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The Effect of Water Scarcity on the Future Growth in the Desalination Industry in GCC Countries

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Abstract:

Gulf Cooperation Council (GCC) countries have extremely dry climates with rare rainfall, high evaporation rates and limited non renewable groundwater resources. The scarcity of water resources and the increasing gaps between demand and available supply in the GCC countries are a major challenging issues facing the development sectors. At present all GCC countries water resources are below the water poverty level and most of the water used is brackish groundwater abstracted from non renewable aquifers. Desalination technology is finding new outlets in supplying water to meet growing demands for future development in the domestic, agricultural, industrial, and economical sectors. The GCC countries hold about 45% of the total global desalination capacity. In the future, desalinated water will play an important role in the realization of sustainable development and integrated water management plans. In this paper the water scarcity situation in the GCC is outlined and its effect on the future growth in the desalination industry is discussed. The future development of desalination in terms of potential unit production cost reduction, increasing operation efficiencies and the potentiality of using renewable energy sources are discussed.

Introduction:

The Gulf Cooperation Council (GCC) countries are devoid of

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permanent surface water bodies such as rivers and fresh water lakes. Annual rainfall does not exceed an average of about 200 mm in any country, with the exception of some areas in the southwest of Saudi Arabia and certain mountains of Oman. The groundwater aquifer systems are over-abstracted and mostly contain brackish groundwater which is used for agriculture irrigation. Renewable freshwater is dependent on sporadic seasonal flash floods which feed the subsurface basin. Currently all the GCC countries use desalination to augment their water supply, either on a national scale or at localized locations. The scarcity of renewable water resources and the growing gap between demand and available supply of domestic water are due to rapid growth in population and urbanization is a major challenge [1].

The desalination market is expected to increase significantly in all GCC countries as drought conditions worsen, populations grow, and water demand per capita increases due to expansion in industrial activities and development of tourism; all compounded by an overall improvement in the standard of living. The latest trend in desalination practice in the GCC countries is to adopt privatization after the successful introduction of independent Power and/or Water Producers (IPP and IWPP) in some countries. Financing schemes via BOO and BOOT systems have been adopted in some of the new desalination projects. Technically, among the newly adopted practices is to build hybrid desalination plants (e.g. MSF-RO in Fujairah in UAE). Normally, in GCC countries, dual-purpose plants are built. Recently, however, the demand is more on water than on power, thus leading to the construction of independent desalination plants. The high demand for water has also lead to a reduction in the delivery time for newer projects. This time lag has been reduced to less than 24 months and, in some urgent cases, to 12 months.

2. Present Status of Water Resources Supply and Demand:

2.1 Water Supply:

Water in the GCC countries is a particularly scarce resource. The GCC countries are mainly dependent on groundwater, desalination and treated wastewater. Natural water is scarcity further worsened by rapidly growing demands, unsustainable use patterns, increased water pollution and weak management institutions and regulations. Many groundwater aquifers in GCC countries are being mined in an uncontrolled and unplanned manner, either because it has not been possible to regulate the access to these aquifers and/or they are non renewable. Unplanned groundwater mining erodes the economic and social sustainability of the communities that depend on the depleting storage. Whether the groundwater mining is inadvertent or planned, there is a need for guidelines to make the concerned communities better prepared economically and socially to cope with the increasing water stresses as the storage is depleted.

Table 1 shows that the annual groundwater recharge in GCC countries is about 5095 MCM. Groundwater abstractions during 2005 exceeded the annual replenishment of about 14532 MCM which is about 75%. Thus, considerable groundwater mining takes place, mainly for irrigation use. Because of the overexploitation, the actual contribution of groundwater to the total use in the region is more than 75%. At country level, groundwater abstractions are currently the main source of water in the GCC countries [2]. Overall, the contribution of groundwater abstractions to total demand ranges from less than 68% (in Kuwait) to more than 90% (in Bahrain) [3].

