Economic and technical assessment of desalination technologies

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John F. Kennedy had said “If we could ever competitively, at a cheap rate, get fresh water from saltwater, …..(this) would be in the long-range interests of humanity which could really dwarf any other scientific accomplishments.” (September 22, 1961)

Outline of the talk

- A global overview of desalination
- The trends of costs of desalination

Introduction to desalination

- 97% of the earth's water is seawater salt content ~ 35,000 mg/liter
- Domestic water supply requires:

  Dissolved solids content <1000 mg/l

  Drinking water < 500 mg/l
- Desalination refers to the wide range of technical processes designed to remove salts from water.

Quality categories for water salinity

Use	Rating	Approximate salinity (mg/l)
Human consumption	Excellent	<100
Human consumption	Good to fair	100-1,000
Human consumption	Poor	1,000-1,200
Human consumption	Unacceptable	>1200
Irrigation	Maximum for healthy growth	3,500

Introduction

Why go for desalination

- Potable water shortage
- Growth of technology and industrial demand for pure water, (Power Plant, Petroleum, Food and Medical Industries, etc.)
- The ongoing deteriorating quality of fresh water sources
- The reduced cost of water produced by desalination.

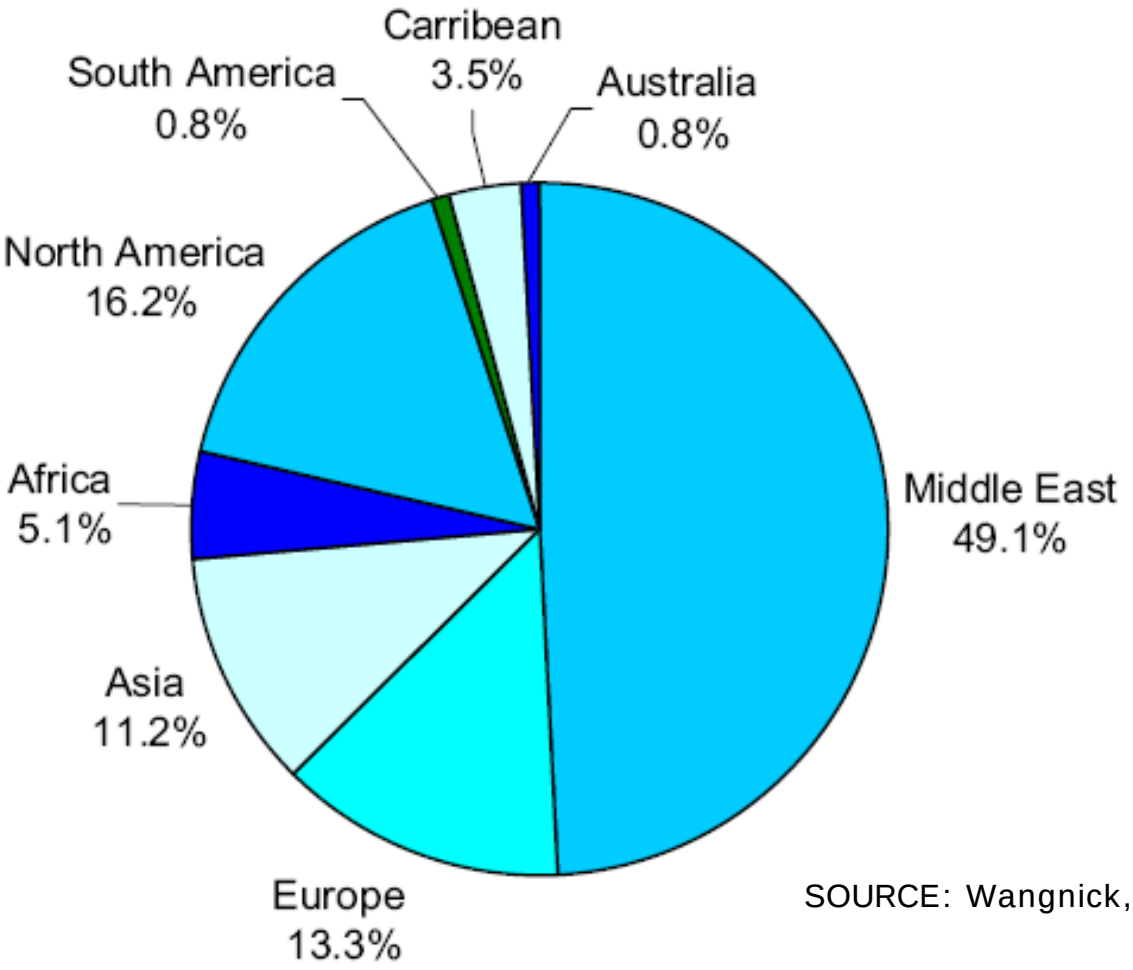
Consumers

Desalination has developed rapidly, and is an important source in parts of

- Middle east
- Arabian Gulf
- North Africa and some islands

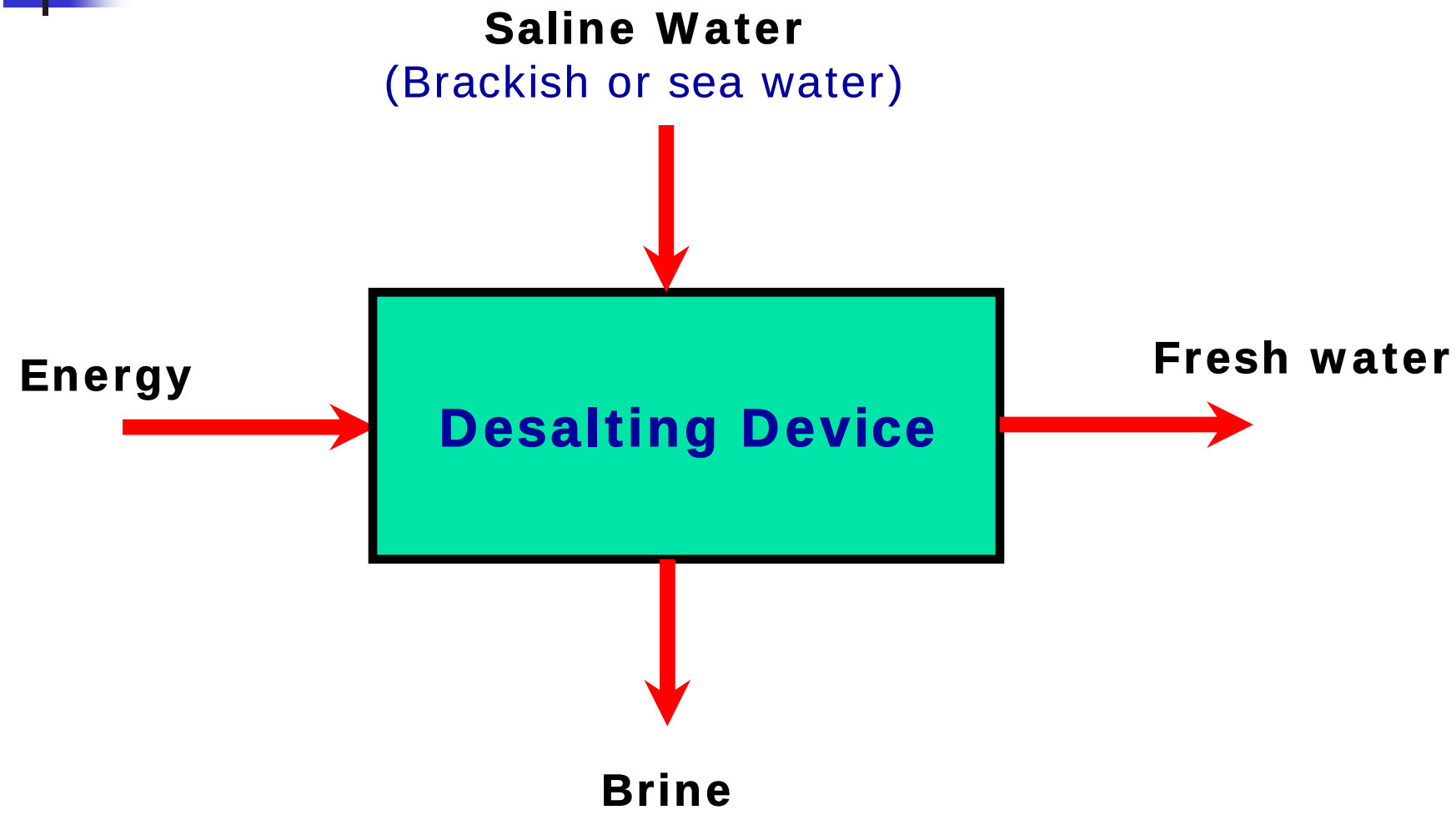
as well, become increasingly explored by many other regions as well

