



تحت رعاية معالي رئيس مجلس الوزراء المصري المهندس شريف إسماعيل  
مؤتمر تحلية المياه الحادي عشر في البلدان العربية

UNDER THE PATRONAGE OF THE EGYPTIAN PRIME MINISTER ENGINEER SHERIF ISMAIL

11<sup>TH</sup> WATER DISALINATION CONFERENCE IN THE ARAB COUNTRIES

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# Forward, Reverse and Hybrid Osmosis Systems: Recent Developments and Future Challenges

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تنظيم

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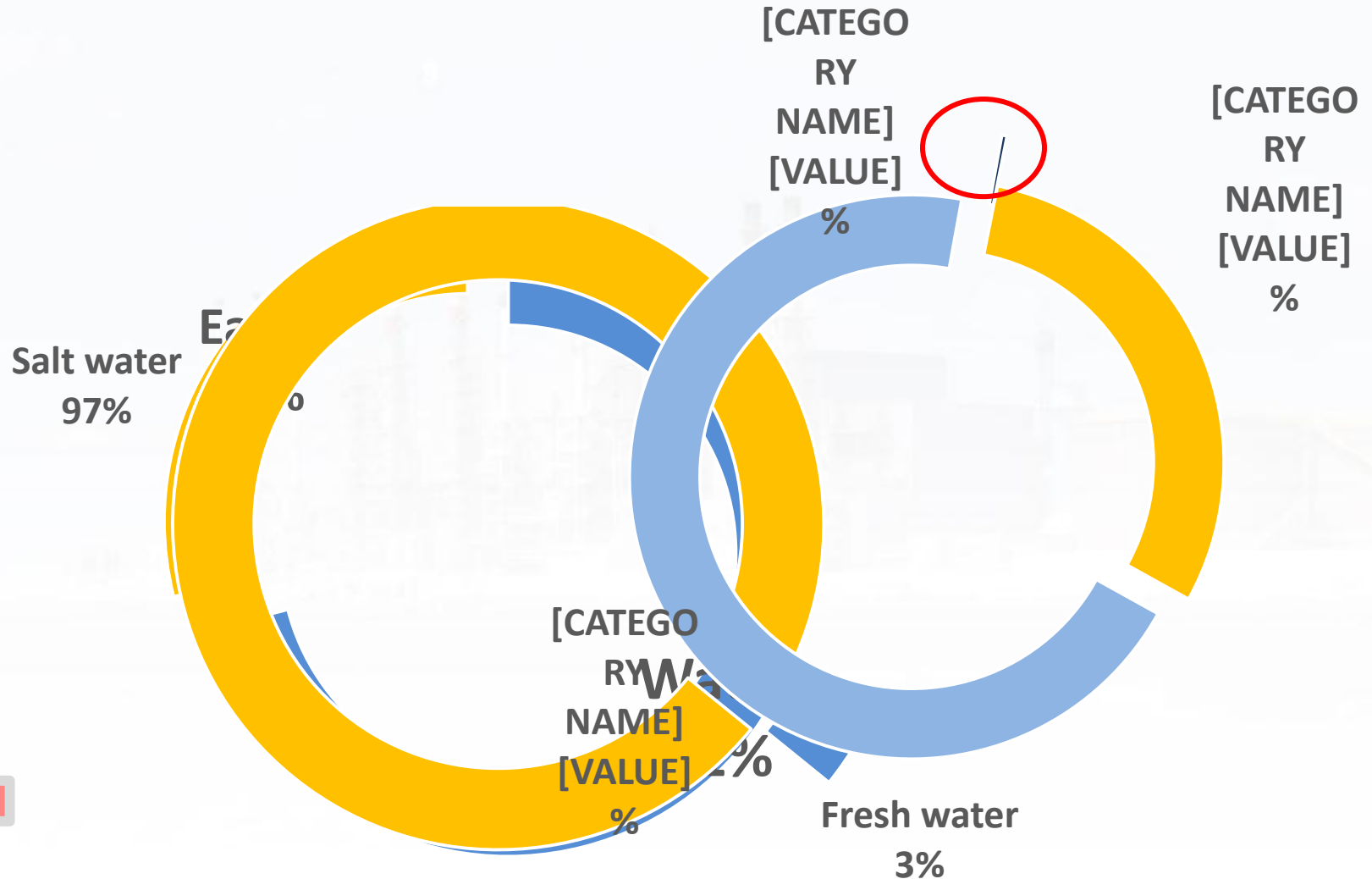


# Contents

- Introduction.
- Forward Osmosis (FO).
- Reverse Osmosis(RO).
- Hybrid Systems (HS).
- Recommendations, Remarks and Conclusions.