Table 1
Renewable water and groundwater use in the GCC countries (2005).

Country	Population (x1000)	Renewable Water Resources (MCM)			GW Use (MCM)	GW significance, in terms of:	
		Surface water	Groundwater (GW)	Total		% of renewable GW to total renewable water	% GW use to total demand (year 2005)
Bahrain	719	0.2	100	100.2	258	99.80	91.49
Kuwait	2326	0.1	160	160.1	405	99.94	68.64
Oman	2718	1000	600	1,600	1690	37.50	89.01
Qatar	712	1.4	85	86.4	185	98.38	53.31
Saudi Arabia	23321	2,230	3,850	6,080	14430	63.32	81.23
UAE	2444	185	300	485	2650	61.8	78.50
Total	32240	3416.70	5095	8511.70	19618	59.86	75.34

By the year 2025, it is estimated that the water deficit in the region will reach about 53% of the renewable plus non-conventional supplies. It is expected that this deficit will have to be met largely from non-renewable groundwater aquifers. Hence, it is important to develop the adequate guidelines and regulations for groundwater mining. Figure 1 shows the percentage of water use by source.

Other sources available are the desalinated water and the treated wastewater. The annual desalinated water production in 2005 is about 2849 Mm3/y. The total designed treatment capacity of the major facilities is more than 1,100 Mm3/y, with a present total treated wastewater volume of more than 915 Mm3/y. However, the recycled volumes of these waters are about 392 Mm3/y, which represent less than 43% of the total treated wastewater. In most of the countries, the remaining unused waters are discharged to the sea. Recycling is used mainly in urban uses (irrigating gardens, roads ornamentals, etc.), fodder crops irrigation, and highways landscaping. Figure 1 shows the percentage of present water use by source.

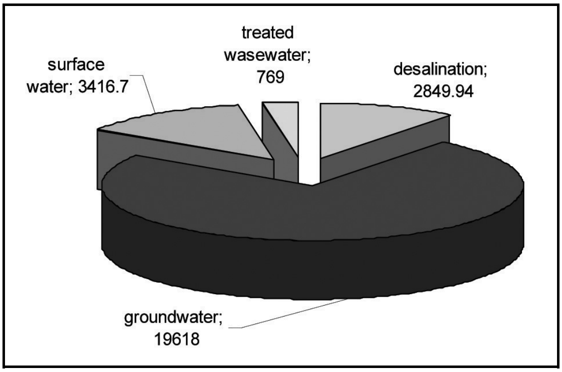

Figure 1: Present Water Use by Source.

2.2 Water Demand:

Population growth and rapid development in the agricultural and industrial sectors in GCC countries are major issues affecting all sustainable socio-economic development. The estimated population in 2005 was 32.24 million with an average growth rate of 3.73 % [4]. The total renewable water in the GCC countries in 2005 amounted to 8511.7 MCM. The high population growth rate in the region exceeds by far the rate of water resource development. Consequently, the annual per capita share of water resources is decreasing at an increasing rate. Five countries in the region have a per capita water use of under 500 cubic meters a year, half the benchmark of 1 000 cubic meters a year which indicates chronic water scarcity. Saudi Arabia and UAE have done so only by mining their groundwater reserves [5]. The national economy of most countries depends on oil and oil-related industries, commerce, light industries, and agriculture, in this descending order. Due to the fast increase in population and urbanization, domestic water and industry needs are escalating at rates with which available water resources cannot keep pace. Furthermore, the adopted policy of food self-sufficiency imposes continual constraints on the allocation of water resources, which would otherwise reduce the share for agriculture in favor of increased domestic and industrial demand. Currently the agricultural sector takes 85% of available water resources followed by domestic water use, 14% and 4% for commercial and industrial use as shown in Table 2 [6].

