wind turbines. The wind speed fluctuations involve a device which meets the wind energy available in the wind turbine and releases extra wind power from a very high speed for a reliable operation in the desalination unit. RO, ED can is suitable technology to be powered by wind turbines but wind/RO is the main use. (59)

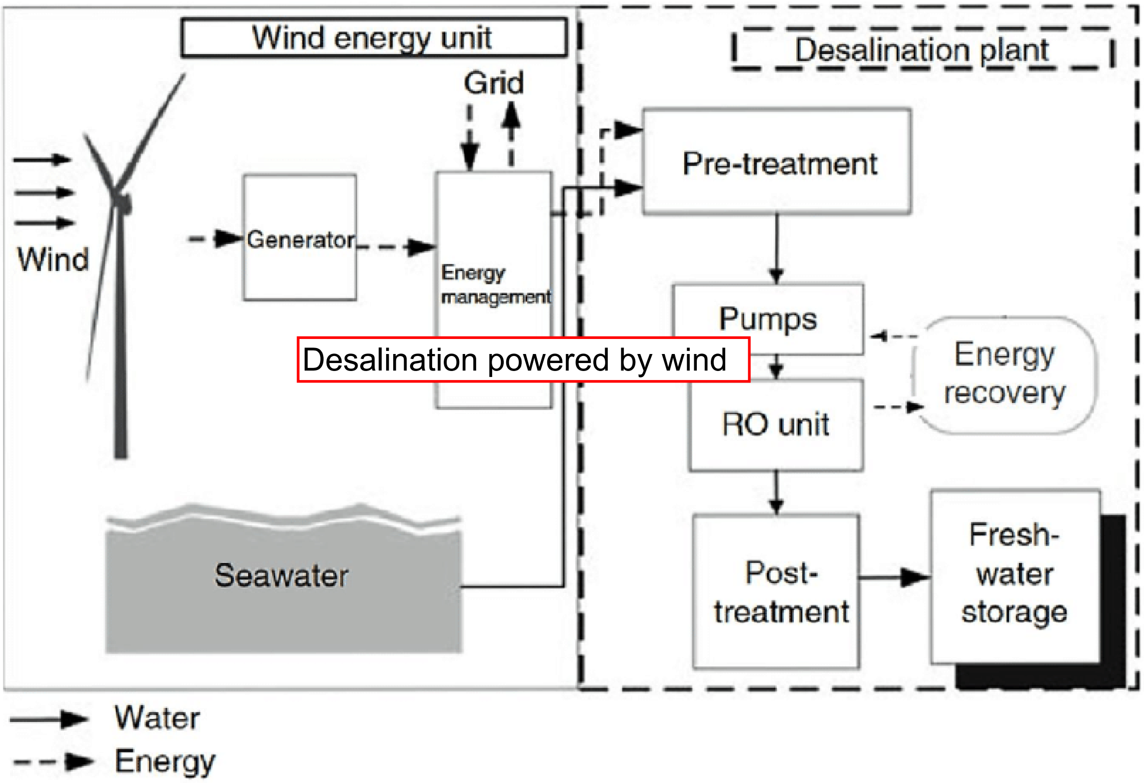


Figure 19

Geothermal-Powered Desalination

Geothermal energy maybe used to produce heat and electricity, such that every large desalination device requiring thermal or electricity can be linked. Geothermal power supplies are temperature-qualified, (>150c), (<100-150c), (<100c). it can also be used for a variety of temperature, from room temp to over 150c. the power is typically collected by earth heat exchangers, whereby heat may be used directly for thermal desalination or indirectly to produce electricity. In 1972 the first geothermal plant was built in the USA and plants in Tunisia, France and Greece were later built. Nevertheless, geothermal electricity is not as similar to the consumption of energy from wind and solar , even though its mature and competitively expensive technology, due to its continuously and predictability its keys benefit that its doesn't require thermal storage. (75)

