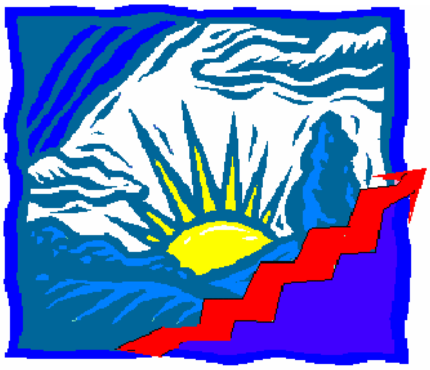
Desalination Units powered by Renewable Energy Systems

Opportunities and Challenges



Proceedings of the International Seminar held in Hammamet, Tunisia 26 September 2005

Organised jointly by:

WIP

INRGREF

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Introduction

This document presents the abstracts of the presentations that have been given in the international conference held in Hammamet, Tunisia on September 26, 2005. The seminar has been organised with financial support from the European Commission as part of the activities of the ADU-RES project. The proceedings are available also in French; you can download them from the project website www.adu-res.org. The presentations themselves are also available for downloading in the project website. In the following table you can see the programme of the seminar. The abstracts in these proceedings are in the same sequence as presented in the seminar.

09:00	**Introduction**	Welcome	Mohamed Nejib Rejeb, INRGREF
09:20		Project ADU-RES	Michael Papapetrou, WIP
09:40	**Water supply situation in Tunisia**	Water Supply situation in the rural areas of Tunisia	Taoufic Brahem, DGGR
10:00		On-Site situation in Central Tunisia	Abedeljellil Afli, CRDA Kairawan
10:20		Questions and discussion	
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11:00	**Market available technologies**	Solar thermal desalination for rural applications	Stefan Thiesen, ZONNEWATER
11:20		The Solco PV-RO system	Ali Kanzari, SES
11:40		The ENERCON Wind - RO System	Frank Hensel, ENERCON
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12:30		*Lunch break*	
13:30	**Pilot Installations**	Description and performance of the pilot plant in Sfax, Tunisia	Aref Maalej, ENIS Sfax
13:50		Using geothermal and solar energy for autonomous water desalination	Karim Bourouni, ENIT Thameur Chaibi, INRGREF
14:10		Spanish Cooperation project in Southern Tunisia: PV-RO desalination unit in the village of Ksar Ghilène	Fernando Castellano, ITC
14:30		Successful plants worldwide	Eftihia Tzen, CRES
14:50		Questions and discussion	
15:00		*Coffee break*	
15:30	**Research and Development**	Solar desalination for water supply in Southern Tunisia	Hammami Naceur, ANME
15:50		Improvements in energy efficiency	MurrayThomson, Loughborough University
16:10		Development of an autonomous solar rankine cycle system for RO desalination	Dimitris Manolakos, AUA
16:30		The ADIRA project	Ulrike Seibert, Fraunhofer ISE
16:50		Socio-technical Factors Related to PV Powered Desalination in Remote Australian Indigenous Communities	Melanie Werner, University of Wollongong
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17:20	**Closing session**	Conclusions and next steps	Panel Discussion
18:00		End	

Co-ordination Action for Autonomous Desalination Units based on Renewable Energy Systems – ADU-RES

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INTRODUCTION

Many arid regions in Mediterranean countries have a great potential to cover part of their pressing water needs by renewable energy based desalination. However, the wide-scale implementation of this technology faces numerous technological, economic and policy barriers.

These barriers are studied and analysed by the ADU-RES co-ordination action. The consortium involves partners from 7 Mediterranean Partner Countries (MPC) as well as institutes and SMEs from 5 EU countries specialised in desalination and renewable energy systems. Here, the main objectives, activities and expected results of ADU-RES are summarised.

MAIN OBJECTIVES AND ACTIVITIES

Further Development of R&D

In recent years, the research community worked intensively on coupling desalination systems with renewable energy technologies in robust and cost effective desalination units. While both components of these set-ups are mature technologies in themselves, few commercial products in combination of those are available. ADU-RES strives to develop further integrated plant designs for mature and cost efficient renewable energy based desalination. The action will bring together the existing R&D work and the results of own technical, economic, social and policy research to design and present specific guidelines for ADU-RES plant construction.

Cost analysis

The high capital costs involved make investors and decision makers reluctant to accept renewable energy powered desalination. However, the comparison to alternative solutions for fresh water supply should take into account the life-cycle costs, including external costs such as the depletion of non-renewable water resources, or the air pollution caused by diesel units powering large-scale desalination plants. ADU-RES will analyse these factors in an effort to provide transparent data of the real costs as well as suggestions for lowering the capital cost of renewable energy based desalination.

