PRODES

Promotion of Renewable Energies for Water Production through Desalination

www.prodes-project.org

Commercial Desalination Products powered by Renewable Energy

Intelligent Energy Europe

January 2010

Acknowledgements

This publication has been produced as part of the ProDes project. The logos of the partners cooperating in this project are shown below and further information about them and the project is available on www.prodes-project.org :

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1 Introduction

Many regions of the world are increasingly turning to desalination of brackish and sea water in their effort to match the increasing demand with natural resources. The trend is intensified by climate change, which already seems to be affecting the water cycle resulting in long periods of drought.

The desalination industry has responded well to the increased demand, and is constantly evolving, reducing the costs and producing water of very high quality.

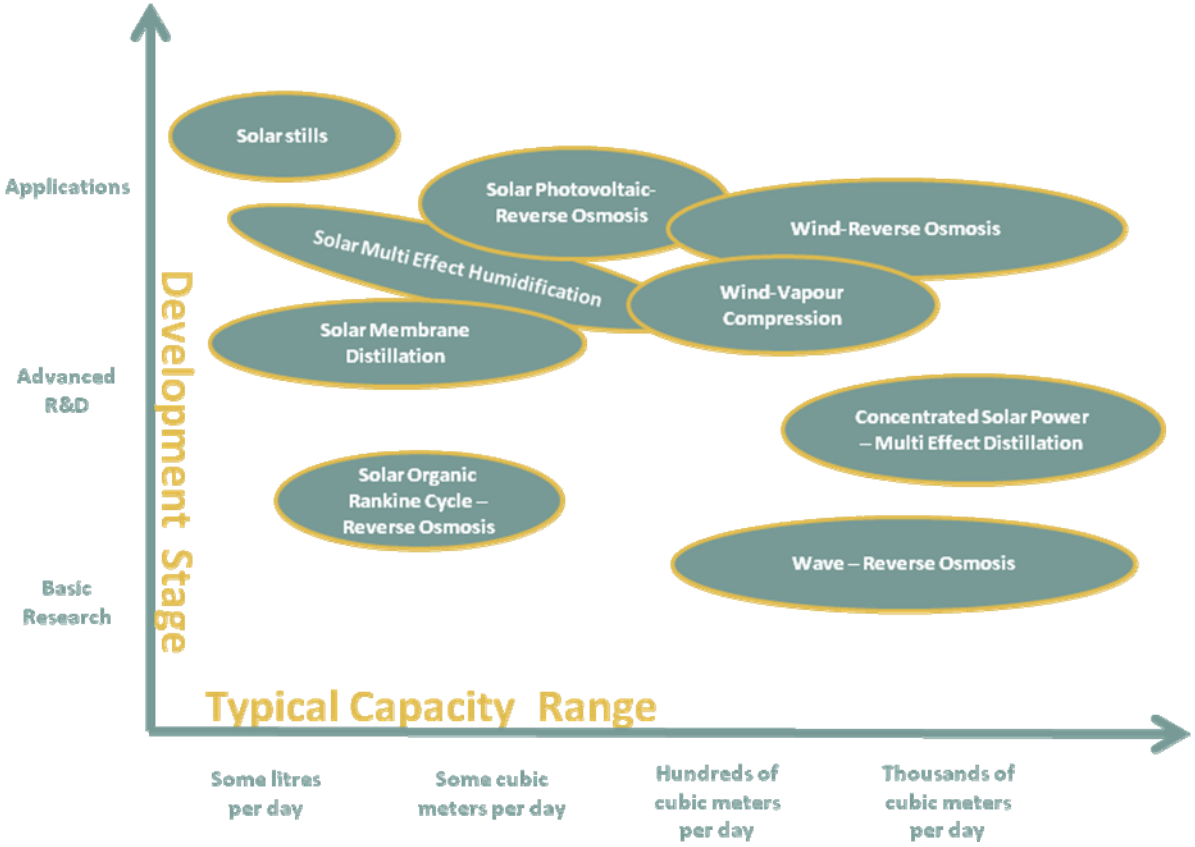
Most innovations focus on reducing the energy demand, since this is associated with the high operating costs. However, the physics of removing salt from seawater define the minimum energy that is needed to drive the process, which is not negligible.

As a result, when desalinating in order to solve the water problem, considerable amounts of energy will be always needed. And when conventional energy sources are used, they contribute to climate change which affects the water cycle, intensifying the original problem that desalination is intending to solve.

For desalination to remain a viable option in a world with a changing climate, renewable energy sources have to be used for powering at least part of its requirements. The scientific community has been working for decades on optimising technological combinations where the desalination process is powered by renewable sources; thermal energy, electricity or shaft power. The industry is also recognising the potential and various companies are active in this field.

There are several possible combinations of desalination systems with renewable energy. They are in various stages of technological development, while each one addresses different market segments. The graph on the next page gives a visualisation of the development stage and the typical capacity range for some common combinations.

This publication presents a small collection of examples with renewable energy powered desalination products that have demonstrated their capacity to operate in real conditions or in plants built for demonstration purposes. The aim is to help the development of the market that is still doing its first steps, by showing to a wide audience that there are various successful products that can cover the requirements of many different consumer groups. Of course this is not an exhaustive collection and there are many other companies doing great work in developing and offering similar products.



