UMassAmherst

Offshore Wind Energy and Water

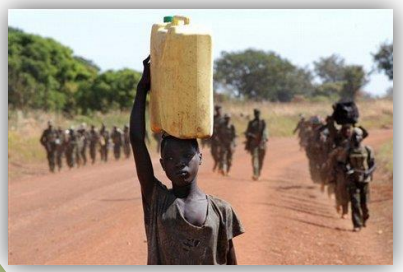
Luis A. Pagán-Quiñones, Ph.D Student
Mechanical Engineering Department
UMass IGERT Offshore Wind Energy Program
April 16, 2015

Water or Energy?

Outline

- Water Security
- Desalination
- Desalinatio technologies
- Economics of desalination
- Renewable energy in desalination
- Future Work

Water Security and Conflicts

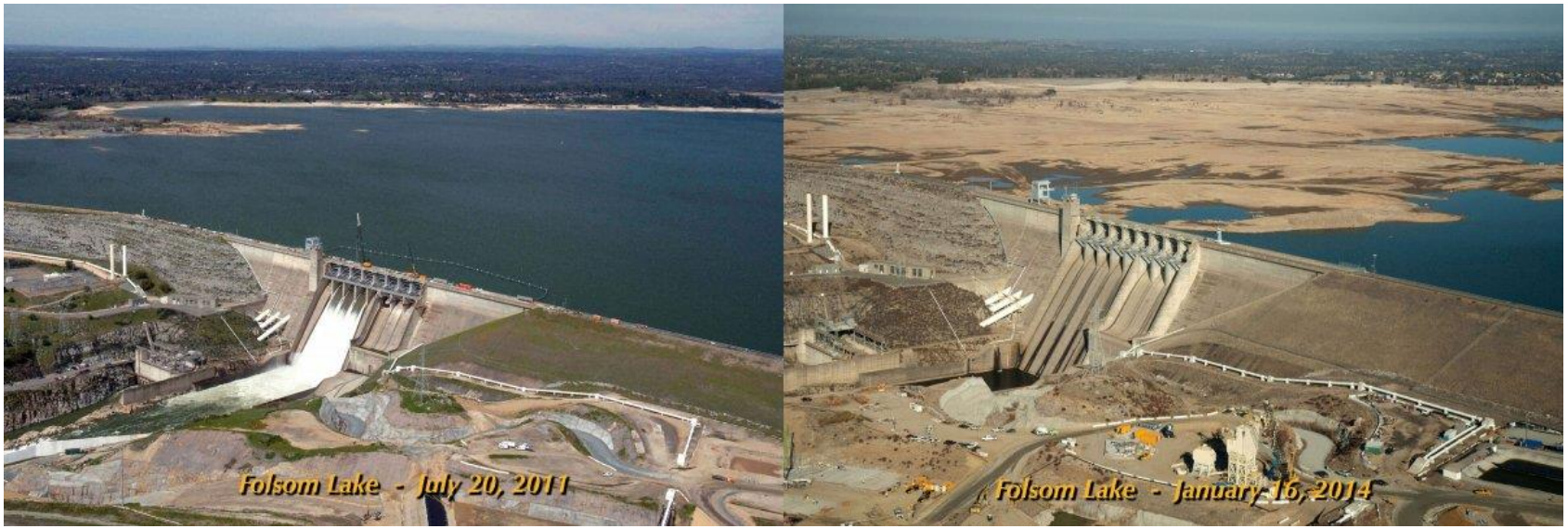


Water Security and Conflicts

Brazil drought

Source: Brazil hit by worst drought in decades (BBC News), 2014 http://www.bbc.com/news/world-latin-america-29583818

Water Security and Conflicts



California drought

Source: California Department of Water Resources, 2014

Water used for electricity

Water Consumption in the Electricity Industry Value Chain
(liters per megawatt-hour)

Source	Raw Materials	Transformation	Delivery
Coal Oil or natural gas Uranium	20–270 See Table 4 170–570	Thermoelectric generation with closed loop cooling: 720–2,700	Minimal
Hydroelectric		Evaporation losses: 17,000	Minimal
Geothermal		5,300	Minimal
Solar		Concentrating solar: 2,800–3,500	Minimal
Wind		Minimal	Minimal

Source: World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century. Geneva.*

Energy used in the provision of water

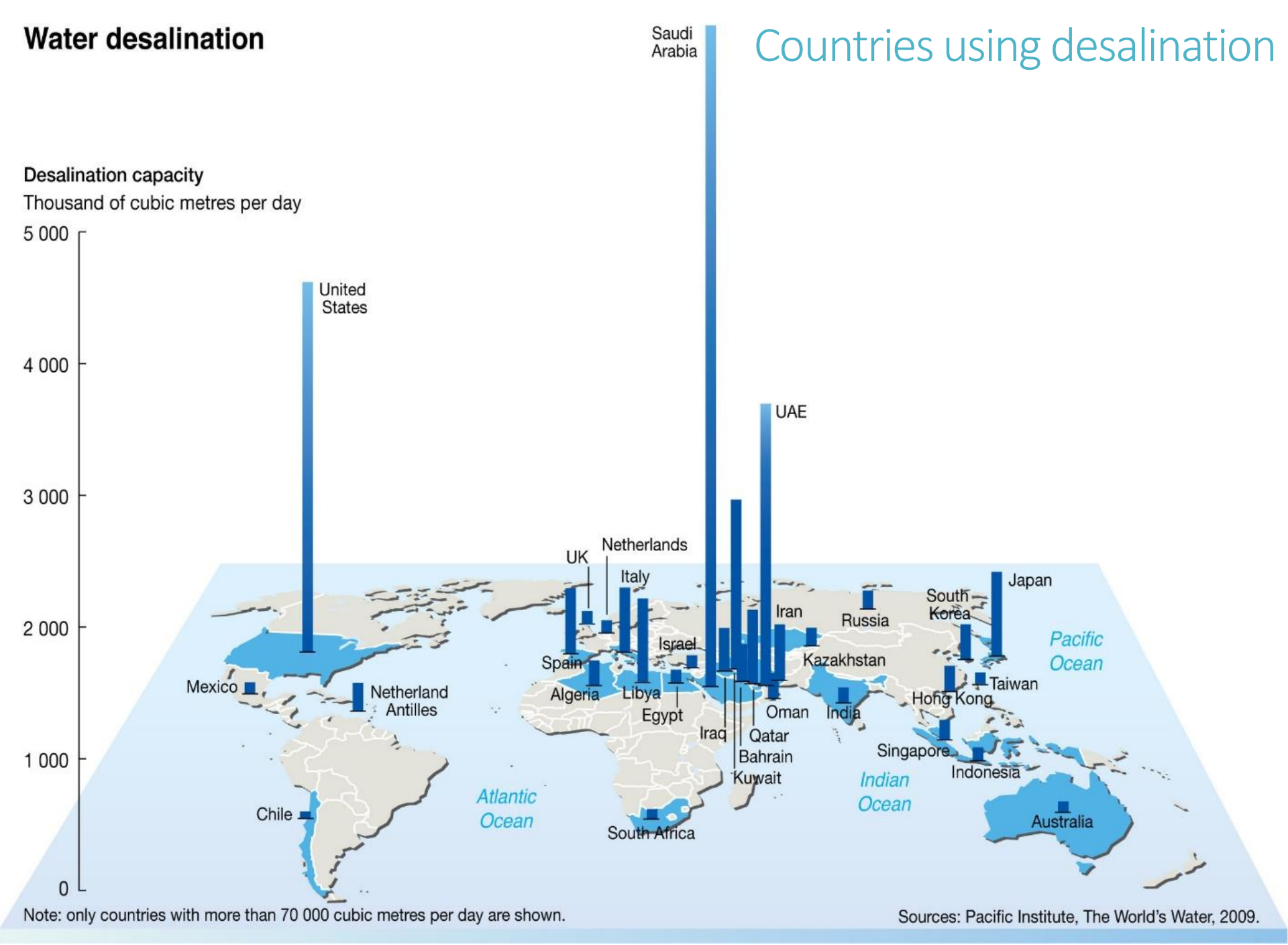
Energy Consumption in Industry Value Chain
(kilowatt-hour per 1,000 cubic meters)

