Desalination

An option for the future

Top 10 desalination countries (2008)

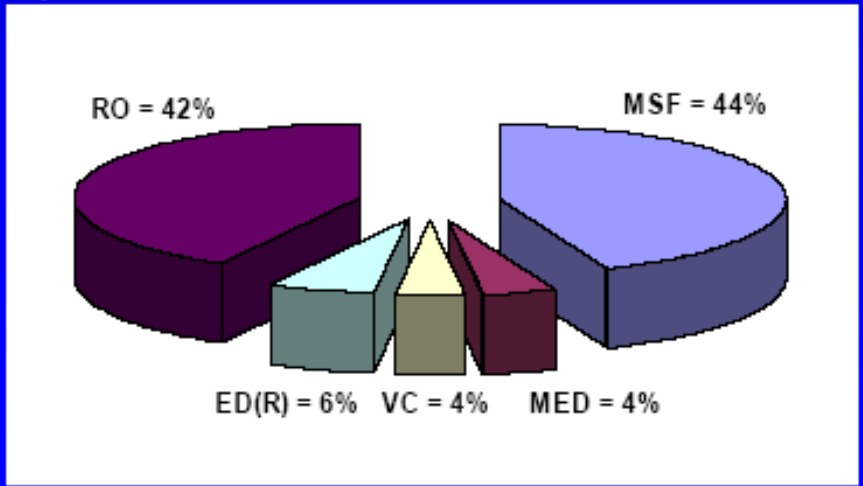
1) Saudi Arabia	10. 8 MCM/d
2) UAE	8. 4 MCM/d
3) USA	8.1 MCM/d
4) Spain	5. 2 MCM/d
5) Kuwait	2. 9 MCM/d
6) Algeria	2. 7 MCM/d
7) China	2. 3 MCM/d (2012)
8) Qatar	1.7 MCM/d
9) Japan	1. 5 MCM/d
10) Australia	1. 2 MCM/d
11) Israel	0.8 MCM /d