Chart showing fraction of the worldwide capacity of desalination plants by region



SOURCE: Wangnick, 2002.

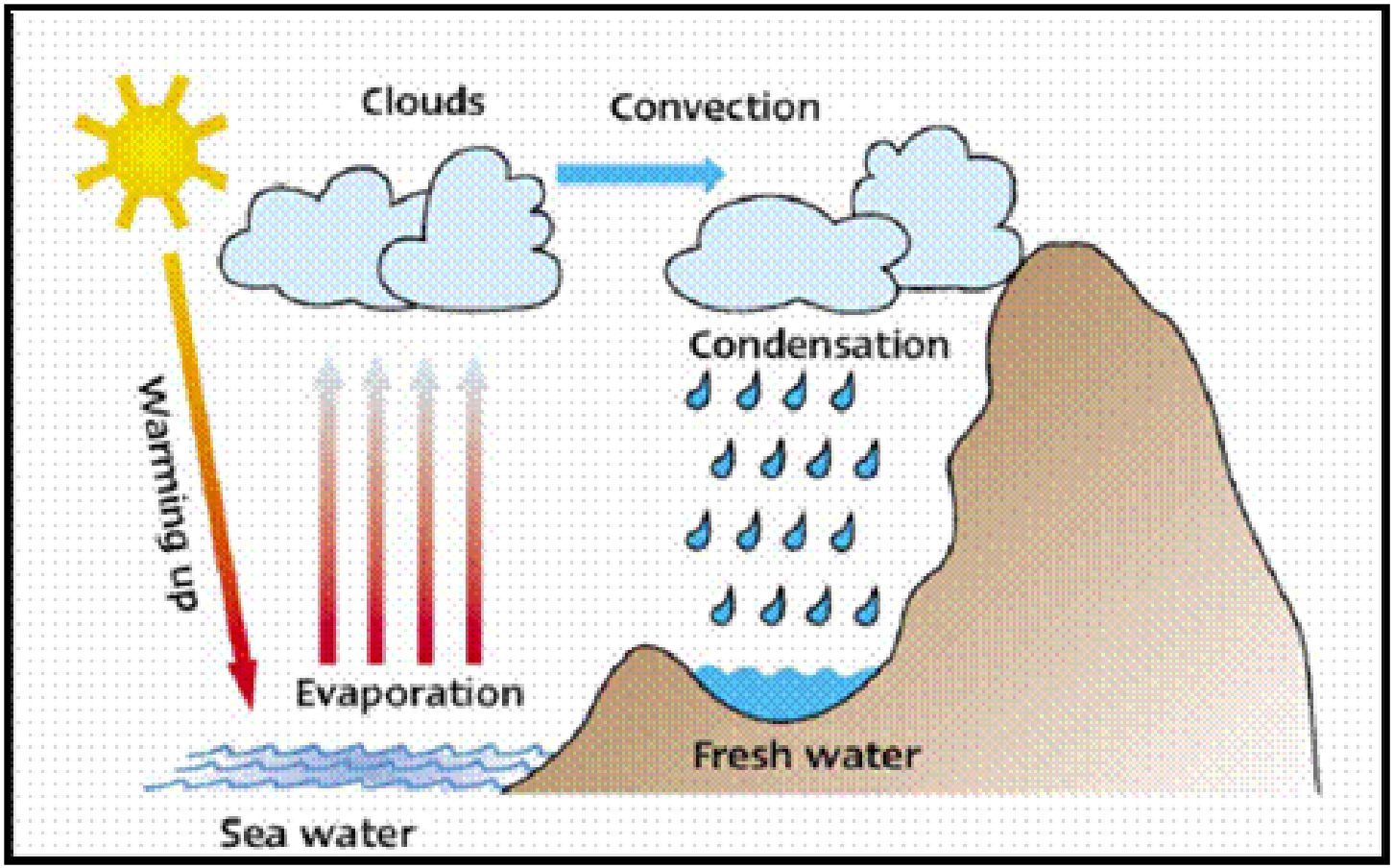
Desalination



Desalination Processes

- Thermal –mimic natural water cycle, produce water vapor, then condensed to form fresh water
- Commercial plants with multi stage Concept
  - Multi Stage Flash (MSF)
  - Multi Effect Distillation (MED)
  - Vapor Compression (VC)
- Normally are used for seawater desalination, because of the high energy requirements for vaporization (phase change)