Formulation of policy initiatives

The implementation of renewable energy based desalination is partly hindered by unfavourable socio-economic framework conditions. For example, in many regions conventional and environmentally harmful water supply is heavily subsidised while no public support can be found for desalination units. As a first step, representative Mediterranean regions with high demand for decentralised desalination units will be selected and their socio-economic and political framework conditions will be analysed. Based on this analysis, a political strategy to boost decentralised renewable energy based desalination units will be developed. At the same time, the relevant EU legislation will be scrutinised, resulting in clear recommendations for improving the framework conditions in favour of enhanced implementation of desalination units.

Political dialogue and dissemination

The Co-ordination Action intends to reach policy makers and think tanks, providing them with an invaluable source of expert analysis and recommendations for the promotion of desalination units. At the same time widespread circulation of reports, methodology and guidelines amongst the research and industry communities will initiate and maintain a fruitful interdisciplinary dialogue on the issue. These dissemination actions in combination with the technical and policy work mentioned above will lead to the creation of international consortia for the exploitation of design concepts and plans developed within ADU-RES.

EXPECTED OUTCOMES

1) Knowledge on relevant R&D actions is shattered between institutes and companies in EU and the Mediterranean.

→ ADU-RES will compile relevant data in comprehensive documents and Internet portals.

2) Basic technical requirements, like drastic cost reduction and improved reliability, have to be fulfilled before the commercial implementation of the technique is possible.

→ ADU –RES will design guidelines with recommendations that will contribute in the progress towards those objectives.

3) Issues related with the environmental and social impacts of any activity are usually neglected causing harm to the environment and opposition of local populations

→ ADU-RES will focus its research on any potential environmental, gender, health and social aspects of decentralised desalination.

4) The awareness for the technical options and the socio-economic barriers of RES based desalination units is rather limited between stakeholders in utilities, industry and policy

→ ADU-RES will enhance the awareness for the desalination based on renewable energy sources, for example with the organisation of the following events:

- *A seminar that will take place in Tunisia in April 2005 and will be dedicated to the presentation of ADU-RES related research results*
- *An event in Jordan in March 2006 that will be dedicated to political decision makers*

5) Practical implementation is hindered by the lack of adequate financial resources

→ ADU-RES will research and define appropriate financial options and will raise awareness among investors and financial institutions

6) There are not many commercially operated plants that would raise the trust in the maturity and efficiency of decentralised desalination units.

→ ADU-RES strives to stimulate the in detail planning of commercial size desalination units based on renewable energies in the Mediterranean.

ACKNOWLEDGEMENT

ADU-RES is supported by the European Commission under contract number INCO-CT-2004-509093. However, the views expressed herein are those of the authors and can therefore in no way be taken to reflect the official opinion of the EC.

ADU-RES started on the 1st of April 2004 and will be completed by October 2006. All relevant stakeholders are invited to take part in the wide dialogue and contribute in the preparation of concrete implementation plans of pilot units.

Special acknowledgments should be given to all the consortium members for their commitment to produce high quality results. A list with the consortium members as well as further information can be found under: **www.adu-res.org**

Water Supply situation in the rural areas of Tunisia

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During the last three decades, fresh water has taken an important place in the economical and social development programmes in Tunisia. These efforts allowed improving the water supply conditions in terms of quality and quantity, either in urban or rural areas. The rate of fresh water supply reached 100 % in urban areas and 87.6 % in rural areas. It is planned to reach by the end of the second programme a rate of supply of 90 % in rural areas at the national level and a regional rate of supply equal or exceeding 80 %.

Beside the investments granted by the state to mobilize water resources and to realize fresh water supply projects (AEP) and in order to improve exploitation and maintenance of SAEP, Tunisia has adopted since the end of 1980's in the hydraulic field a policy based on the management of water resources need (GD/RE) and on the participative management of hydraulic infrastructures. This community management mode (GC) of water resources is a management method that requires the users' involvement in the exploitation and maintenance of fresh water supply systems (AEP) and irrigation. It aims the state disengagement from the direct management (GD) of hydraulic infrastructures and the users' responsibility in taking in charge the management and maintenance of water systems.

To promote this management mode, human and material means and financial means had been reserved to the training and supervising of collective interest groups (GIC). Due to the deployed efforts, the management of all the SAEP and all the small public irrigated perimeters (from drillings) has been transferred to GIC since the beginning of 1990's and since 1998, a programme has been started to transfer the large public irrigated perimeters (from dams) to GIC. The number of GIC went from 100 GIC in 1987 to 2750 GIC in 2004 distributed in 1600 GIC for fresh water supply, 1000 GIC for irrigation and 150 GIC mixed. The evaluations performed by the Direction Générale du Génie Rural et de l'Exploitation des Eaux (DGGREE - general direction for rural engineering and water exploitation) and by the engaged missions of certain stakeholders show that the performances of GIC have improved in very satisfactory manner both financially and organisationally. Financially, the majority of GIC (over 95%) have taken in charge energy and labour costs, but the take in charge of maintenance costs are still quite low (about 20%). From organisational point of view, over 50% of GIC ensure the monitoring of their water systems exploitation.