The water stress experienced by the GCC countries is expressed in Table 3 as the percentage of available water resources actually used. The index reaches values of over 100% in five of the six countries and critical values in the remaining one. This indicates that these countries have already exhausted their renewable water resources and are now exploiting non-renewable reserves. The overall average value of the water stress index is 252%. From this deteriorating water stress index, it is clear that current water resources cannot satisfy future water demand unless positive steps are taken soon to rationalize water demand management, increase and augment supply, and impose realistic controls on use.

Table 2
Past and Projected Water Demand in GCC Countries (million cubic meters)

Country	1995			2005			2025		
	Domestic	Agriculture	Industrial	Domestic	Agriculture	Industrial	Domestic	Agriculture	Industrial
Bahrain	86	120	17	130	158	29	169	271	169
Kuwait	295	80	8	590	132	113	1100	140	160
Oman	75	1150	5	158	1312	91	630	1500	350
Qatar	76	109	9	201	199	18	230	205	50
Saudi Arabia	1508	14600	192	2400	16700	432	6450	16300	1450
UAE	513	950	27	825	1486	41	1100	2050	50
Total	2553	17009	258	4304	19987	724	9679	20466	2229

Table 3
Water Stress Index in GCC Countries (2005).

Country	Population (x1000)	Renewable Water Resources (MCM)	Exploited Water Resources (MCM)	Per capita Water Resources (m3/y)	Water Stress Index (%)
Bahrain	719	100.2	287	164	258
Kuwait	2326	160.1	538	158	156
Oman	2718	1,468	1841	980	74
Qatar	712	86.4	439	466	157
Saudi Arabia	23321	6,080	21155	313	307
UAE	2444	315	3112	316	408
Total	32240	8209.7	25872	358	252

3. Present Use of Desalination in GCC Countries:

In order to meet both the qualitative and quantitative requirements for drinking water standards, domestic water supplies in the GCC countries rely mainly on desalinated produced water, which is used either directly or blended with groundwater. Rural areas are supplied from a number of desalination plants where water is transported over long distances from coastal areas to interior regions as shown in Figure 2. Desalination of seawater and brackish groundwater will continue to be a viable water supply augmentation option for a large number of urban centers in GCC countries. Considering recent cost-cutting innovations in the desalination process, this alternative may prove to be a relatively inexpensive supply option in comparison to the development of conventional sources located in remote locations.

The availability of desalinated water at relatively low cost may also be an attractive means of meeting industrial water demand because industries have been willing to pay for water at rates higher than domestic and agricultural use rates. In 1990 the GCC countries together produced 1557 MCM annually with a daily rate of about 4.26 MCM or per capita 30 liters a day at the national average [7]. In 1995 the total annual desalinated water capacity was about 2012 MCM with a total produced water of about 1548 MCM as shown in Table 4 [8,9].

In order to meet domestic water demands, which is a function of population and urbanization growth, the GCC countries are going ahead with desalination plants construction, despite their relatively high capital costs. The total annual desalination capacity of the GCC countries at present (2005) is about 2850 MCM as shown in Table 5. Many types of desalination processes are used such as MSF, RO, PV, and others. Multi-Stage Distillation (MSD) plants use seawater and dominate the desalination market by more than 74%. Reverse Osmosis (RO) is used mainly for brackish groundwater treatment. A growing trend is toward the application of RO in the desalting of sweater due to the advanced development in membrane technology. Limited numbers of multiple effect distillation (MED) plants are used as shown in Figure 3 [10].

