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THE MIDDLE EAST DESALINATION RESEARCH CENTER

Cost Estimating of SWRO Desalination Plants

**Day 2: Total Capital Costs and
O&M Expenditures**

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14:45-16:30

2.4 Cost of Water Production



Water Globe

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Cost of Water Production - Outline

- ▶ Total Cost of Water Production - Summary
 - Capital Costs
 - O&M Costs
 - Water Production Costs
 - ▶ Fixed and Variable Cost of Water Components
 - ▶ Summary of Costs of Desalination Projects in the MENA Region
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Summary of Construction (Direct) Capital Costs

Cost Item	Percentage of Total Capital Cost (%)	
	Low-Complexity Project	High-Complexity Project
Direct Capital (Construction) Costs		
12. Site Preparation, Roads and Parking	1.5 – 2.0	0.6 – 1.0
13. Intake	4.5 – 6.0	3.0 – 5.0
14. Pretreatment	8.5 – 9.5	6.0 – 8.0
15. RO System Equipment	38.0 – 44.0	30.5 – 36.0
16. Post-Treatment	1.5 – 2.5	1.0 – 2.0
17. Concentrate Disposal	3.0 – 4.0	1.5 – 3.0
18. Waste and Solids Handling	2.0 – 2.5	1.0 – 1.5
19. Electrical & Instrumentation Systems	2.5 – 3.5	1.5 – 2.5
20. Auxiliary and Equipment and Utilities	2.5 – 3.0	1.0 – 2.0
21. Buildings	4.5 – 5.5	3.0 – 5.0
22. Start Up, Commissioning and Acceptance Testing	1.5 – 2.5	1.0 – 2.0
Subtotal Direct (Construction) Costs (% of Total Capital Costs)	70.0 – 85.0	50.0 – 68.0

Summary of Soft (Indirect) Capital Costs

Cost Item	Percentage of Total Capital Cost (%)	
	Low-Complexity Project	High-Complexity Project
Project Engineering Services		
5. Preliminary Engineering	0.5 - 1.0	0.5 - 1.5
6. Pilot Testing	0.0 - 0.5	1.0 - 1.5
7. Detailed Design	3.5 - 4.5	5.0 - 6.0
8. Construction Management and Oversight	1.0 - 2.0	2.5 - 3.5
Subtotal Engineering Services	5.0 - 8.0	9.0 - 12.5
Project Development		
4. Administration, Contracting and Management	1.0 - 1.5	2.0 - 3.0
5. Environmental Permitting (Licensing)	0.5 - 3.5	4.5 - 5.0
6. Legal Services	0.5 - 1.0	1.5 - 2.0
Subtotal Project Development	2.0 - 6.0	8.0 - 10.0
Project Financing Costs		
4. Interest During Construction	0.5 - 2.5	1.0 - 4.5
5. Debt Service Reserve	2.0 - 5.5	4.5 - 8.5
6. Other Financing Costs	0.5 - 1.0	3.5 - 4.5
Subtotal Project Financing	3.0 - 9.0	9.0 - 17.5
Contingency	5.0 - 7.0	6.0 - 10.0
Subtotal Indirect Capital Costs (% of Total Capital Costs)	15.0 - 30.0	32.0 - 50.0

Total Capital Costs - Sum of Direct and Indirect Capital Expenditures

Cost Item	% of Total Capital Costs	
	Low Complexity Project	High Complexity Project
<i>Construction (Direct Capital) Costs</i>	70-85 %	50 – 68 %
<i>Soft (Indirect Capital) Costs</i>	15-30 %	32-50 %
Total Capital Costs (A + B)	100 %	100 %

Capital Recovery Costs (Annualized Capital Costs)

▶ Annualized Capital Costs = Total Capital Cost /
(CRF x Qp x 365 d)

▶ Capital Cost Recovery Factor,

$$\text{CRF} = [(1+i)^m - 1] / [ix(1+i)^m]$$

Where: m – period of repayment of capital expenditures; i – interest rate of capital

