Renewable Energy Desalination: An Emerging Solution to Close MENA's Water Gap

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Dr. Bekele Debele is a Senior Water Resources Specialist at the World Bank. He has over 15 years of experience working on subjects ranging from water resources management, water supply and sanitation, irrigation, desalination and renewable energy to climate change impacts on water and agriculture sectors. Dr. Debele has published extensively in peer-reviewed journals and also has authored chapters in several books in similar fields. Before joining the World Bank, he worked in academia and private sector in Ethiopia, Ireland, and the U.S. While at the World Bank, Dr. Debele has worked in many regions, including South Asia, Latin America, Africa, and Middle East and North Africa. He has worked on, and led, many technical and policy oriented studies and projects in over 20 countries. Over the last two years, Dr. Debele has been leading a MENA region-wide flagship study on desalination and renewable energy nexus.

Relevant Papers:

Renewable Energy Desalination: An Emerging Solution to Close Middle East and North Africa's Water Gap *(http://wrri.nmsu.edu/conf/conf11/re-desal.pdf)*

MENA Regional Water Outlook, Part II, Desalination Using Renewable Energy, Final Report *(http://wrri.nmsu.edu/conf/conf11/mna_rdrens.pdf)*

PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Debele.pdf**

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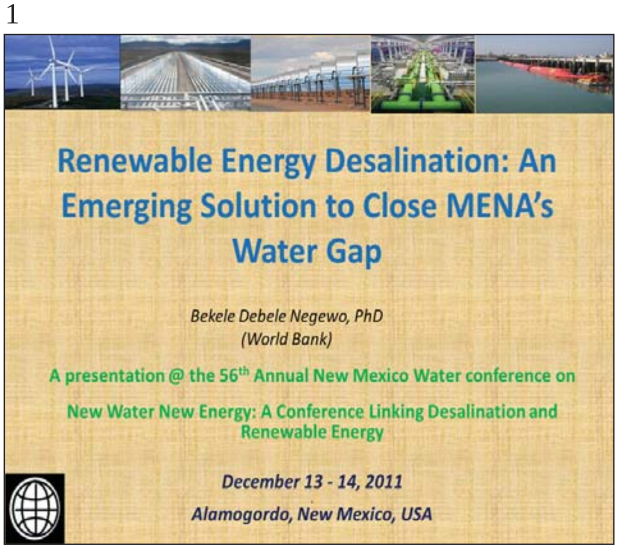

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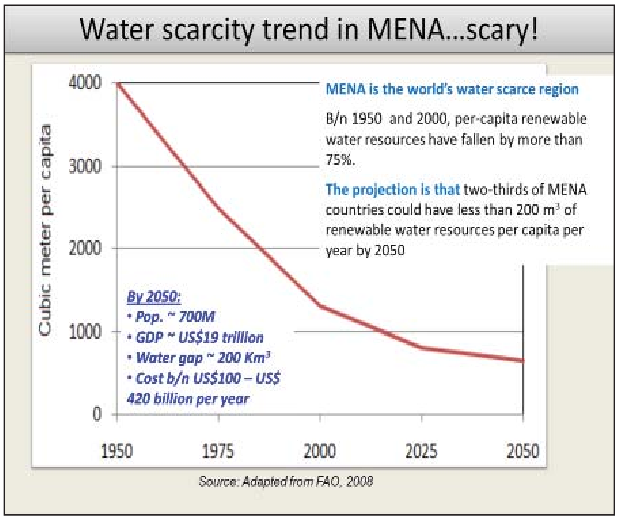
Water scarcity trend in MENA...scary!
Cubic meter per capita
4000
3000
2000
1000
0
1950
1975
2000
2025
2050
MENA is the world's water scarce region
B/n 1950 and 2000, per-capita renewable water resources have fallen by more than 75%.
The projection is that two-thirds of MENA countries could have less than 200 m³ of renewable water resources per capita per year by 2050
By 2050:
• Pop. ~ 700M
• GDP ~ US$19 trillion
• Water gap ~ 200 Km³
• Cost b/n US$100 – US$ 420 billion per year
Source: Adapted from FAO, 2008

