THE 20TH INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE IN THE ARAB COUNTRIES

Energy, Environmental, and Economic Assessment on the Operation and Maintenance of Solar Powered Desalination Plants

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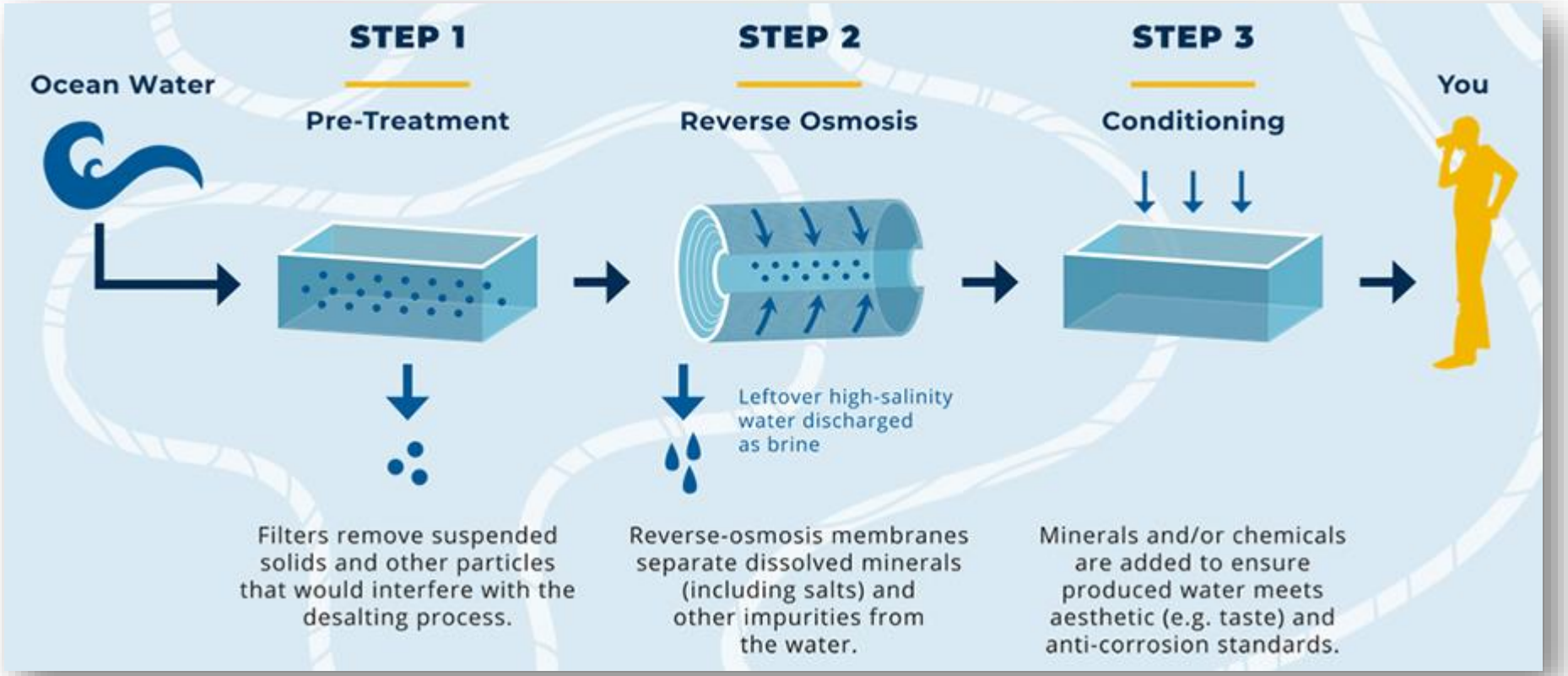
Schematic of Overall Process of Desalination



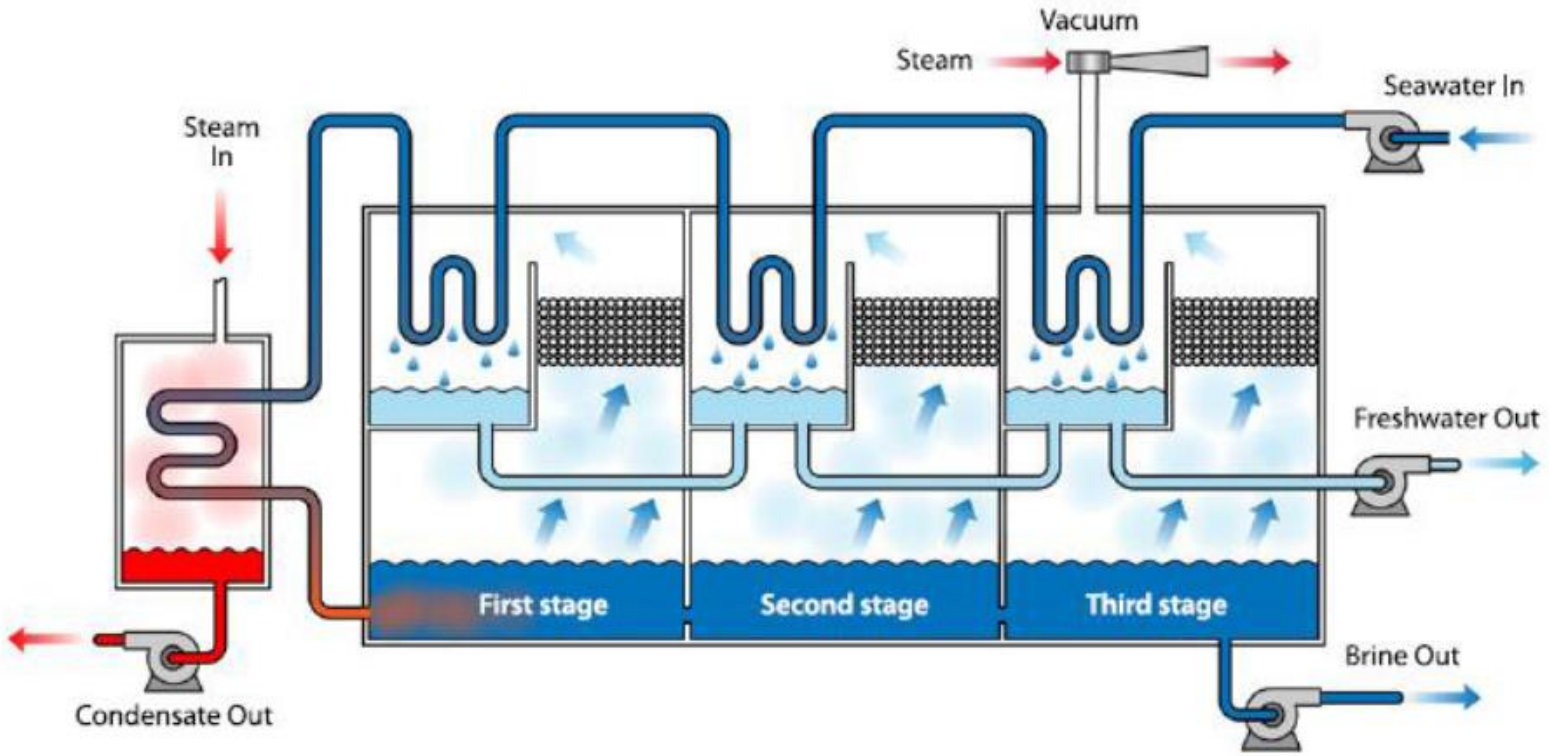
Desalination Technologies

Main commercial desalination technologies

Thermal Desalination	Membrane Desalination
Multi-stage flash	Electrodialysis
Multiple-effect distillation	Reverse Osmosis
Vapour Compression	Membrane Distillation

