

UNIT COST OF DESALINATION

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Desalination Processes

Most Widely Used Processes

Membrane Separation

- Reverse Osmosis (RO)
- Electro Dialysis (ED)

Thermal Separation

- Multistage Flash Distillation (MSF)
- Multi-Effect Distillation (MED)
- Mechanical Vapor Compression (MVC)

RO & MSF Processes Dominate Desalination Market for Both Seawater and Brackish Water with a Total Share of Approximately 90%.

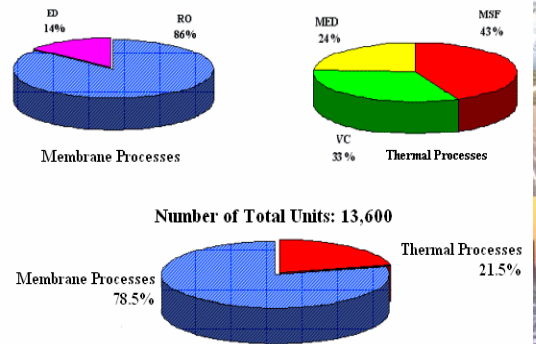


Operating Parameters for Desalination

Desalination Method	TDS Conc. (mg/l)	Operating Temp. (°C)
Thermal Separation	30,000 ~ 500,000	35 ~ 120
Centuries Old Method, Still Widely Applied, Mainly Overseas. Expensive		
Reverse Osmosis	500 ~ 50,000	0 ~ 40
Renewed Interest in 1980's, Low Energy Requirements, Less Expensive		
Electro Dialysis	500 ~ 3,000	0 ~ 65
Cost Competitive with RO in this TDS Range		
The Lowest Operating Temperature for RO and ED is Above-Freezing Temperature		

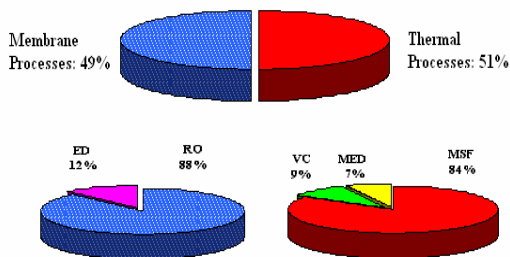


Desalination Plants By Technology



Desalination Capacity By Technology

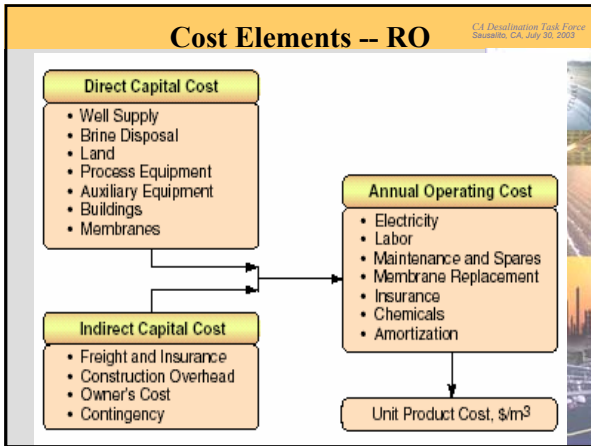
(Total: ~ 7,000 MGD; ~ 7,000,000 AF/Year)



Comparison Between RO & MSF

- RO has Become More Attractive
 - Continuous Improvements in Membrane Materials
 - Membrane can hold More Pressure & Higher Temp.
 - Higher Recovery / Efficiency Ratio
 - Adaptable to a Two Pass Process
- Advantages of RO Over MSF
 - Consumes Less Energy
(RO = 11 - 14 kWh / K gal; MSF = 15 kWh / K gal + Steam)
 - Does Not Need to be Linked to the Power Plant
 - Simpler Start/Stop Operation
 - Delivered in Modules
 - Cheaper than MSF



