

# Current Research Trends for Renewable Energy Driven Reverse Osmosis Desalination



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## Abstract

Fresh water supply is becoming more and more an issue of increasing importance. Traditional sources of fresh water are becoming, either scarce or inaccessible or of low quality in several arid and semi arid areas of the world. Desalination is considered one of the most important methods to tackle the problem of fresh water scarcity. However, it requires high quantities of energy to produce fresh water, especially for seawater desalination. Due to the fact that areas with water scarcity problems usually enjoy high renewable energy resources, using solar, wind and other types of renewable energy technologies is becoming more and more technically and economically feasible. Reverse osmosis is one of the most widely used desalination technologies for both brackish and seawater desalination due to its compatibility for connection to renewable energy systems and due to its low energy consumption. The current paper presents a review of the most recent technological and research trends in water desalination by reverse osmosis powered by renewable energy with emphasis on the reduction of the consumed energy per unit volume of fresh water produced and the matching technologies between reverse osmosis and renewable energy systems.

**Keywords:** Reverse Osmosis; Renewable Energy; Research Trends; Energy Requirements

**Abbreviations:** SEC: Specific Energy Consumption; ERD: Energy Recovery Device; RO: Reverse; Osmosis; RES: Renewable Energy Systems; CNTs: Carbon Nanotubes

## Introduction

### Renewable Energy Powered RO Units Market

According to the latest survey of the International Desalination Association (IDA) in June 2015 and the Global Water Inequality (GWI), there are 300 million people in the world rely partially or totally on desalinated water for their daily needs. There are about 18426 desalination plants operating in over 150 countries worldwide producing daily fresh water of about 86.8 million m<sup>3</sup>/d compared to 78 million m<sup>3</sup>/d in 2013 (10.71% increase in two years) and 47.6 million m<sup>3</sup>/d in 2008. Desalination market earned revenues was found to be \$11.66 billion in 2015 and estimates to reach \$19.08 billion in 2019 [1,2].

The current renewable energy powered desalination market share is about 1-2% of the total worldwide desalination capacity with high potential to increase due to fossil fuels cost escalations and the GHG emissions concerns [3]. The Reverse Osmosis (RO) desalination is the dominant technology with a share of 60% of the worldwide installed desalination plants, while this percentage reaches 82% in China, which is considered one of the fastest developed markets for desalination. RO technology also accounts for 52% of the installed renewable energy powered desalination units (photovoltaic, wind and solar Rankine) [2].

### RO Technology

Reverse osmosis (RO) is a non-thermal membrane separation process that separates the solvent from solute utilizing mechanical energy to pressurize the incoming sea or the brackish water towards semi permeable membranes. The applied pressure should be higher than the osmotic pressure of the incoming feed solution (sea or brackish water). The incoming feed water is pressurized by the feed water pump (low pressure pumping) through the pretreatment system. The feed water then enters the high-pressure pump that increases the feed water pressure to a value higher than the osmotic pressure of the feed water. The semi permeable membranes separate the incoming feed water into two streams, the fresh water and high-pressure brine (also called concentrate). Since most of the energy consumed in the reverse osmosis membranes is dumped with the concentrate stream, medium and large-scale reverse osmosis units are always equipped with hydraulic or electrical energy recovery devices (ERDs) in order to reduce the specific energy consumption - SEC (kWh/m<sup>3</sup>) [4,5].

Desalination by Reverse Osmosis (RO) has many advantages over other desalination technologies, such as: lower Specific

Energy Consumption (SEC), better matching with renewable energy systems, direct production of fresh water (not distilled water), it is suitable for both brackish and seawater desalination, can be used for small, medium and large scales systems, lower O&M costs and robust operation. However, some disadvantages of RO systems include: the need for sophisticated pretreatment system, sensitivity to fouling, and scaling and free chlorine in feed water [6,7].

### Advances in RE Powered RO Desalination

The main technological and research advancements in Renewable Energy powered RO systems aims at reducing the specific energy consumption, better combination and higher penetration percentages of RE, more optimized energy storage devices, system engineering options for the connection of RE and RO and advanced membrane materials to enhance fouling and scaling resistance and to increase flux. The main advances in RE powered RO systems are:

- a) Using Carbon Nanotubes based membrane: being hydrophobic with a smooth surface and inner diameter of 0.6-1.1 nm, enhances the frictionless transport and drastically increase water flux [8].
- b) Graphene based membranes: Graphene Oxide (GO) based membranes have better salt rejection than that of the CNTs membranes. However, it is important to develop grapheme stack to build water pathways [8].
- c) Intermittent operation: instead of operating the RO unit on a constant pressure, the unit is operated in an optimized window of operating points of pressure and flow. Consequently, lowering SEC and optimize the use of available intermittent RE energy. This systematic intermittent operation, especially by using flow reversal method, is now commercially adapted by industrial systems for scaling prevention [6,7].
- d) Batch operation of brackish water desalination systems: this system operating method provides high recovery and lower SEC and still under investigation.
- e) Simultaneous management and optimization of both the desalination system and renewable energy system: by using advanced heuristic methods and computational intelligence techniques, such as multi-agent decentralized energy management system based on distributed intelligence [1].
- f) Short-term energy storage is becoming more and more an issue of great importance in RE powered desalination units due to the intermittent nature of the energy source. Such short-term energy storage includes pressure tanks, flywheel and potential energy storage [1].

### Conclusion

Renewable energy powered RO desalination units are considered a viable solution to the water scarcity problem in many areas in the world. The complementarity between the availability of the renewable energy sources and the water deficit problem makes the combination of both technologies technically accepted and economically viable. Research and industrial trends for RO systems powered by renewable energy aim at lowering SEC, maximizing flux, minimizing scaling and fouling and optimization of energy usage and storage.

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