PV Membrane Procceses

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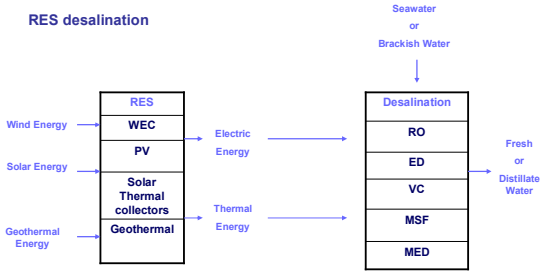
Lecturer: Eftihia Tzen
Wind Energy Sector
Email: etzen@cres.gr

Part of the presentation is prepared with the contribution of PRODES partners

RES desalination



RES Desalination coupling

- Technical feasible
- No significant technical problems have been encountered
- Alternative for the production of fresh water in areas with lack of electric grid
- Economical competitive in remote areas
- Suitable for small and medium scale applications
- Several applications exist
- The majority are stand-alone application
- The majority are pilot/demonstration plants

Promising Technologies Combinations

RES	MSF	MED	VC	RO	ED
WEC			√	√	
PV				√	√
Solar Thermal collectors	√	√			
Geothermal	√	√			

Other RES Desalination Combinations

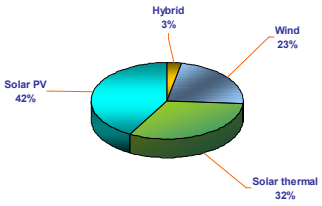
- Solar stills
- Solar Membrane Distillation
- Solar Humidification - Dehumidification
- Solar Ponds
- Reverse Osmosis – Wave Energy

RES - Desalination Selection Parameters

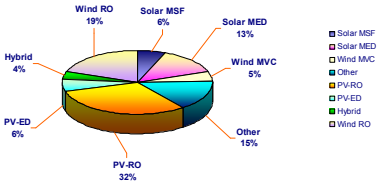
The choice between the different possible couplings mainly depend on the:

- availability of water resources (quantity and quality)
- water demand
- energy requirements and
- energy resources (RES) availability
- size of the system
- land availability and cost

RE Sources for desalination



RES Desalination installations



Solar energy (Photovoltaics) – Membrane Processes Applications

PV / RO Plant (1)

RO Capacity: 3+2 m^3/h (120m^3/day)
Feed water: seawater
PV Nominal power: 100 kWp
No of modules: 2,272
Battery Capacity: 2×2000 Ah

Lampedusa island, (1990)
ANIT, Italy

Source: UNESCO, Morris R.

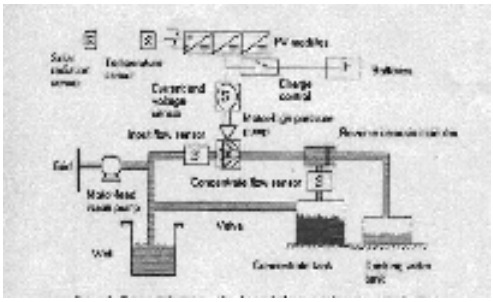
PV / RO Plant (2)

RO Capacity: 0.25 m^3/hr, (6 m^3/day)
Feed water: brackish water
PV Nominal power: 1.1 kWp
No of modules: 20
Battery Capacity: 100 Ah
Spec. Energy Consumption: 4.7kWh/^{3}

Source: DEE-UFC.

Ceara, Brazil,
DEE-UFC, Brazil (2000)

The plant consists of 20 PV modules of 55Wp each, totally 1.1kWp, 8 batteries of 12V, 100 Ah and a charge controller.
The RO unit has a water capacity of 250 l/hr. The pressure of operation of the RO unit is of about 8 bar working in a recovery ratio of 27%.



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Promotion of Renewable Energy for Water production through Desalination

PV / RO Plant (3)

RO Capacity: 0.4 m³/h (9.6 m³/day)

Feed water: seawater, 35,000 ppm TDS

P_{op}: 55 bar

Recovery Ratio: 45%

2 pressure vessels in parallel with 6 membranes each.

PV Nominal power: 4.80 kWp PV

No of modules: 64, mono-crystalline

Battery Capacity: 19 kWh

Source: ITC

Pozo Izquierdo, Gran Canaria
ITC, Spain (1998, 2000)
DESSOL Project

The total installed power of the RO unit is 3 kW, (HPP : 2.2 kW, membrane cleaning pump: 0.75 kW) and the specific energy consumption is 5.5 kWh/m3. The unit operates on an average of 9 hours during summer and 7 hours during winter.

