Nuclear Desalination As A Long-Term Solution to Water Shortage in the GCC Countries

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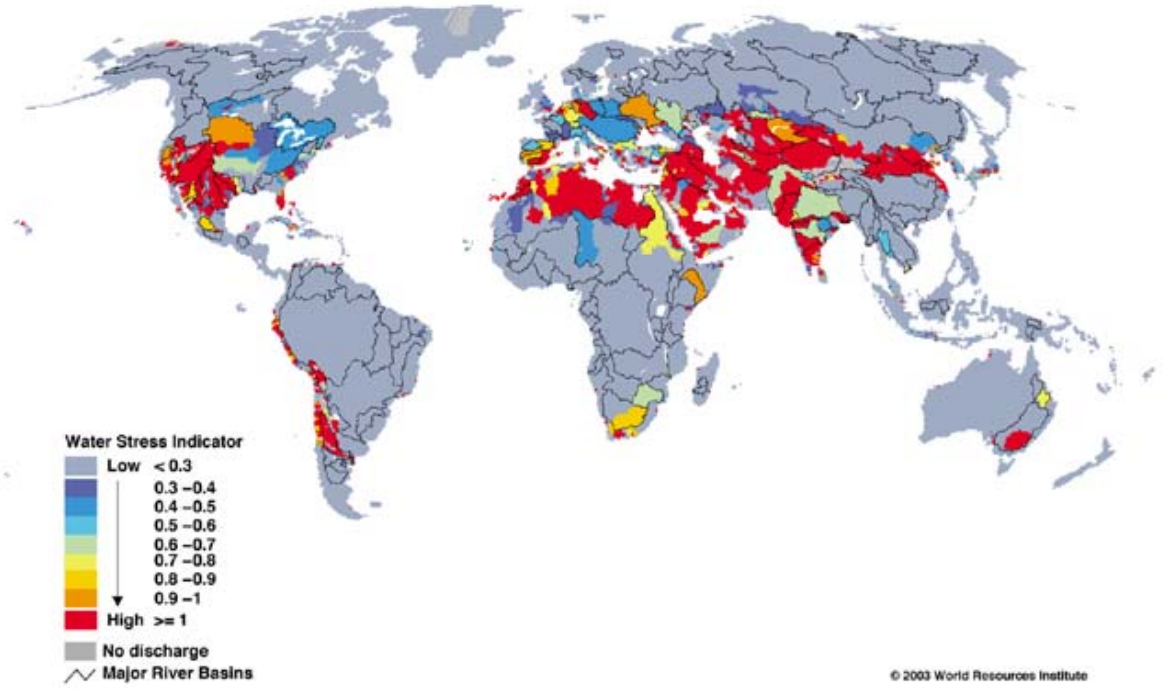
Overview

- GCC Characteristics.
- Current Desalination Status in GCC.
- What is Nuclear Desalination ?
- Experiences in Nuclear Desalination.
- GCC Nuclear Energy Programs.
- Potential of ND implementation in GCC.
- Conclusions.

GCC Characteristics

- Exist in Water Shortages Region



The United Nations World Water Development Report 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