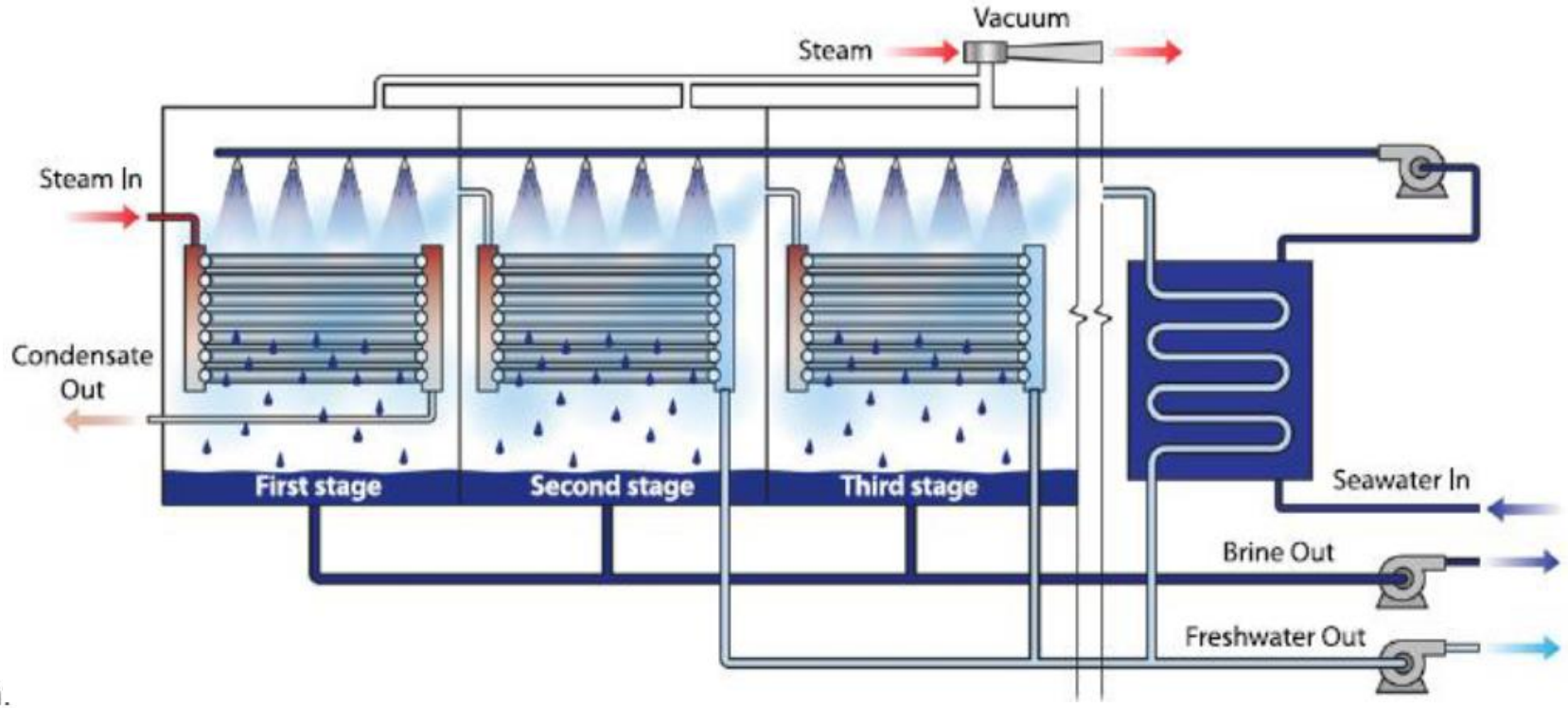
Thermal Desalination

Multi-Stage Flash



Thermal Desalination

Multi Effect Distillation



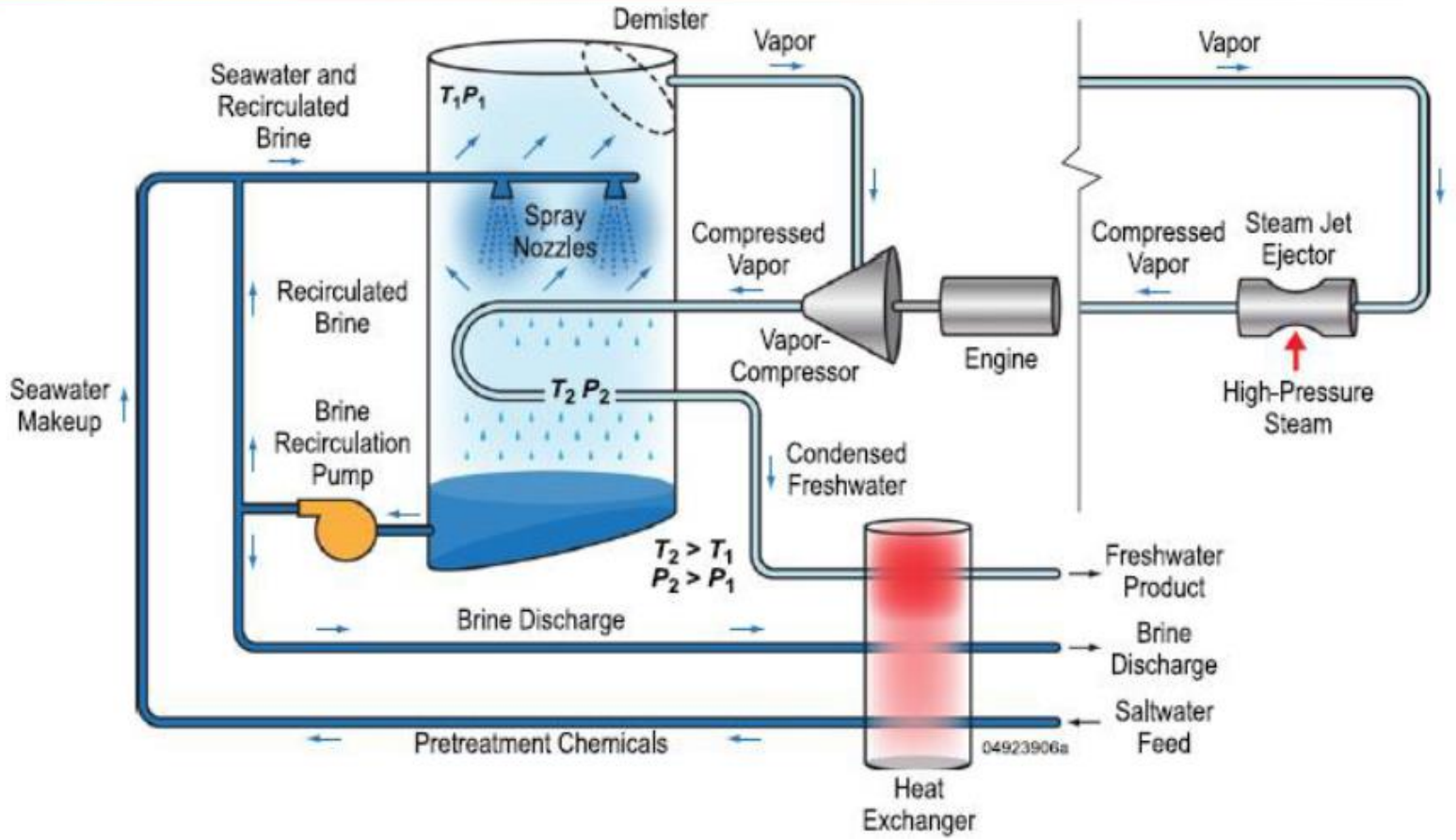
Thermal Desalination

Multi Effect Distillation (MED)