Source	Raw Materials	Transformation	Delivery
Surface water	0–2,400	Treatment: varies with raw water quality	Depends on distance and elevation: 290
Groundwater	40 meters: 150 120 meters: 520	High-quality groundwater: 26 Brackish water: 300–1,400 Seawater desalinization: 3,600–4,500	
Municipal wastewater		660	

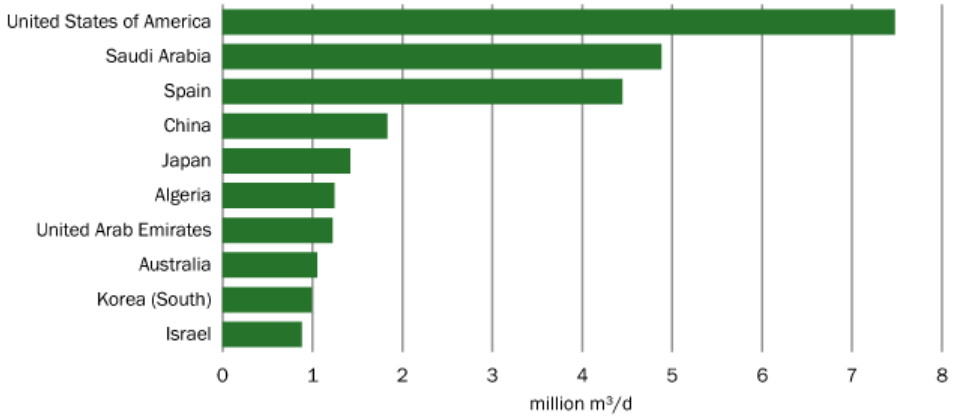
Source: World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century. Geneva.*

Desalination

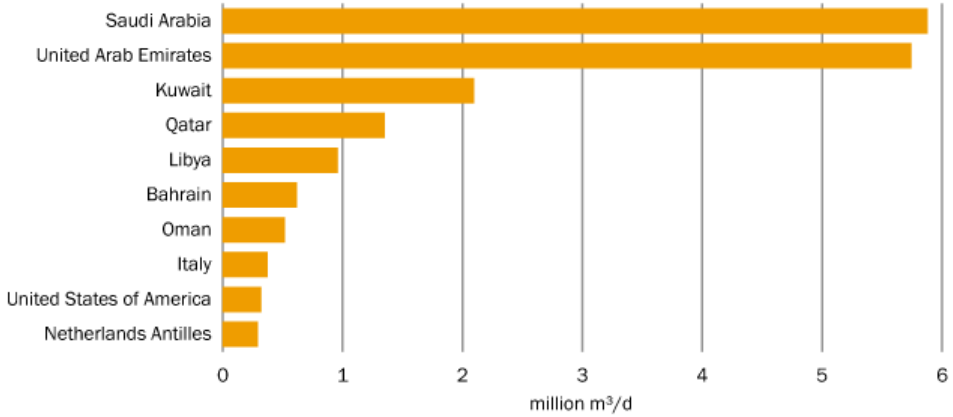
Countries using desalination



Countries using desalination



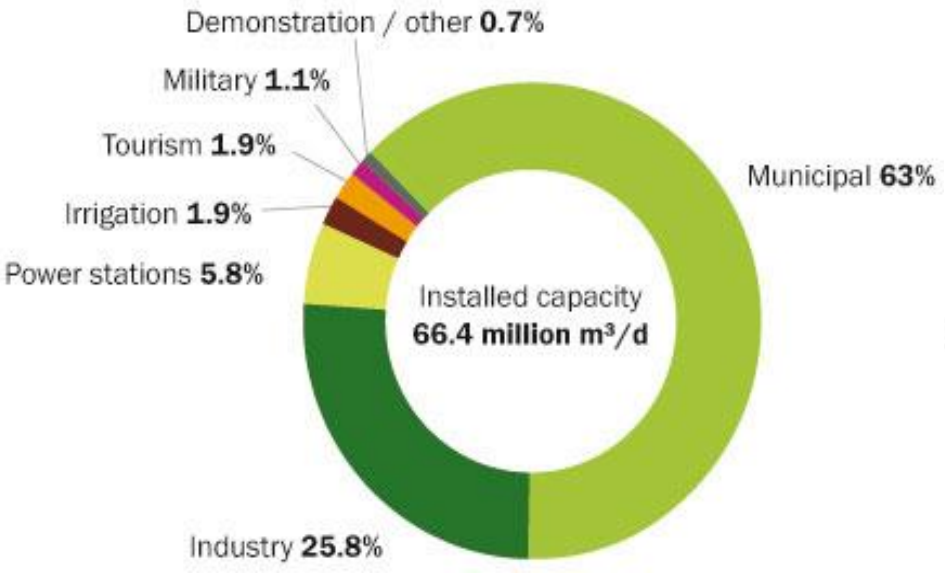
Top 10 countries by total installed membrane capacity since 1945