Thermal desalination



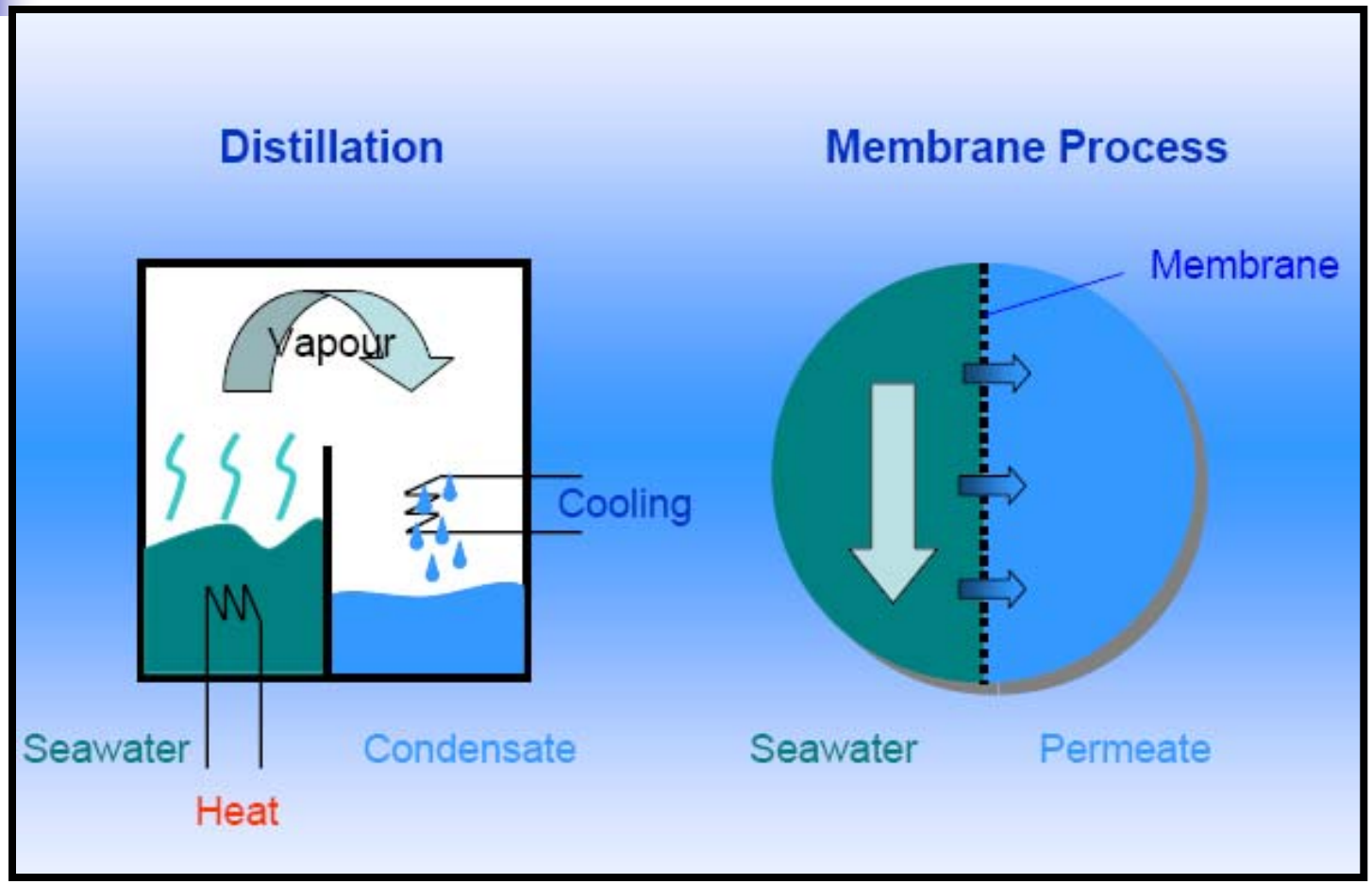
Membrane Processes

- Need to produce water without involving phase change ➔ to reduce energy consumption
- Membranes –needs electrical energy or shaft power
- Two processes emerged:
- ✓ Reverse Osmosis for seawater and brackish water
- ✓ Electrodialysis for brackish water only

Alternative processes

- Renewable energy powered conventional desalination
- Solar humidification
- Freezing
- Membrane distillation

Principles of desalination



Source of energy

- Fossil Fuel ➔ CO_2 emission, costly
- Renewable Energies ➔ Still high cost

Multistage Flash Distillation (MSF)

- It was invented in 1950
- First MSF plant was build in 1957 in Kuwait
- MSF is thermodynamically inefficient process
- MSF is matured and mostly used in the Middle East
- Capital cost is US$ 5 to 6 per installed gallon/day
- Desalinated water cost is US$ 0.8 to 1.5 per cubic meter

Multi Effect Distillation (MED)

- It is adopted from chemical industry to desalination in 1900
- First MED plant was built in 1930 in Saudi Arabia
- MED is thermodynamically efficient process compared to MSF
- Capital cost is US$ 3.5 to 4.5 per installed gallon/day
- Desalinated water cost is US$ 0.7 to 1.0 per m^3

Vapor Compression Distillation

- The operating costs are low compared to multi-stage or multi-effect flash distillation systems
- The equipment is smaller than the multi-stage flash or multi-effect flash distillation systems
- maintenance on compressors and heat exchangers is greater than those of other systems

Reverse Osmosis (RO)

- Has been used commercially since 1982
- Membrane costs have fallen by 86 percent between 1990 and 2002 (Chaudhry, 2004)
- In fact, 2005 unit cost of SWRO are only about a third of 1995 unit cost

Review

Thermal processes are generally used in the following applications:

- To treat highly saline waters (predominantly seawater)
- Where large volumes of product water are required.
- In locations where energy costs are low or where a waste heat source is available.

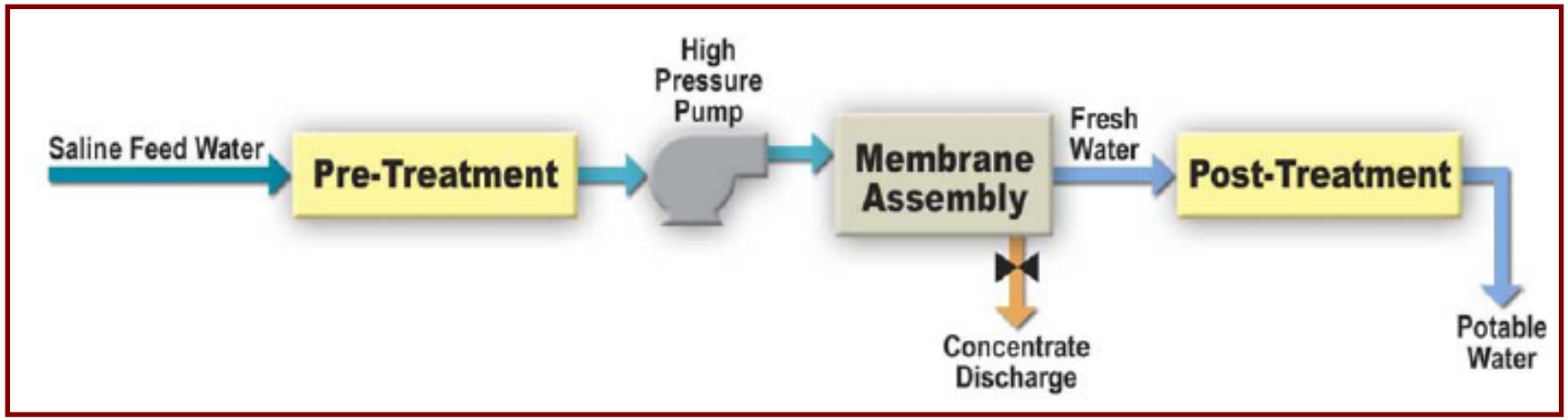
Review

Membrane processes, on the other hand, are more favorable for treating brackish waters (under most conditions) or highly saline wastes where energy costs are high or the flow rates are low.

Advantages of RO

- Quick and cheap to build and simple to operate
- Handle a large range of flow rates
- Energy consumption is low
- High overall water recovery rates
- The startup and shutdown of the process does not take long.

Seawater Reverse Osmosis Plant Flow Chart



Comparison thermal vs. membrane

	MSF	RO
Energy Consumption	~13 kWh_{el}/m^3 (70 kWh_{th} + 3 to 4 kWhel)	4 - 5 kWh_{el}/m^3
Recovery	10% - 20%	30% - 50%
Investment [$/($m^3$/day)]	~ 1,000 – 1,500	~ 7,00 – 1,500 (10% for membranes)
Chemicals [$/$m^3$]	~ 0.03 to 0.05	~ 0.06 to 0.1
Brine Quantity	Distillate x 4 to 9	Permeate x 1 to 4
Brine Quality	Chemicals, Heat	Chemicals
Robustness	High	Fouling Sensitivity, Feed water Monitoring
Improvement Potential	Low	High

Factors Influencing Selection of Desalination Technologies

- Financial issues.
- Energy Requirements.
- Source water characteristics.
- Geographical and location constraints.
- Product water requirements.
- Environmental factors and waste disposal options.
- Operational and maintenance issues
- Utilization rates.

