Future Prospects for Desalination in the GCC Courtiers

Ibrahim S. Al-Mutaz
Chem. Eng. Dept., College of Engineering, King Saud University
P O Box 800, Riyadh 11421, e-mail: almutaz@ksu.edu.sa

Overview

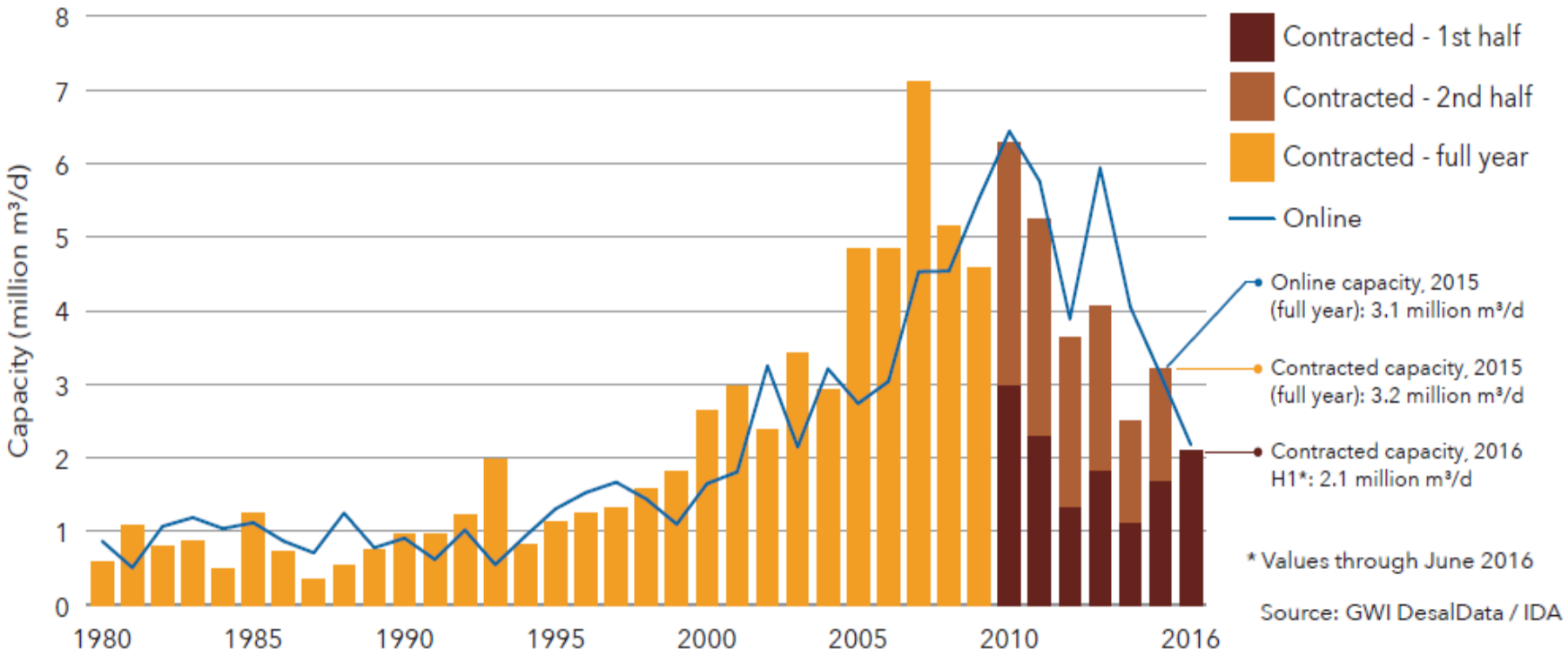
- Introduction.
- GCC Characteristics.
- Water Supply in the GCC Countries.
- Desalination Status in GCC.
- Storage of Desalinated Water.
- Desalination – Energy Sources.
- Conclusions.

Introduction

- It is expected that the world population will increase from 6.8 to 8.9 billion by 2050. Consequently, there has been an increasing trend in installing desalination plants.
- Worldwide production of desalinated water has increased from about 32 Mm^3/d in 2001 to about 75 Mm^3/d in 2013.
- There were about 18,000 desalination plants globally by the end of 2015, with an overall installed production capacity of 86.55 Mm^3/d (22,870 mgd).
- The production capacity is expected to reach 120 Mm^3/d by 2020.