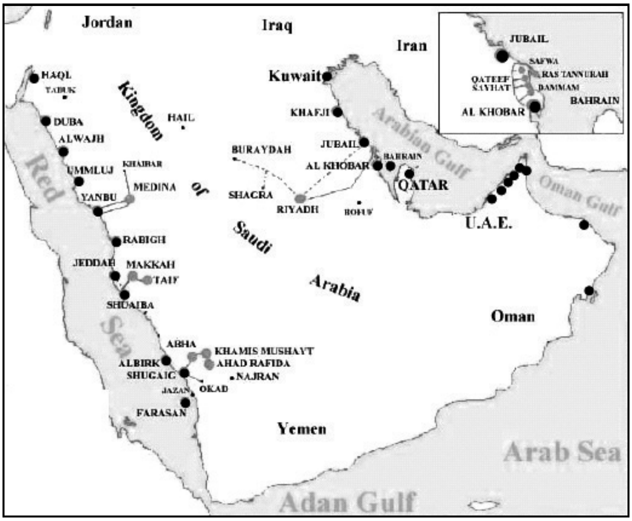

Figure 2: Location of desalination plants in GCC countries.

Selection of a reactor type suitable for water desalination and power generation is a complex process that involves the evaluation of many criteria and requires the professional judgment of many experts in different fields. A reactor type that is suitable for one country might not be suitable for another. This is especially true in the case of GCC countries because of their location, the nature of land, physical properties of seawater, people, and modern technological situation.

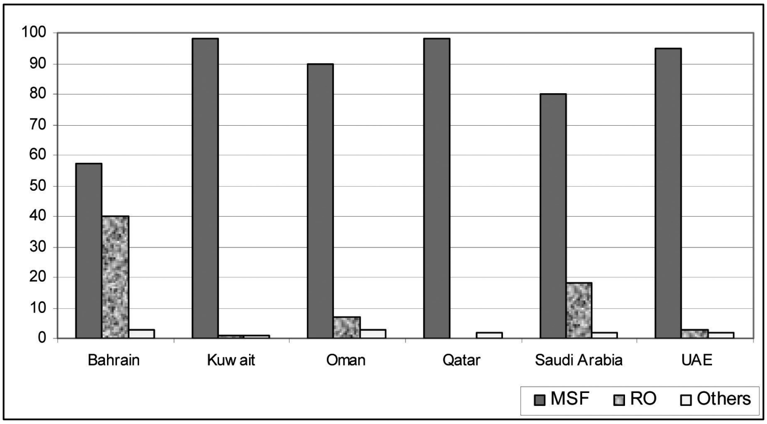

Figure 3: The used desalination process in GCC countries (%share).

The general selection criteria for the desalination method include the following:

1. Quantity of required fresh water (unit/plant capacity)
2. Availability of energy
3. Physical and chemical properties of feed water
4. Environmental factors
5. Economic factors

These and other factors are incorporated into a decision tree to determine the type of desalination technology that best suits a particular scenario as shown in Figure 4. However for desalination to be a realistic option for the supply of fresh water, we must not consider only the economical, technical, and environmental issues but also the social, political, and strategic factors. These last factors always present a pressure for obtaining a fresh water to cover the gap between the available water supply and demand. These factors can be addressed on-case-by-case basis after the feasibility study has been approved.

Table 4
Past and present desalination schemes in GCC countries.

Country	1990			2005		
	Desalination Production (MCM)	Domestic Demand (MCM)	Desalination to Demand ratio (%)	Desalination Production (MCM)	Domestic Demand (MCM)	Desalination to Demand ratio (%)
Bahrain	56	103	54	122.7	130	94
Kuwait	240	303	80	589.1	590	99
Oman	32	86	37	67.932	158	42
Qatar	83	85	98	194.317	201	96
Saudi Arabia	795	1700	47	1063.28	2400	45
UAE	342	540	63	812.61	825	98
Total	1548	2817	55	2849.94	4304	67

Table 5
Present desalination Capacity in GCC countries (2005).

