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Promotion of renewable energy sources for water production through desalination

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ABSTRACT

The balance between water demand and availability has reached a critical level in many areas of Europe, the result of over-abstraction and prolonged periods of low rainfall or drought. Desalination of seawater and brackish water is one of the alternatives for ensuring a reliably supply of drinking water. Renewable energy sources (RES) coupled to desalination offers a promising prospect for covering the fundamental needs of power and water. Various initiatives and projects over the past few years have been covering the field of RE-desalination. The project entitled "Promotion of RES for Water Production through Desalination, ProDes" started on the 1st of October 2008 and it will run for two years. The ProDes project has been carefully designed in order to build on the past and exiting efforts and coordinate its activities with them in order to maximize the expected outcomes. The present paper presents the first results of the project and its general progress.

Keywords: Renewable energy sources; Desalination; Market; Education; Roadmap; Policy makers; Seawater; Brackish water

1. Introduction

ProDes project supports the use of renewable energy (RE) in remote areas where the electricity grid cannot accommodate high penetration of intermittent energy sources. The project focuses on Southern Europe where desalination is an increasingly important energy demand factor. Using renewable energy to power desalination, either in stand-alone or grid connected systems, will allow better load control and consequently wider renewable energy use in these areas. The project has the following specific objectives [1]:

- Develop and communicate a road-map on RE-desalination
- Develop courses and provide training for students and professionals
- Facilitate collaboration between RE-desalination technology providers and SMEs on the local level
- Support communication and understanding between technology providers and investors
- Provide recommendations for the improvement of the legislative and institutional conditions and communicate them to key decision makers
- Familiarize the general public with the technology and its benefits

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3[rd] International Conference on Small and Decentralized Water and Wastewater Treatment Plants (SWAT-III), Skiathos, Greece, 14–16 May 2010

ProDes has brought together a team of 14 companies, research institutes and associations that will work together towards achieving the project objectives. The overview of the partners is given in the following table:

Participant name	Country
WIP Renewable Energies	Germany
Centre for Renewable Energy Sources & Saving – CRES	Greece
University of Palermo – UNIPA	Italy
Instituto Nacional de Engenharia, Tecnologia e Inovação – INETI	Portugal
AoSol, Energias Renováveis	Portugal
Fraunhofer Gesellschaft – Institute for Solar Energy	Germany
Befesa Construcción y Tecnología Ambiental	Spain
AquaMarine Power	United Kingdom
Hellas Energy	Greece
European Desalination Society – EDS	Italy
Technology, Environment and Energy Research Centre – CIEMAT	Spain
Tinox	Germany
Instituto Tecnológico De Canarias – ITC	Spain
Capital Connect	Greece

The core of the project includes four phases that address different target groups. Below is a brief explanation of the four phases named after the target group they address.

Phase 1: Education system and academic community. The first phase of the project deals with the inter-European coordination of activities in the field of renewable energy powered desalination systems and the higher education. All relevant stakeholders are involved in a major effort to link the research community with the needs of the industry and the market on a European level. A working group is formed and incorporated to the European Desalination Society that will sustain these efforts after the end of the project. After a comprehensive consultation process a road-map on RE-desalination has been formed that is laid the foundations for the functions of the working group. The next step is dedicated to the introduction of RE-desalination in the higher education system of the participating countries. This aims to fill the gap in knowledge and help produce the missing experts that will bring forward the research in the field or work with entrepreneurs that will take advantage of the fast emerging market. The course is implemented twice in each involved country (Greece, Italy, Portugal and Spain) within the framework of the project and it is planned to establish and extend it at a later stage. It is also offered as an e-learning course, which will reach a much wider audience. A separate course dedicated to professionals has been already developed and implemented in each of the target countries, aiming at faster results targeting the people that are already active in the water and energy markets.

Phase 2: **Industry – Investors**. The second phase of the project is aimed to the industry and the investors. The strategy is focused on networking that should fill the existing gap in information flow between entities that have products close to commercialization with actors that can take these products and introduce them to the markets where the suitable end users are. Main part of this strategy will be facilitating collaboration with suitable SMEs and entrepreneurs already active in the water and renewable energy markets in the relevant countries. Finally, market analysis will be performed to provide an additional tool to the actors who want to plan their long-term strategies in the field.

Phase 3: **Public authorities and policy makers.** The framework conditions in the target countries and on European level will be analyzed and it will be defined how they can affect the implementation of RE-desalination. As a result concrete recommendations for improvements will be developed and communicated to key decision-makers through a dedicated event in each country. Realistic targets will be set for the future regarding the share of water produced by RE-desalination on the overall desalinated water. Concrete suggestions will be made for local, regional or national schemes that will promote the more efficient use of current public spending in the form of subsidies in order to support sustainable solutions in line with the social and environmental policies.

