POTENTIAL USE OF PV FOR WATER DESALINATION

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ABSTRACT: In the countries of the Eastern Mediterranean Basin agriculture consumes more than 80% of the total water resources. Concurrently the water demand of tourism sites is developing rapidly. The increasing water competition between these two vital sectors endangers the economic prosperity of the entire region. While agriculture provides the living basis for most of the rural population, tourism carries hopes for increasing wealth and employment in the region. Sustainable water management schemes are urgently needed, since the water conflicts lead to severe overuse of the natural water resources. Such a sustainable water management requires the exploitation of the large marginal water sources of the region, including large-scale implementations of water purification and desalination technologies which require huge energy amounts. Renewable energies could provide a good part of this energy. The implementation of renewable energies based water supply schemes needs a comprehensive approach by all stakeholders in the private and public sector tackling simultaneously energy and water related issues. In an effort to achieve this, the MedWater network has set itself the target to elaborate a water management plan for the region of Middle East and Northern Africa.
Keywords: stand-alone PV systems, off-grid, water desalination

1 INTRODUCTION

1.1 Objective

The countries of the Middle East and Northern Africa (MENA) provide a suitable case study for the world-wide water crises. In this region extreme arid climatic conditions meet a quickly growing population and expanding economic development.

Two central sectors for analysing the water situation are agriculture and tourism. Agriculture being the major economic and social basis for the rural population consumes 87 % of the region’s scarce water resources for irrigation purposes. In parallel to that additional water contingents are required for the quickly developing tourism, which is seen as an important tool for generating wealth and employment in the region. The water competition between these two sectors damages the social and economic basis of the region. It forces farmers to abandon agricultural land and raises the investment costs for new tourist projects.

“MedWater Policy” is a project co-financed by the European Commission in the frame of the INCO-MED programme; the project consortium is constituted by a network of water institutes from MENA and Europe, with the task to analyse the concrete water conflicts between the vital economic sectors of agriculture and tourism and to formulate a water policy initiative for intersectorial water management in the selected regions. The major objective is to elaborate working tools that will support decision makers in creating water management plans themselves.

1.2 Methodology

The network “MedWater” analysed the water situation in five target regions, which have important agricultural activities and a quickly expanding tourism sector. The selected target regions were:

- Cap Bon Region in Tunisia
- Dead Sea Region in Jordan
- Fethiye Region in Turkey
- Jericho District in the West Bank (Palestine)
- Naxos Island in Greece

The research monitored the most important water supply sources and water infrastructure as well as the water related energy demand in the target regions. The major focus here was on the use of renewable energies to cover the energy demand for water supply options. In a second step the water demand of the individual tourism and agricultural consumers was defined by quantity and quality at different times of the year.

The research was particularly focused on the socio-economic framework conditions. The water supply expenses and water prices were documented. Relevant actors in the private and public sector were identified.

Further, technologies for enhancing the efficiency of water use, for allowing larger share of water reuse and for exploiting marginal water sources were surveyed.

2 WATER SUPPLY IN THE TARGET REGION

All target regions report a strong overuse of the limited natural resources particularly in the summer months. This leads to a dramatic decline of the natural water resources, in water quantity but especially in water quality. The non-renewable water reservoirs are diminishing rapidly; the remaining resources are threatened by seawater intrusion and by pollution from contaminated effluents. The dramatic water supply situation in the target regions are high-lighted by the fact that in the target regions of Greece, Tunisia and Palestine less than 20% of the remaining water resources have drinking water quality · see Figure 1, where water quality is classified from C1 (freshwater) down to C4 (saline water).