The products presented here are grouped in three different chapters. Chapter 2 presents three different distillation systems, all of them using directly the solar energy. The products presented vary from simple solar stills to more sophisticated devices, and in general are small-scale plants targeted to individual users, like families. Chapter 3 presents distillation systems also, but with more than one effects, which are powered indirectly from the sun with the use of solar collectors. These systems are more complicated but can also produce more water per module, targeting end-users with higher requirements. Finally, in chapter 4 the reverse osmosis systems are presented that have been quite popular over the past years because of the significant technological improvements. The size of these systems depends mainly on the energy source; smaller when combined with PV and larger with wind turbines. A mechanical vapour compression system powered by wind is also included in this chapter.

At the end of each chapter, the main technical characteristics of the products presented are summarised in a table.

This work has been developed within the ProDes project which is co-funded by the European Commission through the Intelligent Energy Programme. ProDes is supporting the market development of renewable energy desalination in Southern Europe through courses, seminars, publications and other similar activities. More information about the project, its partners and its results is available on its website: www.prodes-project.org.

2 Direct Solar Thermal Systems

The simplest and oldest technology to desalinate water is the solar still. It is basically a low "greenhouse" providing ideally, simplicity of construction and requiring very little maintenance. The principle of operation is simple, based on the fact that glass and other transparent materials have the property of transmitting incident short-wave solar radiation. This radiation is absorbed as heat by a black surface in contact with the salty water to be distilled. The water is thus heated and evaporates partially. The vapour condenses on the transparent cover, which is at a lower temperature because it is in contact with the ambient air, and runs down into a groove from where it is collected. Well-designed units can produce 2.5 - 4 l/m² of collector area per day. Solar stills are reliable and have long technical life, and the unit cost is estimated at 40-100 €/m² of collector area.

Beside the simple solar still, alternative systems and configurations have been developed to increase the productivity. For example the RSD solar technology developed an innovative absorption surface that maximises the productivity.

Building on the basic principle of the solar still, more elaborate configurations have been developed. The SolarDew technology for example utilizes an innovative non-porous/non-fouling membrane in a configuration which allows energy to be regenerated. This allows for the production of clean drinking water from seawater or other contaminated sources whilst maximizing energy performance and thus reducing the cost of water for the consumer.

2.1 MAGE WATER MANAGEMENT GmbH - Watercone®

Reference site

Type: solar still
Location: Yemen
Capacity: 1.5 l/d
Year of installation: 2007
Still in operation: yes

Type: solar still
Location: Yemen
Capacity: 1.5 l/d
Year of installation: 2007
Still in operation: yes

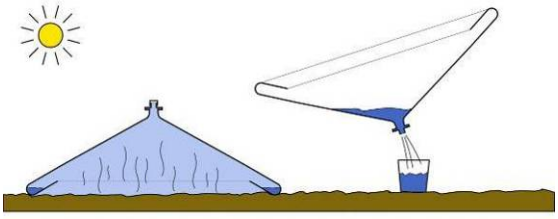
Product history

MAGE WATER MANAGEMENT GmbH has been active in the field of solar energy for more than 12 years. The company develops desalination systems driven by solar thermal energy.

Watercone® is the first cheap mass product in the solar desalination field. It can process any type of contaminated water and generates up to 1.7 litres of potable water per day.

Concept of the system

The Watercone is simple to use, robust, lightweight and is easily manufactured. The user pours saltwater into the base pan, floats the cone on top of the pan and waits for the sun's magnified heat to cause the water inside the cone to evaporate. The water condenses onto the inner walls of the cone and drops trickle down into a collection trough at the base. The desalinated water can then be poured out through a spout at the tip of the cone much like from a bottle. In addition to eliminating salt from seawater, the Watercone can also remove highly toxic elements such as mercury, arsenic or cadmium, similar to all distillation processes.



The Watercone can cover the daily need of drinking water for one person contributing to the Millenium Development Goal for global access to safe water. Its use is taught through a universal set of simple pictograms ensuring that there will be no language or literacy barriers to its wide application.

2.2 RSD Solar

Reference sites

Type: F8, 8 modules 1.25 x 1.25 m²
Location: Alexandria /Egypt
Capacity: average ca. 50-60 l/d
Year of installation: 2004
Still in operation: yes
Usage: drinking water for desert camp

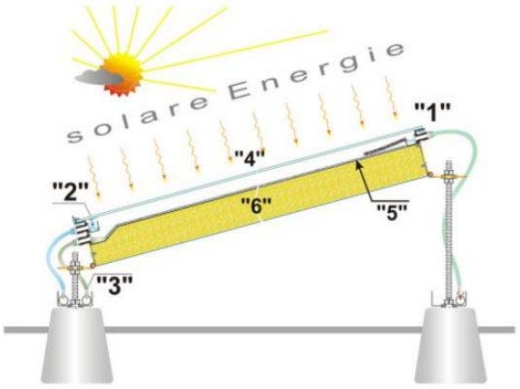
Type: F8, 6 modules 1.25 x 1.25 m²
Location: Cuba
Capacity: average ca. 40 l/d
Year of installation: 2006
Still in operation: yes
Usage: drinking water for a family

Product history

RSD solar /Rosendahl System develops and distributes solar powered installations for water treatment. Any type of water can be treated, but currently most applications are for highly polluted raw water as it occurs in tropical regions. RSD solar has long technical experience and many patents and the Water Agency adds a comprehensive scientific backup.