Fujairah F2 MED plant in United Arab Emirates

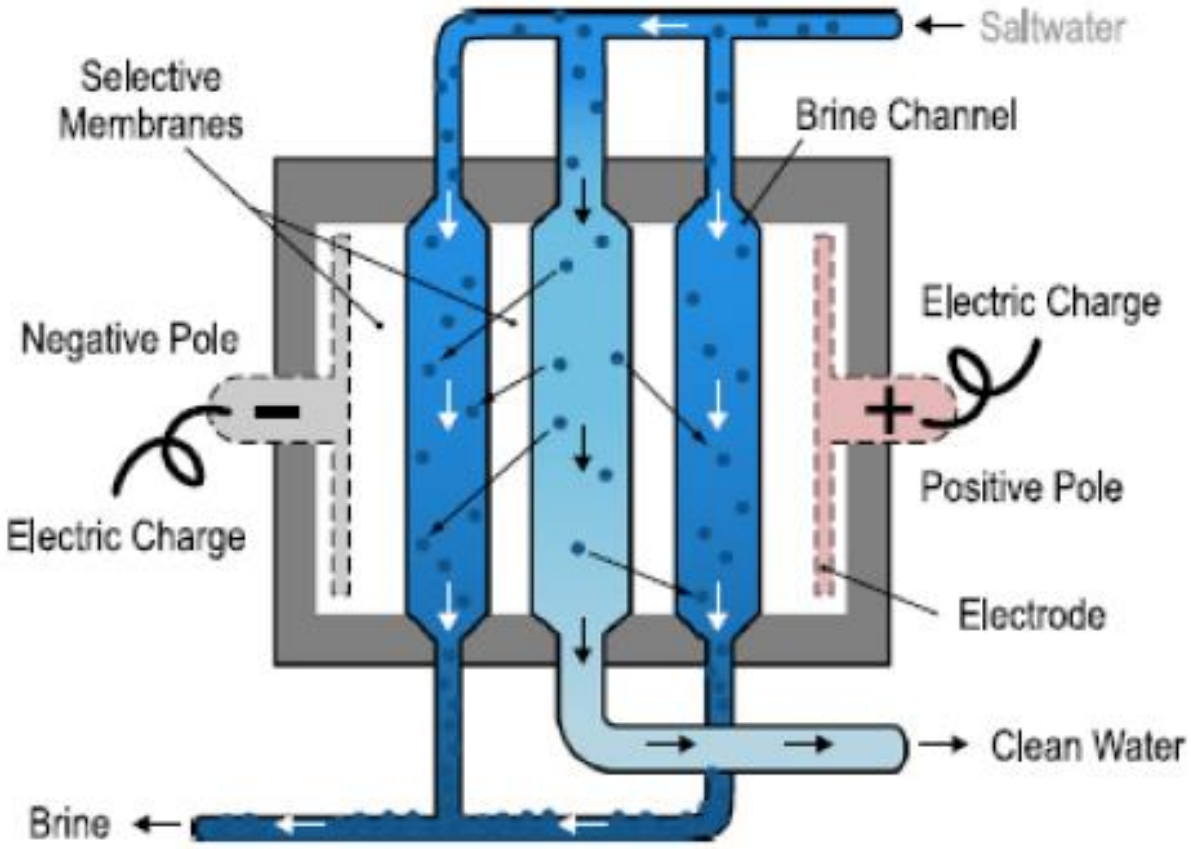
Thermal Desalination

Vapour Compression



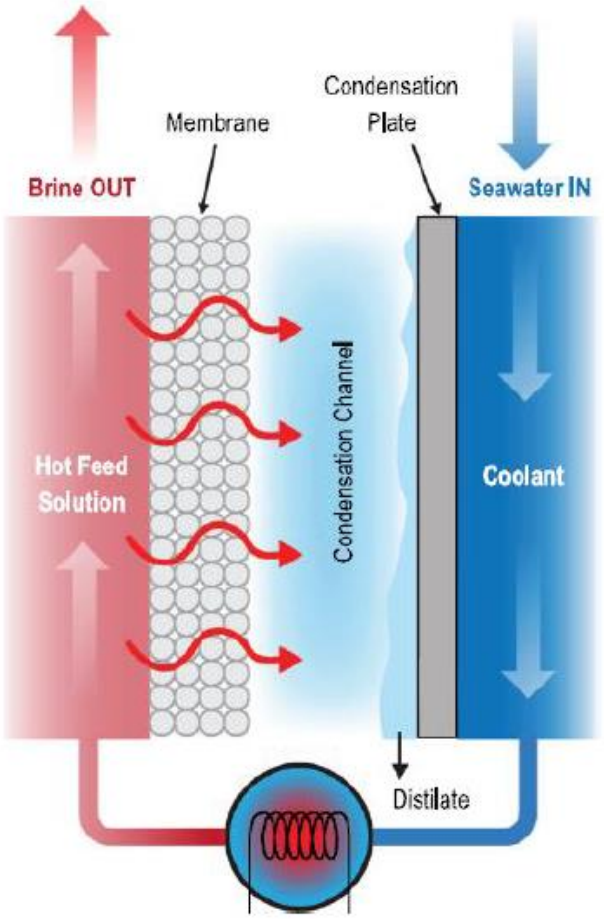
Membrane Desalination

Electrodialysis



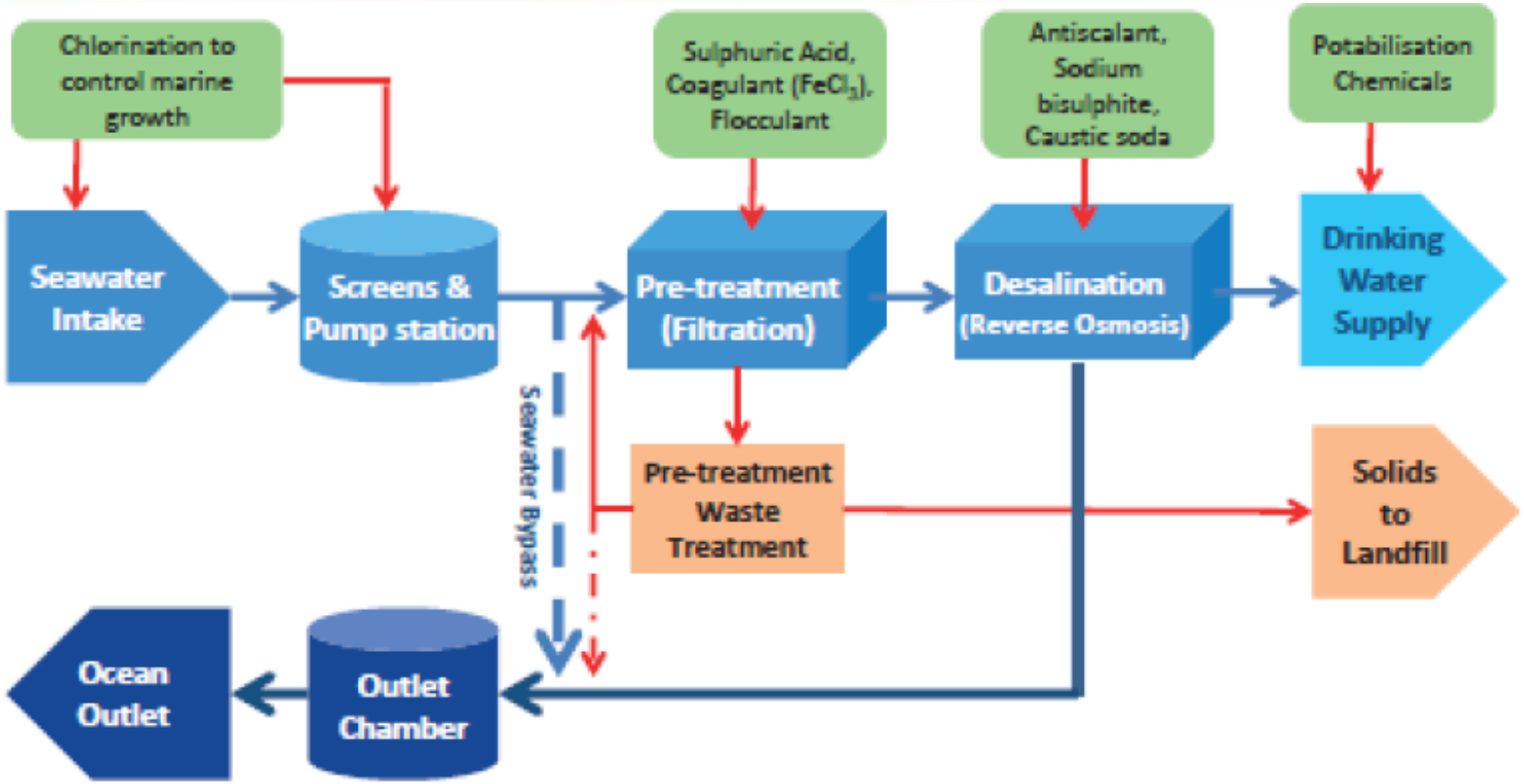
Membrane Desalination

Membrane Distillation



Membrane Desalination

Reverse Osmosis



Schematic of Reverse Osmosis Desalination process

Membrane Desalination

Reverse Osmosis

Pressure Vessels at RO Desalination plant in Jordan

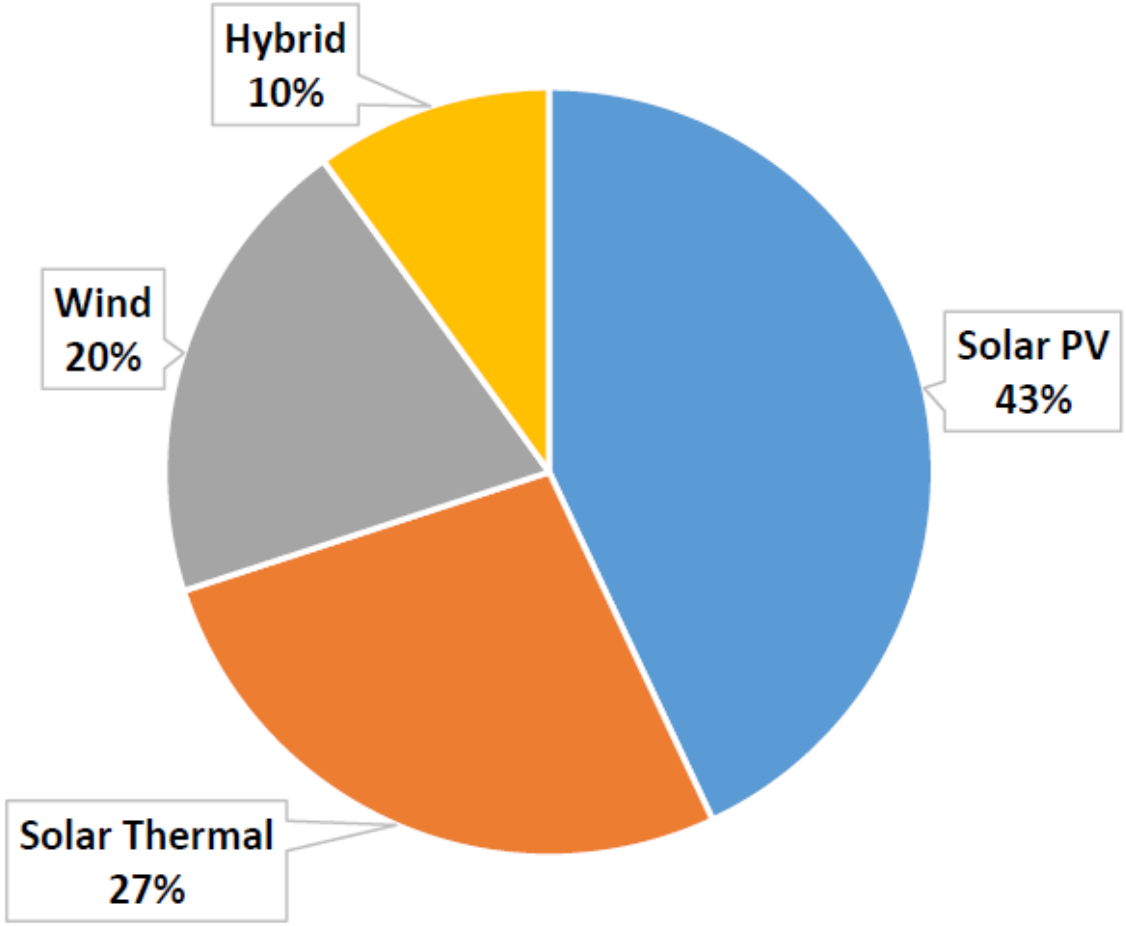
Energy Requirements

Energy Consumption of main commercial Desalination technologies

	MSF	MED	MVC	TVC	SWRO	BWRO	ED
Electrical Energy consumption (kWh/m^3)	2.5 - 5	2 – 2.5	7 – 12	1.8 – 1.6	3 - 6	1.5 – 2.5	0.8 – 5.5
Thermal Energy consumption (MJ/m^3)	190 - 282	145-230	-	227	-	-	-
Equivalent electrical to thermal energy (kWh/m^3)	15.83 - 23.5	12.2 - 19.1	-	14.5	-	-	-
Total energy consumption (kWh/m^3)	19.58- 27.25	14.45-21.35	7-12	16.26	3 - 6	1.5 – 2.5	0.8 – 5.5