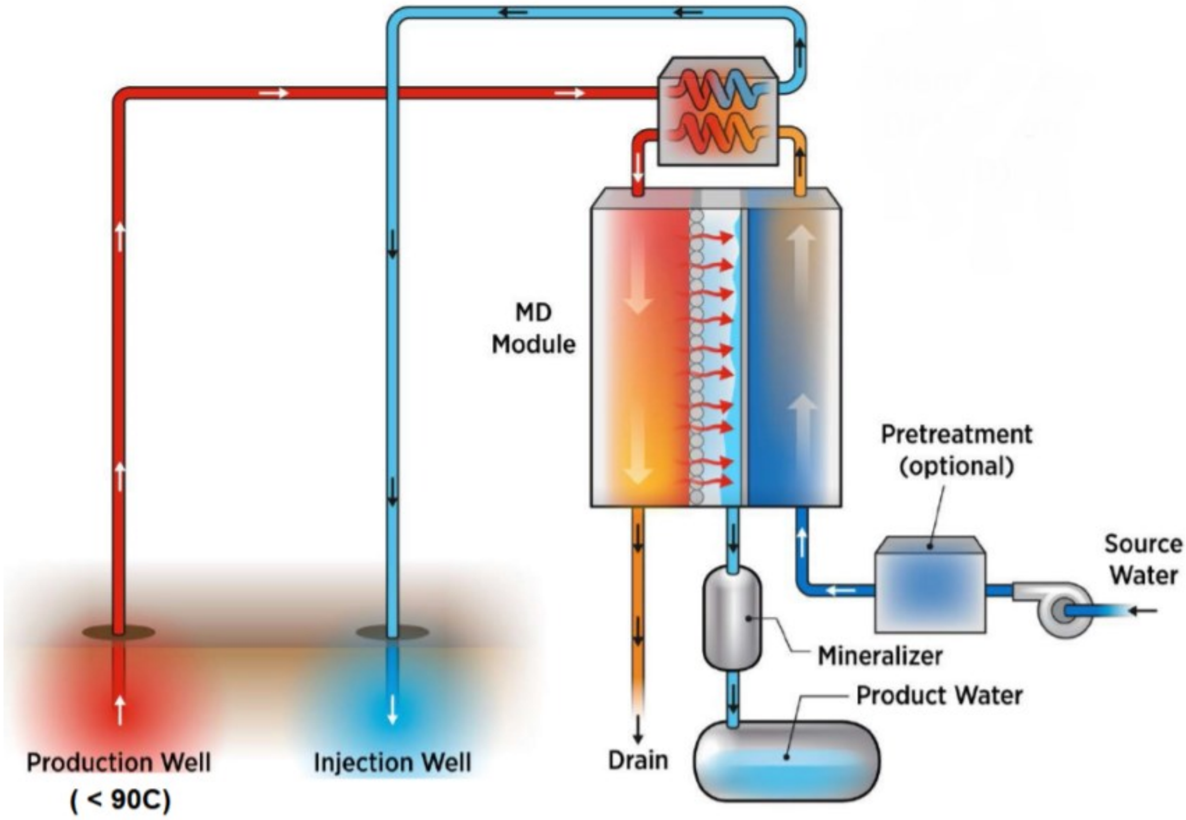


Figure 20

Hybrid-Powered Desalination

The idea of integrating more than one renewable source is considered hybrid-powered. The use of both is optimal to deal with intermittence of renewable sources of electricity, including solar and wind, as their energy generation profile does not coincide at some places. Over the last 3 decades, some experiments have been performed on hybrid desalination systems but none of them have been large-scale, in many of these measures, the ability to refine hybrid configurations was shown to improve efficiency and reduce costs.(76)

