Water Desalination: When and Where Will it Make Sense?

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Agenda

- Water demand and scarcity
- Desalination: basic considerations
- Desalination: introduction of technologies
- Desalination: Implementation and statistics
- Desalination and renewables
- Conclusions
Water demand and scarcity

The world is called the blue planet

- Fresh water 3%
- Saline (oceans) 97%
- Earth’s water
- Fresh water
- Other 0.9%
- Surface Water 0.3%
- Ground water 30.1%
- Icecaps and Glaciers 68.7%
- Rivers 2%
- Swamps 11%
- Lakes 87%
- Fresh surface water (liquid) 0.008%
Water demand and scarcity

Historical development of world population

- World population in billion
- Average annual growth in 10 years

Graph: Deutsche Stiftung Weltbevölkerung
Water demand and scarcity

Relative growth of world population by countries in %
Water demand and scarcity

World water demand 1900 – 2025
According WHO standards the minimum quantity of fresh water per person should be at least 20 liters / day
What is water scarcity?

Water scarcity can be described as the “Imbalances between availability and demand”
Water demand and scarcity

**Increasing demand due to:**

- Exponential growth of population particular in the “dry” regions
- Increase of individual demand
- Industrialization
- Excessive use for agriculture not only to feed the local market
Water demand and scarcity

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**Decrease of fresh water resources due to:**
- Dropping ground water level
- Intrusion of salt water
- Emptying of none regenerative ground water reservoirs
- Pollution of surface water
Water demand and scarcity

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- Exponential growth of population particular in the “dry” regions
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**Decrease of fresh water resources due to:**
- Decreases ground water level
- Intrusion of salt water
- Emptying of none regenerative ground water reservoirs
- Pollution of surface water

**General Problems:**
- Local and seasonal mismatch between availability and demand
- People are not used or not able to pay for water
Water demand and scarcity

According WHO 2008 almost 1 billion people (~15% of world population) mainly in the developing countries have no excess to clean portable water. What are the major effects of water scarcity?

- About 12 million deaths/year are directly related to water shortage or the consumption of improper water.
- About 80% of all diseases in developing countries are caused by an insufficient supply of clean water or improper sanitation.
- 84% of the world population without an improved drinking water source lives in rural areas → Migration from the country site to the cities.
Water demand and scarcity

According to WHO 2008, almost 1 billion people (~15% of world population) mainly in the developing countries have no access to clean portable water. **What are the major effects of water scarcity?**

**Limitations for the commercial sector**

- Agriculture
- Electricity generation
- Industrialization
- Tourism
Desalination can be applied with following boundary conditions:

- Demand for fresh water (domestic use, industry, agriculture, ...)
- Lack of conventional water sources
- Availability of salt water
- Availability of Infrastructure (energy, water distribution network)
- Interest for financing (invest, maintenance, energy, ...)

Basic consideration

Desalination: basic considerations
Desalination: basic considerations

**Basic consideration**

- Standard seawater has a salinity of 35.000 ppm TDS (Totally Dissolved Solids)
- Brackish water has a salinity of 1000 – 10.000 ppm TDS
- Fresh water for human consumption should not exceed 500 ppm TDS. A maximum of 1000 ppm TDS is recommended by WHO.
### General advantages and disadvantages of desalination

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Sea water is an “unlimited” source</td>
<td>▪ Desalination is an energy intensive process</td>
</tr>
<tr>
<td>▪ Many large cities are located next to the sea</td>
<td>▪ Investment and operation costs are very high</td>
</tr>
<tr>
<td>▪ For some countries it is the only excess to fresh water</td>
<td>▪ Brine discharge can effect the environment</td>
</tr>
<tr>
<td>▪ Migration from country site due to fresh water scarcity can be reduced</td>
<td>▪ Brine discharge of brackish water desalination inside the country is difficult</td>
</tr>
</tbody>
</table>
Desalination: introduction of technologies

Desalination technologies

Electrically driven systems
- RO Reverse Osmosis
- MVC Mechanical Vapor Compression
- EDR Electrical Dialysis