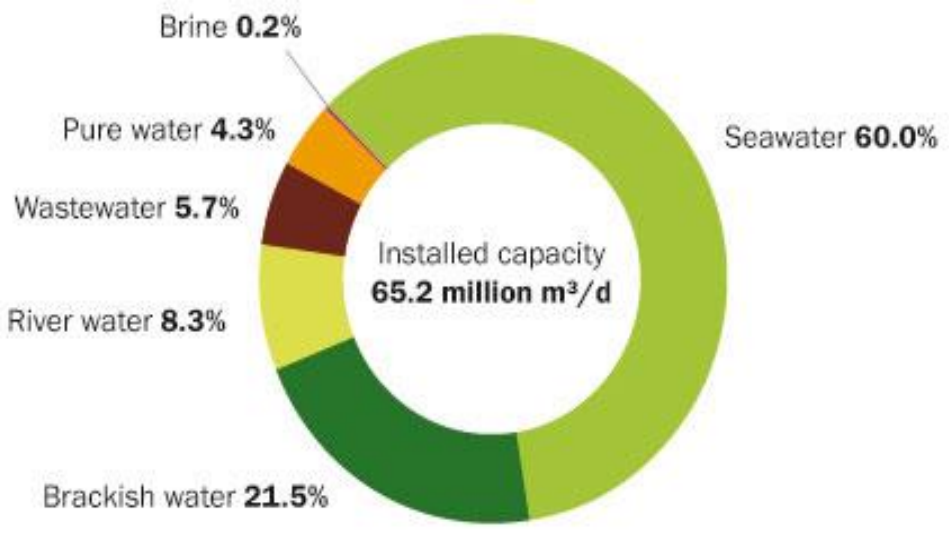
Top 10 countries by total installed thermal capacity since 1945

Source: IDA Desalination Yearbook 2011 DesalData.com

Global desalination capacity and trends



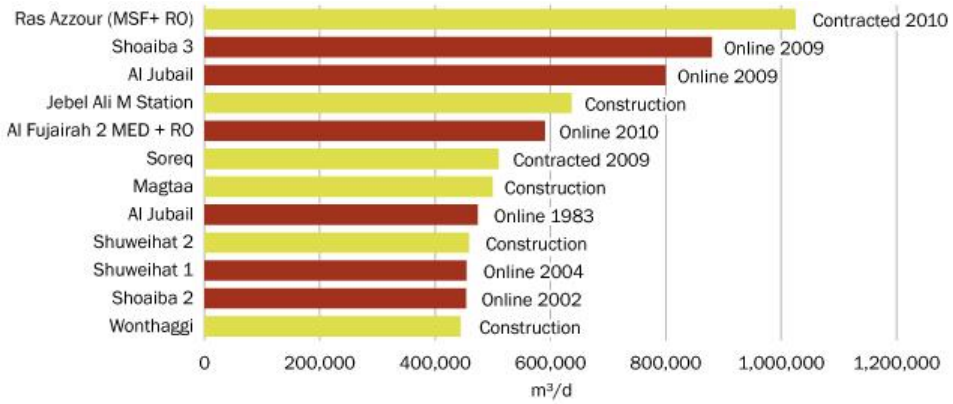
Total worldwide installed capacity by user type



Total worldwide installed capacity by feed water category

Source: IDA Desalination Yearbook 2011 DesalData.com

Global desalination capacity and trends

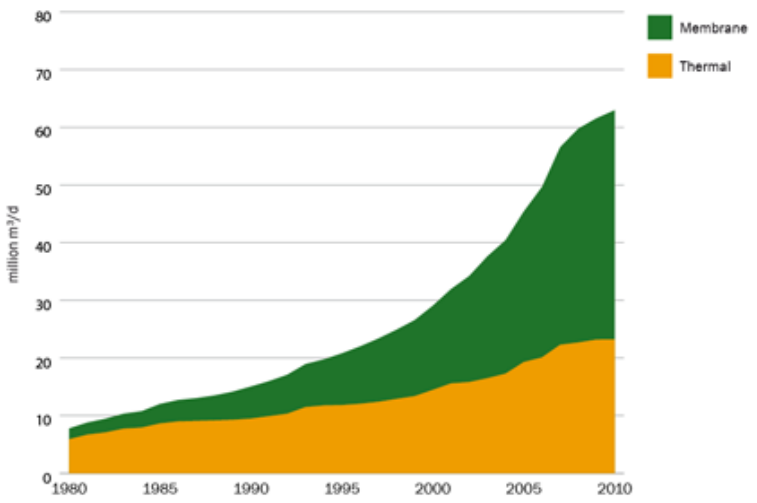


Top 12 plants by capacity

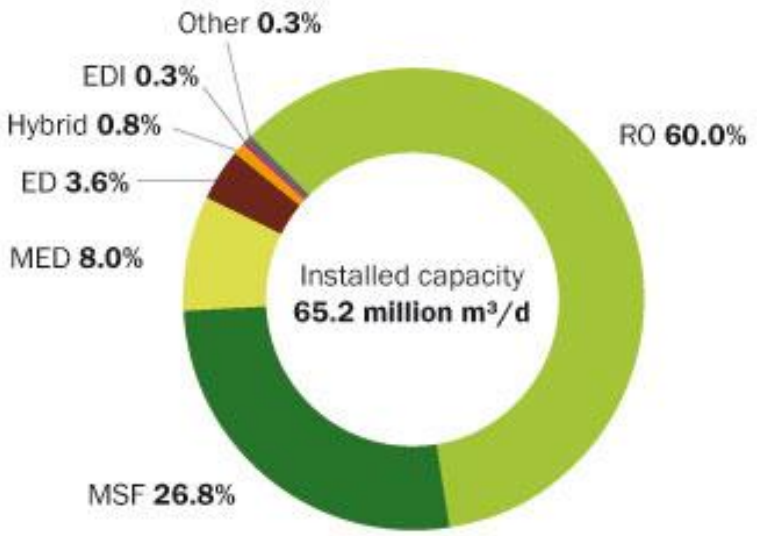
Shoaiba Power and Desalination Plant 3.6 million m³ of water per day

Source: IDA Desalination Yearbook 2011 DesalData.com

Global desalination capacity and trends



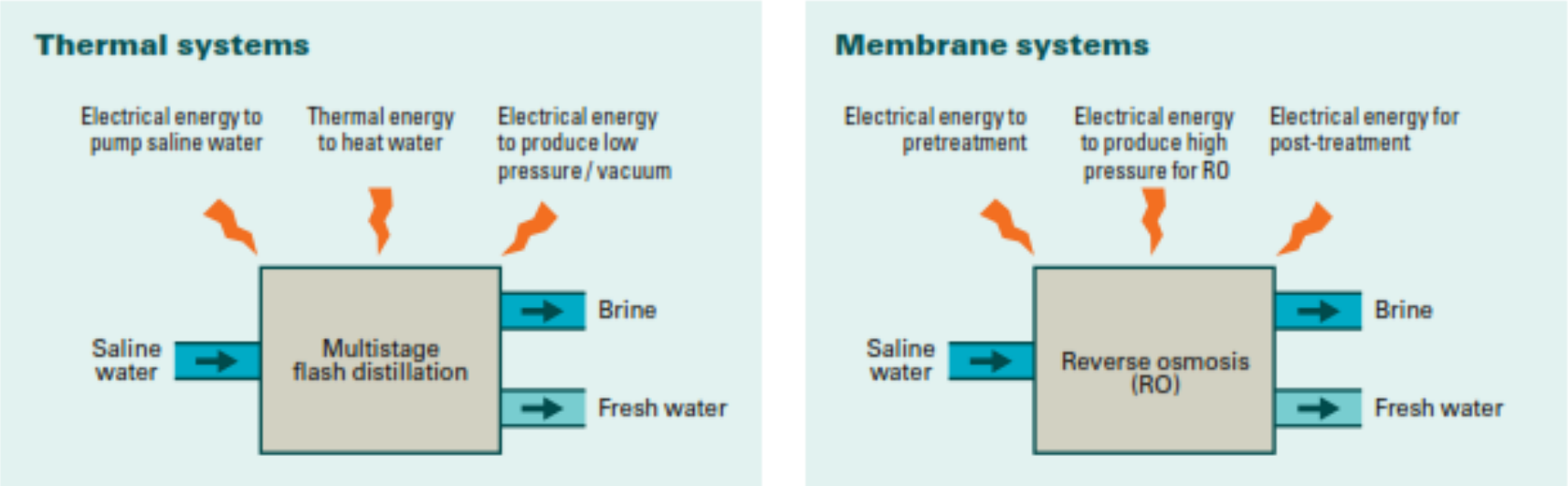
Installed membrane and thermal capacity, 1980-2010 (cumulative)