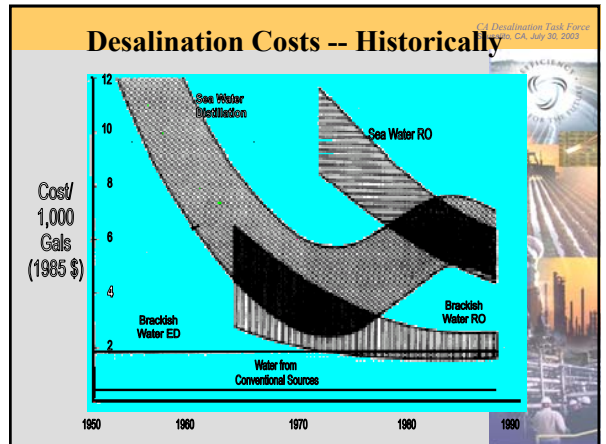
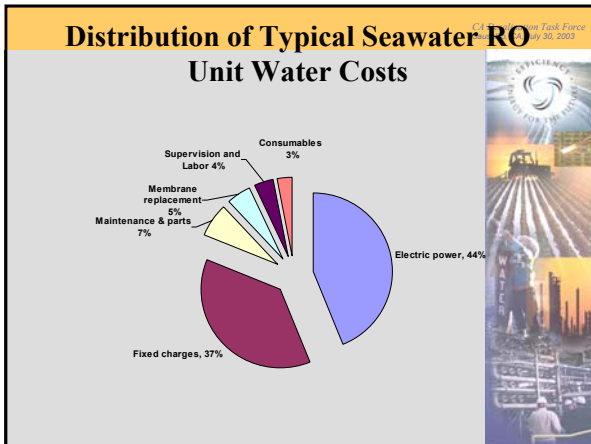


Cost of Desalination

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Function of:

- Plant Capacity/Unit Size
- Feed Water Quality
- Pretreatment
- Process/Technology
- Energy Cost
- Plant Life, and
- Investments/Amortization



Typical Unit Cost of Desalted Water

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Seawater (SW):	
Large Plants (Over 10 MGD)	1.52 – 3.80 \$/K Gallons
Medium (1 - 10 MGD)	3.80 – 5.70 \$/K Gallons
Small (Less than 1 MGD)	Over 5.70 \$/K Gallons
Brackish Water (BW) 0.40 – 3.80 \$/K Gallons	

Adil A. Bushnak – Bushnak Water Group, Jeddah

Desalination Costs Reductions

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Cost Reductions Due to:

- Technological Developments
- Technology Maturity (Improved Material/Pretreatment)
- Increasing Size of Plants
- Lower Finance Rate
- Lower Energy Costs
- Changes in Managing Enterprise Performance
- Intense Competition Between Equipment Suppliers Worldwide

Desalination Cost Reductions – Plant Capacity

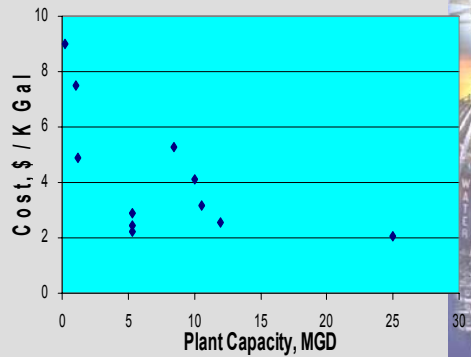
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- Economy of Scale
- Larger Plant Capacity/Unit Size
Due to availability of High-Pressure Pumps & Large Turbines for Energy Recovery.
- Common Size will range from 25 – 75 MGD containing 10 – 20 units.