1% of fresh water comes from desalination

From Dr. Richard Hardiman, Truman centre for peace HUJI

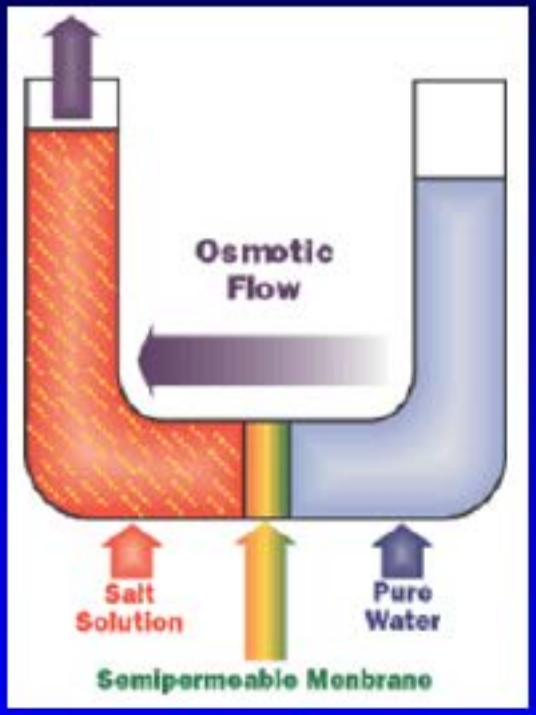
Available Technologies

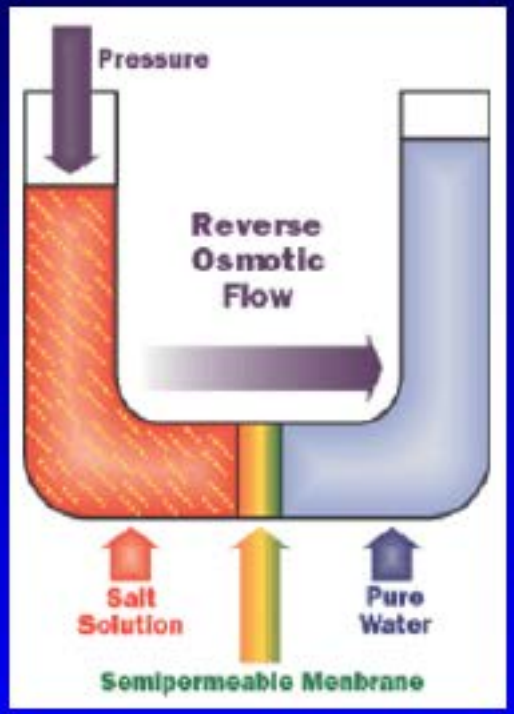
- Membrane-based Technologies
  - Reverse Osmosis (RO)
  - Electrodialysis (ED) and ED Reversal (EDR)
  - [Low pressure membrane technologies = UF, MF]
- Distillation Technologies
  - Multi-stage flash distillation (MSF)
  - Multiple effect distillation (MED)
  - Vapor compression distillation (VC)
- Alternative Technologies
  - Freezing
  - Membrane distillation
  - Solar humidification



World desalination capacity by process

Reverse Osmosis (RO)