# Introduction



# Introduction

## Desalination Techniques:

- Reverse Osmosis (RO)
- Forward Osmosis (FO)
- Membrane Distillation
- Biological Desalination
- Freezing Desalination
- Multi Stage Flash Distillation (MSF)
- Hybrid systems
- Others



# Introduction

**Global Desalination capacity  
66.4 Million m<sup>3</sup>/Day**

**Reverse Osmosis  
and Membrane  
Softening  
60%**

**Multi-stage Flash  
26%**

**Others  
1%**

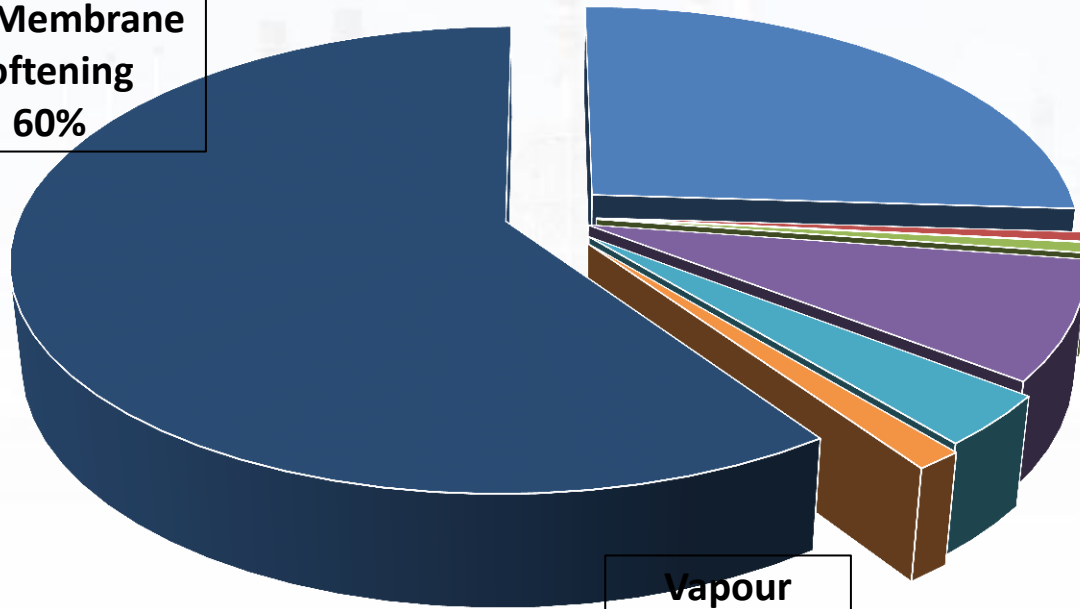
**Hybrid systems  
1%**

**Multi-effect  
Distillation  
8%**

**Electrodialysis  
3%**

**Vapour  
Compression  
1%**

**Desalination capacities by technology  
(as of first quarter of 2012) -**



# Introduction

## Water desalination

Desalination capacity

Thousand of cubic metres per day

5 000

4 000

3 000

2 000

1 000

0

United States

Saudi Arabia

UAE

UK

Netherlands

Italy

Spain

Algeria

Libya

Egypt

Iraq

South Africa

Qatar

Bahrain

Kuwait

Oman

Iran

Kazakhstan

India

Russia

South Korea

Hong Kong

Taiwan

Japan

Singapore

Indonesia

Australia

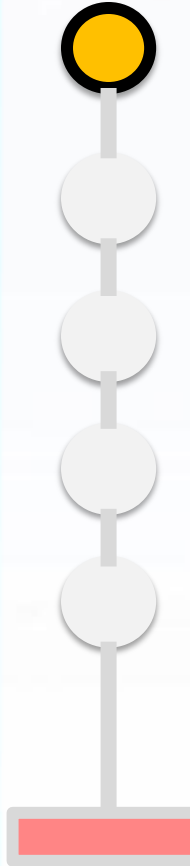
Atlantic Ocean

Indian Ocean

Pacific Ocean

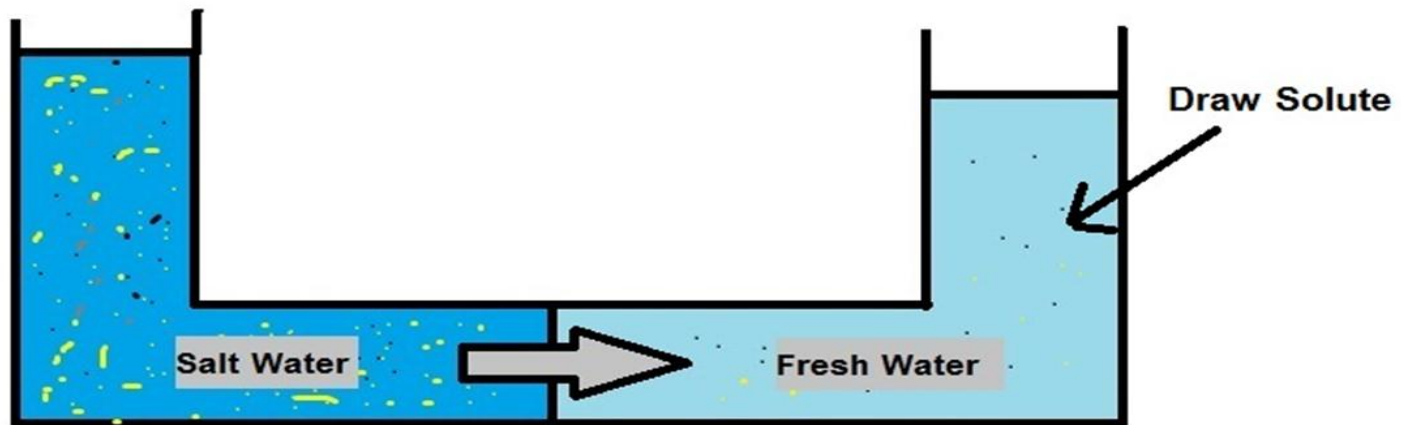
Note: only countries with more than 70 000 cubic metres per day are shown.

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



# Forward Osmosis (FO)

- Background & Principles.
- Energy Consumption & Cost.
- Recent Developments.
- Future challenges.