RO Water Cost vs. Plant Capacity

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Desalination Cost Reductions – Membranes

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- Declining Membrane Costs:
86% Cost Reduction from 1990 to 2002
- Increase in Productivity due to Increased Surface Area:
94% Productivity Increase from 1990 to 2002
- New Pretreatment Approaches:
Such as Using Micro- & Ultrafiltration



Desalination Cost Reductions – Membranes

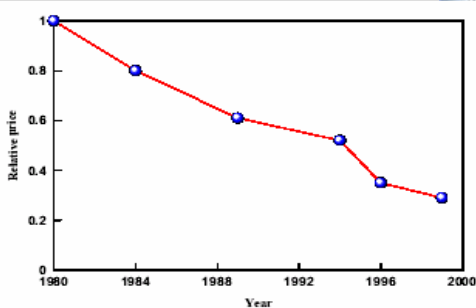
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- Most Common Size Spiral Wound Element:
8" x 40" → Surface Area = 440 sq. ft.
- MegaMagnum Spiral Element:
17" x 60" → Surface Area = 2,400 sq. ft.
- Benefits: 15% Space Savings
Needs Fewer Manifolds and Pressure Vessels
20% Savings in Capital & Civil Works Cost
- Koch introduced World's Largest Membrane in June 2002.



Spiral-Wound Membrane Modules Cost Trends

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Desalination Cost Reductions – Reduced Energy Consumption

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- Use of Larger and More Efficient Pumps
- Improved Pretreatment
- Collocation with Power Plants
- 20 – 25 kWh/K Gal →
11 – 14 kWh/K Gal
(From 1991 to 2002)



Desalination Cost Reductions O&M Cost Reduction

- Mainly from Reduction in Manpower needed in the larger plants
- Smaller savings from Decrease in the Membrane Replacement Costs & Chemicals needed for Pre-Treatment



Desalination Cost Reductions Capital Cost Reductions

- Shared Infrastructure with the Existing Power Plants
- Increased Life Span Due to:
 - Improved Building Materials
 - Use of More Mature Technologies
- Lower Financing Cost
 - Lower Financing Rates
 - Lowered Risk Factor in Project Financing



BW Desalination Cost Comparison – 10 MGD

	Well Water; Not Collocated; Needs ½ mile outfall pipe; TDS: 3000 mg/l; Pretreatment: Ozonation & Granular Media Filtration; RO System: 75% Energy Recovery; Financing @ 6% for 20 Years; Electricity @ 8 cent/kWh.		Estuary Water; Not Collocated; Needs influent/outfall facilities; TDS: 10,000 mg/l; Pretreatment: MF; RO system: 60% Energy Recovery; Financing @ 6% for 20 Years; Electricity @ 8 cent/kWh.	
	\$/gal/day	\$/K gal	\$/gal/day	\$/K gal
Pretreatment	0.05	0.01	0.66	0.25
Desalting	0.93	0.92	1.13	1.19
Intake/Outfall etc.	0.44		0.5	0.01
Indirect Capital \$	0.46		0.73	
Capital Recovery		0.44		0.71
TOTAL, \$/K gal	1.83	1.37	3.02	2.17
TOTAL, \$/AF		446		707

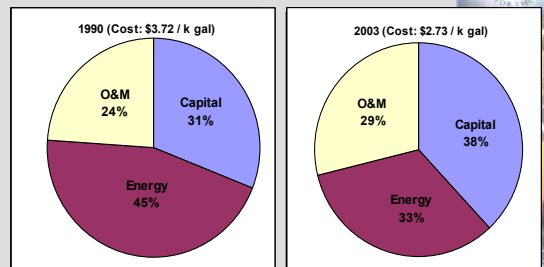
SW Desalination Cost Comparison – 10 MGD