Renewable Energy-Powered Desalination

Renewable energy sources currently utilized for Desalination

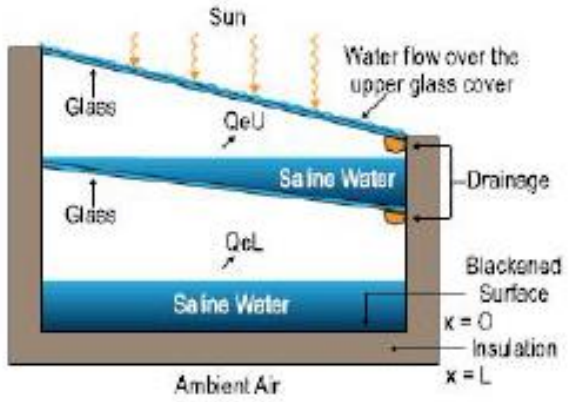


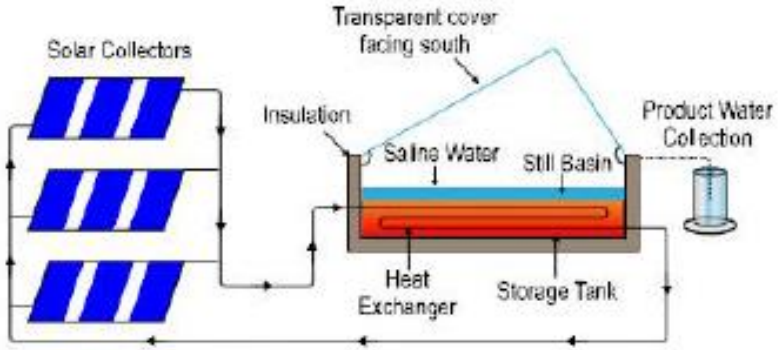
Possible combinations or renewable energy and desalination technologies

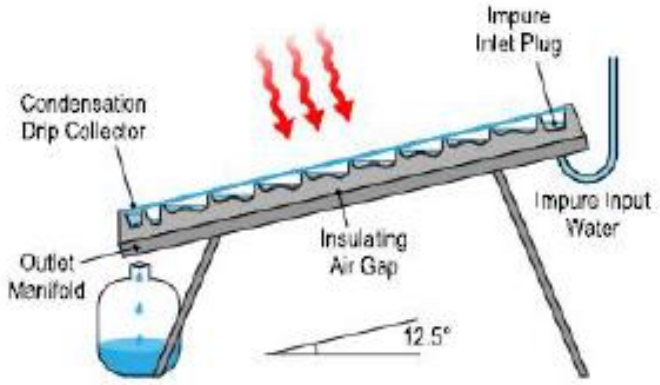
	MSF	MED	VC	RO	ED	MD
Solar PV				○	○	○
Wind				○	○	○
Solar thermal	○	○	○	○	○	○
Geothermal	○	○	○	○	○	○