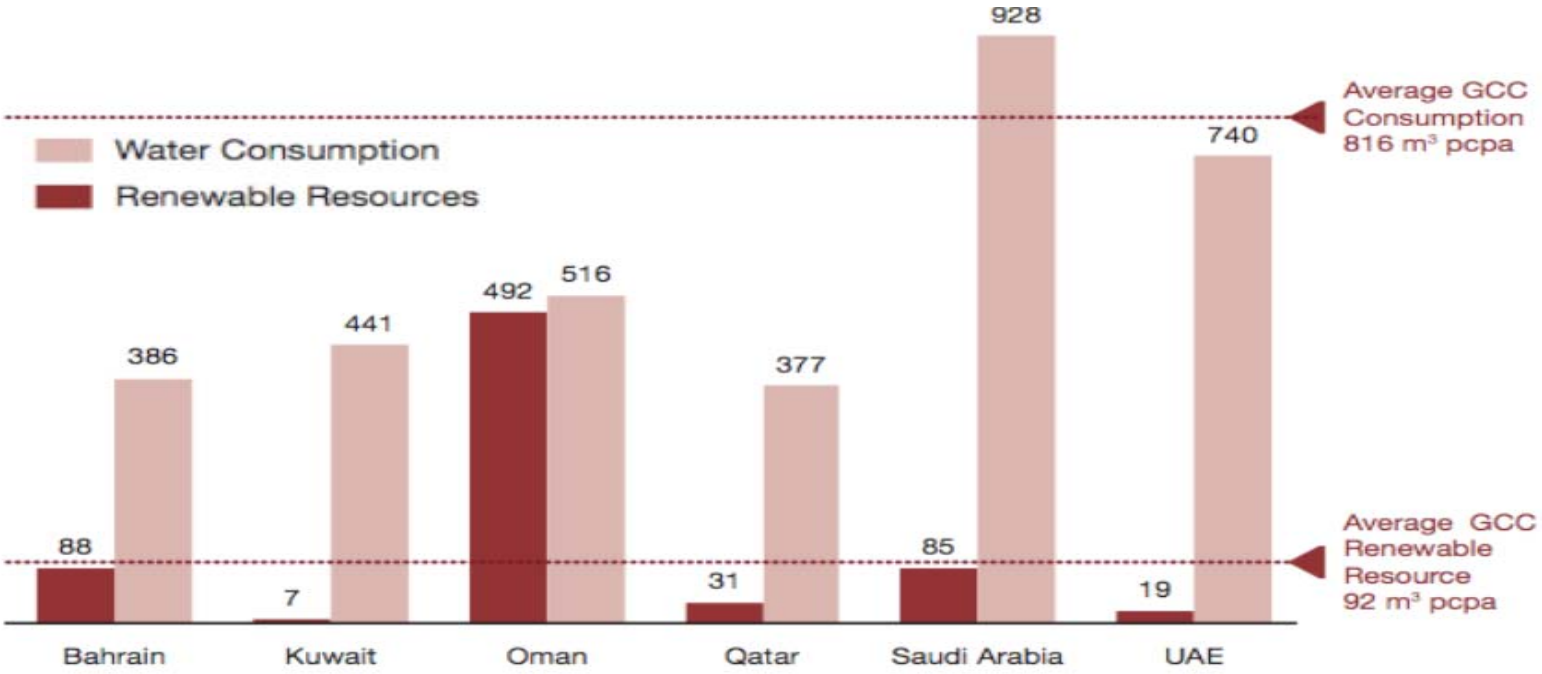
- Shortage of Water Resources

Country	Area (Km^2)	Mean annual precipitation (mm)	Groundwater recharge (M m^3)	Non-renewable reserve (M m^3)	Annual renewable water resources (Km^3/year)	Total renewable water resources per capita (m^3/year/per.)
Bahrain	652	30–140	110	Negligible	11.6	7.65
Kuwait	17,818	30–140	160	n/a	58.3	6.154
Oman	212,460	80–400	900	102,000	0.6	462.84
Qatar	11,610	20–150	50	Negligible	29	29.30
Saudi Arabia	2,149,690	30–550	3850	428,400	33.7	86.45
UAE	83,600	80–160	190	n/a	64.5	16

George O. Odhiamb, "Water scarcity in the Arabian Peninsula and socio-economic implications", Applied Water Science 6 (1), 21-35, 2016.

GCC Characteristics

- High Water Consumption wrt Renewable Resources, m^3 Pcpa



AQUASTAT 2013: FAO's global water information system.

GCC Characteristics

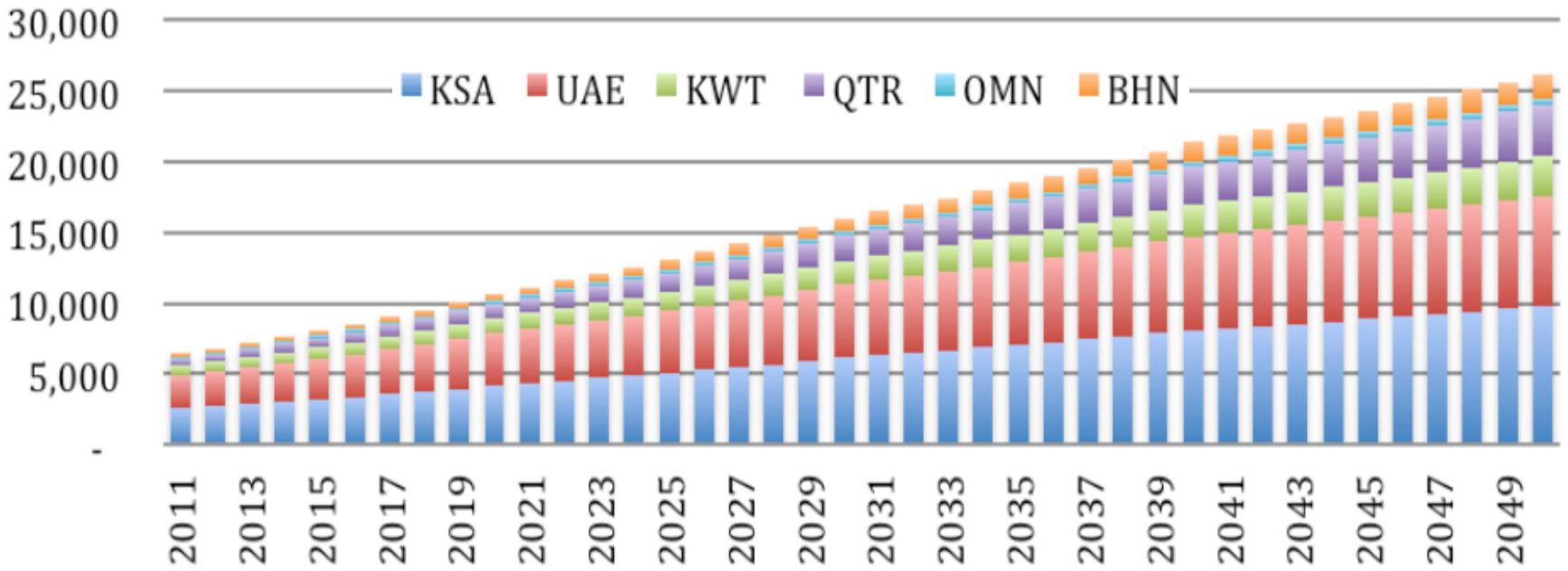
- High Water Demand, mcm/y

	1990			2000			2025			Total demand		
Country	Domestic	Agriculture	Industrial	Domestic	Agriculture	Industrial	Domestic	Agriculture	Industrial	1990	2000	2025
Bahrain	86	120	17	169	124	26	230	271	73	223	319	574
Kuwait	295	80	8	375	110	105	670	140	160	383	590	970
Qatar	76	109	9	90	185	15	230	205	50	194	290	485
Oman	81	1,150	5	170	1,270	85	630	1,500	350	1,236	1,525	2,480
UAE	513	950	27	750	1,400	30	1,100	2,050	50	1,490	2,180	3,200
Saudi Arabia	1,508	14,600	192	2,350	15,000	415	6,450	16,300	1,450	16,300	17,765	24,200
Total	2559	17009	258	3904	18089	676	9310	20466	2,133	19826	22669	31909

ESCWA (Economic and Social Commission for Western Asia), Secretariat from country reports and international sources.