Introduction

- Incremental Contracted and Online Capacity By Year,

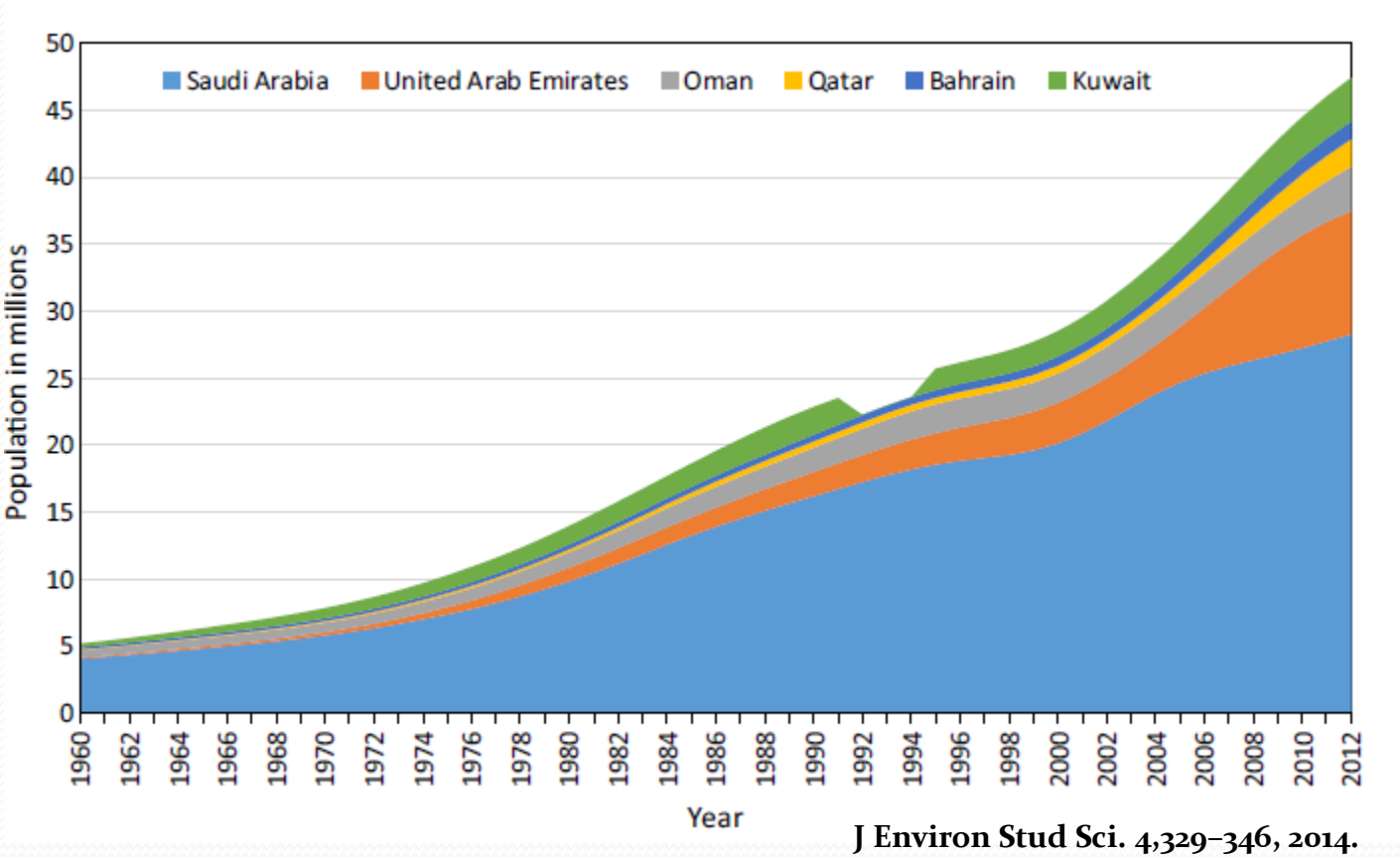


Introduction

- Total area of GCC countries is about 2.6 Mkm^2 with a total population of 53.4 millions in 2016. The per capita total renewable water resources (TARWR) in GCC countries in 2014 was just 86.6 cubic meters, compared to the global average of almost 17,575 m^3.
- It is predicted that water availability in the GCC countries will be reduced significantly by 2030.
- It is expected that the total annual GCC water demand will increase by 40% in 2030 and may reach more than 50 Bm^3. This may lead to a large deficit in the GCC water resources of about 20 bm^3.

GCC Characteristics

- Population Growth of the GCC Countries Since 1960



J Environ Stud Sci. 4,329–346, 2014.

GCC Characteristics

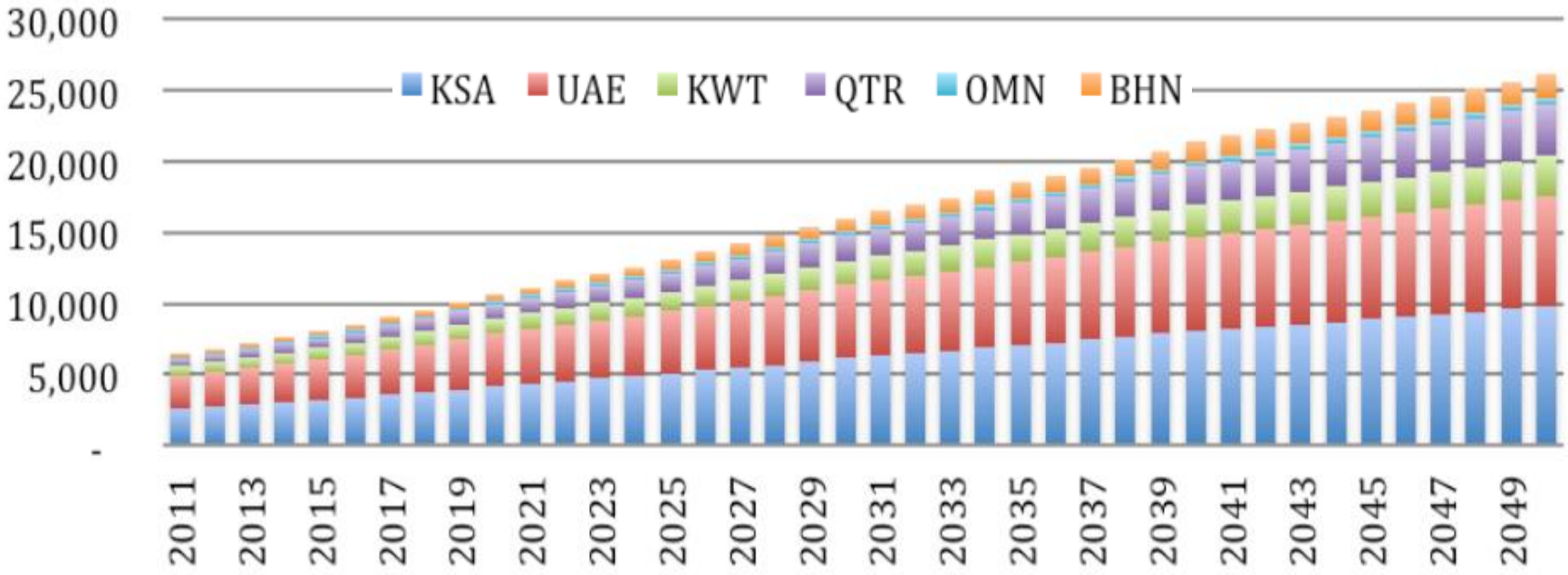
- High Population

Country	Total Population (thousands)			% Inc.
	1970	2010	2050	(2010-50)
Bahrain	220	807	1277	1.5
Kuwait	744	3051	5240	1.8
Oman	747	2905	4878	1.7
Qatar	111	1508	2316	1.3
Saudi Arabia	5745	26,246	43,658	1.7
UAE	225	4,707	8,253	1.9
Total	7792	39,224	65,622	1.7

United Nations, Department of Economic and Social Affairs, Population Division, 2012.