A research by Mohammed et al. proposed a simple approach to measure and simulate a wind-PV-RO hybrid plant, which achieved a convincing value of 5 euro/m for water output. Another research in Eritrea, east Africa with the same arrangement, has shown that a device with 35 m3/day of output consumes about 2.33 kWh/m3. In an even more recent Hossam-Eldin etc analysis analysing the technology based optimization of sustainable hybrid energy system for RO desalination the technology choices are on a number of considerations, suck as energy resources availability, specific design limitations or usable component characteristics and prices . therefore, an iterative approach that assesses all possible energy combinations and there economic feasibility for a given location is more likely to be implemented. The report also concluded that it is vital to decrease the surplus energy produced in order to reduce the net costs of energy production. (77)

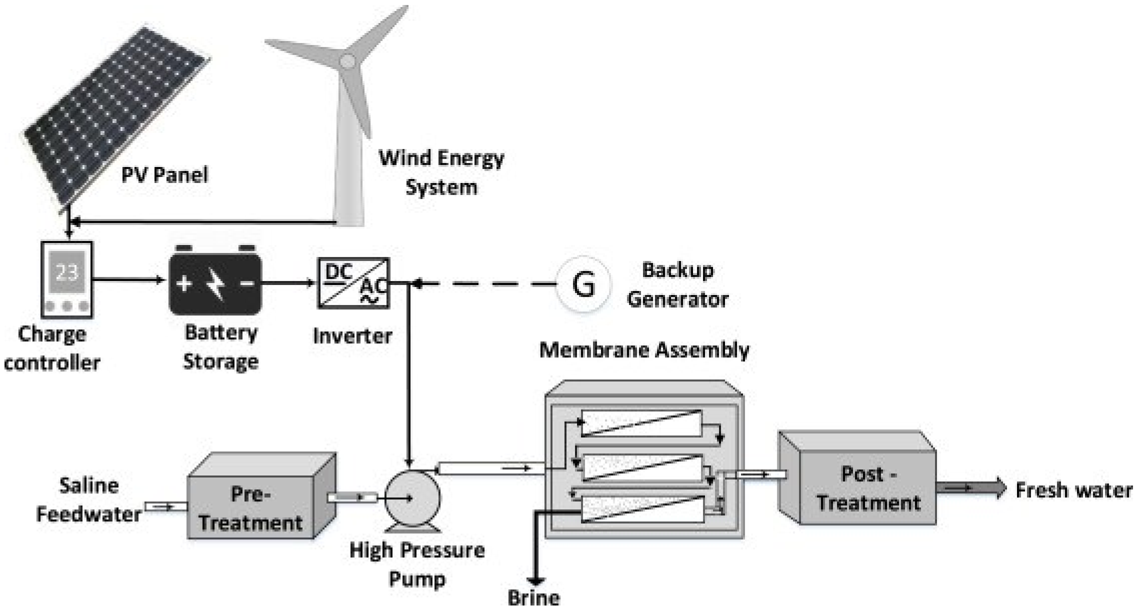


Figure 21

8. Economic of desalination

Desalination has a tremendous potential for advancement worldwide. This is because of the fact that out of 71 largest cities with no nearby access to new supplies of fresh water, 42 are on the coast. 2400 million people, representing 39 percent of the global population, live less than 100 km away from the sea. In some countries, apart from the fact that desalination is the only solution, its growth potential is driving forces allowing it to be more beneficial than the production of traditional resources

In the last three decades, the cost of desalination technologies has been lowered by systematic research, by reducing energy usage and increasing developments. They key two factors influencing the expense of the desalination technology are capital investments and energy prices, while other factors such as operating and repair cost are almost fixed. Salinity of the water, fuel for energy, plant size, land costs and state subsidies are all other factors which affect the cost of desalination. renewable energy sources currently have little effective use of desalination systems relative to fossil fuel, owing to high technical and infrastructure expense of extracting such renewable resources and their requirements. (60)

