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مركز التكامل المتوسطي

Desalination Technologies and Economics: CAPEX, OPEX & Technological Game Changers to Come

Mediterranean Regional Technical Meeting
Marseille CMI, December 12-14, 2016

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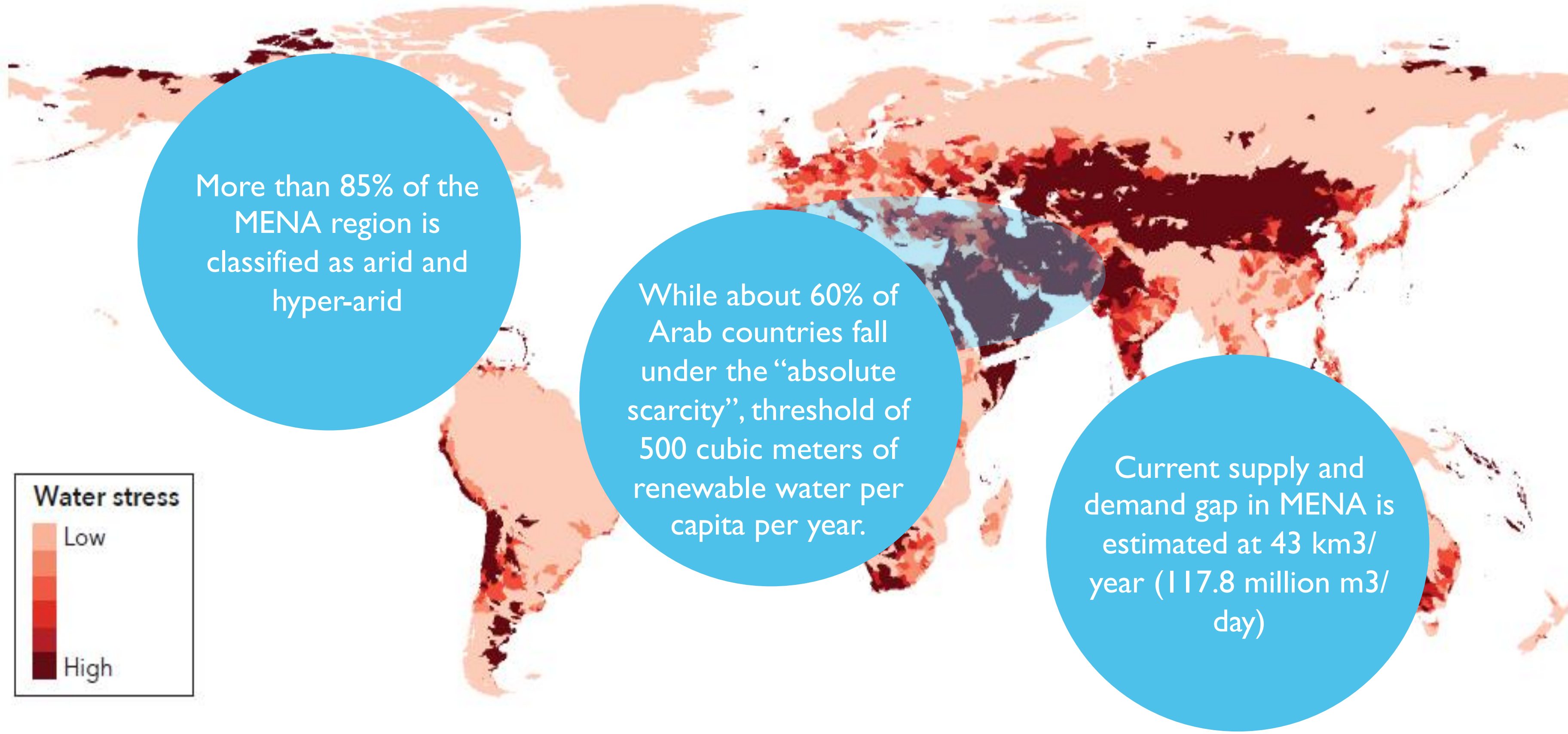
01

WATER MARKET SIZE AND DESALINATION

Water Stress by Region



Source: Adapted from WRI, 2015a

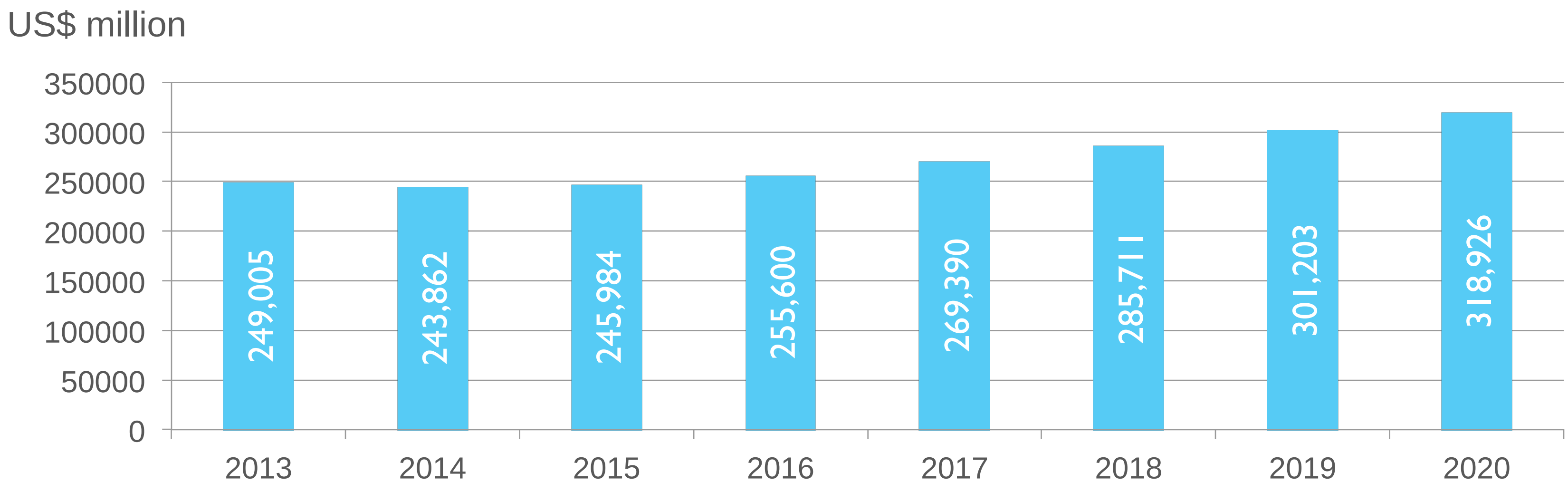
Renewable Fresh water m³/Capita.year

Limited Water Shortage 1000 <RFW< 1700 m^3/C.y
Water Scarcity RFW< 1000 m^3/C.y.
Absolute Water Scarcity RFW < 500 m^3/C.y

Global Water Market CAPEX: Forecast 2013-2020

Water Market Capex in 2016 arises to $255,6 billion
Water Market Capex 2017-2020 estimations will be $1,175.2 billion

Water Market Capex in 2016 as BOT basis arises to $3,6 billion (1.4%).
Water Market Capex 2017-2020 estimations will be $ 21,3 billion (1.8%)



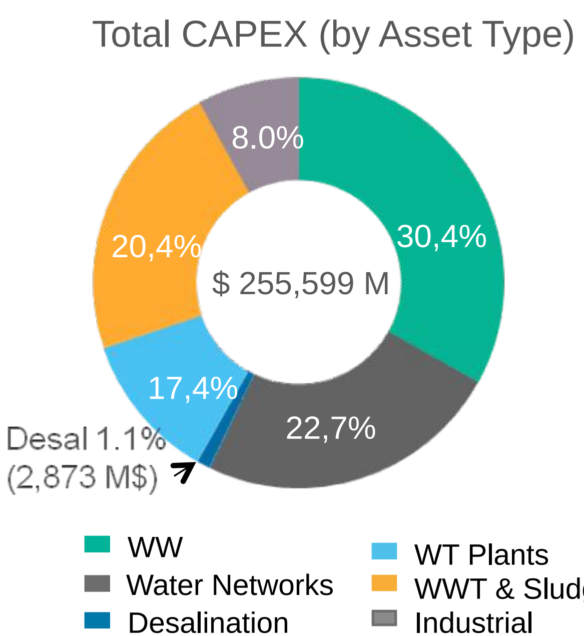
Source:GWI

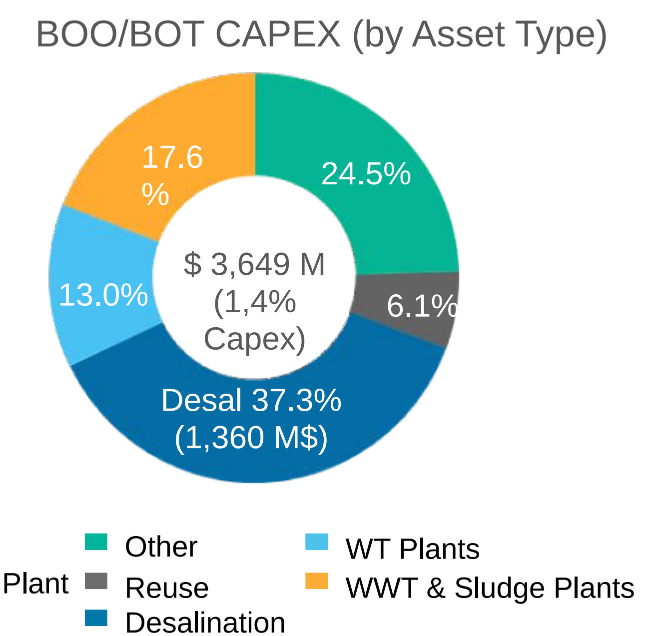
Desalination by Technologies

Global Desalination CAPEX: Forecast 2016

In 2016 Desalination CAPEX represents $2.9 billion (1.1% over total water Capex)…