GCC Characteristics

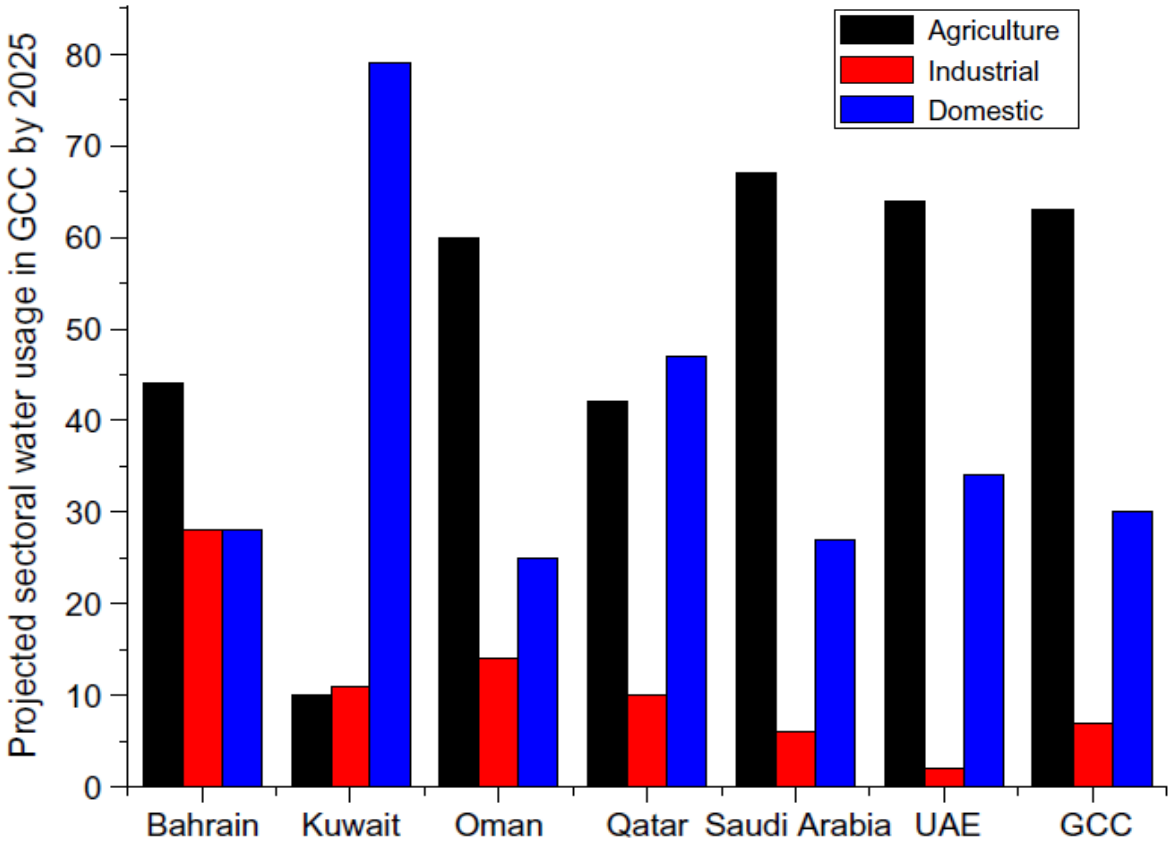
- High Water Demand, Giga Liters



Yousef Almulla, "Gulf Cooperation Council (GCC) countries 2040 energy scenario for electricity generation and water desalination", MSc. Thesis, Kungl Tekniska Högskolan, Stockholm, Sweden, 2014.