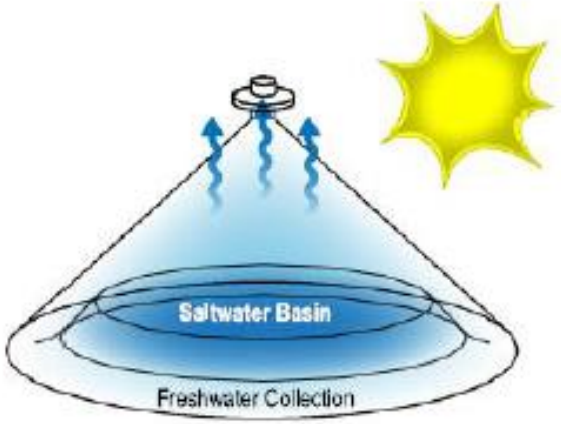
Solar-Powered Desalination

Solar Stills



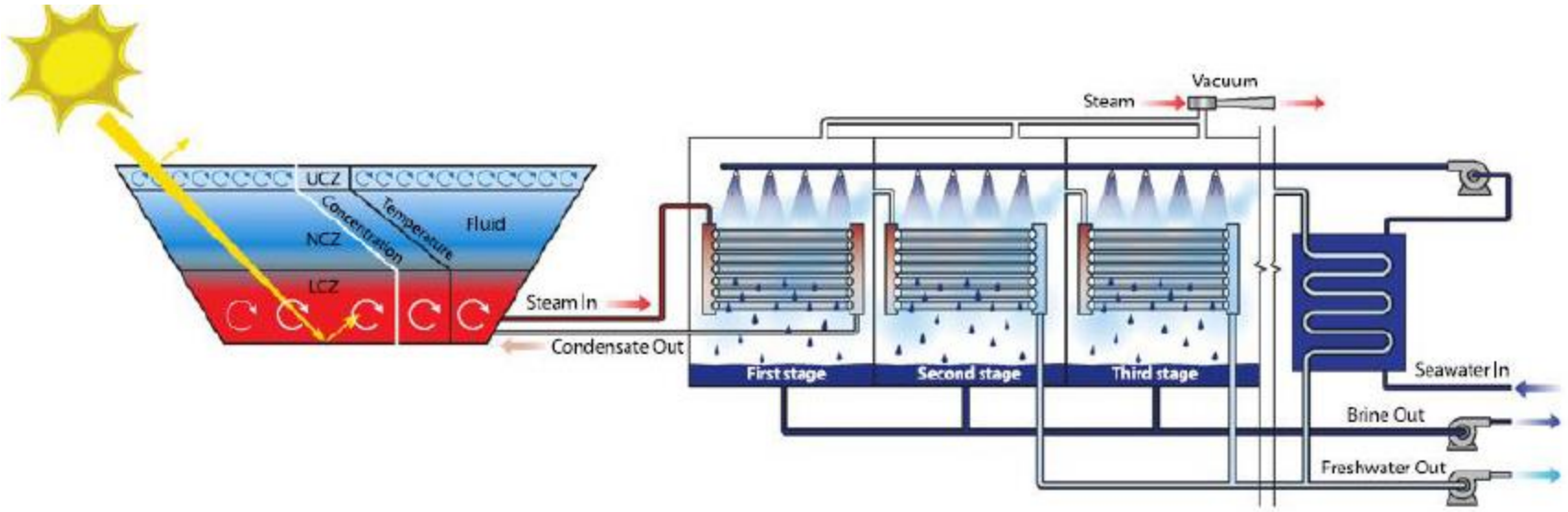






Solar-Powered Desalination

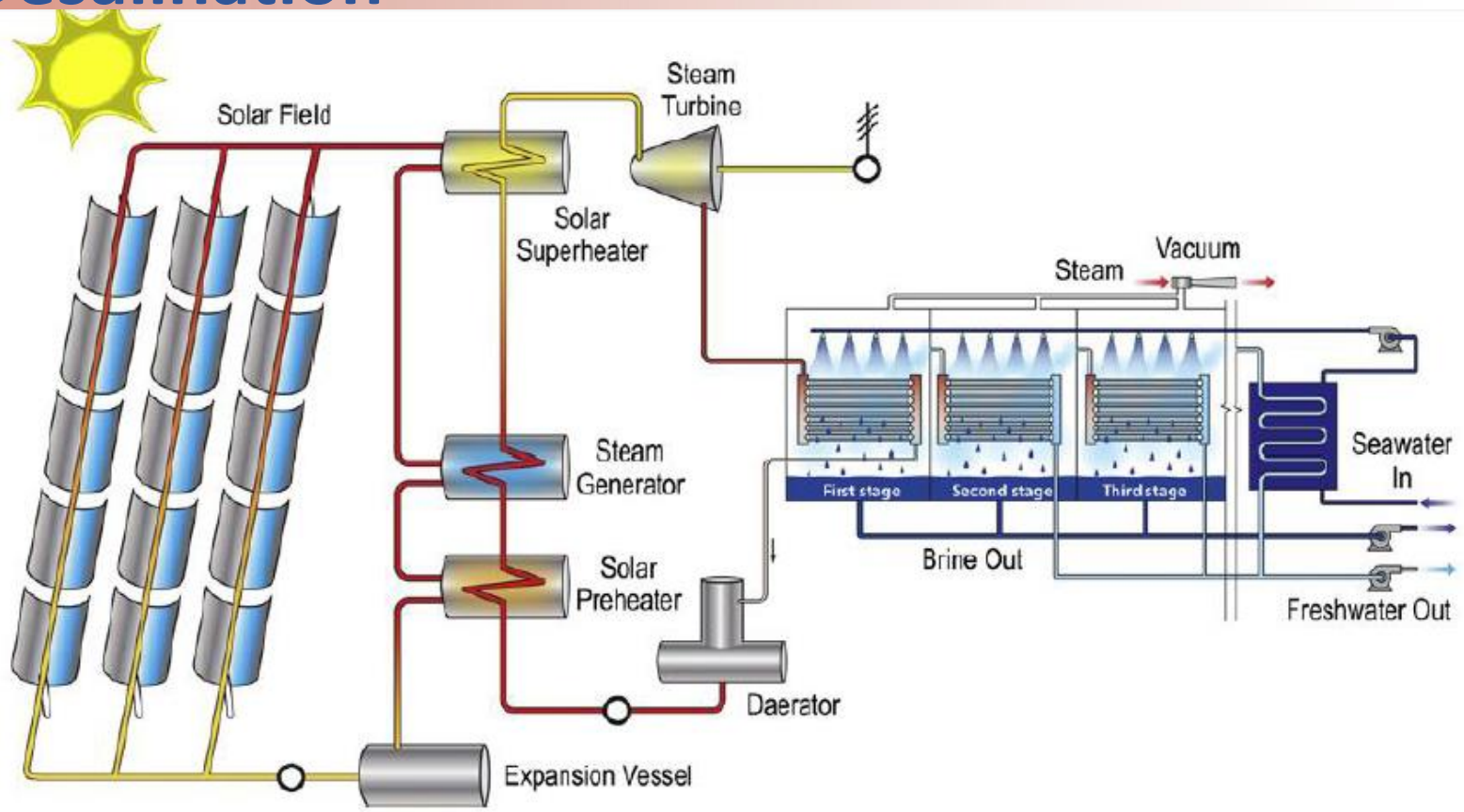
Solar Ponds



Solar Pond with MED desalination

Solar-Powered Desalination

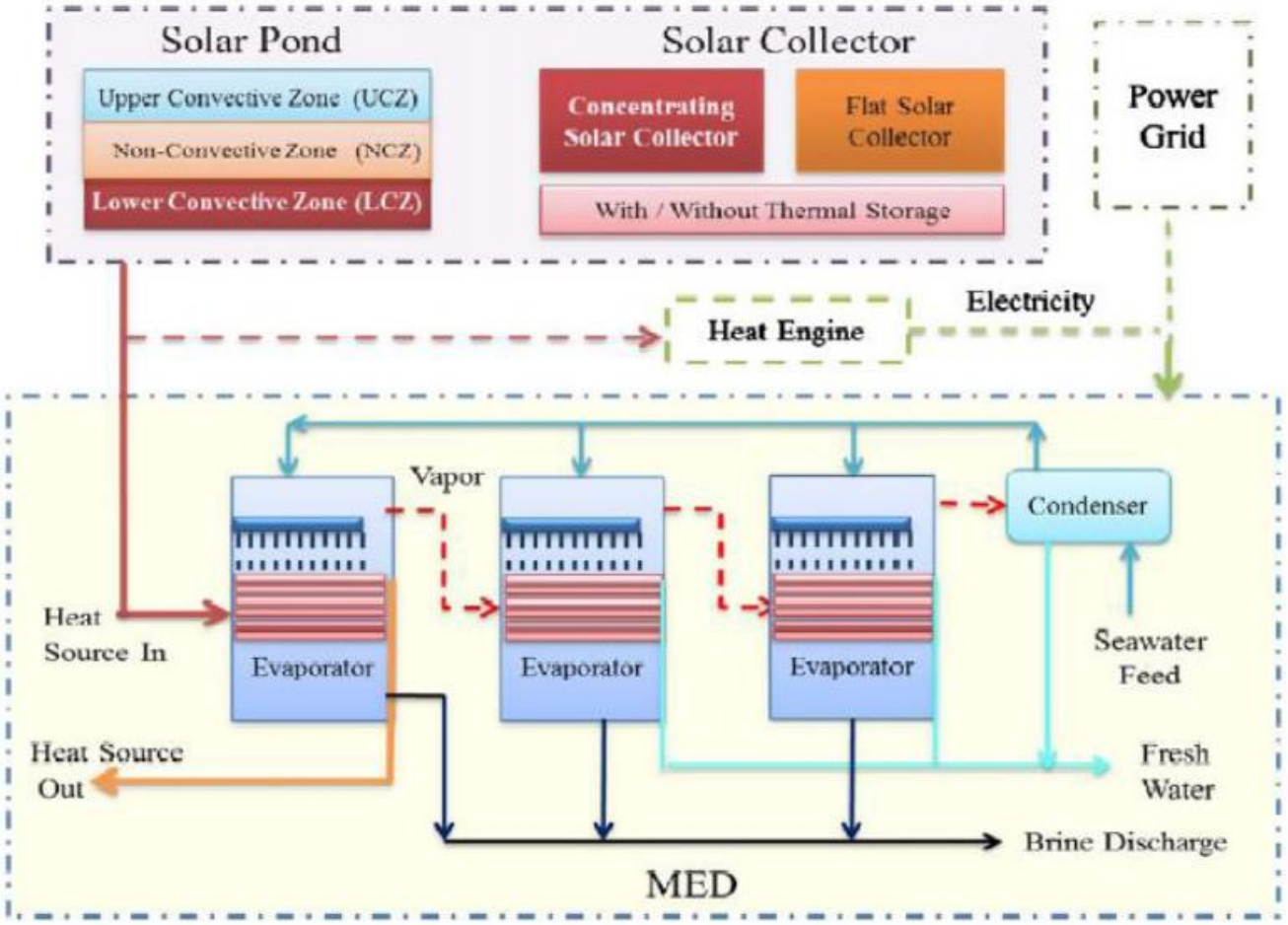
Indirect Solar Thermal



Concentrated solar power (CSP) connected with MED Desalination

Solar-Powered Desalination

Schematic of MED with CSP and Solar Pond



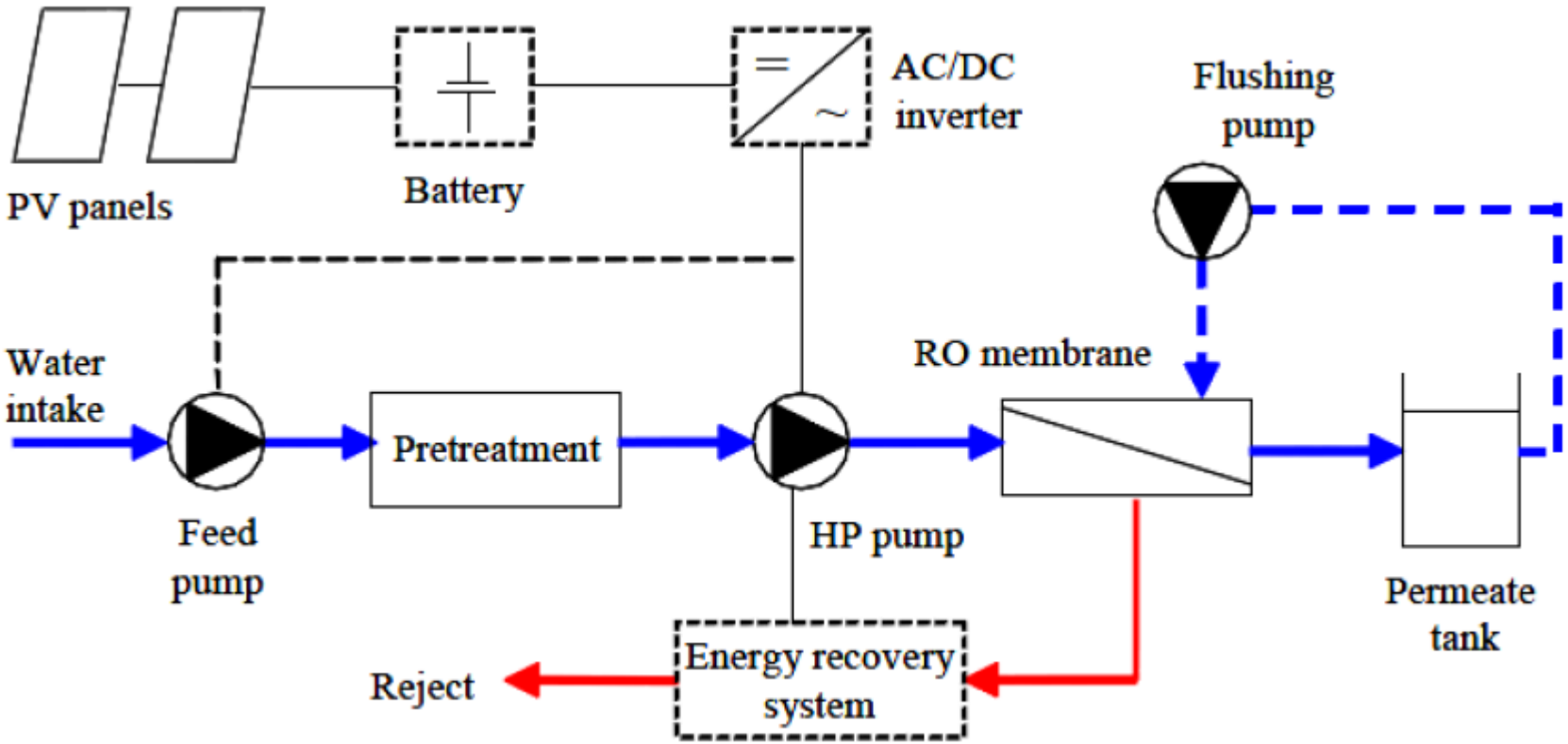