… of which $1.4 billion is executed as BOT (47% over total Desal Capex)





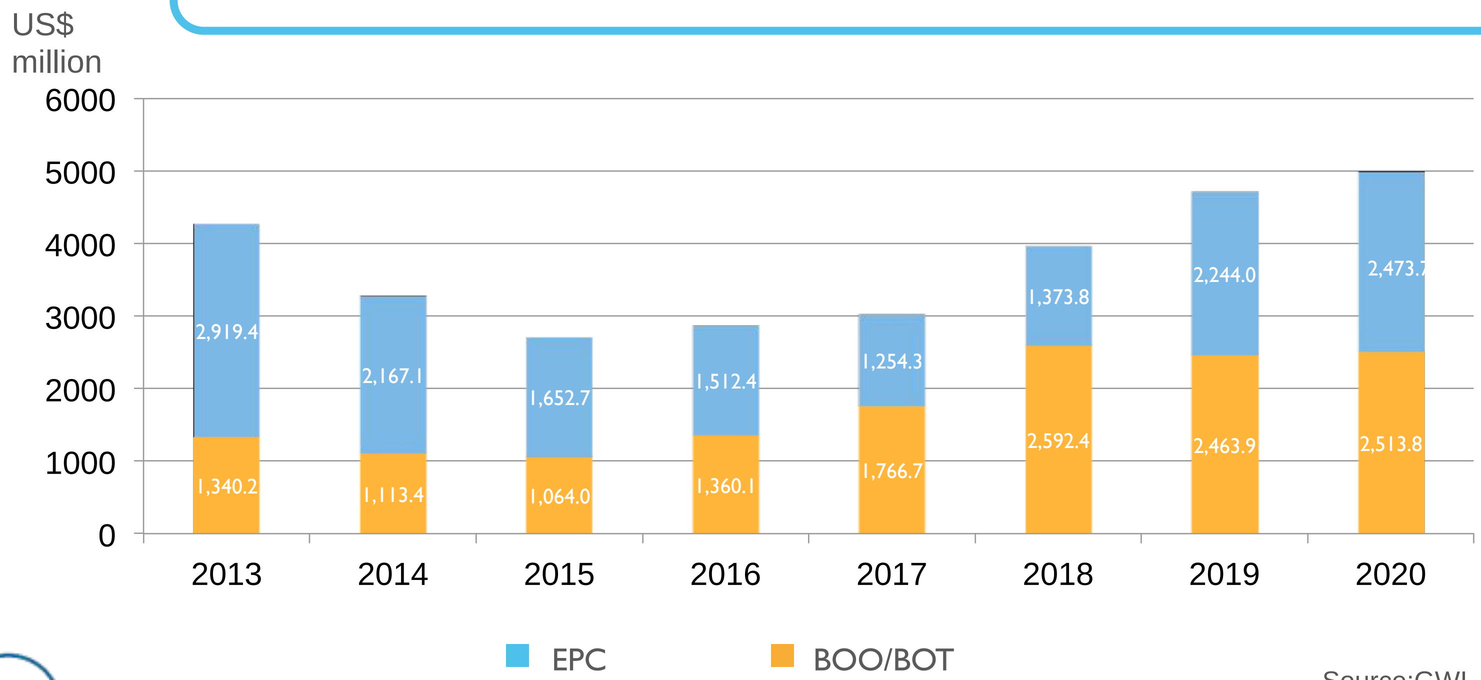
Source:GWI

Desalination by Technologies

Global Desalination CAPEX: Forecast 2013-2020 (by delivery method)

Yearly desalination CAPEX is forecasted to grow 73,6% by 2020.
BOO/BOT scheme will represent almost 50% vs. current 47% over total desal capex.

Global Desalination CAPEX will be around $16.7 b during next four-year time
Middle East and North of Africa will be about $ 10.7 billion (64% market share)



Source:GWI

02

DESALINATION BY TECHNOLOGY & DELIVERY METHOD

Desalination by Technologies

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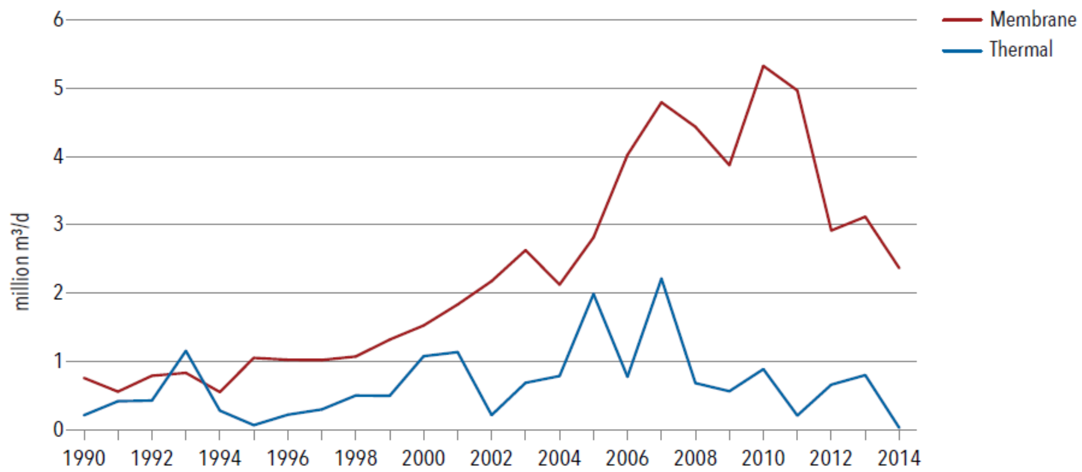
Desalination by Technologies

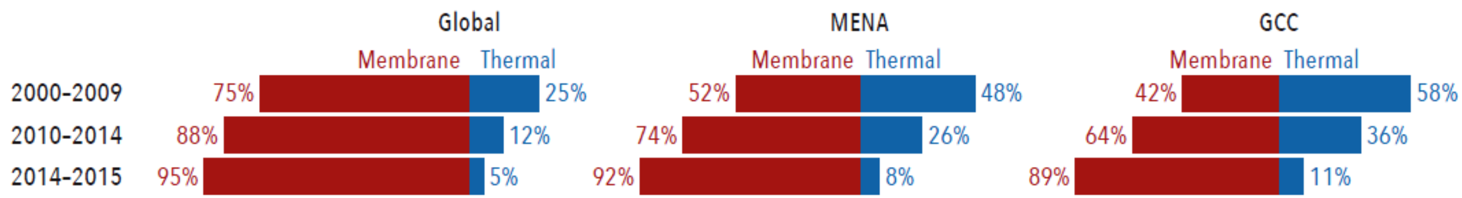
From Thermal Desalination to RO Desalination. Change in Trend

Awarded membrane and thermal desalination capacity, 1990–2014



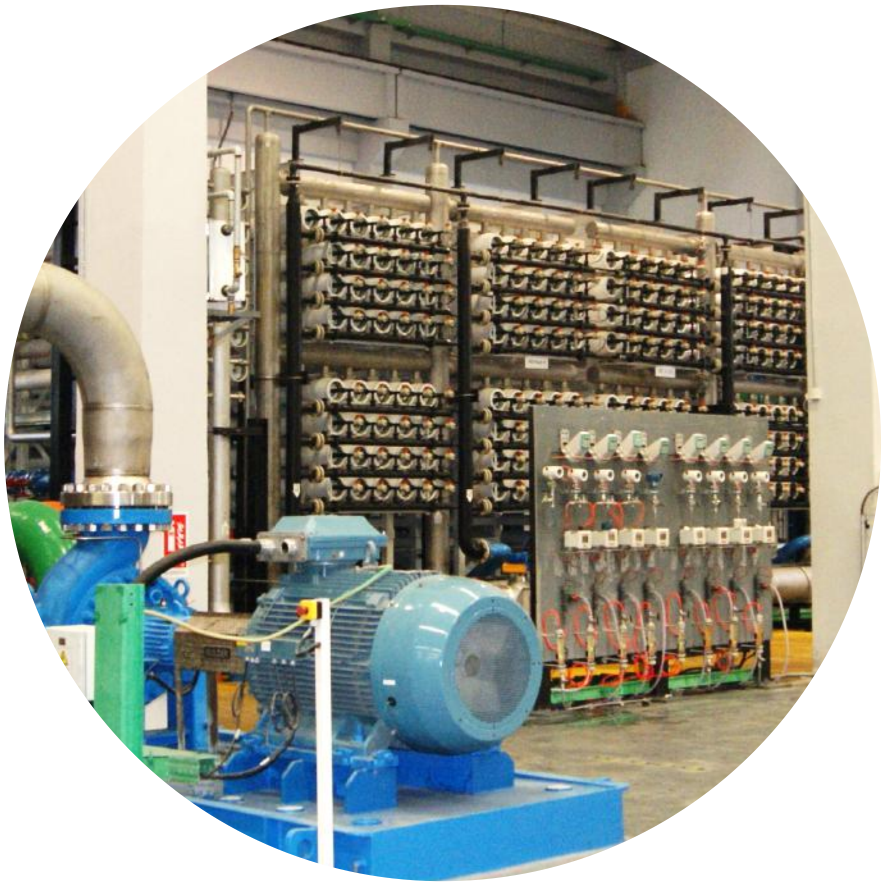
Source: GWI/DesalData

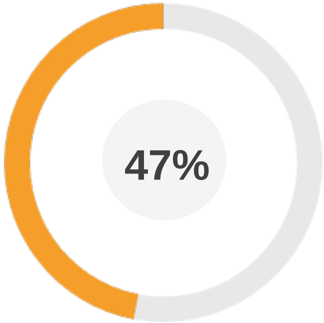
Time evolution of membrane vs thermal technologies