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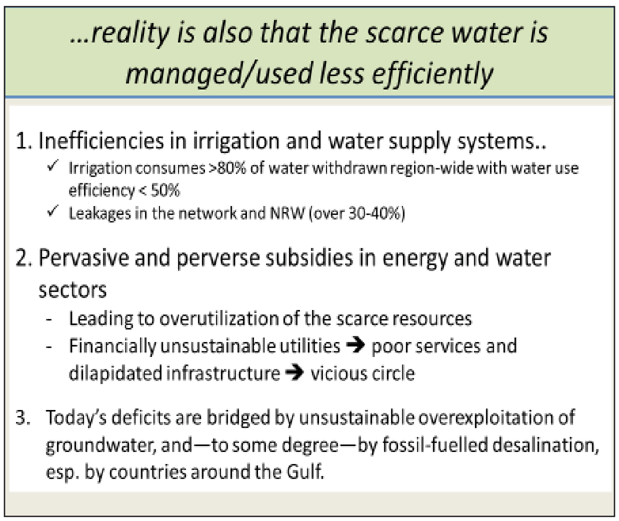
...reality is also that the scarce water is managed/used less efficiently
1. Inefficiencies in irrigation and water supply systems..
✓ Irrigation consumes >80% of water withdrawn region-wide with water use efficiency < 50%
✓ Leakages in the network and NRW (over 30-40%)
2. Pervasive and perverse subsidies in energy and water sectors
- Leading to overutilization of the scarce resources
- Financially unsustainable utilities → poor services and dilapidated infrastructure → vicious circle
3. Today's deficits are bridged by unsustainable overexploitation of groundwater, and—to some degree—by fossil-fuelled desalination, esp. by countries around the Gulf.

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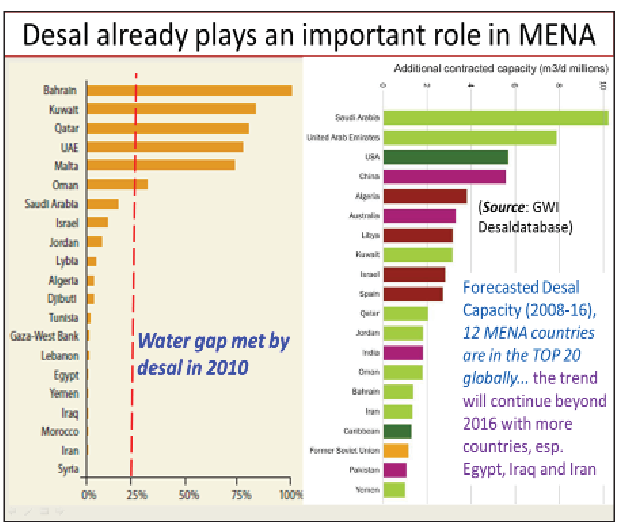
Desal already plays an important role in MENA
Bahrain
Kuwait
Qatar
UAE
Malta
Oman
Saudi Arabia
Israel
Jordan
Lybia
Algeria
Djibuti
Tunisia
Gaza-West Bank
Lebanon
Egypt
Yemen
Iraq
Morocco
Iran
Syria
0%
25%
50%
75%
100%
Water gap met by desal in 2010
Additional contracted capacity (m3/d millions)
Saudi Arabia
United Arab Emirates
USA
China
Algeria
Australia
Libya
Kuwait
Israel
Spain
Qatar
Jordan
India
Oman
Bahrain
Iran
Caribbean
Former Soviet Union
Pakistan
Yemen
(Source: GWI Desaldatabase)
Forecasted Desal Capacity (2008-16), 12 MENA countries are in the TOP 20 globally... the trend will continue beyond 2016 with more countries, esp. Egypt, Iraq and Iran

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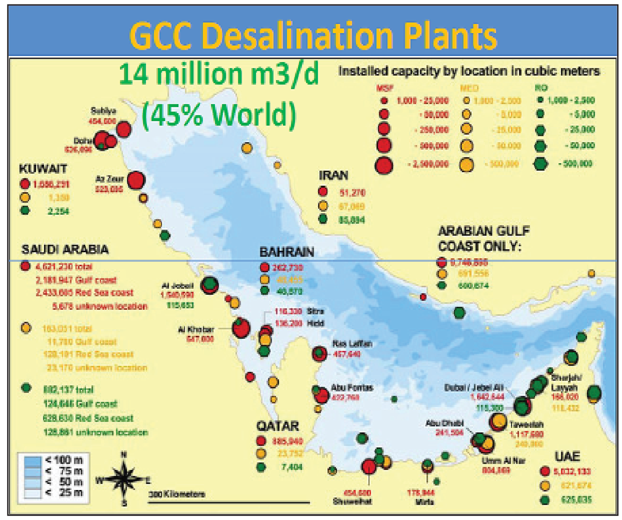
GCC Desalination Plants
14 million m3/d
(45% World)
Installed capacity by location in cubic meters
MSF
MED
RO
KUWAIT
IRAN
SAUDI ARABIA
BAHRAIN
ARABIAN GULF COAST ONLY:
QATAR
UAE
Subiya
Doha
Az Zour
Al Jubail
Al Khobar
Ras Laffan
Abu Fontas
Dubai / Jebel Ali
Sharjah/ Layyah
Abu Dhabi
Taweelah
Umm Al Nar
Shuweihat
Mirfa
300 Kilometers

