Drinking from the sea

Clean water is increasingly in short supply worldwide. Renewable energies can help filter drinking water from the sea. An up to date report from the ProDes initiative describes the potential, but also points out the obstacles.

A reverse osmosis system from the Canary Islands Institute of Technology purifies brackish water in the Tunisian village of Ksar Ghilène. The facility produces up to 2,100 litres of drinking water per hour. The necessary energy is provided by a 10 kW PV installation. Photo: Canary Islands Institute of Technology

Seventy percent of the earth's surface is covered by water. Nevertheless, the precious liquid is in short supply. Almost 900 million people have no access to clean drinking water. Every day, 4,000 children die because dirty water makes them sick. According to a study conducted by the German Aerospace Center (DLR), only four countries in the Middle East and North Africa have enough natural and accessible drinking water resources to be able to supply their inhabitants with more than 1,000 m^3 per capita and year. This value is considered the limit of water poverty. While mere survival is at stake in many countries of the South, the increasing demand is aggravating the water crisis in Europe. For these reasons, more and more people worldwide have to obtain their drinking water from the sea or from inland sources turning ever saltier.

Analysts of the information service Global Water Intelligence estimate that in 2008 a total of 52 million m^3 of water per day were provided by desalination facilities worldwide. It is expected that the volume of drinking water derived from the sea will more than double by 2016. The Arabian countries on the Persian Gulf account for the bulk of this amount. Already today, Saudi Arabia, the United Arab Emirates and Kuwait take the top positions in terms of sea water desalination. Spain ranks fourth; its 700 plants supply water primarily for agriculture. But other European countries such as France, Greece and Italy are also using more and more desalination systems – whether for securing the water supply to islands, settlements or entire cities, or for supplying tourist resorts or irrigating agricultural land.

Report reveals potential of renewable energies

While most big plants depend on oil or gas, small and medium-sized facilities can be partly or completely operated using renewable energies. The report

"Roadmap for the development of desalination powered by renewable energy" by the EU initiative ProDes (Promotion of Renewable Energy for Water production through Desalination) shows ways to improve the utilization of regenerative energies for turning salty sea water and brackish water into drinking water. ProDes is an initiative of fourteen institutions and companies from the regenerative energy and water industries. "The people in charge are often unaware of the available possibilities. And neither do they know how reliably and efficiently desalination plants that are powered by the sun, the wind, and in the future possibly also by the tides, operate", regrets Marcel Wieghaus of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg (Germany). ProDes, in which the Fraunhofer ISE takes part, wants to change that. The aim of the initiative is to provide information and to get all the involved parties together in order to boost the utilization of renewable energies for water desalination.

According to ProDes, there is an increasing interest in sea water desalination driven by regenerative energies, but most of the existing facilities are pilot

In some regions of the earth, the drinking water supply situation is getting more and more acute. In a small town in the Brazilian sertão, a water seller brings the precious good with his cart.

Photo: GTZ / Uwe Rau

The various desalination methods:

Solar distillation (SD): Solar energy evaporates the sea water that has been collected in a flat basin covered with a glass pane. The water vapour condenses on the cold cover. Drops develop, which can then be collected. The condensate is drinking water with the salt removed.

Multiple-effect humidification (MEH): Low-temperature heat, for example from solar collectors, provides the energy for a closed desalination module in which the salt water can evaporate and condense. The vaporization heat can be recovered almost entirely in a condenser.

Membrane distillation (MD): In this method, the heated brine is directed along a water -repellent, porous polymer membrane. Vaporous water molecules penetrate the membrane and condense on the other side. The condensation heat is used to preheat the brine that is fed into the system.

Thermal vapour compression (TVC): The efficiency of the sea water desalination system is increased using a steam jet compressor. It compresses a part of the generated vapour to a higher pressure, so that the vapour can be used for heating the evaporation stages.

Multi-stage flash (MSF): Sea water heated to up to 115 °C is fed into a vacuum chamber, where it expands abruptly and evaporates. The vapour subsequently condenses on a heat exchanger that is also carrying saltwater. The sea water fraction that has not evaporated is fed to the next stage at a somewhat lower pressure, where more of it evaporates due to expansion and condenses on the next tube bundle.