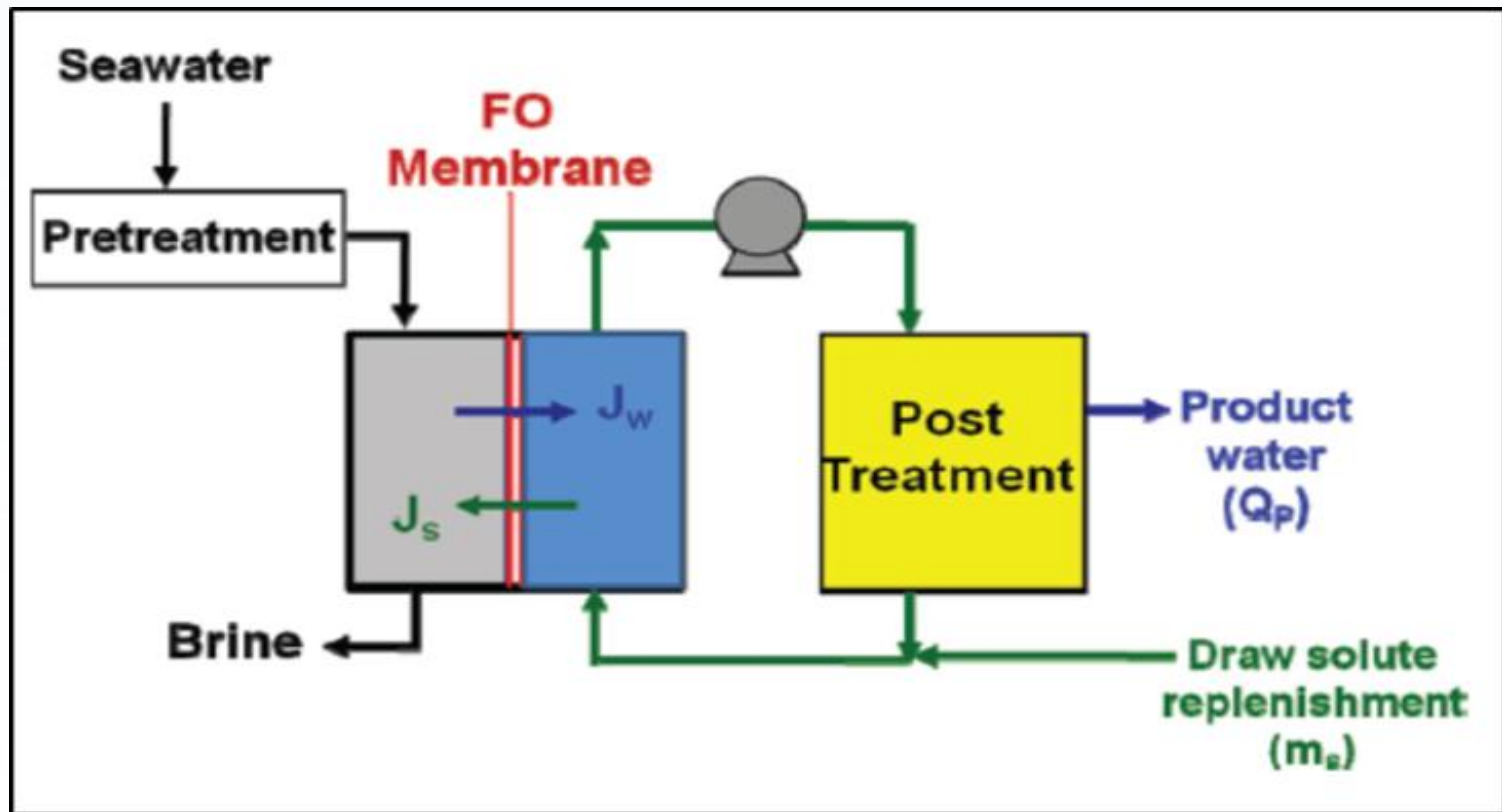


Forward Osmosis (FO) process



# Forward Osmosis (FO)

- Background & Principles:





# Forward Osmosis (FO)

- **Energy Consumption & Cost:**

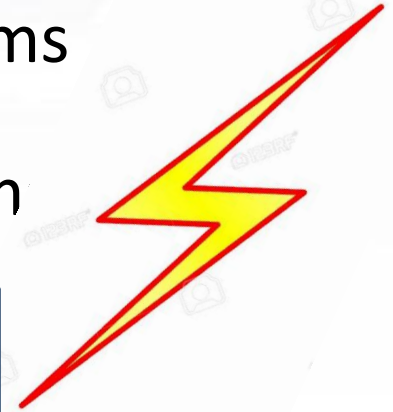
Q: Is the FO technique more Energy efficient than conventional membrane desalination?

FO < Conventional Membrane systems