Costs of desalination

Capital costs

- direct costs

  purchase of equipment, land, construction charges and pre-treatment of water

- indirect costs

  interest, insurance, construction overheads, project management and contingency costs

Annual O&M costs

labor, energy, chemicals, consumables and spares

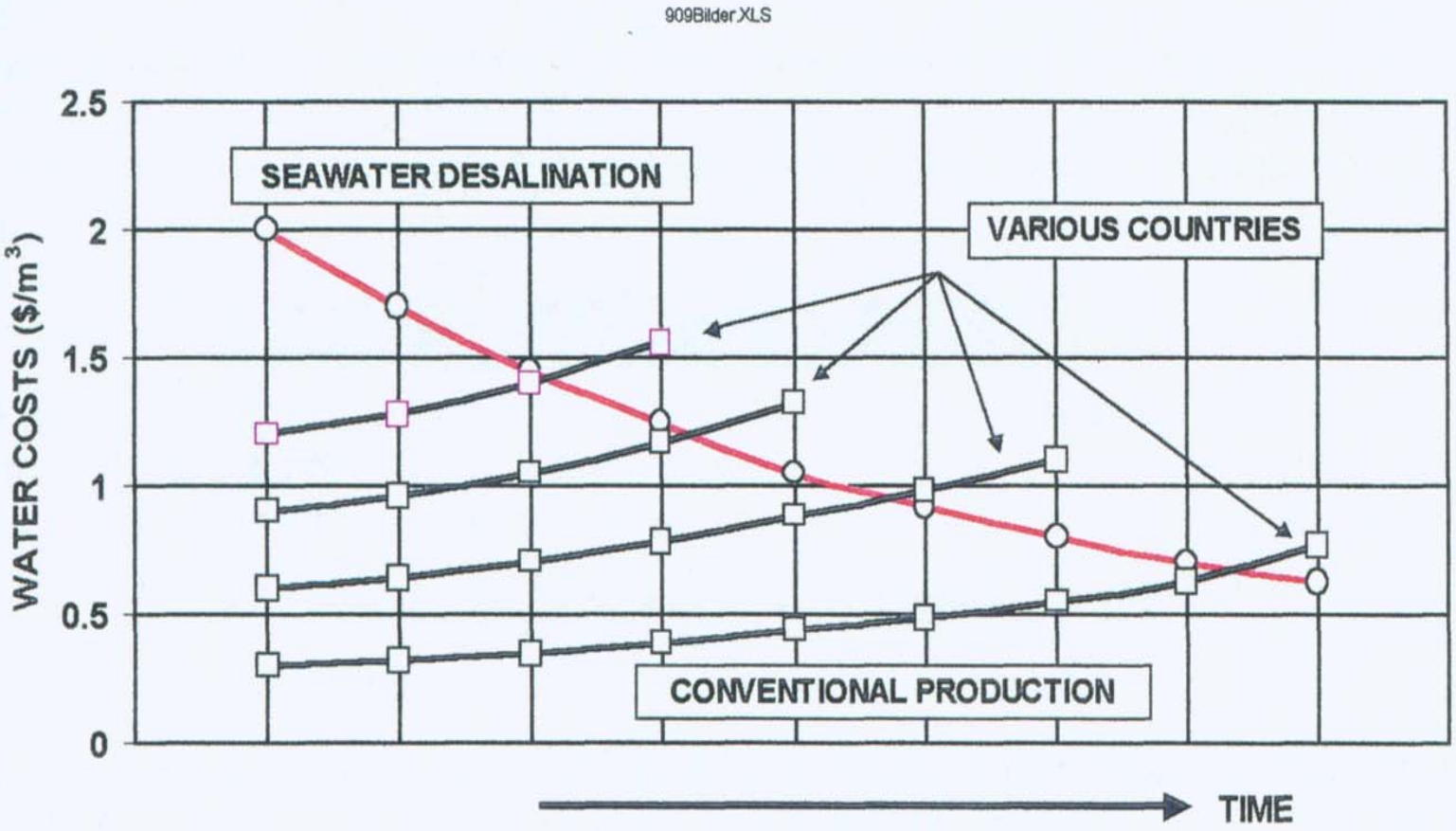
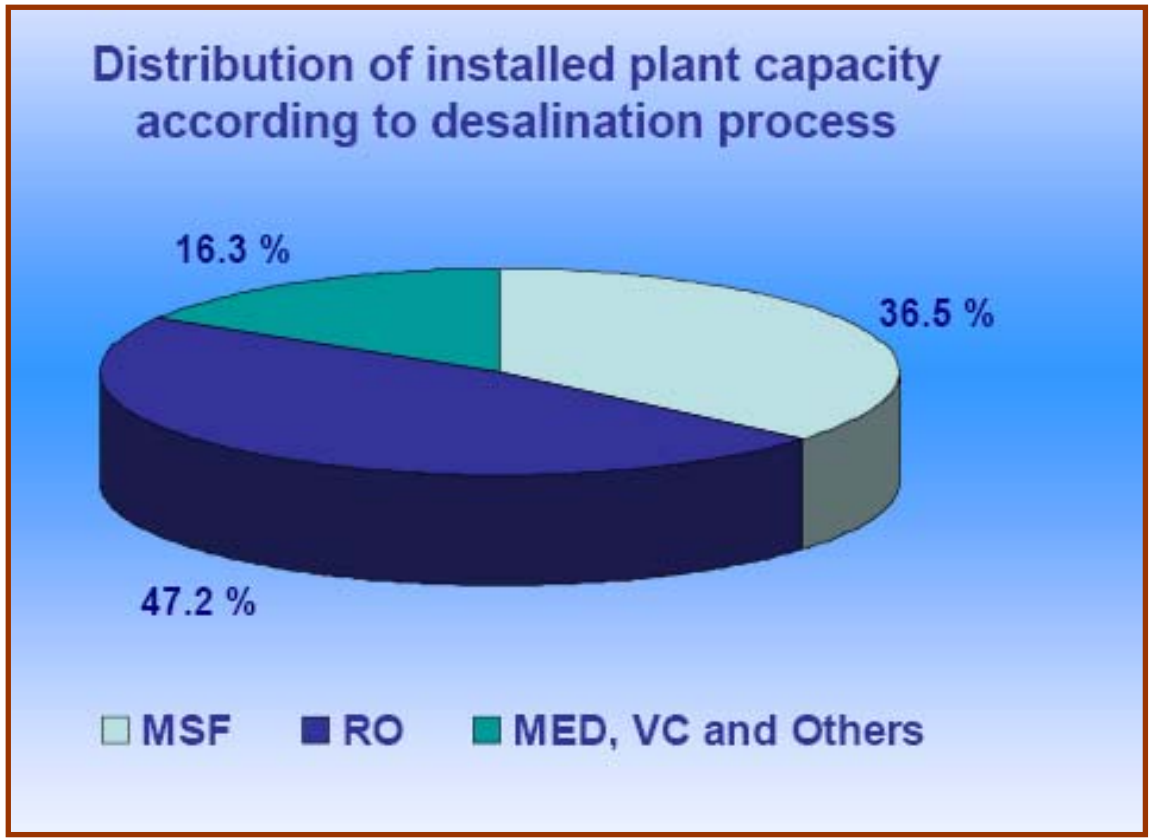
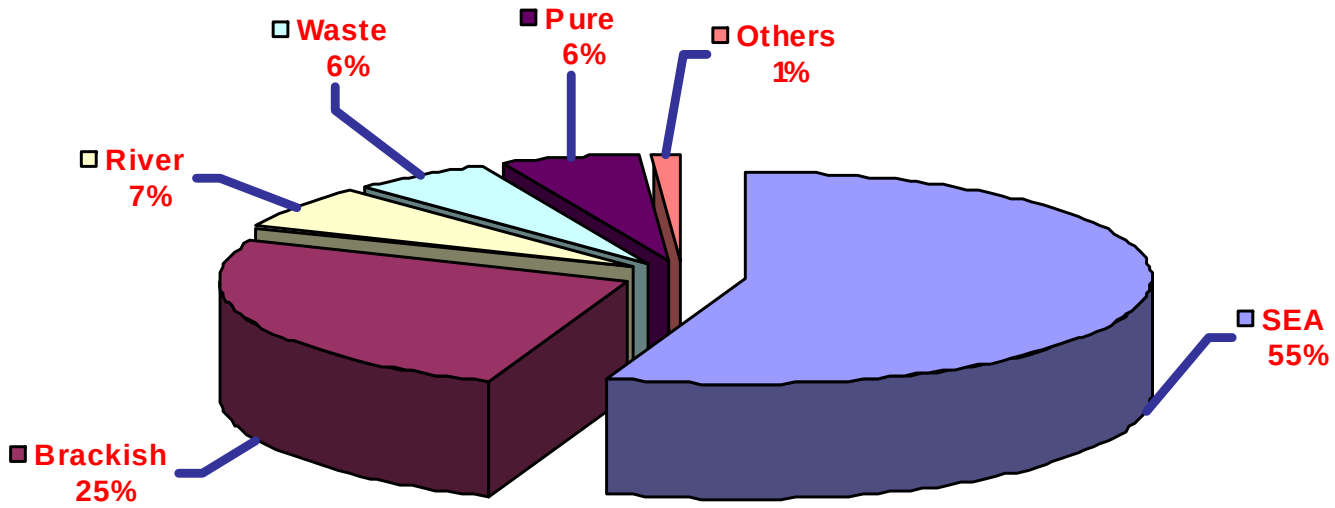


