ELSEVIER

Desalination 186 (2005) 97–109

DESALINATION

www.elsevier.com/locate/desal

Wave-powered desalination: resource assessment and review of technology

P.A. Davies

School of Engineering, University of Warwick, Coventry CV4 7AL, UK
Tel. +44 (24) 7652 4742; Fax +44 (24) 7641 8922; email: philip.davies@warwick.ac.uk

Received 10 February 2005; accepted 9 March 2005

Abstract

The growing scarcity of freshwater is driving the implementation of desalination on an increasingly large scale. However, the energy required to run desalination plants remains a drawback. The idea of using renewable energy sources is fundamentally attractive and many studies have been done in this area, mostly relating to solar or wind energy. In contrast, this study focuses on the potential to link ocean-wave energy to desalination. The extent of the resource is assessed, with an emphasis on the scenario of wave energy being massively exploited to supply irrigation in arid regions. Technologies of wave-powered desalination are reviewed and it is concluded that relatively little work has been done in this area. Along arid, sunny coastlines, an efficient wave-powered desalination plant could provide water to irrigate a strip of land 0.8 km wide if the waves are 1 m high, increasing to 5 km with waves 2 m high. Wave energy availabilities are compared to water shortages for a number of arid nations for which statistics are available. It is concluded that the maximum potential to correct these shortages varies from 16% for Morocco to 100% for Somalia and many islands. However, wave energy is mainly out-of-phase with evapotranspiration demand leading to capacity ratios of 3–9, representing the ratios of land areas that could be irrigated with and without seasonal storage. In the absence of storage, a device intended for widespread application should be optimised for summer wave heights of about 1 m. If storage is available, it should be optimised for winter wave heights of 2–2.5 m.

Keywords: Ocean-wave energy; Renewable energy; Irrigation

1. Introduction

The last decade has seen very significant advances in desalination technology. The cost of desalinated water has halved from about €1/m^3 to €0.5/m^3 and specific energy usage has also halved from about 8 to 4 kWh/m^3. Desalination currently provides about 10 km^3/y of freshwater [1] a figure that is growing rapidly with several new projects underway or planned. For example, Spain has recently cancelled its plans to divert the Ebro river, in favour of installing 0.6 km^3/y of desalination capacity along its eastern coastline [2]. Around

0011-9164/06/$– See front matter
doi:10.1016/j.desal.2005.03.093

the Jordan basin, there are plans for some very large schemes including those taking advantage of hydropower connecting the Dead Sea to the Red Sea or to the Mediterranean. In the case of these Dead Sea hydro projects, capacities as large as 1 km^3/y have been discussed, enough to satisfy one third of the total demand of Israel, Palestine and Jordan [3].

Impressive though these figures are, they still only represent a very small fraction of worldwide water requirements. It is difficult to calculate accurately the total amount of freshwater used by humans, but an estimate of essential water requirements (as presented by the UN) is based on the observation that each person requires a minimum amount of water, most of which is consumed indirectly in producing food. Availabilities below about 1700 m^3/capita/y are generally considered to indicate water scarcity [4]. Multiplied by a global population of 6 billion, this translates to an overall requirement exceeding 10,000 km^3, suggesting that desalination currently only supplies of the order of 0.1% of overall freshwater usage. We should not forget that in certain regions the fraction is much higher, making desalination indispensable for the populations concerned. Even in these cases, however, it is mainly restricted to the supply of municipal water. Desalination is rarely used to supply agricultural water, which accounts for some 70% of overall freshwater withdrawals worldwide.

The rapid expansion of population in arid regions means that desalination projects are likely to be proposed on an increasingly grand scale. It is interesting to ask whether this technology will one day represent a large segment of the world water economy, supplying water for all types of end use including irrigation, or whether it will remain a localised solution for the supply of water for mainly non-agricultural purposes.

A fundamental factor affecting the uptake of desalination technology is its energy consumption. For example, suppose that current desalination capacity were to increase 10-fold, reaching about 100 km^3/y. This would still only represent a small fraction of worldwide water use. Nonetheless, even with the most energy-efficiency desalination technology available today (reverse osmosis), an electrical or mechanical power input of around 30 GW would be needed, resulting in a consumption approaching 100 Mtoe/y (megatonnes of oil equivalent) of primary energy reserve. This is a very large amount, given that the world's total primary energy supply is of the order of 10,000 Mtoe/y [5]. Indeed, increased energy prices could result in the reverse scenario, in which existing desalination plants become non-viable and are decommissioned. Table 1 summarises these broad scenarios relating to the future of desalination technology.

Given the simultaneous scarcity of water and of conventional energy resources, there is considerable interest in using renewable energy to power desalination. Although numerous technical concepts have been proposed in this area, most of the experiments to date have been either with solar distillation, or with reverse osmosis powered by electricity from wind or solar sources, as reviewed elsewhere [6,7]. In contrast, this study concentrates on a relatively immature form of renewable energy technology to drive desalination, based on the exploitation of wind-generated ocean waves. Research in the area of wave energy conversion has generally been sporadic. Recently, however, there have been some significant developments in devices for electricity generation [8,9] and these could well spin off benefits to wave-powered desalination.

Waves will generally be available where seawater is desalinated. But the harnessing of wave energy is, as with other forms of renewable energy, expensive in terms of capital plant and the effort needed to develop the technology. It may well require the intervention of governments or international bodies. To enable appropriate policy decisions to be made, it is therefore important to have general information about the nature and potential of the resource in relation to the demand for water.