Thermally driven systems
- MSF Multi Stage Flash distillation
- MED Multi Effect Distillation
- TVC Thermal Vapor Compression
- MD Membrane Distillation
Desalination: introduction of technologies

Desalination systems

RO Reverse Osmosis

Typical plant capacities: <1m³/day to <450,000m³/day

Source: www.hcti.com

Source: ecotec
Desalination: introduction of technologies

Desalination systems

MSF Multi Stage Flash technology

Source: sidem

Typical plant capacities: <4000 m³/day to < 500,000 m³/day
## Technical key values of different desalination technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Plant capacity [m³]/day</th>
<th>Specific thermal energy consumption [kWh/m³]</th>
<th>Specific electrical energy consumption [kWh/m³]</th>
<th>Operation temperature (typically) [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSF</td>
<td>4000- 450,000</td>
<td>55 - 220</td>
<td>4-6</td>
<td>90 – 120 (112)</td>
</tr>
<tr>
<td>MED</td>
<td>100- 56,000</td>
<td>40 - 220</td>
<td>1.5 – 2.5</td>
<td>50 – 70 (70)</td>
</tr>
<tr>
<td>MVC</td>
<td>5 - 17.000</td>
<td>-</td>
<td>6 - 12</td>
<td>50 -70</td>
</tr>
<tr>
<td>RO</td>
<td>0.01– 360,000</td>
<td>-</td>
<td>2.8 - 12</td>
<td>&lt; 40!</td>
</tr>
</tbody>
</table>
Where are desalination systems installed today?

Fresh water production by desalination

**Infrastructure developed**
- large settlements
- cities

Large scale, well developed desalination systems, capacities up to 600,000 m³ per day
- MSF
- MED
- RO
- VC
- EDR*

* EDR can only be used for brackish water

Use of renewable energy sources
- Solar energy
  - Solar thermal
  - PV
- Wind energy
  - Wind turbine

Use of Fossil fuel
- Diesel from a tank
  - Diesel engine with generator
- Electric current
  - Waste heat

**Infrastructure not developed**
- Small villages in rural areas
- Decentralised settlements
- Small islands
Where are desalination systems applied today?

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Use of renewable energy sources
- Solar energy
  - Solar thermal
  - Still
  - MEH
  - MED
  - MD
- Wind energy
  - Wind turbine
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  - EDR*
  - VC
- Solar thermal
  - Still
  - MEH
  - MED
  - MD

Use of fossil fuel
- Diesel from a tank
- Diesel engine with generator
- Electric current
- Waste heat
Today about 50% of the world population is living in cities. It is expected that this part will rise up to 70% in 2050. Today about 65mio m³/day (0.4% of the total demand) are produced by desalination.
Desalination: Implementation and statistics

**TOP 10 DESALINATING COUNTRIES**

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity (m³/day)</th>
<th>Share of global production (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Saudi Arabia</td>
<td>10 598 000</td>
<td>17</td>
</tr>
<tr>
<td>2. United Arab Emirates</td>
<td>8 743 000</td>
<td>14</td>
</tr>
<tr>
<td>3. United States of America</td>
<td>8 344 000</td>
<td>14</td>
</tr>
<tr>
<td>4. Spain</td>
<td>5 428 000</td>
<td>9</td>
</tr>
<tr>
<td>5. China</td>
<td>2 553 000</td>
<td>4</td>
</tr>
<tr>
<td>6. Kuwait</td>
<td>2 390 000</td>
<td>4</td>
</tr>
<tr>
<td>7. Qatar</td>
<td>2 049 000</td>
<td>3</td>
</tr>
<tr>
<td>8. Algeria</td>
<td>1 826 000</td>
<td>3</td>
</tr>
<tr>
<td>9. Australia</td>
<td>1 508 000</td>
<td>2</td>
</tr>
<tr>
<td>10. Japan</td>
<td>1 153 000</td>
<td>2</td>
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</table>