Concept of the system

The raw water flows through solar thermal collectors and is heated to 80 – 90 °C. About 50% of the raw water evaporates and immediately condenses at the glass cover and rinses out of the system. Because of the robust and inexpensive electronic raw water dosing system the raw water flow is always

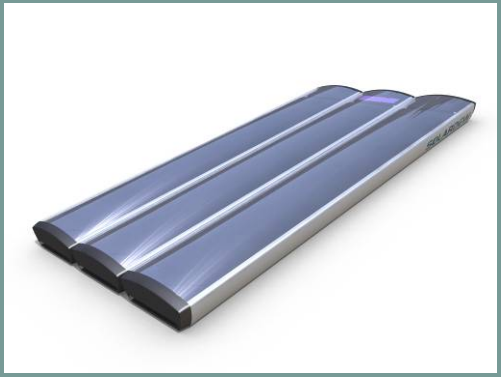


adjusted exactly to the intensity of the actual solar radiation.

The specially developed black absorbing fleece guarantees a large surface with an optimal energy input, while it is heat and UV stable. The technology is continuously improved. For example currently solar induced photochemical processes are integrated to degrade organic toxic ingredients.

2.3 Solar Dew International

Reference sites



Type: Solar Dew Two – Household application
Location: under development
Capacity 8.5-15 l/day
Year of installation: 2010 expected
Usage: Household pure water supply

Type: SolarDew One
Location: South West France
Capacity: 7-12.5 l/day
Year of installation: 2009
Still in operation: yes
Usage: drinking water production

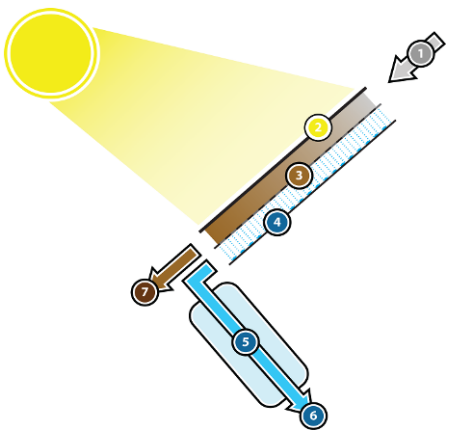
Product history

Based on the membrane developed by Akzo Nobel in 1999, SolarDew International has developed a water purification and desalination system. The membrane is non-porous and thus allows only water vapour to pass, whilst leaving behind other substances including salt, viruses and bacteria. This membrane is non-fouling and non-scaling making it suitable for a wide variety of applications within the water industry.

After SolarDew was taken over by a group of private investors in 2006 the focus shifted to providing a sustainable solution for the production of drinking water in regions where brackish water and sea water is abundant and fresh water is scarce. In addition, the technology is also well suited for regions with high levels of chemical contamination, such as arsenic.

Concept of the system

The SolarDew technology uses a unique non-porous membrane in a process called “pervaporation” to purify water. The feed water (1) when heated by the sun (2) evaporates inside the SolarDew panel and passes through the membrane as vapour (3). Contaminants, such as large organic molecules, and salts are left behind, and pure water condenses on the other side of the membrane (4). The produced water is then



stored (5) and is subsequently ready to be consumed as drinking water (6). The brine is removed separately through an automatic flushing mechanism (7). As a result of this process the system works with any type of saline water and any level of biological or chemical contamination. Of course, like in any distillation process, volatile chemicals, such as gasoline, may pass through the membrane.

Thanks to its triple-layer design, energy is regenerated, more than doubling the efficiency of conventional solar still technologies. As the sun heats the panel, residual heat from the top layer facilitates pervaporation in the second and third layers. Overall the technology is simple, low maintenance, versatile, efficient, safe and affordable.

This technology forms the basis for all SolarDew products incl. the SolarDew One and Two household systems and the WaterStation community systems.

The SolarDew One offers an affordable package which is exceptionally suited for people in regions with limited access to infrastructure. The SolarDew Two is the high tech version with increased performance and user comfort. Both systems are aimed at providing drinking water for families and through their compact and lightweight construction can be easily mounted on the roof.

The SolarDew Water Station is designed to offer larger daily production capacities to meet the needs of people who require greater quantities of water or even for small communities. The SolarDew WaterStation is a modular system with a variety of installation options and it can supply drinking water up to 5,000 litres per day at a lower cost than household models.

2.4 Summary of main technical characteristics

	2.1 Watercone	2.2 RSD	2.3 Solar Dew
Capacities available	1,5 l/d	6 l/m²/d average, scalable to any capacity required	Basic unit: 6-10 l/m²/day. Available products range between 4 and 5,000 litres/day
quality of produced water	Distillate	Distillate	Distillate
pre-treatment	None	Sieving/filtration needed when raw water has organic growth	Removal of sediment through a pre-filter and sedimentation.
post treatment requirements	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste
O&M requirements	Cleaning of the cone and the dish	Regular cleaning & rinsing of the collector surface, when dusty	The brine requires disposal at weekly intervals. After a minimum of 3 years the membrane modules need replacement - a simple task requiring a minimal amount of time

3 Indirect Solar Thermal Systems

Multiple stage basin stills have two or more compartments to recover a part of the condensing heat to heat up the water in an upper compartment. In wick stills the basin is tilted and the salty water is fed into the basin via wicks. Active solar stills are coupled to flat plate solar collectors and can be driven directly and indirectly and optionally with a heat exchanger. An example is the thermal desalination unit with a heat recovery system from the "Energy and environmental engineering office" (IBEU) and the Solar-Institut Jülich. The energy demand for the production of 1m^3 of fresh water is reduced to approximately 120-150 kWh due to the use of several stages in which the water is evaporated with the latent heat of each previous stage. About 15 to 18l of distillate can be produced per square meter collector area per day. Using a seven-layer unit specific energy consumption can be decreased (GOR = 4-5) while production rates decrease to 8kg/m²h. This technology was developed for capacities between approximately 50 and 5000l per day.