Country	Process	No. of Unites	Total Capacity (m3/day)	Capacity (MCM)	Feed Water
Bahrain	MSF	8	238630	87.1	Seawater
	RO	16	97534	35.6	Seawater and brackish groundwater
Kuwait	MSF	58	1613973	589.1	Seawater
Oman	MSF	8	161015	58.77	Seawater and brackish groundwater
	RO	14	18992	6.93	Seawater
	ME	1	3000	1.095	Seawater
	VC	4	3115	1.137	Seawater and brackish groundwater
Qatar	MSF	34	499954	182.483	Seawater
	RO	11	10284	3.754	Seawater and brackish groundwater
	ME	1	2542	0.93	Seawater
	VC	11	19590	7.150	Seawater
Saudi Arabia	MSF	85	2560802	934.69	Seawater
	RO	24	346478	126.46	Seawater and brackish groundwater
	MED	1	3780	1.4	Seawater
	VC	1	2000	0.73	Seawater
UAE	MSF	74	2080959	759.55	Seawater
	RO	8	4000	1.46	Seawater and brackish water
	MED	1	141369	51.60	Seawater
TOTAL		360	7808017	2849.94	

4. Projection of Future Potential in Desalination Growth

The current per capita desalination capacity Q_{2005} m3/cap/day can be calculated from seawater and brackish water desalination for municipal use and attributed to the current urban population in each country according to Equation (1).

$$Q_{2003} = \frac{Q_{sw} . Y_{sw} + Q_{bw} . Y_{bw}}{N_{2003} . U} \qquad (1)$$

Where Q_{sw} and Q_{bw} are seawater and brackish water desalination capacity (m3/d), Y_{sw} and Y_{bw} are the share of municipal water from sea and brackish water desalination, respectively, N_{2005} is the current population in each country, and U represents the share of the population in urban centers [11].

To estimate the potential growth in the municipal water desalination industry, the following assumptions were made:

- Growth in desalination is determined based on the rate of population increase in the GCC countries in the next 25 years.
- Only the population in urban areas will use desalination to augment their current water supply.
- By year 2025, water for municipal (domestic) supply will be met completely from desalinated water and no surface water or withdrawals of groundwater will be used for municipal use in any of GCC countries.

The potential growth in desalination in each of GCC countries was calculated by the difference between the present desalination capacity at year 2005 and the required demand for domestic water supply by the year 2025 and can be expressed by Equation (2),

$$\Delta Q_{2025} = Q_{2025} - Q_{2003} = (N_{2025}.U.WW_{2025}) - \left[\frac{Q_{sw}.Y_{sw} + Q_{bw}.Y_{bw}}{N_{2003}.U}\right] \quad (2)$$

where N_{2025} is the projected population of each country by 2025 and WW_{2025} is the per capita municipal domestic water use by 2025 in (m3/cap/day).

The development of desalination for municipal use between 1990 and 2005, and the projected growth in desalination capacity in the GCC Countries for the next 20 years is summarized in Table 6. The driving force determining the need for the desalination development is assumed to be the increase in population. However, due to limited potential of brackish groundwater, there will also be a need for using desalinated water in agriculture, parks, gardens and forests.. This will most probably increase the desalination production by year 2025 if there is no reform to the agriculture policies in these countries to stop the expansion in, or even reduce the area under irrigation.

Table 6
Estimated future development in the desalination market.

Country	1990		2005		2025	
	Population (x1000)	Desalination Production (MCM)	Population (x1000)	Desalination Production (MCM)	Projected Population (x1000)	Estimated Desalination Production (MCM)
Bahrain	404	56	719	122.7	1483	161.96
Kuwait	1292	240	2326	589.1	4744	749.34
Oman	1503	32	2718	67.932	5517	114.13
Qatar	358	83	712	194.317	1312	252.61
Saudi Arabia	13090	795	23321	1063.28	48051	1690.62
UAE	1459	342	2444	812.61	5355	1357.06
Total	18086	1548	32240	2849.94	66391	4325.71

