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# Economic study for an affordable small scale solar water desalination system in remote and semi-arid region

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ABSTRACT

There is an acute scarcity of potable water in many parts of the world, and especially in the Middle East region. Most of developing countries around the world endeavor to make a balance between declining fresh water supplies and the rapid demands of a rising population. Economic analysis is an essential factor influencing the decision-making in the adoption of desalination technology. This paper presents an economic and comparative evaluation study for a small scale solar powered water desalination system. An economic model has been developed and used to calculate the economic parameters. The results showed that the estimated cost of potable water produced by a solar desalination compact unit was 11 US$/m$^3$ and this could be reduced to 8 US$/m$^3$ when an evacuated tube solar collector with an area of 3 m$^2$ was used. It has been also proved that the cost of fresh water decreased with increasing the lifetime of desalination plant. Development of small scale desalination plants based on the concept of humidification and dehumidification in a compact unit coupled with solar collectors could be considered a unique solution to water shortages in remote and semi-arid areas.



**Contents**



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**Nomenclature**

| | |
|---|---|
| $A$ | solar collector area ($m^2$) |
| $m_y$ | average annual distillate output (kg) |
| $M$ | annual cost of desalination system (US$) |
| $P$ | capital cost (US$) |
| CRF | capital recovery factor |
| $r$ | the interest rate (%) |
| $n$ | life of the system (year) in economic study |
| RO | reverse osmoses |
| $N$ | the annual salvage value (US$) |
| $S$ | salvage value (US$) |
| SFF | the sinking fund factor |
| PC | product cost (US$) |
| $C$ | cost price (US$) |
| HDD | humidification and dehumidification |
| TDS | total dissolved solids |
| MSF | multi stage flash |

## 1. Introduction

Water is one of the earth's most abundant resources, covering about three-quarters of the planet's surface. Yet, there is an acute shortage of potable water in many countries, especially in Africa and the Middle East region. 97.5% of the earth's water is salt water in the oceans, with only 2.5% available as fresh water in ground water, lakes and rivers for the needs of humans and animals [1]. Tackling water scarcity must involve better and more economic ways of desalinating water. Thus, tremendous efforts are now required to make available new water resources in order to reduce the water deficit in countries which have shortages [2]. Thermal water desalination plants are mostly driven by fossil fuel sources, which add a high cost of desalination per unit cost. Therefore the need for sustainable and cost effective new water resource is currently imperative.

The use of solar energy in water desalination has become more popular and is well known, however the challenge is to utilize this solar energy in a cost effective way at reasonable costs.

Solar desalination in rural areas could have a major impact on the health, wellbeing and economic development. However, there are a number of factors that constrain implementation of large scale desalination plants in rural areas, including limitations on efficiency, intermittent power supply and inadequate infrastructure [3].

Semi-arid areas, mainly in the Middle East and northern Africa (MENA region) struggle to balance declining per capita water supplies and the demands of a rapidly rising population. In many of these countries, inadequate sources of energy and fresh water combine with inadequate financial resources. The problem of providing these areas with fresh water can be solved by transportation of water from other locations, and extraction of water from atmospheric air, but these alternatives are still expensive. Arid regions generally have a great solar energy utilization potential, as solar desalination concepts and methods are specifically suited to supply dry regions with fresh water. The key point is that efficient and environment-friendly solar energy coupled with desalination technologies could be an appropriate alternative to produce fresh water on both small and medium scales to conventional humidification and dehumidification solar desalination systems and basin solar stills with a relatively large footprint areas. Such technologies would also contribute to reduce global warming. This solution is suitable for supplying upto a half of the rural population living in arid regions that lack conventional fossil fuels [4]. Small to medium scale desalination plants utilizing the solar thermal processes and powered by solar collectors or photovoltaic (PV) cells, could be the most viable economical solution for providing freshwater to small communities in isolated arid areas with high solar irradiation and access to the sea or brackish water [5].

Cost effectiveness is a major factor in the commercialization of any desalination device. Meanwhile, the selection of the most appropriate desalination technology for a desalination device is affected by many design and economic factors, including plant size, feed water salinity (such as TDS, turbidity, temperature, heavy metals and product water quality), remoteness, availability of grid electricity, infrastructure and the type of solar technology available [6]. There are several possible combinations of desalination and solar energy technologies that could have promising water production rates in terms of economic and technological feasibility. Some combinations are more suitable for large plants, whereas others are more suitable for small-scale applications [7]. Important advances have been made in solar desalination technology, but their wide application has been restricted by relatively high capital and running costs. Until recently, solar concentrator collectors have usually been employed to distill water in compact desalination systems. Currently, it is possible to replace these collectors by more efficient evacuated tube collectors and heat pumps, which are now widely available on the market at a similar price [8]. This chapter presents an economic analysis of a small scale solar water desalination system based on the psychometric humidification and dehumidification solar water desalination system coupled with an evacuated tube solar collector.

## 2. Factors affecting the cost of water desalination

There are many factors to consider that could influence the cost and selection criteria of the desalination technology. The main criteria for estimating costs of small-scale desalination systems do not differ significantly from those of large-scale systems. A number of studies provided relevant information on reliable, and affordable desalting units that constitute capital investment, operational and maintenance costs, and it has been found that the desalination production cost is mainly depending on site conditions and equipment suitable for region use, especially by the specific desalination system chosen governments of countries with the greatest need [9]. Table 1 presents the most relevant parameters that affect the cost effectiveness of small to medium scale desalination plants in remote areas.

The advantage of using free and clean energy is to increase the amortization costs. However distillation with solar energy remains one of the most favorable technologies in the remote areas due to the aforementioned reasons.

A comparison between the conventional desalination system (membrane, and thermal desalination) and the renewable desalination system is presented as percentages in Table 2, which shows that, in the case of renewable energy sources, investment costs are the highest, but energy costs are the lowest. A major barrier to determine the economic cost of water desalination systems operated by renewable energy is the limited data analysis available for this purpose. Few researchers have conducted an economic analysis of their solar desalination systems in general such as Fiorenza et al. [13] for the techno-economic evaluation of a solar powered water desalination plant. Similarly Riffat and Mayere have presented generally the economics of small scale desalination system with trough solar collector [14]. Therefore in this study we will carry out a detailed