Introduction

Lecture 1

Course group

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Can we drink salt water?

The Rime of the Ancient Mariner

Water, water, everywhere
And all the boards did shrink
Water, water, everywhere
Nor any drop to drink
-Samuel Taylor Coleridge

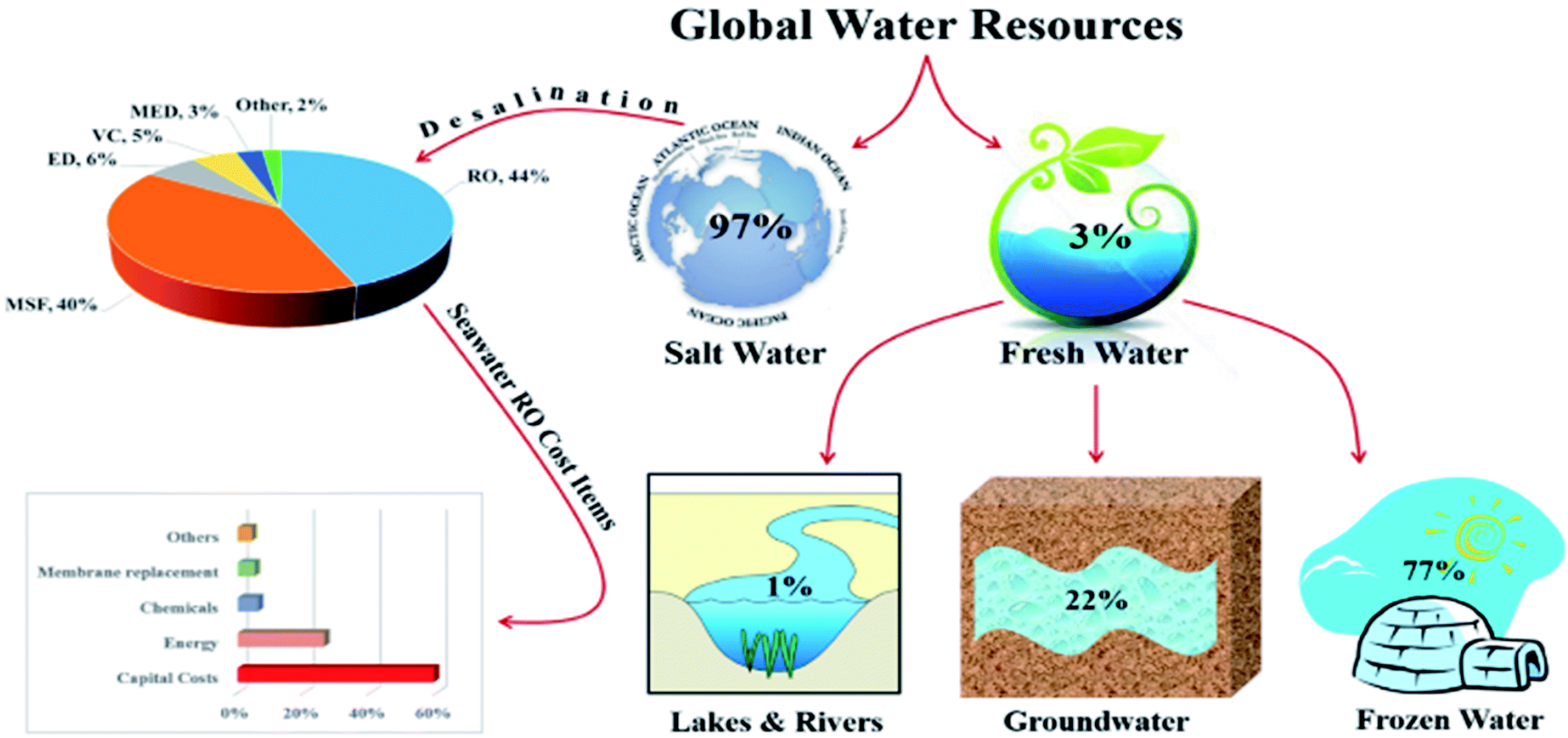
Small quantities are not harmful, but it is counterproductive (it just makes you more thirsty!)

Eventually, it can be dangerous, ultimately producing heart arrhythmias and kidney failure

Desalination Technologies

- Desalination also called desalinization or desalting.
- It refers to a water treatment process that removes salts from water making it potable, and can be used for domestic, municipal, irrigation and industrially.
- Almost 97% of the earth surface is covered by salty water, which is too salty to sustain human life or farming, the remaining 3% presents fresh Water (e.g.; rivers, lakes).

Desalination Technologies

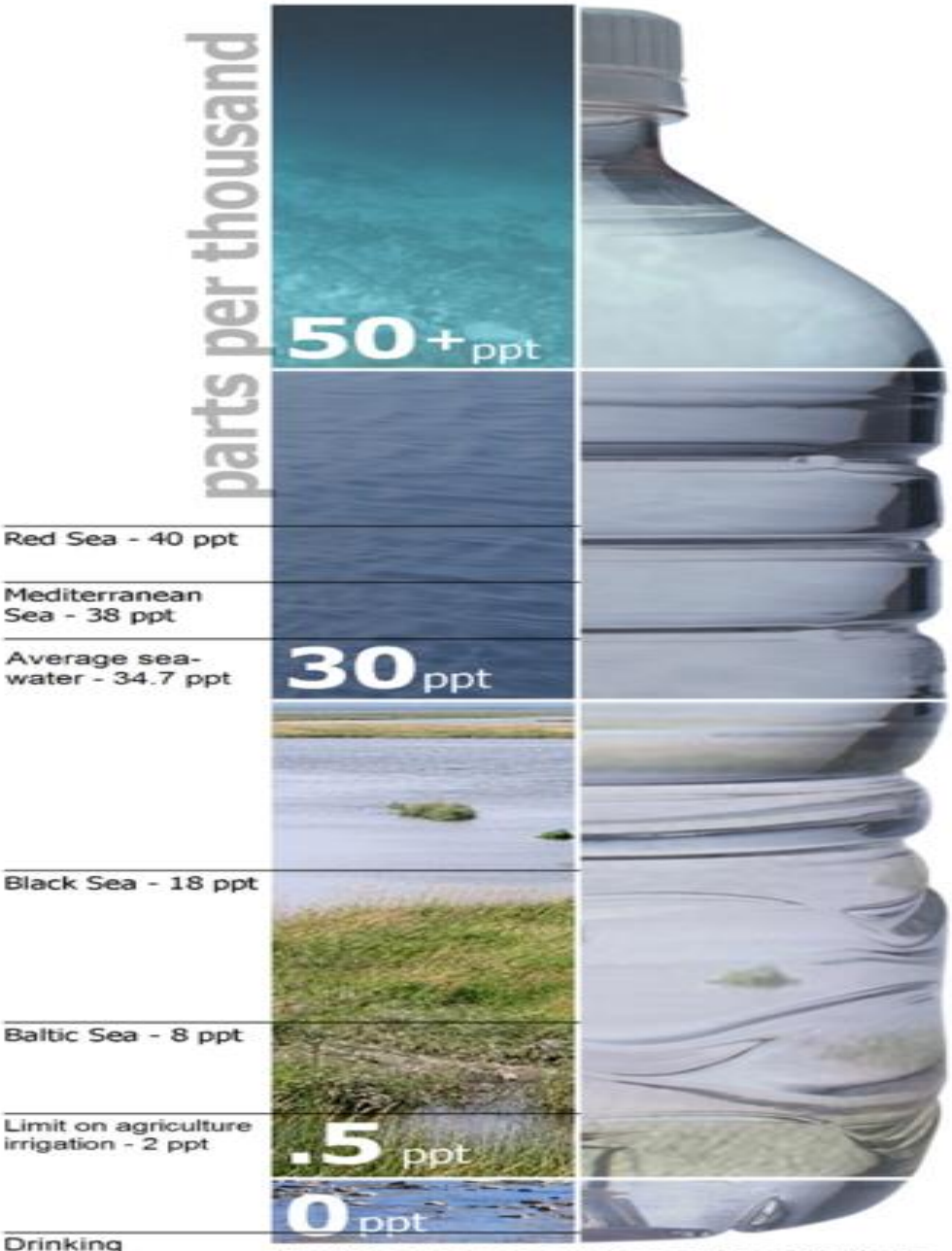


Desalination Technologies

- Shortage of potable water are recently triggering wars among nations and is a great problem that has to be solved rapidly.