Fig. 4/1: Development of water costs

Desalination Technologies



World desalination capacity



by raw water quality

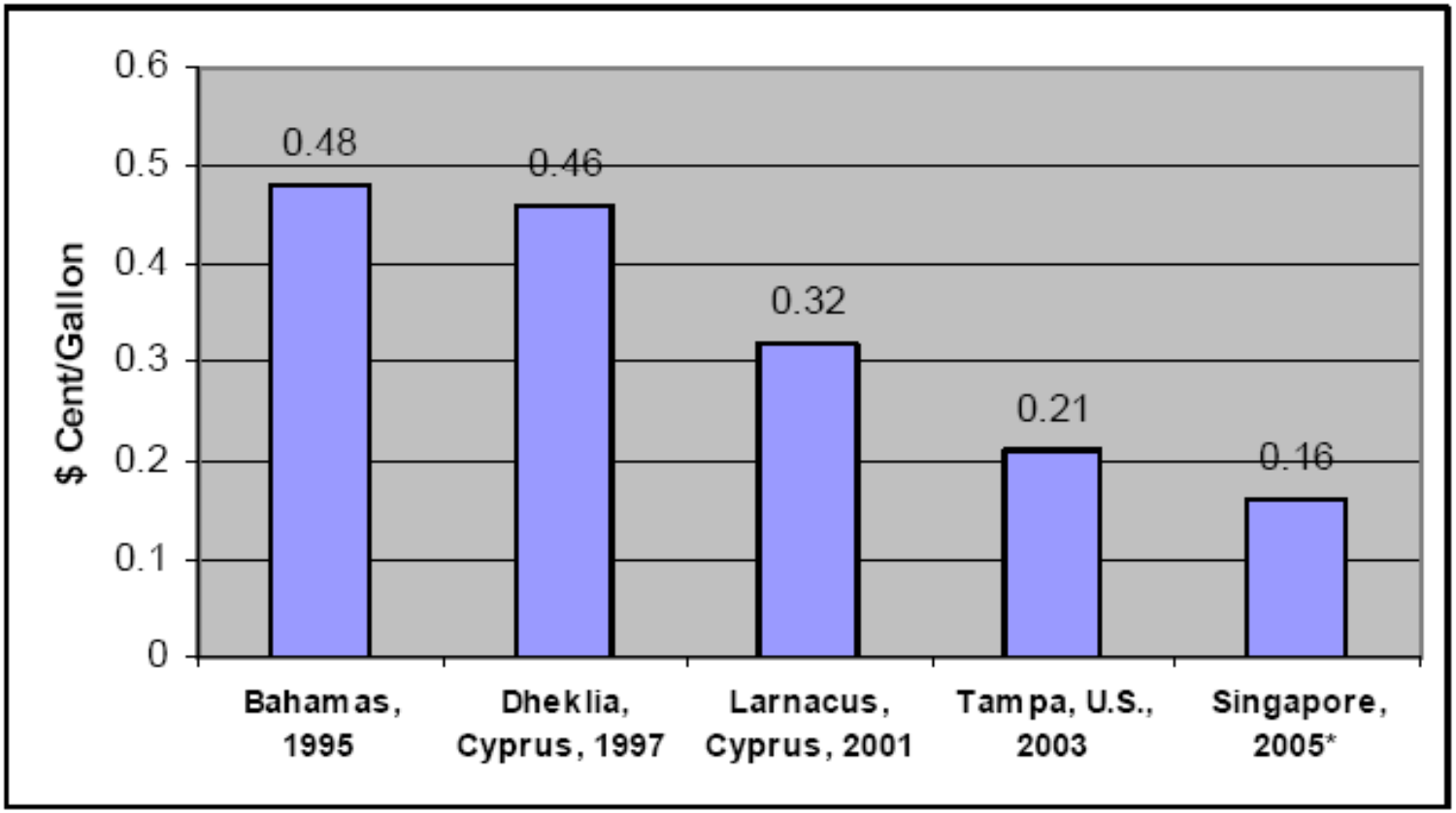
Economics of Desalination

	MSF	MED	VC	RO
Specific Investment Cost [$/m³/day]	1,200 – 1,500	900 – 1,000	950 – 1,000	700 - 900
Total Cost Product [$/m³]	1.10 – 1.25	0.75 – 0.85	0.87 – 0.95	0.68 – 0.82

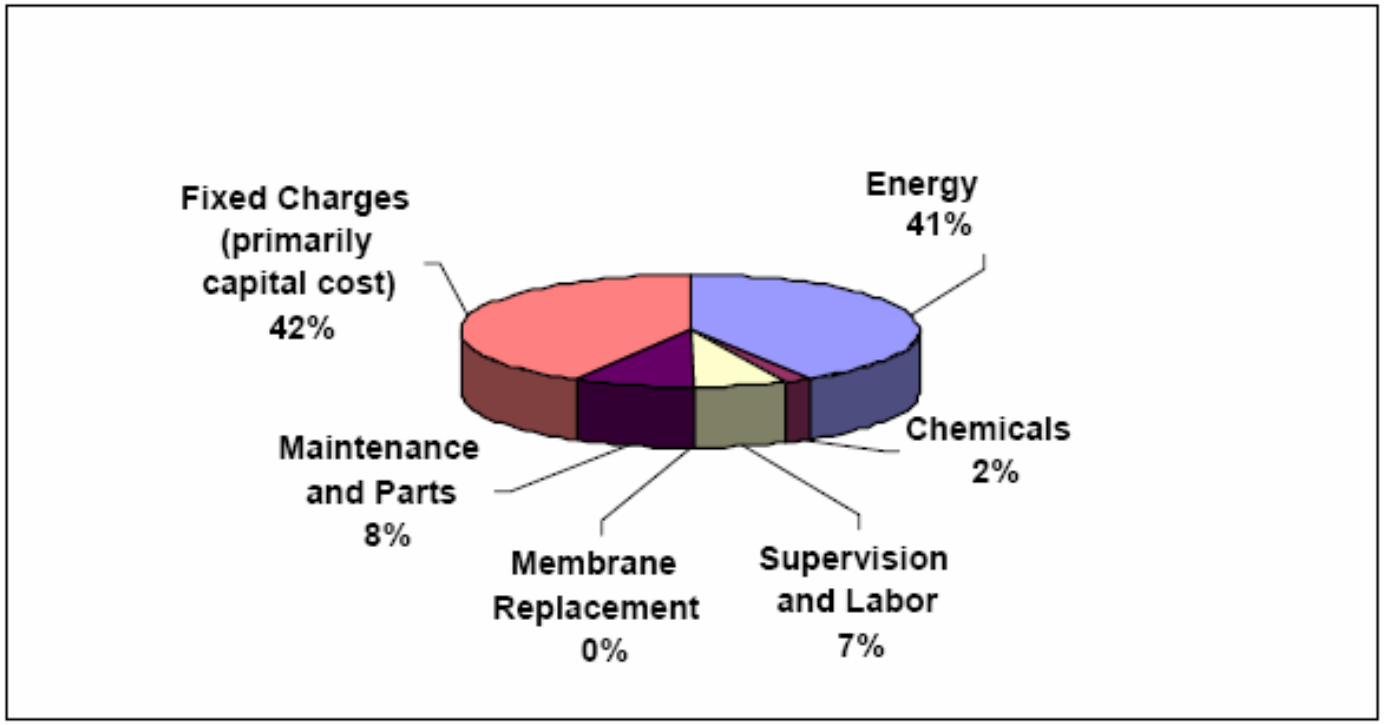
Hypothesis:	Plant Capacity	30,000 m³/day
	Interest Rate	7 %
	Project Life	20 years
	Price Electricity	0.065 $/kWh

