# WHY USE RENEWABLE ENERGY FOR DESALINATION

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## Contents



## Summary

In remote arid areas of the world where solar or wind energy is available, desalting of brackish or seawater using such renewable energy sources can be achieved with a minimal environmental cost and, in some locations, lower economic cost compared with the alternative of using conventional fossil fuel. The use of renewable energy for desalination for many remote areas such as islands and coastal arid regions has already demonstrated its reliability as well as its technical and economic viability as witnessed by small plants which has been in operation for many years, such as the solar plant in Abu Dhabi, UAE, which has been in operation since 1984.

Many of the tourist islands in the Mediterranean, for example, are facing a big problem of water supply, such as in the Balearic Islands where part of the water demand is supplied from a dwindling underground resource and part from water transported by tanker from the mainland. The cost of transporting water by tankers from the mainland is usually very high and can be as much as \$15 per $m^3$ as reported by Mentzelopoulos et al. (1996).

Several desalination plants have already been constructed and are in operation in the Spanish Balearic Islands, the Greek Islands of the Aegean Sea, Malta, Cyprus and Sicily to augment the declining fresh water supplies and cope with the increasing demand for water. Many other desalination plants are built in remote desert areas such as in the

Arabian Gulf region. Many of these areas are endowed with either a high wind energy potential (such as in islands) or a high solar energy potential (such as in the Gulf region) which can be harnessed as an energy source for desalination.

## 1. Introduction

The scarcity of fresh water resources and the need for additional water supplies is already critical in many arid regions of the world and will be increasingly important in the future. It is very likely that the water issue will be considered, like fossil energy resources, to be one of the determining factors of world stability. Many arid areas simply do not have fresh water resources in the form of surface water such as rivers, lakes, etc. and have only limited underground water resources that are becoming more brackish as abstraction of water from the aquifers continues. The world-wide availability of renewable energies and the availability of mature technologies in this field makes it possible to consider the coupling of desalination plants with renewable energy production processes in order to ensure the production of water in a sustainable and environmentally friendly scheme for the regions concerned.

Solar desalination is used by nature to produce rain which is the main source of fresh water on earth. All available man-made distillation systems are a duplication on a small scale of this natural process.

Recently, considerable attention has been given to the use of renewable energy as sources for desalination, especially in remote areas and islands, because of the high costs of fossil fuels, difficulties in obtaining it, attempts to conserve fossil fuels, interest in reducing air pollution, and the lack of electrical power in remote areas.

## 2. The Need of Desalination for Economic Development in Remote Arid Areas

Water, the source of all life, is one of the most abundant resources on earth, covering three-quarters of the planet's surface. Ninety seven per cent of the earth's water is salt water in the oceans, and only 3 per cent of the earth's water is in ground water, lakes and rivers, and this is the main supply of potable water available to mankind. Man has been dependent on this potable water reservoir for millenia to supply his fresh water requirement for his domestic, agricultural and industrial activities. However, the rapid growth in water demand resulting from the rapid population growth in the world, higher standard of living and rapid industrial growth has resulted in a large escalation in water demand. Added to this is the problem of pollution of some rivers and lakes by the discharge of industrial and sewage effluents which is rendering the use unfit for consumption without prior treatment.

Seawater is the only inexhaustible source of water available to mankind. Its main drawback, however, is that it has a high salinity which renders it unsuitable for human consumption without being treated by desalination plants.

Water is receiving increased attention because of the obvious shortages and challenges our planet is currently facing. The reliable and safe provision of fresh water supplies is one of the major constraints countries around the Mediterranean Sea, including the

southern European regions, North Africa and the Middle East are currently facing. In addition to the continuing desertification in some of these regions, there is the dilemma of a generally increasing demand versus finite resources with decreasing availability.
Desalination of seawater and brackish water is one of the ways of meeting future fresh water demand. Conventional desalination technology is fairly well developed and some of the processes may be considered quite mature although there is still considerable scope for improvement and innovation. Conventional desalination technology is energy intensive and one of the major cost items in operating expenses of any desalination plants is the energy cost. Thus, one of the major concerns about using desalination as a means of supplying fresh water is this cost.

Apart from the cost implications, there are environmental concerns with regard to the effects of using conventional energy systems and resources. In recent years, it has become clear that environmental pollution caused by the releases of greenhouse gases resulting from the burning of fossil fuel is responsible for ozone depletion and atmospheric warming. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. The Intergovernmental Panel on Climate Change (IPCC) reached consensus conclusions in June 1990 that increased atmospheric concentrations of greenhouse gases may result in an additional warming of the Earth's surface. In order to stabilize atmospheric concentrations of greenhouse gases at present-day levels, immediate reduction of global man-made emissions of $CO_2$ and $NO_x$ by more than 60 per cent needs to be achieved.