Types of water:

- Brackish water which contain about 10g/L dissolved solids.
- Sea water contains an average of 32g/L dissolved solids and may reach up to 60g/L in area such as the Dead sea.
- This limitations of fresh water has restricted the size and location of communities around the world.



*traditional ways to express salinity is in "parts per thousand" or ppt

brine water

brine pools

50+ ppt

saline water

seawater, salt lakes

30-50 ppt

brackish water

estuaries, mangrove swamps, brackish seas and lake, brackish swamps

.5-30 ppt

freshwater

ponds, lakes, rivers, streams, aquifers

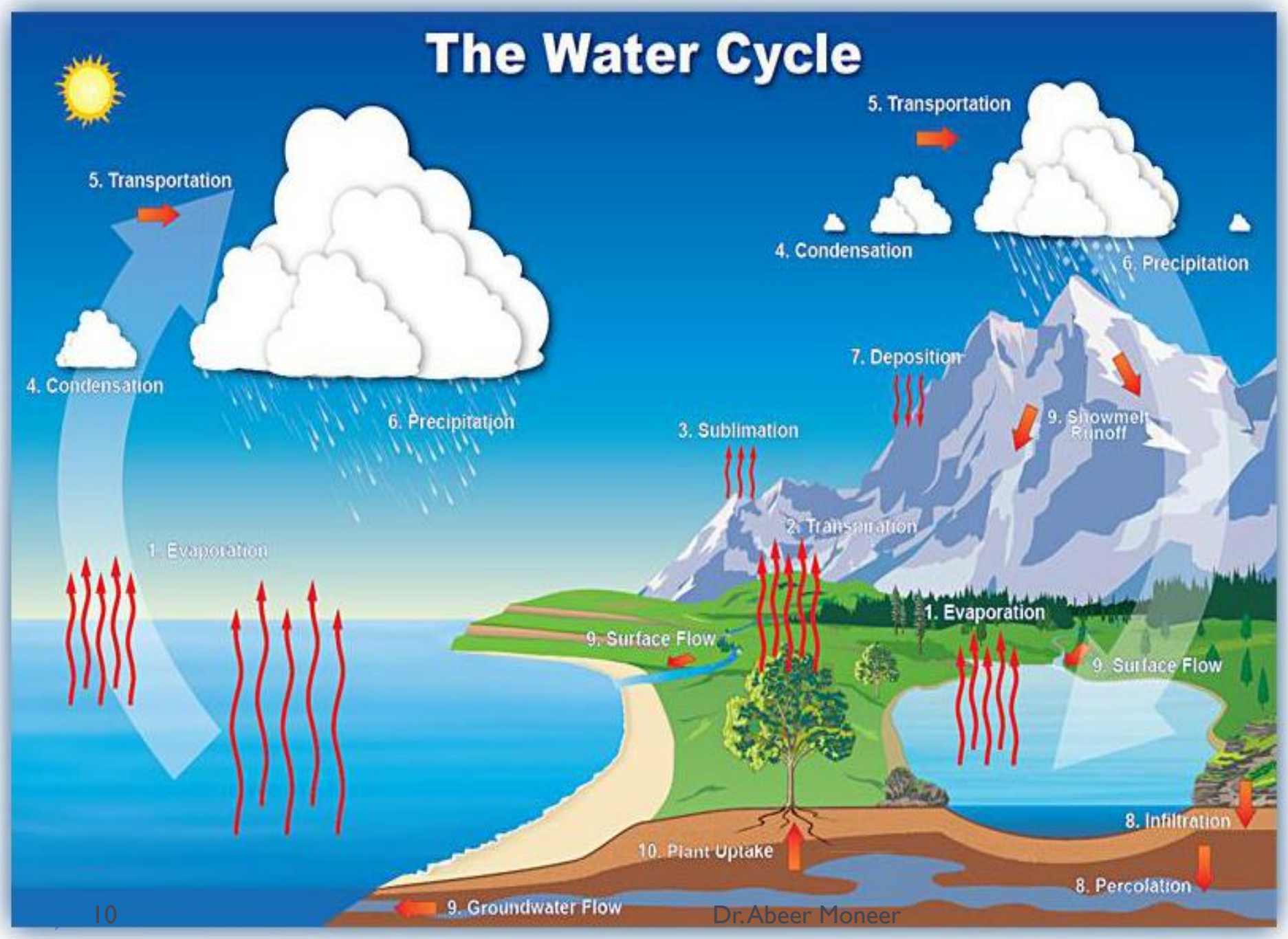
0-.5 ppt

Desalination Technologies

- The applications of desalting technologies over the past 60 years have changed this in many places .
- Villages, cities, and industries have now developed or grown in many of the arid and water-short areas of the world where sea or brackish waters are available and have been treated with desalting techniques.

The Development of Desalting

- Desalting is a natural, continual process and an essential part of the water cycle.
- Rain falls to the ground.
- Once on the ground, it flows to the sea, and people use the water for various purposes as it makes this journey.
- As it moves over and through the earth, the water dissolves minerals and other materials, becoming increasingly salty.
- While in transit and upon arrival in the world's oceans or other natural low spots, a part of the water is evaporated by the sun's energy.
- This evaporated water leaves the salts behind, and the resulting water vapor forms clouds that produce rain, continuing the cycle.


The Water Cycle
5. Transportation
4. Condensation
6. Precipitation
5. Transportation
4. Condensation
6. Precipitation
7. Deposition
9. Snowmelt Runoff
3. Sublimation
2. Transpiration
1. Evaporation
9. Surface Flow
1. Evaporation
9. Surface Flow
8. Infiltration
10. Plant Uptake
8. Percolation
9. Groundwater Flow

The Development of Desalting

- A major step in development came in the 1940s, during World War II, when various military establishments in arid areas needed water to supply their troops.
- The American government, through creation and funding of the Office of Saline Water (OSW) in the early 1960s and its successor organizations like the Office of Water Research and Technology (OWRT), made one of the most concentrated efforts to develop the desalting industry.

The Development of Desalting

- The American government actively funded research and development for over 30 years, spending about $300 million in the process.
- This money helped to provide much of the basic investigation and development of the different technologies for desalting sea and brackish waters.
- By the late 1960s, commercial units of up to 8,000 cubic meters per day (m3/d) were beginning to be installed in various parts of the world.
- These mostly thermal-driven units were used to desalt seawater, but in the 1970s, commercial membrane processes such as electrodialysis (ED) and reverse osmosis (RO) began to be used more extensively.

The Development of Desalting

- Originally, the distillation process was used to desalt both brackish water and seawater.
- This process could be expensive and restricted the applications for desalting to municipal purposes.
- When ED was introduced, it could desalt brackish water much more economically than distillation, and many applications were found for it.
- This breakthrough in reducing the potential costs for brackish water desalting was significant because it focused interest, especially in the USA, on the potential to use desalting as a means to provide water for municipalities with limited fresh water supplies.