Solar-Powered Desalination

Solar Photovoltaic

Solar PV plant powering Desalination plant in Yuma

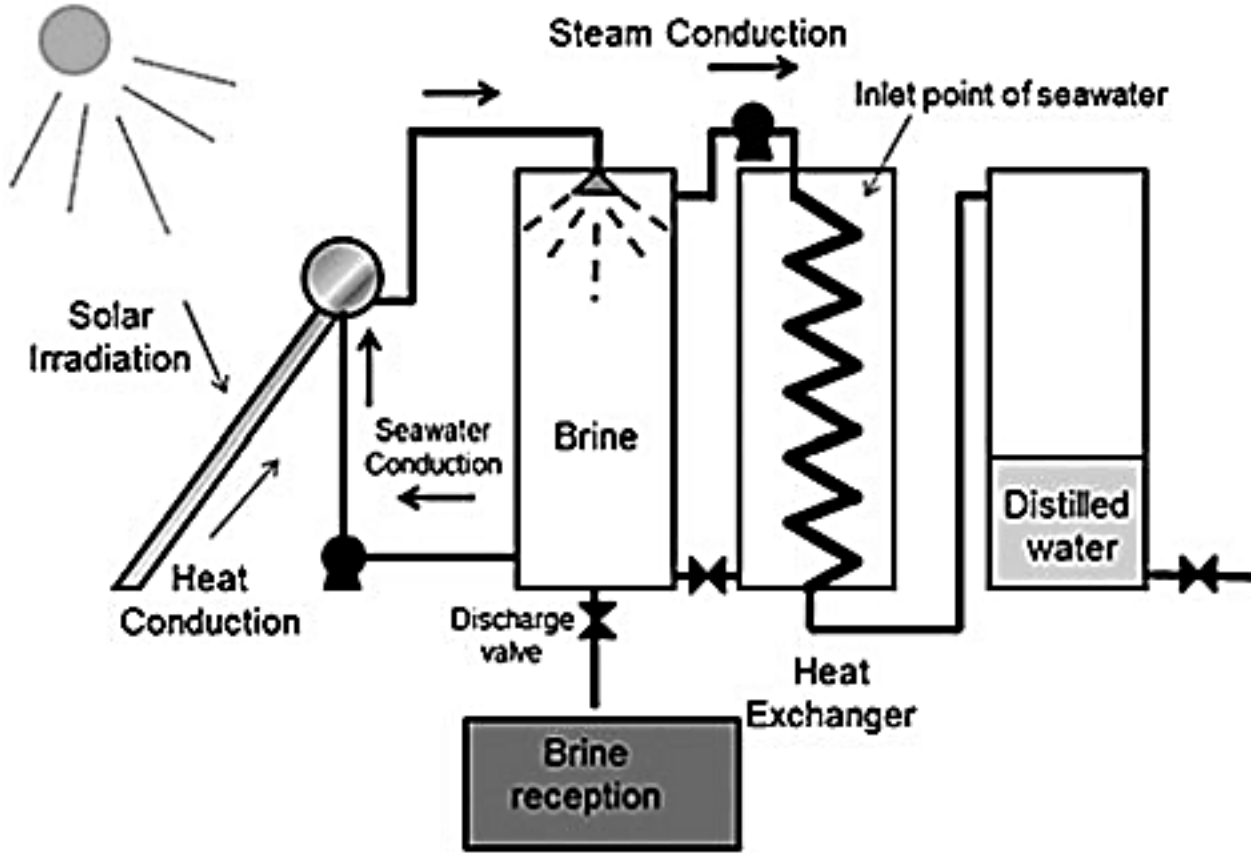
Solar-Powered Desalination

Schematic of PV-RO system



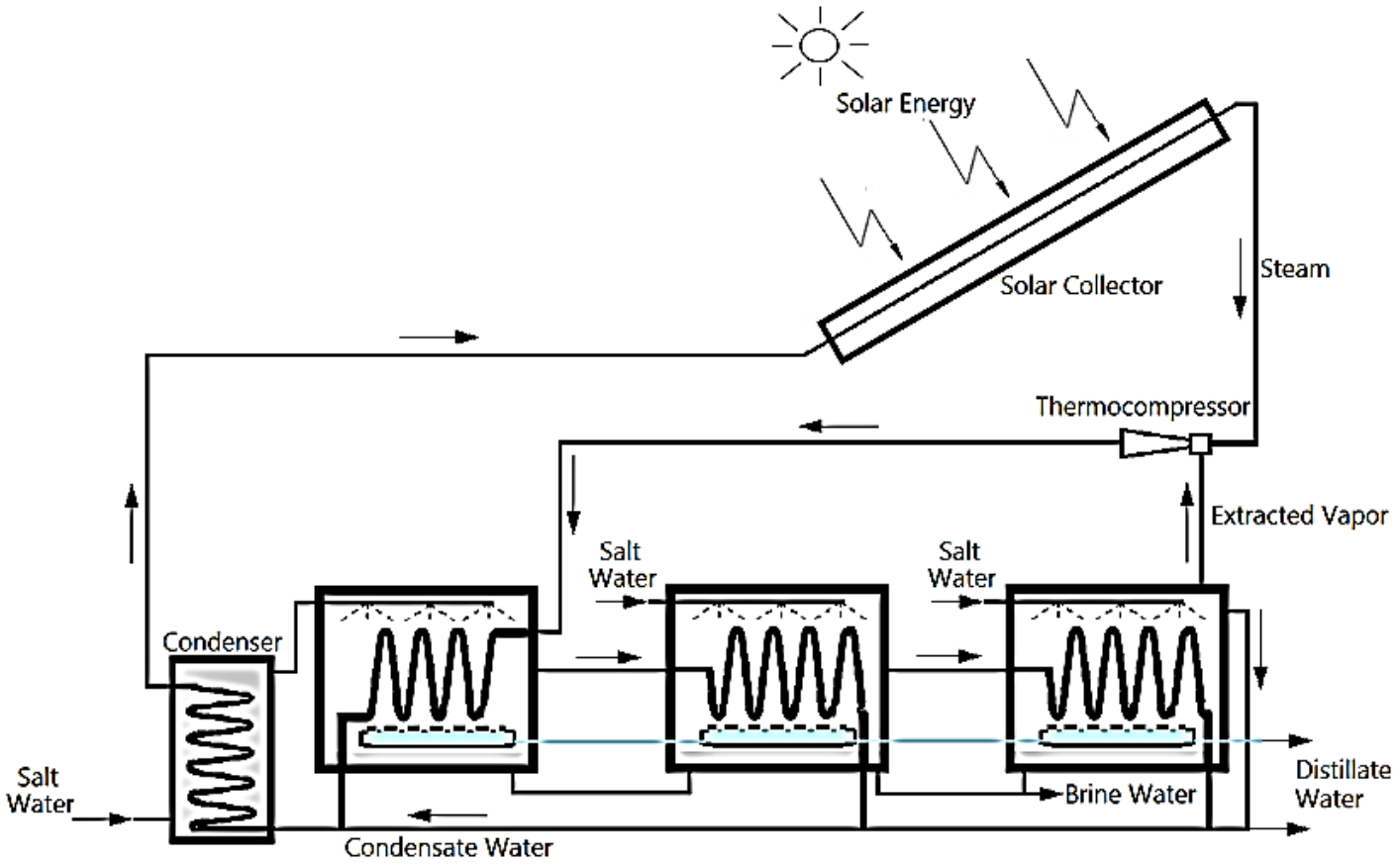
Solar-Powered Desalination

Humidification-dehumidification System



Solar-Powered Desalination

Multiple Effect Solar Distillation with Thermo-compression



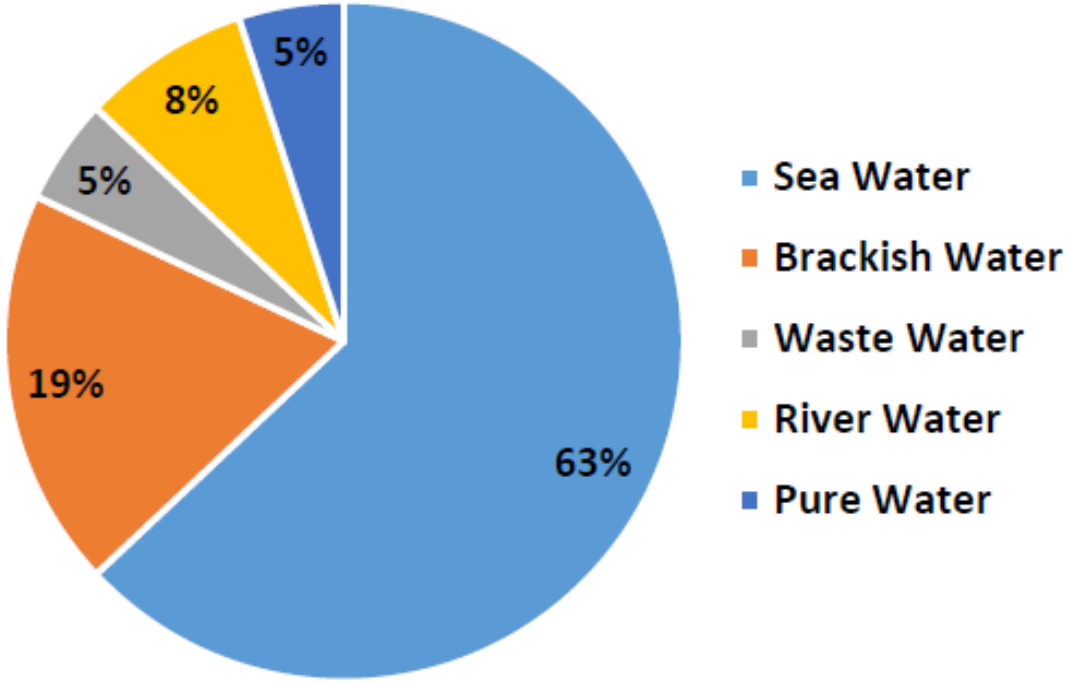
Wind-Powered Desalination

Sydney Wind-RO plant during construction