Source: GWI/DesalData

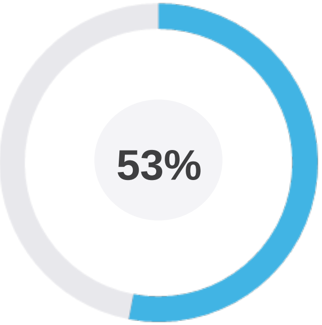
Type of Desalination Technology used in MENA





RO

16.0 Million m^3/d
RO Desalination

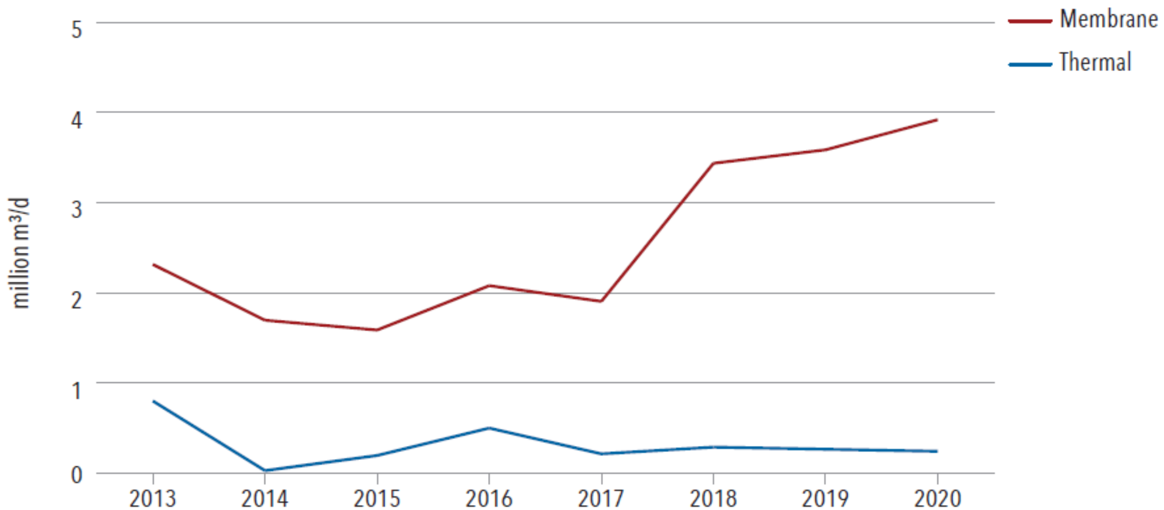


THERMAL

18.1 Million m^3/d
Thermal Desalination

From Thermal Desalination to RO Desalination. Change in Trend

Annual contracted global capacity by technology, 2013–2020



Technology (m³/d)	2013	2014	2015	2016	2017	2018	2019	2020
Thermal	799,356	27,460	194,996	498,938	213,339	287,648	264,565	241,715
Membrane	2,313,190	1,694,560	1,585,982	2,077,714	1,903,344	3,434,439	3,583,692	3,917,107
Total	**3,112,546**	**1,722,020**	**1,780,978**	**2,576,652**	**2,116,683**	**3,722,087**	**3,848,257**	**4,158,822**

Source: GWI/DesalData

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Capital Cost Breakdown of Desalination Projects in MENA Region

	Direct Capital Construction Cost	Project Engineering Services	Project Development	Project Financing
THERMAL	70-85%	5.0-8.5%	2.5-5.5%	2.5-6.0%
RO	52-68%	10-15 %	6-9%	6-10%

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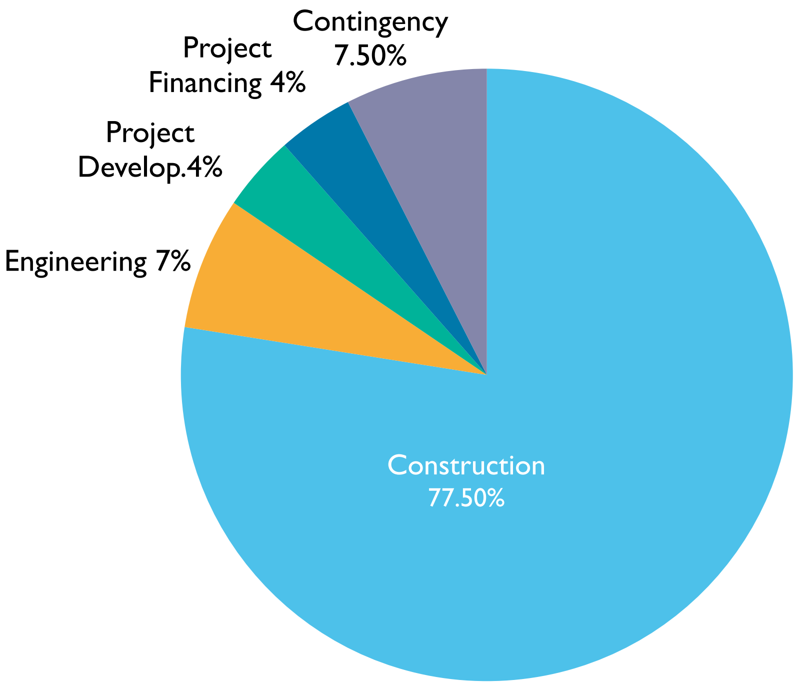
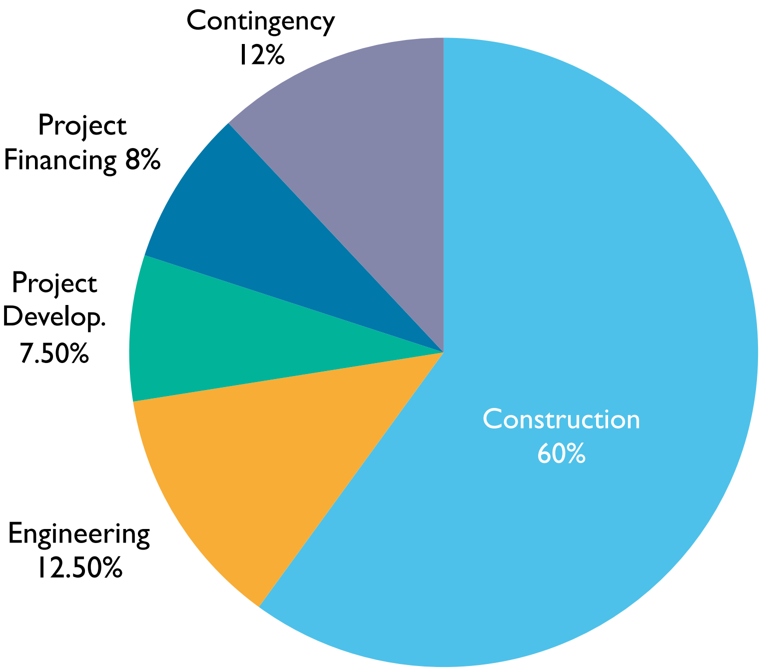
Desalination by Technologies

Average Capital Cost Breakdown of Desal Projects in MENA Region

Thermal Desalination Projects



SWRO Desalination Projects



O&M Cost Breakdown of Desalination Projects in MENA Region

Project Type	Thermal Desalination	SWRO Desalination
Variable O&M Cost	62.0-83.0%	53.5-68.0%
Energy Consumption	49.5-55.5%	37.0-45.0%
Chemicals, Membranes, Waste disposal	5.0-7.5%	16.5-23.0%
Fixed O&M Cost	17.0-38.0%	32.0-46.5%
Environmental, Monitoring & Indirect Cost	5.5-18%	7.0-17.0%
Labor & Maintenance	11.5-20%	16.5-23.0%
TOTAL O&M Cost	100%	100%

