Economic Feasibility and Environmental Sustainability Analysis for Co-Location of Desalination Facilities in Power Plants Using Renewable Energy

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Abstract

Desalination facilities are utilized to bring clean drinking water to inhabitants of the areas surrounding said facilities. A proposed alternative of co-locating a Solar Power system and a Desalination plant creates a renewable energy source for the desalination plant. Research shows that this facility reduces fossil fuel emissions into the atmosphere as well as reduce long-term energy costs. This paper presents the cost, efficiency, and environmental sustainability of this system through new advancements. This paper can assist engineers and other parties involved in the construction and expense of this type of facility. These findings help to discover how this facility is able to support a region with clean water without having a severe long-term monetary or environmental impact. This research integrates several disciplines including engineering, economics, and environmental sciences and shows how this facility would be effective and efficient. It also serves to educate K-12 students about renewable energy options.

Keywords

Desalination Facility, renewable energy, solar power, environmental sustainability

Introduction

With an exponential increasing population in today's world, there is increasing pressure for the water supply we currently have access to to fulfill the needs of such an extreme amount of individuals. With a population predicted to be around 9.9 billion by the year 2050 consuming our most valuable resource, this may make our current collecting methods inefficient and unusable. To combat this scientists have turned to new methods such as desalination to create freshwater from brackish or salt water, which previously would have been unusable for drinking. This process of desalination, primarily through reverse osmosis, is currently still being refined, as it is a tedious and expensive process that involves using large amounts of energy and has very high costs as well. The primary energy use for these desalination sites is coal and oil, both nonrenewable resources that do not leave a positive impact on the environment in the area of the site. With renewable resources such as solar energy becoming increasingly affordable and efficient, the use of said energy sources could be the turning point for the mass use of desalination plants in regions that continue to receive minimal amounts of fresh water. This is especially applicable to areas that do not have much monetary excess to spend large sums of money to create these plants. Producing fresh water while leaving the surrounding wildlife and nature untouched as well as creating energy that will pay for itself once initial costs are covered are two of the main reasons why co-locating a desalination and solar power plant is the future for these industries.

Desalination

Reverse Osmosis

With such a vast amount of salt water in our world's oceans, desalination plants make a strong case for being the future of water collecting as current methods become increasingly more difficult and because its main resource is so readily available. As science has progressed there have been several variations of desalination that have been developed but the leading type that is used in over 60 percent of desalination plants worldwide is the reverse osmosis method[1]. This method takes a salinized amount of water and pressurizes it up against a membrane through which passes the filtered, product desalinated water and what is left is a more concentrated salt filled water which is taken out of the system. Figure 1 presents the description of the reverse osmosis process[2].

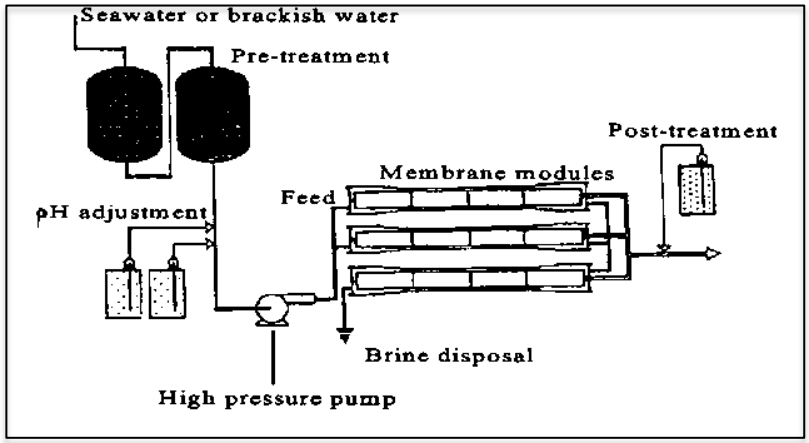

Figure 1 Reverse Osmosis description

Energy Use

Despite salt water being so abundant, the amount of energy required to pressurize large amounts of brackish and salt water/seawater is enormous. Both brackish and seawater are used because locations usually have one or the other. For seawater, there are slight variations of exactly how much energy per cubic meter of water is needed to achieve the desired water purity but for a medium-size desalination plant with a capacity of 31,822 m^3/day and 11,615,030 m^3/year is approximately 6.7 to 8.0 kWh/m^3. At this point in our technological advancements reverse osmosis is the leading desalination method because other types can reach up to 50 kWh/m^3. That high of energy usage is very tough to turn a profit on when having to find an energy source cheap enough to fuel those energy expectations[3].