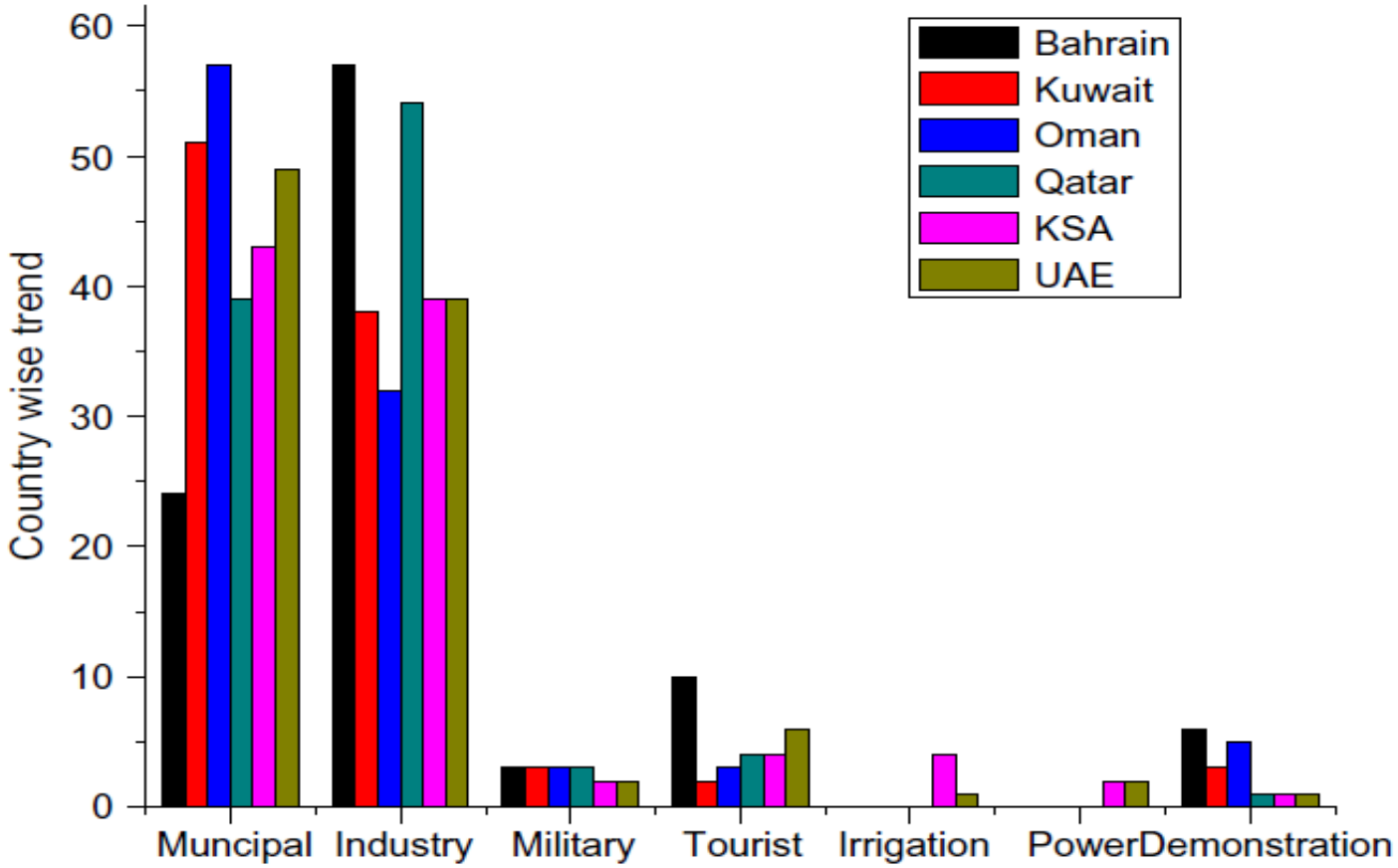
GCC Characteristics

- Projected water usage plan up to 2025 in the GCC countries



GCC Characteristics

- Trends of Water Usage in the GCC Countries



Water Supply in the GCC Countries

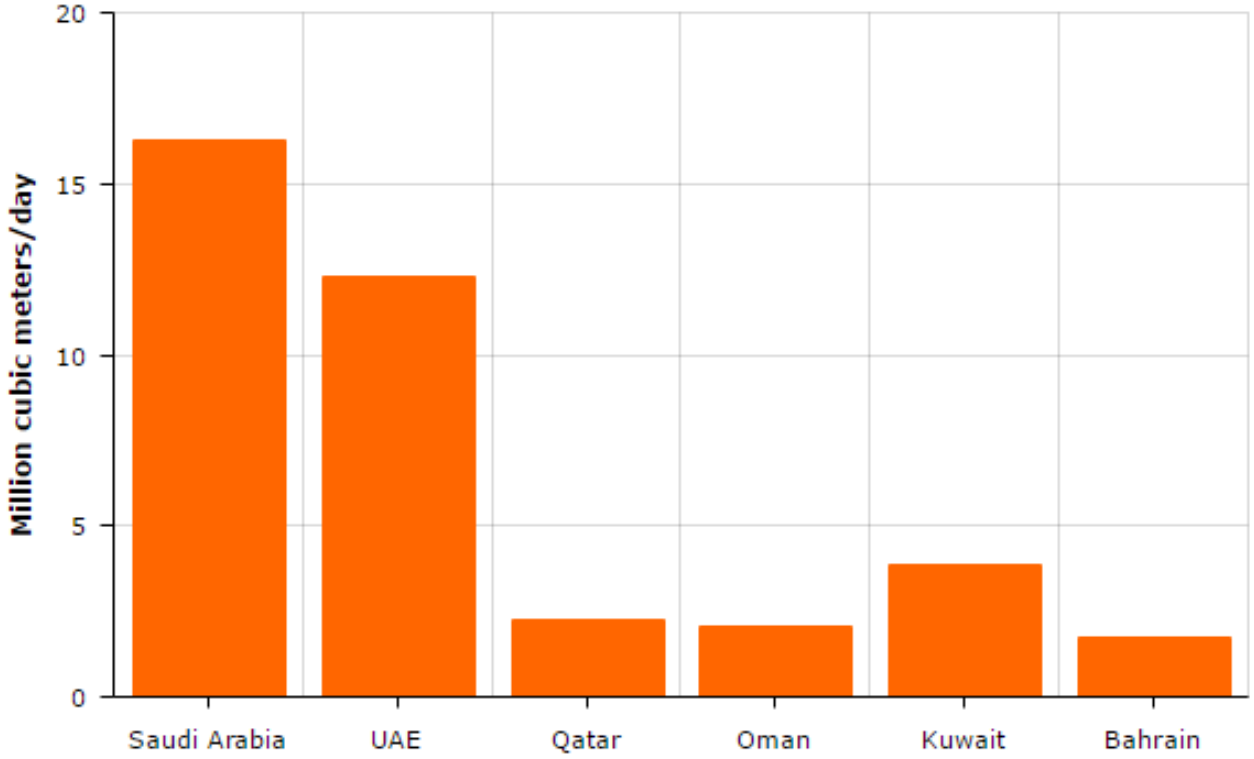
- Desalination is considered the major water supply in the GCC countries. About 63% of the water supply in GCC countries comes from desalination. The current GCC seawater desalination capacity is nearly 18.2 Mm^3/d (4,000 migd).
- Conventional water resources such as fresh surface water and renewable groundwater are limited.
- Reuse of treated wastewater is about 900 Mm^3, which is equivalent to 31.0% of the total treated wastewater. Treated wastewater is used mainly for irrigating green areas.
- Historically, GCC countries have relied almost entirely on groundwater resources, which are split into shallow and deep fossil aquifers.
- Potable water shortage remains a major problem in the GCC.

Water Supply in the GCC Countries

- The major commercial technologies used on an industrial scale are MSF, MED and RO.
- The maximum production capacity of 90 Mm^3/d of water every day is at MSF Ras Alkhair plant.
- About 27.7 Mm^3/d of potable water is produced by thermal desalination, accounting for 31% of all installed desalination capacity in the world.
- About 75% of all thermal desalination plants are located in the GCC, where Saudi Arabia produces 12.9 Mm^3/d and UAE of 7.8 Mm^3/d.
- Most common thermal desalination plants in the GCC region are the MSF, MED and MED-TVC.