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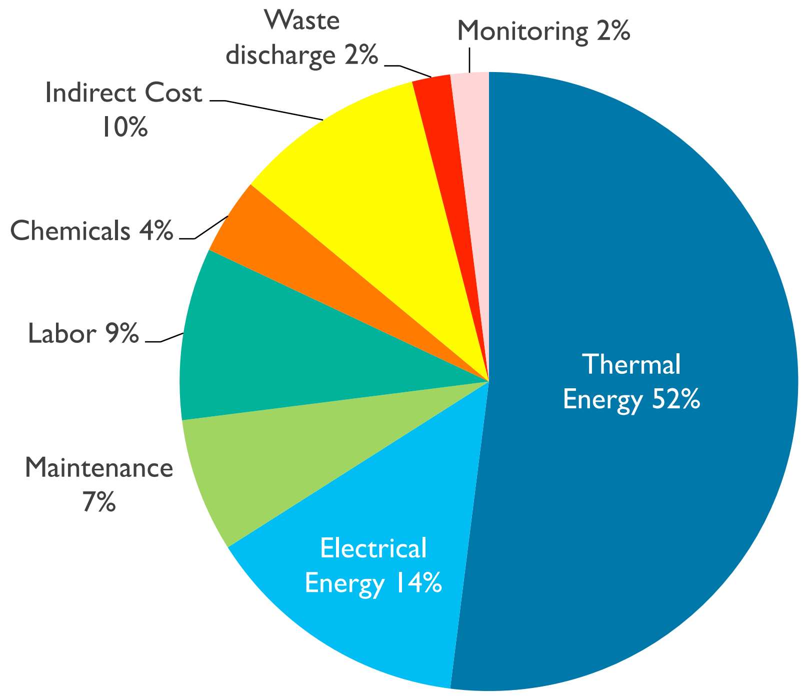
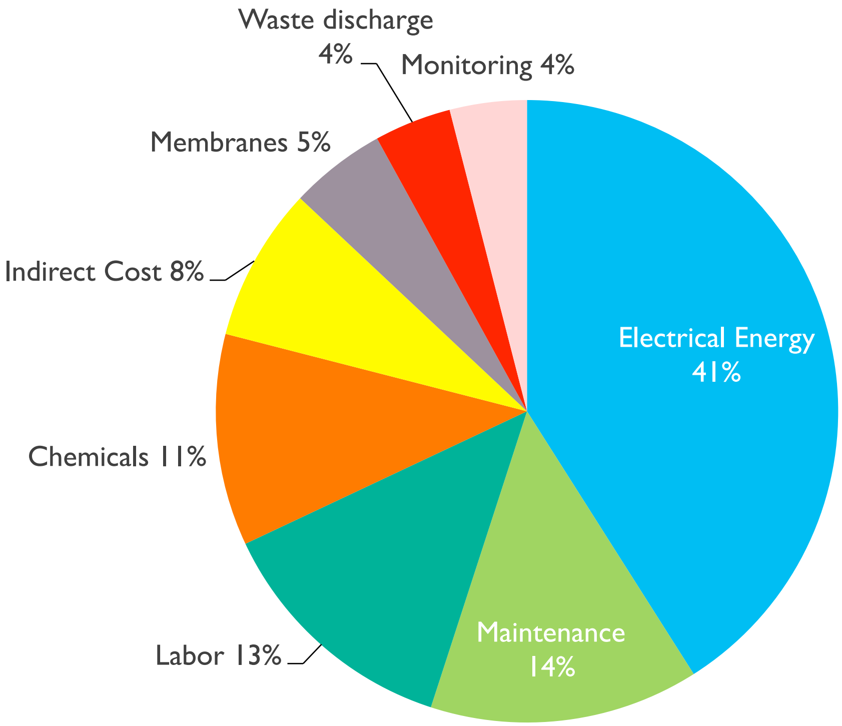
Desalination by Technologies

Average O&M Cost Breakdown of Desal Projects in MENA Region

Thermal Desalination Projects



SWRO Desalination Projects



Source: Water World Consultants

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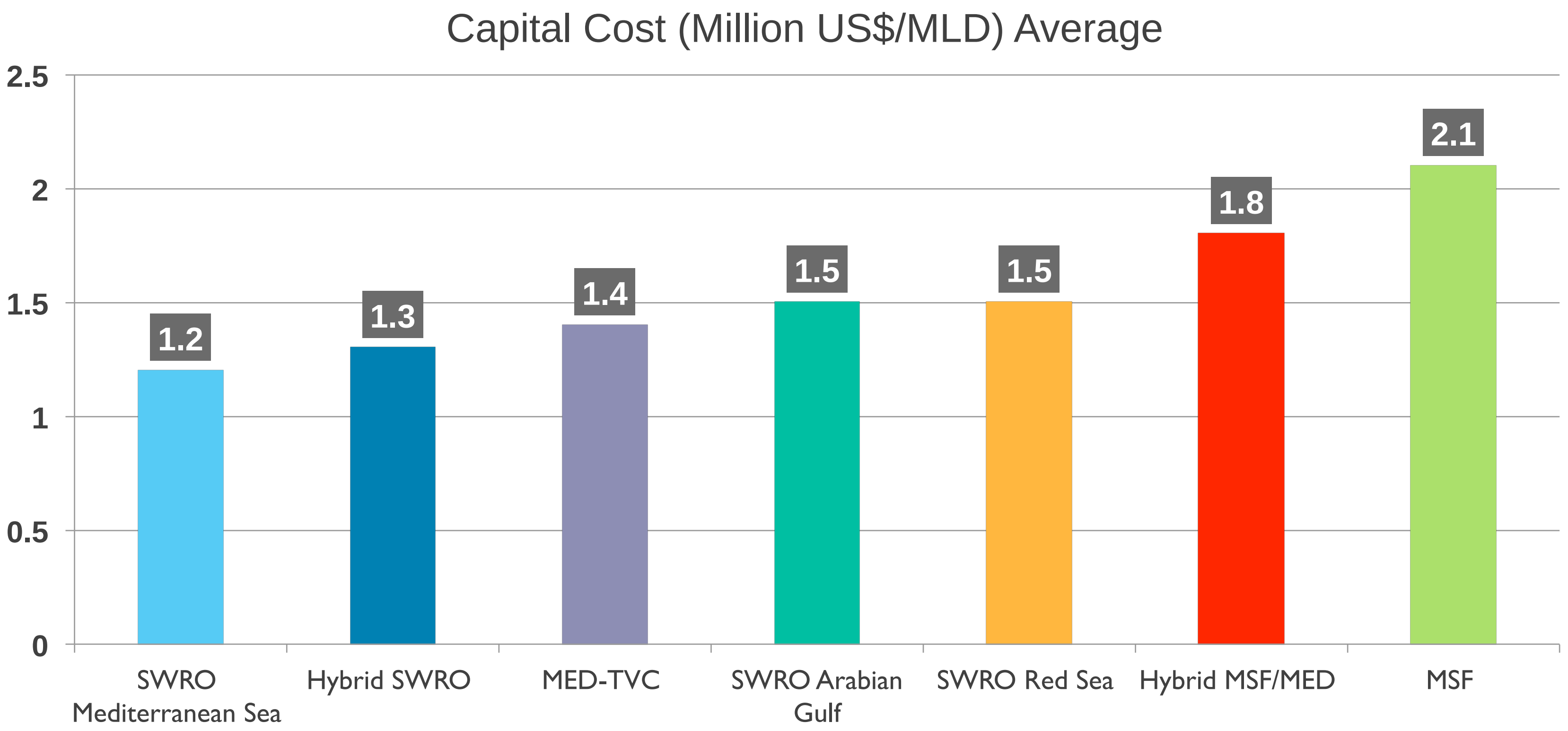
CAPEX & OPEX. Summary of Desalination Costs in MENA Region

Desalination Plant Type	Capital Cost (Million US$/MLD)		O&M Cost (US$/m^3)		Cost of Water Production (US$/m3)	
	Range	Average	Range	Average	Range	Average
MSF	1.7-3.1	2.1	0.22-0.30	0.26	1.02-1.74	1.44
MED-TVC	1.2-2.3	1.4	0.11-0.25	0.14	1.12-1.50	1.39
SWRO Mediterranean Sea	0.8-2.2	1.2	0.25-0.74	0.35	0.64-1.62	0.98
SWRO Arabian Gulf	1.2-1.8	1.5	0.36-1.01	0.64	0.96-1.92	1.35
SWRO Red Sea	1.2-2.3	1.5	0.41-0.96	0.51	1.14-1.70	1.38
Hybrid MSF/MED	1.5-2.2	1.8	0.14-0.25	0.23	0.95-1.37	1.15
Hybrid SWRO	1.2-2.4	1.3	0.29-0.44	0.35	0.85-1.12	1.03