In general, the functioning of GIC relies on four pillars:

- The design and correct functioning of water systems.
- The solidarity and adhesion of population to GIC.
- The competence and engagement of the personnel and voluntary representatives of GIC.
- Training and efficient monitoring by the administration (political-administrative environment).

In most cases, these pillars are not always sturdy, there is generally at least one condition that is defaulting which causes a significant lack in monitoring the management and functioning of GIC. Experience shows that; in one hand, voluntary service, competence and availability are conditions difficult to gather in members of GIC CA, and on the other hand, organised and disciplined worked of certain amount cannot be demanded from a voluntary.

- In consequence, the collective voluntary mode of management is profitable in
- Localities having high social cohesion and where SAEP are not complex.
- Localities that do not have alternative resources.
- GIC that comport voluntary actives that do not act for personal interest.

But SAEP that are more or less complex and/or GIC that do not comport engaged voluntary representatives, the collective voluntary management mode did not perform satisfactorily, and the rescue to the enrolling of qualified agents or toward private sector is proved necessary to improve the management and exploitation of projects.

The Situation of Drinking Water Supply in Kairouan

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Located in the centre of Tunisia, the Governorate of Kairouan occupies a strategic position at a national level. With its agricultural-oriented labour force, the Governorate keeps an important place in the national economy. It counts 11 delegates, 12 communes & 114 Imadats.

The drinking water sector has always been an important aspect in economic and social development plans. Continuous efforts allowed improving the conditions of drinking water supply, in terms of quality and quantity, both in urban and rural areas
The service of the major country zones is with individual or collective character, assured through public fountains. Besides drinking water for the population, water supply systems in the rural areas allow the watering of farm animals and the irrigation of fruit trees during dry seasons.

The served population is 312,984 out of 372,601 inhabitants at the end of 2005, that is to say a total service rate of 88.2 %.

This paper deals with the rural population which represents 68.2 % of the total on a country level. In Kairouan, the urban population is completely served. On the other hand, the served country population is estimated at 327,163 capita, representing 87% of the total rural population; the drinking water supply of the not yet served country zones collides with certain problems.

The realisation of domestic water supply systems (AEP) was always linked to the availability of water resources with normalized characteristics. However, the last years it has been recorded that the chemical quality of the water has been deteriorating, both in phreatic water table as well as in deep ground water tables (increase of the dry residue which exceeded 2,5 g/l in the south of Governorate: delegations of Nasrallah and Bouhajla). This drew away an under-exploitation of the AEP system and we assist at an allocation of some drinking water projects in different use than domestic water consumption. Moreover, it is important to note that the water systems with an estimated poor quality are 11.

Some regions of Kairouan are characterized by the scarcity of good quality water resources, for example the delegations El Alâa and Bouhajla. In certain zones, the hilly landscape and difficult access create problems for the realisation of AEP projects. To overcome these constraints, the CRDA of Kairouan undertakes the water transfer of water for long distances to supply certain regions with their water needs; this had as consequence the very expensive cost of the projects and management difficulties for some GIC. It is important to mention that a huge amount of future projects are more and more located in rural areas with hilly landscape and difficult access.

The management of AEP systems is entrusted to groupings of collective interest (GCI) which assure the operation and maintenance of the plants. However, several difficulties have been observed, which hinder the GCI to assure the management of their plants by themselves. This requires more effort of awareness and training to allow these structures to play their role.

The problems faced by the GCI can be summarized as below:

- complex water system, difficult to manage

- high price of the water m^3
- inoperative of directors board
- Inadequate training of key members of the administrative board

Solar Thermal Desalination for Rural Applications - a few current views upon an old technology and its possible new role in the global Water Crisis

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An outline of the history and functionality as well as technical strengths and weaknesses of simple solar distillation is given in the context of the changing global water situation. Simple small scale solar stills have been in wide use and production until the 1960s with decreasing importance after the introduction of fossil energy based large scale desalination and centralized water treatment. In the context of the global degradation of water resources, peaking oil production, increasing energy prices and general resource scarcity in the 21st century, the importance of this technology as a supplementing technology to provide a source of renewable energy based independent decentralized drinking water supply is stressed. Western nations spend between 3 and 5 Percent of their GDP for water supply and treatment – depending on country up to € 8000 per household and year. This figure shows the extent of the water crisis and the gap between developed nations and developing nations, the latter often having lower total annual household incomes. Strengths and weaknesses of different options to approach the water crisis are discussed including centralization, privatization, stressing that small scale single household systems also are a form of privatization. An integrated approach is suggested applying appropriate central, decentral and private as well as community solutions on different scales and utilizing existing technological, social and economic structures and expertise wherever possible.