Cost

With a high energy level required pushing un-pure water through membranes to produce clean filtered water you're going to need a high amount of energy that has to be cheap in order to make this system profitable. The most widely used resource is fossil fuels and to be more specific, petroleum. According to the U.S. Energy Information Administration, approximately .07 gallons of petroleum or .00175 barrels of petroleum will generate 1 kWh[4]. Armed with this information, we can calculate the price of petroleum on a world level by the barrel to estimate the amount of money it would cost to generate the amount of energy a desalination plant the size demonstrated above would operate year round using this energy method. For comparative purposes 8 kWh/m^3 will be used for the reverse osmosis rate. At this rate, a desalination plant generating 31,822 m^3/day and 11,615,030 m^3/year would use 445.508 barrels/day and 162610.42 barrels/year. Although the cost of petroleum per barrel is very cyclical we will be using 87 dollars per barrel to estimate costs because that was the average cost per barrel for the year 2014 according to U.S. Energy Information Administration. Using this 87-dollar, the total cost using petroleum would be $38,759 a day and $14,147,106 a year. The scarcity of a product (and the one we are looking at currently, petroleum) depends on the demand, which influences the price. As the world increasingly use more fossil fuels to power everything that we do from electricity to transportation to desalinations plants, this limits the amount of petroleum that exists in the earth thus driving up prices[5].

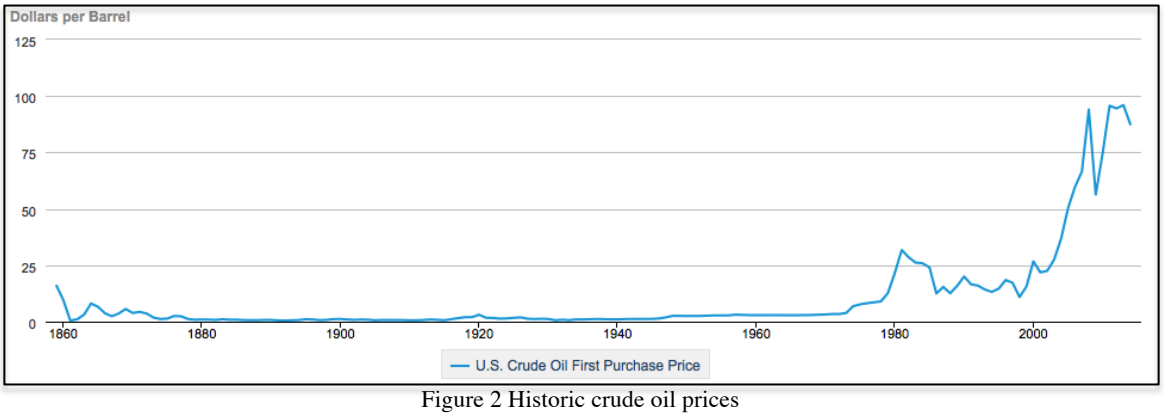

Figure 2 Historic crude oil prices

Figure 2 presents the historic crude oil prices[6]. It shows the increased use and value of crude oil and will look to continue to rise. As the price of this commodity increases and becomes scarcer this mode for generating energy in a desalination plant becomes less feasible and less cost efficient which means the price estimate above will only rise making costs at a desalination plant rise.

Environmental Impact

Because desalination plant requires a large amount of energy to run its daily functions, large amounts of fossil fuels need to be burned to create said energy. The byproducts of these processes are harmful to the environment and to the life that lives in the coastal region that the desalination plant is most likely located next to. One of the biggest impacts with burning fossil fuels to use as energy is the sulfuric oxide and nitrogen oxide that are released into the atmosphere and act as greenhouse gases[7]. Another potential issue is if this fuel source arrives by the coastal port there is the potential for an oil spill, which has the potential to destroy the ecosystem and damage plant and animal life indefinitely[8].