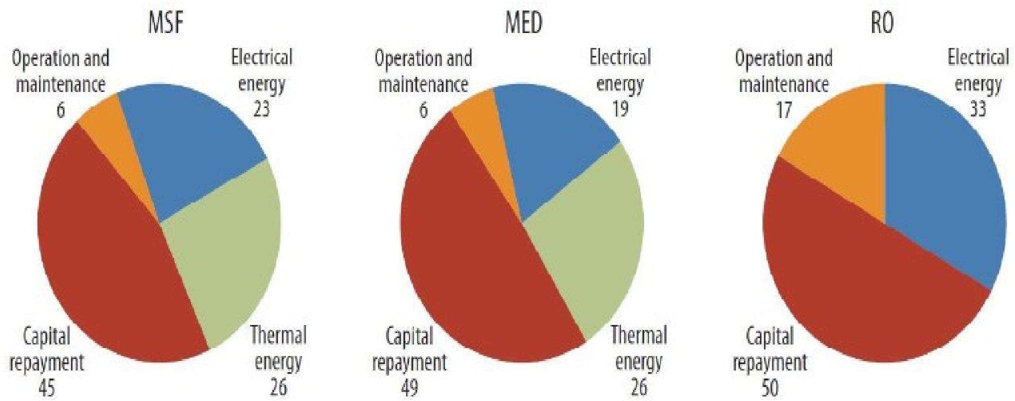


Figure 23

Capital and investment

The capital cost includes all costs related to a specific desalinizing project from planning, authorisation, funding, development, commissioning and approval check for regular service. Capital costs are referred to as CAPEX. The overall fixed expenditure plus maintenance expenses for the contract duration is TWC. The costs are determined by dividing the amortized capital expenditures by the total annual amount of water supply by the annual costs of operations. TWC excludes distribution costs generally, particularly in alternative delivery contracts. Operating and maintenance consist of fixed costs and variable costs.

Fixed costs include premiums and amortization (annual direct and indirect expense interest) expenses. They key operational costs (OPEX) include labour costs, electricity costs, water materials (chemicals, membrane replacement, pump replacement), repair costs and replacement parts, which depend on the ties between the production and distribution centre and the facility site. Direct and indirect charges are included in the capital cost. The direct expense included the constructed process facilities, auxiliary equipment and the piping and equipment involved, civil function, intake (wells or sea) and bring discharge. Usually, building expenses are between 50% and 85% of the overall cost of the capital.

Indirect capital costs represent overheads, operating capital, freight and insurance, contingencies, import duty, the administration of project and the charge for architectural and technical purposes. Usually, these costs are measured in the form of a proportion of the average direct costs for the capital of 30% to 45% (78) (79)