GCC Characteristics

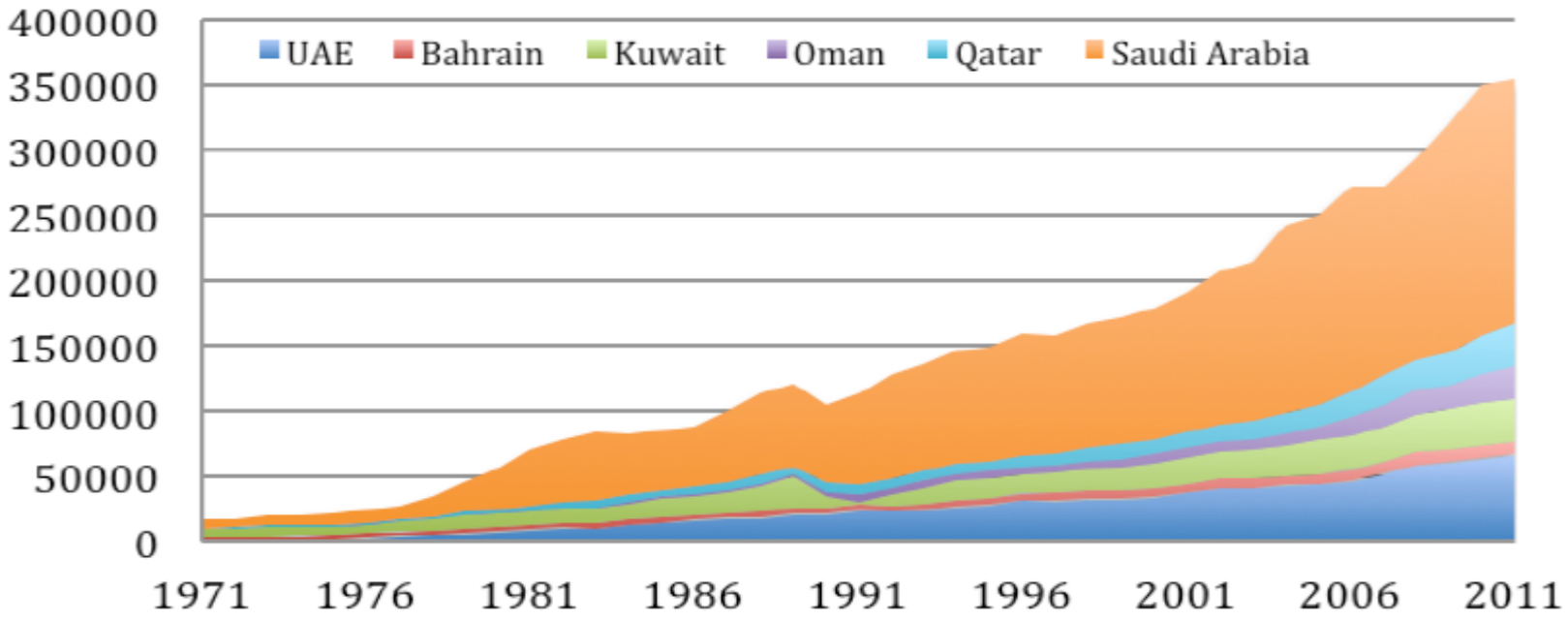
- High Water Demand, Giga Liters



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

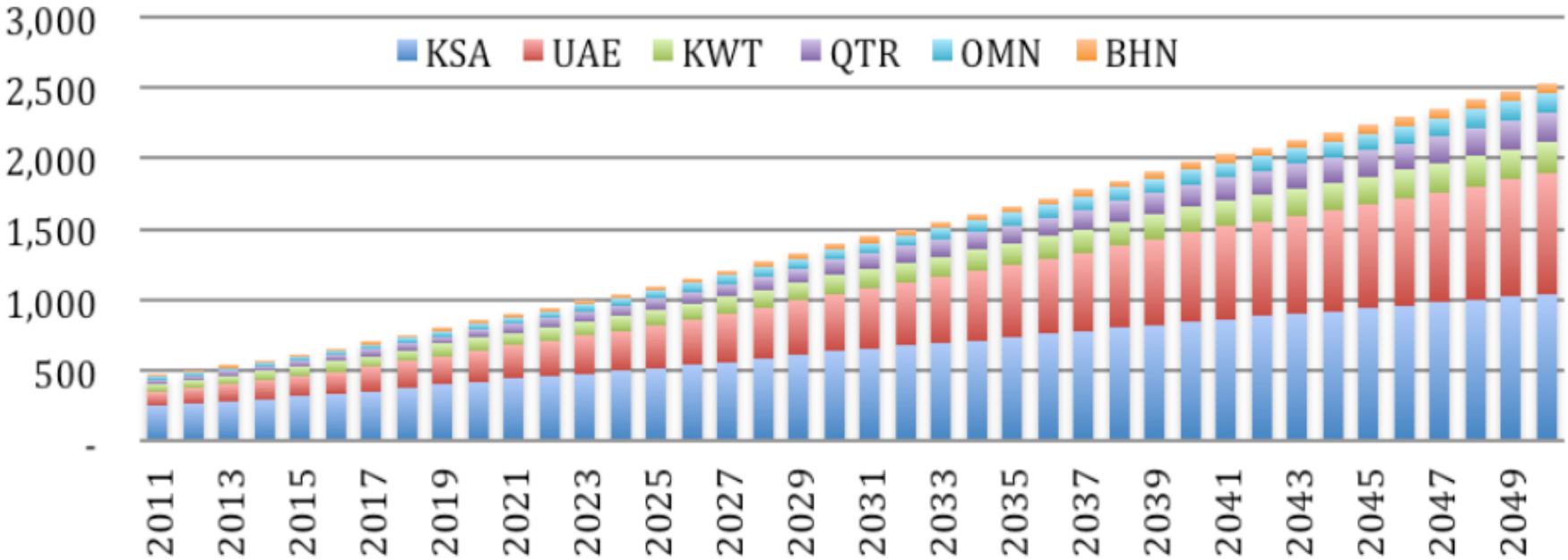
- High Energy Consumption in the, ktoe



International Energy Agency (IEA), Statistics & Balances, 2014.