Zonnewater's optimized solar still technology "Aqua Solaris" is presented and explained. It uses separated evaporation and condensation chambers, concentration mirrors, energy recovery and intelligent micro-controlling, controlling the air flow to optimize the humidification and dehumidification process at high temperatures above 80-85 °C. The basic physics of the humidification process is explained and the economics of various systems are compared.

Zonnewater data, based upon testing of a field prototype on the island of Bonaire, to date show an output of 40 litres per day. Currently tests at various locations in India and southern as well as northern Europe are carried out and optimizations are under way, taking into consideration the various test results and also utilizing modern approaches. The goal is a reliable technology with a daily production of 40 litres of high grade drinking water from a wide range of sources under a wide range of climate conditions. Jan de Koning, inventor of the Aqua Solaris and founder of Zonnewater, is confident to achieve this goal within the foreseeable future.

The conclusion is that small scale solar thermal desalination units will find increased applications in meaningful market niches alongside larger scale wind, solar and hybrid powered Reverse Osmosis as well as classic centralized water treatment and desalination plants.

The Solco PV-RO system – Maldives Case Study

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INTRODUCTION

The creation of a working Water Purification Unit was the focus of a three month pilot project initiated and run by Solco Ltd between March and July 2005. The purpose of the project was to prove that Solco Ltd could establish an environmentally sustainable decentralised water purification system in a remote area, which could also be made economically sustainable through the sale of water produced by the system.

PREPARATION

Community consultation was conducted both remotely - via a community survey and an application process (indicating which communities were interested in participating in the project trial) - and through personal visits to ten different island locations, with the purpose of winning community approval and support, as well as identifying a suitable site for the project. In order to achieve local support, the island's chief and its residents had to be educated about the benefits of the project. Convincing the Kulhudhuffushi community to buy bottled water from their own source was the first obstacle to be overcome. In order to achieve this, educational brochures and programs for the schools and the wider community were provided to help raise awareness of health issues relating to drinking the existing water. The IDC granted Solco access to a site next to the island guesthouse, and during the project's construction Solco frequently communicated with the community, who in turn assisted with the implementation of the project. This served to provide locals with hands-on experience with the system.

The Maldives is a series of low lying coral atolls. Rainfall, also known as recharge, creates a small pocket of fresh water between the ground surface and the existing sea water, commonly known as the freshwater lens. The freshwater lens on Kulhudhuffushi was being depleted due to reduced rainfall, and had also suffered biological contamination due to the absence of any sewage treatment facility. Initial water tests for salts and E. coli levels were conducted at two-metre intervals, up to a total depth of 10 metres. At 9 metres we identified total dissolved salt (TDS) levels of between 3500 and 5000 parts per million (ppm). This water, which was not used by locals because of its high salt concentration, was capable of being processed by the Solco water purification system. We therefore installed our solar pump at a 9 metre level to draw off this water for processing.

OPERATION

A Sun Mill solar pump drew approximately 6,000lt of brackish water from 9m below the surface each day. This water then passed through a coarse filter bank and into a 9,000lt header tank, which was located on the roof of the sea container. Coarse filtration started at 80 microns and went down to 25 microns. Water was then gravity-fed through primary filtration, starting at 25 microns and going down to 5 microns, before being pumped through two Solarflow reverse osmosis units, which recovered approximately 16% of the 6,000lt of water that passed through the membrane daily. Effectively, 1,000lt of clean purified water was collected from the 6,000lt of brackish water entering the system every day, and this product water was stored in a second 4,800lt tank.

Prior to sale, bottles were cleaned and sterilised using a Sodium Metabisulphate solution and then filled with the purified water. The water was sold to the community at approximately half the going rate per litre of the alternative bottled water available. The waste stream of approximately 5,000lt per day was returned into a secondary bore 20 metres below ground. At this level, water quality is almost equivalent to seawater, so there was no negative impact on the freshwater lens.

The system was run by two full-time local employees from the community, hired by Solco. Salt levels in feedwater and product water were measured and recorded daily, and E. coli levels were tested periodically to ensure that the water quality was fit for human consumption. Employees had been fully trained in maintaining the system and servicing all equipment, and an outline of service procedures was posted on the sea container wall. The employees' daily responsibilities included sterilising returned bottles and refilling them with filtered water, and washing the system filters.

The bottled water could be ordered by phone or in person, and the bottles were distributed in boxes of 10 via motorbike or trolley. Money was collected by the delivery employee and banked with the Bank of Maldives, which has a branch on each of the major islands. The Kulhudhuffushi system was capable of producing 50 bottles per day, but this number could easily have been expanded. Flow metres were installed on the system to record the volume of water produced.

CHALLENGES

The community has been drinking groundwater for thousands of years, and, more recently, bottled and rain water. In order to convince the community of the benefits of purifying the island's groundwater, an extensive education and marketing campaign was implemented.