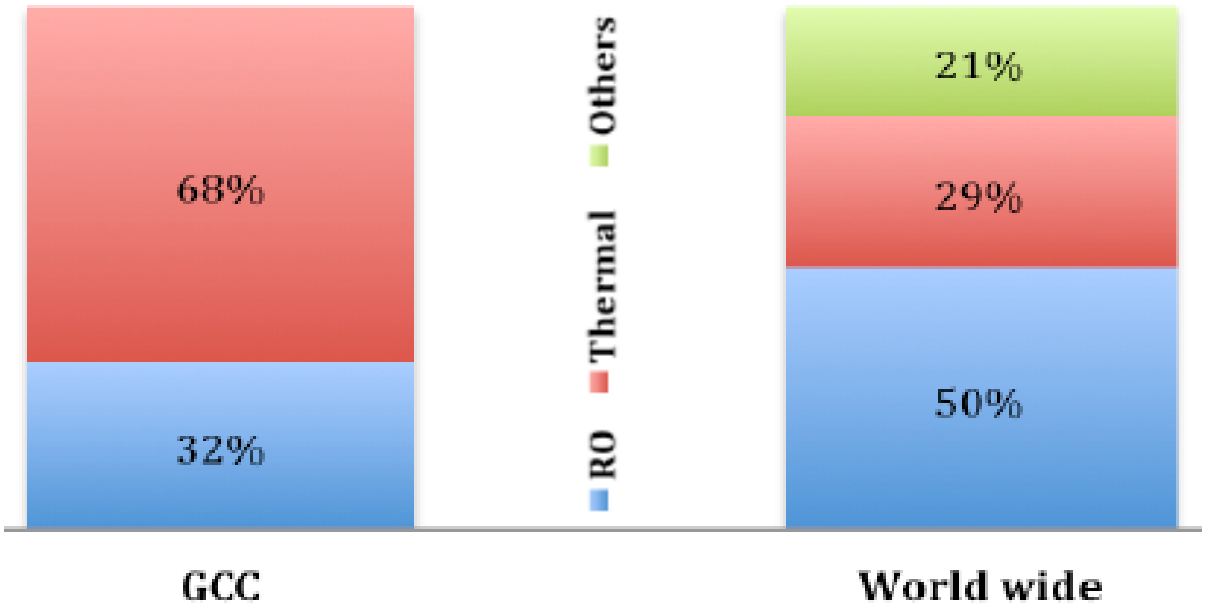
Water Supply in the GCC Countries

- Total Production of GCC Desalination Plants, 2016



Water Supply in the GCC Countries

- High Share of Thermal Desalination Processes



Water Supply in the GCC Countries

- About 70% of the desalinated water in the GCC comes from thermal desalination plants including MSF and MED.
- The trend in the desalination plant in the GCC is 30% RO and 70% thermal. However, these percentages vary from one to another country depending on feed water quality and expertise. For example, desalination options provide 27% of total water demand in Oman to 87% in Qatar
- The advantages of RO over thermal technologies are well known in terms of lower energy consumption and the cost of produced water.
- High feed water salinity, variation in water quality and reliability are contributed to the dominance of thermal plants.

Water Supply in the GCC Countries

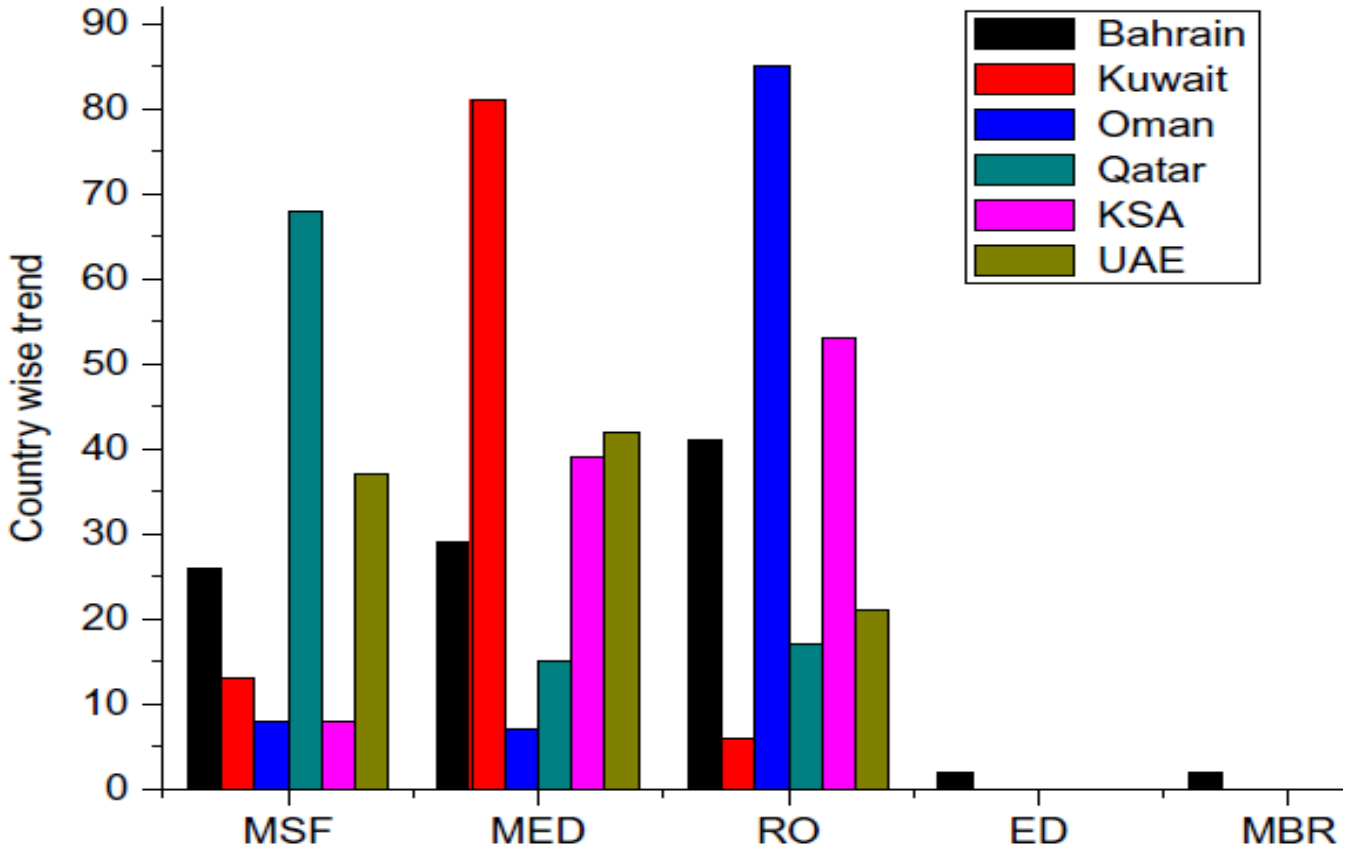
- Saudi Arabia is the largest producer of desalinated water with 17% global desalinated water capacity.
- Two feasible sources water supply have the potential to meet future water supply demands; desalination and water reuse (treated wastewater effluent reuse).
- Continued reductions in desalination costs are anticipated based on the enhanced use of renewable energy sources and the use of hybrid facilities to help reduce overall energy consumption.