For example, for m = 20 years & i = 5%

$$\text{CRF} = [(1+0.05)^{20} - 1] / [0.05 (1+0.05)^{20}] = 12.462$$

Example: 40 MLD Project with Total Capital Cost = US\$58 MM

Annualized Capital Cost =

$$\text{US\$58,000,000} / (12.462 \times 40,000 \text{ m}^3/\text{day} \times 365 \text{ days}) = \text{US\$0.32/m}^3$$

Total O&M Costs – Sum of Fixed and Variable Costs

Annual O&M Cost Breakdown		
Cost Item	Percentage of Total O&M Cost (%)	
	Low-Complexity Project	High-Complexity Project
Variable O&M Costs		
5. Power	45.0 – 61.0	35.0 – 58.0
6. Chemicals	3.0 – 6.5	5.5 – 9.0
7. Replacement of Membranes and Cartridge Filters	5.0 – 9.0	6.5 – 11.0
8. Waste Stream Disposal	2.5 – 5.5	3.5 – 7.0
Subtotal - Variable O&M Costs	55.5 – 82.0	50.5 – 85.0
Fixed O&M Costs		
5. Labor	5.0 – 9.5	4.0 – 11.0
6. Maintenance	6.5 – 12.5	3.0 – 13.0
7. Environmental and Performance Monitoring	0.5 – 4.0	1.0 – 5.0
8. Indirect O&M Costs	7.5 – 18.5	7.0 – 20.5
Subtotal - Fixed O&M Costs	19.5 – 44.5	15.0 – 49.5
Total O&M Costs	100 %	100 %

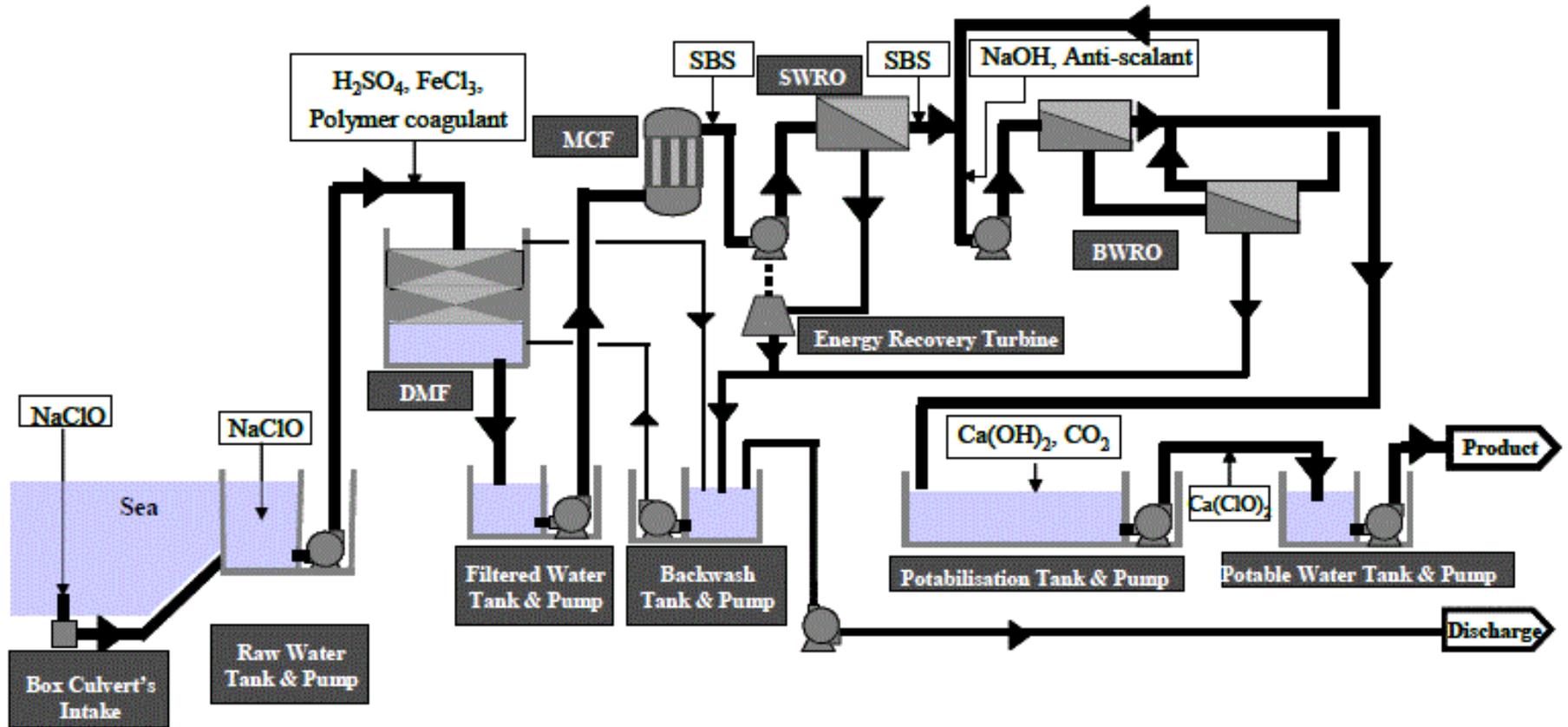
Cost of Water Production - Fixed & Variable Components

