

Αυτόνομα συστήματα αφαλάτωσης με ΑΠΕ - Δραστηριότητες του ΓΠΑ

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Presentation Structure

1. Introduction and Desalination in the world
2. Desalination technologies
3. Renewable energies and desalination
4. Wind, solar PV, solar thermal
5. Conclusions

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Introduction

- Water is an essential component of the life support system
- Why go for desalination?
 - Lack of water resources
 - Deteriorating quality of fresh water sources
 - Reduced cost of water produced by desalination
 - Security of supply
- Source of water for desalination
 - Brackish water
 - Seawater

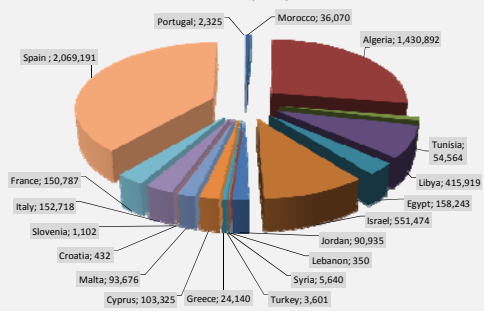
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Desalination should be the ultimate solution

- Water saving, especially in agriculture, e.g.
 - New water irrigation methods
 - Water distribution networks - maintenance
- Surface water collection at regional and local level (houses)
- Motivation of renewable energy driven desalination

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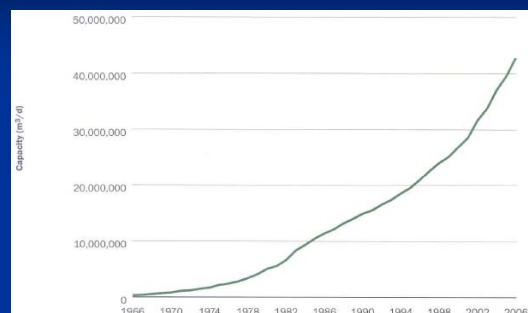
Desalination production capacity in the
Mediterranean countries in 2006
values in m³ per day



Source: MEDRC, Koussai 2008, ADIRA workshop Athens

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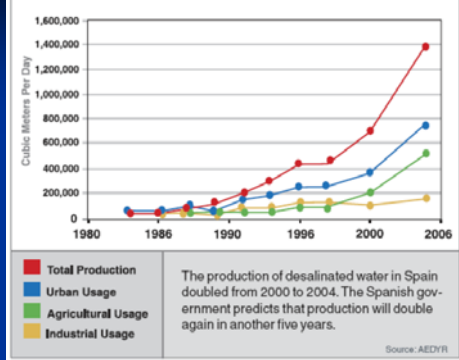
Global installed capacity since 1966



Source: MEDRC Koussai 2008, ADIRA workshop Athens

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Use of Desalinated Water in Spain



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Desalination processes

- Desalination Processes
 - Thermal - needs thermal and electrical energy
 - Membranes - needs electrical energy only
- *Both are energy intensive, accounting for 40-75% of the operating cost*

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Energy requirements

- It is the energy needed to get fresh water from saline water
- Depends on the technology (specific energy consumption kWh/m³)
- Increases as salinity increases

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Thermal desalination

- Normally, source of energy is fossil fuel
- Energy required to heat pure water from 25 °C to boiling at 100 °C and then evaporate to produce 1 m³ of pure water is over 700 kWh
- Ways to affect this requirement
 - Use multi-stage concept to recover energy from condensing steam and hot brine leaving plant
 - Use low quality energy. Low grade steam from power plants (dual purpose plants)

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Thermal desalination

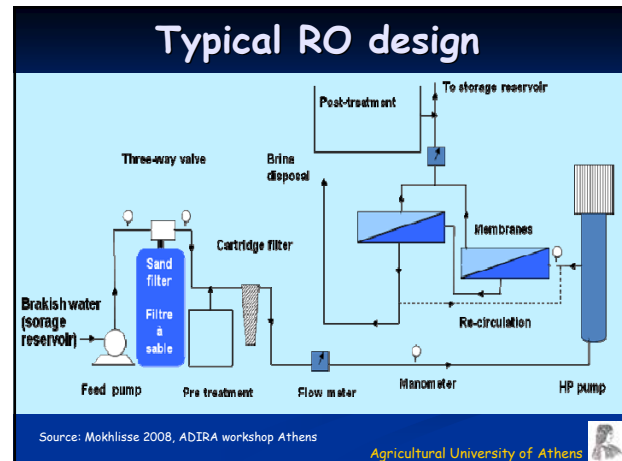
- Processes with multi stage concept to reduce energy consumption
 - Multi Stage Flash (MSF)
 - Multi Effect Distillation (MED)
 - Vapor Compression (VC)