Desalination Status in GCC

- Basic parameters for choosing the appropriate desalination process are :
  - Co-generation: require careful analysis of various possible dual schemes for cost optimization.
  - Availability of energy resources: survey for available energy resources, conventional or renewable energy sources, waste or low grade heat.
  - Plant size : depend on water demand. However, limitations on the size of each process should be considered.
  - Allowable concentration ratio: avoid scale formation .

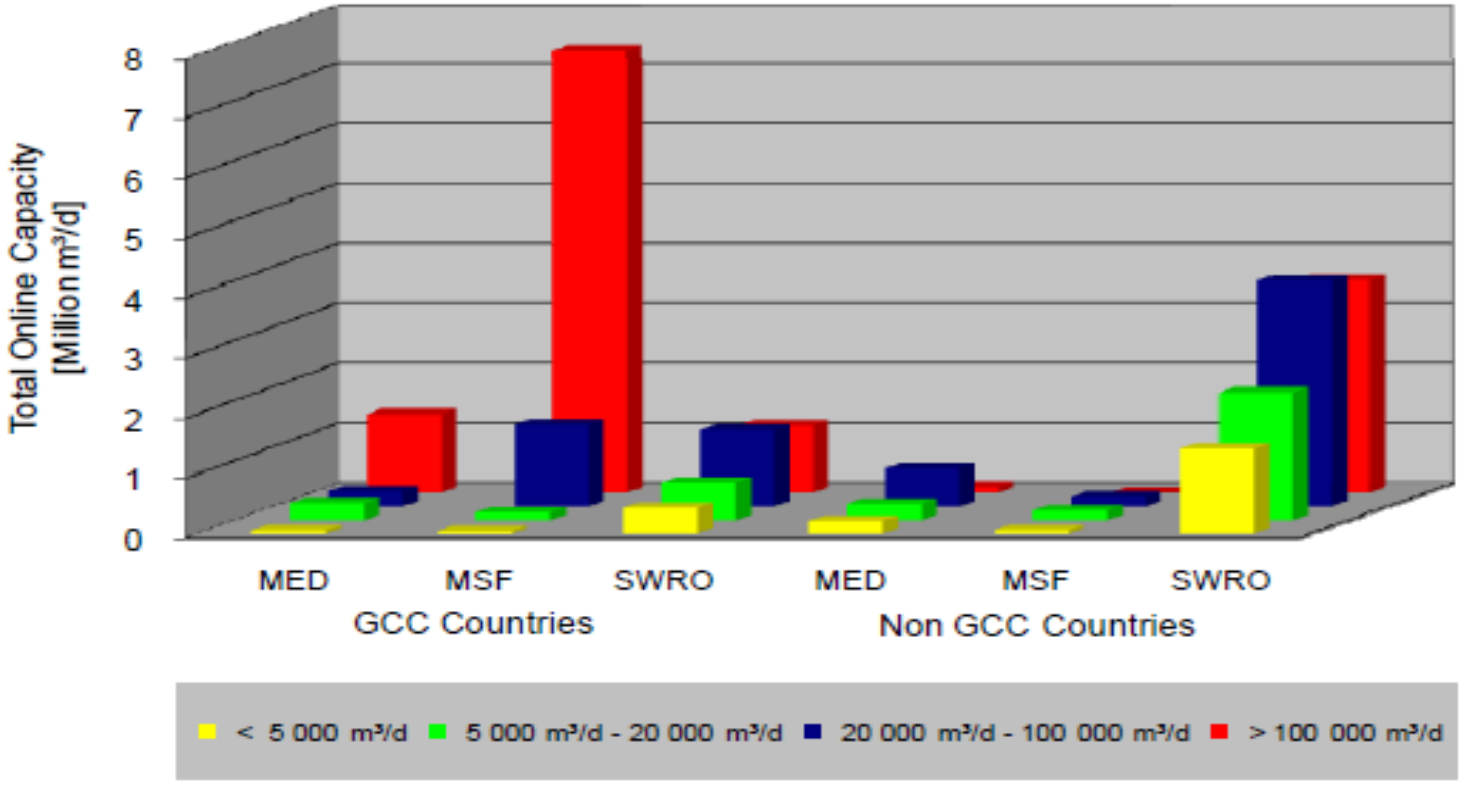
Desalination Status in GCC

- Desalination Technologies in the GCC Countries



Desalination Status in GCC

- Cumulative capacity of main desalination processes in and outside the GCC countries



Desalination Status in GCC

- Thermal Processes
  - It is energy intensive. MSF is more energy consuming than MED. Both processes are widely used in GCC where energy is relatively cheap.
  - It is driven by low pressure steam (extract or back pressure steam from a power plant). Waste or low grade heat can be utilized. Operation up to 120 ^{o}C maximum to avoid scale formation.
  - MSF/MED plants are robust with life-time exceed 25 years.
  - Large amount of cooling water is required.
  - High quality of water (10-30 mg/l) is produced requires re-mineralization to prevent corrosion in the distribution system.

Desalination Status in GCC

- Thermal Processes
  - MED is the oldest desalination technology. It is more efficient thermodynamically than MSF.
  - The use of low top brine temperature in MED results in less scaling and fouling problems compared with MSF.
  - Kuwait's first desalination plant based on MED technology went online in 1953 and had a capacity of 9,200 m^3/d.
  - The introduction of MSF desalination in the early 1970s.