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Promotion of Renewable Energy for Water production through Desalination

PV / RO Plant (4)

RO Capacity: 62 lt/h

Feed water: brackish

PV Nominal power: 540 Wp

Battery Capacity: no battery

Source: ITN

ITN Energy Systems, Inc. Nevada, Colorado (2002/3)

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Promotion of Renewable Energy for Water production through Desalination

PV / RO Plant (5)

RO Capacity: 3.4 m³/h

Feed water: brackish (3500-4000ppmTDS)

PV Nominal power: 16 kWp

Battery Capacity: 73.44kWh

Source: NERC

Aqaba, Jordan
(2004/5)

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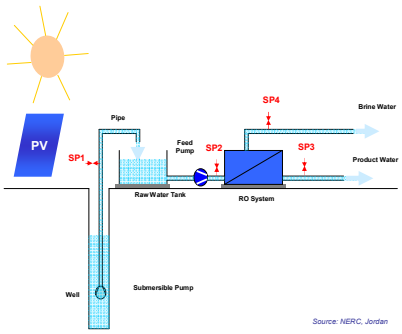
Promotion of Renewable Energy for Water production through Desalination



Source: NERC, Jordan

PV RO Aqaba plant

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Promotion of Renewable Energy for Water production through Desalination

Aqaba PV RO plant Description

High potential of solar energy on the site. The annual daily average of solar radiation on a horizontal surface reaches 5.5 kWh/m²/day.

The PV power supply system consists of the following main components:

- A PV generator with a total peak power of 16.8 kWp, 140 silicon mono-crystalline PV panels each rated at 120 Wp.
- A battery bank with a total storage capacity of 73.44 kWh. The battery bank consists of 24 sealed lead acid batteries each rated at 12V / 255Ah. The battery bank is configured as 6 parallel strings with 4 series batteries in each string to obtain the required system DC voltage (48 V).
- Charge controllers prevents the batteries from overcharging.
- Three inverters are installed to obtain a three-phase power supply (380 V / 50 Hz) which will energize the electric loads.
- The system operates as a stand-alone power system, independent of the utility grid. When the system is no longer able to keep up with the power requirements of the ac load, the inverters connected to the utility grid.

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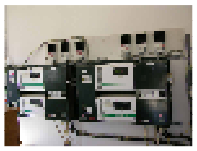
Fresh Water Production: 50 m³/day (18250 m³/year)

Total Required Electricity: 180 kWh/day (65.7 MWh/year)

Total PV Produced Electricity: 84 kWh/day (30 MWh/year)

Total Required Grid Electricity: 96 kWh/day (25 MWh/year)

Energy Consumption: 3.6 kWh/m³



Source: CRES

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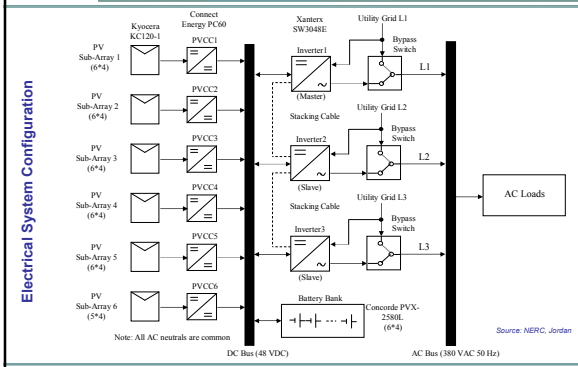
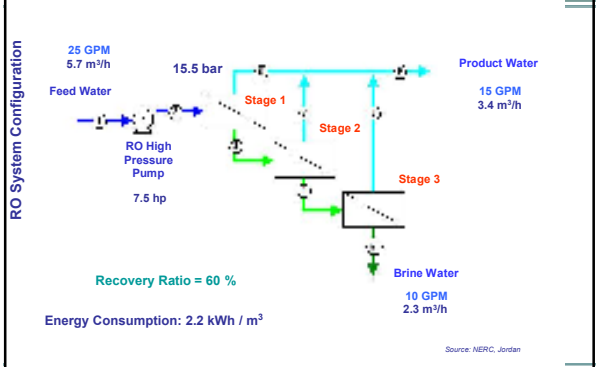
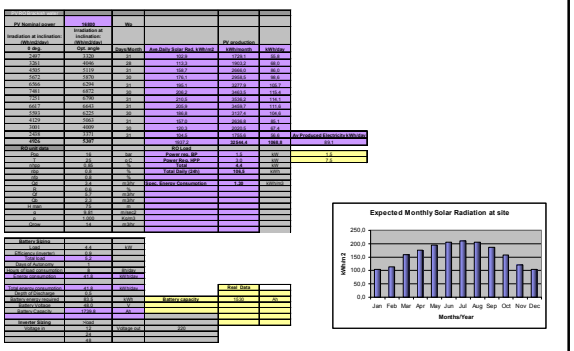