Phase 4: General public. The last phase of the project is dedicated to dissemination activities targeted to the general public. The work will create general awareness about the benefits of the technology especially in the participating countries and the local populations in the areas with RE-desalination potential. The main tools used will be the internet and the local, regional and national media, especially exploiting the occasion of the various project events.

The success of each step and of the project as a whole depends mainly on the motivation of the critical mass of stakeholders in order to raise awareness and bring the technology to the market. The involvement of key partners and associations from strategic countries and the European level ensures that the necessary critical mass will be reached.

2. RES desalination technology

Renewable energy systems convert the naturally occurring energy source (sunlight, wind, etc.) into usable electric, mechanical or thermal energy. Most of these systems are well established and reliable, with a sufficient number of applications around the world. Seawater desalination (distillation or membrane processes) is a well proven technique with several applications world-wide. However a major disadvantage is the high energy requirement of the processes involved [2].

Renewable energy systems, mainly wind and solar energy, can be coupled to desalination systems in order to provide the necessary energy input, which by itself may become a significant contribution in remote (off-grid) and arid areas. By the same token, the desalinated water can be used as temporary energy storage, thus providing a means for the 'regulation' of one of the most important inherent characteristics of the RES, their intermittence. Where the system is grid connected, the desalination plant can operate continuously as a conventional plant and the renewable energy source merely acts as a fuel substitute. However, even in such cases, the desalination load could be used for moderating the amount of energy injected to the grid, which tends to become a very useful concept in view of hybrid electricity systems with high penetration of intermittent renewable electricity sources [3]. Based on the literature the most developed RES desalination couplings are as follows [4–6]:

RES technology	Desalination technology
Solar energy	
Solar thermal	Multi-effect distillation (MED) Multi-stage flashing (MSF) Membrane distillation (MD) Humidification–dehumidification Solar stills
Photovoltaics	Reverse osmosis (RO) Electrodialysis (ED)
Wind energy	Reverse osmosis (RO) Mechanical vapor compression (MVC)
Geothermal	Multi-effect distillation (MED)

The selection of the appropriate RES desalination technology depends on a number of factors. These include plant size, feed water salinity, required product water quality, remoteness, energy requirements and availability, technical infrastructure and the type and potential of the local renewable energy resource [4]. The choice of a renewable energy source for electricity production is mainly influenced by factors such as the RES potential at the specific site, land availability and accessibility, type of connection (grid connected or stand-alone), budget constrain and financial support. These factors will affect the final decision and unit electricity cost.

The final unit water cost of a RES desalination system is "site and system specific". Each system is a different case; different site data, different design, impacts and cost.

The unit water cost from already installed stand-alone RES desalination plants ranges from around 1 up to 10 €/m^3. For example, for the PV SWRO[1] plant in Lampedusa, Italy, during its autonomous operation, a unit water cost of around 6.5 ECU/m^3 (1996) has been reported. The photovoltaic unit has a nominal capacity of 100 kW_p and the RO unit has a product water capacity of 5 (3 + 2) m^3/hourly.

Another example is the stand-alone PV SWRO plant in Pozo Izquierdo, Gran Canaria (DESSOL project) in which a unit water cost of 9 €/m^3 (2000) has been reported. The plant consists of a 4.8 kW_p photovoltaic system and a SWRO unit of 0.4 m^3/h product water capacity [11,12].

Regarding wind RO applications, for the wind SWRO plant in Pozo Izquierdo (AEROGEDESA Project) a unit water cost of 3–5 €/m^3 has been considered [11,12]. The unit consists of a 15 kW wind generator and a 0.80 m^3/h SWRO plant (Figs. 5 and 6). Regarding distillation, a MED plant of 80 m^3/day water capacity has been installed in Kimolos Island, Greece. The unit is driven by geothermal energy. For the unit in Kimolos island, a unit water cost of around 0.8 €/m^3 has been estimated.

Economy of scale is another major parameter that affecting cost, however in stand-alone units there is a limit on size since desalination requires a stable power for its operation and energy storage, in most times, is a requirement for the optimum operation of the unit.