The **MED** process has been used since the late 1950s and early 1960s. Multi-effect distillation occurs in a series of vessels (effects) and uses the principles of evaporation and condensation at reduced ambient pressure. In MED, a series of evaporator effects produce water at progressively lower pressures. Water boils at lower temperatures as pressure decreases, so the water vapour of the first vessel or effect serves as the heating medium for the second, and so on. The more vessels or effects there are, the higher the performance ratio, but its number is limited to 15-20 depending on the process configuration due to practical and economical reasons.

Multiple Effect Humidification desalination units indirectly use heat from highly efficient solar thermal collectors to induce multiple evaporation and condensation cycles inside thermally isolated, steam-tight containers and requiring temperatures of between 70 and 85°C. By solar thermally driven humidification of air inside the box, water-vapour and concentrated salt solution are separated, because salt and dissolved solids from the fluid are not carried away by vapour. During re-condensation of the generated saturated humid air most of the energy used before for evaporation is regained and can be used in subsequent cycles of evaporation and condensation, which considerably reduces the thermal energy input required for desalination. Over the years, there has been relevant research carried out into MEH systems and they are now beginning to appear on the market. The thermal efficiency of the solar collector is much higher than for solar stills and the specific water production rate is in the region of 20 to 30 litres per m² absorber area per day.

The **membrane distillation** technology of SolarSpring GmbH uses a membrane that is permeable for vapour only and separates the pure distillate from the retained solution. typically operates at a temperature of 60-80°C. Due to the nature of the hydrophobic membrane it is less sensitive to biofouling and scaling. The process itself does not need a constant operation point as required in MED or MSF, which makes it attractive for intermittent energy supplies like the use of direct solar heat without heat storage.

3.1 IBEU, Solar Institut Juelich - AQUASOL

Product history

As solar energy utilisation involves high costs and requires large areas, an energy-saving technique has to be employed for solar seawater desalination. Two prototype models with a daily drinking water output of 50-60 litres were developed from the Solar-Institut Juelich (SIJ), the Aachen University of Applied Sciences and the "Energy and environmental engineering office" (IBEU). In the frame of the research project AQUASOL, co-funded by the German government and the partners, the systems have been tested and optimised under real conditions.

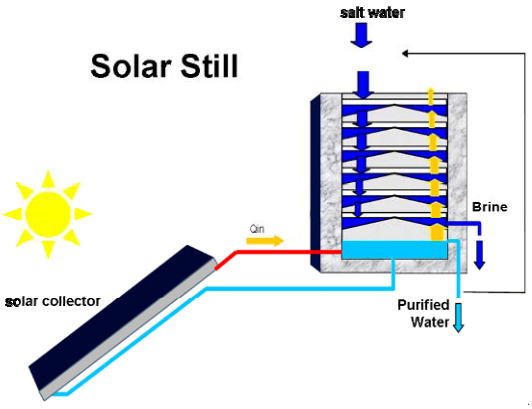
The intention is to license and market the new technology. Besides the test field in Gran Canaria, there were field tests at the Federal University of Ceara, in Fortaleza, Brasilia and in Bangalore (TERI), India.

Reference site

Type: Multi Stage Solar Basins
Location: India
Capacity: 50-60 l/day
Year of installation: 2005

Concept of the system

AQUASOL is a solar thermal desalination system conceived as a multi-stage evaporator unit. The use of a multi-stage design for the condensation processes allows a heat recovery mechanism of the condensing energy, which substantially increases the drinking water output rate.



A heat recovery tower uses multiple condensation trays, made of stainless steel and arranged one over the other. Each tray or stage recovers heat from the lower stage. Solar heat can be supplied by flat plate collectors, parabolic trough or evacuated tube collectors. Saltwater in the lower stage is heated up to 95 °C – 100 °C and evaporates (natural convection of humid air). The enthalpy of evaporation is released in the condensation process and is transferred to the above stage, heating the water there. This again drives evaporation-condensation in the next stage. This heat recovery process saves a substantial amount of energy when compared to the simple solar still. Depending on the number of condensing stages, the production rate can be improved by a factor of 3 to 5.

The system is self- adjusting and works without electrical energy. There are no moving parts and low maintenance requirements.

3.2 MAGE WATER MANAGEMENT GmbH- MEH-System

Reference sites

Type: Solar Thermal MidiSal™5000 Desalination System
Location: Dubai, 160 m^2 flat plate collectors
Capacity: 5,000 l/d
Year of installation: 2008
Still in operation: Yes
Usage: Drinking water for a desert camp

Type: Solar Thermal MiniSal™1000 Desalination System
Location: Cyprus, 45 m^2 flat plate collectors for the desalination system
Capacity: 1,000 l/d
Year of installation: 2007
Still in operation: Yes
Usage: For water losses in a local swimming pool