Source: Kaufler

Cost Evolution of the SWRO Process

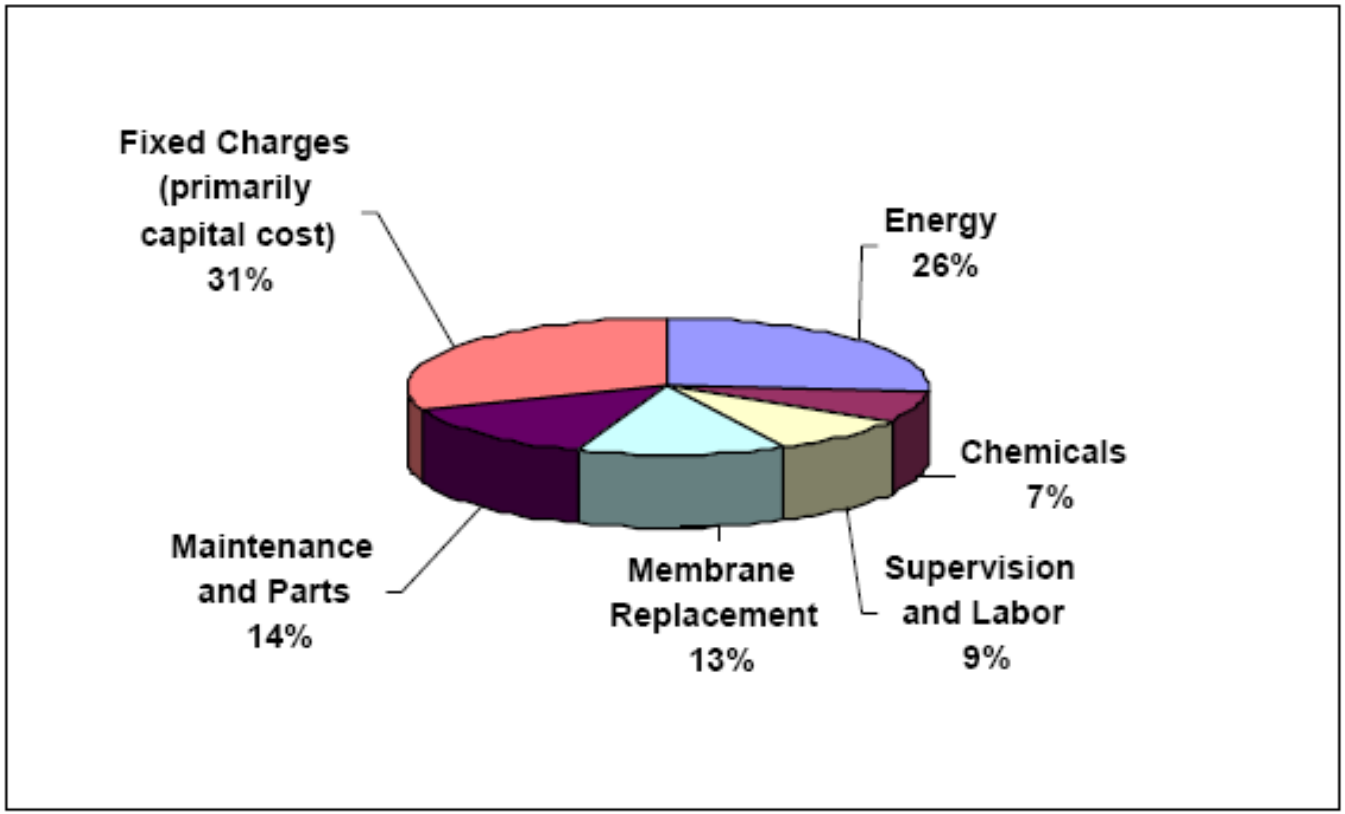


Cost composition for a representative seawater MSF plant



Source: Ebensperger and Phyllis Isley (2005)