Total worldwide installed capacity by technology

Source: IDA Desalination Yearbook 2011 DesalData.com

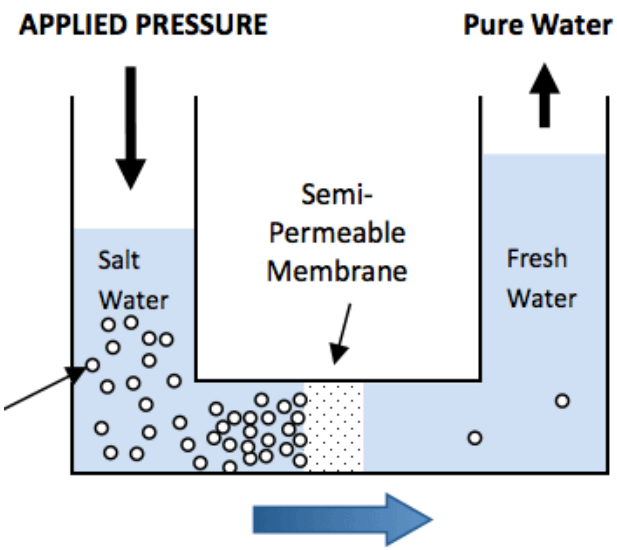
Desalination technologies



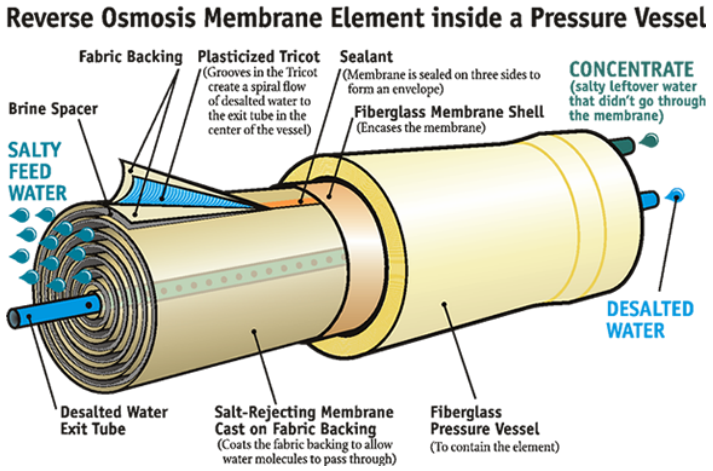
Schematic diagrams for major desalination technologies.

Source: Water in the energy industry: An introduction (BP), 2013

Desalination: Membrane (Reverse Osmosis)



Reverse Osmosis

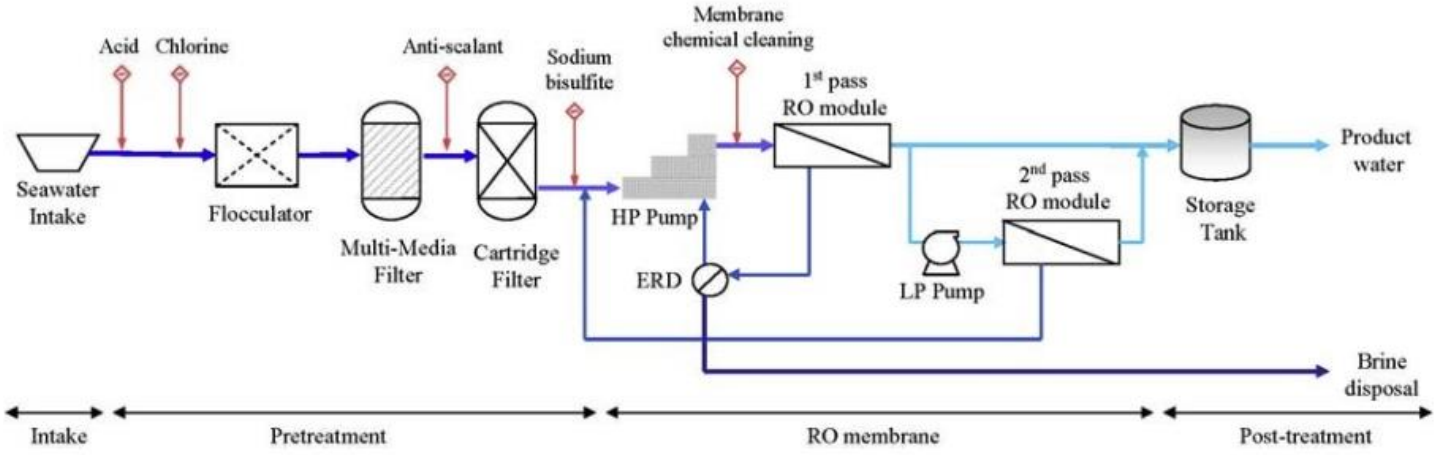


Membrane

Source: PureTec Water http://puretecwater.com/what-is-reverse-osmosis.html
U.S. Department of Interior http://www.usbr.gov/lc/yuma/facilities/ydp/yao_ydp_operations_ro.html

Desalination: Membrane (Reverse Osmosis)