Desalination by Technologies

CAPEX. Summary of Desalination Costs in MENA Region



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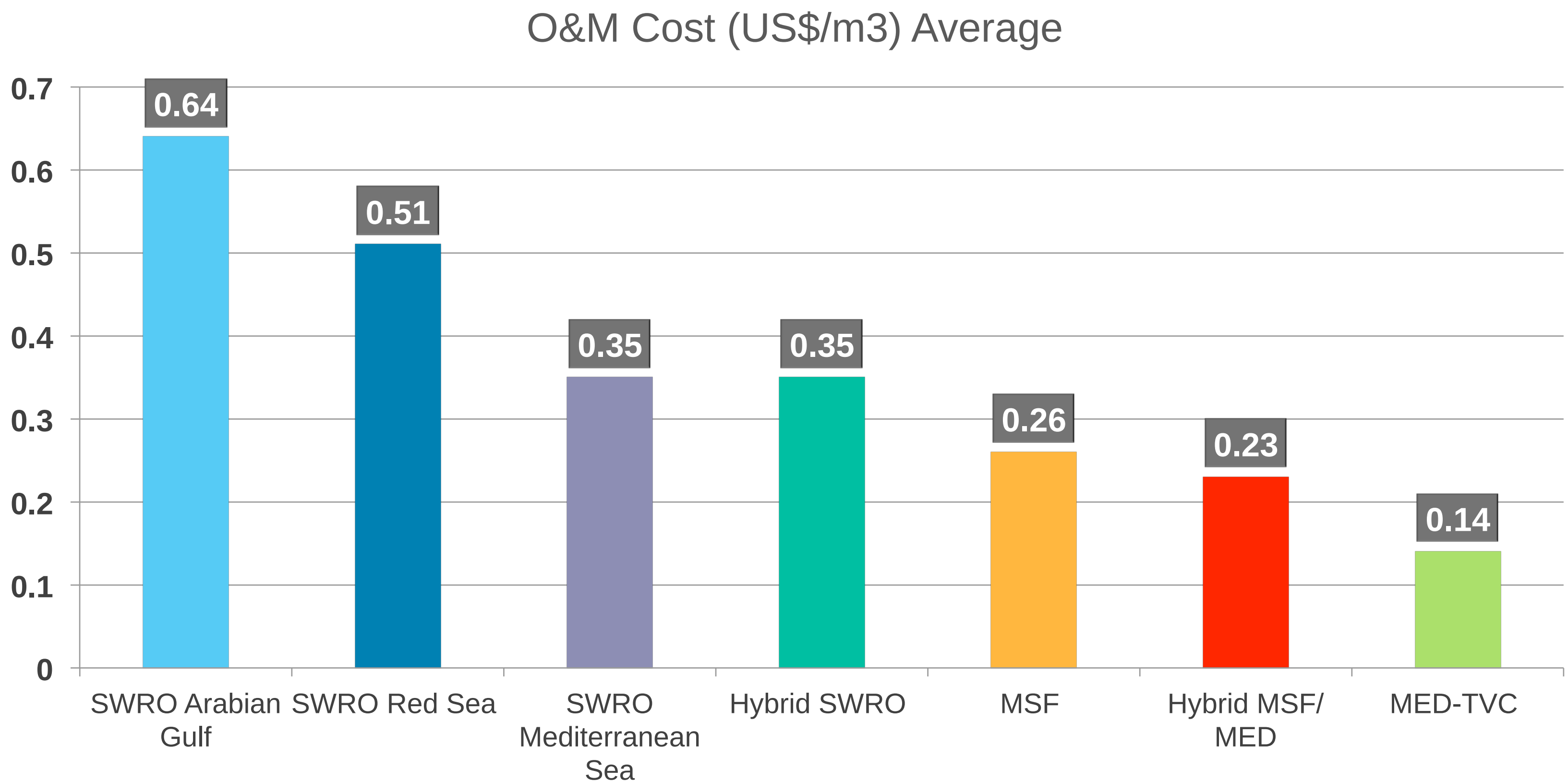
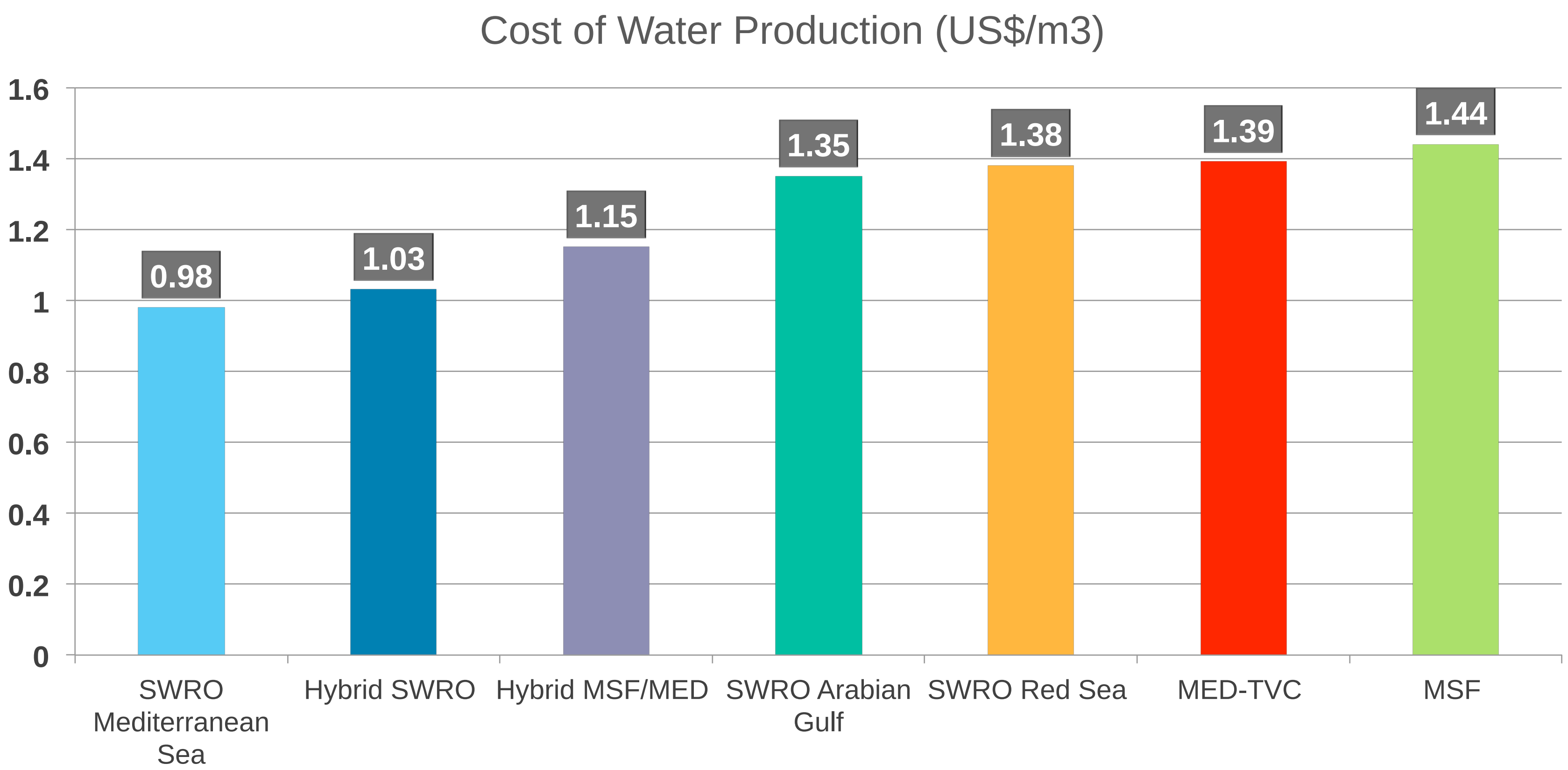
OPEX. Summary of Desalination Costs in MENA Region

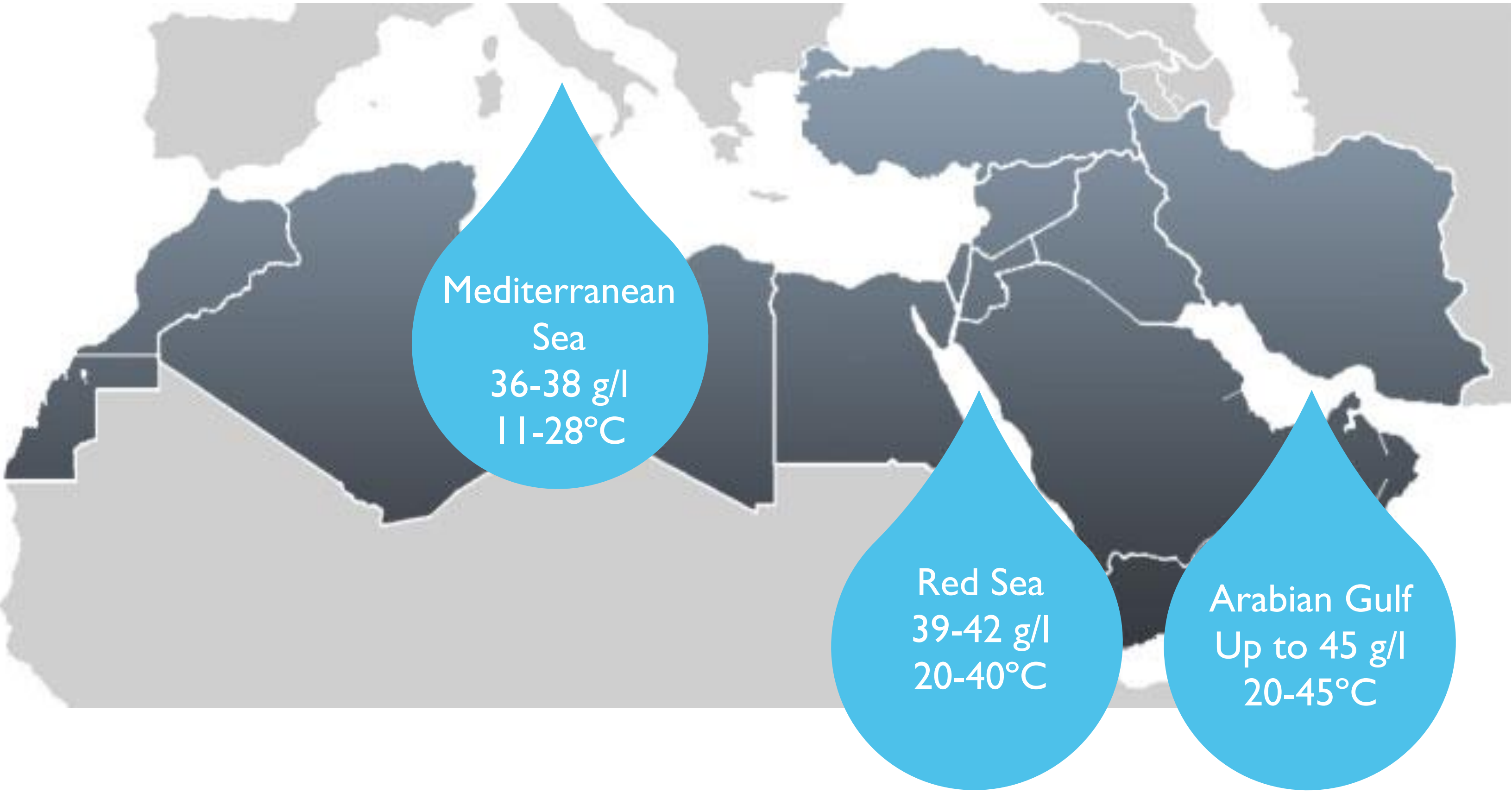


Desalination by Technologies

CAPEX & OPEX. Summary of Desalination Costs in MENA Region



Desalination by Technologies



Summary on CAPEX & OPEX

- In terms of costs **Reverse Osmosis (RO) desalination is the most competitive technology in the Mediterranean Sea**. Reasons: (i) lower salinity and (ii) lower membrane biofouling potential (higher plant availability).
- Over last 15 years **RO technology has rocketed in Middle East** vs. thermal desalination technology. Reasons: (i) significant lower energy consumption, (ii) competitive water production costs.
- **Reverse Osmosis (RO) and thermal evaporation technologies** make comparable outcomes in **Red Sea and Arabian Gulf.**
- **Thermal MSF is the most costly desalination technology in terms of capital investments** but it is (i) the most proven & reliable in the region, (ii) the easiest to be operated, (iii) the one with highest economy of scale for mega-projects.
- **Thermal MED-TVC technology is more competitive than MSF for small & medium size desalination projects**. Total production costs are (i) comparable to RO in Red Sea and Arabian Gulf, (ii) higher than RO in Mediterranean Sea.
- In Red Sea and the Arabian Gulf regions, **hybrid RO & thermal desalination projects** (i.e. 1/3 RO – 2/3 thermal evaporation) are more competitive than one-technology projects (either thermal or RO).
- **New large number of hybrid desalination projects in Qatar, UAE, and KSA.**

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Desalination by Delivery Method

Desalination by Delivery Method

Contracting Models

The type of the selected contracting method mainly depends on:

1.Type of owner (public agency or private entity)
2. The project risk profile
3. Owner's experience with similar projects
4. The source of project funding – loans, grants, bonds, equity or a mixture of these funding sources

The main contract models used up today are:
1.EPC
2.DBO
3.BOOT

Other variants are DBB, Construction manager at Risk, and Alliance (Australia).

