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ENERGY & WATER
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BEST PRACTICES ON HYBRID POWER APPLICATIONS
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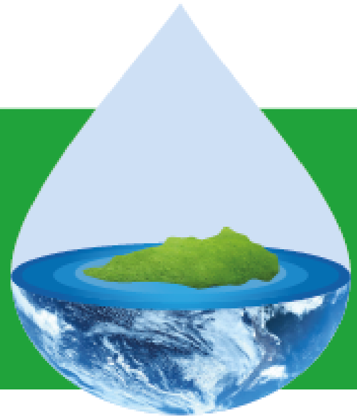

SUSTAINABLE WATER AND ENERGY: THE EU-FP7 MEDIRAS AND REAPOWER RESEARCH PROJECTS

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Within the 7th European Framework Programme two cooperative research projects have been carried out by the University of Palermo with specific focus on sustainable production of water and energy for islands and remote locations.
The MEDIRAS (MEmbrane DIstillation in Remote AreaS_www.mediras.eu) project aims at developing modular systems, based on the use of Membrane Distillation, able to produce fresh water in remote areas at a competitive cost and in a reliable way.
The REAPower (Reverse Electrodialysis for Alternative POWER production_ www.reapower.eu) project is based on the adoption of the Reverse Electrodialysis technology to produce electric current from salinity gradient between concentrated brines and seawater. The final scope was that of constructing a prototype able to operate under real environmental conditions.
Additional information on the two projects are reported in the following.

The MEDIRAS project deals with the optimization a solar desalination system and demonstration of its cost effectiveness and reliability. The modular system set-up is based on the innovative Membrane Distillation (MD) technology.
MD is a relatively new process that is being investigated worldwide as a low cost, energy saving alternative to conventional separation processes such as distillation and reverse osmosis[1]. Nowadays, the possibility of driving the process via solar thermal energy and waste heat has further enhanced the interest towards this technique[2]. MD is a separation technique combining the features of both thermal and membrane-based distillation processes. Thermal energy causes the liquid to vaporize in an evaporator channel, while a hydrophobic micro-porous membrane allows the passage of vapour only to a condenser channel. MD is favourably

applicable for small-distributed desalination systems in the capacity range between 0.1-20 m^3/day. The technology is very robust against different raw water conditions and is suitable for operation with renewable sources, like solar energy. The consortium of the MEDIRAS project worked on developing some auxiliary components that will allow the MD based system to be available for stand-alone applications on both inland and coastal locations. The work programme includes the development of scalable system configurations in order to adapt them to different customer demands. Five systems of different sizes were installed to supply with drinking water real end-users, demonstrating the cost effectiveness and reliability of the technology. The project started on 1st September 2008 and run for 3 years. MEDIRAS scope was to reduce the cost of water produced through Membrane Distillation, make the technology suitable for a wider spectrum of end-users and integrate systems that monitor and maintain the water quality until it reaches the consumer. The last phase of the project was that of setting up, operating and monitoring some demonstration systems: in total 3 compact systems and 2 multi-module two loop systems were installed:
- brackish water compact system in Tunisia;
- seawater compact system in Tunisia;
- multi-module two loop system in Spain;
- compact two loop system in Tenerife;
- multi module two loop system in Italy (Fig.1). This last one is installed in a 8 MW diesel power plant in the small island of Pantelleria. The nominal production is 5000 l/day. The system use waste heat from the refrigeration of the engines and solar heat from the solar collectors. Main characteristics of this last installation are: two loop system; thermal energy:20 % solar collectors + 80 % waste heat, 40 m^2 solar collectors, waste heat recovery: Q= 10 m^3/h, T=90°C; brine cooler; operation 24h/day; water intake: 35.000-37.000 ppm; water management protocol: regular monitoring of water temperature, conductivity, production etc..

Fig.1: Multi module two loop system in Pantelleria, Italy. On the left: solar thermal collectors; on the right: membrane distillation modules.