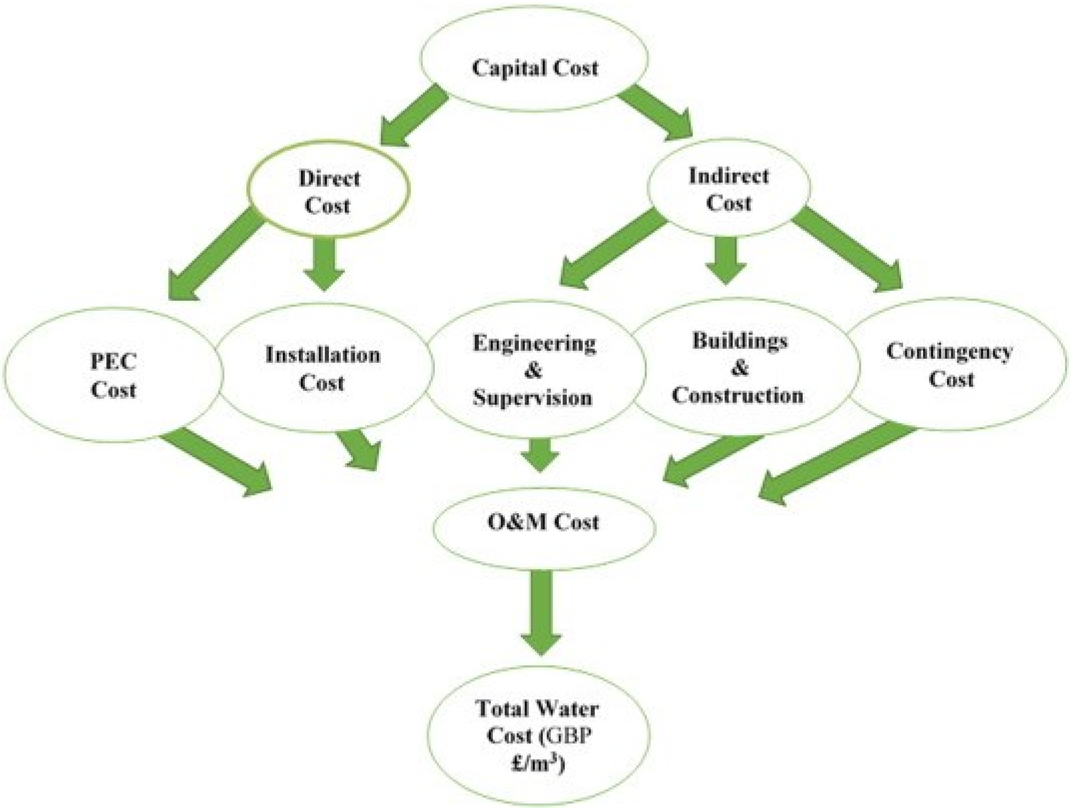


Figure 24

Desalination Contracts

Governments have been the primary source of financing for these programs, although many governments agree that the private sector has a role to play in the growth because of the scale of the foreseen investments. Many policymakers still seek to harness innovations in technology and management in the private sector. These considerations led to effective models for public-private transactions. Two types of contractors the independent water and power producers and build own operate or build own operate transfer which is without initial government ownership contracts but guarantee contracts. Development has led consultancy firms to transcend their standard construction position and become a private developer structure owner for a desalination or a power plant. Therefore, it is important to define and standardize the factors which contribute to the desalinated water unit cost for any technology and to establish an effective costing methodology which will take all of the factors into account, the use of different methodologies by various project providers may be on reason of the poor precision in water cost estimation also for related projects.

Most recent desalination facilities are BOO/BOOT water projects with private funding. A long term customer procurement agreement is provided for the BOO project which is paid for the supplied utilities (water, gas, fuel). The project bid winner does the same tasks with the boot program, but at the completion of the supply contract period, the project is passed to the customer.

Technology developments that have contributed to cost reduction

Major changes in the efficiency of such technologies in the last decades have led to cost saving in all desalination processes (81) (82) (82) (84)

. Thermal processes

- MSF

1. Optimization of the process and specific equipment
2. Unit size grew from 19000 to 90000 m3/d
3. Enhance of load of brine chamber
4. Improved plant reliability and heat generation
5. Enhanced building materials and structural component
6. Installation cost reduction, considering increased raw material and labour costs

- MED

1. Unit size grew from 3800 to 22700 m3 /d.

2. Improved coefficients of heat transmission with correct transmission surfaces
3. Low temperature stabilization and aluminum use of the surface heat transfer

Membrane process

In RO processes there are several significant recent developments in desalination technology, the overall desalination capability in the Arab gulf is of the world using RO technology is steadily growing. Although energy is cheap and raw water quality is less adequate for RO technology, it requires a sophisticated pre-treatment scheme to primarily prevent fouling and bio-fouling of RO membranes. Compared to every other system, the overall global RO capability is the largest the enormous reduction of RO desalination cost has contributed to the desalination by many countries for domestic and commercial water sources.