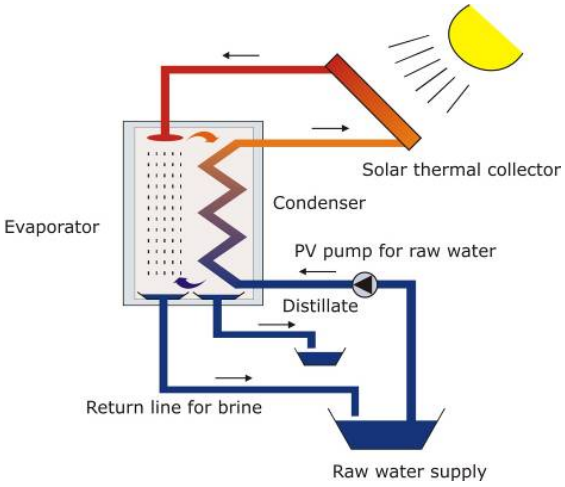
Product history

MAGE WATER MANAGEMENT GmbH has been active in the field of solar energy for more than 12 years. The company develops desalination systems driven by solar thermal energy.

The MEH-System is an efficient and economic solar powered saltwater desalination system for drinking water production in remote locations and it can be powered exclusively by renewable energies if desired.

Concept of the system

The MEH-desalination process developed by MAGE-Water Management is based on the evaporation of salt water and the subsequent condensation of the generated steam. The steam is completely clear and does not carry any solvents. After condensation, the water is clear and healthy.



Sea water is heated by the sun or by waste heat - transferred by highly corrosion protected heat exchangers. It enters an evaporation chamber made from high-grade corrosion free materials – very important for reliable long term operation. Herein the seawater

evaporates from efficient antibacterial fleece surfaces.

The generated humidity is fed into the condenser continuously – completely without any additional energy demand. Like in nature, natural convection enables the best performance in the water production process - optimized by the well engineered geometric collocation of surfaces within the module.

The desalination unit itself works without any mechanically moving parts, no valves or blowers are needed in the distillation chamber. This is the basis for extremely reduced maintenance demand and a continuous operation comprising very low electrical energy demand.

During condensation, the main part of the energy used for evaporation is regained applying materials with extremely low heat flux resistance.

3.3 TERRAWATER GmbH – Solar distillation

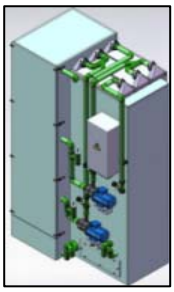
Reference sites

Type: Module TW 5
Location: Thailand, using industrial waste heat
Capacity: 5m³/day
Year of installation: 2009
Still in operation: yes
Usage: waste water concentration, RO brine, Pilot

Type: Module TW 5
Location: India, using industrial waste heat
Capacity: 5m³/day
Year of installation: 2009
Still in operation: yes
Usage: waste water concentration, RO brine, Pilot

Product history

Terrawater technology is based on the bypass patent from 2002 of Dr. Brendel. Since then several pre series modules were built and tested and new patents have been granted.

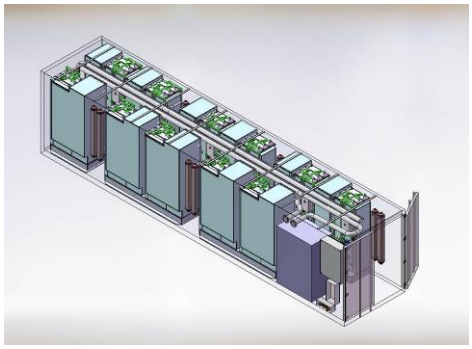


Terrawater produces potable- and process water (distillate) out of mostly all fluids (salt-, brackish- and waste water). Additionally it could be used for waste water concentration (Near zero liquid discharge). Thereby it uses waste heat from technical processes, geo thermal or solar thermal energy. Terrawater is based on the natural process of evaporation (water cycle). The system does not use any chemicals for the treatment of the raw water.

Due to its robust construction (fully out of plastic) Terrawater is also useful under bad conditions and there are no special materials needed for operation. Therefore it is extremely environmentaly friendly.

Concept of the system

Terrawater is based on the natural process of evaporation. By its patented bypass technology, its holds a lot of the thermal energy inside the system.



Terrawater is a modular system. The basic module TW5 produces 5 m³/day and has the dimensions of (WxDxH): 1.8 x 0.9 x 2.6 m. Several modules could be combined to units. The installation can be made in a building or in containers (e.g. TW55 = 40' Container = 55 m³/day). Beginning with a daily production capacity of 300 m³ the usage of the Tower is possible. This leads to a further

reduction of the water costs. The Tower needs a height of 8.5 m with the same footprint. The Tower is also available as a container solution.

In April and in July 2010, Terrawater will install 2 solar driven systems (one in Namibia, one in Egypt), each producing approx. 5 m³ during day time. Additionally, it is forseen to realize waste heat driven projects in the industrial sector.

3.4 SOLAR SPRING - Oryx 150

Reference sites

Type: Oryx150
Location: Tenerife, Spain
Capacity: 120l/day
Year of installation: 2007
Still in operation: yes

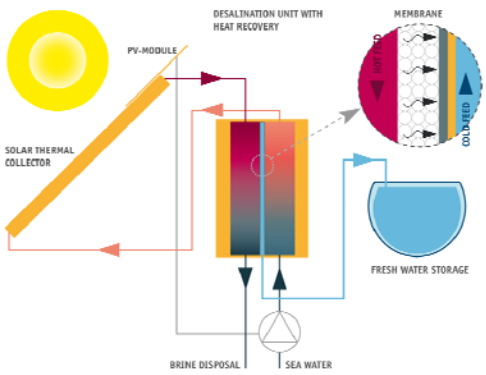
Type: Two-Loop System
Location: Gran Canaria, Spain
Capacity: 1800l/day
Year of installation: 2005
Still in operation: extension 3m³/day

Product history

Fraunhofer ISE started R&D in the field of solar thermally driven Membrane Distillation in 2001. The first field system was installed in 2004. To date a compact system called Oryx 150 and a two-Loop System, designed for larger capacities, have been developed. In total 9 systems have been installed so far. In 2009 SolarSping was established as a spin-off company for the further development and commercialization of the technology.