The Development of Desalting

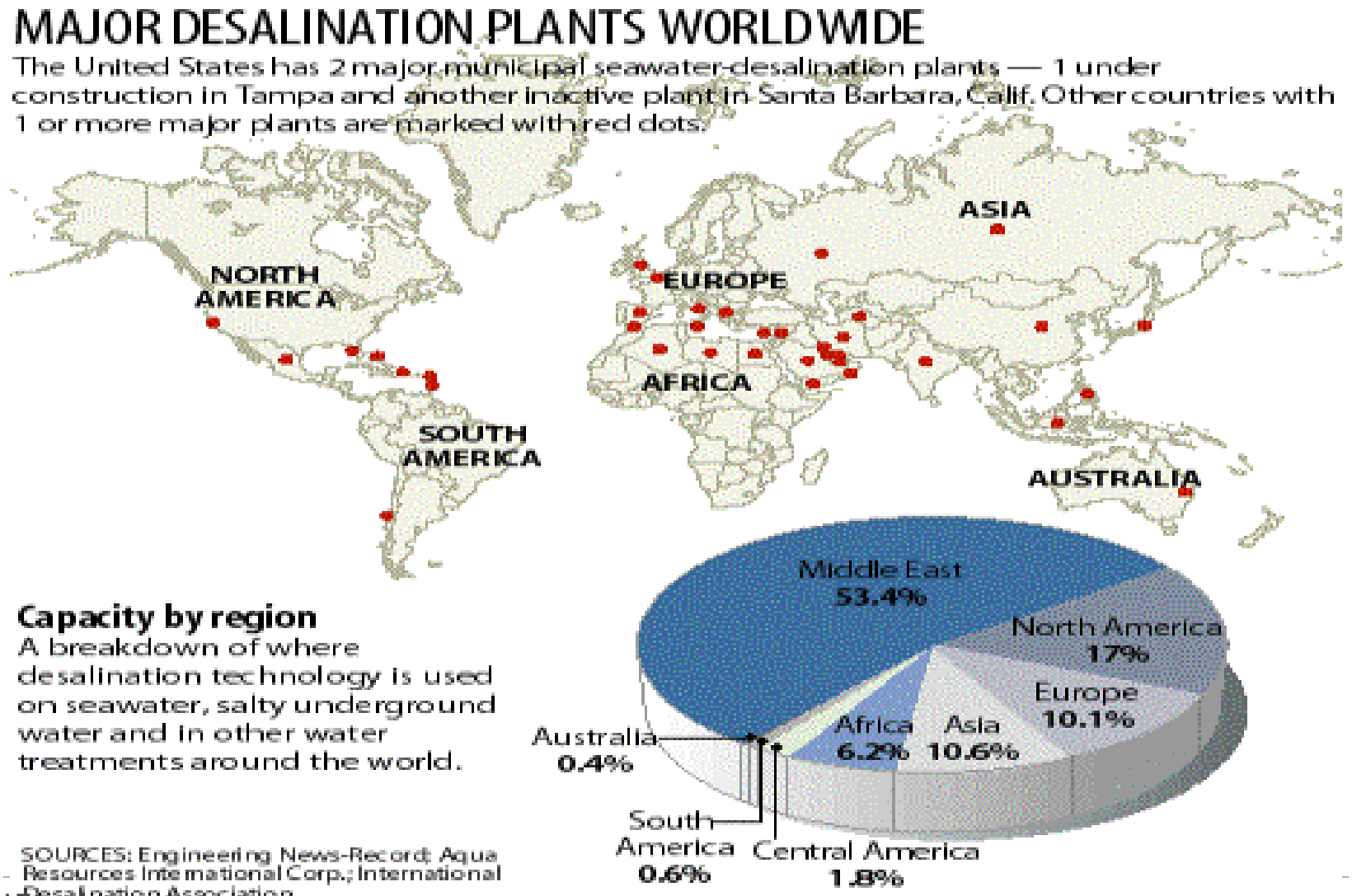
- By the 1980s, desalination technology was a fully commercial enterprise.
- The technology benefited from the operating experience achieved with the units that had been built and operated in the previous decades.
- By the 1990s, the use of desalting technologies for municipal water supplies had become commonplace.

- In the Arab world, four countries of the region are quite large in land area while seven countries are quite small.

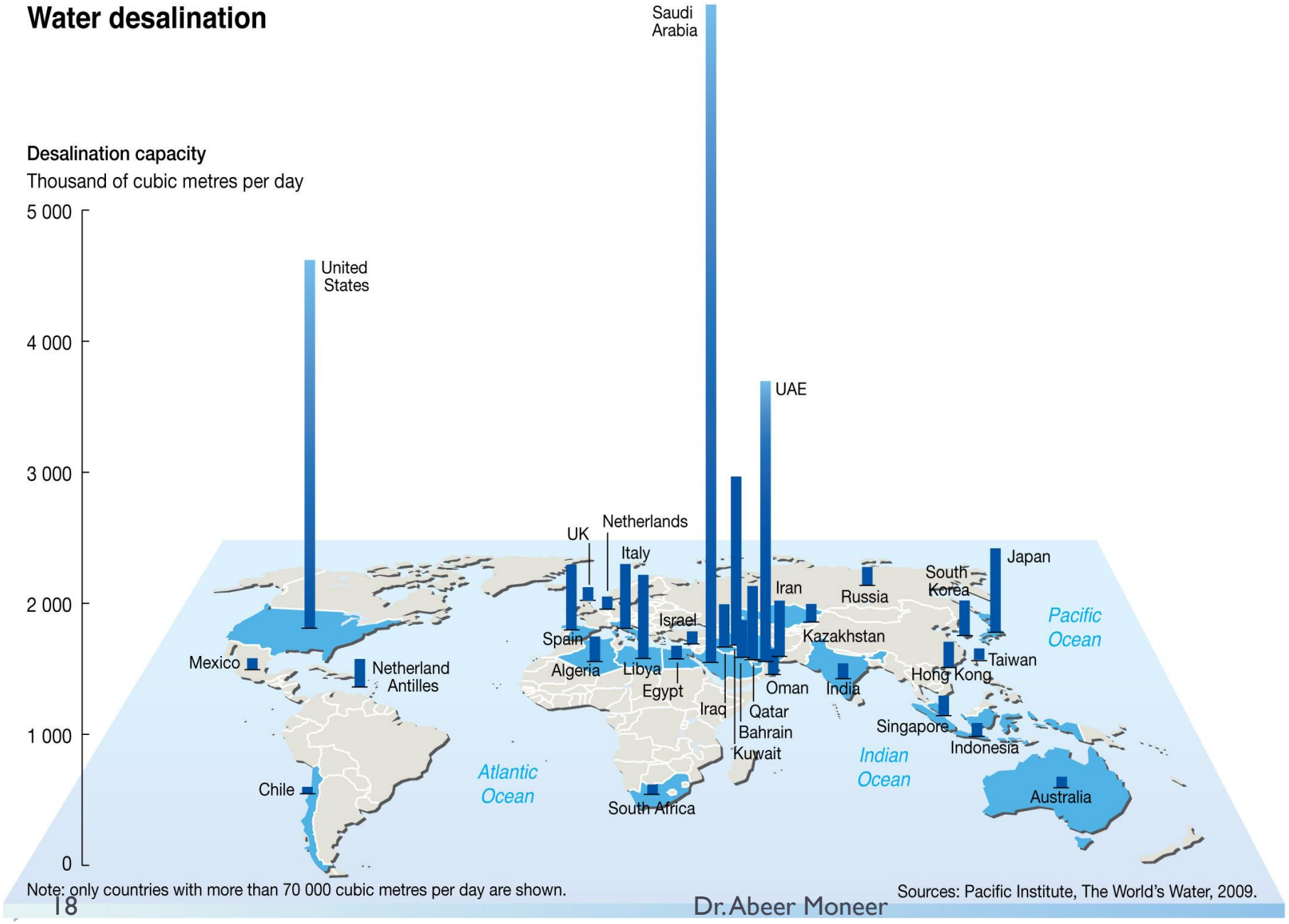
Desalination Technologies

- The arable lands in Arab world occupies a total area of about 1367 million hectares, where 22 countries extending from Arabian Gulf (east) to the Atlantic Ocean (west).
- The Arab region has very low rain fall and many of its parts have large unpredictable rain fall variations from year to year.

Desalination Technologies



Water desalination



Note: only countries with more than 70 000 cubic metres per day are shown.

Sources: Pacific Institute, The World's Water, 2009.

- The population and water resources (conventional and non-conventional) in Arab region

Region	Population (million)	Rainfall (mcm)	Conventional Resources			Unconventional Resources	
			Surface Water (mcm)	Ground water (mcm)		Desalination (mcm)	Reclaimed wastewater/ water reuse (mcm)
				Fossil Reservoir	Rechargeable		
Arab Mashreq: Jordan, Syria, Libanon, Palstine and Iraq	36.640	510	111,800	8,475	13,361	12	55
Arab Maghreb: Mauritania, Moracco, Algeria, Tunisia and Libya	64.70	290	44,800	20,030	1,546,867	19	70
Arabian Peninsula: Saudi Arabia, Kuwait, Bahrain, Qatar, U.A.E., Oman and Yemen	30.910	107	6,800	6,220	130,772	1,557	433
Central Region: Egypt, Sudan, Somalia and Djibouti	89.100	1,304	129,850	8,800	6,039,000	8	90
Total	221.620	2,211	293,250	43,525	7,730,000	1,596	648

- Levels of water stress in thirteen Arab countries, 2006

Critical water stress (More than 10,000 persons per million cubic metres)	**Serious water stress** (Between 5,000 and 10,000 persons per million cubic metres)	**Significant water stress** (Between 2,500 and 5,000 persons per million cubic metres)	**Slight water stress** (Less than 2,500 persons per million cubic metres)
Kuwait	Bahrain	Jordan	Egypt
UAE	Iraq	Saudi Arabia	Lebanon
	Occupied Palestinian Territory		Oman
	Qatar		Syria
	Yemen		

Source: UN-ESCWA 2007.