GCC Characteristics

- High Electricity Demand, TWh



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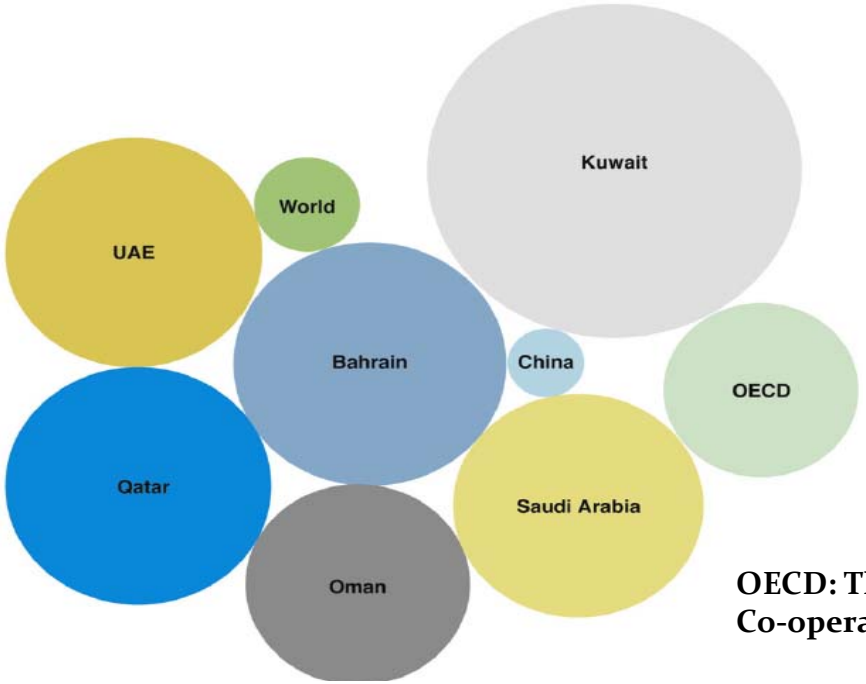
GCC Characteristics

- High Electricity Consumption



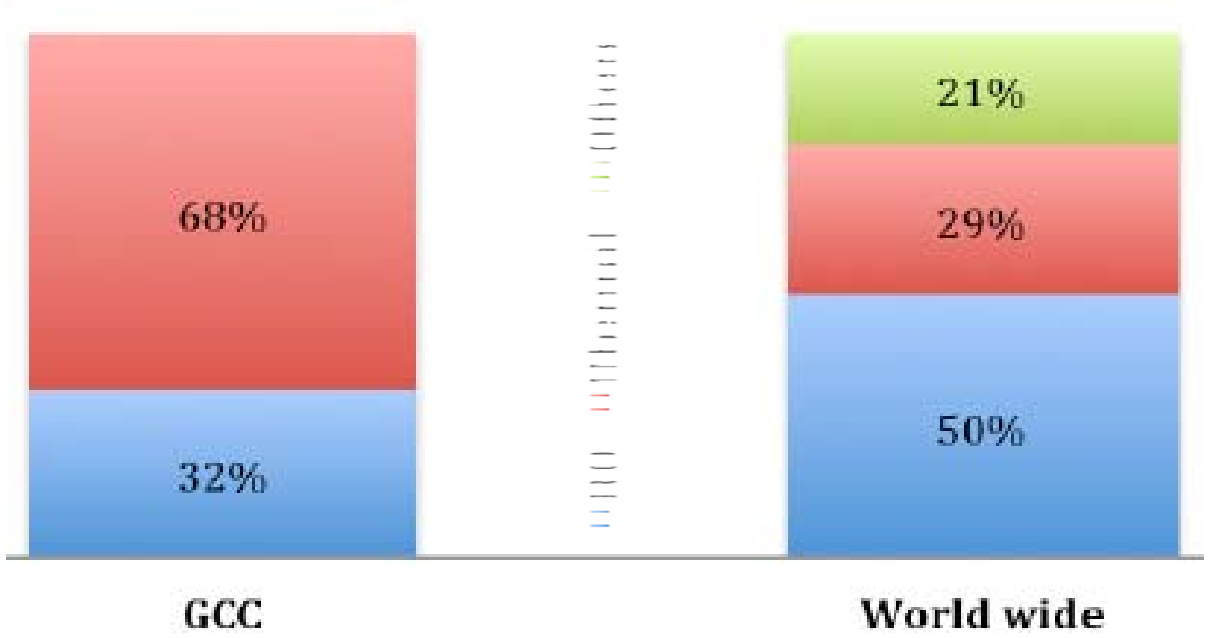
Comparative size of per capita residential electricity consumption in 2010

OECD: The Organization for Economic Co-operation and Development.

IEA, 2014. World energy balances. IEA World Energy Statistics and Balances Database) http://dx.doi.org/10.1787/data-00512-en.