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Membrane processes

- Thermal processes involve phase change (evaporation) high energy requirements
- Need to produce water without involving phase change to reduce energy consumption
- Two processes emerged: Reverse Osmosis and Electrodialysis. RO is predominant

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Reverse osmosis

- Energy consumption initially high, $\rightarrow 12 \text{ kWh/m}^3$
- How to reduce energy consumption ?
- Major method \rightarrow Recover energy from reject brine with energy recovery devices

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Energy recovery

- Recuperation of energy from brine with the maximum efficiency:
 - 55 - 75% of pressurized feed water leaves the system with about 60 bar pressure in the concentrate stream
 - High pressure concentrate is fed into recovery devices where it produces a rotating powerful output. Energy recovery systems lead to energy savings up to 40%

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Energy recovery

- Turbo-machine systems, e.g.
 - Reversible Pumps
 - Pelton Turbines
- Volumetric Systems, e.g.
 - ERI (Pressure Exchanger)
 - Axial Piston Pressure Exchanger Pump (LATEST)

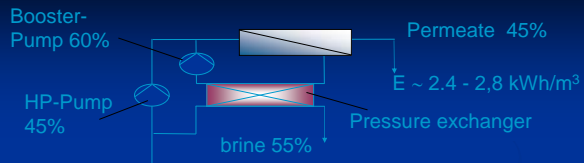
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Energy recovery - turbine

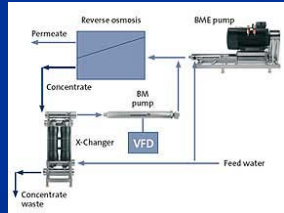
The top part of the image shows a schematic diagram of an energy recovery turbine system. It features an 'HP pump' (100%) and a 'Turbine' (55% reject). The 'Permeate' (45%) is shown as a separate stream. The energy recovery is quantified as $E \sim 3.5 \text{ kWh/m}^3$. Below the diagram are two photographs: one of a large industrial turbine unit and another of a smaller, more compact turbine component.

Source: Zaara 2008, ADIRA workshop Athens
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Energy recovery - pressure exchange

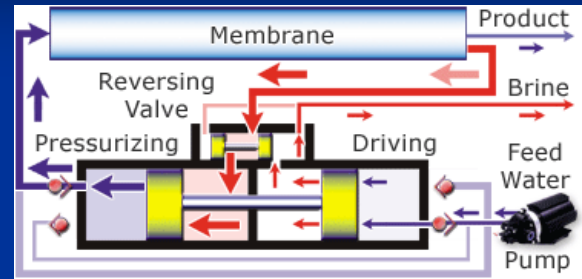


Source: Zaara 2008, ADIRA workshop Athens



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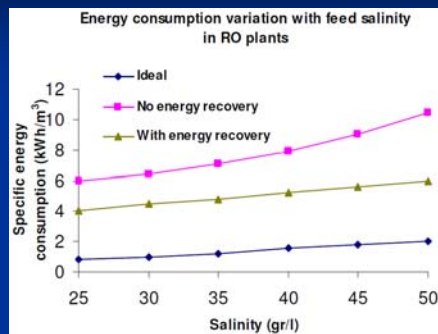
Hydraulic energy recovery



Source: Spectrawater

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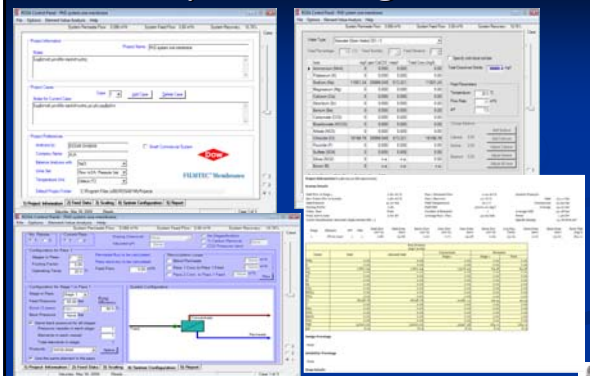
Reverse osmosis



Source: Mohamed 2009

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RO system design tools



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Desalination and renewables

- Attractive to **reduce dependence on fossil fuels and CO₂ emissions**
- Capital costs still high
- Operating costs very low
 - Solar thermal systems, photovoltaic, wind, wave, and geothermal can provide thermal, electrical or mechanical energy
 - Can be used in remote and rural areas for small scale applications
 - Can be used for medium scale plants
 - True but commercialization is forthcoming