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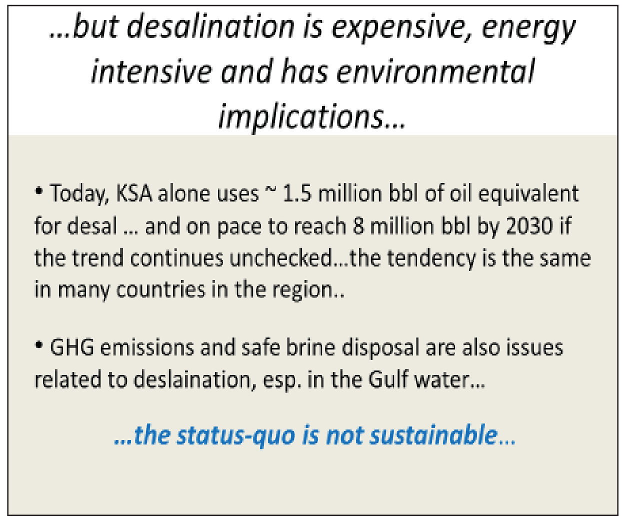
...but desalination is expensive, energy intensive and has environmental implications...
• Today, KSA alone uses ~ 1.5 million bbl of oil equivalent for desal ... and on pace to reach 8 million bbl by 2030 if the trend continues unchecked...the tendency is the same in many countries in the region..
• GHG emissions and safe brine disposal are also issues related to deslaination, esp. in the Gulf water...
...the status-quo is not sustainable...

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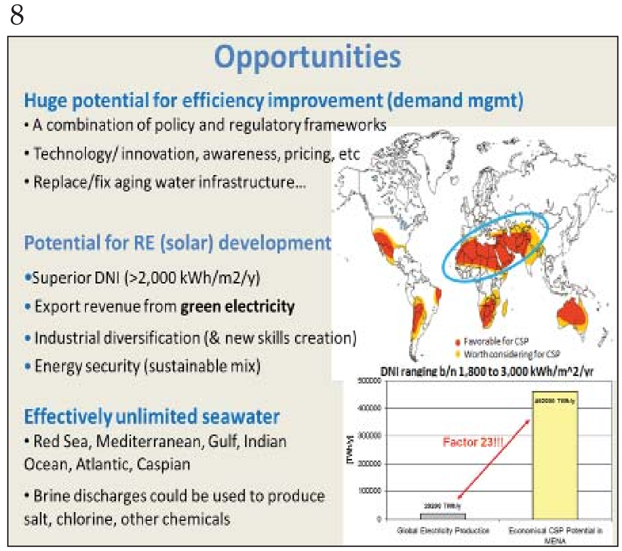
Opportunities
Huge potential for efficiency improvement (demand mgmt)
• A combination of policy and regulatory frameworks
• Technology/ innovation, awareness, pricing, etc
• Replace/fix aging water infrastructure...
Potential for RE (solar) development
•Superior DNI (>2,000 kWh/m2/y)
• Export revenue from green electricity
• Industrial diversification (& new skills creation)
• Energy security (sustainable mix)
Favorable for CSP
Worth considering for CSP
DNI ranging b/n 1,800 to 3,000 kWh/m^2/yr
Effectively unlimited seawater
• Red Sea, Mediterranean, Gulf, Indian Ocean, Atlantic, Caspian
• Brine discharges could be used to produce salt, chlorine, other chemicals
Factor 23!!!
Global Electricity Production
Economical CSP Potential in MENA