	Collocated. Use the same influent/ Effluent facilities; TDS: 32,000 mg/l; Pretreatment: MF; 40% Energy Recovery; Financing @ 6% for 20 Years; Electricity @ 4 cent/kWh.		Not-Collocated; Needs influent/outfall facilities; TDS: 32,000 mg/l; Pretreatment: MF; Latest Energy Recovery System in place; Concentrate disposal: Ocean discharge 2 miles from shore; Financing @ 6% for 20 years; Electricity: 8 cent/kWh.	
	\$/gal/Day	\$/K gal	\$/gal/Day	\$/K gal
Pretreatment	0.66	0.25	0.66	0.25
Desalting	1.43	1.09	1.54	1.40
Intake/Outfall etc.	0.12		0.69	0.01
Indirect Capital \$	0.71		0.92	
Capital Recovery		0.69		0.90
TOTAL, \$/K gal	2.93	2.03	3.81	2.56
TOTAL, \$/AF		661		834

Cost Reduction Comparison (Two 5.3 MGD RO Desalination Plants)

	Canary Island 1991		Israel 2003	
Capital Cost	\$20 million		\$20 million	
Energy Cost	\$1.14/K Gal (@ 8% for 20 Years)	31%	\$1.02/K Gal (@6.5% for 20 Years)	38%
O&M Cost	\$0.91/K Gal	24%	\$0.80/K Gal	29%
Total cost	\$3.72/K Gal		\$2.73/K Gal	

Cost Reduction Comparison (Two 5.3 MGD RO Desalination Plants)



Tampa Bay Desalination Plant A Footprint in Desalination

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Capacity	25 MGD (~ 95,000 m ³ /day)
Sea Water TDS (mg/L)	18,500 – 30,500 mg/L (Avg. 26,000 mg/L)
Pretreatment	Two Stage Sand Filtration
Recovery Rate	60%
Fresh Water Quality	< 500 mg/L
No. of Trains	7 @ ~ 16,000 m ³ /day
Energy Consumption	11.2 kWh/1,000 gal (~ 3 kWh/m ³)
Energy Cost	4 cents/kWh
Water Cost	< \$2/1,000 gal (<\$0.53/m ³) (<\$652/AF)

California SW Desalination Experience – An Expensive Start

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- Chevron's Gaviota Oil & Gas Processing Plant (1987)
0.4 MGD 46 kWh/1,000 gallons \$12.2/1,000 gal
Status: Active
- City of Morro Bay (1991)
0.6 MGD 27 kWh/1,000 gallons \$5.4/1,000 gal
→ 1.2 MGD Status: Operational when Needed
- City of Santa Barbara (1992)
6.7 MGD 20 kWh/1,000 gallons \$5.9/1,000 gal
Status: Sold
- Monterey Bay Aquarium (1991)
0.04 MGD \$5.5/1,000 gal
Status: Active
- SCE's Santa Catalina Island RO plant (1991)
0.13 MGD \$6.1/1,000 gal

Proposed SW Desalination Plants in CA

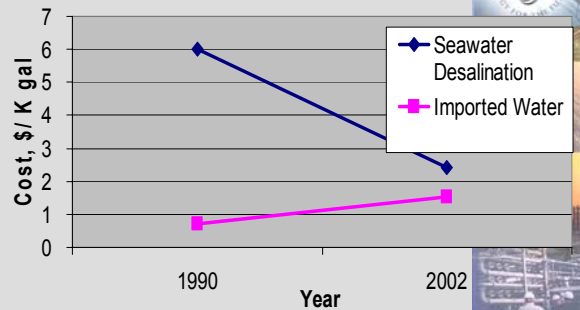
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Agency	Capacity (MGD)	Capital Cost (million, \$)	Production Cost [*] (\$/k gal)	Production Cost [*] (\$/AF)
West Basin	20	130	2.77	904
SDCWA	50	272	2.77	909
Orange County Municipal WD	25	114 – 140	2.63 – 3.09	860 – 1,007
Long Beach Water District	9	62 – 92	2.18 – 3.59	711 – 1,171
LADWP	12	70	3.17	1,033

* Before any subsidy from MWD

Overall Water Cost Trend

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Desalination Cost Target

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1990 2003 2006

\$6/K Gal → \$2/K Gal → 1.50/K Gal

Mission Not Impossible

Questions/Answers/Discussion