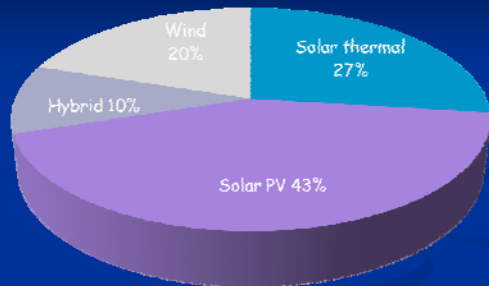
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Desalination and renewables

- Most attractive renewable energy sources
 - Wind energy
 - Solar energy (photovoltaics and solar thermal collectors)
 - Geothermal energy

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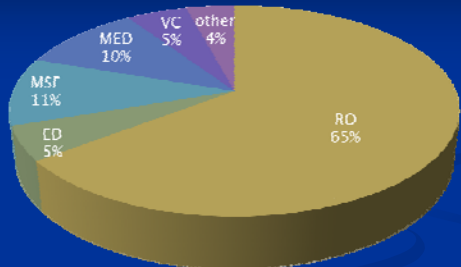
Desalination and renewables



Source: Mathioulakis et al. 2007

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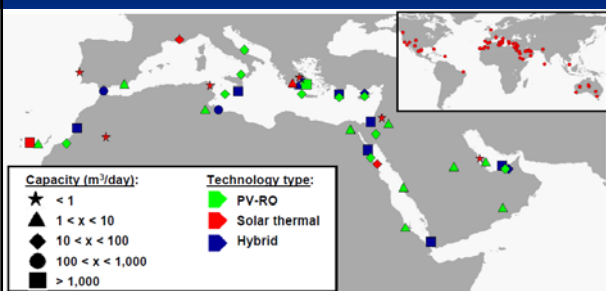
Desalination and renewables



Source: Mathioulakis et al. 2007

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Solar-driven RO desalination systems: geographical distribution and type in Mediterranean and MENA countries, and worldwide



Source: Ghermandi & Messalem, DWT 2009

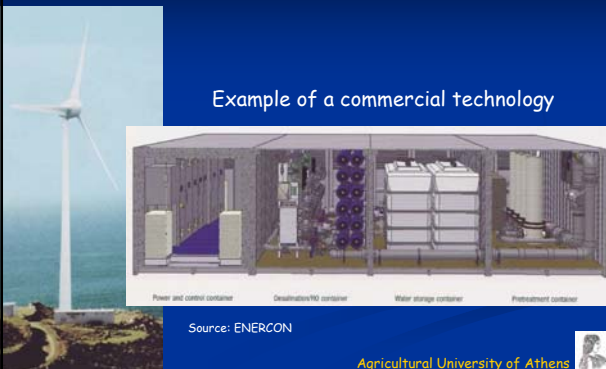
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Desalination and renewables

- Wind energy
 - Electricity production to power reverse osmosis
 - Problems with the variation of the wind power production - need for storage and power regulation

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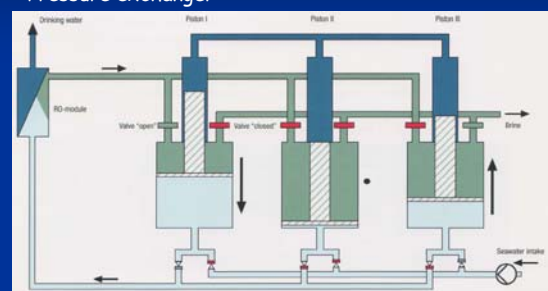
Desalination and wind energy



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Desalination and wind energy

Pressure exchanger



Source: ENERCON

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Solar Energy and RO

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graph TD; SolarEnergy([Solar Energy]) --> PV([PV]); PV --> Electricity([Electricity]); Electricity --> MechanicalWork([Mechanical work]); MechanicalWork --> Membranes([Membranes]); Membranes --> Product([Product (fresh water)]); Product --> Evaporation([Evaporation]); Evaporation --> Heat([Heat]); Heat --> Collectors([Collectors]); Collectors --> SolarEnergy; Heat --> RankineEngine([Rankine engine]); RankineEngine --> MechanicalWork; RankineEngine --> Heat
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The diagram illustrates a closed-loop system for solar energy and reverse osmosis (RO). It starts with Solar Energy (teal oval) which feeds into PV (blue oval). PV produces Electricity (blue oval), which is converted into Mechanical work (blue oval). Mechanical work drives Membranes (blue oval) to produce Product (fresh water) (teal oval). The Product is then processed by Evaporation (orange oval), which feeds into Heat (orange oval). Heat is used by Collectors (orange oval) to regenerate Solar Energy, completing the solar loop. Additionally, Heat is used by a Rankine engine (red oval) to produce Mechanical work, creating a secondary power loop. The Rankine engine also feeds back into the Heat source.