FO = Conventional Membrane systems

FO > Conventional Membrane system

More Studies are Critically needed

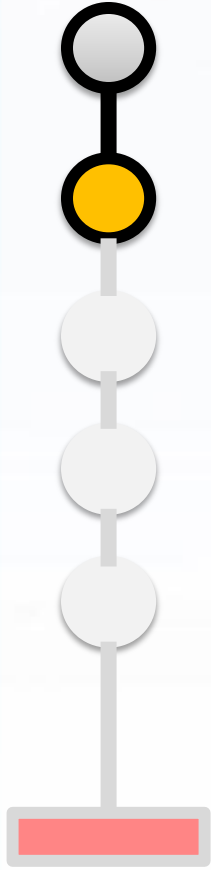


# Forward Osmosis (FO)

- **Recent Developments and Future Challenges:**

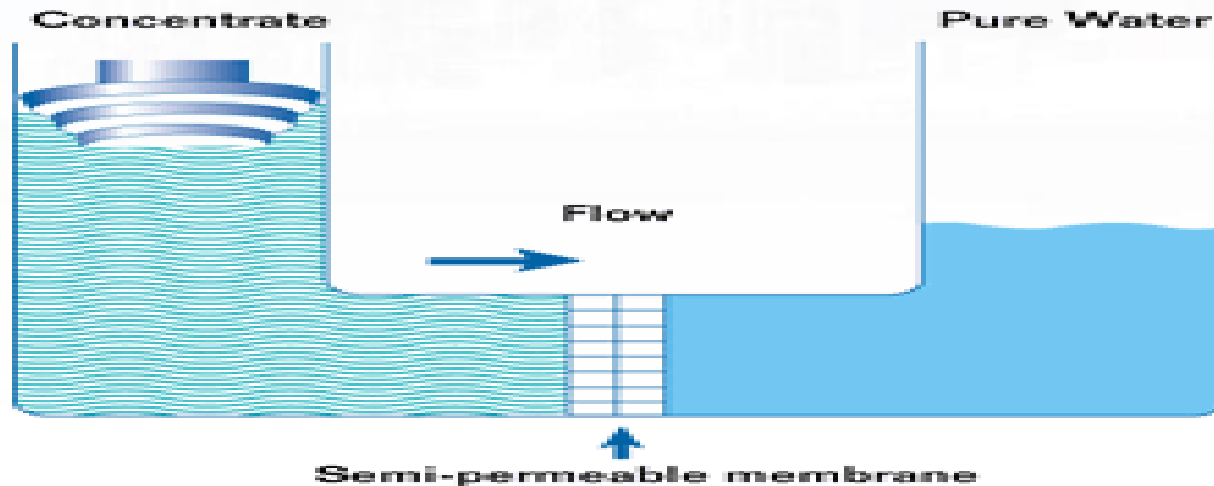
Areas of Developments and future researches include:

- Draw Solutes.
- Membrane materials and Characteristics.
- Energy consumption estimation.
- Overall cost assessment in comparison with other conventional desalination technologies.



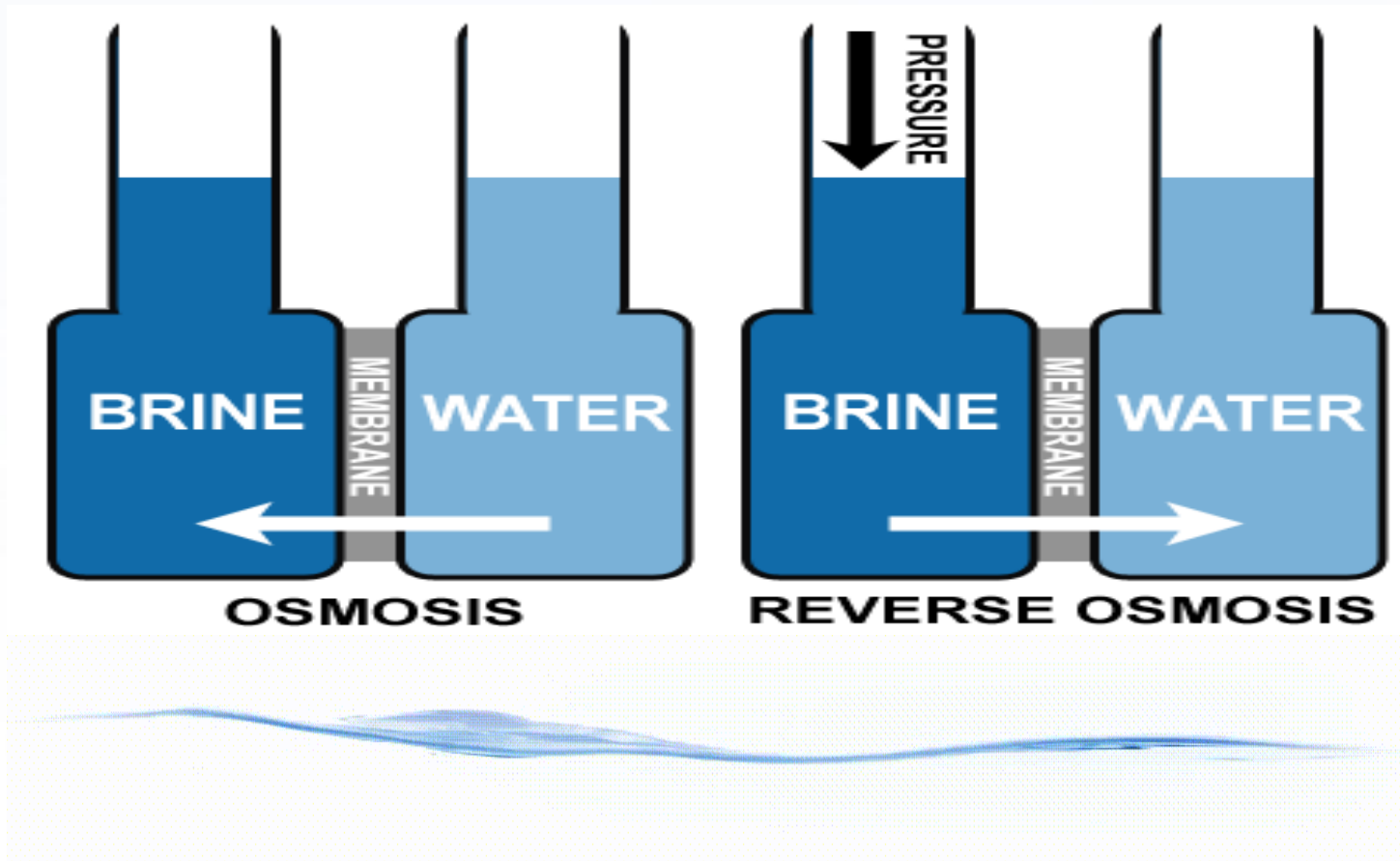
# Reverse Osmosis (RO)

- Background & Principles.
- Energy Consumption & Cost.
- Recent Developments.
- Future challenges.