Concept of the system

The main components of the system are a 500 l feed storage, one MD module, a 6.7 m^2 sea water resistant solar thermal collector, a pump and a PV module. While the feed storage is mounted above the collectors, most of the hydraulic components are installed in a closed housing underneath the collectors. For the serial connection seawater resistant solar thermal collectors have been developed in cooperation with a partner company.



Membrane Distillation (MD) is a separation technique which joints a thermally driven distillation process with a membrane separation process. The thermal energy is used for phase changing of liquid water into vapour. Unlike membranes for reverse osmosis (RO), which have a pore

diameter in the range of 0.1 – 3.5 nm, membranes for membrane distillation generally have a pore diameter of 0.1 – 0.4 μm. The separation effect of these polymer membranes is based on their hydrophobic nature. This means that up to a certain limiting pressure, the surface tension retains liquid water from entering the pores, but molecular water in the phase of vapour can pass through the membrane.

To date 7 Compact Systems have been installed, four of them within the framework of two EU projects. The first system was installed in Pozo Izquierdo - Gran Canaria, Spain, in December 2004, others in Alexandria, Egypt in July 2005, in Irbid, Jordan in August 2005, and one in rural village in Morocco in September 2005. In December 2007 we set up another Compact System in Tenerife, Spain, this time with an improved new design. Another Oryx150 was installed in the Middle East in 2008. In 2010 its foreseen to install 4 more Oryx150 units as demonstration units to accelerate the local market in different regions. Moreover 3 Two-Loop systems are planned for 2010, this time with a daily capacity up to 5m³. Two of them will be 100% solar-driven and one hybrid driven with a combination of solar and waste heat.

3.5 Summary of main technical characteristics

	3.1 AQUASOL	3.2 MEH-System	3.3 Terrawater	3.4 Solar Spring
Capacities available	30-70 l/d 100- 250 l/d hybrid system Modular up to 5m³	MiniSal™ 1000 l/d MidiSal™ 5000 l/d MegaSal™ 10000 l/d MaxiSal™ 50000 l/d	TW 5 Modules up to 6000 l/d combining TW5 modules up to 500 m³/day	Compact System: 150 l/d Two Loop System: > 1,000 l/d
quality of produced water	Distillate	Distillate	Distillate	Distillate
pre-treatment	Use of a sand filter if necessary - depends on the feedwater	50 µm backwash Filter or sand filter	in some cases coarse filter < 1mm	Standard pre-filtration at 80-150 micron filter element depending on raw-water quality
post treatment requirements	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste
O&M requirements	plants can be cleaned by simple demounting of the condenser steel trays	cleaning of solar thermal collectors and PV (monthly) Backwashing of raw water filter if turbid raw water is used (weekly to yearly) Exchange of evaporation sheets (easy and cheap, every 1-2 years) Maintenance of circulation pumps (every 5 years)	Visual check every Month (water tightness) Change pumps and ventilator (every 3 years) Change humidifier material (every 5 years) cycles depending on raw water quality	Every 2 years acid and chlorine cleaning (depending on the raw water source) New MD-Module every 5 years, Pump every 10 years

4 Reverse Osmosis and Vapour Compression Systems

During the Reverse Osmosis (RO) process salt water is pressurized against a membrane. The membrane only allows water to pass, the salt remaining on the other side. For autonomous operation the RO process can be powered by PV, wind or a combination of the two.

The PV-RO system consists of a photovoltaic field that supplies electricity to the desalination unit through a DC/AC converter. Investment costs are relatively high, as is the case with most RE-desalination technologies, resulting in specific costs of drinking water in the range of 3.5 – 7 €/m^3 for brackish and 9 – 12 €/m^3 for seawater RO units, with the higher end of the range for systems with capacities below 5m^3/day. Despite these high costs compared to conventional large scale desalination plants, this solution is economically feasible in remote locations where the alternatives are limited and also expensive.

Both PV and RO are mature technologies and have a wide list of suppliers in many countries. Moreover, there are intensive R&D efforts to increase the PV conversion efficiency and improving the RO process. Also innovative combination topologies of PV-RO have been investigated in the last 3-4 years. Therefore, it is expected that costs of PV-RO systems will be reduced significantly in the future.

Wind energy has been used as a power supply to desalination systems, mostly reverse osmosis. In this case a wind generator is coupled to a RO plant by including batteries as a back up and a buffering system. The highly fluctuating wind power requires a control system adapting the energy requirements to the available wind and restricting or dumping the surplus wind energy in order to achieve a stable operation.

The cost of water produced by wind powered RO systems is in the range of 4 – 6 €/m^3 for small RO plants (less than 100 m^3/day), and estimated in 2 – 4€/m^3 for medium capacity RO units (1,000 – 2,500 m^3/day).