- Water scarcity in Arab world

Afghanistan
China
Czech Republic
Germany
Ghana
India
Iran
Kenya
Mali
Poland
Togo
Senegal
South Korea
Romania
Ukraine
Armenia
Azerbaijan
Bangladesh
Belgium
Burkina Faso
Dominican Republic
Hungary
Iraq
Malawi
South Africa
Turkmenistan
Algeria
Bahrain
Egypt
Eritrea
Israel
Jordan
Lebanon
Libya
Mauritania
Moldova
Morocco
Namibia
Netherlands
Niger
Oman
Pakistan
Qatar
Rwanda
Saudi Arabia
Somalia
Syria
Tunisia
Uganda
United Arab Emirates
Uzbekistan
Western Sahara
Yemen

Stress
Scarcity
Extreme Scarcity

Regions that will face WATER SCARCITY by 2025

Desalination Technologies

- A variety of desalting technologies have been developed over the years and, based on their **commercial success**, they can be classified into **major** and **minor** desalting processes.

Desalination Technologies

Major Desalination Processes:

1- Thermal Processes:

a. Multi-stage flash distillation (MSF).

b. Multi-effect distillation (MED).

c. Vapor compression distillation (VCD).

2- Membrane Processes:

a. Electrodialysis (ED) and Electrodialysis reverse (EDR).

b. Reverse Osmosis (RO).

Minor Desalination Processes:

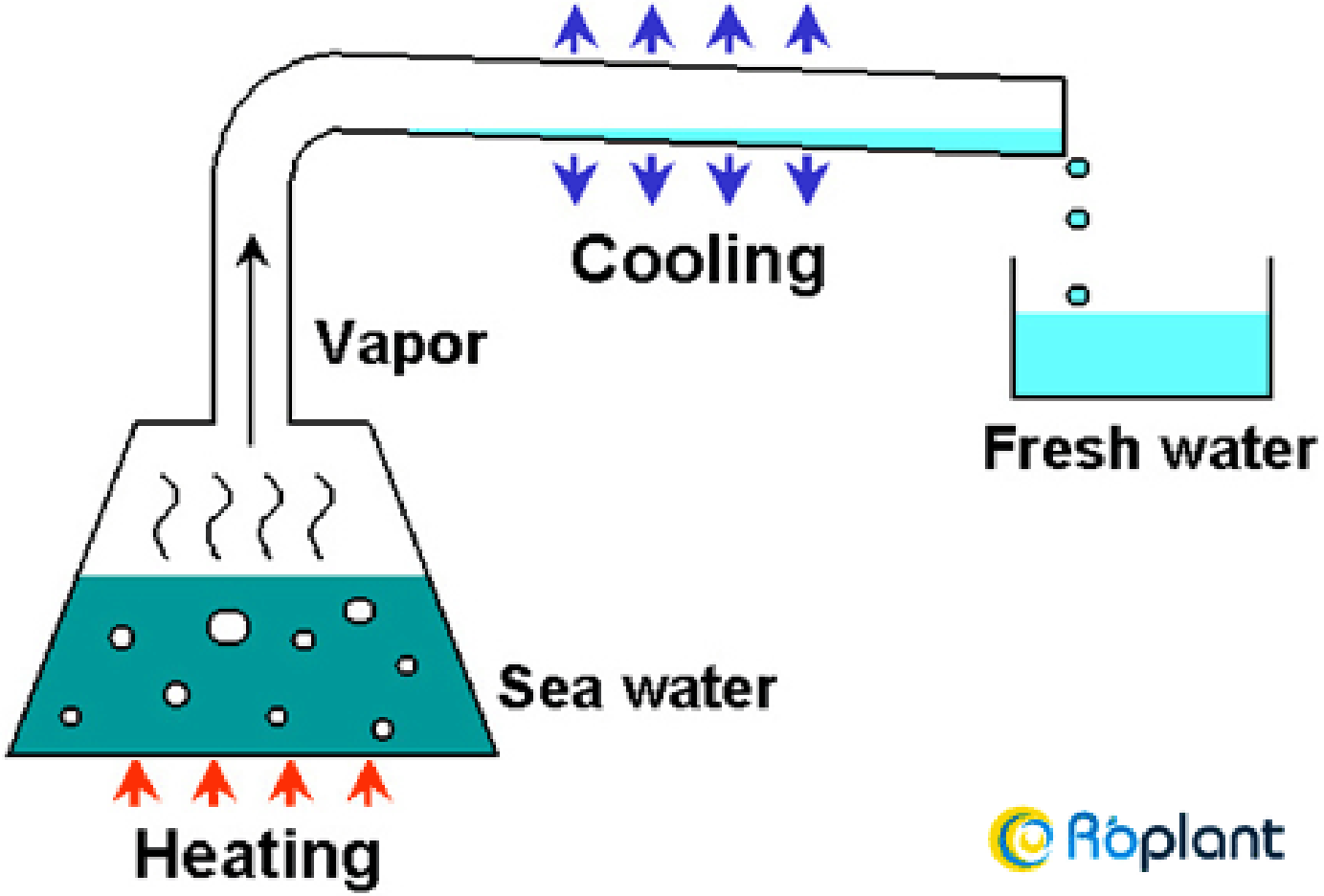
a. Freezing (Fr).
b. Membrane distillation (MD).
c. Solar distillation (SD).
d. Electrosorptive deionization (EDI) or capacitive deionization (CDI).
e. Ion exchange (IE).
f. Pervaporation (PV).
g. Liquid membrane (LM).
h. Humidification-Dehumidification (H-D).

MSF and RO processes make-up about 86% of the world's total capacity.

The remaining 14% is made up of the MED, ED and VCD processes.

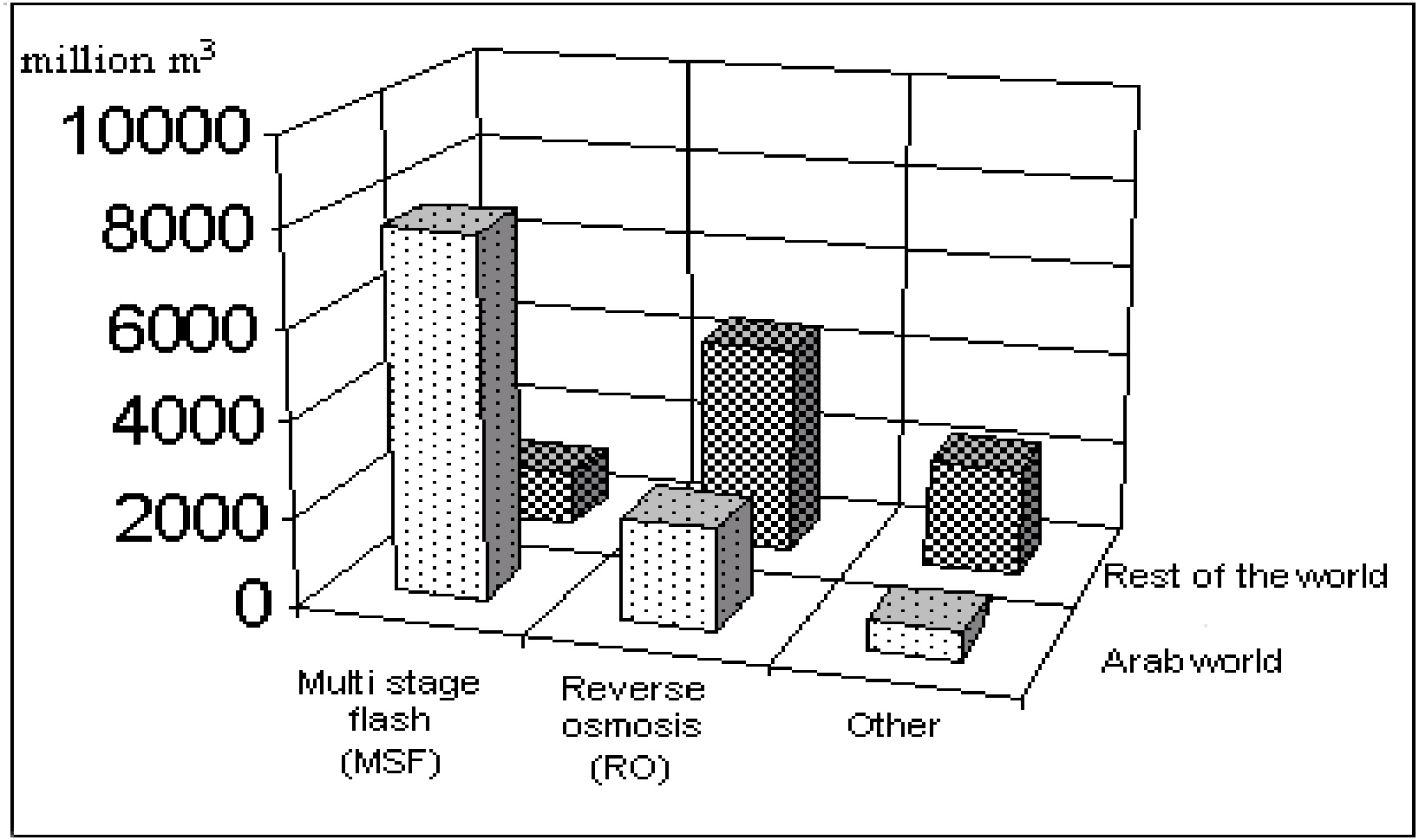
The minor processes amount to <1%.