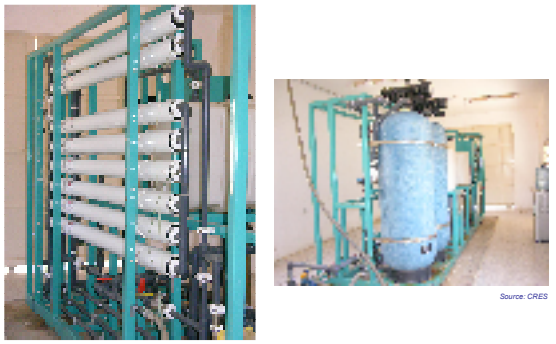


TUTORIAL

PV RO Aqaba plant

Brackish Water Desalination





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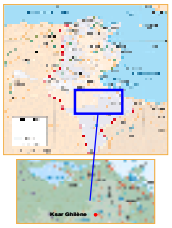
Promotion of Renewable Energy for Water production through Desalination

Autonomous PV-RO unit in Ksar Ghilene, Tunisia (since 2006)

- The village of Ksar Ghilène 1st African location with 2 years operating PV-RO system.
- 300 inhabitants with no access to electric grid (nearest at 150 km) or fresh water.



Building partially underground (in summer T > 50 ºC)
PV power 10.5 kWp.

Operating more than 3,100h producing 6,000 m³ of drinking water in 27 months.

Raw water salinity 3.500 mg/l.

2.1 m³/h BWRO plant Dessol®.

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Promotion of Renewable Energy for Water production through Desalination

PV-RO: CASES OF STUDY. KSAR GHILÈNE

Design parameters:

Water consumption:	15 m³/day (summer)
Average Global Horizontal radiation per year:	5,6 kWh/m²
Ambient temperature:	0 – 60 ºC
Salinity of brackish water:	~ 3500 mg/l
Temperature of brackish water :	28 – 35 ºC

Equipments of the installation:

Photovoltaic field:	10,5 kWp
Batteries:	660 Ah/C10 of capacity at 120V_{DC}
Charger- Inverter:	10 kW
Desalination plant :	50 m³/day (2,1 m³/h)
Recovery:	70%

Source: ITC

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Promotion of Renewable Energy for Water production through Desalination

PV-RO: CASES OF STUDY. KSAR GHILÈNE

Design & operational data

	Water production (m³)	Days of operation	Hours of operation
TOTAL Since June 06	4,565	483	2,370.6
1º year	2,537	281	1,356.5
2º year (Until March, 2008)	2,028	202	1,014.1
Mean 1º year	6.9 m³/day	23.4 days/month	3.7 h/day
Mean 2º year	7.4 m³/day	22.4 days/month	3.7 h/day

	Design	Real
Water production (m³/year)	4,200-4,500	2,537
Days of operation/year	320-350	281

1º year: July 06-June 07
2º year: July 07-March 08

	Summer		Winter	
	Design	Real	Design	Real
Hours of operation/day	7	4.25	5	3.3

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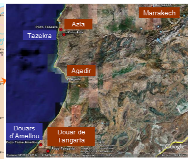
Promotion of Renewable Energy for Water production through Desalination

PV-RO: CASES OF STUDY. MOROCCO

Autonomous PV-RO units in Morocco (since 2008)

- Four PV-RO systems installed in 4 locations of Morocco.
- Raw water is brackish water from inland wells (salinity 2.500 – 8.700 mg/l).



Dessol®.

1 m³/h RO unit

Co-funded by EU, MEDA-water programme

4 kWp PV field

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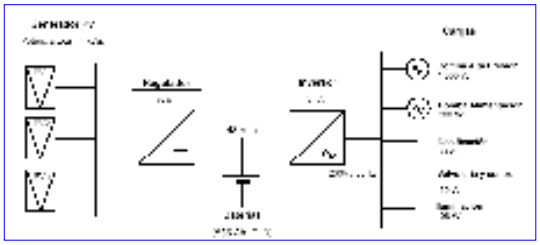
PV-RO: CASES OF STUDY. MOROCCO

Basic design - Electric diagram



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PV-RO: CASES OF STUDY. MOROCCO

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Promotion of Renewable Energy for Water production through Desalination

PV-RO: CASES OF STUDY. MOROCCO

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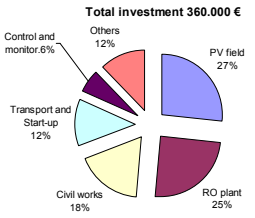
PV-RO: CASES OF STUDY. MOROCCO