Vapour compression (VC) units have been built in a variety of configurations. Usually, a mechanical compressor is used to compress vapour, which generates heat. This heat is used for evaporation. Mechanical vapour compression (MVC) coupled to wind systems have also been developed, like the WME system presented in this publication. VC requires a minimum time to achieve the operating conditions.

4.1 Canary Islands Institute of Technology (ITC) – DESSOL®

Reference sites

Type: PV-RO for brackish water
Location: Morocco
Capacity: 1,000 l/h
Year of installation: 2008
Still in operation: yes
Usage: supply to local people

Type: PV-RO for brackish water
Location: Tunisia
Capacity: 2,100 l/h
Year of installation: 2006
Still in operation: yes
Usage: supply to local people

Product history

The Canary Islands Institute of Technology - ITC is a public body owned by the Canary Islands Government. This R&D institution has been researching renewable energy powered desalination systems since 1996. More than 10 different combinations have been installed and tested during this period, mostly focused on wind and PV technologies. One of the most outstanding results is an international patent of autonomous desalination systems - DESSOL® - based on an autonomous small reverse osmosis unit, which is 100 % powered by a solar photovoltaic field, including batteries. This kind of system has already been installed in places with a real necessity of drinking water: one unit in Tunisia (2.1 m^3/h) and four units in Morocco (3 x 1 m^3/h + 1 x 500 l/h).

Concept of the system

The concept of the system is an off-grid PV field supplying electricity to a brackish water or seaweater reverse osmosis plant (up to 5 m^3/h) through a DC/AC converter, with the support of a batteries bank, connected to the PV field by a charge controller.

Through the various applications for water supply in isolated areas, the system has been optimised for autonomous operation. In the brackish water examples illustrated in the pictures specific energy consumption between 0.53 and 1.7 kWh/m^3 have been achieved.

4.2 ENERCON GmbH – Wind RO

Reference sites

Type: Seawater Desalination System
Location: Greek Island
Capacity: 500m³/day
Year of installation: 1998
Still in operation: no, until 2004
Usage: Public water supply

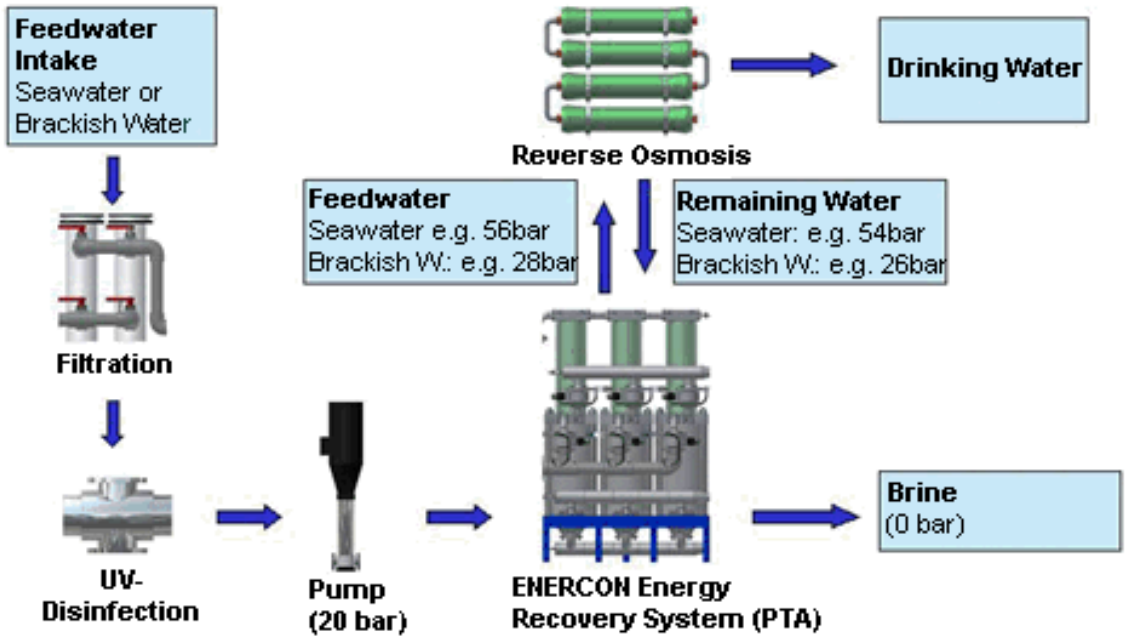
Type: EDS 1200 SW
Location: Aurich, Germany
Capacity: 1200m³/day
Year of installation: 2004
Still in operation: yes
Usage: Demonstration

Product history

ENERCON, as the leading manufacturer of wind turbines, sees a major challenge in improving water supply with the aid of regenerative solutions. Its product portfolio also includes self-developed RO desalination plants.

These plants can be operated via the public grid, by means of a wind energy converter or as a complete wind-diesel or stand alone system. The ENERCON energy recovery system guarantees very low energy consumption and a highly energy efficient connection to wind energy systems – without using any chemicals.