Because of the project's isolation, local employees had to be trained to operate and maintain the water purification system. Solco therefore endeavoured to design a system which was both simple and reliable. It was, however, necessary for spare parts of some of the technically complex items to be stocked on the island, allowing them to be replaced by local employees and returned to Australia for servicing whenever necessary. Another consequence of the island's geographical isolation was to make preliminary and ongoing E. coli tests difficult to conduct.

The Maldives, being a series of coral atolls, presented logistical challenges for freight. In addition, the administrative structure of the islands consists of four distinct levels of bureaucracy, all of which needed to be consulted to gain official approvals.

CONCLUSIONS

- The containerised water purification system helped to solve the water needs of Kulhudhuffushi and the island resort of Dhon Kuli.
- Average water quality improvement from approx. 2500ppm TDS to 100ppm TDS
- Water sold in community for half the bottled water price.
- Water sold to nearby 6 star resort
- Fulltime employment for 2 locals
- Small footprint, minimum environmental impact and quiet operation.
- Project cash flow positive within one month
- Trial successful and terminated after 3 months
- Element in the community not in favour of continued operation due to negative impact on sales of imported bottled water.

Introduction of a new Energy Recovery System – optimized for the combination with renewable energy.

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ENERCON's focus is concentrated on the combination of desalination processes with wind energy. Instead of transporting oil or gas for the energy supply of desalination plants we prefer to use the energy you can get for free directly from the location. As a rule, costal locations are often excellent positions for wind energy.

The ENERCON Desalination Department has developed a new Energy Recovery System for RO desalination plants, optimized for the combination with wind energy converters.

The main problem for the combination of desalination processes and wind energy is the fluctuation of power supply generated through renewable energies. Conventional desalination plants (and the belonging energy recovery system) work at a fixed operation point or in a very small range, they could be combined with renewable sources with a "on/off-operation" only.

ENERCON developed a system that can adjust the operation in a range of 12,5 -100% energy availability - in a very energy efficient way!

The energy recovery system consists of a low pressure pump (20bar) an three combined pistons (there is no need for a second/booster pump). This "piston type accumulator" is able to transfer the pressure up to 70 bar, needed for the desalination process.

As a side effect we can also avoid the use of chemicals for the anti-scaling and antifouling problem. We managed to avoid additives by a low recovery rate.

In the combination with the very efficient energy recovery system we experienced an energy consumption within the RO unit between 2-2,8 kWh/m³ for seawater and between 0,8-1,3 for brackish water with our prototype plants in the Mediterranean Sea.

The ENERCON design enables a reduction of operation costs through low energy consumption and the avoidance of chemicals. Furthermore it is also a benefit for the environment.

With the presentation in the ADU-RES seminar we like to present the results and the concept of a new Energy Recovery System. It's not a theoretical approach – our plants run successfully since 2001.

Our goal: A reliable, sustainable drinking water production of finest water quality!

Using geothermal and solar energy for autonomous water desalination units

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In arid areas of Tunisia potable water is very scarce and the establishment of a human habitat in these areas strongly depends on how such water can be made available. On the other hand, these regions have important resources of underground brackish (salinity more than 3g/l) and often geothermal (temperature between 40°C and 90°C) water. Hence, these resources can not be used directly.

Brackish water desalination is one of the ways to provide water in these regions for drinking and irrigation purposes. On the other hand, the conventional desalination technologies are not adapted for this situation. In fact, the investment and operating costs are so high that the recourse to this solution is justified only for large scale utilization. Moreover, the conventional energy supply of remote areas presents technical and economical problems. In this case, production of fresh water using desalinations technologies driven by renewable energy sources (solar, wind, geothermal, etc.) can be promising.

Since the brackish water is often geothermal in the south of Tunisia, the solar energy is abundant, and the water demand is low, the use of geothermal and solar energy for water desalination can be promising.

In this paper we present a state of the art on using renewable energy sources, notably geothermal and solar, for brackish and seawater desalination in the world and in Tunisia. An example of coupling an innovative desalination unit including horizontal-tubes falling-film evaporator and condenser, made of polypropylene with a geothermal spring and solar collectors is presented. The use of the renewable energies is compared to conventional ones. The advantage of this plant is that it is made from cheap materials (polypropylene) allowing the use of low temperature energy (60°C to 90°C), which corresponds to the geothermal water temperature in the south of Tunisia. Moreover, the plant can be used for geothermal water cooling before utilization for irrigation or drinking.

Spanish Cooperation Project in Southern Tunisia: PV-RO Desalination Unit in the Village Of Ksar Ghilène

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INTRODUCTION

The supply of water and energy is the main problem in North African countries, where great part of the rural population does not have access to the general electrical grid and water resources. The village of Ksar Ghilène, situated in the south of Tunisia in the region of Kèbili, is a typical example of these lacks.

In the framework of the Spanish -Tunisian cooperation, a project for the supply of drinking water through a desalination unit driven by solar photovoltaic energy has been approved. The partners of this project are the Spanish International Cooperation Agency (AECI), the National Agency for the control of energy consumption (ANME), the Regional Directorate for Agricultural Development of Kèbili (CRDA), and the Government of the Canary Islands through the Canary Islands Institute of Technology (ITC).

