

DME S-006-2013 – Lecture 05



Stand Alone Driven Desalination Systems

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DME - Seminar **Key Solutions for Key Markets**

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Jeddah – Saudi Arabia



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Stand alone Solar Driven Desalination Systems



Fraunhofer Institute for Solar Energy Systems ISE



- Founded in 1981
- Largest solar research center in Europe
- Staff > 1300
- 2012 Budget about € 77 million
- 8 Areas of business
 - Energy Efficient Buildings
 - Applied Optics and Functional Surfaces
 - Solar Thermal Technology
 - Silicon Photovoltaics
 - Photovoltaic Modules and Systems
 - Alternative Photovoltaic Technologies
 - Renewable Power Supply
 - Hydrogen Technology

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Outline



- Introduction
- PV- driven Reverse Osmosis
- Thermally driven Membrane Distillation
- Conclusions

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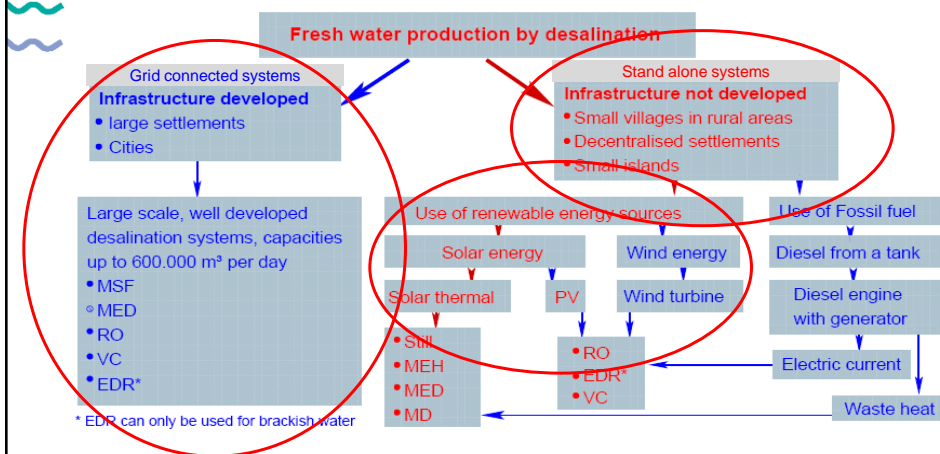


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Introduction



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Introduction

Stand alone systems

Use of renewable energy sources

Solar energy

Wind energy

Solar thermal

PV

Wind turbine

- Still
- MEH
- MED
- MD

- RO
- EDR*
- VC

Challenging approach because:

- Energy supply is not constant during the course of a year, during day and night time and during daytime even within seconds intensity can change
- Qualified technical staff for operation and maintenance is not available

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Introduction

Solar energy for desalination

Different approaches for the utilization of solar energy as the prime mover for desalination processes

Solar Radiation

PV

Solar Thermal Powerplant (CSP)

Solar Thermal Low Temperature Generation

Electricity

Electricity

Wst. Heat

Heat

Desalination

Filtration and Disinfection

Pumping

RO

ED

UF

MF

UV

Well / circul.

MSF

MED

VC

STIL

MEH

MED

MD

RO: Reverse Osmosis
ED: Electrodialysis
MSF: Multi Stage flash Distillation
VC: Vapor Compression
STIL: Simple Solar Stil
MEH: Multi Effect Distillation
MD: Membrane Distillation

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PV- driven Reverse Osmosis

PV- RO desalination systems for transient operation

Transient operation of RO systems:

- For stand alone applications without electrical storage (batteries are costly and have limited life time,...)
- As flexible load in grid connected systems with highly dynamic feed in from RE sources