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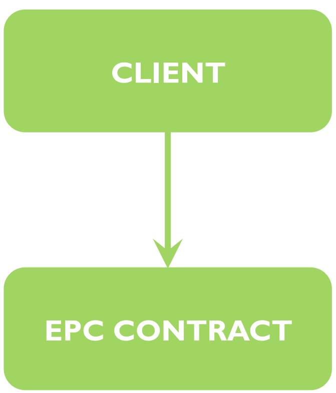
Desalination by Delivery Method

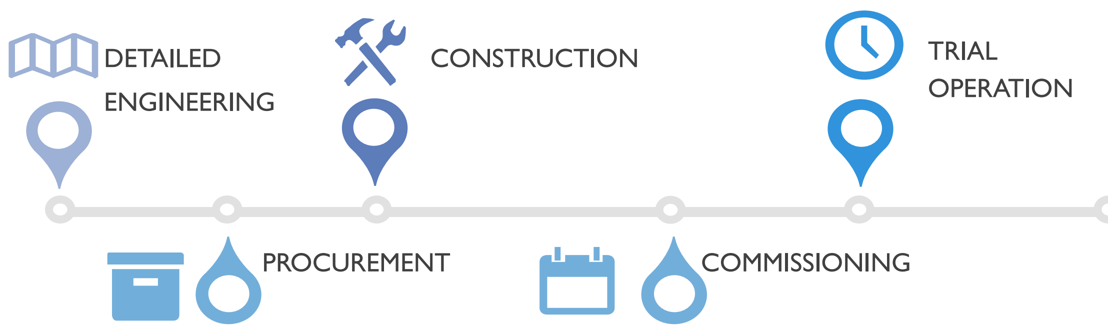
Contracting Models

Engineering, procurement & construction (EPC)/design-build (DB):

The client appoints an engineer to draw up a broad specification for a project, then put out to bid with contractors given a reasonable leeway to design a solution that achieves the utilities' objectives.

EPC Main Project Structure





In the United States this is known as DB.
Outside the United States it is normally referred to as EPC.

1. The client pays for the project in installments across the construction period.
2. There is typically a commissioning period
3. There is a period of up to two years when the contractor has staff at the site to train the client's operators and ensure the smooth running of the plant.

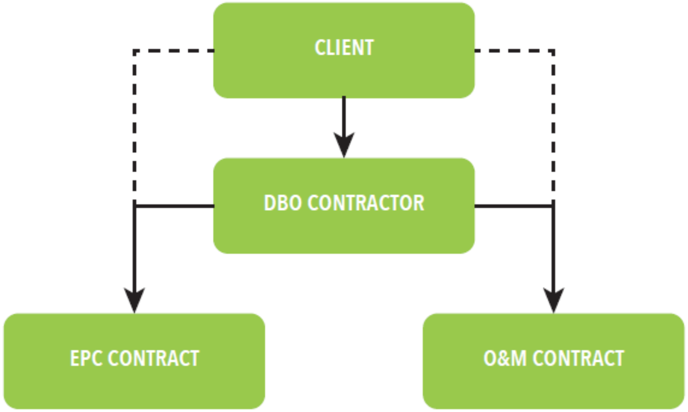
Desalination by Delivery Method

Contracting Models

Design-build-operate (DBO)

This is essentially an EPC/DB contract with an outsourced operations contract included.

DBO Main Project Structure



Source: GWI

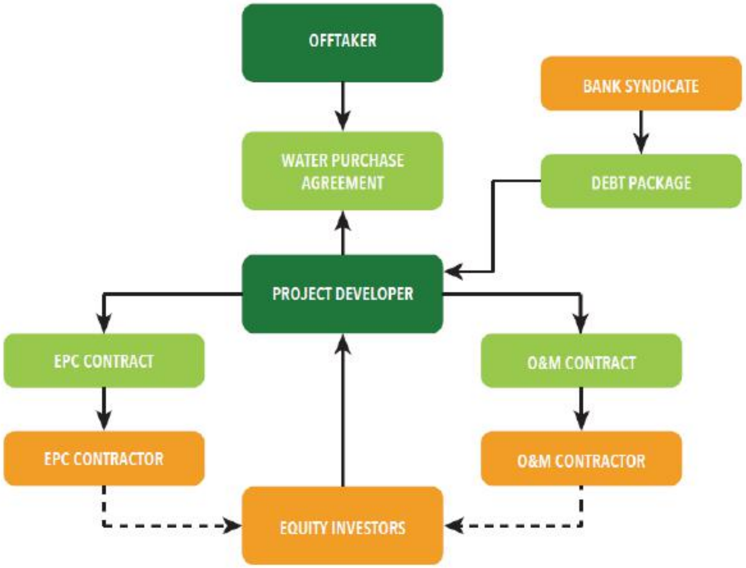
Desalination by Delivery Method

Contracting Models

Build-operate-transfer (BOT) and its variants:

Involves a private developer building, owning and operating a facility for an initial contract period.

At the end of the contract period it may be transferred back to the client (BOT) or held by the developer and a new supply contract put in place (BOO). Other variants are BOOT, DBOT, IWP, IWPP, BOO.



Source: GWI

BOT Main Project Structure

The BOT model remains popular in the Middle East, although raising finance is a problem in Egypt and Libya.

Within the GCC, combined power and water plants are standard.

Kuwait and Dubai have adopted BOT/BOOT

Abu Dhabi, Oman and Qatar remain committed to it (with the provision that Qatari IWPPs are developed by QEWC).

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Desalination by Delivery Method

Population

- Growth of population
- Ageing of population
- Desire of quality improvement

Private Sector

- Extensive Know-how
- Innovation and efficiency
- Risk management

Seeking financial alternatives

Upward trend
4 factors

PPP vs EPC

Seeking long-term returns

Public Sector

- Energy crisis
- Gov. budget constrains
- Increase social policies

Financial Sector

- Global Investment niches
- Excess of liquidity
- Secure Investments

Desalination by Delivery Method

Project Preparation and Development Cost

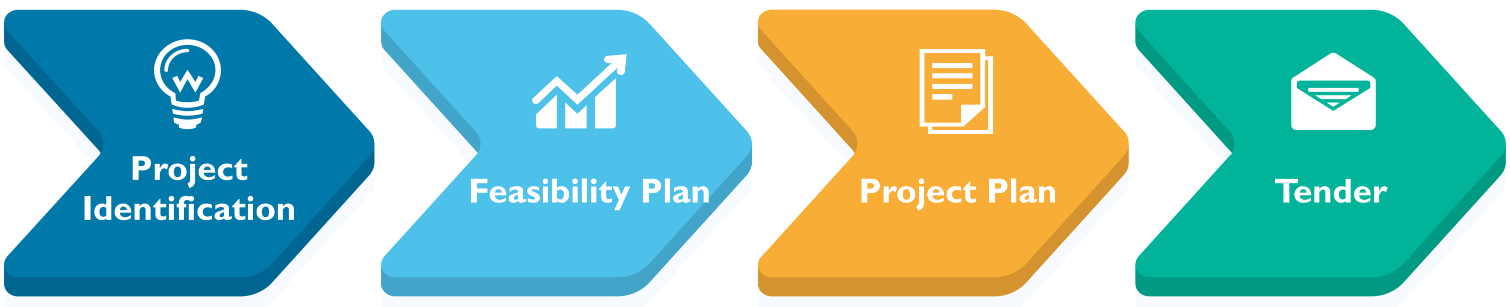
Project preparation is usually considered to include all those activities short of a final decision to implement:

Identification of the Project

- Marketing study
- The species to be cultured.

Detailed Project Plan

Preparation of detailed plan of the project



- Availability of land area
- Adequated raw water source, must all be investigated and determined

Preparation of Feasibility Plan

- Technical studies
- Financial Feasibility
- Permits requirement
- Environmental policies

Tender documents

Preparation of tender documents of the project

Project Preparation and Development Cost

Project Development Models, Private Sector Participation

Private Sector Participation in Infrastructure

- Competitive Solicited procurement processes (tenders)
- Unsolicited Proposals or Private Initiative

70%

Countries percentage with developed legal framework for Unsolicited Proposals

Development Cost 50 M

Project CAPEX 900 M

SAWS PROJECT (Texas)
Vista Ridge Project private development cost reached 50 US$ Million (until FC).