Desalination Technologies



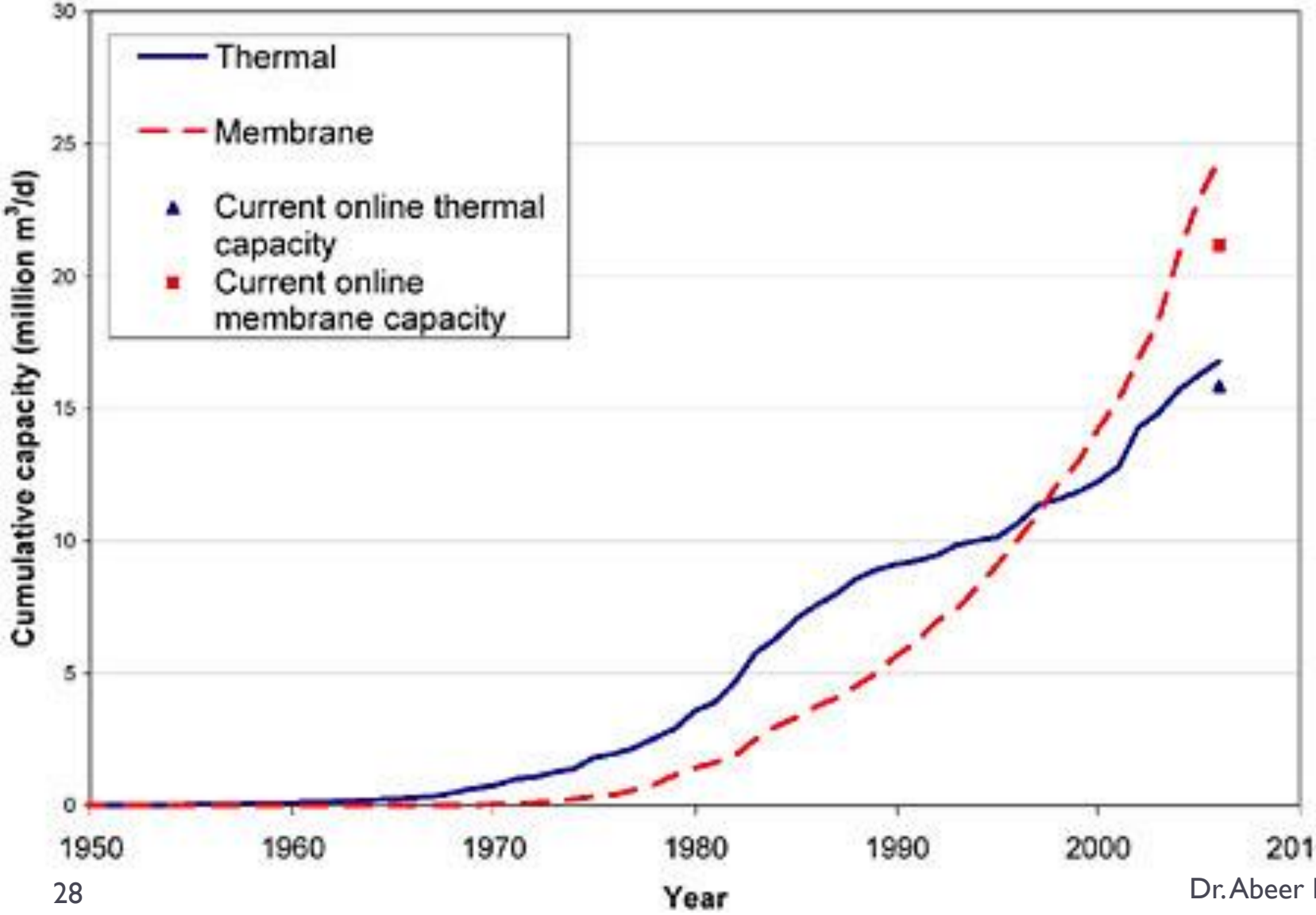
〈Thermal Desalination Principle〉

Desalination Technologies

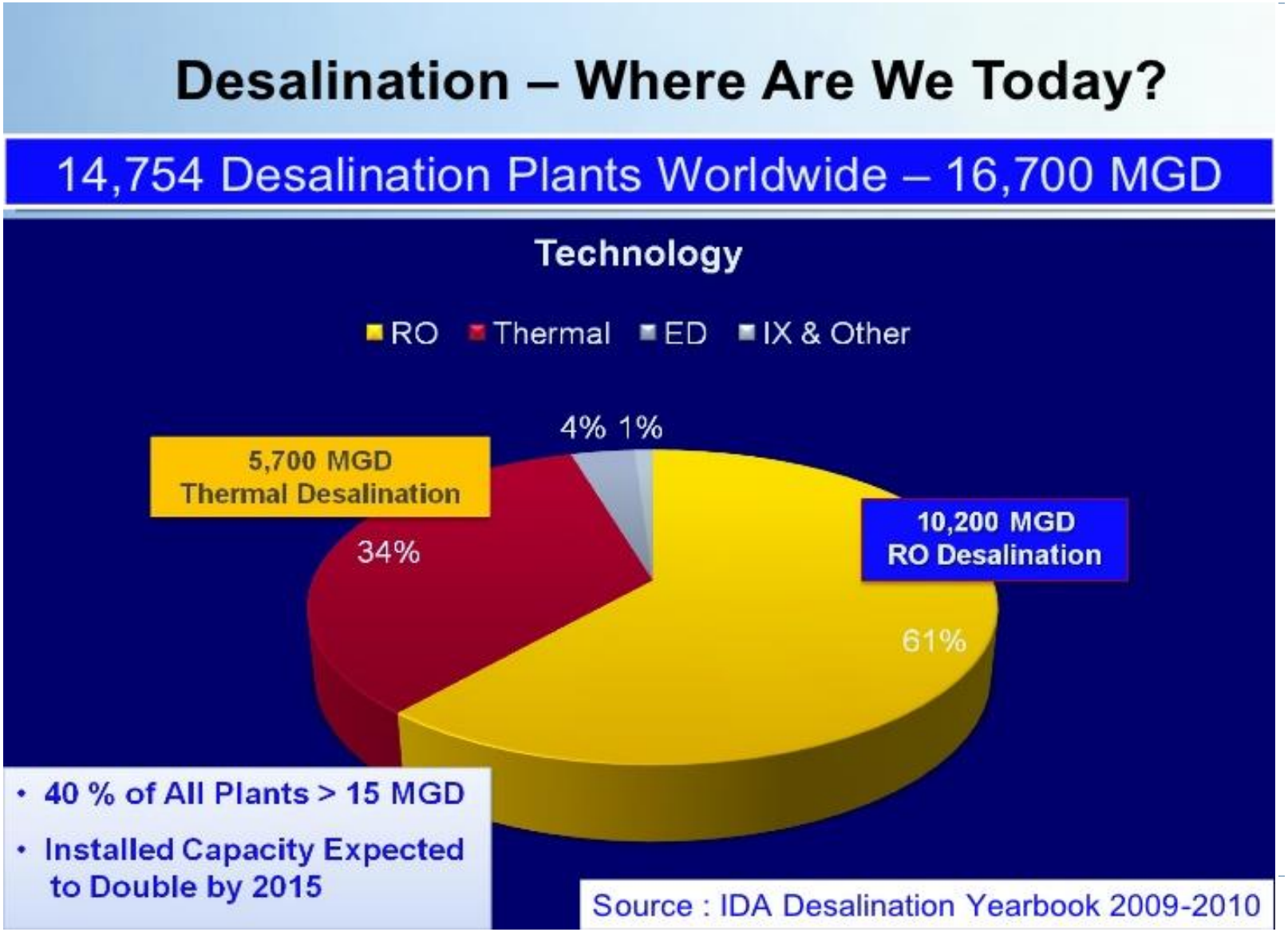


Source: Dabbagh, Belhag (1997)

Desalination Technologies



Desalination Technologies



Desalination in Egypt

- Water is the backbone of our economy as safe and sustainable water supply is vital for various economic activities i.e. Agriculture, industry, and human consumption.
- As a nation we are facing increasing water supply challenges in form of demand growth due to population growth and the expected decrease of existing resources in the near future due to several reasons.