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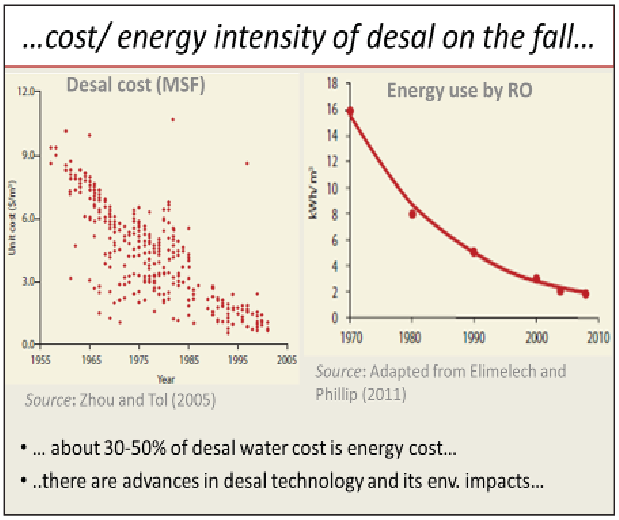

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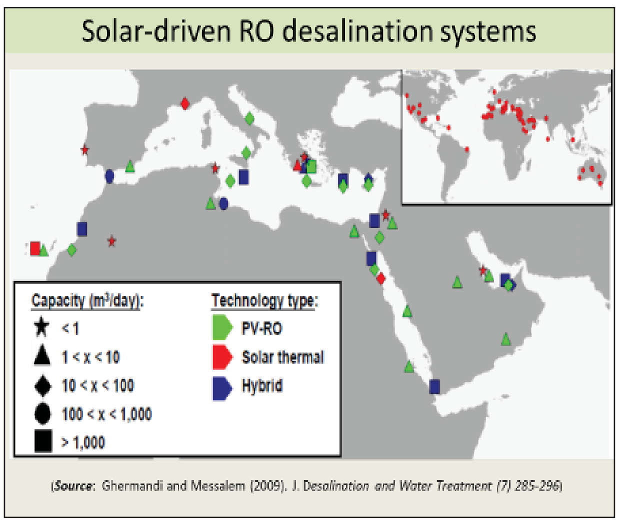

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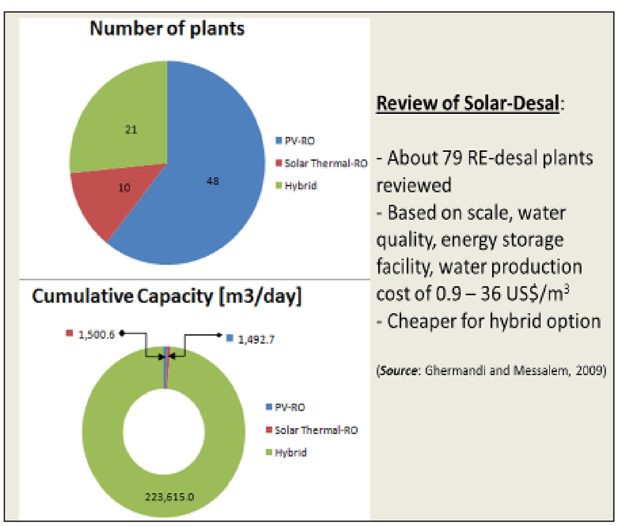

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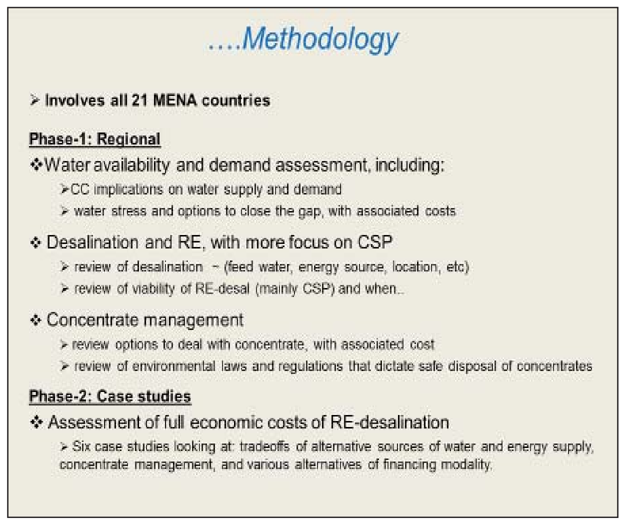