5. Desalination Economics:

5.1 Cost Estimate:

Cost is a primary factor in selecting a particular desalination technique for fresh water production. Desalination costs have decreased markedly in the last few decades as shown in Figure 4. The recent studies and analysis indicate that the cubic meter cost of desalination for seawater based on the Gulf seawater quality having a TDS of 45,000 ppm in GCC countries ranges from 0.86 to 1.06 US dollars depending on the ratio of recovery [12,13]. Table 7 summarizes the cost elements included in a seawater desalination plant. However the cost for desalinating the brackish groundwater will be less than these figures using RO technology. The costs of desalinating brackish groundwater in GCC countries using RO have reduced from 2.5 to 0.38 US dollars/m^3 and this will continue decreasing in line with improved membrane plant performance (e.g. decreased water pressure requirements, increased injection of salt, longer operating lifetimes, improved energy recovery, and plant automation) and improved economics associated with large scale production of membranes. It is Also very important to mention that in any evaluation of desalination costs, it is important to consider the hidden costs associated with using water with a high salt or mineral content.

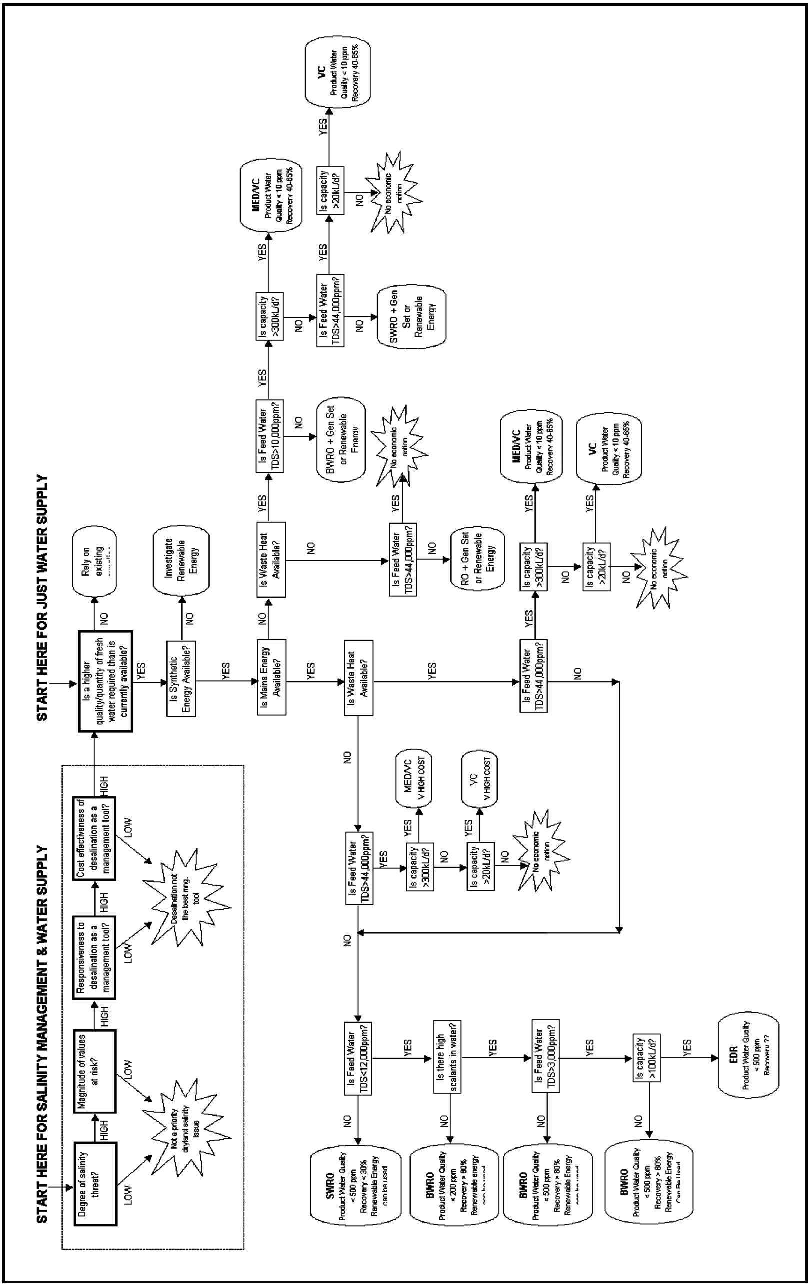

Figure 4: Desalination decision tree.