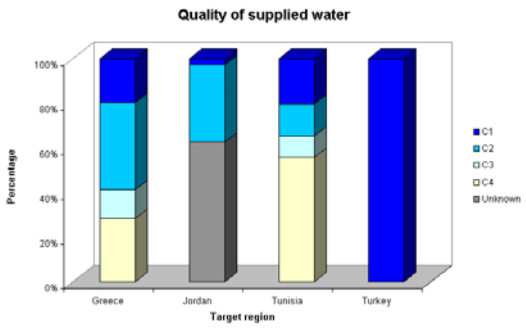

Figure 1: Water supply in the target regions

3 THE OPTION OF NON CONVENTIONAL WATER SOURCES

The entire MENA region has abundant marginal water resources, particularly sea and brackish water. The exploitation of non conventional water sources with desalination technologies is a major tool of any sustainable water planning. The global implementation capacity of desalination plants is expected to double to 40-50 million m^3/day within the next 15 years [1].

To enable decision makers to design and install the optimal desalination plant, „MedWater‰elaborates a survey on all existing sea and brackish water desalination technologies and formulates selection criteria. This paper reports on the results of this survey on desalination technologies under the aspect of using renewable energies.

4 SEA AND BRACKISH WATER DESALINATION TECHNOLOGIES

4.1 Survey on the existing technologies

There are two main types of technologies used in commercial desalination, thermal processes and membrane processes. Thermal processes involve distillation, where water is evaporated from a saline solution and condensed as fresh water. The most commonly used thermal processes are Multi-Stage Flash Distillation (MSF), Multi-Effect Distillation (MED), Vapour Compression (VC) and Solar Distillation. Membrane processes make use of semi-permeable membranes to selectively separate water from the saline solution. Highly developed membrane processes are Reverse Osmosis (RO), both for seawater (SWRO) as for brackish water (BWRO) and Electrodialysis (ED).

4.2 Selection criteria

The choice of a particular desalination process is based on a variety of factors including the salinity of the raw water to be treated, the fresh water requirements, the energy source at hand and the size of the plant required.

Thermal distillation processes have an advantage if the feed water concentration exceeds 55,000 mg/l of total dissolved solids content. Membrane processes are well established in the desalination of brackish waters (< 20,000 mg/l), as well as seawater (> 20,000 mg/l) in the case of reverse osmosis.

The thermal distillation processes, MSF and MED are feasible for larger evaporators, usually greater than 5,000 m^3/day, while RO due to its modular structure can be installed in all capacity ranges.

4.3 Covering the plantsÊenergy demand

Desalination requires large energy amounts which are supplied either by heat or by electric energy. Steam is typically used in the MSF and MED distillation processes whereas electricity is used in all other processes. In all cases, complementary energy usually in the form of electricity is needed for the auxiliary services such as pumps, dosifiers, vacuum ejectors, etc. The energy consumption of the process itself accounts for about 85 - 90 % of the total energy

The estimated energy consumption today of the different processes are summarised in Table I. The specific energy consumption can be considered roughly independent of plant capacities. The share of thermal energy used in the MSF and MED processes has been recalculated and expressed as an electric energy equivalent to allow for a better comparison with other processes.

For new communities without electrical power and fresh water sources, but with salt-water resources, co-generation of electrical power and desalinated water may be an appropriate solution. For example in the Persian-Arabian Gulf area most of the large plants are dual-purpose. Particularly in isolated areas without grid connection and with relatively low water needs, desalination units can be based on renewable energy sources.

Table I: Estimated Energy Consumption by Desalination Process [1]

Process	Exergy of steam (kWh_{el}/m^3)	Electric energy equivalent consumption (kWh_{el}/m^3)
Seawater desalination		
MSF	7.5 · 11.0	10 · 14.5
MED	4 - 7	6 · 9
VC		7 · 15
SWRO		4 · 8
MED/SWRO		3.2 · 3.6
Brackish water desalination		
BWRO		0.5 · 2.5
ED		0.7 · 2.5

5 RENEWABLE ENERGY SOURCES FOR THE ENERGY SUPPLY OF DESALINATION UNITS

Taking into account the environmental implications of the combustion of coal, oil and gas for power production for desalination, renewable energy (RE) is a clean, non-polluting alternative. RE is independent of the grid and can reach remote areas. The introduction of RE in the world market is prompted also by the necessity to gain independence from importation of fuel.

The three RE systems (RES) most suitable for combination with desalination systems are: Wind energy converters (WEC), photovoltaic energy (PV) and Solar Thermal.