- ▶ Fixed Capital Cost Components
 - Capital Recovery Costs
 - Fixed O&M Costs
- ▶ Variable Cost Component
 - Variable O&M Costs
- ▶ Total Cost of Water Production = Sum of Fixed and Variable Costs

Cost of Water – Variable and Fixed Components

Cost of Water Item	Low Complexity Project, % of Total	High Complexity Project, % of Total
Variable Cost of Water Components		
Power	25.0-45.0%	12.0-36.0%
Chemicals	1.5-3.0%	2.5-3.5%
Replacement of RO Membranes & Cartridge Filters	2.5-4.5%	4.0-5.5%
Waste Stream Disposal	1.0-2.5%	2.5-4.0%
Total Variable Costs	30.0-50.0%	25.0-45.0%
Fixed Cost of Water Components		
Capital Recovery Costs	30.0 – 58.0%	42.0-45.0%
Labor	4.0-5.0%	2.0-7.5%
Maintenance	4.0-6.0%	4.0-8.5%
Environmental & Performance Monitoring	0.5-2.0%	1.0-7.0%
Other O&M Costs	3.5-7.0%	3.0-10.0%
Total Fixed Costs	50-70%	55-75%
Total Water Production Costs	100 %	100 %

Example 40 MLD SWRO Plant



Capital Costs - 40,000 m³/day Plant

Cost Item	Cost (US\$)	% of Total
Intake	2.76 MM	4.8 %
Pretreatment	4.64 MM	8.0 %
RO System Equipment	18.56 MM	32.0 %
Post Treatment	1.16 MM	2.0 %
Concentrate Disposal	1.45 MM	2.5 %
Buildings	1.74 MM	3.0 %
Waste and Solids Handling	0.87 MM	1.5 %
Electrical & Instrumentation	1.30 MM	2.2 %
Other Items	2.90 MM	5.0 %
<i>Construction (Direct Capital) Costs</i>	<i>35.38 MM</i>	<i>61 %</i>
Engineering Services	5.80 MM	10.0%
Development, Financing & Contingency	16.82 MM	29 %
<i>Indirect Capital Costs</i>	<i>22.62 MM</i>	<i>39 %</i>
TOTAL	\$58.0 MM	100 %

O&M Costs for 40,000 m³/day Plant w/ Low-Cost Intake & Outfall

Cost Item	Cost (US\$/yr)	US\$/m ³
Energy @ US\$0.055/kWh and 4.03 kWh/m ³	3.24 MM/yr	0.22
Chemicals	0.35 MM/yr	0.02
Replacement of RO Membranes & Cartridge Filters	0.62 MM/yr	0.04
Waste Stream Disposal	0.26 MM/yr	0.02
<i>Total Variable Costs</i>	<i>4.47 MM/yr</i>	<i>0.30</i>
Labor	0.33 MM/yr	0.02
Maintenance	0.38 MM/yr	0.03
Environmental & Performance Monitoring	0.09 MM/yr	0.01
Other O&M Costs	0.57 MM/yr	0.04
<i>Total Fixed Costs</i>	<i>1.37 MM/yr</i>	<i>0.10</i>
TOTAL ANNUAL O&M COSTS	\$5.84 MM/yr	100 %