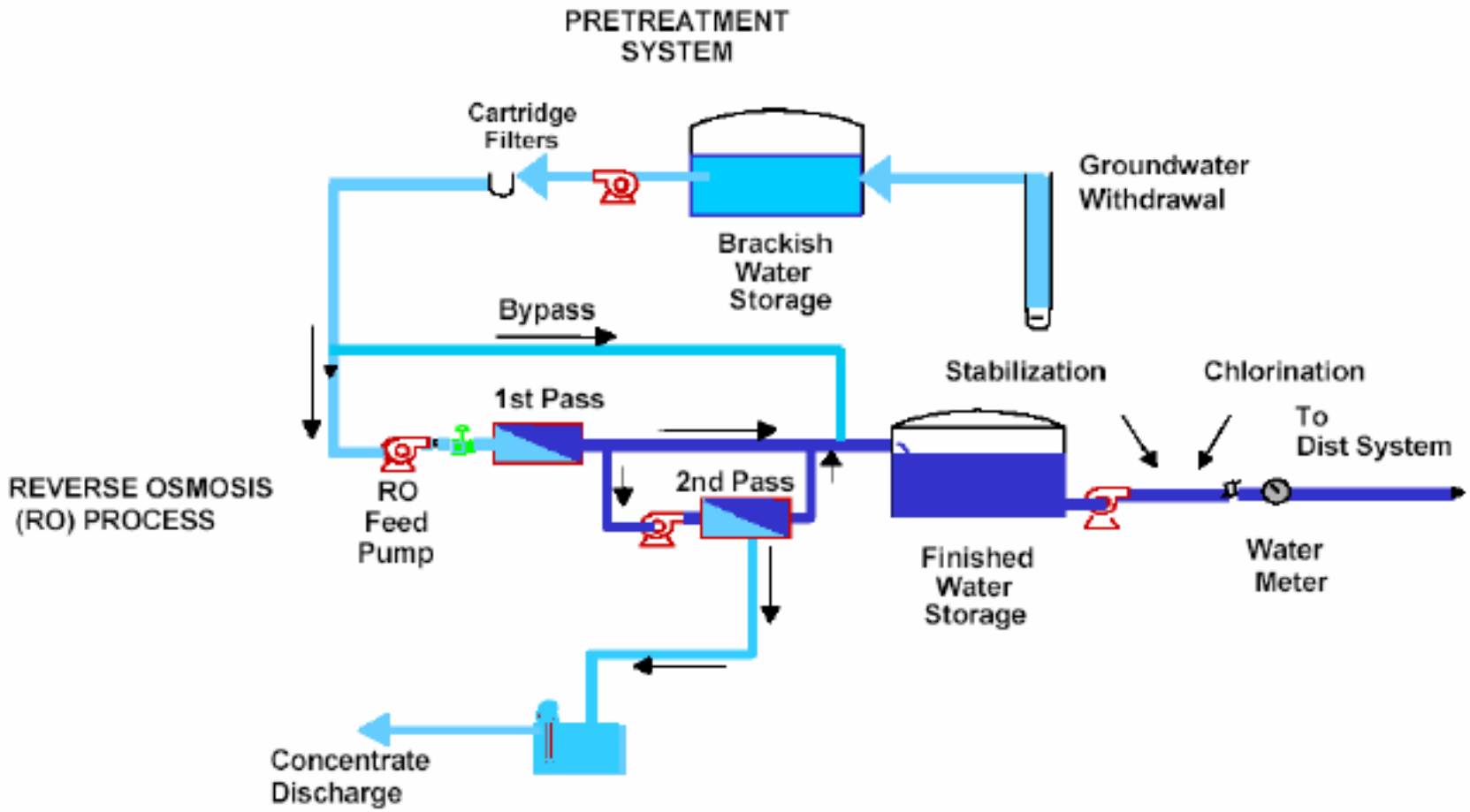
Source: AWWA

2 MGD Oceanside, CA RO Installation

Membrane-Based Technologies

- Microfiltration (MF): 10-0.1µm - bacteria, suspended solids
- Ultrafiltration (UF): 0.05-0.005µm - colloids, volatile organics, macromolecules, virus (and color&odor)
- Nanofiltration (NF): 5-0.5nm – sugars, dyes, divalent salts; water softening, sulfate removal
- Reverse Osmosis (RO): 0.5-0.05nm – monovalent salts, ionic salts
- Electrodialysis (ED) and electrodialysis reversal (EDR)

