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Solar desalination: A sustainable solution to water crisis in Iran

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ABSTRACT

Water has a significant role in all our daily activities and its overall consumption is growing every day because of increasing scheme of mankind living standards. Iran is located in the dry belt of the earth, where nearly 70% of its area is located in arid and semi-arid regions. At the present time, Iran is experiencing a serious water crisis. It has been projected that the total per capita annual renewable water of the country will reach to about 800 m^3 by 2021, which is less than the global threshold of 1000 m^3. In this context, seawater desalination seems to be a potential solution to meet the water supply and demand balance in Iran as the country is surrounded by three main water bodies of the Caspian Sea at northern and Persian Gulf and Sea of Oman at the southern borders. Annually, about 120 million cubic meter of freshwater supply is from conventional desalination plants centralized in the southern coastal regions of Iran. The fossil-fuel powered desalination systems are no longer sustainable to overcome the water crisis in the country due to both depletion risks of available energy resources and increase of greenhouse gas emissions. This is while that Iran has excellent solar energy potentials of about 15.3 kWh/m^2/day, which can effectively be harnessed to run desalination processes. Therefore, in the modern time, solar desalination is an emerging solution to close the water gap in the country by considering the required change in terms of policy, financing, and regional cooperation to make this alternative method of desalination a success.

Contents

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1. Introduction

Availability of freshwater is becoming an increasingly significant worldwide issue. This problem is much more serious in arid regions that are facing with a severe shortage of freshwater. Out of the total water on the earth, about 96.54% is salt water and the remaining of 2.53% is freshwater. While just less than 0.36% of the freshwater is directly available to human as over two thirds of the freshwater is frozen in glaciers and polar ice caps and the remaining unfrozen freshwater is found mainly as groundwater, with a small fraction present above the ground or in the air [1–3]. Water scarcity resulting from economic and population growth is considered as one of the most important threats for human societies and an obstacle for sustainable development. It has been estimated that within the next decades, water will become the most strategic resource, especially in arid and semi-arid regions of the world [4]. Water and energy are two inseparable entities that govern the lives of humanity and develop the civilization [5]. Due to this close relationship, water shortage is expected to consequently intensify the relevant problems of the energy crisis [6–9]. In such situations, policy makers try to solve water scarcity problems through dam building, groundwater recharge, cloud seeding, desalination, wastewater reuse, and developing massive water transfer projects, among others [4]. The only approximately endless water resources are the oceans. But, their main obstacle is their high salinity. Therefore, it would be attractive to tackle the water scarcity problem by desalinizing seawater.

Although desalination is one of the key solutions to the human's water shortage problem and also reduce dependence on precipitation cycles and enable the use of traditionally unusable water, but it dramatically increases the costs and the water supply's reliance on energy [2,10,11]. Therefore, it is projected that the future of desalination is linked to the availability problem of conventional energy resources, depletion, cost, and environmental impacts as well [10,12,13].

Therefore, the type of energy used is also an important issue due to the side effects, including pollution, cost, and fuel security and therefore requires worthy of additional consideration. The mentioned problems can be a source of motivation for the construction of a number of desalination facilities powered by renewable energy resources. Several studies are allocated to this issue and a detailed description of which can be found in the literature [2,5,7,8,11,14–29,30].

Iran is located in an arid and semi-arid region with an average annual precipitation which is less than one third of the global average. Uneven rainfall distribution pattern over the country is an additional problem that has worsen the situation [31,32]. In such a climatic condition, many severe or mild droughts are unavoidable to come up. Any drought can inflict a severe damage on the agricultural, domestic and industrial sectors of the country [31].

With respect to the importance of water in the economic development of Iran and its basic role in production and distribution processes, the water sector has become a special issue in the development plans [33,34]. Conditions like water scarcity, water supply volatility, and poor water quality in several regions of the country, motivate the use of desalination plants which deteriorate these conditions by contaminating the air, land, and water including pollutions leading to the climate change [35,36]. In such a situation, a key solution is integrating desalination systems with renewable energy resources to decrease energy consumption as well as eliminate atmospheric pollutions associated with conventional desalination systems.

Among all the renewable energy resources, solar energy has the highest potential in Iran. Therefore, the solar-powered desalination option seems not only logical but also in some cases essential. Altogether, enjoying Iran from the high potentials of solar energy, and the access to the saltwater due to being surrounded by Sea of the Oman and the Persian Gulf in the south and the Caspian Sea in the north, there is a favorable condition for implementation of solar desalination systems. Although, it seems that the initial conditions for implementation of solar desalination facilities in the country is completely provided, but turning the energy-related policies towards employing solar powered desalination plants to close the water gap in the country is crucial to make this technology a success.

2. Characteristics of the study area

2.1. Iran's topography

Iran is located in West Asia and borders the Caspian Sea in the north, and the Persian Gulf and Sea of Oman in the south. The country ranks the second largest country in the Middle East (after Saudi Arabia) and the 18th largest country in the world with the area of 1,648,195 km^2 [37,38]. Iran is a country with a diverse topography. Its lowest point is on the southern coast of the Caspian Sea (28 m below sea level) and the highest point is Mount Damavand (5671 m above sea level) which is not very far from the Caspian Sea coast [38]. While, the Lut Desert at 56 m altitude is the lowest internal point [39]. Generally, Iran is a mountainous land consisting more than half of the mountains, one-fourth being plains and deserts and less than one-fourth constituting arable land. The rest is worn to mountains and highlands [39–41].

2.2. Iran's climate

Iran enjoys a high climatic diversity, mainly affected by the subtropical high-pressure belt. Temperatures can vary considerably (from -20 to $+50\,^{\circ}C$) throughout the country and during the different months of the year. The monthly average temperature in January is between of $-6\,^{\circ}C$ and $21\,^{\circ}C$ and in July is in the range of 19–39 °C which are respectively the coldest and the warmest months in most cities of the country [38,40,42]. On the northern edge of the country (the Caspian coastal plain) temperatures rarely fall below freezing and the area remains humid for the rest of the year. In the south, winters are mild and the summers are very hot, having average daily temperatures in July exceeding 38 °C [43,44]. The very hot and dry climate of the interior areas changes suddenly to the wet and moderate coastal climates of the Caspian coastal areas to the north of