Source: Manolakas 2007

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PV and RO

Photovoltaic panels

P.1
P.2
P.3

Battery Charge controller

dc

Inverter

230V/50Hz

Batteries

High pressure Pump
Feed water pump
Desalination pumps
Microcontroller control
Loging

Source: Mokhlisse 2008, ADIRA workshop Athens

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[illegible]

AUDESSY Decision Support Tool

AUDESSY ANALYSIS

Introduction to AUDESSY ANALYSIS

AUDESSY has been developed by the Agricultural University of Athens within the framework of the ADSS project, which is co-funded by the European Union.

The goal of the Decision Support Tool is to introduce the idea of water distribution powered by renewable energy sources and to assist the user in selecting the optimal combination and size of desalination system and renewable energy source according to the user's not only the expert, but also to people with much less expertise.

- Help Pages
- Save project
- Create new project

User Guide

Technical assistance

Help with this

- **AUDESSY** is a comprehensive **DST** for sizing and cost analysis of ADS

- On line data base & handbook for operators & installers


- AUDESSY was developed by AUA and it can be freely downloaded at: www.adira.gr

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The ADIRA HANDBOOK

- The ADIRA **HANDBOOK**: A guide to Autonomous Desalination Concepts
- A guide to decision makers, project developers and interested end users for the implementation of renewable energy driven desalination systems
- Designed for the non-specialist / non-engineer
- Provides instructions for planning, installing and maintaining of ADS and ready made material for training local users

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Autonomous PV-RO (Msaim Morocco)



- System type: BWRO
- PV power: 3 kW_p
- Water production Capacity: 1 m³/d

Source: ADIRA project

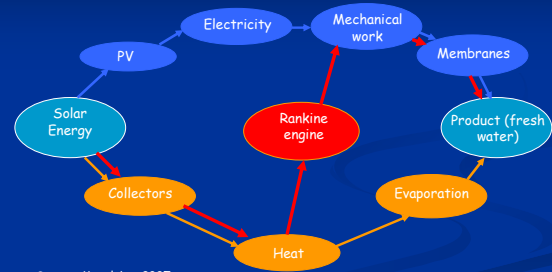
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ADIRA project (MEDA)

Country	System type	Use
Cyprus	Humidification/Dehumidification	Eco-tourism
Turkey	PV-RO	School
Turkey	PV-RO	Tourism
Jordan	PV-RO	School
Morocco	6 PV-RO systems	Rural villages

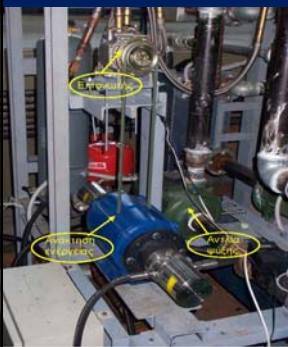
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Solar Energy and RO



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Solar organic Rankine RO



Source: Manolakas 2007

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Desalinated water as energy storage in mini-grids

- RO desalination is an attractive technology of storing energy in the form of water
- It offers possibilities of increasing renewable power penetration in weak autonomous grids (mini-grids) such as those of the Greek islands
- Excess electricity produced from renewables can be used to desalinate water

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Hybrid system (PV+wind+FC) and microgrid with RO



Source: Mohamed 2009

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A microgrid system in Egypt



Source: HYRESS project 2009

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Storage: Batteries and water



Source: HYRESS project 2009

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What about the costs ?

- Wind powered RO desalination can be competitive at good wind potential
- Even PV driven RO desalination is competitive to transported water in the Greek islands
- Geothermal energy fits well to thermal desalination methods

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Are there any environmental effects ?

- Yes
 - Energy use
 - Brine disposal

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Conclusions

- Desalination increases at dramatic rates due to fresh water demand and decreasing production cost
- Carbon foot print of desalination will increase. Need for measures to be introduced for RE application
- Commercialisation of renewable energy driven desalination has just started
- Environmental problems can become significant especially in closed seas - research is necessary
- Research should continue for developing further the combination of renewable energy technologies with desalination technologies and reduce costs

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Thank you for your interest

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