Solar Power

Concentrated Solar Power

In an age of exploration into alternative and sustainable power sources, solar power is a leading candidate for mass use renewable energy around the world. For the sake of potentially powering a desalination plant, Concentrated Solar Power would be the most logical mode for collecting solar power. Because of its use commercially and for large-scale energy collection this is a mode that would fit the massive energy requirement that a desalination plant needs to function.

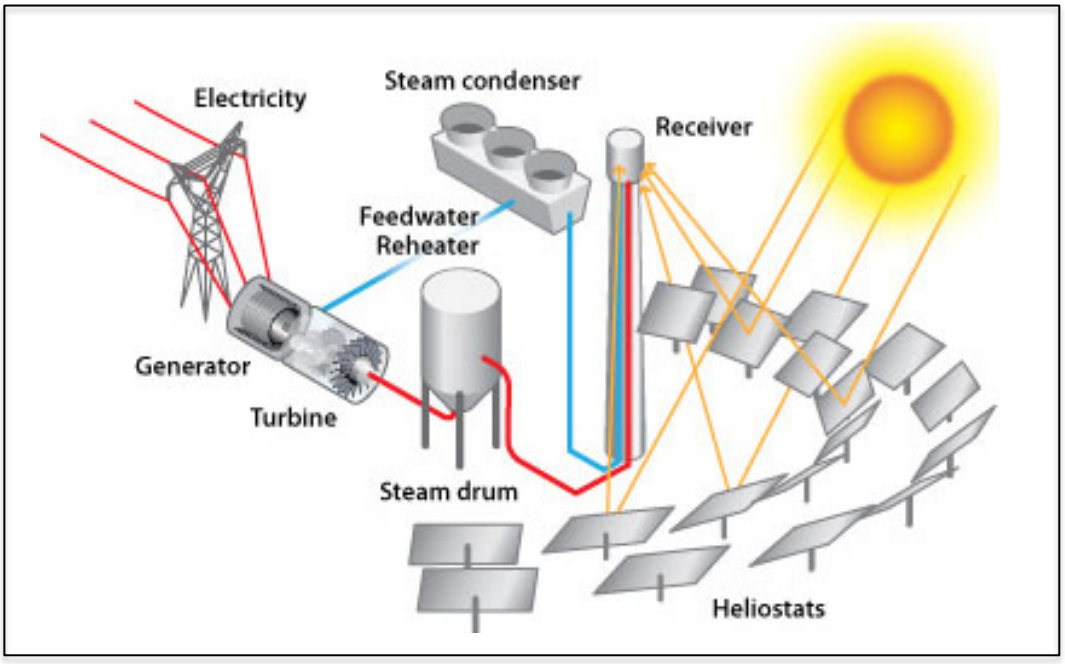

Figure 3 Concentrated Solar Power energy description

Concentrated Solar Power is generated by using a large collection of mirrors called heliostats which are shown in Figure 3.[9] The heliostats focuses all the radiation and energy to a central point which is then collected and converted into heat which is used to turn a turbine thus creating electricity and energy[5].

Cost

Because this method is not as developed or readily available for use like fossil fuels may be there is some drawback to the initial expense to install and keep up the solar panels that will generate power for a desalination plant. Studies have been done on Concentrated Solar Power systems and right now an excepted value for the amount of output per kWh costs $.19-$.43 with a potential reduction of about 50% in cost expected in 10 years due to the potential for more streamlining of collection processes[10]. Using the average estimate for solar cost and the previously mentioned 31,822 m^3/day and 11,615,030 m^3/year desalination plant with an approximate output of 6.7 to 8.0 kWh/m^3 to compare directly with the fossil fuel statistic, total costs for solar power output would be $78,918 per day and $28,805,274 per year. Additionally as mentioned[10] there is the potential in the next 10 years for those prices to drop to $39,459 per day and 14,402,637 per year. These numbers are similar to the nonrenewable options described earlier and this solar option proves to be additionally attractive as you look at other factors like transportation of the petroleum, drilling for oil or mining for coal as well as the fact that the solar power won't need to be transported. In addition, the future potential for substantially decreasing costs due to scientific advancements put Concentrated Solar Power in a potentially much better situation economically than the cheapest fossil fuel options in the next 10 years[11]. Figure 4 is a proposed outline of a co-located reverse osmosis and concentrated solar power plant along with Table 1 which presents the increasing reduction in solar power cost along with the existing fossil fuel cost[10,11].