Desalination Status in GCC

- Membrane Processes
  - RO is gaining its share mainly because of its lower cost, simplicity, and flexibility in operation due to its modular design.
  - Energy recovery systems has made the process energy efficient. It is applicable for renewable energy sources. However, an efficient pre-treatment of the feed water is required.
  - RO requires for production of 1 m^3:
    - 4.0 kWh for brackish water,
    - 6.0 kWh for seawater, without ER systems,
    - 2.5-4.0 kWh for seawater, with ER systems.
  - RO desalination is an ideal choice for a small-scale plant.

Desalination Status in GCC

- Membrane Processes
  - In GCC, the total salinity is 41,000–45,000 ppm. Seawater has high fouling potential due to its high turbidity. High ambient temperatures which may deteriorate the performance of RO plant.
  - Suitable feed water pretreatment is necessary before RO. Pretreatment may involve conventional methods such as chemical treatment followed by coagulation, sedimentation, sand filtration, flocculation, etc.
  - RO desalination is an ideal choice for a small-scale plant.

Desalination Status in GCC

- RO Membranes Suppliers

			Membrane material			Membrane configuration			Application	
Manufacturer	**Owner**	**Country**	**Cellulose Triacetate**	**Cellulose Acetate**	**Polyamide**	**Hollow Fibre**	**Plate**	**Spiral Wound**	**BW**	**SW**
Dow Filmtec	Dow Chemical	USA			X			X	X	X
Fluid Systems	Koch	USA		X	X			X	X	X
Hydranautics	Nitto Denko	USA - Japan		X	X			X	X	X
Toray	Toray	Japan		X	X			X	X	X
Osmonics	General Electric Power	USA			X			X	X	
Rochem	PALL	Germany - USA			X		X			X
Toyobo	Toyobo	Japan	X			X				X

Storage of Desalinated Water

- Unique feature of the GCC power/water demand pattern is that power demand has a very seasonal fluctuation, while water demand is relativity constant in comparison.
- Power generation is most cost effective during times of continuous facility operation at near maximum capacity, but electrical power can be generated, but not effectively stored.
- Desalinated water can be stored using aquifer storage and recovery (ASR), creating a link between the stored desalinated water with power plant operations, leading to greater operational efficiencies for both facilities and lower costs.

Storage of Desalinated Water

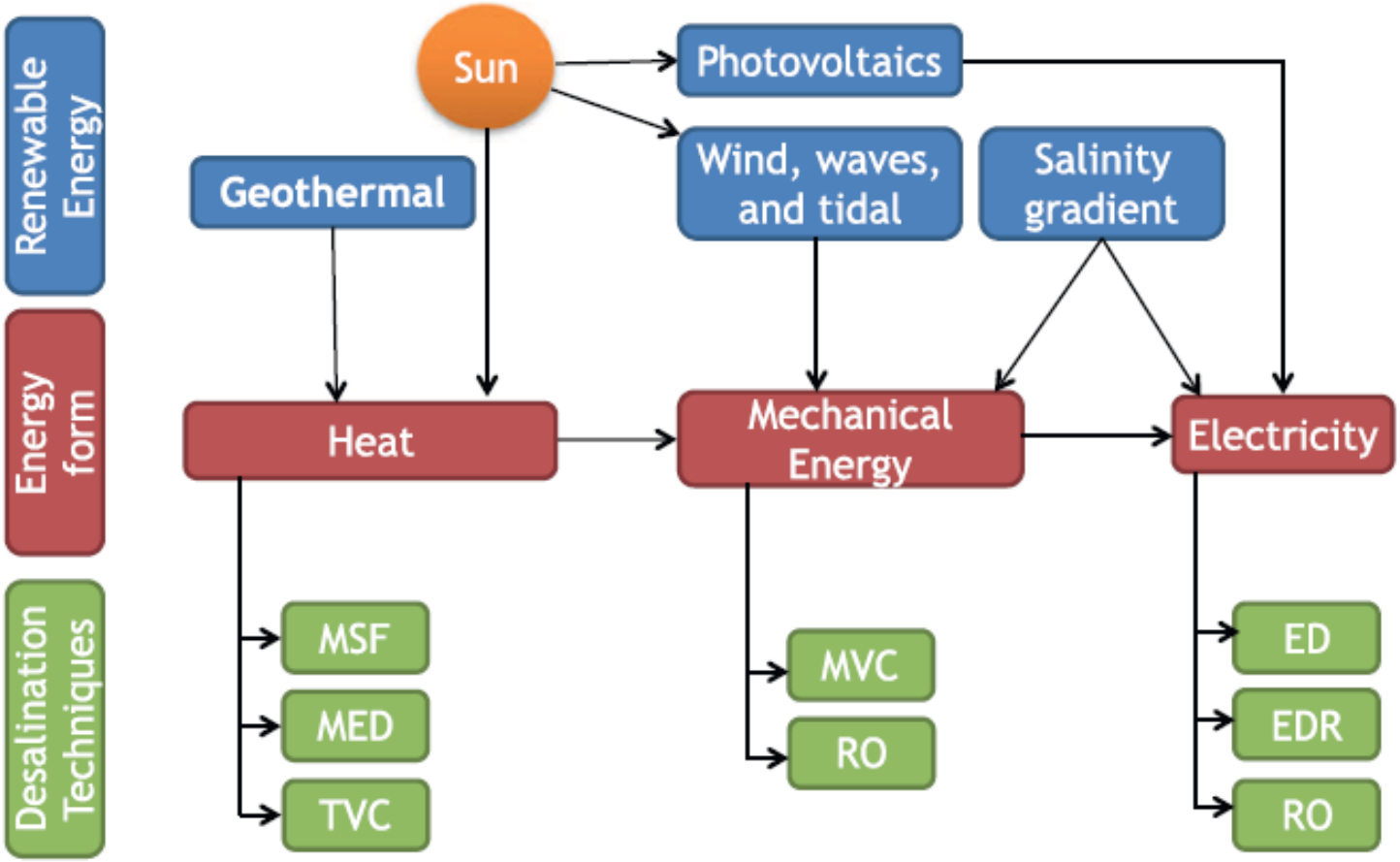
- RO plants may be installed to utilize the idle power in the winter from the co-generation systems instead of operating the power plant at a lower load due to lower electricity demand.
- Beneficial reuse of domestic wastewater and perhaps industrial wastewater is necessary to reduce the demand for desalinated water used for non-potable uses, such as landscape irrigation, agricultural irrigation, and industrial uses including cooling water.
- The treated wastewater could be used for drinking water, this is rarely acceptable from a cultural standpoint.