Geothermal-Powered Desalination

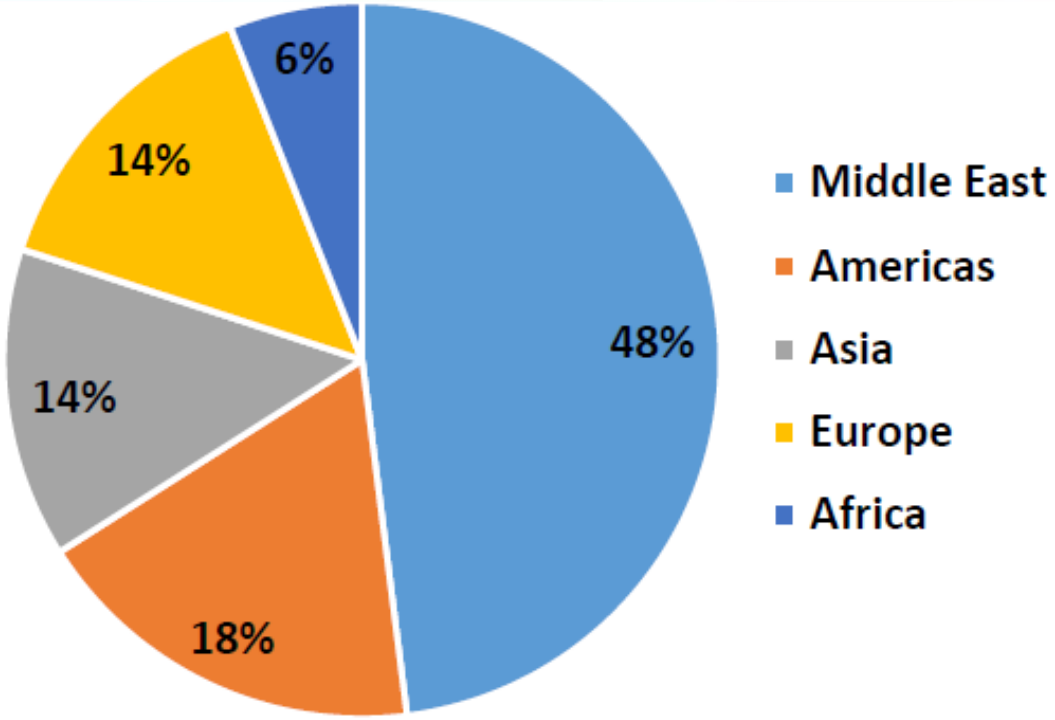
Geothermal energy can be used for heat and electricity generation, making it an option to couple with any major desalination system that requires thermal or electrical energy. Geothermal energy sources are qualified in terms of measured temperature: low (<100 ºC), medium (100-150ºC) and high temperature (>150ºC).

Desalination Markets



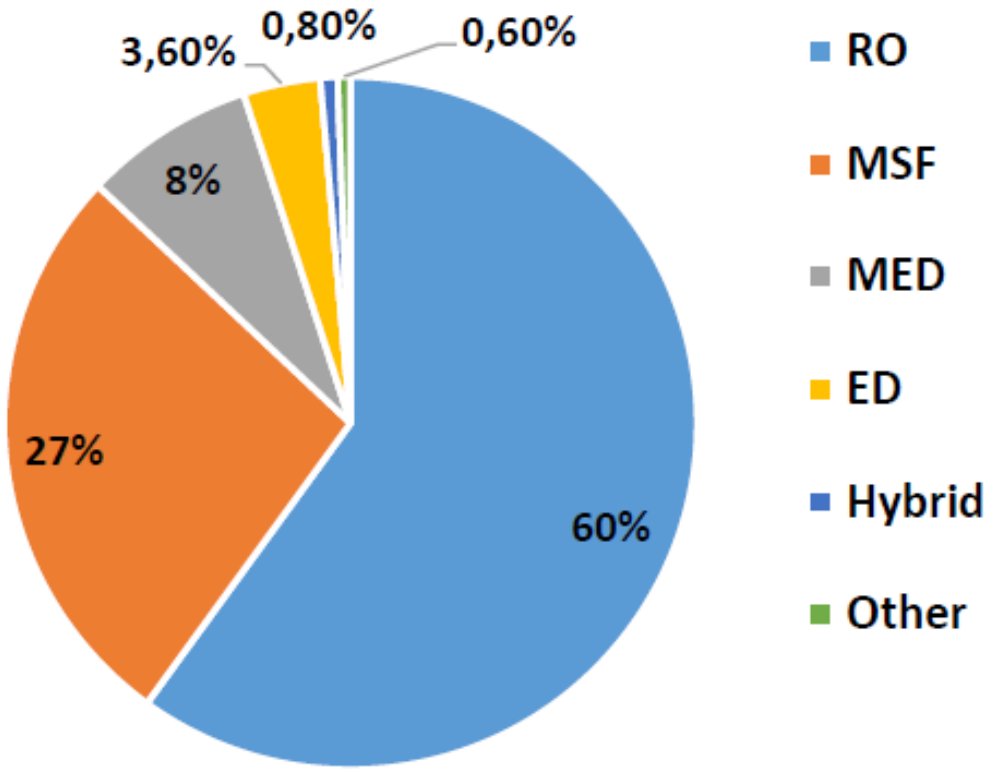
Sources of Feed Water for Desalination processes