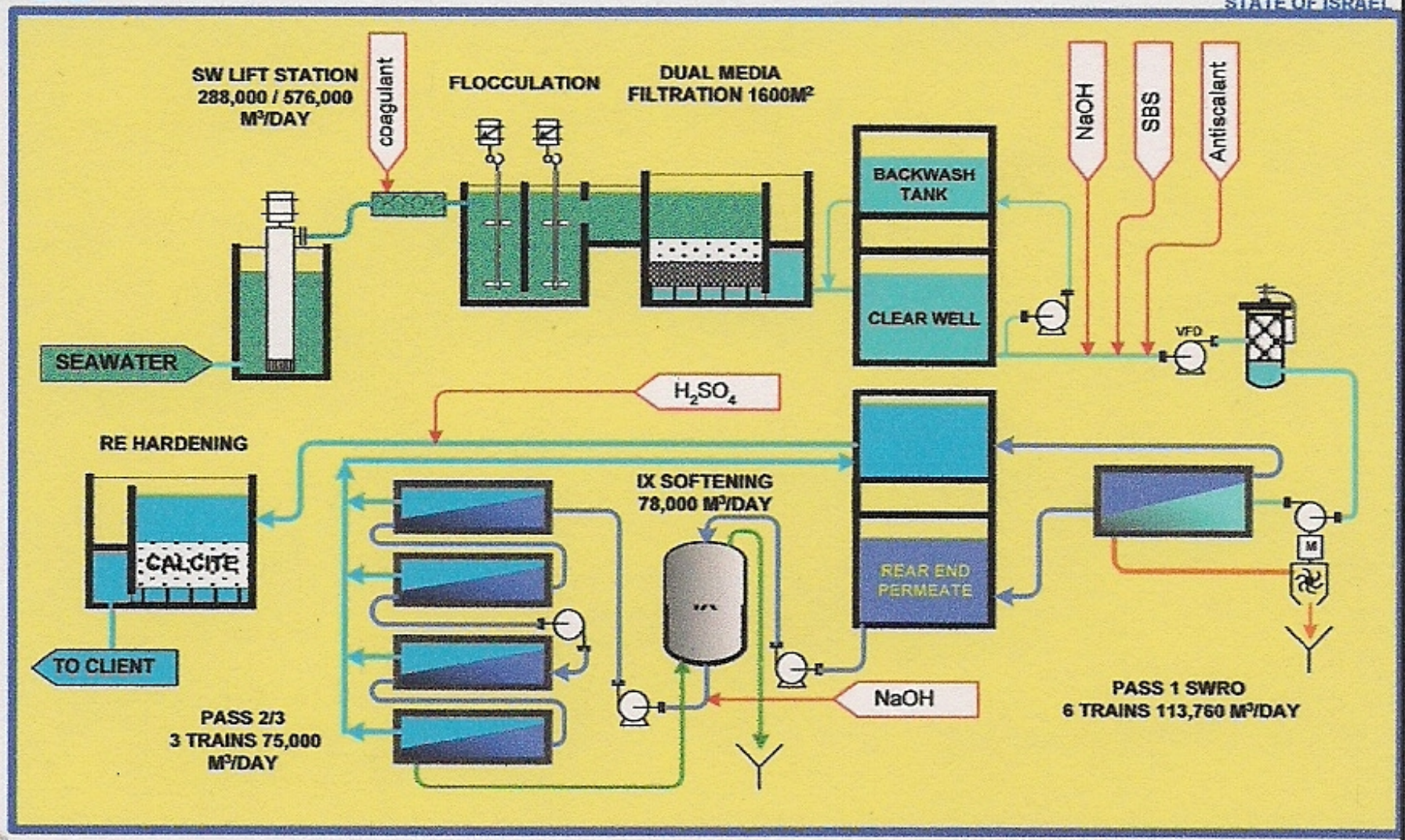
BWRO Plant Process



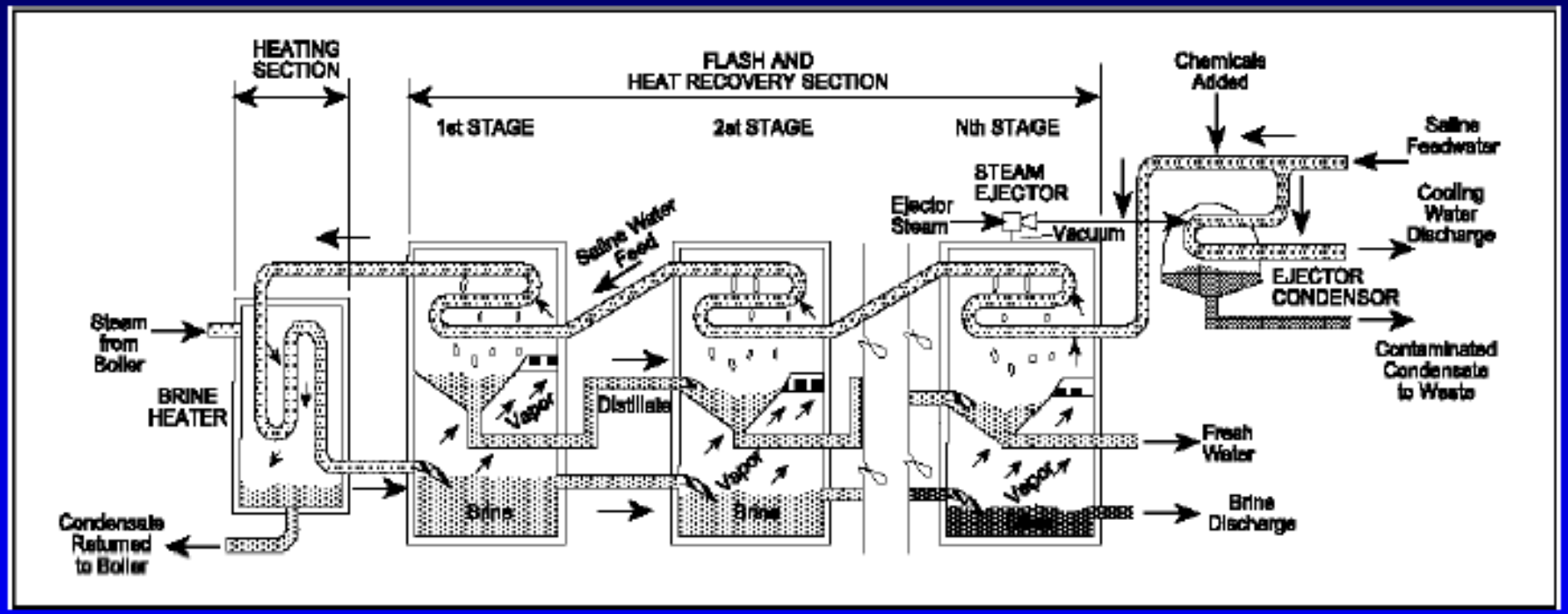
From R.W. Beck

SWRO Process Diagram

STATE OF ISRAEL



Multi-Stage Flash Distillation (MSF)



Source: ABC of Desalination, O.K. Buros, 2000

Process Characteristics

	RO	EDR	MSF/MED
Preferred Water Source	Any	Brackish	Seawater - Brine
Susceptibility to scaling	high	low	low
Bacterial Contamination	Possible	Post-treatment always needed	Unlikely
Final Product Salinity	On demand (<500 mg/L TDS)	On demand (<500 mg/L TDS)	Can be <10 mg/l TDS
Energy Cost	Moderate, increases with salinity	High, increases fast with salinity	High, independent of salinity
Recovery	Typically 50% for seawater, >80% for brackish water	>80% for brackish water	Poor= 10-25%
Plant Size	Modular, easy to operate, small footprint	Modular, easy to operate, small footprint	Large complex plants

Pre-treatment

- Pre-treatment is an important step of RO and could be a significant fraction of total cost:
  - Removal of particulates: MF
  - Removal of colloids to limit membrane fouling: chemical coagulation (alum, activated silica) or UF
  - Scaling issues: lime addition, softening (NF or ion exchange) to remove Ca/Mg, acidification to regulate pH

Desalination Economics

- Main problem over-high cost and investment cost
  - Municipal water tariff expected to converge with cost of desalination 2010-2015,
  - Sea water 0.6-1.0 USD/m^3,
  - Brackish water 0.3 USD/m^3
  - Cf. regular drinking water 0.3 USD/m^3

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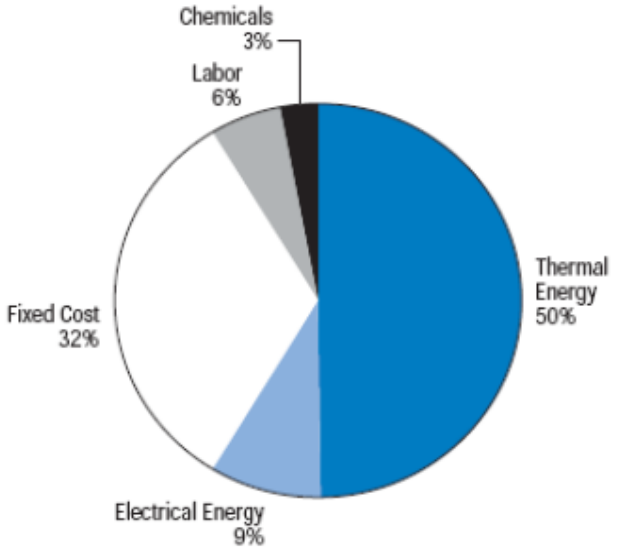
Notes on Cost

- RO pressure requirement for brackish water is much less than that for seawater, desalination of brackish water is less expensive than desalination of sea water.
- EDR is currently cost-effective only for low salinity sources
- Distillation-based technology cost is not function of salinity, they make sense only for higher salinity sources (seawater)