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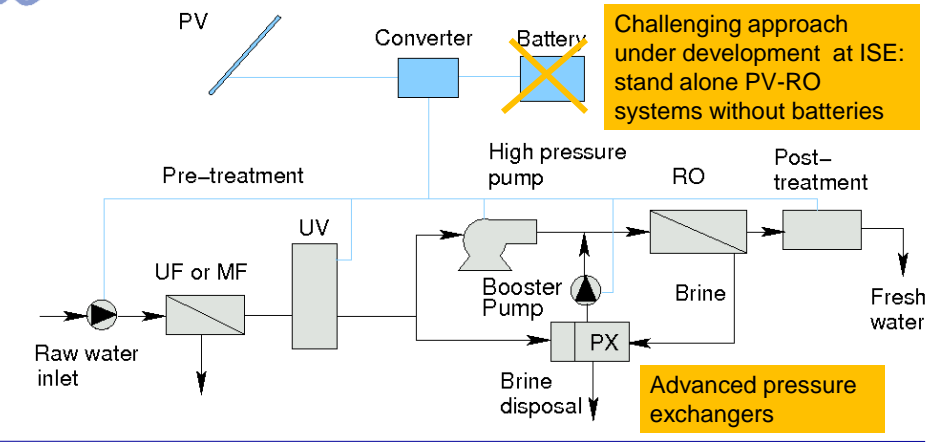
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PV- driven Reverse Osmosis

PV-RO - stand alone system configuration



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PV- driven Reverse Osmosis

PV Reverse Osmosis Desalination System for Cyprus

Technical Requirements:

- System dimensions:
 - daily water withdrawal 5 m³
 - system capacity 1.1 m³/h
 - Spec. Energy cons. 4.4kWh/m³
- Powered by photovoltaics
- No battery storage
 - dynamic and intermittent operation
 - good partial load performance
- With energy recovery
- Durable, long lifetime



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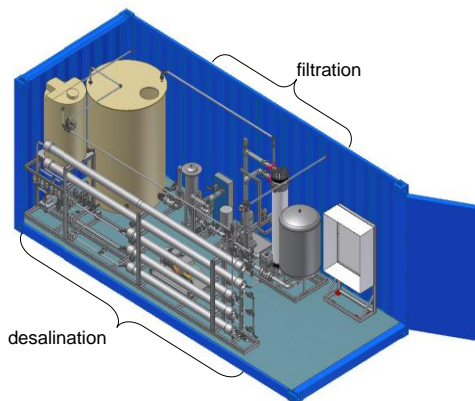
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PV- driven Reverse Osmosis

Plant design – hydraulic part




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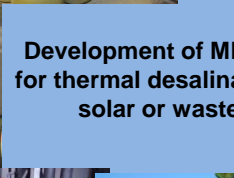
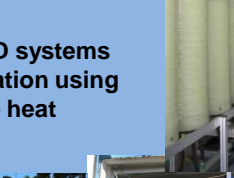





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Thermally driven Membrane Distillation

**Development of MD systems
for thermal desalination using
solar or waste heat**

Thermally driven Membrane Distillation

Driving forces in MD are established by a temperature profile across both membrane interfaces

The graph shows vapor pressure (bar) on the y-axis (0 to 1) versus temperature (°C) on the x-axis (0 to 100). Two curves are plotted: a blue curve for $S=0$ and an orange curve for $S=150$. The $S=0$ curve is higher, reaching 1 bar at 100°C. The $S=150$ curve is lower, reaching approximately 0.9 bar at 100°C. Vertical dashed lines are drawn at 80°C and 90°C. Horizontal dashed lines extend from the curves at these temperatures to the y-axis, labeled $\Delta p_{80-90, S=0}$ and $\Delta p_{80-90, S=150}$ respectively. The schematic on the right shows a cross-section of the membrane distillation process. A red block on the left is labeled 'Heater' and has a temperature T_h . A blue block on the right is labeled 'Condenser' and has a temperature T_k . A white porous membrane is in the center. The membrane has a thickness δ_1 on the heater side and δ_0 on the condenser side. The membrane is labeled 'Hydrophobic, micro-porous membrane, pore diameter 0.1-0.4 μm'. The temperature profile across the membrane is shown as a curve starting at T_1 on the heater side and ending at T_0 on the condenser side. The pressure profile is shown as a curve starting at P_1 on the heater side and ending at P_0 on the condenser side. The driving force for mass transfer is N_w (water vapor flux) and the driving force for heat transfer is Q_M (heat flux).