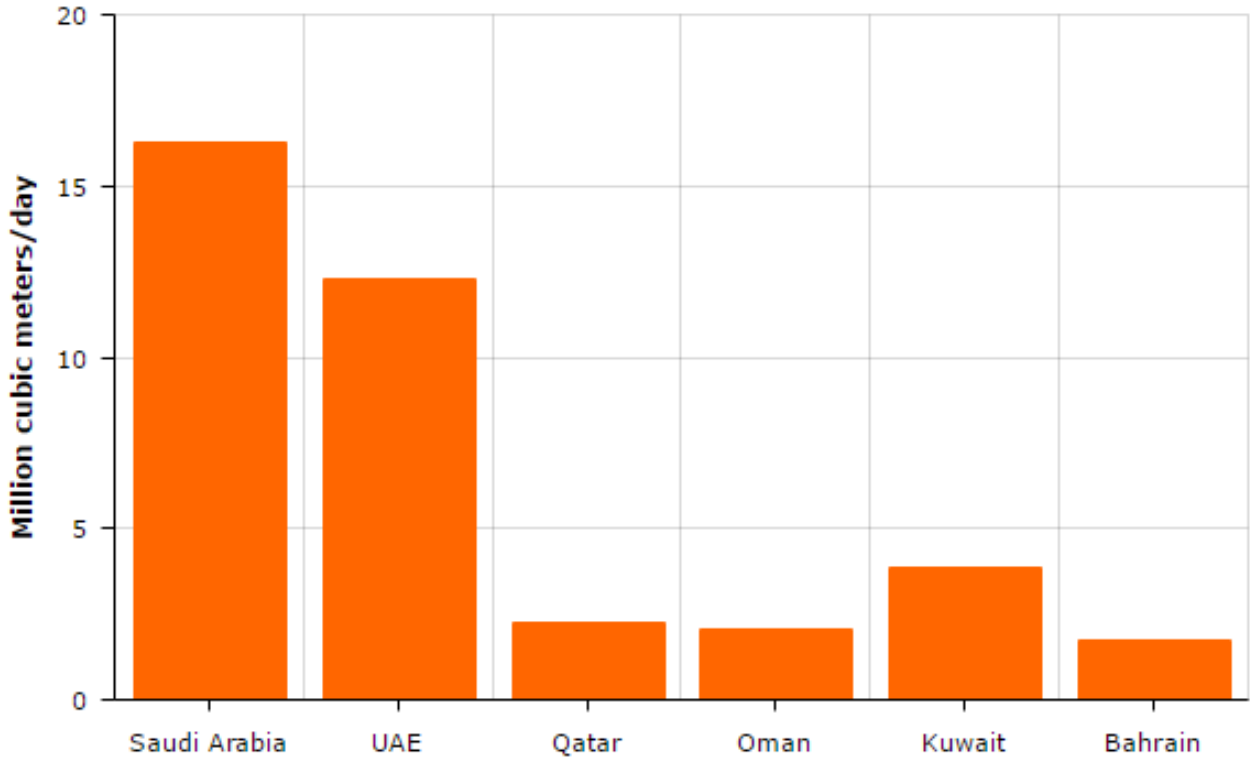
GCC Characteristics

- High Share of Thermal Desalination Processes



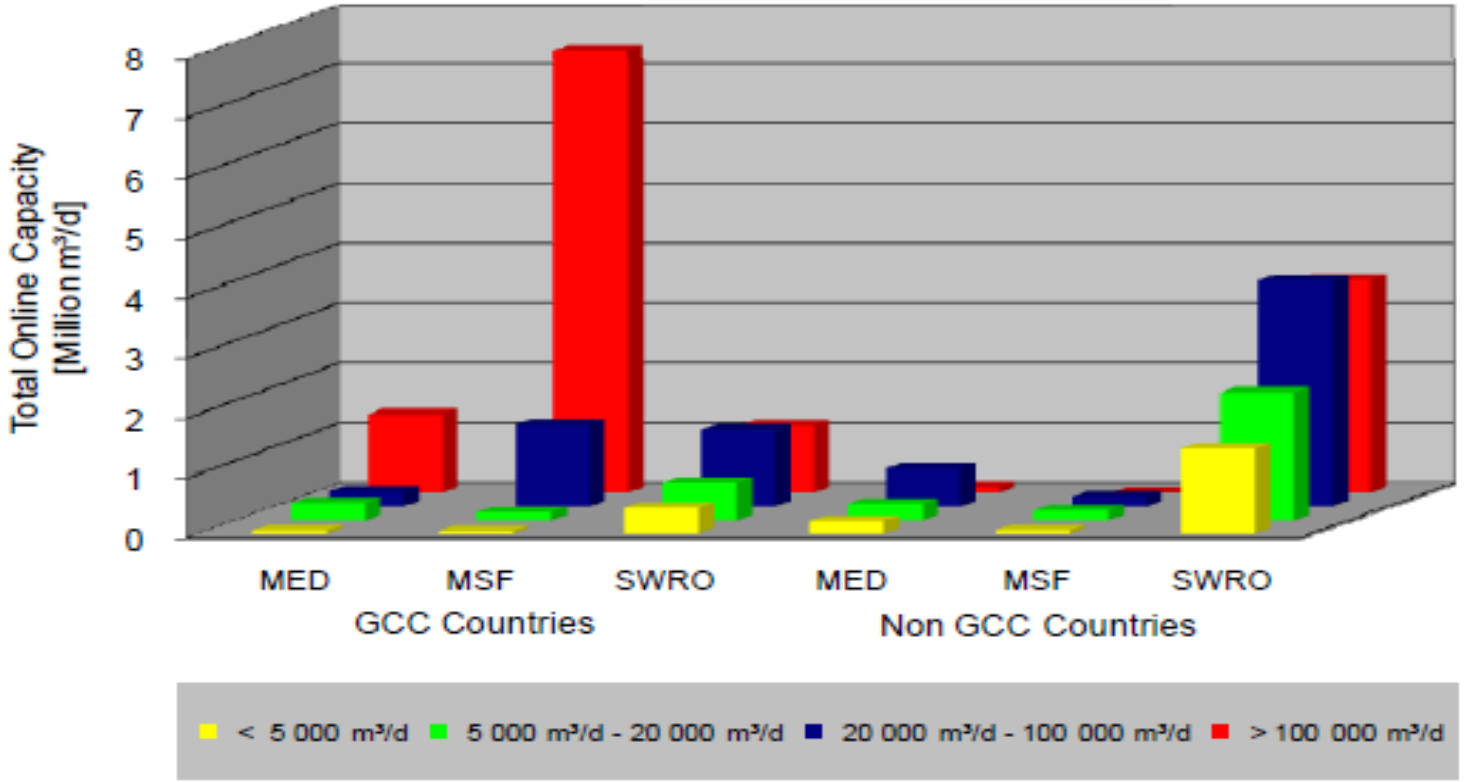
Current Desalination Status in GCC

- Total Production of GCC Desalination Plants, 2016



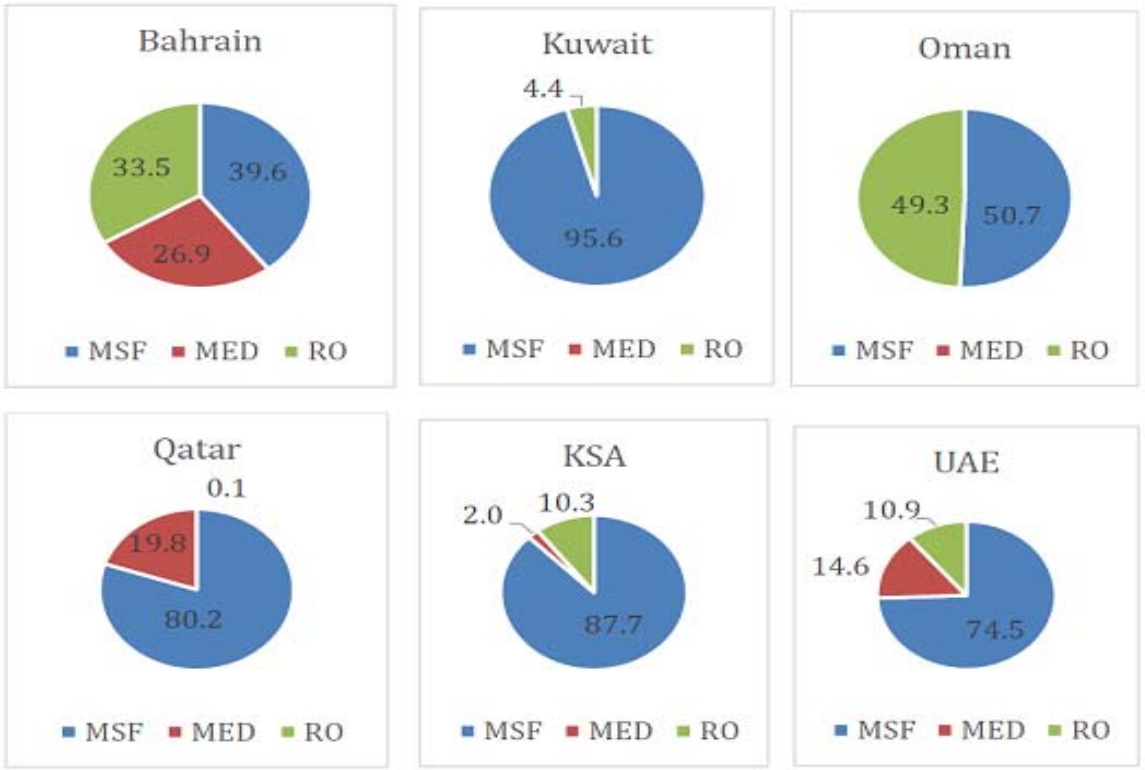
Current Desalination Status in GCC

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



Current Desalination Status in GCC

- Desalination capacity as per desalination process



What is Nuclear Desalination

- Nuclear desalination is the production of potable water from seawater using electrical and/or thermal energy provided by nuclear reactor which can be coupled to an appropriate desalination process.
- **First Option**: single purpose, the nuclear reactor produces only heat which can be used in various hybrid water desalination process.
- **Second Option**: cogeneration coupling; the nuclear reactor is used to produce both electricity and desalted water.
- **Third Option**: Harvest of the important amount of waste heat from the reactor cooling system and used it in the desalination facilities.

GCC Nuclear Energy Programs

- GCC
  - In December 2006 GCC announced that the Council was commissioning a study on the peaceful use of nuclear energy.
- Bahrain
  - It was declared in 23 December 2010 that Bahrain plans will be “to have nuclear power by 2017.”
  - However the “Plans to implement nuclear power in the country have faced some problems due to a lack of local experience and the high demand for nuclear expertise in the area.”

GCC Nuclear Energy Programs.

- Kuwait
  - In 2009, Kuwait established the National Nuclear Energy Committee (KNNEC) to consider the development of four nuclear plants with a capacity of one GW each. In 2011, however, triggered by other environmental risks, Kuwait retracted from pursuing nuclear power as part of the country's energy mix and the government disbanded KNNEC; the nuclear program has been reduced to research and training components under the responsibility of KISR.
- Oman
  - Oman is still in the process of serious discussions to formulate policies for adopting nuclear power for peaceful applications.

GCC Nuclear Energy Programs.

- Qatar
  - Based on business development planner at KAHRAMAA "the nuclear plan would be based in Umm Bab and have a capacity of 1,080MW by 2018".
- Saudi Arabia
  - In 2011, the Kingdom announced that it is planning to invest Up to $100 billion to expand power generating capacity, including the construction of a nuclear plant and the deployment of 5GW of solar energy capacity by 2020.
  - In April 2013 KA-CARE projected 17 GWe of nuclear capacity by 2032 of total 123 GWe, but the nuclear target is now for 2040.