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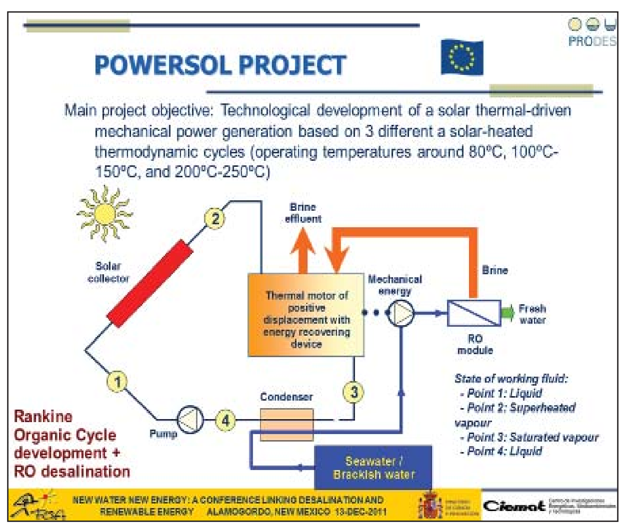

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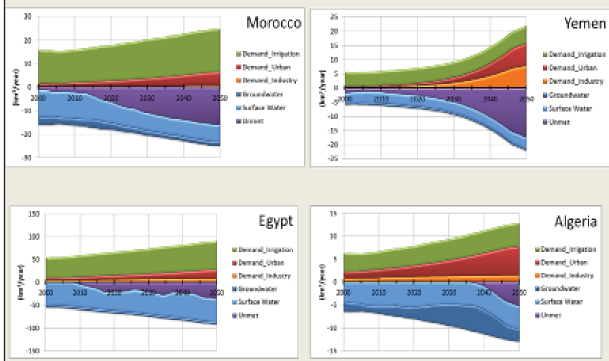
Country Specific Water Balance…examples



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Closing water gap … adaptation cost

	Water Shortage (MCM)	Costs (US$ mil)	(US$/m³)	(US$/capita)	(% of GDP 2020–30)	(% of GDP 2040–50)
UAE	3,189	3,116	0.98	716	2.36	0.79
Iraq	54,860	39,574	0.72	647	**7.56**	**2.52**
Saudi Arabia	20,208	15,849	0.78	271	1.41	0.47
Israel	3,418	2,788	0.82	265	0.49	0.16
Bahrain	383	335	0.87	248	0.78	0.26
Morocco	15,414	13,104	0.85	236	**4.72**	1.57
Libya	3,650	1,860	0.51	170	0.56	0.19
Qatar	246	158	0.64	170	0.2	0.07
Jordan	2,088	1,746	0.84	164	**4.04**	1.35
West Bank & Gaza	925	769	0.83	151	N/A	N/A
Oman	1,143	846	0.74	116	0.75	0.25
Kuwait	801	600	0.75	112	0.30	0.10
Egypt	31,648	11,321	0.36	76	2.44	0.81
Lebanon	891	363	0.41	72	1.19	0.40
Yemen	8,449	5,927	0.70	63	**11.82**	**3.94**
Malta	36	26	0.72	57	0.4	0.28
Syria	7,111	1,926	0.27	54	1.45	0.49
Iran	39,939	3,112	0.08	29	0.24	0.08
Algeria	3,947	83	0.02	1	0.01	0
Tunisia	837	17	0.02	1	0	0
MENA	199,183	103,520	0.52	148	1.61	0.54

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Closing about 200 km³/yr water demand gap is challenging and expensive

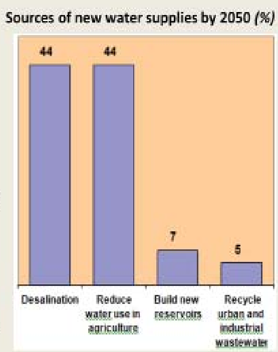
1) The basic principle was to use the least expensive water first and the most expensive water last.

2) Demand management
- Improved irrigation (AWM)
- leakage reduction and tariff reform

3) Supply augmentation
- Water harvesting, reservoirs
- Reuse and desal

4) Cost vary b/n US$ 300 - 420 billion/yr by 2050, if desal is the only option;
- with cost optimized approach, the cost can be reduced to US$ 104 billion/yr

5) Costs vary significantly among countries…up to 6% of GDP per year



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PLANET EARTH: A WORLD OF WATER

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Total Annualized Cost of Desalinated Seawater *(US$/m³)**

CSP-Desal

Feed water source	Desalination option MSF	MED	RO
Mediterranean	-	1.97–2.08	1.52–1.74
Red	-	1.88–1.98	1.58–1.66
Gulf	2.05	1.78–1.88	1.79–1.87
Ref. (conven. energy desal)	2.05	1.9 – 2.1	1.5-1.9