Concerning the utilisation of renewables for the energy supply of water desalination units, RO is the most versatile desalination technology and can deal well with fluctuations in the energy demand having also the smallest specific consumption. More than 60% of the installed RES-Desalination systems use RO.

The type of RES to be used with a particular desalination process depends on RES availability, plant capacity and the specific energy consumption of the desalination process. However, the main challenge of RES-Desalination is in interfacing the two technologies. RE sources are by their nature characterised by intermittent and variable intensity. Desalination processes are designed for continuous steady state operation.

Two approaches to solving this problem have been identified. These are modulating the process to cope with variable energy input, or by including an energy buffer to even out the energy supply. To date battery storage has always been used in order to maintain a stable power source. However, storage investment costs are high and battery storage is therefore restricted to small capacities. For longer storage periods, consideration may also be given to storing energy as drinking water in a tank, rather than as electricity in a large battery.

PV-RO and WEC-RO are the two most attractive system combinations which have been satisfactorily realised in several instances.

PV-RO is a promising solution especially for small-scale desalination and for stand alone operation and can be economical in many cases.

Figure 2 below shows a block diagram of a PV-RO system typically composed of the PV cell array, a PV generator to convert the sun light into electricity (DC current), DC/AC inverters to convert the DC-current into AC current, a storage battery block and the RO system with a fresh water storage tank.

Some examples of installed PV-RO plants include:

a) The DESSOL project [3]: RO desalination plant (3m^3/d) driven by an isolated photovoltaic array (peak capacity 4.8kW). The system has been designed to produce a minimum of 0.8m^3/d under normal conditions of solar radiation in subtropical areas.

The desalination plant has been specifically designed to work isolated from the electrical grid and the system is fully automated.

b) In Lampedusa, Italy, a PV-SWRO system was commissioned in 1990 [2]. The plant consists of two RO units of a desalination capacity of 120m^3/d and a PV of 100kW with battery storage.

The PV-RO plant has had a successful operation of more than five years, proving that with an improved sizing and without any incentive, it is feasible to produce and sell water at prices definitely lower than from other water sources, like water transportation.

c) The PV-RO demonstration plant by CIEA-ITC in Gran Canaria is a system for a drinking water production of 0.8 · 3 m^3/d and a PV capacity of 4.8kWp [4].

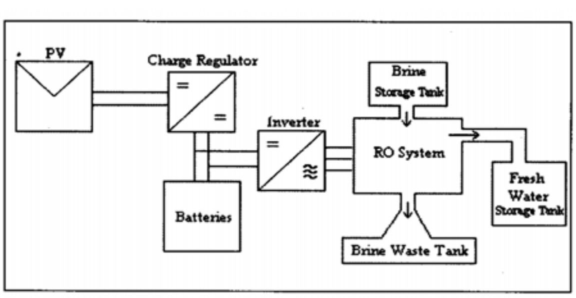

Figure 2: Block diagram of RO desalination system powered by PVs [5]

6 ECONOMIC FEASIBILITY OF RES BASED DESALINATION UNITS

At first appearance, a major restriction on the widespread use of desalination is the high cost. On closer examination, however, the most critical factor for the evolution of desalination in general is the pricing policy of water. Water management is generally in the hands of governments and municipalities as a consequence of which water is often heavily subsidised. In all target regions of the „MedWater study‰water scarcity has driven up expenses for fresh water supply. In certain cases even, the exploitation of non-conventional water sources in decentralised units will soon become more cost effective than additional exploitation of natural resources. Therefore the public subsidies should be channelled into new decentralised desalination units rather than into additional storage and conveyor infrastructure. Table II shows a comparison of the expenses for exploiting different water sources in one of the target regions of the „MedWater study‰

Capital cost of transporting water is high. The longer the distance, the higher the cost. Further, to the capital cost of transportation, a storage system must be added for the long-term storage of water and special care on hygienic conditions must be taken. In addition water transportation by piping has no flexibility for increasing water flow rate, if larger amounts of water supply will be needed in the nearby future. In contrast, desalted water is an industrial product that depends on fixed charges and operation cost, but has greater flexibility in increasing capacity.