Annual O&M Costs = US\$5.84 MM/(40,000 m³/dayx365 days)

Annualized Capital (Capital Recovery) Costs 40,000 m³/day

▶ Capital Costs, Cap = US\$58 MM

For 20 years payment term 5% interest rate

$$\text{CRF} = [(1+0.05)^{20} - 1] / [0.05 (1+0.05)^{20}] = 12.462$$

▶ Capital Recovery Costs = Cap/(CRF x Q_p x 365 d)
= US\$58 MM/(12.462 x 40,000m³/d x 365 d) = **\$0.32/m³**

Cost of Water – Variable and Fixed Components

Cost of Water Item	Costs, (US\$/m ³)	Costs, (% of Total)
Variable Cost of Water Components		
Power	0.22	30.5%
Chemicals	0.02	2.8%
Replacement of RO Membranes & Cartridge Filters	0.04	5.5%
Waste Stream Disposal	0.02	2.8%
Total Variable Costs	0.30	41.6%
Fixed Cost of Water Components		
Capital Recovery Costs	0.32	44.4%
Labor	0.02	2.8%
Maintenance	0.03	4.2%
Environmental & Performance Monitoring	0.01	1.4%
Other O&M Costs	0.04	5.6%
Total Fixed Costs	0.42	58.4%
Total Water Production Costs	0.72	100 %

Typical Cost and Energy Ranges (Medium & Large SWRO Plants)

Classification	Cost of Water Production (US\$/m ³)	SWRO System Energy Use (kWh/m ³)
Low-End Bracket	0.5 – 0.8	2.5 – 2.8
Medium Range	1.0- 1.5	3.0 – 3.5
High-End Bracket	2.0 – 4.0	4.0 – 4.5
Average	1.1	3.1

Costs of Recent SWRO Desalination Projects - North Africa & Mediterranean

Plant	Size (MLD)	Year of Cost Bid	Cost of Water (US\$/m ³) For Year of Cost Bid & in (2013\$)
Dhekelia, Cyprus	50	1997/2007	1.19/0.88 (1.18)
Larnaka, Cyprus	54	1999/2009	0.76/1.0 (1.22)
Arzew, Algeria	86	2005	0.90 (1.33)
Beni Saf, Algeria	150	2008	0.70 (0.89)
Cap Dijnet, Algeria	100	2005	0.73 (1.09)
Douaouda, Algeria	120	2005	0.75 (1.11)
Hamma, Algeria	200	2008	0.82 (1.05)
Skikida, Algeria	100	2008	0.74 (1.13)
El Tarf, Algeria	50	2008	0.89 (1.14)
Magtaa, Algeria	500	2008	0.56 (0.72)
Tenes, Algeria	200	2008	0.59 (0.75)
Palmahim, Israel (NanoH ₂ O)	82/123	2005/2013	0.78 (0.78)
Hadera, Israel	368/456	2008	0.60 (0.77)
Ashkelon, Israel	326	2008	0.53/(0.78)
Sorek, Israel	410	2013	0.59

Costs of Recent SWRO Desalination Projects - Middle East

Plant	Size (MLD)	Year of Cost Bid	Cost of Water (US\$/m ³)
Al Taweelah C, UAE	325	2000	0.72 (1.12)
Shuaqaiq, Saudi Arabia	214	2006	1.03 (1.45)
Jeddah – Barge, S. Arabia	52	2008	2.27 (2.88)
Jeddah – Land, S. Arabia	240	2009	1.15 (1.40)
Ras Azzur, Saudi Arabia	300	2010	1.09 (1.26)
Fujairah, UAE	140	2004	0.86 (1.10)
Fujairah II, UAE		2008	0.81 (1.03)
Sur, Oman	80	2010	0.98 (1.13)
Al Dur, Bahrain	218	2012	0.95 (1.00)
Shuwaikh, Kuwait	136	2012	1.10 (1.16)
Shuaibah, Saudi Arabia	150	2011	0.94 (1.04)



Questions and Discussions