In the last three decades there have been several advances that have led to reducing the unit water costs of RO desalination, particularly membrane efficiency and energy consumption caused by more effective system for energy recovery. The important improvements in RO technology are (85) (86):

1. Pre-treatment process improvement
2. New intake concept development
3. Plant improvements using various configurations and connection process improvements
4. Development of a high boron refuse membrane producing an appropriate permeate concentration without needing RO systems for secondary passes
5. Reduction in the use of increased membrane quality chemicals. Acid and anti-scaling injection are not always needed. A new study found that an SWRO plant without chemical substances operates consistently without scaling
6. Low pressure membranes may minimize or prohibit the use of coagulation agents in SWRO pre-treatment
7. Desalination, capacity increase

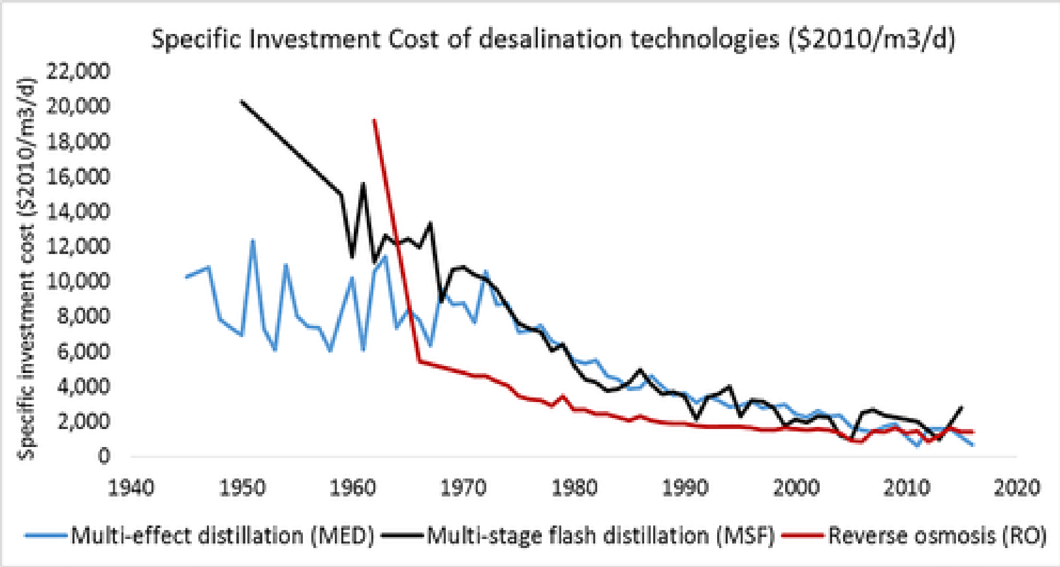


Figure 25

9. Saudi Arabia Conventional cost VS Re-enable cost

Conventional cost

Type of technology	**Capacity**	**Cost of water (US$/m3)**
MSF	Large	0.56-1.75
MED	Large	0.52-1.01
	Medium	0.95-1.5
	small	2.0-8.0
RO	Large	0.45-0.66
	Medium	0.48-1.62

Table 6

Thermal process

For MSF plants, the estimating water output cost varied from 0.52 us dollar to 1,75/m3, varying from and the MED plants are estimated from 0.52 to 1.01 taking in to consideration the capacity of the desalination plants for both technologies. (61)

Membrane processes

With the developments of the membrane technology in the past few years, the estimated output cost range between 0.45 to 0.66 us dollar m/3. (61)

RE-Desalination cost

The use of renewables in declination systems currently is inadequate compared with the use of the fossil fuel because of the high technological and infrastructure expenses of extracting these renewable energies. However more research and development will minimize the cost in the near future.