***Note**: based on desal capacity of 100,000 m³/day*
** the costs exclude scaled up environ. mitigation, and land and transport cost*
** = depending on site, scale, energy storage facility, unit costs of 0.9–32.0 US$/m³ have been reported for small scale RE-Desal plants …*

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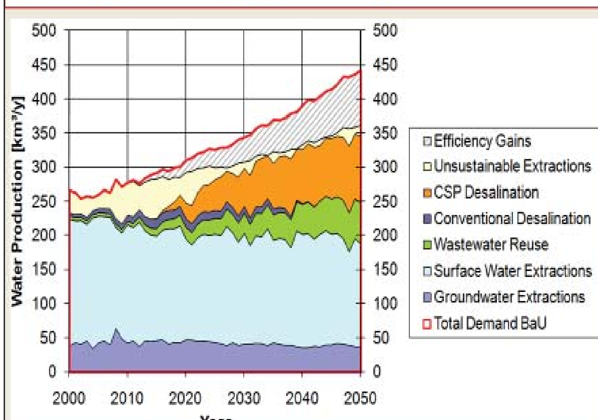
Closing demand gap … an optimized scenario



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RE can provide a win-win solution

- Coupling RE sources with desal could provide a sustainable source of potable water.
- With future advances in RE and desal technologies and economies of scale, RE may be a cost-effective alternative to conventional energy…

  …. b/c fossil fuel (GHG, limited resources, volatile and will be expensive due to competition).
- Increased RE use will reduce CO_2 emissions.
  - Using RE-desal could save up to 400 million tons of CO_2 equivalent emissions by 2050 …. scaling up RE use economy wide could cut emissions from 1.5 billion tons by 2050 (if current trends continued) to 265 million tons by the same year.
  - Can reduce volume of brine produced due to flexibility to employ RO instead of thermal desal…

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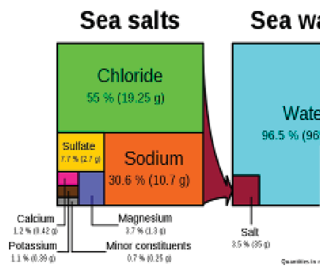

Chemical Ion	concentration ppm, mg/kg	part of salinity %	mmol/kg
Chloride Cl^-	19,345	55.03	546
Sodium Na^+	10,752	30.59	468
Sulfate SO_4^{2-}	2,701	7.68	28.1
Magnesium Mg^{2+}	1,295	3.68	53.3
Calcium Ca^{2+}	416	1.18	10.4
Potassium K^+	390	1.11	9.97
Bicarbonate HCO_3^-	145	0.41	2.34
Bromide Br^-	66	0.19	0.83
Borate BO_3^{3-}	27	0.08	0.46
Strontium Sr^{2+}	13	0.04	0.091
Fluoride F^-	1	0.003	0.068
TOTAL	35,151		

Seawater composition

Although salinity of seawater may well vary depending on the specific region of the world, the percentage composition of seawater is essentially constant throughout the world (i.e. the proportions of the major constituents are constant).

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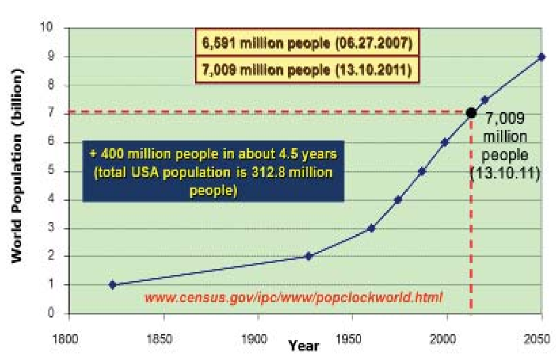
World population evolution



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Next steps..

Case studies/Report:

1. Summary of best practices in desal (technology selection, financing modality, brine management, etc)
2. Barriers against adoption of alternative energy and water supply options (policy, financing, etc)
3. Full economic analysis:
   - Algeria—InSalah
   - Egypt – Marsa Alam
   - Yemen—Taiz
4. On phase-1 report:
   - **Background material** WWW.WorldBank.org/mna/watergap
   - **Comments are welcome until Dec. 23, 2011**
   - **Launch for the 6th WWF 2012…**

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