## 3. The Need of Energy for Desalination

Desalination processes require considerable amounts of energy to achieve separation of dissolved salts in seawater or brackish water. It has been estimated by Kalogirou (1996) that the production of 1000 $m^3$ per day of fresh water requires 10 000 tons of oil per year. This is highly significant as it involves a recurrent energy expense which few of the water-short areas of the world can afford. The Middle East is unique in that, because of the oil income, it has the financial resources required to invest and run desalination equipment. Many other areas of the world have neither the cash nor the oil resource to allow them to develop in a similar manner.

Even if oil were much more widely available, could we afford to burn it in such a manner as to provide everyone with fresh water? Given the current understanding of the greenhouse effect and the importance of carbon dioxide levels in the atmosphere, environmental pollution caused by burning fossil fuel for desalination is a major concern.

The thermal energy required for desalination using thermally-driven distillation processes can be achieved by collection of solar energy using flat plate collectors, evacuated tube collectors or solar ponds. Such devices can achieve temperatures of 80-130°C which are quite suitable for such desalination processes. Solar energy can also be

converted to electrical power using either photovoltaic panels or high-temperature concentrating collectors associated with a heat engine operating on a thermodynamic cycle. Such electrical power can then be used to operate power-driven desalination processes such as reverse osmosis or vapor compression.

Conventional desalination technology is fairly well developed and some of the processes may be considered quite mature, although there is still considerable scope for improvement and innovation. Conventional desalination is energy intensive. Thus, one of the major concerns to developing water production by desalination is the cost of energy. Apart from the cost implications, there are environmental concerns with regard to the burning of fossil fuels. The coupling of renewable energy sources with desalination processes is seen by some as having the potential to offer a sustainable route for increasing the supplies of potable water. Renewable energy processes are less mature but are developing rapidly. Wind energy and photovoltaics (PV) in particular have made enormous advances over the last two decades but still have plenty of scope for improvement.

The amount of energy used in the world for desalination is comparable to the total energy requirement of an industrialized country such as Sweden. This gives an idea of the amount of $CO_2$ emitted by this industry. Global phenomena such as the greenhouse effect must receive due attention. Last but not least there are regions where a significant fraction of the total energy consumption is due to desalination and which are deficient in conventional sources. In these cases regional or national economies may benefit from a reduction of oil imports.

## 4. The Availability of Renewable Energy

The sun is the main source of renewable energy available on earth. It is widely recognized that the inexhaustible energy of the sun is received on the earth in sufficient quantities to make major contributions to the future needs of the world. Solar energy can be converted into useful form by either a man-made device such as a solar collector or a solar pond, or it can be naturally converted on the earth's surface giving rise to wind and weather, the growth of plants and warm surface waters in the oceans. Each of these natural energy forms can be further converted by man for use in desalination or a host of other processes.

If the large polar regions of the earth are omitted, the average solar energy falling on the earth's surface is about 5.2 kWh $m^{-2}$ per day. In very sunny arid regions, such as the Sahara desert or parts of Arizona, California and New Mexico in the USA, the solar energy received at the ground level can reach 6.2 kWh $m^{-2}$ per day.

Wind energy is created by the uneven heating of the earth's atmosphere by the sun. At the warm equatorial regions, air is heated and the resulting buoyancy causes the air to rise. In the absence of additional effects, the air migrates in the upper atmosphere to the colder polar regions where it would cool and descend, subsequently flowing at a lower level back to the equator where circulation would be repeated. Electricity-generating wind machines driving RO desalination plants have a good potential in many areas of the world. Preliminary data indicate an abundance of sites for individual wind machines

and wind farms for desalination throughout the world's northern temperate zone, especially along Africa's northwest coast, the Caribbean and Mediterranean regions where the only source of electricity is expensive diesel generators.

Potential sites for installing Wind-RO plants require a mean annual velocity not less than 6 m $s^{-1}$ for the current level of wind turbine technology (Rados 1996). Many islands in the Mediterranean and arid coastal areas can meet this criterion.

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**Bibliography and Suggestions for further study**

A. Wokaun. Beyond Kyoto: The risks and how to cope. UN Framework Convention on Climate Change. Bonn, Germany, 16-25 June 2004

Al Ansari M S (1992) State of Bahrain - Country Report on Water and Agriculture in Bahrain (Proceedings, Vol. II, Symposium on Greening of the GCC Countries, Tokyo, Japan, Oct. 26-28, 1992).

Al-Karaghouli A.A., Alnaser W.E. (2004), Experimental comparative study of the performance of single and double basin solar-stills. Appl Energy **77**(**3**), pp. 317-25.

Al-Karaghouli A.A., Alnaser W.E. (2004), *Performances of single and double basin solar-stills.* Solar Energy **78**(**3**), pp. 347-54.

Al-Shammiri M., Safar M(1999). Multi-effect distillation plants: state of the art. Desalination , 126:45-59.

Bader T and Mounir M (1992) Greenification of Hyper-Arid Area (Proceedings Vol. II, Symposium on the Greening of the GCC Countries, Tokyo, Japan, Oct. 26-28, 1992).