RE-Desalination Technology	Capacity (m3/day)	Cost Water (us$/M3)
Solar still	<100	1.3-6.5
Solar MD	0.15-10	10.5-19.5
Solar pond/MED	20,000-200,000	0.71-0.89
Solar pond/RO	20,000-200,000	0.66-0.77
Solar PV/RO	>100	11.7-15.6
Wind/RO	>1000	1.95-5.2

Table 7

Solar still

The technology of solar still is very basic, its capital costs are minimal, and no fuel use to evaporate the water. But due to the low efficiency of the still, the cost production is high. The cost ranges between 1.3 and 6.5 us$/m3. (62)

Solar membrane distillation

Because of the low capacities characteristics of the MD system and its high energy usage, it is still not on the market commercially, this technology water cost range between 10.5-19.5 us$/m3. (62) (63) (64) (65) (66) (67)

Solar pond desalination

The temperature of the solar pond storage are could exceed 90C, such energy can be used both for MED and MSF desalination for low heat and for electricity generation for RO systems. The estimated cost for the MED technology ranges from 0.71 to 0.89 us$/m3. (68)(62)

PV-RO desalination

This technique has been used extensively in rural areas in the majorities of the countries, but on small plants, causing the cost to be high ranging between 11.7 to 15.6 us$/m3. (69)

Wind-RO system

In various parts of the world a wide variety of medium wind-ro plants were developed and tested. The cost is between 1.8 and 5.2 US/m3. (70)

Saudi Arabia Conventional cost and Re-enable cost

Conventional Technology	Cost (US$)	RE-Technology	Cost (US$)
RO	151456219.5	Solar/MED	11556800.54
MSF	858633266.1	Solar Pond/RO	222135788.6
MED	8464135.61	Solar PV/RO	3937861707
		Wind/RO	656310284.5

Table 8

In brief, desalination facilities in the Kingdom Can be run using traditional and renewable energy sources and owing to the technological and economic challenges, almost all the desalination plant in the kingdom are using fossil-fuel even worldwide rather than using renewable energy. From the information above water cost generated by desalination has been concluded. systems that use traditional energy sources are much lower than those powered by renewable energy. A selection of criteria is used for the cost of RE desalination. A RE system is needed for circumstances, plant architecture, energy storage or lack of it, the desired energy production and its hour distribution, the direct relation between large-scale renewable energy systems with large desalination plants is already an occurring idea in the Kingdom of Saudi Arabia. Government and public-private investment models are main sources of financing for such ventures. While some countries provide financial assistance for green energy-produced power, this aid is not yet popular for desalination plant energy displaced by renewable energy sources. With respect to small industrial networks that provide renewable energy with desalination technologies in a small packaging procedure, they are generally designed for rural areas where power is not possible and currently niche and specialist applications. Different data suck as local water use, local energy use, percentage of water extracted already from desalinisation and availability of local renewable energy resources should be also considered for determining the demand opportunity. Since the market of RE desalination is a novelty, there are few information about its commercial potential and its features, that is why it is difficult to assess investment risk and return. Furthermore, in several countries price mechanisms and water supply subsidies can generate situations where investments in RE desalination may remain inefficient or high risk. Moreover, even in situations where RE desalinating water is cheaper in cost than other options, the hight start-up costs and resulting low operating costa could not appear enticing, dissuading consumers from having little financial capacity

10. Future of desalination

Apart from the consumption of energy and land needed for renewable energy desalination plants, it is important to consider what would change in the near future. This is vitally important because we have to recognize the desalination trend, how quickly it is growing and what desalination can make an important contribution to water consumption. Forecasting global supply for water and capacity desalination is needed to this end.

Despite the many modifications already made to seawater desalination processes, they nevertheless remain little expensive. They key explanation why many countries do not afford it, is due to the huge volume of energy footprint. However, for certain developing nations, the classification of their fresh water supply is strongly contributing by the desalination process. There are now some 21,123 global desalination plants spanning 150 countries, with a combined accumulated desalination capability of about 126.57 million m3/d in 2019. Its projected the by the 2030 the globally installed capacity will reach 200 million m3/d.

This indicated that the desalination power will most be likely be contributing twice as much in 2030 across the world as it now is. The contribution will rise to 4% from 2.1% to the overall demand for water.