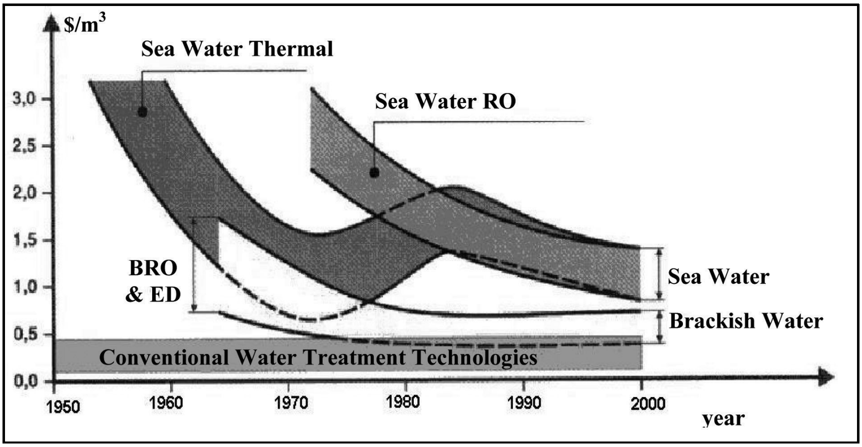

Figure 5: Approximate desalination costs.

Table 7
Total capital and running summary costs for seawater desalination.

Cost Item	Cost in US dollars/m^3 (35% recovery)	Cost in US dollars/m^3 (45% recovery)
Capital costs	0.35	0.29
Operation staff	0.048	0.048
Chemicals	0.10	0.08
Energy	0.43	0.33
Maintenance	0.138	0.11
Total (US dollars)	1.06	0.86

5.2 Effect of Energy Cost on Desalination:

Energy costs represent a remarkable contribution to the cost of produced water from the different desalination systems, with an average that varies between 20% to 30% and up to 50% for MSF. As a result, energy costs could become prohibitive for the MSF and it would far exceed the membrane replacement unit cost. In this case, the economic advantages of the RO system would be very significant. Figure 5 illustrates the effect of fuel prices on the cost of desalinated water using MSF and RO systems. The figure shows the slight impact of energy prices on RO systems and the remarkable impact on MSF systems and that this would also vary with the capacity of these systems as shown by the range of prices [14].

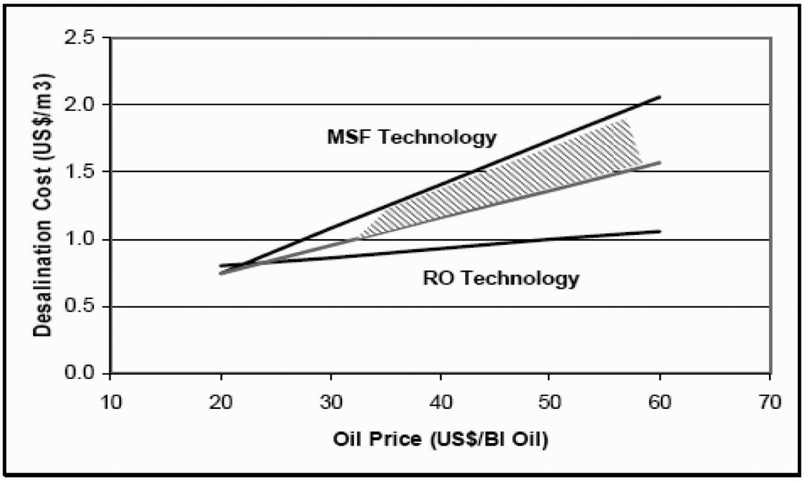

Figure 6: Effect of energy cost on the cost of desalinated water using MSF and RO.