Challenges Facing the Water Sector

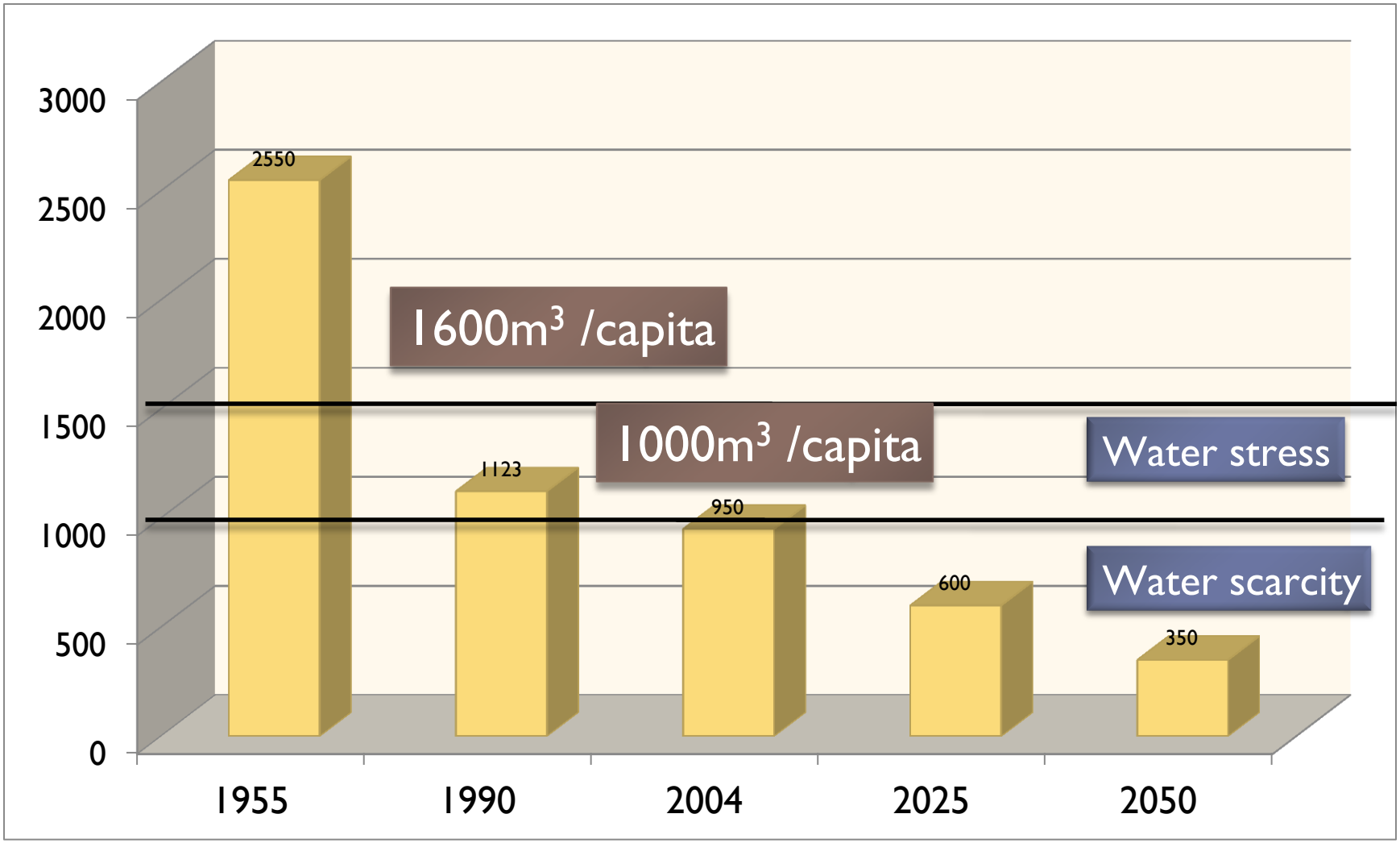
- Rapid growth and unbalanced distribution of the population.
- Rapid urbanization.
- Water quality deterioration.
- Government's policy to reclaim new land.
- Unsustainable water practices.

These constraints developed a situation which places higher demand on water resources far exceeding the available supply and are imposing limits on the economic development of the country.

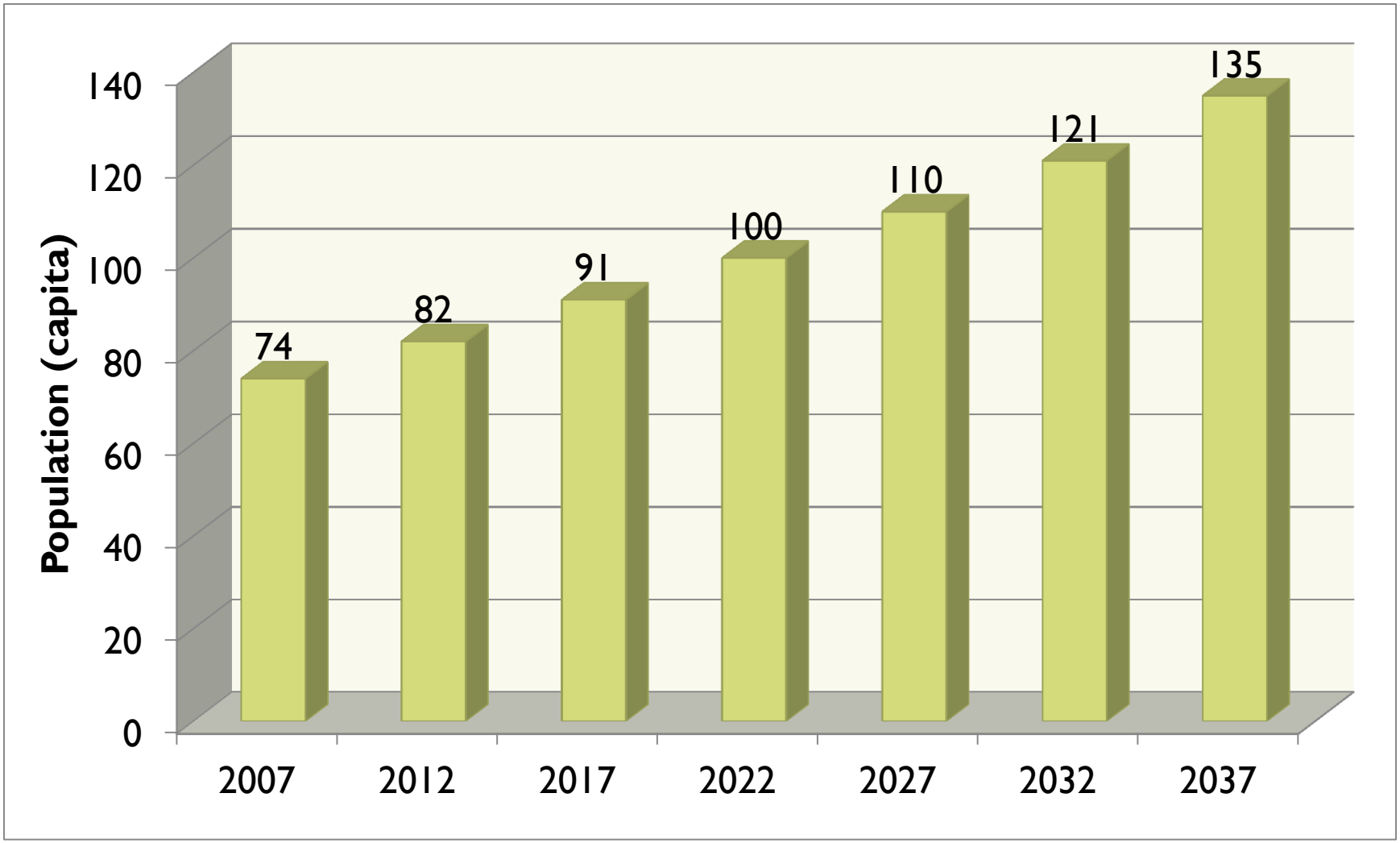
Desalination in Egypt

- In order to face these challenges the following must be considered:
- Optimize the use of unconventional sources of water:
- Wastewater reuse
- Desalination
- Rain harvesting
- Ground water