The REAPower project adopts the Reverse Electrodialysis technology to exploit the salinity gradient of two different saline solutions. Salinity gradient power (SGP) represents a viable renewable energy source associated with the mixing of two solutions of different salinity. Reverse electrodialysis (SGP-RE or RED) is a promising technology to exploit this energy source and directly generate electricity. However, although the principle of this technology is well known since several years, further R&D efforts are still necessary in order to explore the real potential of the RED process. In particular RED processes commonly called Blue Energy make use of river water as diluted solution and seawater as concentrated solution. The use of river water in the diluted compartment causes a high electrical resistance, which reduces the amount of energy that can be produced. In this regard, the aim of the REAPower project is the development of an innovative system for power production by RED process, using sea (or brackish) water as a diluted solution and brine as a concentrate. The use of sea or brackish water (instead of fresh water) as diluate allows reducing the electrical resistance of the diluate compartment and increasing the achievable power output. The REAPower project started on 1st October 2010 and run for 4 years. The R&D activities carried out within the project particularly focus on membranes development, stack design and process modelling. An extensive

experimental campaign has been performed on a lab-scale unit, allowing to reach a power density among the highest, so far presented in the open literature. These results provided useful information for the final goal of the project, i.e. the construction of the first RED system on a small pilot-scale, in order to demonstrate the feasibility of the future scale up for this technology. In the following, the most relevant results achieved for enhancing the performance of RED are summarized. Most of these results have been presented in more specific literature works[3-4]. The main efforts have been focused on the following issues:
(1) development of new ion exchange membranes suitable for highly concentrated solutions;
(2) selection of the best conditions for the electrode compartments as well as for flow distribution inside the stack;
(3) experimental investigation on the newly developed lab-scale stack;
(4) development and validation of a predictive (multi-scale) modelling tool for the SGP-RE process;
(5) use of the modelling tool for the design of the SGP-RE prototype and relevant perspectives analysis;
(6) system scale up from the lab-scale to the small pilot-scale.

As a final goal of the REAPower project, at the end of all these activities a pilot plant (Fig.2) was constructed and installed at the "Ettore & Infersa" saltworks in Marsala near Trapani (Sicily, Italy) for a total of about 1kW of installed power. The plant consists of a small (44x44cm^2, 125 cell pairs => 24 m^2 cell pair area) and 2 larger prototypes (44x44cm^2, 500 cell pairs each => 121 m^2 cell pair area each) which are currently under operation. The small prototype has been working for 5 months without any performance loss. The other two prototypes are now under monitoring. The electric power produced can vary according with the operating conditions: each large prototype was able to produce up to about 350W.

Fig.2: RED pilot plant. On the left the small prototype; on the right the larger two prototypes.

The developed pilot plant is (i) the largest worldwide RED installation under operation and (ii) the first one operating with brine and brackish water under real environmental conditions. Further investigation on the operating pilot plant will provide precious indications for the future scale-up of the present technology thus hopefully leading to a future industrial application.

[1] K.W. Lawson, D.R. Lloyd, Membrane distillation, *Journal of Membrane Science* **124**, 1–25 (1997).
[2] R. Schwantes, A. Cipollina, F. Gross, J. Koschikowski, D. Pfeifle, M. Rolletschek, V. Subiela, Membrane distillation: solar and waste heat driven demonstration plants for desalination, *Desalination* **323**, 93–106 (2013).
[3] M. Tedesco, A. Cipollina, A. Tamburini, G. Micale, J. Helsen, M. Papapetrou, REAPower: use of desalination brine for power production through reverse electrodialysis, *Desalination and Water Treatment*, in press. doi: 10.1080/19443994.2014.934102
[4] M. Tedesco, A. Cipollina, A. Tamburini, I.D.L. Bogle, G. Micale, A simulation tool for analysis and design of reverse electrodialysis using concentrated brines, *Chemical Engineering Research and Design*, in press. doi: 10.1016/j.cherd.2014.05.009.

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