03
DRIVER COSTS

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Driver Costs

CAPEX and OPEX driver costs

PLANT SIZE & MATURITY

- Cost/Scale
- Maturity

REGION/AREA

- Cost CW/Personnel
- Competence
- Regulations

4 major factors which can affect the costs on the Desalination Sea Water Plant

TECHNOLOGY

RO vs.
Thermal

WATER QUALITY

Salinity
TSS
Biofouling
Temperature

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CAPEX and OPEX driver costs

PLANT SIZE & MATURITY

- Cost/Scale
- Maturity

❖ SWRO technology yields the highest rate of economy of scale as compared to all other thermal desalination technologies.

❖ MSF and MED technologies,

1. Are much more mature than SWRO (104 past 50 years).
2. Allows the same economy of scale to be maintained in practically all unit sizes.

Driver Costs

PLANT SIZE & MATURITY:

ALGERIA: SKIKDA vs TENES

SWRO desalination projects in Skikda (100 MLD) and Tenes (200 MLD) use the same RO technology concept. However,

- A double plant size in Tenes
- Maturity of the technology in Algeria between Skikda (bid date was 2004) and Tenes (2008)

have permitted to catch economies of scale and scope resulting a better contract price in Tenes (20% down).

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CAPEX and OPEX driver costs

REGION/AREA

- Cost CW/Personnel
- Competence
- Regulations
- Funding

❖ Desalination market in MENA is a mature market and the financial cost and return rates in MENA are better than other regions outside of MENA, due to,

1. Major project financing and technology risks are well known.
2. Local currencies are stable and usually pegged to the US dollar.

Driver Costs

REGION / AREA:

MELBOURNE SWRO vs AL DUR SWRO

Cost CW/Personnel – Competence – Regulations – Funding

1. Same state-of-the-art intake, discharge and desalination technologies
2. Designed, built and operated by the same experienced international contractor.

Main factors contributing to the disparate costs are overly stringent environmental regulations, and renewable power use related requirements.

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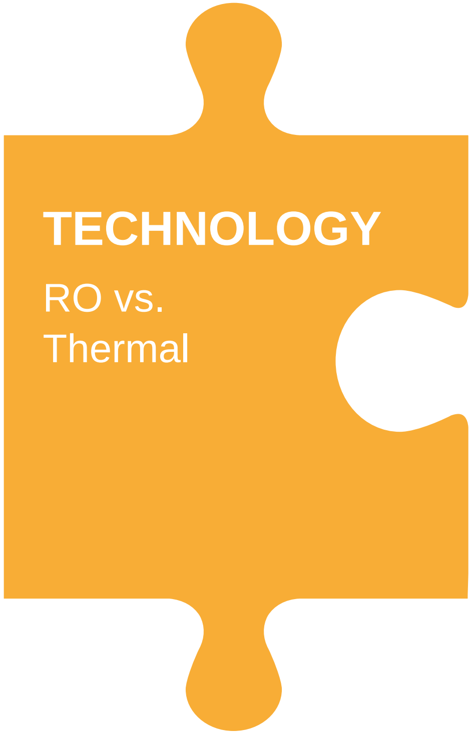
CAPEX and OPEX driver costs

- Technological and production improvements in all the areas over the past two decades are now rendering desalination by SWRO more competitive than thermal desalination.

- In the next 5 years, is expected to reduce the cost of Desalinated water by RO up to 20%.



CAPEX and OPEX driver costs

- The design of the sea water Intake and the pretreatment are two of the most important factors for the Desalination process efficiency.

- Over algae blooming stage, Thermal desalination will be less affected than a Membrane System without an efficient pretreatment.

WATER QUALITY

Salinity
TSS
Biofouling
Temperature

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Driver Costs

WATER QUALITY:

MINJUR (INDIA) vs QINGDAO (CHINA)

Salinity – TSS – Biofouling - Temperature

Minjur desalination plant second largest desalination plant in India (100,000 m^3/day).

Seawater salinity is close to 36 g/l.
Sea water temperature above 30º C
Monsoons and cyclones changing seawater TSS
Exhaustive pretreatment

Qingdao desalination plant is the largest potable Desal plant in China (100,000 m3/day)

Seawater salinity under 34 g/l.
Water temperature in winter below 4º C.
Summer algae blooming episodes
Compacted plant with UF pretreatment.

04

OTHER NON CONVENTIONAL WATER SOURCES

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Conventional Water Sources



Non Conventional Water Sources



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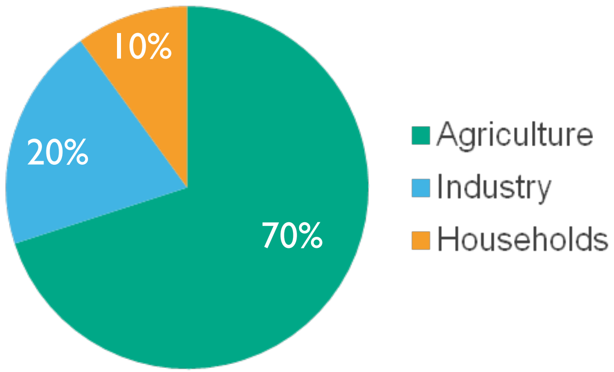
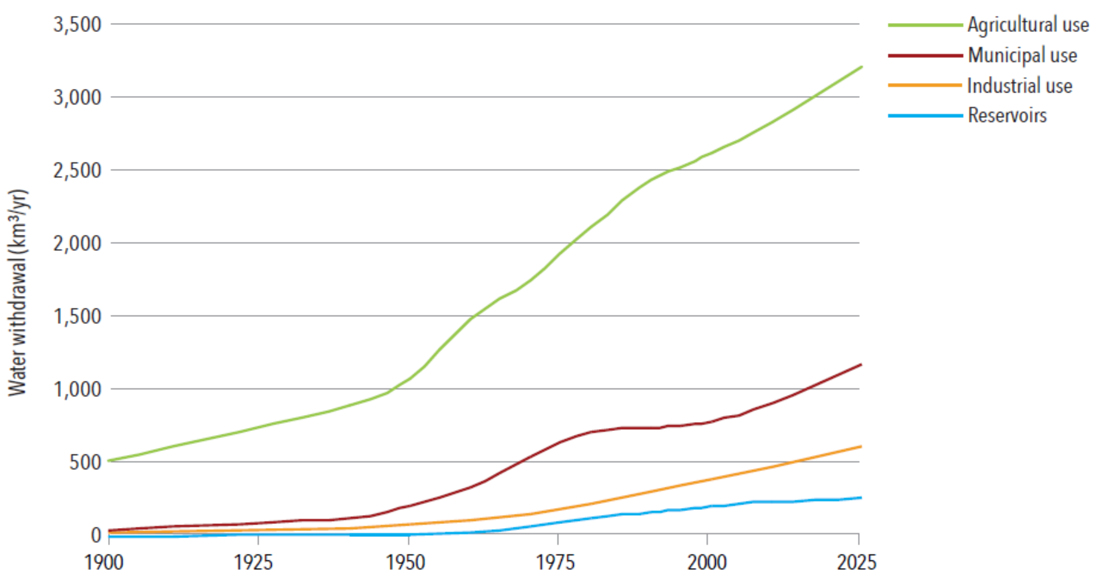
The Dynamics of Water Use

Worldwide around 70% of water is used in agriculture, 20% in industry and 10% by households.



The dynamics of water use, 1900-2025



Source: Unesco

Other non Conventional Water Sources

Alternative water sources:

Many municipalities around the world, with many utilities, are now exploring alternative water sources, such as reused wastewater, brackish water and seawater.

Increasing water reuse:

Indirect potable reuse continues to grow, especially in areas where access to freshwater is limited or where aquifers suffer from seawater intrusion.

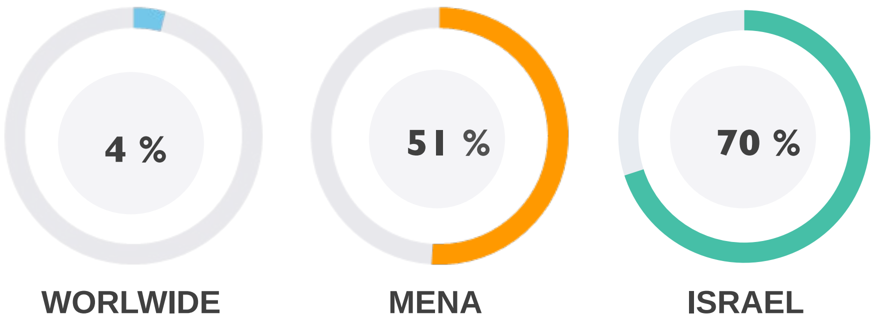
For potable use, cost savings are evident in relation to:

1. The reduced need for pumping to import water from outside sources
2. The cost of seawater desalination.

Other non Conventional Water Sources

Wastewater treatment

REUSED WASTEWATER



Volume of wastewater generated in the Middle East and North Africa (MENA) region is 22.3 cubic kilometers per year, which 51% (11.4 cubic kilometers per year) is treated.

MENA uses 51% of treated wastewater for irrigation.

Saudi Arabia intends to increase wastewater reuse up to 65% by 2016.

Israel already reuses 70% of the wastewater generated in the domestic sector.