Concept of the system



a) Windturbines: The number of installed wind turbines: More than 13.000 in a range of 100 kW to 6 MW all over the world – also in very remote locations (e.g. Antarctica, Greek islands,…)

b) Wind-Diesel and Stand-Alone Systems: Based on Enercon windturbines and the Enercon Power Management System (PMS) the company offers solutions for fuel and cost savings in remote locations. These systems are designed for smaller communities. The connection of e.g. desalination system is possible. Enercon wind-diesel or stand-alone systems are installed in: Antarctica, Aurich, Falkland Islands, Bonaire, Utsira.

c) Desalination Systems: Enercon Desalination Systems (EDS) are specially designed for combination with wind energy – the Enercon Energy Recovery System is designed and optimized for fluctuating energy sources

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4.3 WME – Wind driven vapour compression

Reference sites

Type: wind-vapour compression
Location: Rügen Island, Germany
Capacity: 15 m^3/h
Year of installation: 1995
Still in operation: yes
Usage: drinking water

Type: wind-vapour compression
Location: Symi, Greece
Capacity: 20m^3/h
Year of installation: 2009
Still in operation: yes
Usage: drinking water

Product history

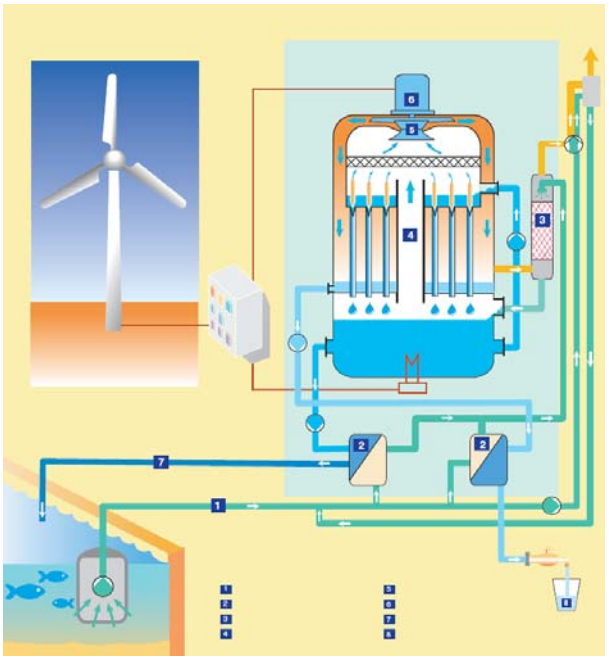
WME-Company was founded in 1997 and is based in Dranske on the Island of Rügen, Germany. WME concentrates on R&D activities in the field of desalination, especially by using renewable energies, like wind and solar. The company operates wind driven desalination plants to gather experience in the use of mechanical vapour compression for water desalination and waste water concentration.

WME owns the relevant patents and the wind driven desalination plant on the Island of Rügen in the Baltic sea. It consists of a 300 kW wind energy converter, the connecting transformer to the public grid and the mechanical vapour compression desalination plant with vertical evaporation-condensation tubes (type MVC-VT).

Concept of the system

The saltwater is first filtered and pumped into a reservoir. The saltwater passes through two plate heat exchangers, where the heat is transferred from the outgoing distillate and brine to the incoming saltwater. The pressure is reduced close to the evaporation pressure of the preheated saltwater by using a vacuum pump. The gases dissolved in the saltwater are removed by the vacuum pump and the degasified saltwater reaches the combined evaporator/condenser unit. A circulation pump distributes the water uniformly at the entry of the vertical tubes. This leads to a uniform falling film at the inner surface of the tubes. The evaporator and the condenser are a combined unit, because they consist of a common set of tubes. Saltwater evaporates at the wet inner surface of the tubes and the vapour is compressed from above the tubes by the compressor. At the outer surface of the

tubes the compressed and heated vapour condensates. The condensation heat of the condensating vapour transfers through the wall of the tubes and is used to evaporate an equivalent amount of preheated saltwater.



Due to the low evaporation temperatures (less than 85 °C) an increase of the vapour pressure of less than 100 mbar is enough to realize a temperature difference of 3 - 5 °C for the total heat transfer. This indicates an effective heat transfer through the walls of the tubes. Using the MVC process, only 2 - 3 % of the energy is needed which is necessary for the direct evaporation of saltwater.

The plant can be powered by electricity of the electrical grid, by mechanical energy of a diesel generator, by photovoltaic energy or by a wind energy converter.

The distillate production depends on the compressor speed and the evaporation temperature respective to the power required by the compressor. This value can be adjusted by the control panel.

The remineralisation can be achieved by dosing with the adequate minerals or blending with disinfected brackish water or saltwater.

4.4 Summary of main technical characteristics

	4.1 DESSOL	4.2 Enercon	4.3 WME
Capacities available	3.5-20 m^3/d	300 - 1,200 m^3/day	100 – 1000 m^3/day
specific energy consumption	BW: 0.53-1.7 kWh/m^3	SW: 2,5 kWh/m^3	7 – 13 kWh/m^3
quality of produced water	150-650 ppm	WHO/EU requirements	< 5ppm Remineralisation possible if required
pre-treatment	Physical: Sand filter + carbon active filter + cartridge filter Chemical: Sodium hypochlorite – Acid – Antiscaling	project specific	Raw filtration
post treatment requirements	Sodium hypochlorite	no	no
O&M requirements	Daily: Visual inspection, flushing the membranes Weekly: Cleaning the PV, chemical product stocks, cleaning the filters Monthly: Revision of leakages, batteries density Yearly: Checking the electric connections, batteries state, chemical cleaning of membranes; reposition of cartridges 4-5 years: change of membranes	Remote control system and fully automatic operation Care-taker on site for small O&M works is recommended Annual O&M by Enercon	Automatic operation, lubrication of bearings once a year

5 Company Contacts

Paragraph	Company name	Company address	Contact person	Email	Telephone
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