Cost composition for a typical seawater RO plant

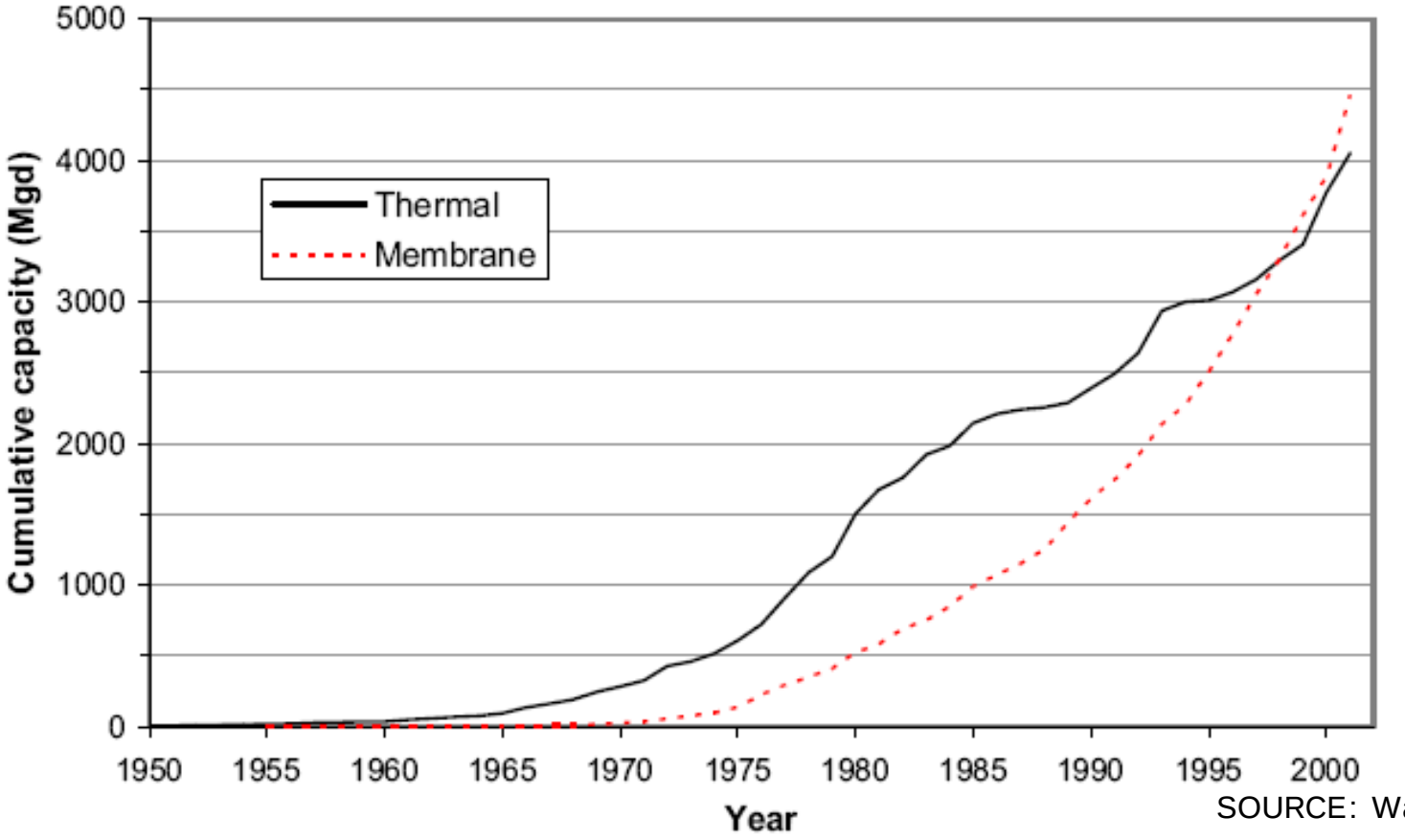


Source: Ebensperger and Phyllis Isley (2005)

Cost with relative to RO

Cost component	MSF	MED	MVC	RO
Capital investment	120	114	118	100
Energy related costs	215	175	140	100
Membrane replacement	---	---	---	100
Other remaining costs	103	89	100	100
Overall product cost	114	109	107	100

Total capacity of desalination plants worldwide by type of technology used



SOURCE: Wangnick, 2002.

Trends in Desalination Technologies

- Reverse Osmosis world-wide dominates new installations of desalination capacity
- New thermal plants restricted to Gulf Region (MED with largest improving potential)
- Availability of temperature-resistant RO- Membranes ?
  - ⇨ Potential for Gulf Region
- Reduction of energy costs
  (approx. 30 - 60 % of water production costs !!) by:
  - ➢ Increasing energy efficiency (RO, energy recovery)
  - ➢ Increasing substitution of fossil by renewable energy systems (RES) expected ...

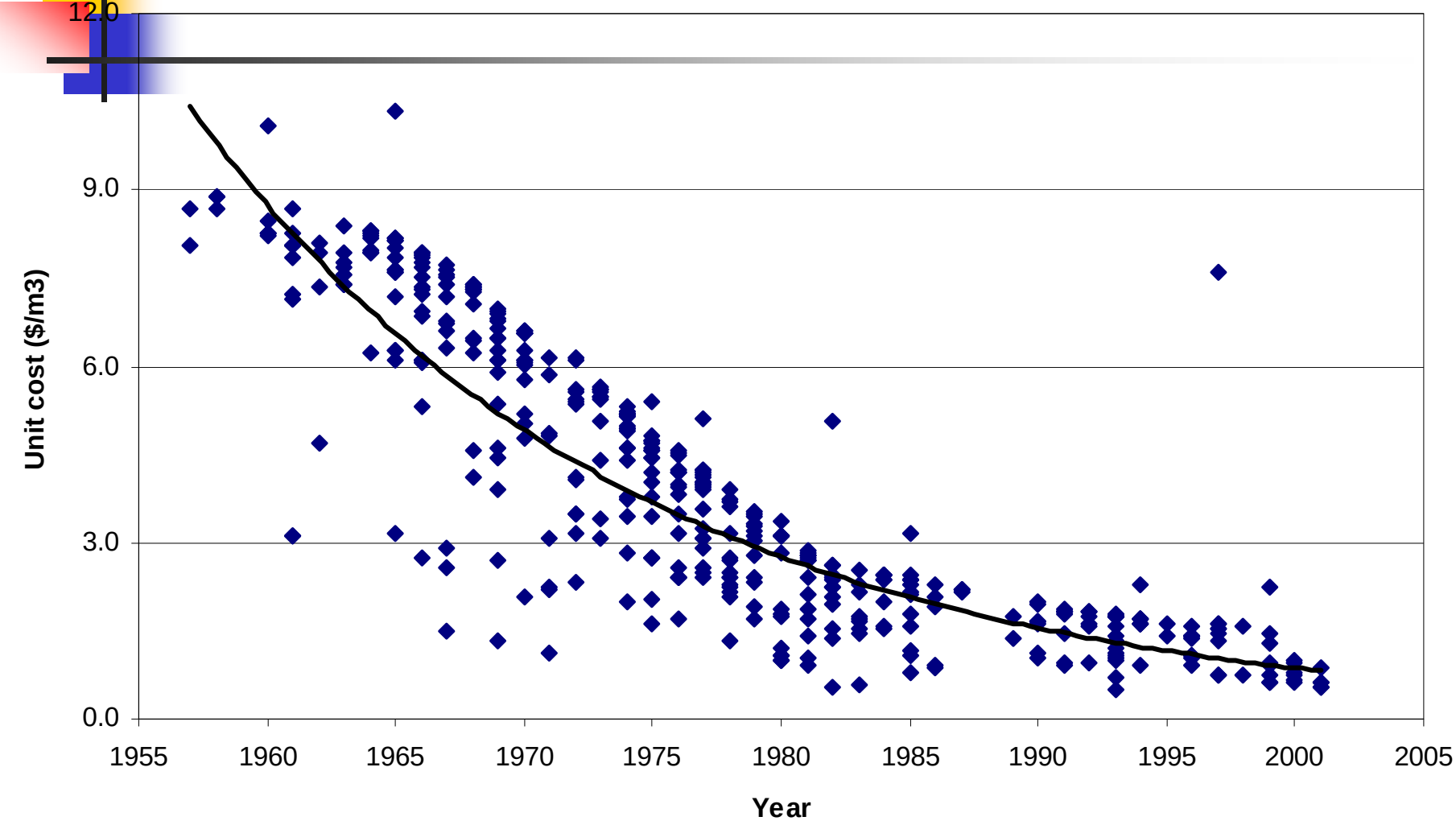
Zhou and Tol analysis

Data from IDA Worldwide Desalting Plants Inventory Report No.17

Contain about 3000 data points from 1950 up to 2003 for MSF and RO

Data include country, location, total capacity, units, process, equipment, water quality, user, contract year and investment costs.