Bazuhair A S and Hussein M T (1990) Springs in Saudi Arabia. *Journal of King Abdulaziz University, Earth Sciences*, 3, 251-258.

Chadjivassiliadis J, Samarakou M, Nielsen M, Contaxis G, Kabouris J, Zouros N, Manos G, Kenellopoulos D and Vitalis N (1996) Development of water desalination plant through RO powered by wind energy in the Island of Patmos (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Chafik, E., 2003. A new type of seawater desalination plants using solar energy. Desalination

Corrado Sommariva ,(2010),COURSES IN DESALINATION, Thermal Desalination

Delyannis E. (2003), *Historic background of desalination and renewable energies.* Solar Energy **75**(**5**), Elsevier pp. 357-66.

Florides G., Kalogirou S. (2004), *Ground heat exchangers – a review.* Proceedings of third international conference on heat power cycles, Larnaca, Cyprus, on CD-ROM.

García-Rodríguez L. (2003), "Renewable energy applications in desalination: state of the art", Solar Energy 75, 381-393.

García-Rodríguez, L., 2002, Seawater desalination driven by renewable energies: a review. Desalination 143: 103-113

Gregorzewski, A. and Genthner, K., High efficiency seawater distillation with heat recovery by absorption heat pumps. Proceedings of the IDA World Congress on Desalination and Water Reuse, pp. 97-113, Abu Dhabi, November 18-24, 1995.

Kalogirou S (1996) Solar energy for sea-water desalination selection of the best system based on technoeconomic factors (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Kalogirou S. (2003), *The potential of solar industrial process heat applications.* Appl Energy, **76**(**4**), pp. 337-61.Lysen E. (2003), *An outlook for the 21st century.* Renew Energy World, **6**(**1**), pp. 43-53.

Kalogirou S. (2004), *Solar energy collectors and applications.* Prog Energy Combust Sci, **30**(**3**), pp. 231-95

Karameldin, A. Lotfy and S. Mekhemar (2003), *The Red Sea area wind-driven mechanical vapor compression desalination system*, Desalination **153**, Elsevier pp. 47-53.

Kudish A.I., Evseev E.G., Walter G., Priebe T. (2003),*Simulation study on a solar desalination system utilizing an evaporator/condenser chamber*. Energy Convers Manage **44**(**10**), Elsevier, pp. 1653-70.

M.A. Darwish , Iain McGregor, (2005), *Five days' Intensive Course on - Thermal Desalination Processes Fundamentals and Practice*, MEDRC & Water Research Center Sultan Qaboos University, Oman

Margat J, Nogaret E, Mayer D and Neirac F (1996) Potential for water desalination with renewable energies in the Southern Mediterranean countries (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Mentzelopoulos P and Drosinou A (1996) Small wind desalination market potential in the Aegean Sea Greek islands (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Millow B. and Zarza E., Advanced MED solar desalination plants. Configurations, costs, future – Seven years of experience at the Plataforma Solar de Almería (Spain), Desalination 108, pp. 51-58, 1996.

Müller-Holst, H., 2007. Solar Thermal Desalination using the Multiple Effec Humidification (MEH) method, Book Chapter, Solar Desalination for the 21st Century, 215–225.

Parekh S., Farid M.M., Selman R.R., Al-Hallaj S. (2003), Solar desalination with humidification-dehumidification technique – a comprehensive technical review. Desalination **160**, Elsevier pp. 167-86.

Rados K G, Assimacopoulos D and Zervos A (1996) Application Possibilities of Wind Reverse Osmosis Desalination Plants in Greek Islands (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Sakellariou N, Gulyutlu I and Ramirez L (1996) Integration of renewable energy sources in Mediterranean rural areas (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Sardi L (1996) RO desalinators powered by PV Systems for small/medium Italian islands (Proceedings, Mediterranean Conference on Renewable Energy Sources for Water Production, June 10-12, 1996, Santorini, Greece).

Sayig A.A.M. (2004), *The reality of renewable energy*. Renewable Energy, pp. 10-15.

Soteris A. Kalogirou (2005), *Seawater desalination using renewable energy sources*, Progress in Energy and Combustion Science **31**, Elsevier, pp. 242-281.

Thomson M., Infield D. (2003), A photovoltaic-powered seawater reverse-osmosis system without batteries. Desalination **153**(1-3), pp. 1-8

Tiwari G.N., Singh H.N., Tripathi R. (2003), *Present status of solar distillation.* Solar Energy 75(5), Elsevier, pp. 367-73.

Tzen E., Morris R. (2003), *Renewable energy sources for desalination.* Solar Energy **75**(**5**), Elsevier, pp. 375-9.

United Nations, Water for People, Water for Life – UN World Water Development Report, UNESCO Publishing, Paris, 2003.

Wangnick K (1992) 1992 IDA Worldwide Desalination Inventory, Rept. 12, April 1992.

Wiseman, R., Desalination business "stabilised on a high level" – IDA report, Desalination & Water Reuse 14(2), pp. 14-17, 2004.

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