PROJECT DESCRIPTION

The village has a population of 300 inhabitants dedicated to the agriculture and cattle raising. An artesian well (brackish water - 3500 mg/l-) located inside the oasis is used for agricultural purposes. The drinking water supply depends on arriving tankers coming from a well located 60 km away. There is no possibility of electrical grid connection, being the nearest point at 150 km. The climatic conditions are an annual average daily solar irradiation of 5.6 kWh/m², with a mean ambient temperature of 26 ºC (temperature varies from 0 to 45 ºC).

Several previous actions undertaken have provided the village with a hydraulic grid for general water supply, solar thermal heating in the community bathroom, electrification by Solar Home Systems and solar lighting street lamps. Consequently, the main current lack is the access to drinking water, with an estimated mean consumption in the village of 15 m3/day.

The appropriated solution proposed in these conditions is a PV-RO desalination unit. The main objectives of this project are the supply of drinking water to the population, the further management of the produced water and the final dissemination of the results.

The project is structured in the following phases: design of the desalination unit and the solar PV generator, study of infrastructures, hydraulic and civil engineering works, equipment transportation to the village, installation and starting-up of the whole system, complemented by the practical training of local technicians, and the follow-up and evaluation of the project.

The adopted technical solution consists of a PV solar generator of 10 kWp providing electricity to the desalination unit through a 10 kW inverter and a batteries capacity of 600 Ah at 120Vdc. The RO desalination unit includes a 1kW feed water pump, a pre-filtration system, a 3kW high pressure pump and a RO module (1x3 membranes of 8”) with a recovery of 70%. The RO module will produce 2.1 m3/h with a concentration less than 500 ppm.

To avoid the impact of high temperatures onto the equipments, passive cooling architectural solution has been considered. The building containing the desalination unit and the power control equipments will be semi-buried, using the shade of the solar PV modules that will be placed on the building roof to avoid overheating inside.

At the present moment, both, the solar PV generator and the RO desalination unit have been designed and are in process of manufacturing. At the time, the civil and hydraulic works have been carried out. The starting-up of the system is expected for the beginning of May 2006, while the final delivery after the testing period will be on December 2006.

Successful RES Desalination Applications

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The need of water is rising in many parts of the world including the Mediterranean rim, due to domestic, agricultural, industrial as well as tourist pressures. Moreover all around the world there is a number of small isolated communities like islands and remote villages without access to electricity grid and potable water. New water supplies will increasingly be required and desalination of seawater and brackish water provides an attractive solution.

Production of fresh water using desalination technologies driven by Renewable Energy Sources (RES) is thought to be viable solution to the water scarcity at remote areas characterized by lack of potable water and lack of electricity grid.

Desalination units driven by RES, such as those driven by solar and wind energy, guarantee friendly to the environment, cost effective and energy efficient production of desalinated water in regions with severe water problems, which nevertheless are fortunate to have renewable energy resources.

There are a number of possible combinations of desalination processes with different RE sources as it is shown in Figure 1.

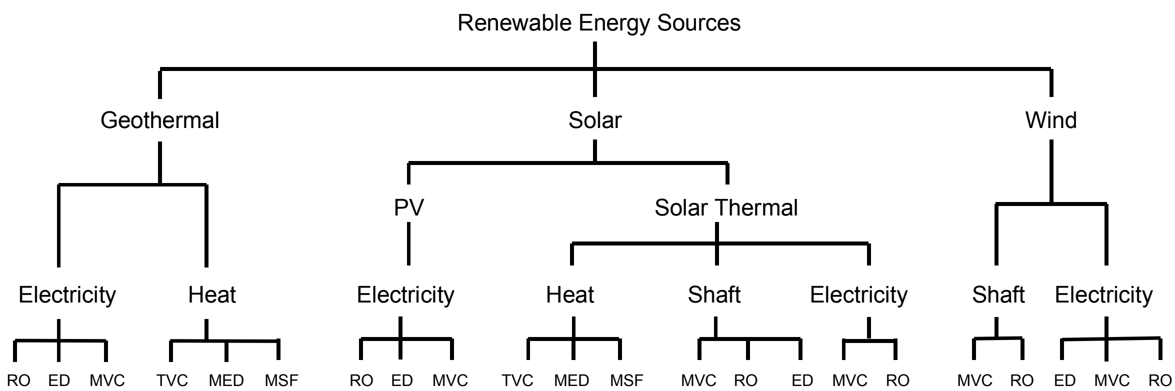

Fig 1. RES Desalination combinations

PV is particularly good for small applications while wind energy is more attractive in larger systems or in small sizes in combination with an alternative source, such as PVs. The sizes of the installed desalination RES plants in average are small since most of them are installed for research and demonstration.