Costs analysis of MSF



Costs of desalting by MSF

- The unit costs declined over time from 9 $/m^3 to 0.9 $/m^3 in 2000

- Based on the exponential projection presented in the figure, the average cost will go down to about 0.3 $/m^3 in 2025. (Associated with great uncertainty)

Developments of RO process

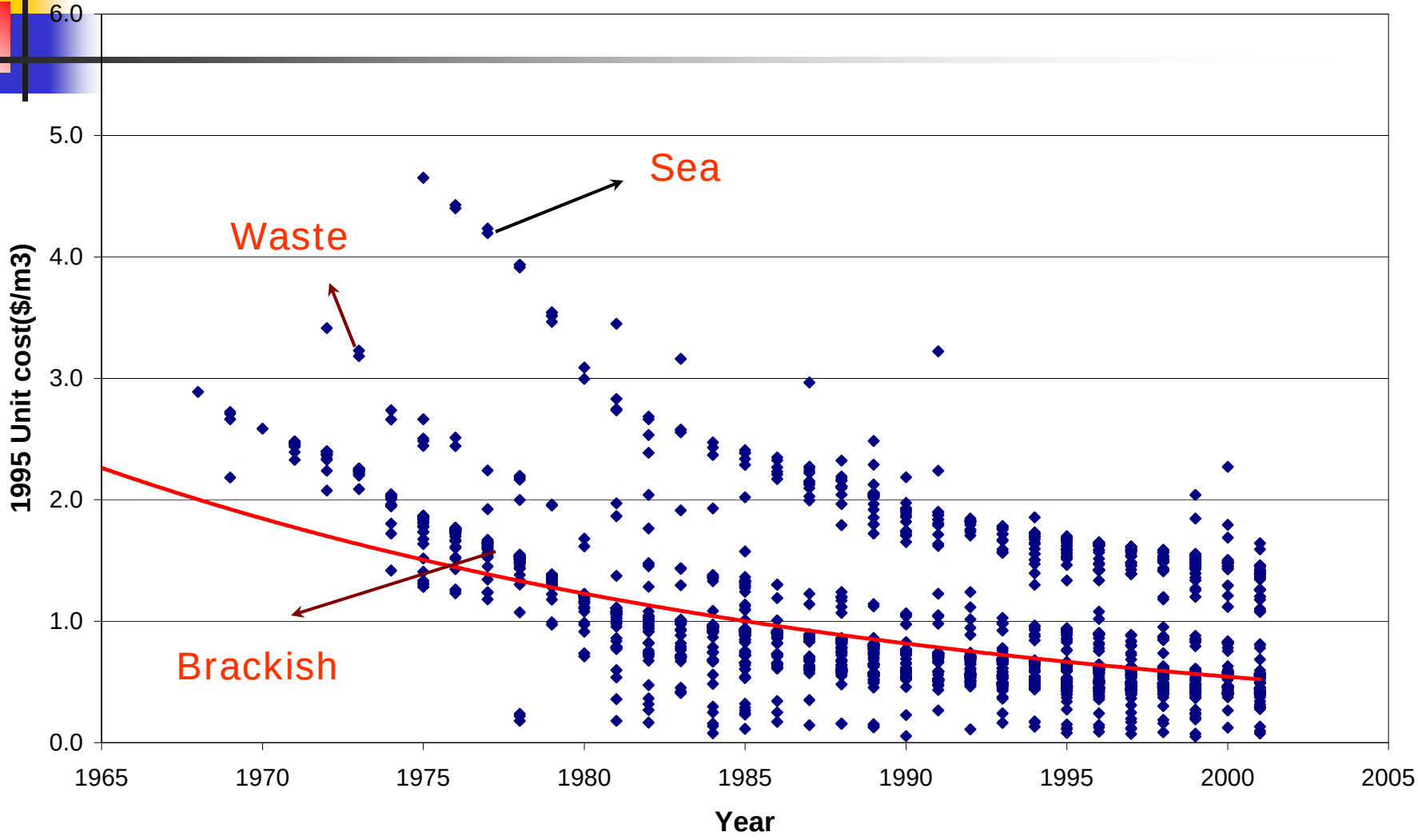
RO became more popular during the last decades

Operating costs reduced:

- lower-cost, higher-flux, higher salt-rejecting membranes that can operate efficiently at lower pressures
- use of pressure recovery devices

Costs analysis of RO

(converted to 1995 base year level)



Costs of desalting by RO

Unit costs vary with:

- Raw water quality
- Location
- Capacity

RO today

- 0.6 $/m^3 brackish or wastewater
- 1.0 $/m^3 seawater

- become lower with time, especially RO

Conclusions

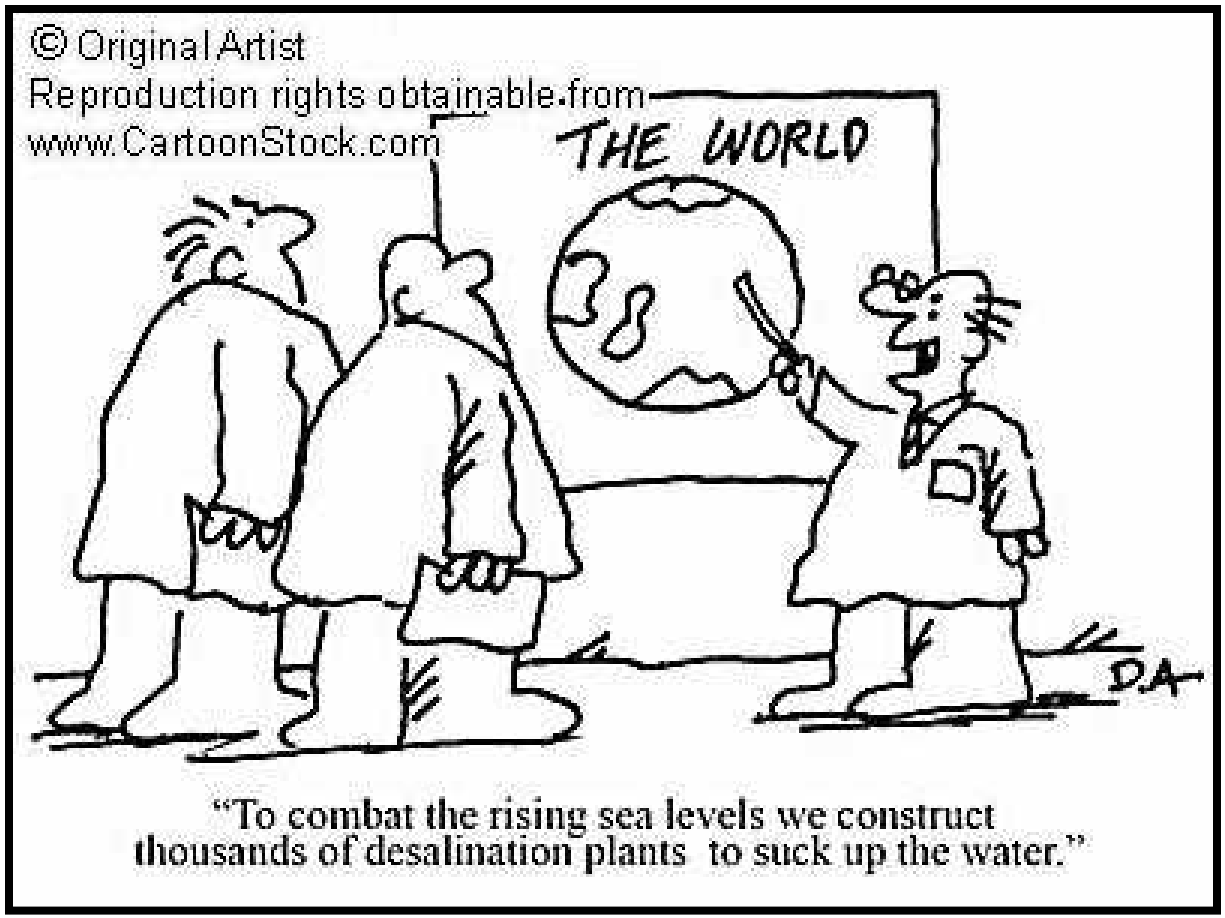
Improved desalination technologies have been playing important roles to reduce the unit cost of water noticeably over time.

To date, the average cost of desalted water using MSF has been reduced to about 0.9 $/m^3 (seawater) and RO to 0.5 $/m^3 (brackish), very competitive for traditional water resources

Conclusions

Desalination can provide reliable water supply and will be economically feasible, therefore it is requested to invest in and undertake consistently research on brine disposal.

Thank you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D.A.
"To combat the rising sea levels we construct thousands of desalination plants to suck up the water."