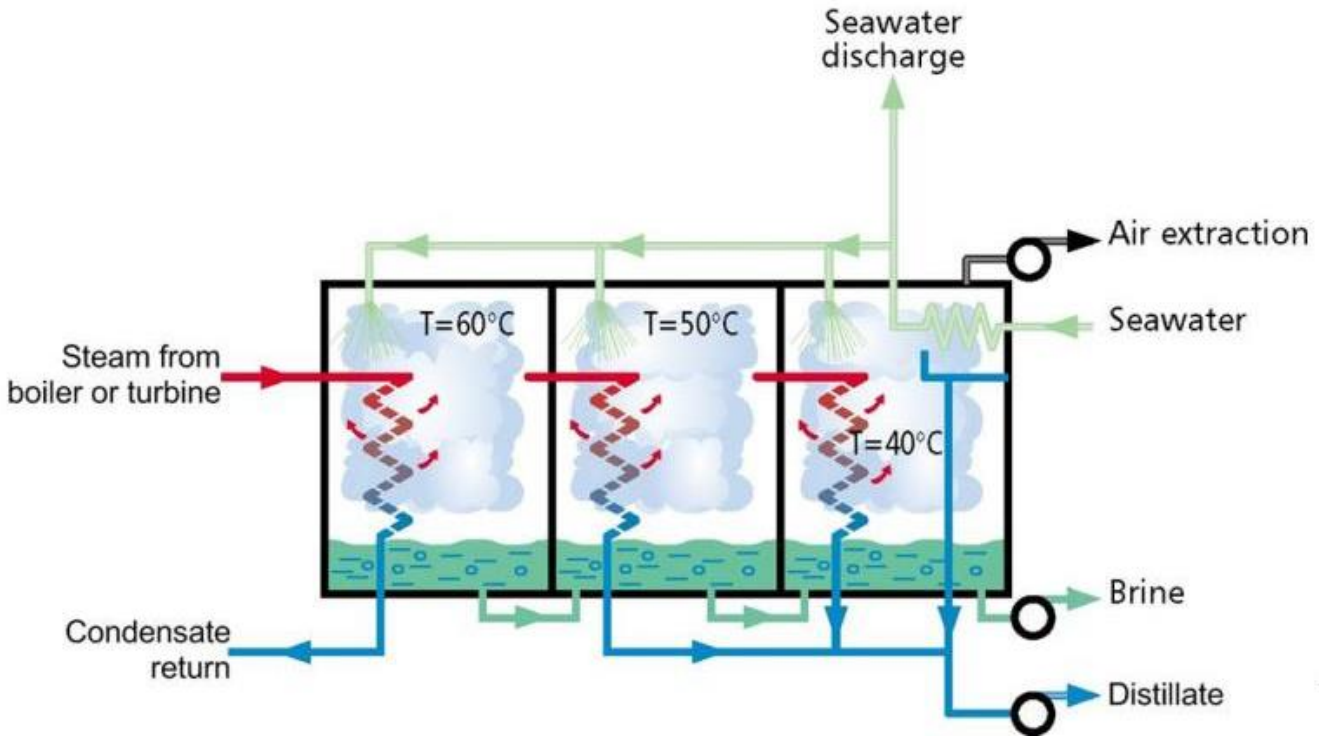
- Seawater intake
- Pretreatment
- High pressure pumping unit
- Membrane element assembly unit
- Energy Recovery Device
- Permeate treatment
- Storage tank*



Schematic diagram of a typical SWRO desalination process

Source: Membrane Desalination Technology; Mark Wilf, 2007
Diagram: Overview of systems engineering approaches for a large-scale seawater desalination plant with a reverse osmosis network Joon Ha Kim, 2008

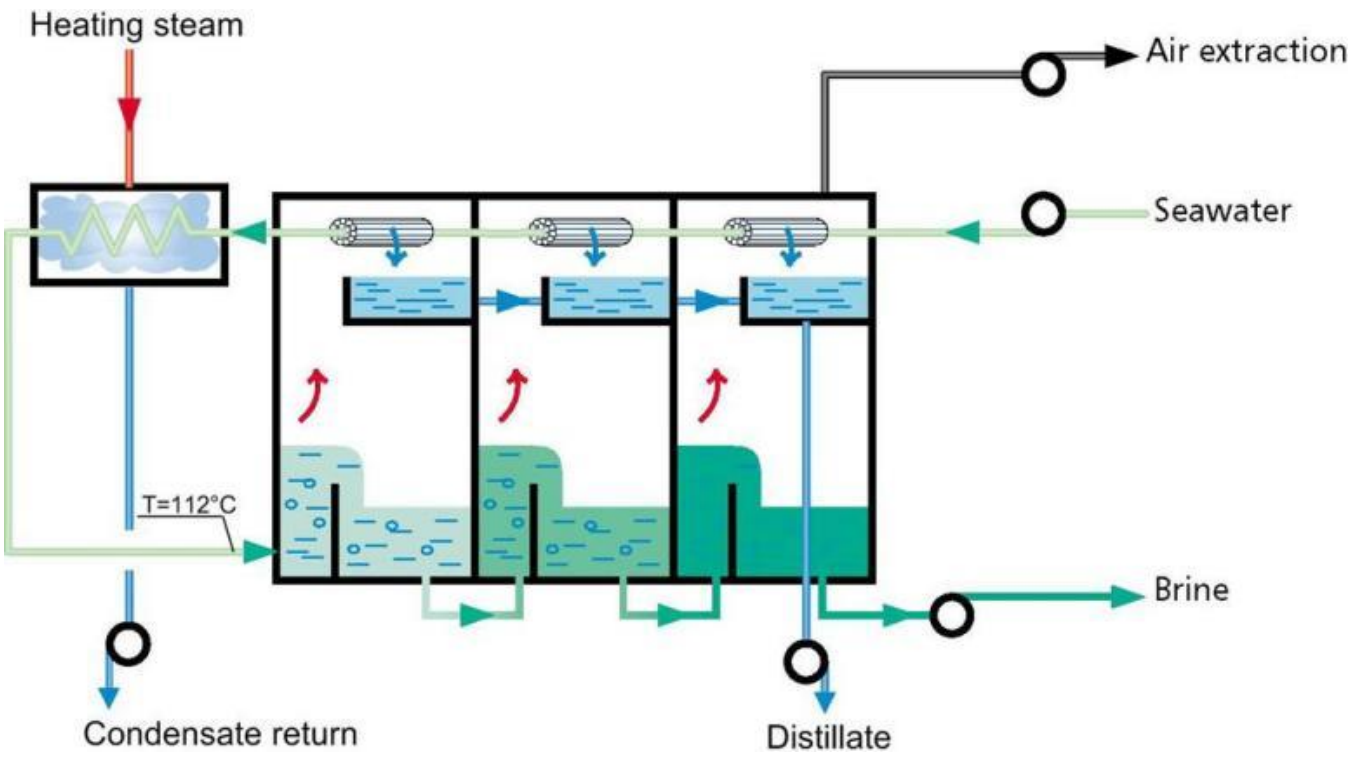
Desalination: Distillation (MED)