Data source IDA 2008
Desalination: Implementation and statistics

Global cumulative online capacity / million m³/d

Global annual new online capacity / million m³/d

All feedwater types:
Seawater, brackish water, river water, waste water

2010: data for 6 months only

Data source IDA year book 2010-2011
Desalination: Implementation and statistics

Global cumulative contracted capacity

All feed water types:
Seawater, brackish water, river water, waste water

Cumulative contracted for 2011: 77mio m³/day

Data source IDA year book 2010-2011
Desalination: Implementation and statistics

Total world wide installed capacity by feedwater category

- **Seawater**: 60.0%
- **Brackish water**: 21.5%
- **River water**: 8.3%
- **Wastewater**: 5.7%
- **Pure water**: 4.3%
- **Brine**: 0.2%

**Installed capacity**: 65.2 million m³/d

Data source IDA year book 2010-2011

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Desalination: Implementation and statistics

Total worldwide installed capacity by desalination technology

- **RO** - Reverse osmosis: 60.0%
- **MSF** - Multi-stage flash: 26.8%
- **MED** - Multi-effect distillation: 8.0%
- **ED** - Electro-dialysis: 3.6%
- **EDI** - Electro-dionization: 0.3%
- Hybrid: 0.8%
- Other: 0.3%

Installed capacity: 65.2 million m³/d

All feed water types:
- Sea water
- Brackish water
- River water
- Waste water

Data source: IDA year book 2010-2011
Desalination: Implementation and statistics

Development of desalination capacity by membrane and thermal processes

Data source: IDA year book 2010-2011
Desalination: Implementation and statistics

Fresh water production by desalination

Infrastructure developed
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- Cities

Large scale, well developed desalination systems, capacities up to 600,000 m³ per day
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- EDR* (EDR can only be used for brackish water)

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- PV

Use of Fossil fuel
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Infrastructure not developed
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Wind energy
- Wind turbine

Electric current
- Waste heat

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Desalination: Implementation and statistics

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Desalination and renewables

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Use of Fossil fuel
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  - Electric current
    - Waste heat
Challenging approach because:

- Energy supply is not constant during the course of a year, during day and night time and during daytime even within a couple of seconds
- Qualified technical maintenance is not self-evident for small remote sites
Desalination and renewables

Potential of solar energy e.g. 6kWh/(m²d) → 0.6 l oil /(m² d) → 220 l oil /(m² y)
Desalination and renewables

Solar energy for desalination

Different approaches for the utilization of solar energy as the prime mover for desalination processes

- PV: Solar Thermal Powerplant (CSP)
- Solar Thermal Low Temperature Generation
- Electricity
- Wst. Heat
- RO: Reverse Osmosis
- ED: Electro Dialysis
- MSF: Multi stage flash
- MED: Multi Effect Distillation
- VC: Vapor Compression
- STIL: Simple Solar Stil
- MEH: Multi Effect Distillation
- MD: Membrane Distillation
For the desalination of sea water approximately 10m² PV per 1m³/d permeate are needed!
Desalination and renewables

PV driven RO system in Ksar Ghilene, Tunisia, developed and installed by ITC, Gran Canaria. Design capacity (brackish water) 16m³ in 8 hours of operation
Desalination and renewables

Membrane distillation (MD)
System Technology

Compact system (Oryx 150)
Target capacity 100 -150l/day

Application in remote areas for drinking water supply of single households or small communities
Desalination and renewables

**MD System in Namibia**
July 2010
Concentrating solar power combined with MED:
Vapor of 70°C from the steam turbine is condensed in the first stage of the MED plant

- Efficient use of low grade heat
- Loss of electrical efficiency by ~10%
- Specific local requirements do not always match
When the following priorities are considered:

1st Priority water saving
2nd Priority collecting, reuse and treatment of polluted fresh water
3rd Priority desalination

Where sea water or brackish water and infrastructure is available and an additional water supply...
...can improve the basic living condition of people
...can create economy
...is essential for agriculture

Where...
...desalination does not effect the environment
...the supply of desalinated water to big cities is essential (almost 60 mio m³/day are state of the art)
...decentralized treatment of salt water in remote areas is needed to avoid migration (Technology is still under development)
Thank you for your attention ...