GCC Nuclear Energy Programs.

- UAE
  - the UAE established a Nuclear Energy Program Implementation Organization which has set up the Emirates Nuclear Energy Corporation (ENEC) as a public entity, initially funded with $100 million, to evaluate and implement nuclear power plans within UAE.
  - In December 2009, a KEPCO-led consortium was awarded the contract to build four APR-1400 reactors at Barakah, UAE. Construction of Barakah Unit 1 started in July 2012, Unit 2 started construction in May 2013, Unit 3 started construction in September 2014 and Unit 4 started construction in September 2015. It is expected that Barakah Unit 1 will be in operation in May 2017.

GCC Nuclear Energy Programs

- UAE

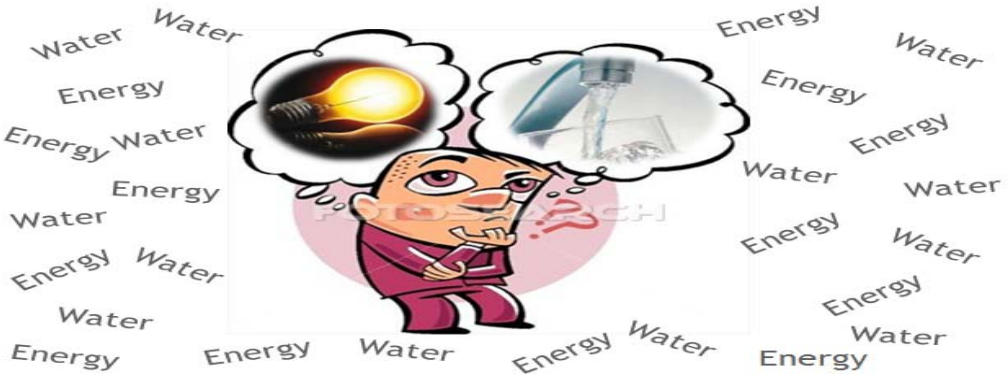
The Barakah nuclear power plant is UAE's first nuclear power station. Four APR-1400 nuclear reactors are planned to start operation between 2017 and 2020.

Potential ND Implementation

- Nuclear Desalination= Solution (High Power + Water)

Power Situation

Water Situation



Potential ND Implementation

- Desalination processes are energy intensive processes. They consumed large amount of energy for water production.
- Coupling the water production with power generation in a dual purpose arrangement reduces the specific fuel energy consumption for water production to around 50% less than that required by single purpose water production desalting plant.
- When connected to a co-generation plant, the energy needed for desalination is not a major component.
- Desalination plants make use of low-grade heat that would otherwise be rejected by the generating plant cycle.

Potential ND Implementation

- Both nuclear and desalination technologies are mature and proven by experience, and are commercially available from a variety of suppliers.
- There are benefits in combining the two technologies together (economic, sustainability, conservation of depletable resources).
- Nuclear energy is the solution to overcome the two challenges of sustainable supply of electricity and water and in addition it is environmentally friendly without gaseous pollution.

Potential ND Implementation

- Reactor Types and Desalination Processes

Reactor Type	Location	Desalination Process
LMFR	Kazakhstan (Aktau)	MED, MSF
PWRs	Japan (Ohi, Takahama, Ikata, Genkai)	MED, MSF, RO
	Rep. of Korea, Argentina, etc.	MED
	Russian Federation	MED, RO
BWR	Japan (Kashiwazaki- Kariva)	MSF
HWR	India (Kalpakkam)	MSF/RO
	Pakistan (KANUPP)	MED
NHR-200	China	MED
HTRs	France, The Netherlands, South Africa, USA	MED, RO

LMFR: liquid metal fast reactor; PWR: pressurized water reactor; BWR: boiling water reactor; HWR: heavy water reactor, NHR: nuclear heat producing reactor; HTR: high temperature reactor MED: multi-effect distillation; MSF: multi stage flash distillation; RO: reverse osmosis

Potential ND Implementation

- Example of Nuclear Desalination Plants

Plant name	Location	Gross power [MW(e)]	Capacity [m^3/d]	Energy/Desalination
Shevchenko*	Aktau, Kazakhstan	150	80 000 – 145 000	LMFBR/MSF&MED
Ikata-1,2	Ehime, Japan	566	2000	PWR/MSF
Ikata-3	Ehime, Japan	890	2000	PWR/RO
Ohi-1,2	Fukui, Japan	2 x 1175	3900	PWR/MSF
Ohi-3,4	Fukui, Japan	1 x 1180	2600	PWR/RO
Genkai-4	Fukuoka, Japan	1180	1000	PWR/RO
Genkai-3,4	Fukuoka, Japan	2 x 1180	1000	PWR/MED
Takahama-3,4	Fukui, Japan	2 x 870	1000	PWR/RO
NDDP	Kalpakkam, India	170	6300	PHWR/Hyb. MSF-RO
LTE	Trombay, India	40 [MW(t)]	30	PHWR/LTE
Diablo Canyon	San Luis Obispo, USA	2 x 1100	2180	PWR/RO

* Shevchenko was shut down in 1999, after 26 years of operation.