Multiple effect distillation unit

Source: Veolia http://www.sidem-desalination.com/en/Process/MED/Process/

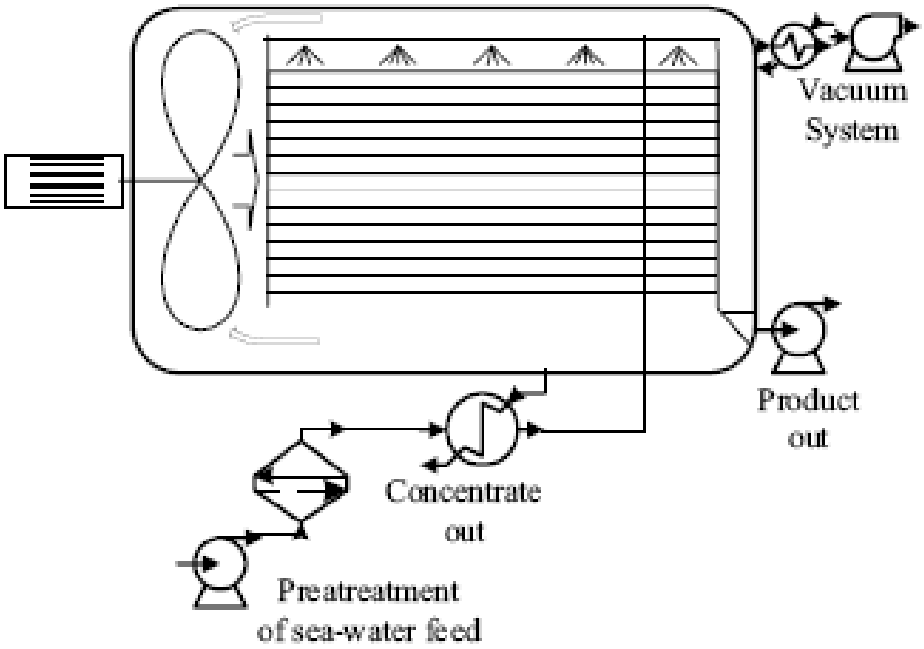
Desalination: Distillation (MSF)



Multi-stage flash unit

Source: Veolia http://www.sidem-desalination.com/en/Process/MSF/

Desalination: Distillation (VC)



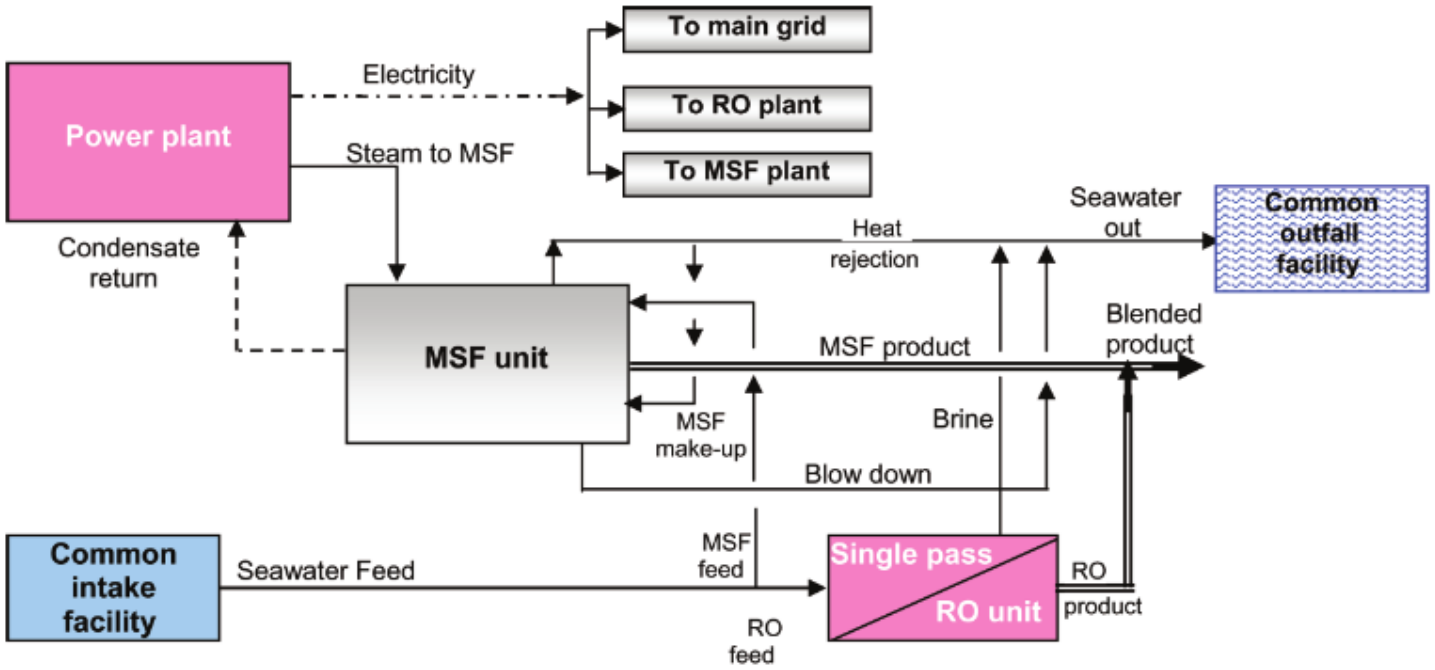
Vapor compression unit

Source: University of Wisconsin-Eau Claire. Course ENPH 441:Water and Wastewater http://people.uwec.edu/piercech/desalination/VCD.htm

Desalination: Energy Requirements

Process/energy type	MED	MSF	VC	RO
Electric energy equivalent, kwhr/m3	4.5	14.0	-	-
Electric consumption, kWh/m3	1.2-2.0	3.0-4.0	8.5	3-5
Total electric energy equivalent, kWh/m3	5.7-6.5	17-18	8.5	3-5

Hybrid Systems



Schematic diagram of commercially available simple hybrid desalination plants.

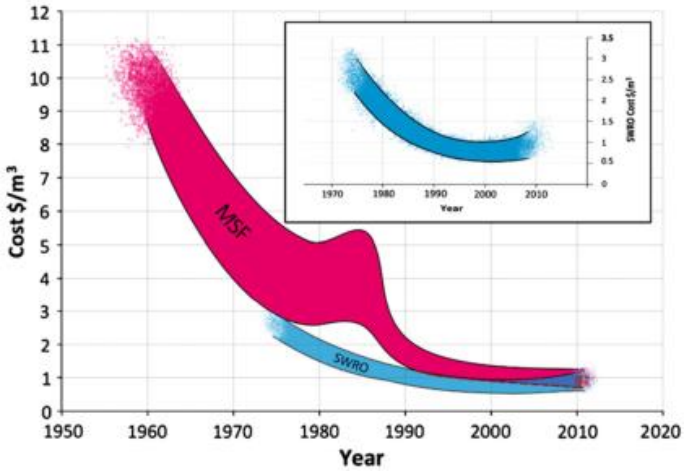
Source: Overview of hybrid desalination systems — current status and future prospects (Osman A. Hamed, 2005)