5.3 Approaches for Cost Reduction:

One way to reduce the cost of desalinated water is to improve the desalination technology and increase the performance ratio (the ratio of fresh water to the amount of energy consumed). There is a wide variety of water production costs, depending on plant size and energy prices. Usually, costs decrease with increased plant capacity [15]. Costs reported by the GCC countries are usually less than for countries in the rest of the world because of subsidized energy charges. For example, the cost of producing 1 m3 of water in Saudi Arabia ranges from $0.48 to $2.20; from $1 to $1.45 in the United Arab Emirates; $1.14 to $1.64 in Qatar and $0.56 in Bahrain. In other parts of the world, where energy costs are not subsidized, production costs are somewhat higher; for example, in Florida and the United States Virgin Islands, costs range from $2.06 to $2.60; in Malta the cost is $1.18, and in the Canary Islands it is $1.62 over the past 15 years, major advances have been made in certain desalination technologies, which have resulted in notable cost reduction [12]. Several approaches were proposed by different experts in the field for reducing the cost of desalinated water from conventional desalination plants.

6. Energy Supply Option for Water Desalination:

Although the GCC countries have extensive fossil and renewable energy resources, all desalination plants are dependent on fossil energy resources, except for the solar-assisted seawater MED demonstration plant that was established in Abu Dhabi in late 1984. The majority of water desalination plants in the GCC countries acquire their electric power requirements either directly from an electric grid or from an adjacent electric power plant in a power water cogeneration system. Thermal energy for distillation-based plants can additionally be obtained from waste heat from the power plants. A variety of power generation systems, all compatible with the desalination system, are available in the GCC countries. These include steam boilerturbine-generator power cycle, gas turbine power cycle, combined power plants cycle and diesel engines. However, renewable solar thermal, photo-voltaic (PV) and wind energy, in addition to biomass technologies have reached such a level of maturity that within a short to medium time frame, renewable thermal and electric energy will become viable sources of energy for desalination processes. In addition, desalination requires a large seawater inlet flow for processing and cooling. The rejected brine and cooling seawater with the chemicals or their by-products are in turn discharged into the sea at a higher temperature. This has an impact on the marine environment.

Reduction of Desalination Energy Requirements:

The following statements are valid:

- The trend for using large capacity MSF plants: Recent research indicates that doubling MSF unit capacity results in a 20% reduction in investment costs (capital cost) and about a 24% saving in operation costs.
- Develop concepts and schemes for optimal integration, by cogen-

eration or otherwise, of various energy sources and desalination technologies.

(a) Hybrid systems.

(b) Solar energy integration.

(c) Desalination dedicated power plants.

- Identify novel schemes for improving desalination processes and/or energy recuperation.
- Using Hybrid RO/MSF seawater desalination to compromise quality cost constraints.
- Using RO plants with high recovery rate.
- Using off-peak electrical energy in seawater RO desalination systems.
- Using high effective MED plants
- Integrated solar energy with desalination systems

7. Conclusions and Recommendations:

- It is clear that the water desalination industry is currently at an important stage, where the need for water availability and quality is increased in many places, especially in GCC countries. The production cost is declining due to healthy competition, while performance is improving along with production efficiency. No arguments are needed in respect to the quality of the water; the main struggle is still the cost of the production. It is clear, however, that the cost of water is steadily declining so that more people can afford desalination.
- Expanding desalination capacity in the next 20 years will be possible by building new plants or upgrading the existing facilities in GCC countries. This process, however, will require high economic investment.
- The driving force determining the need for desalination development in municipal domestic water supply is assumed to be the population growth from 18 millions in 1990 to 32.24 millions in 2005 and to the projected 66 millions by 2025. This will cause a continuous decline in the non-renewable groundwater resources.

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