Hydrophobic, micro-porous membrane, pore diameter 0.1-0.4 μm

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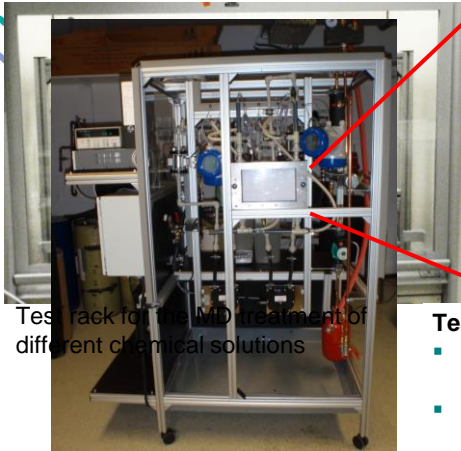
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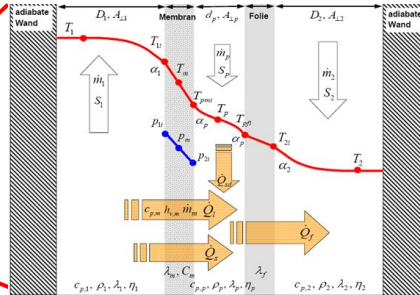


Thermally driven Membrane Distillation

Experimental test facilities – test cell



Test rack for the MD treatment of different chemical solutions



Test cell for membrane samples format A4

- All different MD configurations can be realized
- Characterization of membranes as service for membrane manufacturers
- Validation of single node simulation models

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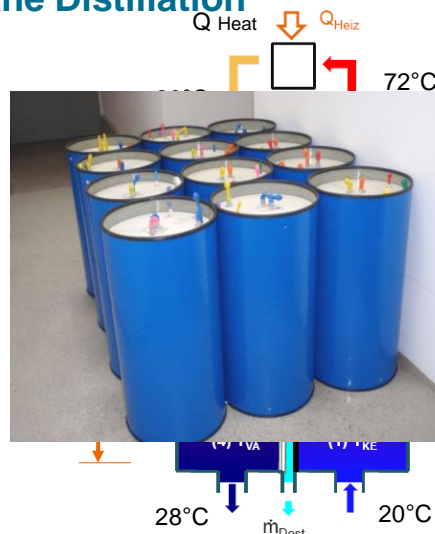
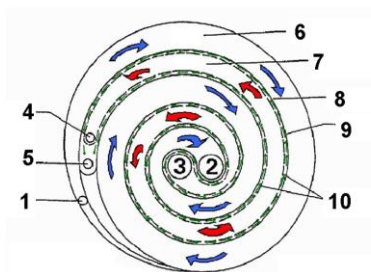
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Thermally driven Membrane Distillation

Configuration of spiral wound MD modules with internal heat recovery



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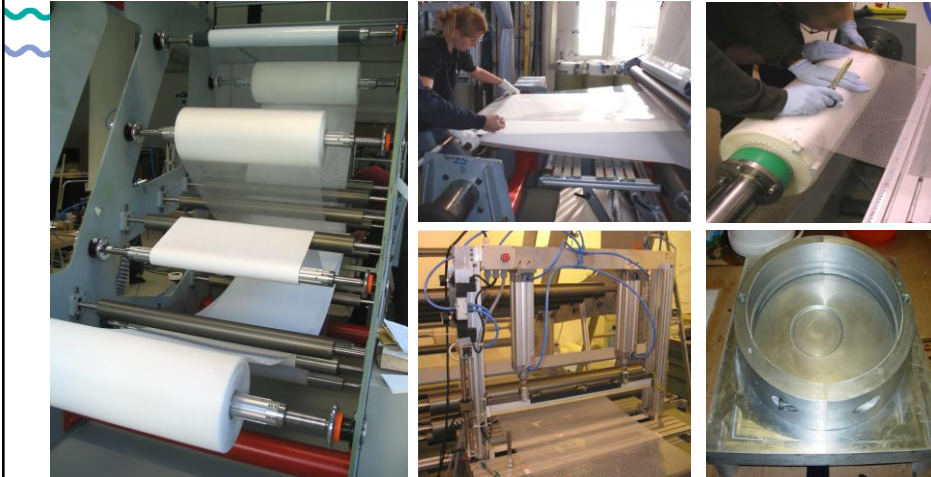
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Thermally driven Membrane Distillation