Desalination Markets



Worldwide Desalination Capacity

Desalination Markets



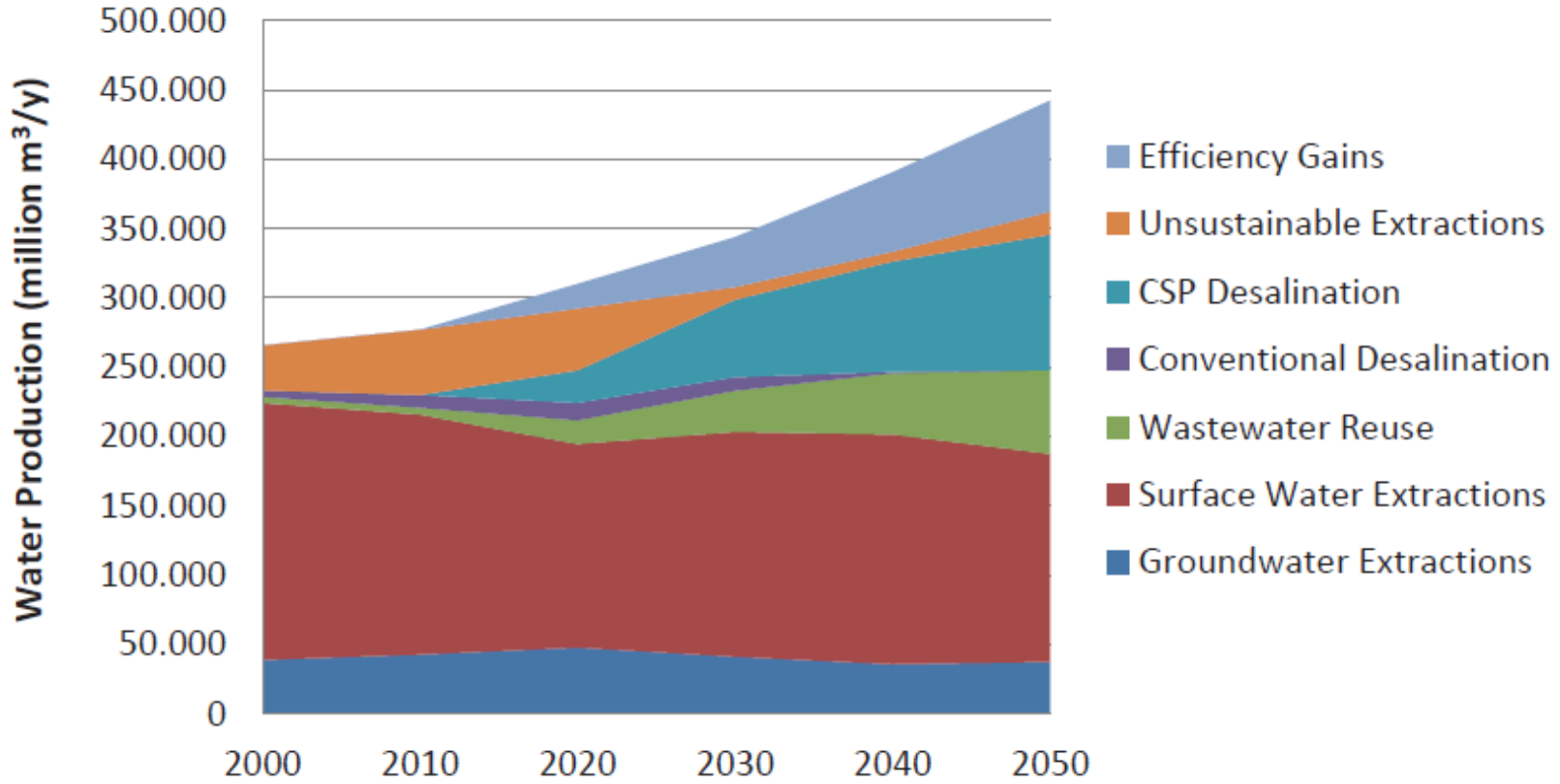
Desalination Technology Market

Economic Assessment

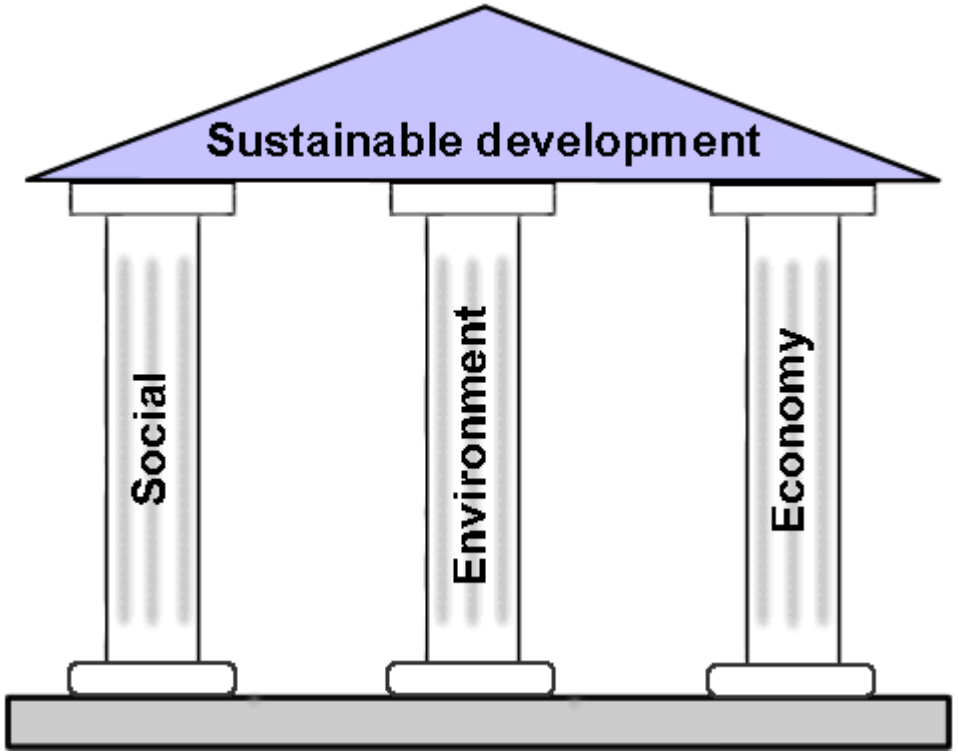
Water Cost of different RE Desalination combinations by production capacity

Technology	Capacity (m^3/day)	Production Cost ($/$m^3$)
Solar Still	0.1	1 – 5
Solar MED	1-100	2 – 5
Solar MD	0.1-10	8 – 15
CSP-MED	>5000	1.8 – 2.2
PV-RO	<100	5 – 7 (BW) 9 – 12 (SW)
PV-ED	<100	8 – 9
Wind-RO	1000	1.5 – 4
Wind-MVC	<100	4 – 6

Water demand scenario in MENA, 2000–2050



Sustainability Pillars In Solar Powered



Operation and Maintenance Cost Breakdown

Cost association	Parameter	Total O&M Costs
Maintenance	Instruments Pump upkeep Facility upkeep, including intake pipeline pigging Minor equipment replacement Video/CCTV intake/wells and associated cleaning	6%
Legal/Permitting	Environmental monitoring Permit compliance	2%
Operations	Labor	6%
	Sludge and solids waste disposal Barrack and band screen solids waste disposal	4%
	Cartridge filters and membrane replacement	11%
	Power (energy)	55%
	Chemicals	6%
	Others related	10%

Design Considerations

1. Plant capacity
2. Plant location
3. Plant technology
4. Input resources

Samples with Different Properties with O&M Costs

Parameter	Mediterranean Sea	Aegean Sea	Black Sea
Salinity, ppm	43210	38760	20000
Energy, %	65	66	64
Membrane replacement, %	14	11	10
Chemical cost, %	9	9	11
Filter Renewal (Cartridge, Hardening and Sand Filter), %	2	3	3
Maintenance and Service, %	10	11	12

Environmental Impacts

1. Land usage
2. Energy consumption
3. Brine disposal

Socio-cultural Factors

1. What is the level of the public's awareness and commitment to desalination technology as opposed to other alternatives?
2. Acceptability of desalination technology.
3. What are the concerns/needs/priorities (desires) of the public as they concern desalination?
4. What social attitudes and social taboos could affect the water needs?
5. What is the target population's growth rate and age profile?
6. How do religious beliefs and lifestyle choices affect the population?

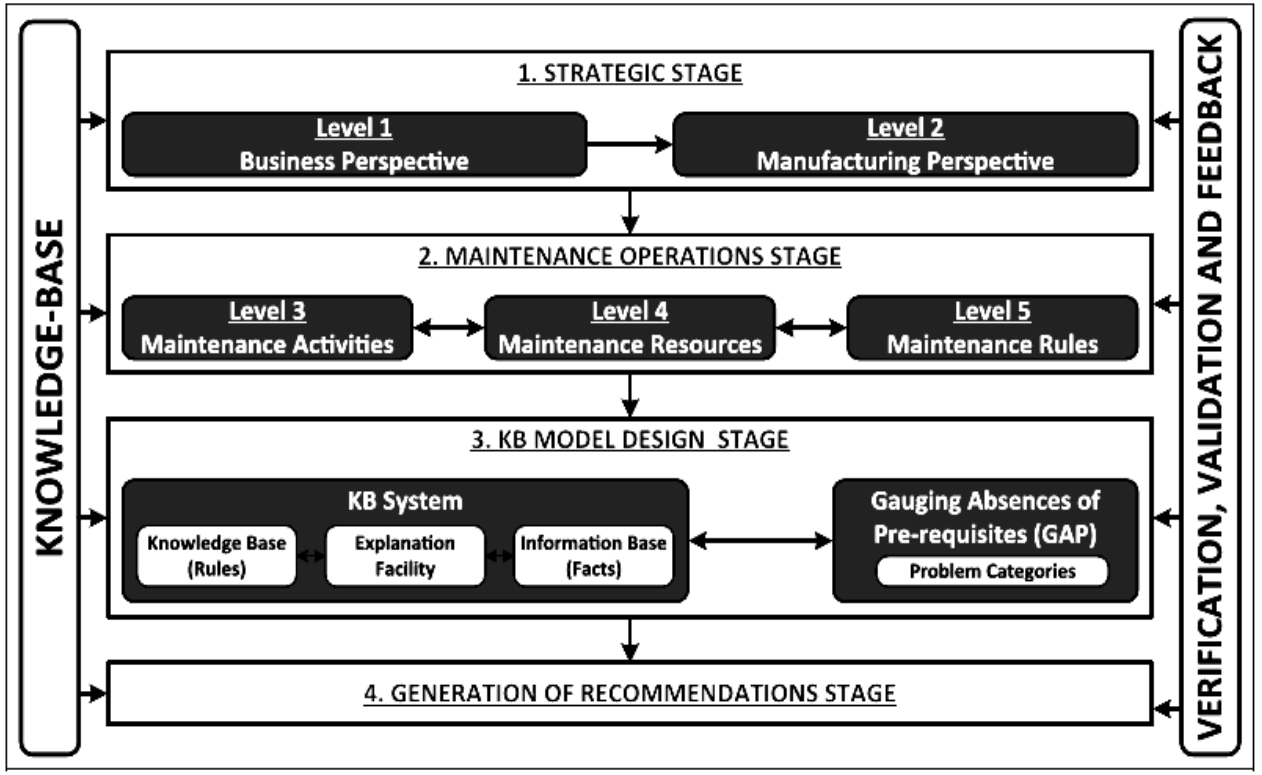
Economical Aspects

1. Plant costs
2. Energy sources
3. Plant life
4. Site costs
5. Interest rates
6. Pretreatment
7. Plant load factor
8. Availability of skilled labor
9. Disposal of rejected brine
10. Storage and distribution of fresh water

Operating Considerations

1. Feed fluids flow rate
2. Heat transfer enhancement additives concentration
3. Cooling fluid temperature
4. Feed water temperature
5. Energy consumption

Design and Operating Considerations Relationship



Cost Drivers Identification

1. Scale Formation and Fouling
2. Efficiency of solar power source
3. Raw water specifications
4. Efficiency of pumping devices
5. Operating practices
6. Maintenance strategy adoption
7. Lack of data collection

Conclusion

1. Indirect desalination technologies are characterized by both of high operational cost and the need for highly skilled maintenance.
2. Operation and maintenance varied according to the specifications of input resources into the desalination plant.
3. The capital costs of plant and water production costs are significantly reduced as a function of plant capacity to a certain extent.
4. Appropriate cost drivers must be identified, in order to trace overhead costs of water product.

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