Types of Hybrid Systems

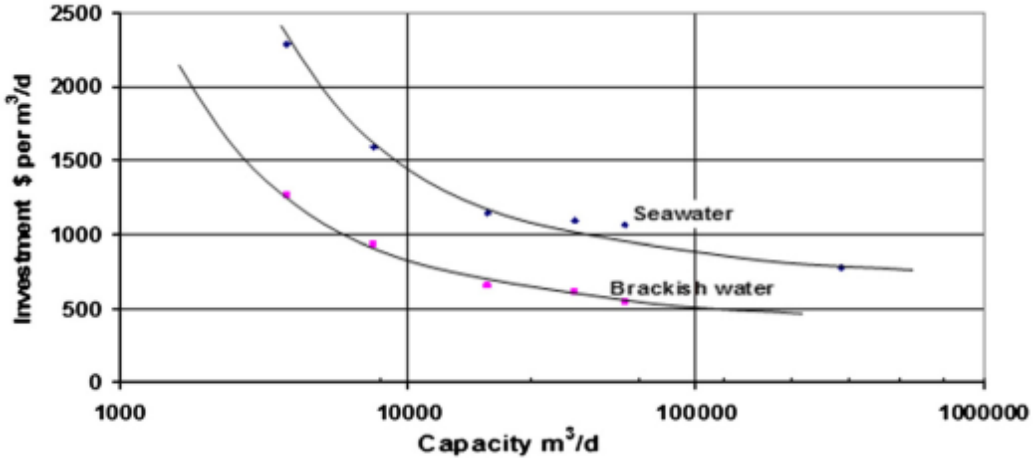
- Simple hybrid: combined with new or existing desalination process
- Integrated hybrid: application in new desalintion complexes.
- Power/water hybrid:
  - Seasonal demands of electricity and water
  - Power-to-water ratio
  - Minimization of fuel consumption and increase in the power plant effiency
  - Minimization of environmental impact of CO2

Desalination: Economics

"The cost of desalinated seawater has fallen below ***US$0.50/m for a large scale*** *seawater reverse osmosis plant at a specific location and conditions while in* ***other locations the cost is 50% higher (US$1.00/m3)*** *for a similar facility." (*Ghaffour, et. al, 2012)



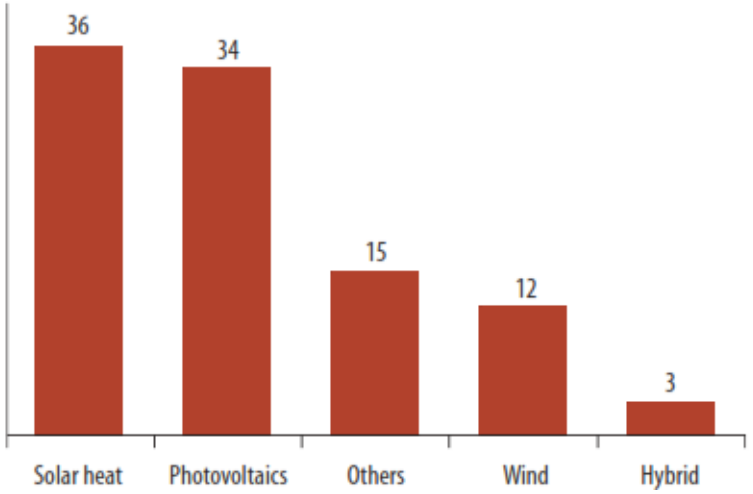
Unit water cost trends by SWRO and MSF processes.



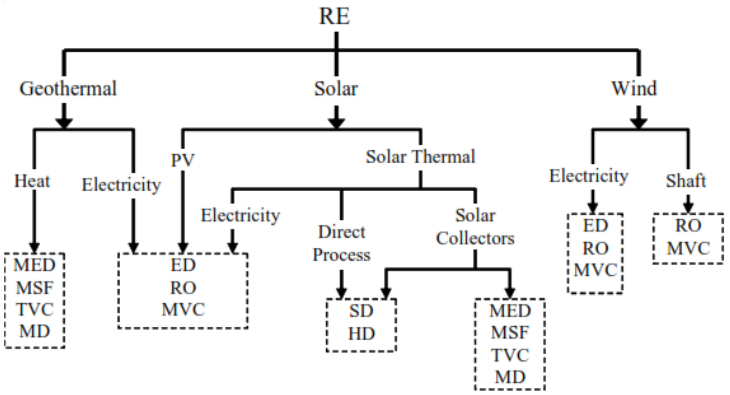
Investment costs in RO processes vs. capacity

Source: Technical review and evaluation of the economics of water desalination: Current and future challenges for better water supply sustainability. (Noreddine Ghaffour, 2012)

Renewable Energy Powered Desalination



Global Renewable Energy Desalination by Energy Source, 2009 (percent)