Production of spiral wound MD modules at ISE and SolarSpring



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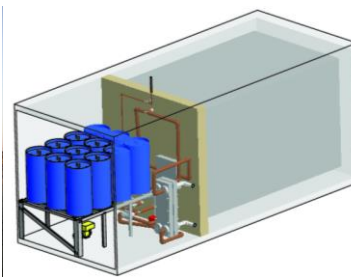
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Thermally driven Membrane Distillation

Development and operation of MD pilot systems in different locations

15 solar or waste heat driven MD desalination systems in the capacity range between 100 and 5000 l/day have been tested in the field since 2004



Gran Canaria Spanien

Solar field: 180m²

Capacity: 5(3)m³/day

Pantelleria Italien

Waste heat

Capacity: 5m³/T

Amarika Namibia

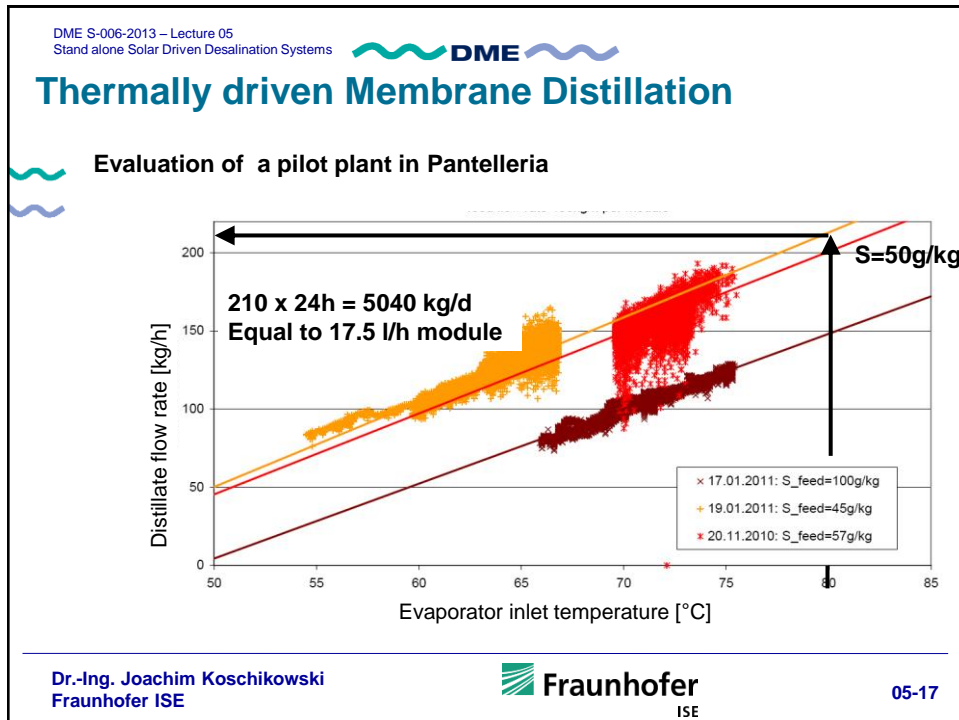
Solar field: 225m²

Capacity: 5(3.5)m³/T

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Conclusions

- All desalination technologies have advantages and disadvantages and must be chosen with respect to particular boundary conditions
- Small and medium size stand alone, solar driven desalination systems are still under development
- Long term experience for realistic life time estimations are not available but are important with respect to realistic water production costs
- Solar driven desalination systems are almost not on the market because they are considered as “too expensive” but there is a huge demand
- Cost savings due to decentralized production must be considered more carefully for the comparison of water production costs (no transportation, no grid, no subsidies for conventional energy,...)

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Thank you for your attention



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