11. Limitation

Comparing energy use through current desalination technologies is a dynamic challenge because of many issues to be addressed. The most significant and important elements are equipped. Desalination process, capacity, type of feed, energy demand and pre-treatment are the variables with a great effect on the energy footprint. These factors decide the larger part of the overall desalination energy demand and footprint, however there are also several factors which are not taken into account including such

Post-treatment: it can be needless at; this depends heavily on the function of the desalinated water. For instance, for e.g., if suck water is being used for industrial or agricultural uses post-treatment is not required, but in the case of fresh water, it must be used.

Life-span of the desalination plant: the reduction in productivity could contribute to this serious corrosion emitter for technologies of thermal desalination. The concern is that some components that are still exposed to the degradation of salty water. In order to deliver same volume of water through the same membrane, it is essential over time , to decrease the permeability of the membrane, which obviously contributes to greater energy consumption due to higher strain.

Building years: technologies are subject to many technological advances and less energy usage. In recent decades, reverse osmosis energy consumption has been reduced, and without a doubt , the earlier designed desalination plants, that was built earlier has a lower energy efficient power efficiency than the other, plant that was constrained at the present times

12. Conclusion

Water and energy sources are interconnected, and they can no longer be viewed as two distinct concerns and/ or threats. Immediate and long-term water challenges would need sustainable water supply usage strategies around the globe, both water and electricity, depending on water management and energy sources, may be non-sustainable or renewable, and it is also clear that fossil fuels are not renewable. When both commodities have increasingly degraded at an unprecedented pace, environmental effects, including GHGs and brine disposal have contributed to global climate change pollution. This study examined one of the possible solutions available. The recent technological advances which enable low-cost desalinated water production and increased energy efficiency indicate a medium-term potential for long-term growth in integrated renewable-energy desalinisation. Mixes of energy from renewable energy sources, including solar, wind and geo-thermal, should become a standard procedure. In areas of extreme water shortages. E.g the kingdom of Saudi Arabia, the studied renewable energy technologies are promising, although their use has so far been minimal, instead of using fossil fuels, the use of renewable energy sources can become that of electricity demand, maintained for the next decades.

The primary obstacles for desalination plant powered by green energies are the reduction/financing of initial energy expenditure resources and the decrease in energy use in desalination processes by using more efficient energy recovery systems. The balancing of the generation of the RE energy to the energy requirement of the desalination process is another problem. This needs more research and focus in order to achieve water safety with rising environmental impacts in relation to the effects of desalination on the ecosystem. Different desalination technology and various clean energy solutions are available to drive them. RE desalination systems be iteratively developed, decisions on the appropriate solutions to be used need to analyse different design parameters quality of water, required quality of water, supply of sustainable energy supplies, capital costs, operating and maintenance costs, energy usage.

AS both solar and desalination systems can be individually built and then linked, they can be analysed independently, but a systematic approach is preferable. The solar photovoltaics coupled with RO desalination is a superior option among the available options, this finding has many reasons: RO is currently available as the most energy efficient desalination method and only require electricity to power mechanical auxiliary systems, capital costs of solar photovoltaic systems can be reduced further, rendering the desirable and affordable fossil fuel systems. Many emerging technologies like FO, MD, AD and hybrid systems are now being built with the concept of taking account of energy use. Some of these modern, creative developments prove that not only are they energy effective but much more efficient through the use of RE. these solutions consume less electricity and additives, which in turn generate less GHGs for the future and climate change. In order to satisfy rising water and energy requirements, more energy-efficient and advanced technologies are required

Lastly, the MENA are is the world's largest desalination market. Centred until recently on the availability of conventional energy supplies in the installation of large-scale desalination systems. The association of RE with desalination would, however enable the introduction of RE in other areas, which it would entail with the decreasing prices for RE contributing to the expansion of RE desalination market.

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