Multiple-effect desalination (MED): Like the MSF method, the MED technique evaporates and condenses the supplied sea water in successive chambers with decreasing pressure levels. In the MSF process, warm sea water flows through the heat exchanger tubes, and the distillate condenses on the outside of the tubes. In the case of the MED procedure, however, the heat exchanger tubes are usually sprayed with hot sea water, and the water vapour condenses on the inside.

Electrodialysis (ED): An external direct current field attracts the ions from the salt water (sodium+ and chloride-) towards membranes carrying the corresponding charges. The higher the salt water concentration, the more energy is needed for the process. Therefore, it is often only worthwhile for brackish water.

Mechanical vapour compression (MVC): A mechanical compressor generates the necessary process heat. It sucks all the vapour from the last evaporation stage in order to feed it to the first evaporation stage as compressed heating steam. Here, the steam condenses on cooled heat exchanger surfaces on the other side of which sea water is sprayed, boils and partially evaporates.

Reverse osmosis (RO): The sea water is exposed to a pressure exceeding the osmotic pressure, so that it is pressed through a semipermeable membrane. The bulk of the salt is retained in the saline solution. An electrically driven high-pressure pump is needed to build up the necessary pressure.

On the Spanish island of Gran Canaria, German researchers from the Fraunhofer ISE set up a membrane distillation system driven by solar thermal energy in 2005. It delivers up to 1,800 litres of drinking water per day.

Photos (2): Fraunhofer ISE

Comparison of the different desalination technologies

Technology	Typical capacity	Energy demand	Water generation cost	Technical development stage
Solar Still (SD)	< 0.1 m³/d	solar passive	1-5 €/m³	applications
Solar Thermal Multiple Effect Humidification (MEH)	1-100 m³/d	100 kWh/ m³ thermal 1.5 kWh/m³ electrical	2-5 €/m³	applications/advanced R&D
Solar Thermal Membrane Distillation (MD)	0.15-10 m³/d	150-200 kWh/m³ thermal	8-15 €/m³	advanced R&D
Solar Thermal/CSP Multiple Effect Desalination (MED)	> 5,000 m³/d	60-70 kWh/m³ thermal 1.5-2 kWh/m³ electrical	1.8-2.2 €/m³ (prospective cost)	advanced R&D
PV Reverse Osmosis (RO)	< 100 m³/d	brackish water: 0.5-1.5 kWh/ m³ electrical salt water: 4-5 kWh/ m³ electrical	brackish water: 5-7 €/ m³ salt water: 9-12 €/m³	applications/advanced R&D
PV Electrodialysis (ED)	< 100 m³/d	only brackish water: 3-4 kWh/ m³ electrical	brackish water: 8-9 €/m³	advanced R&D
Wind Reverse Osmosis (RO)	50-2,000 m³/d	brackish water: 0.5-1.5 kWh/ m³ electrical salt water: 4-5 kWh/ m³ electrical	units under 100 m³/d brackish water: 3-5 €/ m³ salt water: 5-7 €/m³ units about 1,000 m³/d: 1.5-4 €/m³	applications/ advanced R&D
Wind Mechanical Vapour Compression (MVC)	< 100 m³/d	only salt water: 11-14 kWh/m³ electrical	4-6 €/m³	basic research
Wave Reverse Osmosis (RO)	1,000-3,000 m³/d	pressurised water: 1.8-2.4 kWh/m³ 2.2-2.8 kWh/m³ electrical	0.5-1.0 €/m³ (prospective cost)	basic research

Source: ProDes

or demonstration projects. And this despite the fact that the renewable energies offer a wide variety of technologies for turning salty water into drinking water. Solar thermal energy and photovoltaics can be used to operate desalination systems, as well as wind power and geothermal or wave energy. The possibilities range from simple solar distillation units with a capacity of just a few litres per day up to wind-driven reverse osmosis systems for up to 2,000 m³. So far, reverse osmosis systems powered by PV modules have dominated. According to a ProDes count, about a third of all the regenerative desalination systems installed worldwide are based on this principle. No information is available, however, on the number of simple solar distillation units in operation. Hence, they are probably underrepresented in the list.

