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Energy efficiency and desalination in the Canary Islands

Julieta Schallenberg-Rodríguez *, José Miguel Veza, Ana Blanco-Marigorta

Department of Process Engineering, Universidad de Las Palmas de Gran Canaria, Las Palmas, Spain

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ABSTRACT

Faced with the challenge of meeting high water and energy demands with no conventional energy resources and a lack of potable water, the Canary Islands have been using desalination plants for nearly 50 years. The first desalination plant in Europe was installed in 1964 in Lanzarote. Today, desalination capacity in the islands stands at over 600,000 m^3/d (covering 55% of water demand). Powering the plants consumes nearly 12% of total electricity demand at a cost of over 200 million Euros yearly. Though desalination continues to be the main way of meeting water demand, its major drawback is the strong dependence on conventional energy. The islands have always looked for reducing the energy consumption in desalination processes. This paper describes the relationship between energy and desalinated water and its evolution in the islands over the past 50 years, examining the trends in energy efficiency and the technological changes in the desalination systems, which also explains the predominance of reverse osmosis plants in the current scenario. A series of case studies describe various challenging desalination projects (including operating data) that have been installed in the Canary Islands.

Contents

Abbreviations: GDP, Gross Domestic Product; RES, Renewable Energy Sources; PV, photovoltaic; MSF, multi-stage flash; ME, multi-effect; VC, vapour compression; RO, reverse osmosis; ED, electrodialysis; BAT, best available technology; ER, economy ratio; ERD, energy recovery device; ERI, energy recovery incorporated; PES, pressure exchange system; hm^3, cubic hectometer (1 million m^3)

* Corresponding author.
E-mail address: jschallenberg@dip.ulpgc.es (J. Schallenberg-Rodríguez).

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1. Energy-water in the Canary Islands

The Canary Islands is a Spanish Archipelago located in the subtropical area. The Islands have no electrical grid connection with mainland and are highly dependent on external energy sources. At the same time, fresh water production is scarce in the islands and it is not enough to serve its population.

1.1. Water situation in the Canary Islands

The Canary Archipelago is a part of Spanish national territory and is comprised of seven main islands: Lanzarote, Fuerteventura, Gran Canaria, Tenerife, La Palma, La Gomera and El Hierro. The Archipelago is located off the Western Sahara (parallel 28) in the subtropical area.

The characteristics shown in Table 1, particularly the strong impact of the tourist industry and its associated fresh water needs, explains the huge water demand.

The seven Canary Islands are known as the "Fortunate Islands" partly because of their year round temperate climate, but nowadays they are far from fortunate in terms of water resources. On average, there are less than 300 m^3 of water available (including natural water resources and desalinated water) per inhabitant and year, whereas continental Spain has 1113 m^3 per inhabitant and year, a value which is in turn low in comparison with most other European countries. More importantly, the vast majority of these water resources are underground and very difficult to extract [1].

To reach these groundwater resources, the Canary people historically relied on ingenuity and hard work. In the 19th century, landowners and farmers started digging wells and horizontal galleries (similar to gold or diamond mines) to mine water. They initially dug near the sea but, as the more accessible waters were extracted, they were forced to go further and deeper to meet the rapidly increasing demand. Consequently, aquifers dwindled: whereas 100 m long galleries were sufficient in 1900 to find water, the average length in 2000 was between 3.5 and 4.5 km and some galleries were up to 6 km long [1]. Things had come to such a pass by this time that, in islands like Gran Canaria, the groundwater level was falling 20 m yearly, forcing the digging of wells of up to 600 m [2]. The public sector started to invest massively in desalination, as they did not believe that groundwater resources, even if managed in a sustainable way, would be sufficient to meet the increasing demand [1].

Today, water desalination in the Canary Islands is more than merely a technique for water treatment. For the last 50 years, it has been a means of continued existence for many communities.

Table 1
The Canary Islands: some data of interest.

No. of islands	7
Population	2.2 Million
Tourists per year	12 Million
Surface	7447 km^2
Coastline	1531 km
Average rainfall per year	300 mm
Water consumption	470 hm^3/y

No electricity grid connection with mainland Each island generates its own electricity No conventional energy resources.

Indeed, the survival of the islanders and the maintenance of their living standards cannot be conceived without desalination. Desalination is a vital cog in the human and financial activities of the Archipelago. It is difficult to imagine how life in the Canary Islands would have been without the extensive application of the different desalination techniques. In the past, islands with almost no ground or underground water resources (like Lanzarote and Fuerteventura) were supplied by water tank vessels from the Navy. The remaining islands used mainly their underground waters. It can justifiably be argued that the rise in population, the growth of the tourist sector and the development of agriculture would have been impossible without desalination technologies [3]. For example, the natural water resources of Fuerteventura (mainly brackish underground water), an island with a population of 110,000 inhabitants, are barely sufficient to meet the demands of a population of 10,000 [2]; less than 10% of its current population. In the case of Lanzarote, the island that most strongly depends on desalination, 99% of consumed water comes from desalination plants.

Currently, desalination capacity in the Canary Islands is about 600,000 m^3/d, representing around 1% of total worldwide desalination capacity [4]. In 2010, total water consumption in the islands was 470 hm^3 , 55% of which (260 hm^3) came from desalination [5]. This percentage of 55% desalinated water has remained more or less constant for the last decade.

1.2. Energy situation in the Canary Islands

The Archipelago is highly dependent on external energy sources. Nearly 98% of primary energy consumption is based on imported oil brought to the islands by ships. In 2012, 93% of electricity production came for these sources [6]. Though the Canary Islands have no conventional energy sources, there is a lot of potential for the exploitation of renewables, mainly wind and solar.

As a result of the geographical distance between the Canary Islands and the European mainland there is no electrical grid connection between the former and the latter. The only submarine cable is of limited power and lies between the islands of Lanzarote and Fuerteventura. The seven islands are powered using six autonomous weak electrical grids. Given the lack of conventional energy resources, it can be stated that there is total external energy dependency [7].

Total installed electrical power in the Canary Islands at the end of 2012 was 3163 MW, 11% of which was from renewable energies, though in production terms this value falls to just 7% [6]. The RES (Renewable Energy Sources) used in the Canary Islands are mainly wind and solar photovoltaic, 145 MW and 162 MW respectively in 2012 [6]. Most of the PV power was installed on land (PV farms) and only a small percentage on rooftops.

One of the priorities of the islands is to increase the level of energy self-sufficiency. This can only be done by deploying RES to reduce conventional energy dependency. RES deployment can also actively contribute to foster employment and to encourage regional development [8]. For the year 2015, the Canary Islands Energy Plan has determined that 30% of the electricity generation should be supplied by RES, mainly wind and solar. Wind energy should reach 1025 MW, photovoltaic 160 MW and wave energy 50 MW [9].

Since water production in the Canary Islands is highly dependent on the shipping of imported oil, the reduction of conventional