When several alternative RES desalination schemes are applicable for a specific case, the final decision concerning the most prominent combination should be based, once again, on criteria such as [7]:

- Commercial maturity of technology. An appropriate way to validate this is by examining the performance of similar existing applications
- Local support availability (installers, technicians, etc.)
- Simplicity of operation and maintenance of the system

The above factors, in conjunction with the already mentioned available technical information (feed water quality, output water requirements, RES potential) provide a starting point for the engineer and the decision maker.

Among the several possible combinations of desalination and renewable energy technologies, some seem to be more promising in terms of economic and tech-

[1]SWRO: seawater reverse osmosis unit.

nological feasibility than others. However their applicability strongly depends on the local availability of renewable energy resources and the quality of water to be desalinated. In addition to that, some combinations are better suited for large size plants, whereas some others are better suited for small scale application. With regard to existing installation the most popular combination of technologies is the use of photovoltaics (PV) with reverse osmosis (Figs. 2 and 3). PV is particularly good for small applications in sunny areas [10]. For large units, wind energy may be more attractive. This is often the case on islands where there is a good wind regime and often very limited flat ground. With distillation processes (Fig. 4), large sizes are more attractive due to the relatively high heat loses from small units.

In recent years the European Union has intensified R&D efforts in this field [4]. Worldwide, several RES desalination pilot plants have been installed and the majority has been successful in operation. According to the data have been selected from the literature and within several EU project, THERMIE 1998 , ADU RES 2005, and ProDes 2008–2010, around 130 plants, in majority stand-alone plants, have been installed around the world. Virtually all of them are custom designed for specific locations and utilize solar, wind or geothermal energy to produce fresh water [6]. Some of them have been dismantled after several years of operation. Fig. 1 presents the share of each RES desalination technology coupling.[2]

In general, distillation plants are not preferred in small scales since they are not so efficient and their cost is high. Reverse osmosis for seawater and brackish water desalination is the most preferable technology and less costly in a large range of sizes.

According to ProDes results the barriers of the RES desalination development are separated in technical, economical and financial. Regarding the technical and economical barriers the most important is the fragment on the size of the autonomous systems because of the need of desalination systems to operate at constant energy supply, whilst most RES provide variable energy.

The use of large autonomous systems mainly requires a significant energy storage capacity and a clever control system, both leads to a high capital and O&M cost. Additionally, most RE Desalination units are not developed as single system but are combinations of components developed independently.

Promotion of co-operation between companies from the energy sector, water sector and other specialists to achieve fully functional integrated products is important.

Also, support development of standardized, reliable and robust systems offering competitive performance guarantees.

Concerning with the institutional barriers, some of these are:

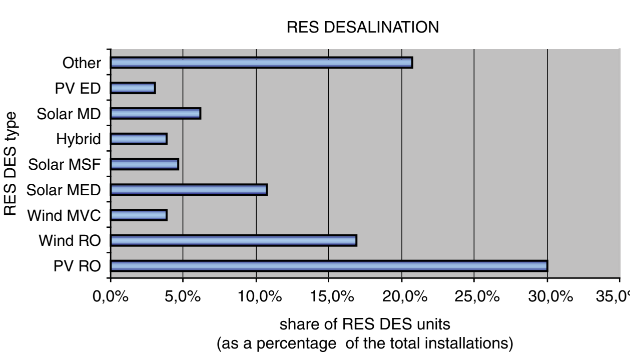

Fig. 1. Desalination processes used in conjunction with RES (Source: E. Tzen, CRES).

Fig. 2. BWRO 3.4 m^3/h, Aqaba, Jordan, 2005 [10].

Fig. 3. 16 kWp PV plant, Aqaba, NERC, Jordan.

[2]Note on Fig. 1: "Other" RES Desalination combinations includes geothermal MED units, solar distillation, solar humidification, solar pond desalination, geothermal distillation, other desalination combinations.

- Lack of training and infrastructure
- Cultural gap between project developers and the end-users
- Bureaucratic structures not tailored for independent water production; separation of energy and water policies
- Limited support by the Governments on the investment of RES desalination
- Creation of unfair competition because of pricing structures and subsidization of water supply

These common needs should be jointly promoted to organizations that fund R&D, like the European Commission and the national governments, to include the RE Desalination needs in their programmes and priorities. The target should be the development of standardized, reliable and robust systems integrating the renewable energy with the desalination unit offered to the end user with comprehensive performance guarantees [8].