Potential ND Implementation

- Example of Suppliers of Commercial Reactors

Supplier	Alliance Members	Reactor Design	Reactor Type
AREVA	France: Commissariat à l'Energie Atomique (CEA) industry, Framatome, and Cogema Germany: Siemens	EPR	Gen-III PWR
GE	USA: General Electric (GE) Japan: Hitachi and Toshiba	ABWR ESBWR	Gen-III and – III+ BWR
WH	Westinghouse (WH) owned by Toshiba, (67%), and IHI (3%) in Japan, The Shaw Group, Inc. (20%) in USA, and Kazatomprom (10%) in Kazakhstan.	AP600 AP1000	Gen-III+ PWR
CANDU Owners Group	Canadian Utilities: Ontario Power Generation, Hydro-Quebec, and New Brunswick Power Atomic Energy of Canada Limited	ACR700 ACR1000	Gen-III HPWR
Atmea	France: AREVA NP Japan: Mitsubishi Heavy Industry	APWR, 1100 MWe	Gen-III+
Gidropress	Russia: Gidropress	VVER1200 VVER1500	Gen-III APWR Gen -III+ APWR
Hyundai Construction	The Republic of Korea	OPR-1000 APR-1400	Gen-III APWR Gen-III+ APWR

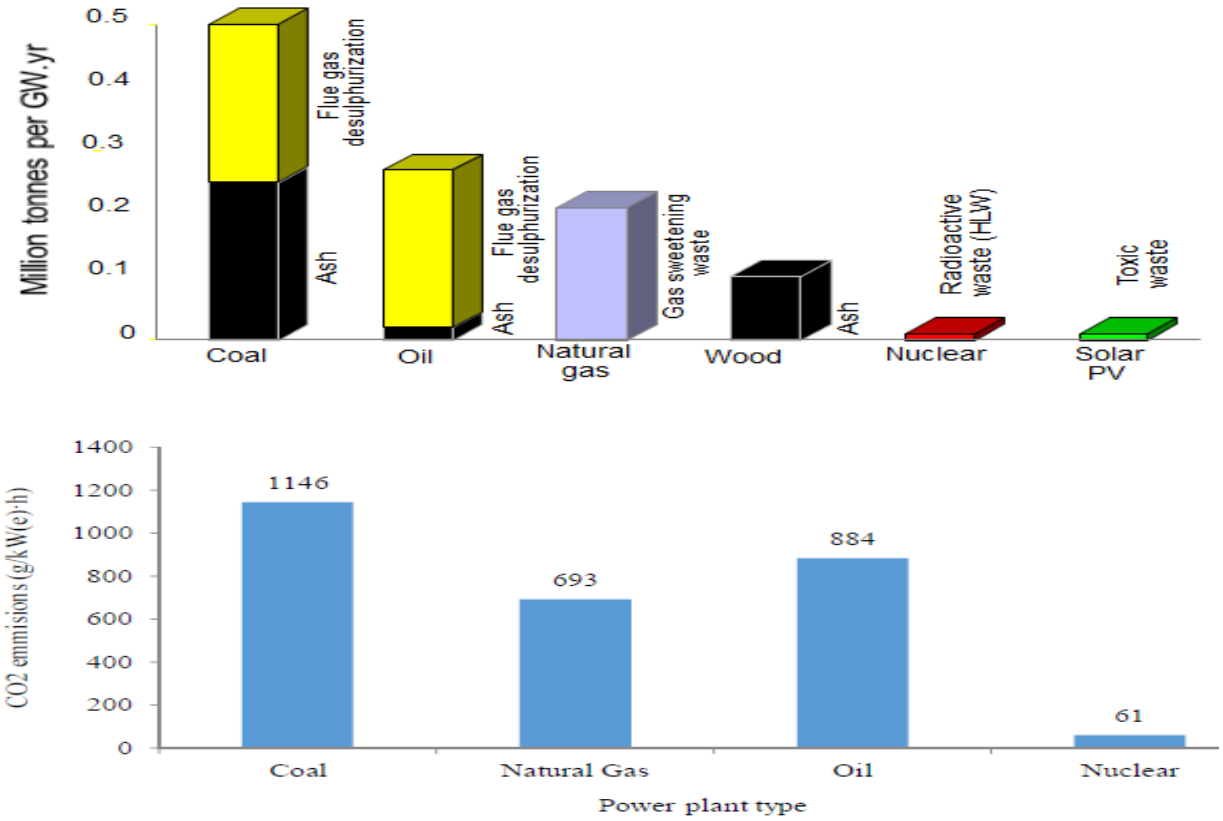
ABWR: Advanced Boiling Water Reactor, ACR: Advanced CANDU Reactor, AP: Advanced Passive, APR: Advanced Pressurized Reactor, APWR: Advanced Pressurized Water Reactor, EPR: Evolutionary Power Reactor, ESBWR: Economic Simplified Boiling Water Reactor, OPR: Optimized Power Reactor, VVER: Russian abbreviation stands for water-water energy reactor

Potential ND Implementation

- Driver for the development of nuclear power:
  - Deployment of nuclear power technologies for energy production allows oil resources to be dedicated to more valuable export purposes.
  - Nuclear power deployment in GCC is consistent with the efforts to achieve sustainable economic development.
  - Nuclear power has high capacity factor than fossil units.
  - Nuclear power stations provide significant electricity and heat properties perfectly matched to desalination needs.
  - Nuclear power provides the largest source of clean, carbon-free technology in the world. It protects the environment and mitigate the greenhouse gases (GHGs) emissions.

Potential ND Implementation

- Driver for the development of nuclear power



Conclusions

- Desalinated seawater is the main source of drinking water across GCC countries, due to limited groundwater availability.
- Given the high salinity and high temperature of the Gulf water, thermal desalination technologies are usually better suited.
- The medium and long-term solution of energy demand and water scarcity of the GCC countries is the nuclear desalination.
- It is urgent to start from now preparing the required infrastructure and human resources to apply this strategy.
- The second main benefic of this strategy is the nuclear technology which englobe all high-tech available technologies.


Thank You