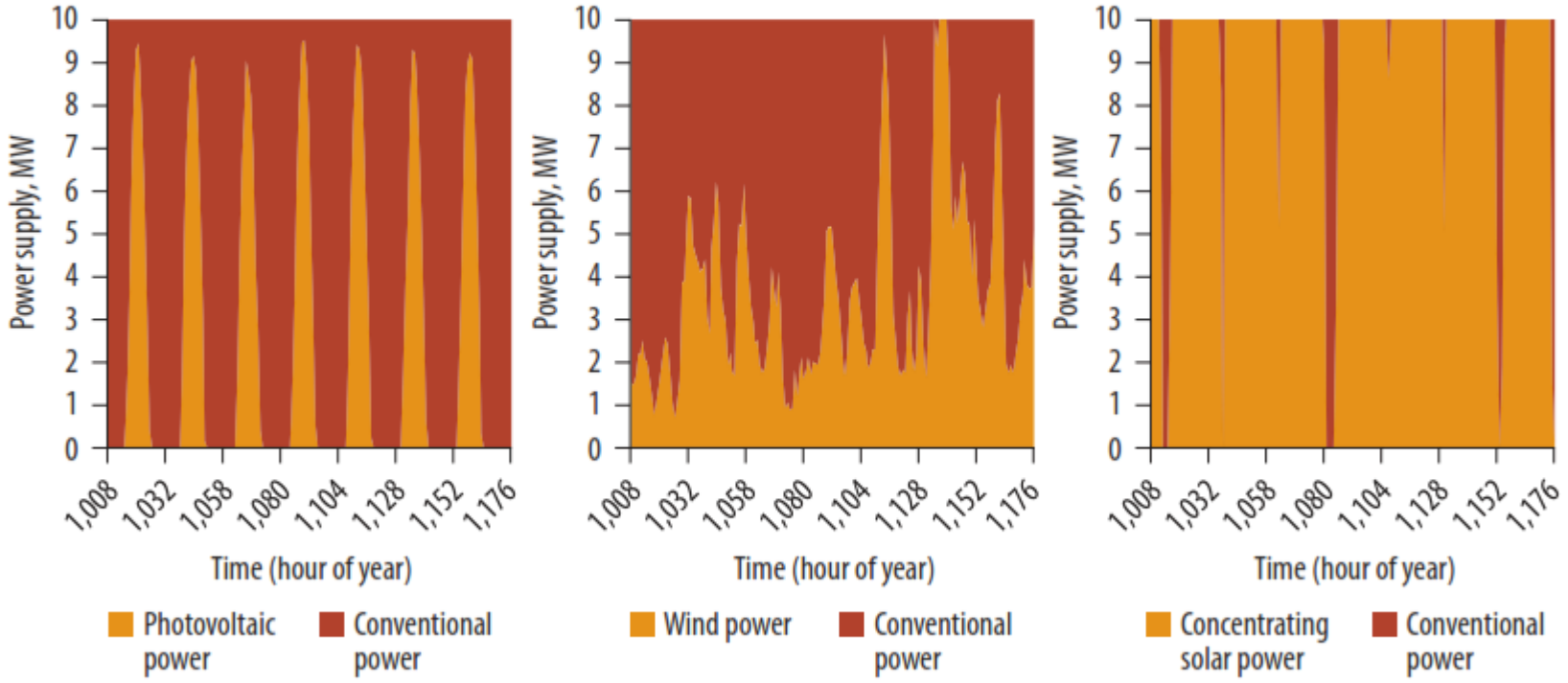


Possible technological combinations of the main renewable energies and desalination methods.

Source: Overview of hybrid desalination systems — current status and future prospects (Osman A. Hamed, 2005)
Renewable Energy Desalination. An Emerging Solution to Close the Water Gap in the Middle East and North Africa. (The World Bank,2012)

Renewable Energy Powered Desalination

Renewable Energy Production from Photovoltaics, Wind, and Concentrating Solar Power at Hurghada Site, Egypt, Arab Rep.



Source: Fichtner and DLR 2011.

Source: Renewable Energy Desalination. An Emerging Solution to Close the Water Gap in the Middle East and North Africa. (The World Bank,2012)

Renewable Energy Powered Desalination

RE source	Solar heat			PV			Wind	
Desalination technology	CSP-MED	MEH	Stills	EDR	RO	MVC	RO Small	RO Large
Production (m^3/day)	>5,000	1–100	<0.1	<100	<100	<100	50	1,000
Cost (€/m^3)	1.8–2.2	2–5	1–15	8–9	9–12	4–6	5–7	1.5–4.0

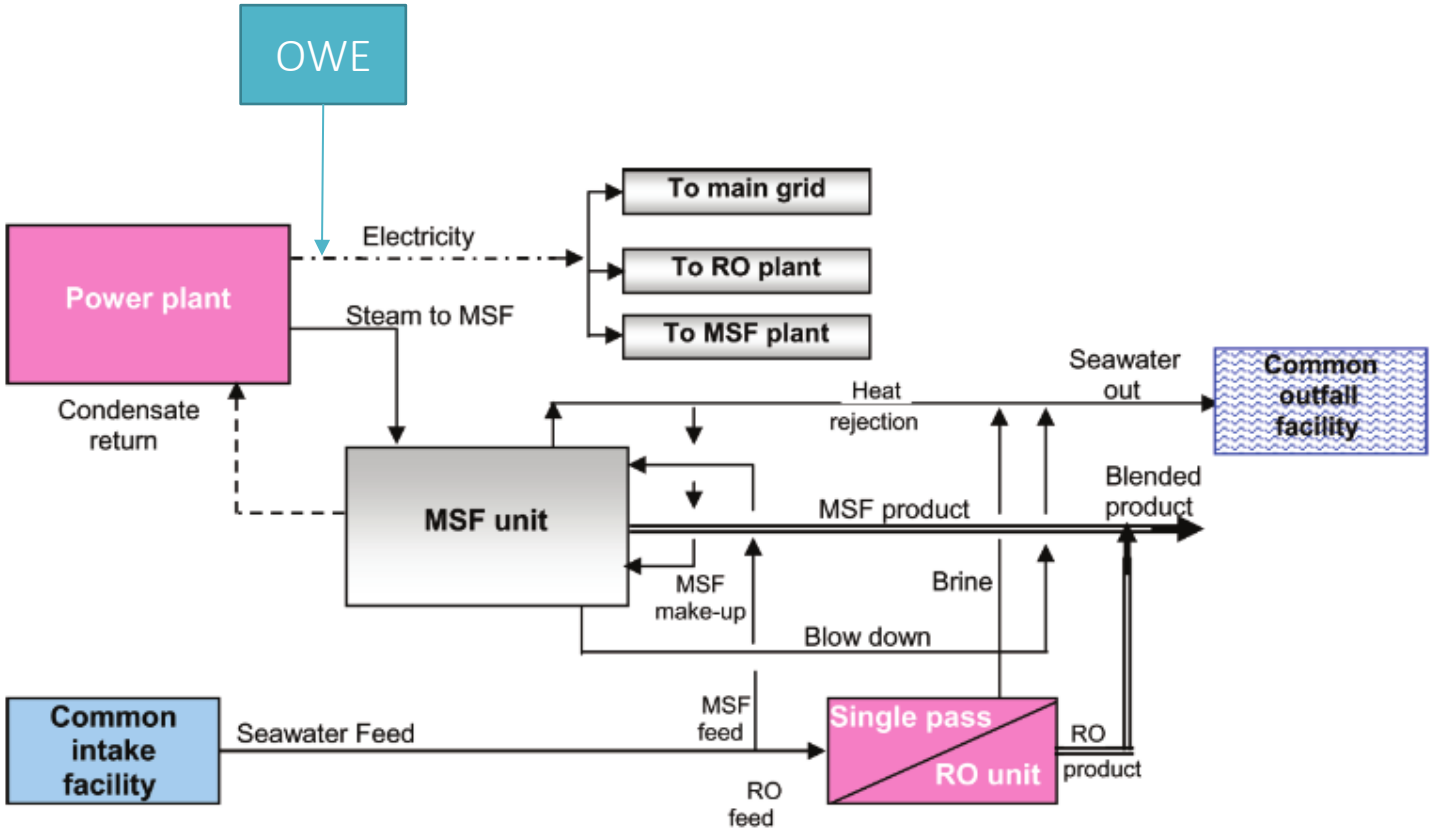
Source: After ProDes 2010, table 1.2.

Note: €1.0 = US$1.40; EDR = electrodialysis reverse; MEH = multi-effect humidification; MVC = mechanical vapor compression.

Cost of Desalinated Seawater from Renewable Energy Alternatives

Source: Renewable Energy Desalination. An Emerging Solution to Close the Water Gap in the Middle East and North Africa. (The World Bank,2012)

Offshore Wind and Desalination



Schematic diagram of commercially available simple hybrid desalination plants.

Source: Overview of hybrid desalination systems — current status and future prospects (Osman A. Hamed, 2005)

Research Questions and Future Work

- What is the desalinate water cost with offshore wind energy?
- Benefits of offshore wind in desalination industry and posible markets
- Technical aspects of this integration
- Backup system (grid, storage or other energy source) to be coupled with offshore wind in desalination system.
- Modeling optimization in the integration of offshore wind energy with desalination systems
- Case Study (Caribbean?)

Thank You!