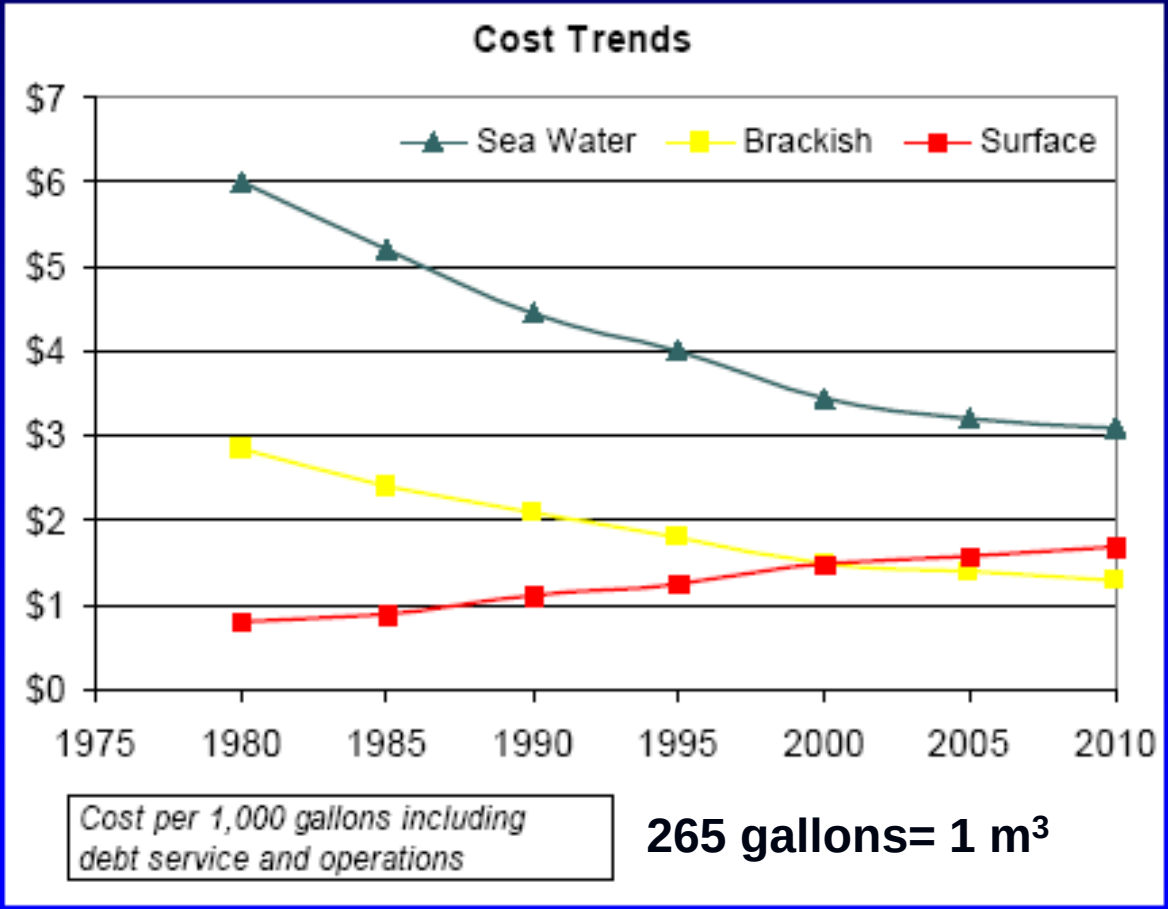
Economics

- Co-location
- Cogeneration
- Improved technology
- Decreasing capital and operational costs
- Energy price variability



Typical costs for a very large seawater thermal desalination plant

Cost Trends



Energy: In 6 years costs have dropped from 12 kWh/m^3 to 3.2 kWh/m^3

Source: Southmost RWA

Cost of recycling

Table 3.2 Wastewater Treatment Cost for Major Industrial and Domestic Sectors

Sector	Treatment cost (yuan/ m^3)
Coal mining and washing	2.00
Food processing	3.20
Food manufacturing	1.95
Beverage manufacturing	1.65
Textile manufacturing	2.50
Paper and paper products manufacturing	2.50
Raw chemical materials and products	3.70
Petrochemicals	3. 80
Medicines manufacturing	1. 90
Chemicals manufacturing	3. 70
Chemical fibers manufacturing	2.80
Non-metallic mineral products	2.65
Iron and steel smelting and pressing	3. 50
Power generation and heating	2. 00