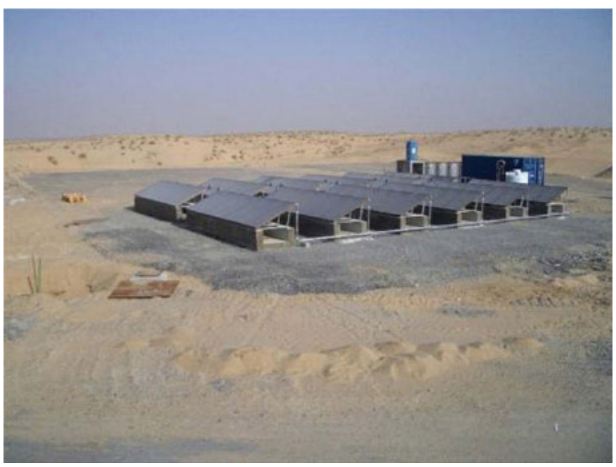

Fig. 4. Dubai, 5 m^3/day solar BW MED unit, 160 m^2 flat plate collectors, TINOX, Germany.

Fig. 5. 15 kW W/G, Pozo Izquierdo, Gran Canaria ITC, 2004.

Fig. 6. SWRO 19.2 m^3/day, Gran Canaria ITC, 2004 [11,12].

3. RES desalination market

The RES market has been steadily increasing over the last 20 years. RES technologies has had years of commercial acceptance all over the world and in a wide variety of applications. In parallel, the seawater desalination market is well established with many potential applications worldwide. In recent years, a few manufacturers/suppliers, are providing the market with compact RES desalination solutions for electricity and water production [3,9]. For instance, two German companies supply to the market such units, in a range of 175–2,000 m^3/day, packed in containers. The systems can operate as stand-alone or connected to an electricity grid. A Danish company also provides turnkey solutions for freshwater production, with the use of wind turbines. The RO units are designed as containerized modules with production capacities from 10 to 3,800 m^3/day. Several other companies seem to be ready for their entering in the market with small PV RO units, small scale solar distillation systems and medium scale Wind Mechanical Vapor Compression seawater desalination units. According to the market suppliers several large pilot projects are planning to be installed in the near term, in several places in the Middle East and North Africa. The expected increase on the RES desalination market is expected to raise the competitiveness and reduce the cost of such systems.

4. Conclusions

ProDes partners will continue to work in order to achieve their objectives on the promotion of RES desalination, by supporting the market, examining the framework conditions and providing new schemes, minimize the barriers, and by educated professionals and students on these technologies. The outcomes of the project will improve the technical, economical and institutional issues on RES desalination and this is expected to have a snow-ball effect with implementation rates increasing fast every year. The latest project results are available in the project website: www.prodes-project.org.

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References

[1] M. Papapetrou, Chr. Epp, The ProDes methodology for supporting the use of renewable energy systems in desalination applications, Desalin. Water Treat., 3 (2009) 204–209.

[2] E. Tzen and R. Morris, Renewable energy sources for desalination, Sol. Energy, 75 (2003) 375–379.

[3] E. Tzen, Wind and wave energy for reverse osmosis, in Seawater Desalination, Conventional and Renewable Energy Processes, A. Cipollina, G. Micale and L. Rizzuti (editors), Springer, New York, 2009, pp. 213–245, ISBN: 978-3-642-01149-8.

[4] Desalination Guide Using Renewable Energies, Centre for Renewable Energy Sources, CRES, Greece, 1998, ISBN: 960-90557-5-3.

[5] S. Kalogirou, Renewable Energy Sources Used for Seawater Desalination, NOVA Science, New York, 2008, pp. 67–144, ISBN: 978-1-60456-567.

[6] Roadmap for the Development of Desalination Powered by Renewable Energy, ProDes Project, IEE/07/781/SI2.499059, 2009.

[7] E. Tzen, Renewable Energy Sources for Seawater Desalination—Present Status and Future Prospects, NOVA Science, New York, 2008, pp. 145–160, ISBN: 978-1-60456-567-6.

[8] R. Morris, Renewable Energy Powered Desalination Systems in the Mediterranean Region, United Nations Educational, Scientific and Cultural Organization, 1999.

[9] Commercial Desalination Products Powered by Renewable Energy, ProDes Project, IEE/07/781/SI2.499059, 2010.

[10] K.J. Touryan, Solar Powered Desalination and Pumping Unit for Brackish Water, National Renewable Energy Laboratory, NREL, Golden, CO, 2006.

[11] V. Subiela, Juan A. de la Fuente, G. Piernavieya and B. Penate, Canary Islands Institute of Technology (ITC) experiences in desalination with renewable energies (1996–2008), Desalin. Water Treat., 7 (2009) 220–235.

[12] New Technologies in Spain – Desalination, Technology Review, published by MIT, www.technologyreview.com/spain/water.