In most Aegean Islands for example, which face severe water shortage problems, the only available, alternative to cover water demand is water transportation by ships. The cost of this option ranges from 2.9 · 3.5 Ï/m^3. These are subsidised resulting in water prices in the range of 1.5 · 1.7 Ï/m^3.

Table II: Water supply expenses for the Cap Bon region (Tunisia)

Water source	Supply expenses in Cap Bon [Euro/m^3]
Surface water	0,54
Ground water	0,097
Treated waste water	0,1
Desalinated water	0,61

Comparing the RES-desalination water cost with the non-subsidised cost of water transportation, most of the RES-desalination alternatives become competitive on economic terms.

Market prices of renewable energies are generally high in comparison to the large conventional systems, and energy prices are a bargain. Wind energy averages

0.06 Ï/kWh for grid-connected electricity and geothermal 0.08 Ï/kWh. Solar power is more expensive at, 0.2 · 0.5 Ï/kWh. Nevertheless RES is getting more and more economically convenient over the time and in the near future will be competitive to conventional energy sources at least for some places. Figure 3 below summarises the cost of renewable energy production in (Ï/kWh) versus energy consumption of desalination (in kWh/m^3) for different RES-Desalination systems showing also the thereby resulting water production costs (in Ï/m^3).

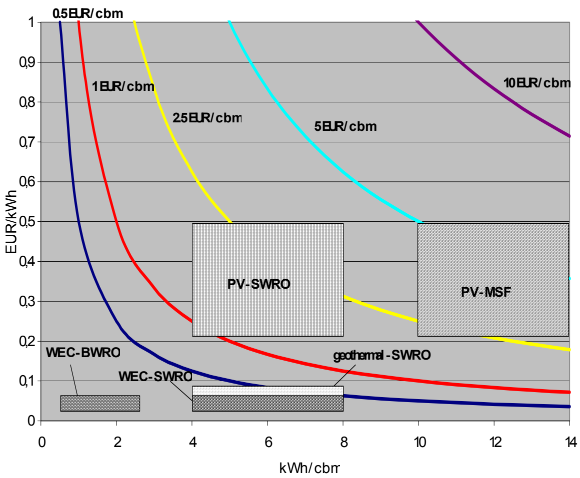

Figure 3: Summary of water production costs for different RES-Desalination systems.

7 CONCLUSIONS

The looming water crises in many arid regions of the world and particularly in MENA can be significantly eased by the exploitation of the abundant brackish and saline water resources. Renewable energies provide the optimal option to generate the energy demand for small decentralised desalination units in remote areas.

The entire Mediterranean region has very rich solar radiation. The annual irradiation ranges between 4 · 6 kWh/m^2 per day in average.

Intense research has shown that the PV-RO application is the most suitable solution for decentralised water desalination in the rural regions of MENA. Several pilot plants or demonstration systems are under operation today. Commercially sized plants will follow soon. While technology is close to maturity, there is still potential for improvement. Research work has to focus on the successful interface of the various components and improvements in energy consumption [2]. Energy storage is a major issue and is almost always required for these types of systems.

The large scale implementation of these systems is still hindered by non-technical barriers. The high investment costs of RES based desalination plants have to be covered by a change in the regionÊs subsidy schemes for water supply. Appropriate investment incentives would expand markets where RES powered desalination provides a competitive option [2]. Moreover, the awareness and expertise for the installation and operation of these plants has to be raised by intense PR and training activities aimed at bringing EuropeÊs expanding PV industries into a good starting position on a very important future PV market.

Sustainable water schemes will only be achieved on the basis of comprehensive water management plans addressing water supply and demand side of a certain region and combining efficiency measures with the enhanced exploitation of non conventional resources. The project „MedWater Policy‰ is elaborating an integrated model for local and regional water management that will turn to an important tool for creating a sustainable water supply in the entire region of MENA.

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