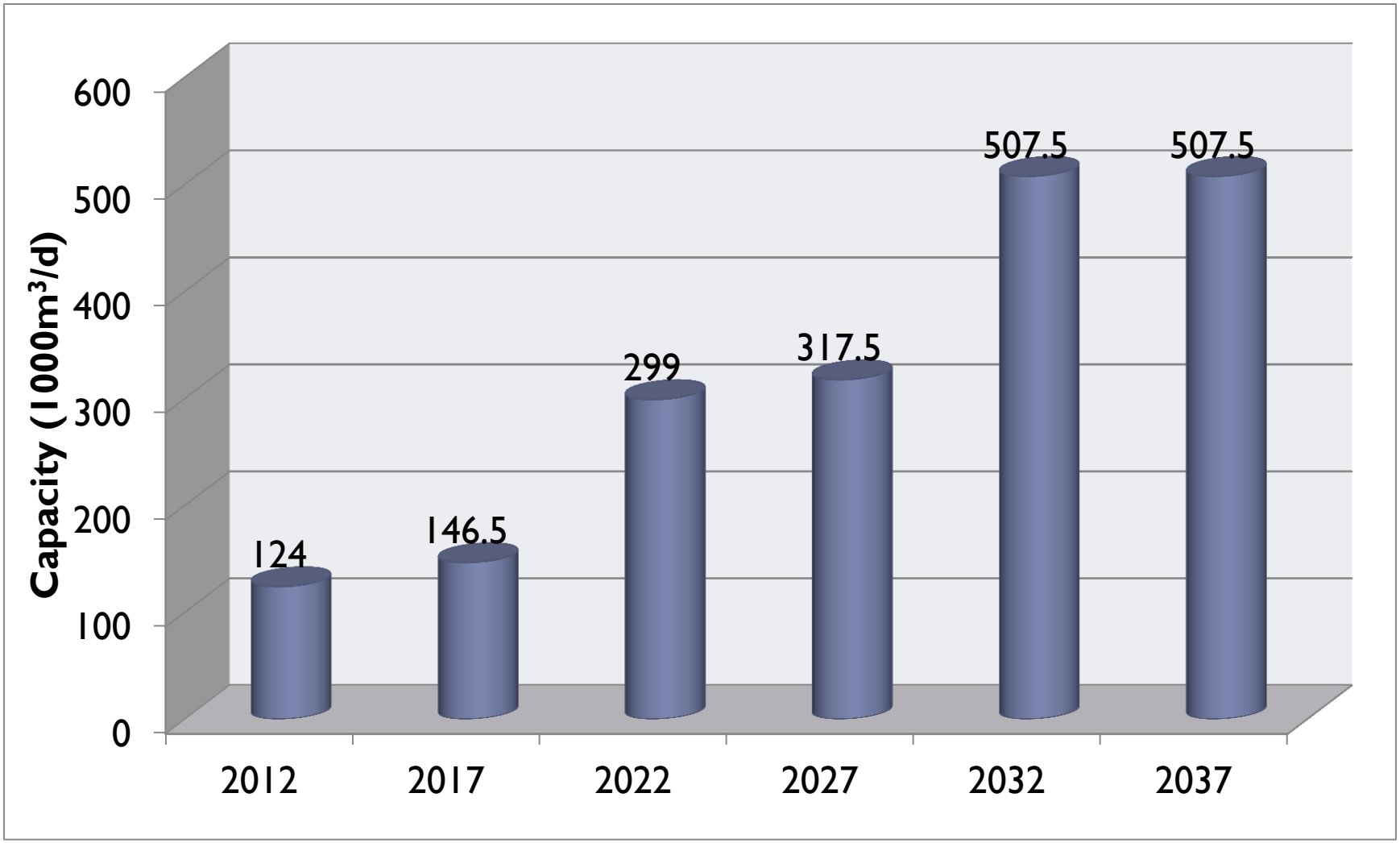
Water supply and water demand in Egypt



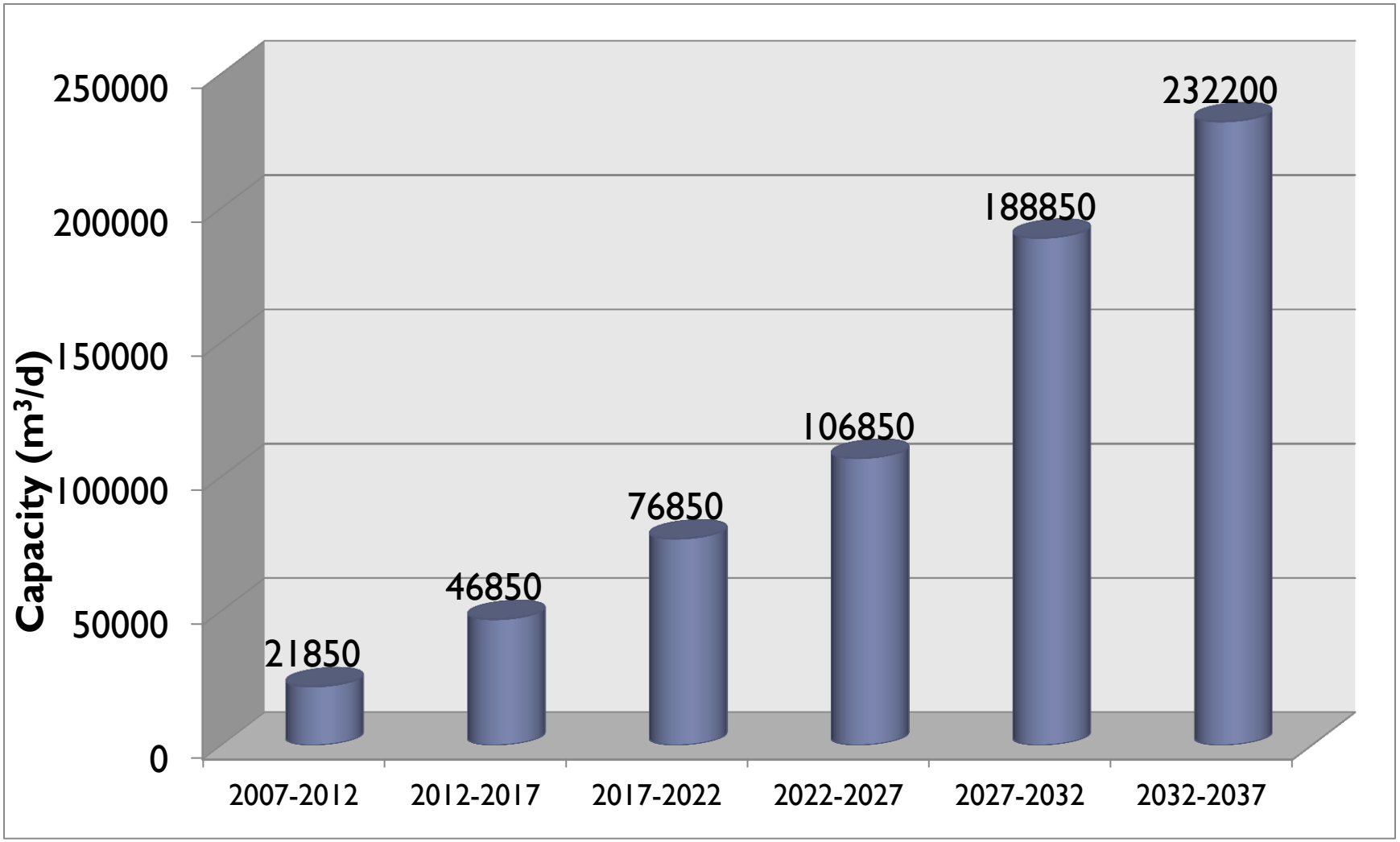
Population Growth



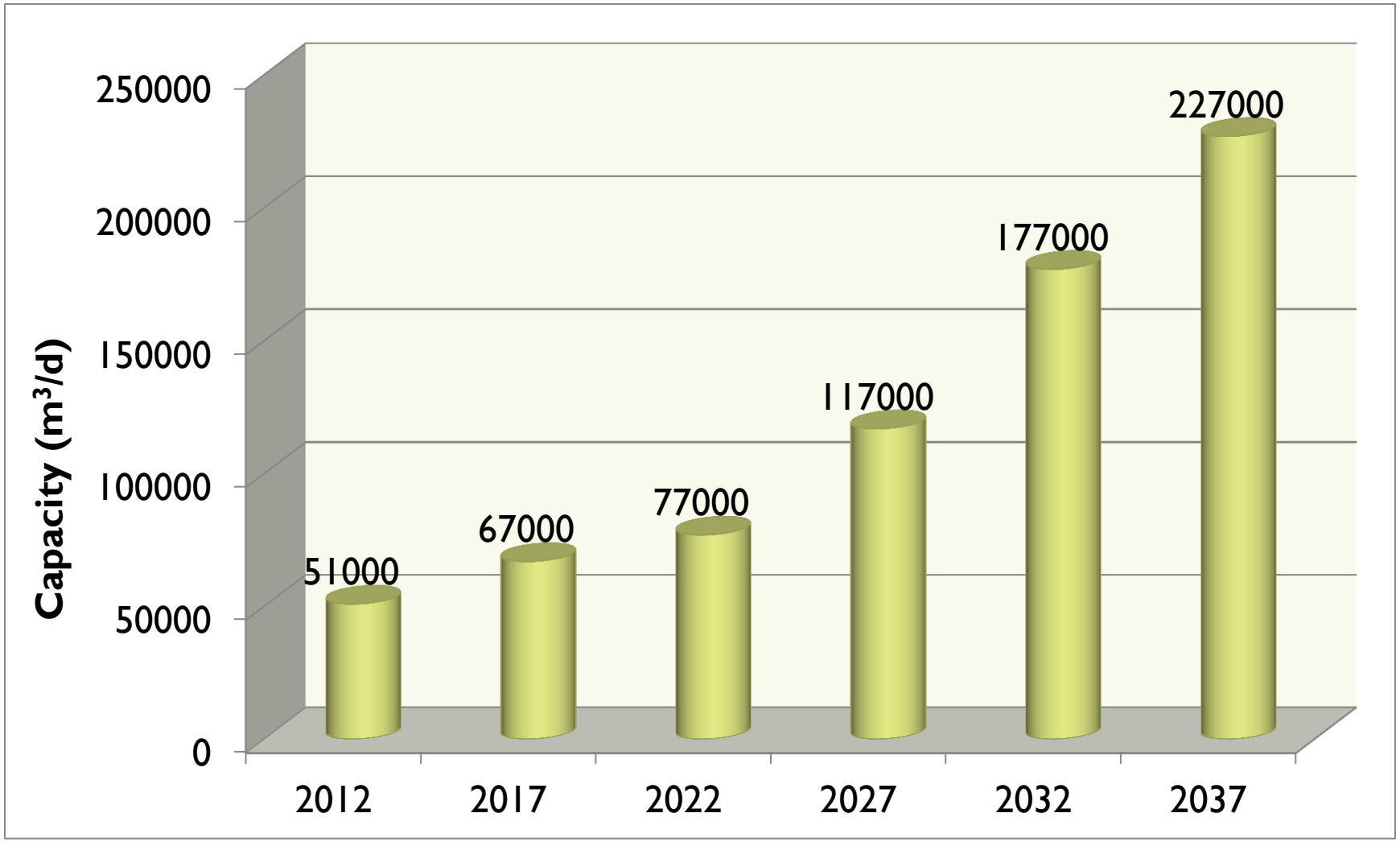
Total capacity for desalination plants in Red sea till 2037



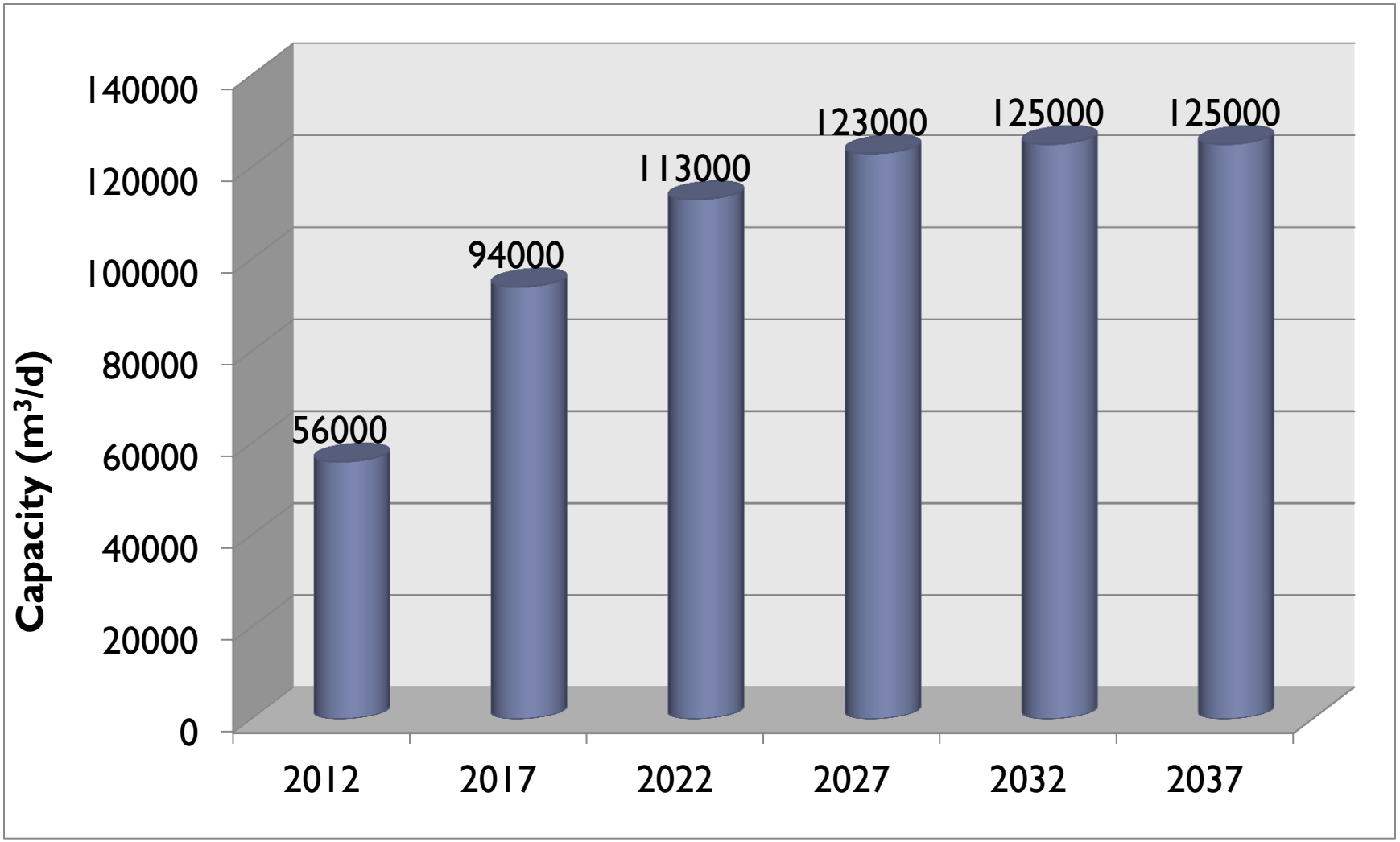
Total capacity for desalination plants in North Sinai till 2037



Total capacity for desalination plants in South Sinai till 2037



Total capacity for desalination plants in Matrouh till 2037



Questions:

- Answer with Yes or No and correct the false statements:

1. Desalination is also called desalinization or desalting.
2. Desalting refers to a process that removes organic material from water.
3. Potable water should contain less than 0.5g salts/L (500ppm).
4. Potable water can only be used for domestic purposes and irrigation and not industrially.
5. Brackish water and sea water contain about 32 and 10g salts/L respectively.
6. 95% of the earth's surface is covered by salty water.

Questions:

- Choose the correct answer:

1. Desalination technologies are divided into:

A) Major processes and membrane processes.

B) Thermal processes and minor processes.

C) Major processes and minor processes.

2. Minor desalination processes include:

A) MD, HD of air and EDR

B) Freezing, EDI and IE

C) ED, MD and VCD