Cost of treatment: 0.3-0.6 USD/m^3

Construction Costs of Multi Stage Flash Desalination plant

- MSF Plant
  - Construction Cost US$1700/$m^3$/day output
  - Fresh water Cost 0.75 USD/m^3
  - Uses water from power plant using 6,000 m^3/day costing 0.35 USD/m^3
  - Desalination costs kept down by using steam from the power plant

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Other Issues

- **Problem: pre-treatment – If the sea is polluted cost of pre-treatment is high**
- Cost of Pre-treatment (Steam distillation vs. Reverse Osmosis)
  - Partly overcome by chemical by-products (c.f. Dead Sea Works)
- State Oceanic Administration (SOA) and brine
- Linkages between water supply under MWR and SOA
- In 2006 market US$55-70m in 2006 and should reach US$600-860m in 2012-15

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CONCENTRATE DISPOSAL

Concentrate Disposal Options

- Fate of concentrate is the biggest issue facing desalination:
  - Ocean: typically several miles offshore with diffusers (dilution)
  - Surface water, sewer, land application (dilution)
  - Evaporation pond
  - Deep well injection
  - Zero-discharge=Industrial re-use: chemical/plastic industry, beneficial use

Deep-Well Injection in Texas

- Regulated by Clean Water Act, Underground Injection Control, and state and local regulations (Title 30 of TAC)
- Class I Injection well applications are expensive and technically complex, but this is currently the only class allowed to accept desalination wastes
- Injection along with produced waters into Class II wells for pressure maintenance or for EOR could greatly simplify the process to the benefit of both desalination and oilfield operators

Surface Discharge

- Convenient from sea water plants with high volume of concentrate
- Inland surface water body and evaporation pond discharge requires permitting by state and local regulations (Title 30) and must observe Clean Water Act regulations

- Question: Desalination energy costs high
- Should one go in the direction of Desalination of seawater costing 5 RMB/m^3
- When recycling and cleaning of domestic sewage is only 0.8-1.0 RMB/m^3; industrial polluted water 1.7-3.0 RMB/m^3

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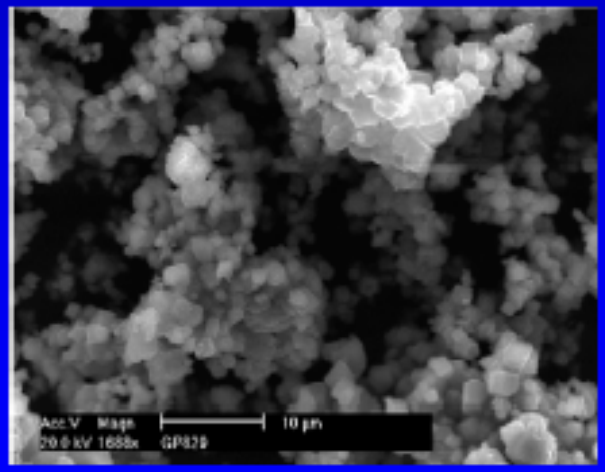
Zero Discharge

- Maximize water recovery
- May improve public acceptance
- Can have high operational and investment costs: need to evaporate brine to dry products
- Cost can be offset by beneficial use of by-products (brine or specific salts)



Source: Geo-processors Limited PTY, AU

Precipitated Calcium Carbonate (PCC)

Desalination

Future Plans

(million m^3/year)

- 2013: 600
- 2020: 720
- 2020: 55 (brackish water)

Reverse Osmosis Cost
2002: 12 kwh/m3
2008: 3.2 kwh/m3

Current (2010)

(million m^3/year)

- Ashkelon (2005): 110
- Palmachim (2007): 30
- Hadera (2010): 100
- Current Total: 240

Under construction

- Haifa: 30
- Ashdod: 45

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