The matching of the desalination process to a RE source is not very simple mainly because desalination process is best suited to continuous operation. The majority of the renewable energy sources is distinctly non-continuous and is in fact intermittent often on a diurnal basis. Unpredictable and non-steady power input, force the desalination unit to operate in non-optimal conditions and this may cause operational problems.

In the present work several desalination plants driven by RES are presented. Technical descriptions, cost data and lesson learnt are also mentioned. Two seawater solar thermal MED plants, a seawater Wind MVC, seawater and brackish water PR RO plants as well as hybrid RO plants are analyzed. Several ideas and recommendations are discussed.

Energy Efficiency in Reverse Osmosis Systems

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Energy efficiency in reverse osmosis systems is especially important in systems that are to be powered by renewable energy.

For perspective, the theoretical minimum energy required to desalinate seawater is around 1 kWh/m3. In practice, most systems consume several times this amount. Simple distillation (boiling the water and condensing it) uses vastly more energy: 627 kWh/m3 in theory. In practice, it is possible to reduce this greatly by re-using the heat from the condenser to heat new feed water, as is done in large-scale thermal desalination plants: Multi-Effect Distillation (MED), Multi-Stage Flash (MSF) and Vapour Compression (VC). Furthermore, it must be stressed that this is heat energy, which is usually much less expensive than electrical or mechanical energy. Converting the heat consumption figures of large MED, MSF and VC systems into equivalent electricity yields consumptions in the region of 6 - 16 kWh/m3. Moving to Reverse Osmosis (RO), typical consumptions are 3 - 8 kWh/m3, while best practice RO achieves around 2 kWh/m3. Thus, we see the attraction of RO from an energy perspective.

With seawater RO, typically one third of the feed water is desalinated (“recovery ratio” 33%), the remaining two-thirds being rejected as concentrated brine. The feed water must be pressurised to around 60 bar, and the pump to achieve this is the main consumer of energy.

Taking the above example figures, and assuming pump and motor efficiencies of 90% each, gives an energy consumption of 6.2 kWh/m3 in a simple system. Notice, however that roughly two-thirds of this energy is being wasted in the brine, which exits the RO modules at a pressure only slightly below that of the feed.

A Pelton turbine can be used to recovery energy from the brine and provide it back to the main pump. A turbine with 80% efficiency would reduce the energy consumption in our example to 3.3 kWh/m3: a vast improvement but still not ideal.

To achieve even better energy efficiency various devices are available that transfer energy directly from the brine to the feed water. Examples: DWEER and ERI. These devices, and their similar competitors, help to achieve very low energy consumptions (sometimes approaching 2 kWh/m3) in medium and large-scale systems. Unfortunately, these devices are not well suited to small-scale systems.

The Clark pump from Spectra Watermakers Inc provides excellent energy efficiency in very small systems and is widely used on sailing yachts. The Sea Recovery - Ultra Whisper operates on a similar principle. These devices have been demonstrated in various renewable-energy-powered RO systems, but they are complex and maintenance remains a consideration.

Axial-piston hydraulic motors, such as the Danfoss Nessie, have also been demonstrated in renewable-energy-powered systems. The recovered energy is available as shaft power and thus has to go back through the main pump, which can make the system less efficient overall.

Many small systems are still built without any energy recovery.

All of the above has focused on seawater. Brackish water RO is different in that it recovery ratios are typically a lot higher. Therefore, a smaller proportion of the energy is contained in the brine and energy recovery less critical. A notable exception is the SOLCO PV-powered brackish water RO system, which has a recovery ratio as low as 16%, and has energy recovery integrated in pump.

Conclusions: Energy recovery is critical for efficient seawater RO, but does make designs more complex. Proven devices are available at large-scale. Less so at small scale

Low-Temperature Solar Rankine Cycle System for Reverse Osmosis Desalination

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The work regards the presentation, of an innovative low temperature solar organic Rankine cycle system for Reverse Osmosis (RO) desalination. The thermal processing taking place is described briefly below:

Thermal energy produced from the solar collectors array evaporates the working fluid (HFC-134a) in the evaporator surface, changing the fluid state from sub-liquid to super heated vapour. The super-heated vapour is then driven to the expanders where the generated mechanical work produced by the processing drives the High Pressure pump of the RO unit, circulation pumps of the Rankine cycle (HFC-134a, cooling water pump), and the circulator of the collectors. The saturated vapour at the expanders' outlet is directed to the condenser and condensates. HFC-134a condensation is necessary in the Rankine process. On the condenser's surface, seawater is pre-heated and directed to the seawater reservoir. Seawater pre-heating is applied to increase the fresh water recovery ratio. The saturated liquid at the condenser outlet is then pressurised by the HFC-134a pump.