Storage of Desalinated Water

- To ensure water security, some countries (e.g. Kuwait, Qatar) have conducted feasibility studies or pilot projects for underground storage of freshwater.
- In 2016, the UAE completed a large-scale ASR system to create a strategic storage of desalinated seawater: The Liwa ASR project in Abu Dhabi for storage of a 90 day emergency supply of 15.5 Mm^3.
- The reuse of treated wastewater for non-potable purposes seems to be gaining importance: Urban areas are commonly well equipped with wastewater treatment facilities, reclaimed water is already used for municipal landscaping.

Desalination – Energy Sources

- Possible applications of renewable energy sources.



M. A. Abdelkareem and et. al, Desalination 435, 97-113, 2018.

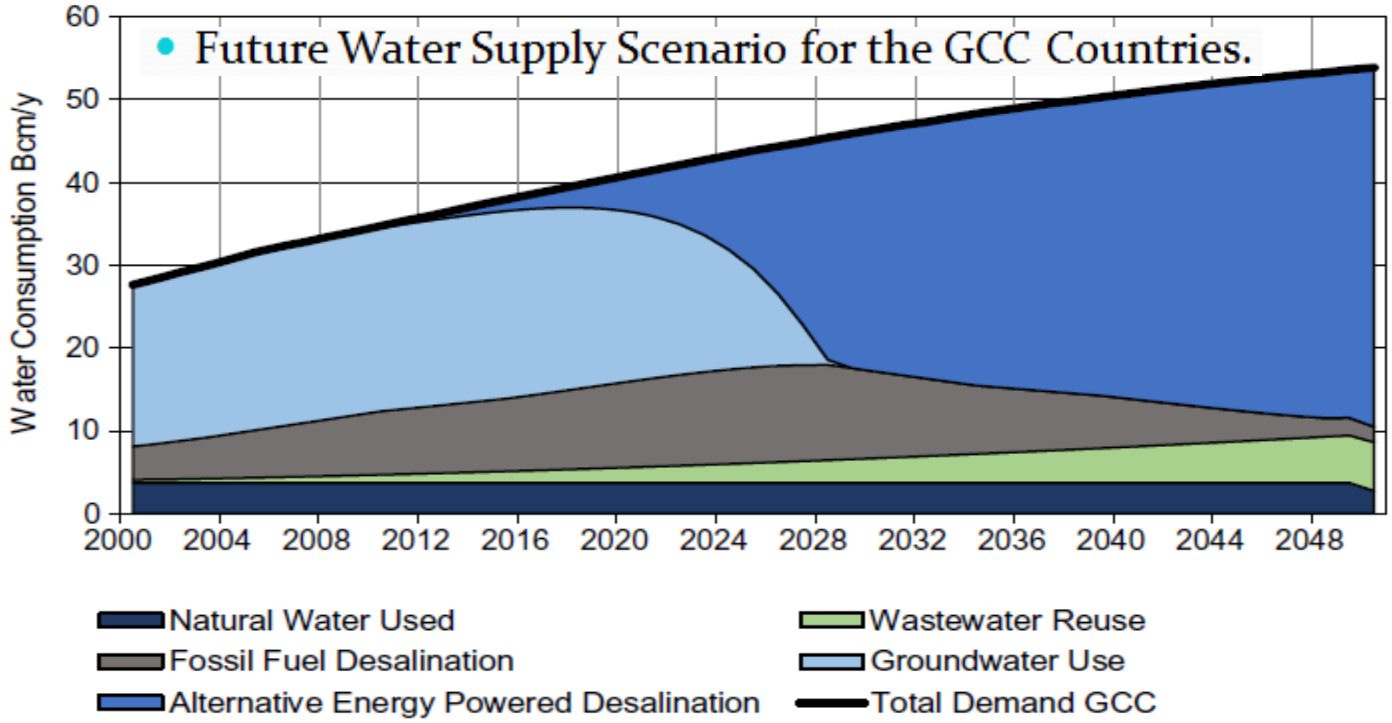
Desalination – Energy Sources

- Solar photovoltaic (PV) system is a mature technology having life expectancy of more than 25 years.
- "The use of renewable energy globally has increased from 2% in 1998 to 16% in 2009 and to 19.3% in 2015". *
- The increase in RO can serve as an opportunity for greater integration of renewables, such as solar PV and wind, as they become cost-effective alternatives to fossil-fuel-based electricity generation.
- Either gradually electrifying desalination along with gradually integrating higher shares of renewables into the overall electricity mix, or co-locating desalination and renewable installations.

* M. A. Abdelkareem and et. al, Desalination 444, 178, 2018.

Desalination – Energy Sources

- It is expected that by 2050 desalination irrespective of its fuel source would account for 84% of all water needs for the GCC region in all sectors.



F. Trieb et. al, Desalination 220, 165-183, 2008.

Conclusions

- Fossil fuels will continue to have an important role in a least cost future for the region.
- Despite the high renewable energy technologies potential, their penetration proved to be limited in the GCC.
- Desalination will be a major source for water supply in GCC countries for the foreseeable future due to limited groundwater availability and limitation in renewable fresh water sources.
- Given the high salinity and high temperature of the Gulf water, thermal desalination technologies are usually better suited.
- Constructing the dual purpose large-scale desalination plants has contributed to reduce the cost and produce large volumes of desalted water.

Conclusions

- The achievements in the field of improving membrane technology will lead to reduction in costs of RO desalination process and increasing membrane life.
- Small RO plants run by solar photovoltaic power in agriculture or solar well pumps diminish the need of fossil fuel electricity.
- Research and development efforts in the field of using solar and nuclear energy in desalination are expected to reduce the production, operation and maintenance costs for producing water.
- Nuclear energy will be able to power large-scale RO plants and provide cheaper energy source for thermal desalination processes.


Thank You