Total water cost: 5.3 €/m³

O&M: 3,5 €/m³

COSTS: Investment of one BWRO unit (1 m³/h): 90.000 €

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PV / EDR Plant

Capacity: 2.8 m³/d

Feed water: brackish

PV nominal power: 2.3+1 kWp

Battery Capacity: 625 Ah

Spencer Valley, New Mexico (1995)

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Promotion of Renewable Energy for Water production through Desalination

Hybrid – Reverse Osmosis Applications

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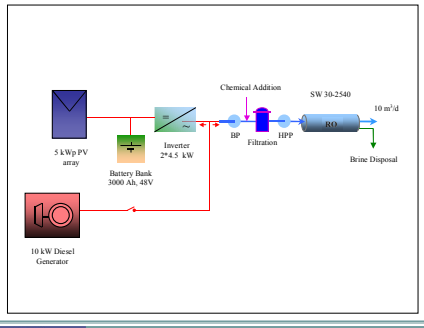
Promotion of Renewable Energy for Water production through Desalination

Typical diagram of a Hybrid RO unit



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Detailed stand-alone configuration

Source: ENERCON

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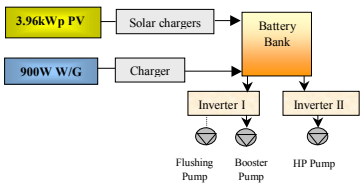
Hybrid RO plant

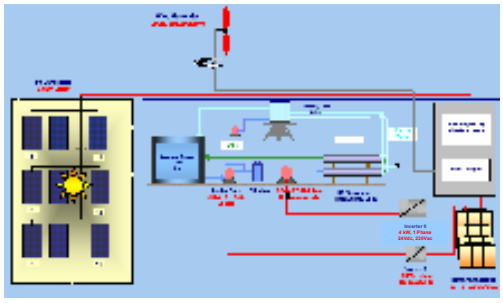
Desalination: 3 m³/day RO plant
Feed water: seawater
Power Supply: 900 W W/T - WHISPER H-40
4 kWp PV, SM110 SIEMENS SOLAR
Energy storage: 1850Ah/100h Battery bank, 2V,
12 elements in series

- 3 solar chargers, 45A
- Inverter I, 4 kW, 24 Vdc, 230 Vac
- Inverter II, 1.5 kW, 24 Vdc, 230 Vac

CRES, Keratea, Greece
(2001)

Simplified Schematic Diagram of CRES unit





Seawater Reverse Osmosis (RO)

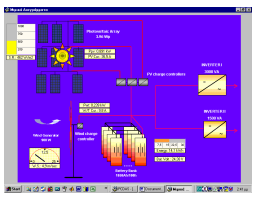
- Hourly Production: 130 lt/h
- Op.Pressure: 53-55 bar
- Recovery Ratio: 13%
- Product Conduct.: ~230 μS/cm
- Pretreatment: carbon filter
  cartridge filters,25 μ,5μ

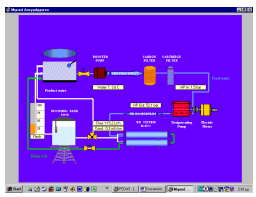
Unit installed power:

Booster Pump:	Lowara 2HMS3/A, 300 W, Motor: 470 W
High Pressure Pump:	Danfoss APP1, Motor 2200 W
Flushing pump:	Lowara BGM3/A, 370W, Motor 670 W
Total load:	470 W + 2200 W = 2670 W (BP+HPP)

Monitoring & Control System

- Capability of the software to collect and present the online data
- Presentation of the basic on line measurements by 2 diagrams





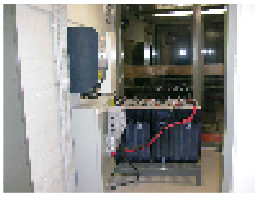
13 signals from analogue instruments /4-20 mA, 0-5 V Output

RO Measurements

- Feed water temperature
- Feed water pressure before the HPP
- Feed water pressure after the HPP
- Flow rate of permeate water
- Conductivity of permeate water

PSS Measurements

- Pyranometer
- Anemometer
- Current signal from W/T
- Current signal from PVs
- Current, Voltage signals from the battery
- Power signals at the exit of the inverters



HYBRID WIND & PV- RO: CASES OF STUDY. MORENA

Hybrid wind & PV driven RO unit (since 2005)

- MORENA system (energetically self-sufficient rural module) is a Wind/PV/battery hybrid system powering a SWRO desalination unit (552 W) and a DC load.
- System mounted in & on a container of 15 m² divided into 3 zones: one for the desalination unit and ERD, the battery bank and the electrical acquisition panels.

RO unit 154 l/h

WT 890 W, PV array 600 Wp, battery 21 kWh

RO unit 154 l/h, 3.74kWh/m³

Thank you for your attention