Matching the technology to the conditions

The desalination procedures can be classified into those that are thermally driven and those that are powered by electricity. The thermal procedures are methods of distillation. The systems evaporate water and subsequently condense the vapour. Because only the water evaporates, not the salt, the systems deliver distilled water. In order to be able to evaporate water, however, quite a lot of energy is needed: up to 200 kWh or the equivalent of 20 litres of petrol for 1,000 litres of drinking water. Therefore, many developers use multi-stage methods, which recover a large part of the vaporization heat in the following stage.

The German Solar Institute Jülich, for example, has developed a system for a small daily output, in which several evaporation pans are arranged above each other. The bottom stage of the desalination system simultaneously serves as the first stage of the evaporation column and as the collecting pan for the distillate. It is supplied with heat from solar collectors. The rising vapour condenses on the bottom of the next higher pan. There, the condensation heat generates vapour again, which in turn condenses on the next higher level etc. Also in the case of the concept of membrane distillation, which has been developed at the Fraunhofer ISE, the internal heat recovery reduces the specific energy demand. In this procedure, the heated salt solution is directed along a water-repellent, porous polymer membrane. Water vapour molecules penetrate it and condense on the other side. The condensation heat in turn serves to heat the brine that is fed to the system.

A less energy-consuming process is reverse osmosis, in which the salt ions of the sea water are separated using osmotic pressure. A high-pressure pump keeps the process running. This method requires a maximum of 5 kWh of electricity to desalinate 1,000 litres of sea water. Which technology is best to use, however, does not depend on energy input alone. Other factors that play a role are the salt content of the input water, the local infrastructure and the required volume of water. "The remoter the region, the more profitable it is to use regenerative systems and to establish a water processing facility that is independent of any external energy supply", explains Marcel Wieghaus of the ISE in Freiburg.

Initiative wants to establish an association

But until regenerative systems become a real option for sea water desalination, quite a few obstacles – social as well as political and technical – need to be overcome. In its report, ProDes lists a number of problems. They range from bureaucratic hurdles that prevent the implementation of independent, small-scale drinking water production, via the lack of financial support that might lower the barrier of the high initial investment, up to technical faults. For example, there is still a lack of technologies that are adapted to small-scale application, and a lack of suitable storage systems that would help smooth out the fluctuating energy supply from renewable sources.

In their report, the specialists discuss in detail the problems resulting from technology transfer from outside. Many an aid project in a rural community has failed because the initiators did not consider the local structures or, even worse, because the well-intentioned technology was perceived as a means of external control and as a loss of autonomy. According to the specialists, it is a basic problem that energy policy and water supply are seen as completely separate issues in many countries. For example, feeding electricity from regenerative sources into the grid is supported, but not the production of drinking water by means of renewable energies.


Desalination system set up by the Fraunhofer ISE in Mexico.

The specialists do not stop at simply an in-depth problem analysis. In their report, they make detailed proposals for solutions. Their top priority is an appeal to all the developers of regenerative desalination technologies to join forces. For example, they point out the necessity to coordinate research efforts. There is a need, for instance, to develop sea water resistant materials, as well as control technology for optimizing the operation of the systems. In order to get the message of the potential of regenerative sea water desalination across to society and politics, ProDes intends to establish a lobby organization before 2012. Such a step is definitely necessary. After all, it is planned to raise the market share of regenerative sea water desalination to 5 % by 2016.

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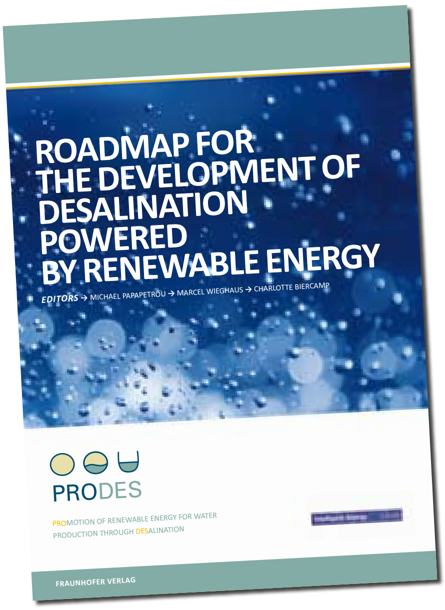
Further information:
www.prodes-project.org



In its study on sea water desalination, the EU initiative ProDes points out strategies to overcome legal, financial and political obstacles. Any interested person can download the report from the initiative's website, where information about workshops and an e-learning course on the topic are also available.