Specific innovations of the system are:

Low temperature thermal sources can be exploited efficiently for fresh water production; solar energy is used indirectly and does not heat seawater; the RO unit is driven by directly mechanical work produced from the process; the system condenser acts as sea water pre-heater and this serves a double purpose; (1) increase of feed water temperature implies higher fresh water production (2) decrease of temperature of "low temperature reservoir" of Rankine cycle implies higher cycle efficiencies. Such a system can be an alternative to PV-RO systems, while low temperature energy sources like thermal wastes may be used for RO desalination. Based on the design results, a prototype installation is going to be realised.

Basic data of the size of the system are illustrated for the purpose of the seminar, while a first approach of cost analysis is given.

The ADIRA project

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Autonomous desalination system concepts for sea water and brackish water in rural areas with renewable energies – Potentials, Technologies, Field Experience, Socio-technical and Socio-economic impacts – ADIRA

ADIRA aims at the development of sustainable concepts for fresh water supply in rural areas derived from salty water (sea water and brackish water). Units powered by renewable energy with a fresh water output in the range of 100 l/day to 10 m³/day are in the focus of this project.

Motivation

In order to gain a wide and pro-found knowledge of small-scale ADS (autonomous desalination system) powered by renewable energies, it is essential to move out of the laboratories and to study real applications in the field. All the crucial and important steps like for example identification of suitable regions and sites, to preparation of the system design or operation and maintenance, must be performed under real working conditions. The summarised experience gained, will help to overcome water shortage problems in countries and areas which depend on sea or brackish water as water source.

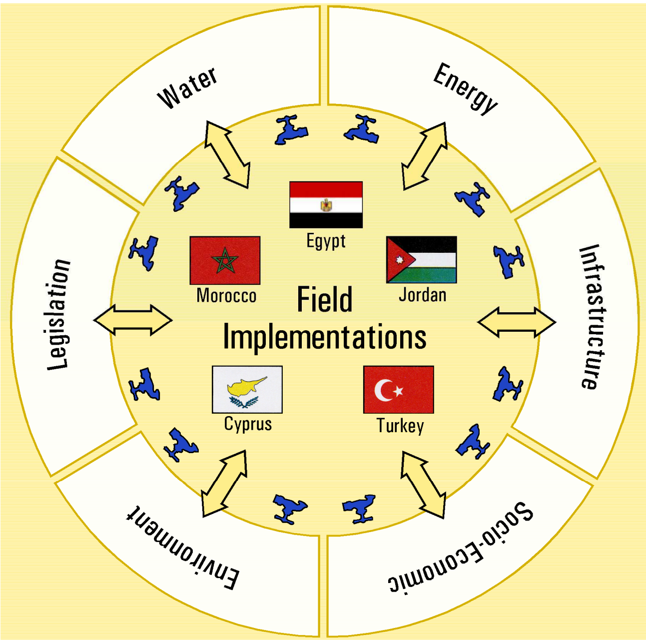

Fig. 1: Aspects for installation of ADS in MEDA-countries

Approach

The project includes the implementation of a large variety of different small-scale (0.1 up to 10 m³/d) ADS. These ADS are installed in five different countries: Cyprus, Egypt, Jordan, Morocco and Turkey. ADIRA follows an interdisciplinary approach, taking into account not only technical, but also legal, social, economical, environmental and organisational issues. This approach is essential to guaranty a high sustainability.

Specific results

In the future the following achievements of ADIRA will be available and support everybody working in the field of desalination:

- Full description of 10 – 15 different small-scale desalination installations including a monitoring system
- Data of this monitoring system are available on the ADIRA web-site (www.adira.info)
- Detailed business plans for each installation to guarantee the sustainability
- Installation / operation / maintenance guidelines
- Monitoring guidelines
- Decision Support Tool
- Data base (with data from market and country surveys)
- Proposal to the national and regional government on how to support the rural water supply infrastructure (master plans)
- Workshop for stakeholders in each participating country
- Education and training of the users
- Handbook for users, decision makers and installers

Acknowledgements

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PV-Powered Desalination in Australia: Technology Development and Applications

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The environment in Central Australia is well suited to solar-powered desalination, with ample sunshine and significant groundwater supplies which are affected by salinity and in some cases trace contaminants as well. The Reverse Osmosis Solar Installation (ROSI) has been designed for use in such situations, and combines photovoltaics with a dual-stage membrane process, using ultrafiltration as a pre-treatment stage and nanofiltration or reverse osmosis for desalination and trace contaminant removal. The potential users of such a system are small communities in remote parts of Central Australia with access to brackish groundwater sources but limited or no access to the electricity grid. Such groups include small Indigenous communities, farmers, National Parks staff and visitors, and roadhouses. For the unit to be successful it needs to be technically optimised for the water quality in each setting, and the socio-technical factors which will support its operation must also be examined. A field trip planned for October 2005 will examine in detail both the technical performance of the unit with variations in water quality and environmental conditions, as well as community and institutional responses to the unit and capability to support it.