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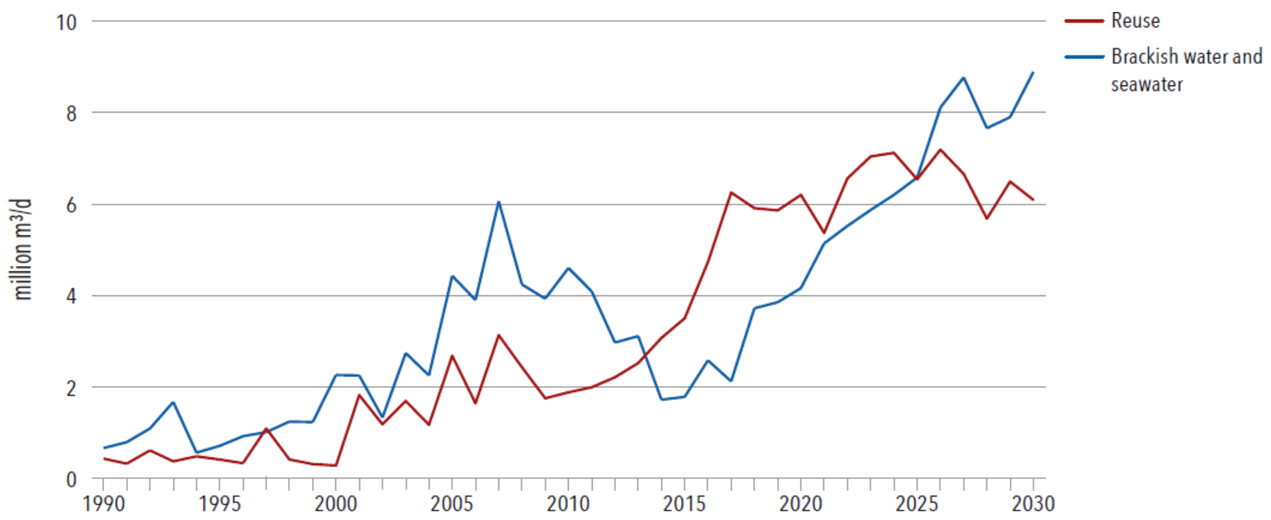
Other non Conventional Water Sources

New Contracted Alternative water sources



Note: Due to the difficulty in distinguishing spending on reuse from spending on wastewater treatment, it is not possible to realistically estimate spending on reuse in monetary terms. Instead, we have estimated the market by contracted capacity.

Source: GWI

CAPEX and OPEX in Tertiary Treatments

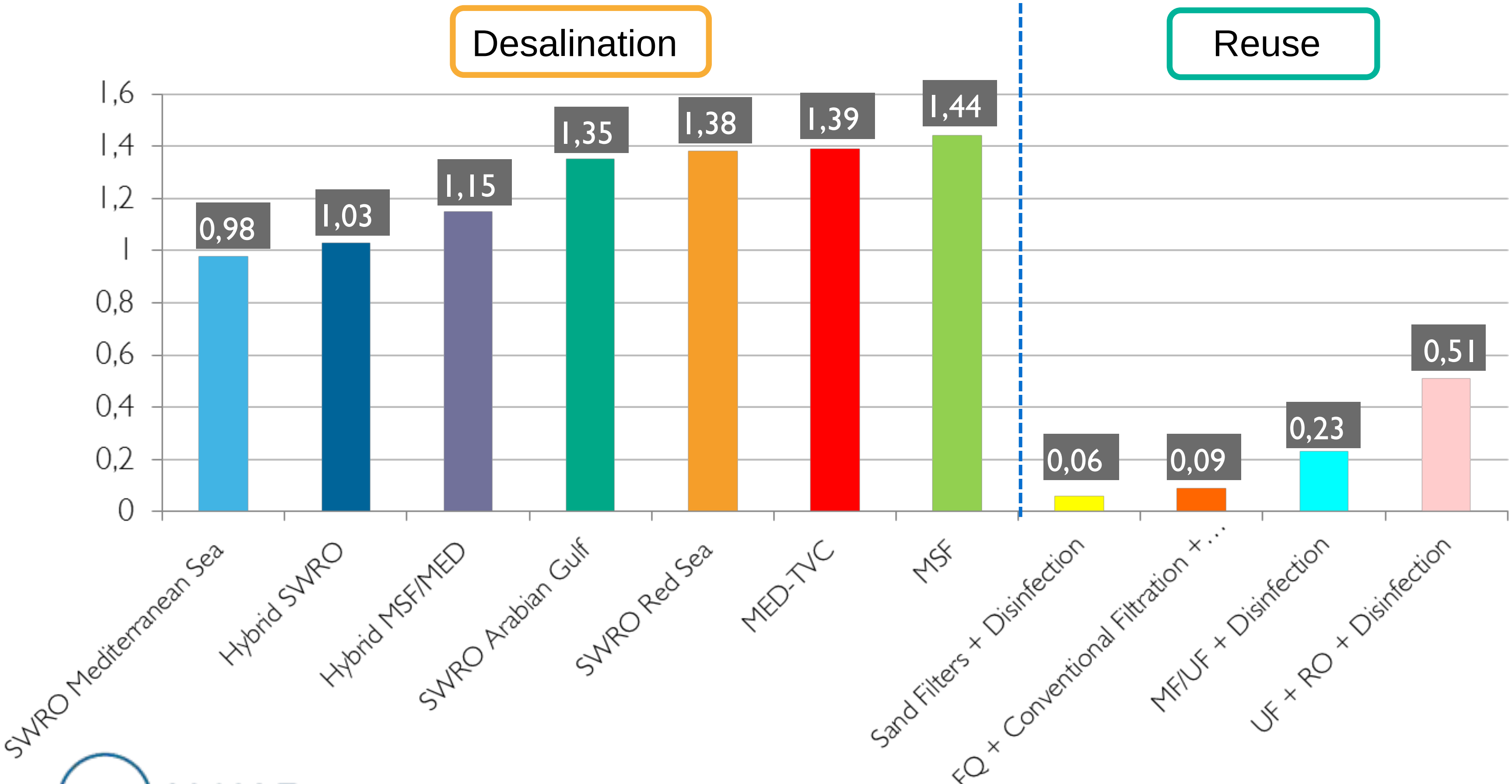
Production cost of high quality water reuse from sewage is about 0.4 – 0.6 $/m3

Tertiary Plant Type	Capital Cost (Million US$/MLD)		O&M Cost (US$/m^3)		Cost of Water Production (US$/m3)	
	Range	Average	Range	Average	Range	Average
Sand Filters + Disinfection	0.01-0.02	0.02	0.04-0.07	0.06	0.04-0.08	0.06
FQ+ Conventional Filtration + Disinfection	0.03-0.05	0.04	0.06-0.10	0.08	0.07-0.10	0.09
MF/UF + Disinfection	0.2-0.43	0.31	0.15- 0.21	0.18	0.18-0.27	0.23
UF + RO + Disinfection	0.45-0.79	0.62	0.37-0.48	0.43	0.43-0.59	0.51

Source: Europeam Comission. October 2016

CAPEX and OPEX in Desalination and Reuse

Cost of water production US$/m3



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05

FUTURE TRENDS

Future Trends

Technology

The numerous advantages of RO: lower capital costs and energy requirements, combined with advances in operating efficiency led to dramatic decreases in the cost of water desalinated.

Expected SWDP Water Cost within 20 years

1 RO Desalination Technology

Costs now average around $0.2–0.75/m^3, including both brackish and seawater desalination.

2 Efficiency improvement

Significant development in membrane construction, which increase operational efficiency, better permeate flux, and biofouling control.

3 Energy savings

Energy savings from the eventual adoption of energy recovery devices and centralized pumping.

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Future Trends

Renewable Energy Source

Solar power is the most abundant renewable energy source in MENA.

Solar power key advantage and challenge:

- High intensity and reability of solar irradiation
- Relatively lower construction and O&M costs
- Large amount of land for installation.

1 MLD SWRO:

- Solar Power Field 0.5-1 ha
- Capital cost Solar Power Plant equal to 60-80% of SWRO Capital Cost

3-5 cents US$/kwh

Fossil-Fuel based electricity production costs in MENA

5-6 cents US$/kwh

Current new Projects Solar electricity production costs in MENA

4-6 US$/m^3

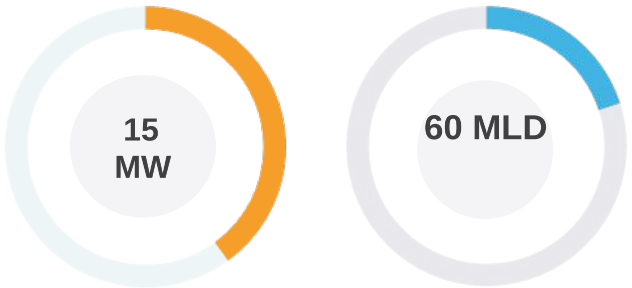
Cost of water served by trucks in most remote municipalities in the MENA region

Future Trends

Renewable Energy Source

SWRO plant in Al Khafji, KSA

The largest desalination plant with solar power supply under construction in the MENA, planned to be in operation by the end of 2017.

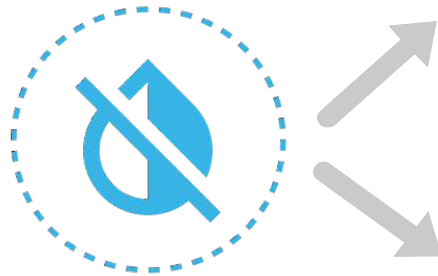


PV SOLAR POWER GENERATION

SWRO

Future Trends

Regional



Water scarcity

Industrialization

IRAN

Water infrastructure

GULF COAST AND SEA OF OMAN

Industrial processes (BOT)

SAUDI ARABIA

Brackish water solutions (groundwater) and

Desalination (BOT)

EGYPT

First IWPP (BOT)

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Contractual

- Small and medium SWRO

DBB/DBO

Most of the brackish desalination small and medium size projects in the MENA region are delivered as DBB/DBO.

- Large SWRO

BOOT

Large SWRO desalination projects are typically implemented using the BOOT method of delivery.

06

CONCLUSIONS

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Conclusions

- RO and hybrid RO & thermal desalination projects are the most competitive technologies.
- Private sector (BOT) is an useful tool for governments to achieve their commitments.
- Non conventional water sources will increase the water availability.
- An urgent plan is required to increase the water availability in the region.

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THANK YOU