Table 1 Various prices for solar and petroleum power

Power Option	Current Low Average (per year)	Current 50th Percentile Average (per year)	Current High Average (per year)	Future Low Average (50% reduction in price/kWh) (per year)	Future 50th Percentile (50% reduction in price/kWh) (per year)	Future High Average (50% reduction in price/kWh) (per year)	Current Price (per year)
Concentrated Solar Power	$17,654,845	$28,805,274	$39,955,703	$8,827,422	$14,402,637	$19,977,851	-
Petroleum	-	-	-	-	-	-	$14,147,106

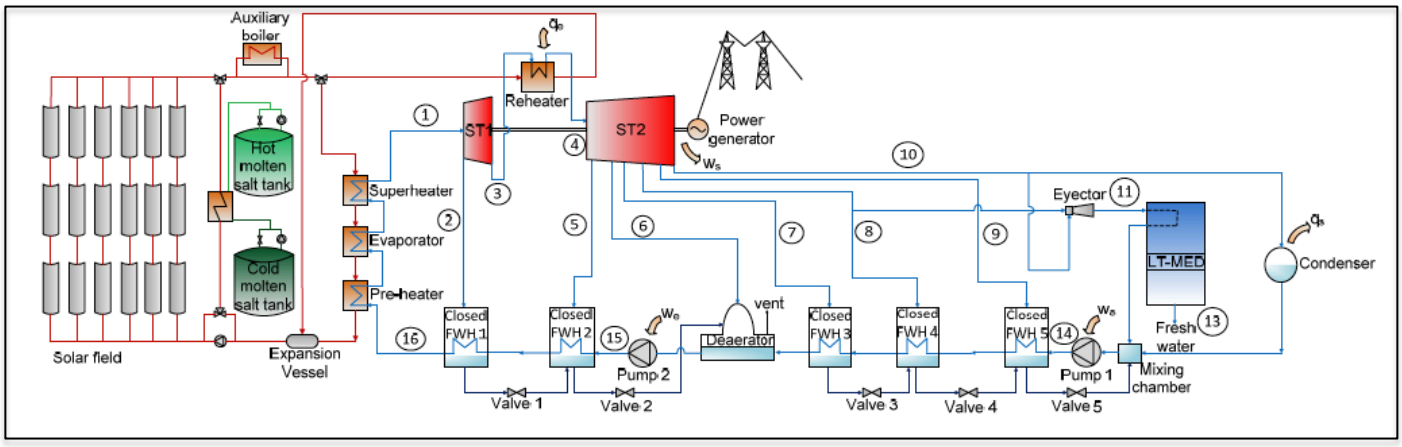

Figure 4 Concentrated Solar Power co-located with Desalination plant concept

Environmental Impact

Solar power, and specifically Concentrated Solar power, contributes a very slim amount of harmful chemicals into the atmosphere. The process of creating power from collecting the suns rays uses zero fossil fuels, which are linked to climate change. The only part of the Concentrated Solar Power equation that contributes negatively to the environment is in the machines giving off fumes from fossil fuels being burned to build the site but that would happen for any power plant being constructed[12].

Educational Application

Armed with this information, the purpose is to ensure that areas in which desalination plants are located have drinkable water using energy sources that aren't easily depleted. Educating the next generation of engineers starting in K-12 programs about this information through presentations is crucial. Depletion of fossil fuels is very important and needs to be reinforced. As more fossil fuels are used there is more carbon dioxide released and more harm done to the environment. Once the students recognize this, the must recognize that the solar power alternative is carbon free and would have a positive environmental impact. Also the students must recognize that water will be a scarce resource and we must be smart and conserve now as well as look to other water sources such as the ocean. Co-location of desalination and solar power facilities provides everything in one place, a sustainable system, and saves money on transportation and additional land costs.

Conclusion

The co-locating of a Reverse Osmosis desalination plant and a Concentrated Solar Power plant would be economically as well as environmentally beneficial. Using Table 1, fossil fuels and specifically petroleum based energy options are more cost efficient right now but with environmental negatives as well as future scarcity this option will be looked at more cautiously. Utilizing Concentrated Solar Power instead to generate energy provides a consistent, reliable, and clean source of energy that will become increasingly cheaper and over time will bring much needed clean water to areas that don't have as much monetary availability.

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