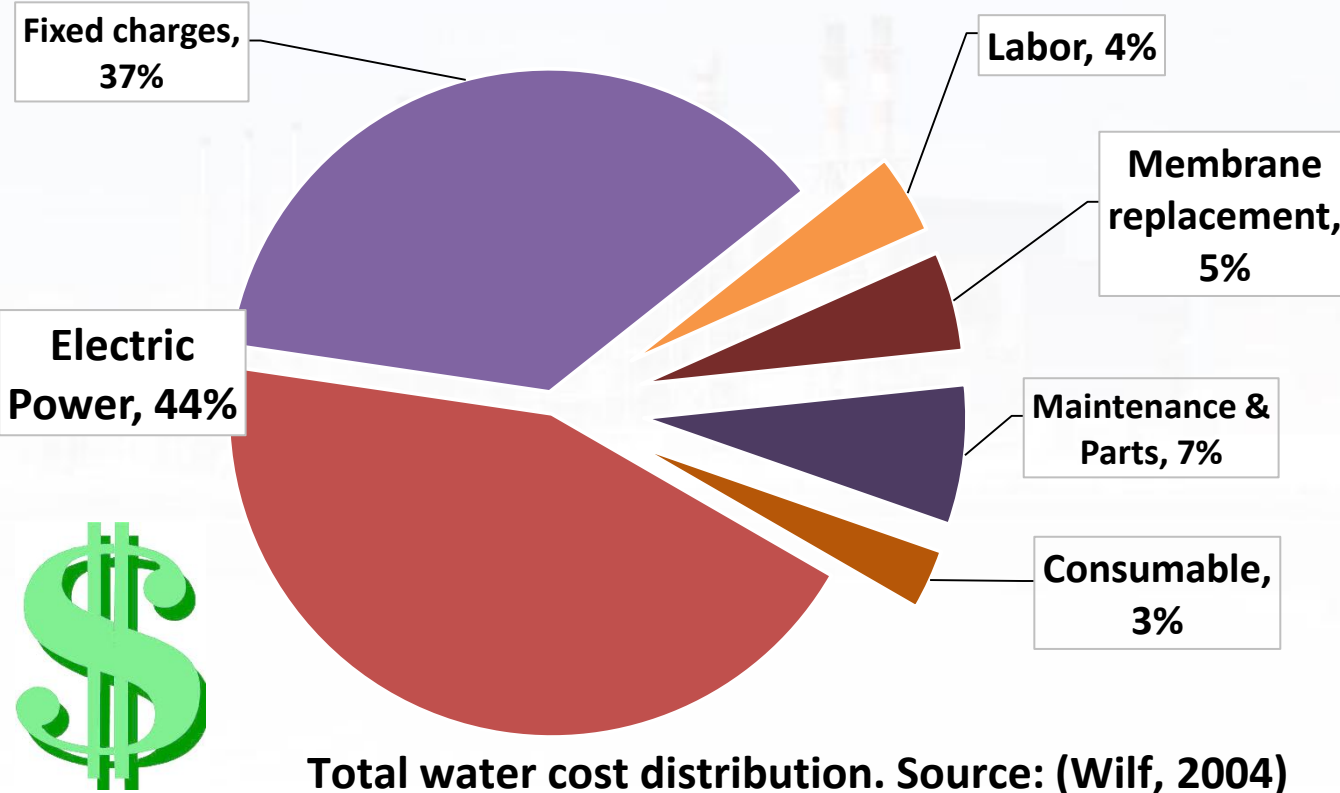
# Reverse Osmosis (RO)

- Background & Principles:



# Reverse Osmosis (RO)

- **Energy Consumption & Cost:**



Total water cost distribution. Source: (Wilf, 2004)

# Reverse Osmosis (RO)

- **Energy Consumption & Cost:**

First High  
pressure  
pump, 81%

Pretreatment  
system, 2%

Sea water  
supply, 4%

Miscellaneous,  
2%

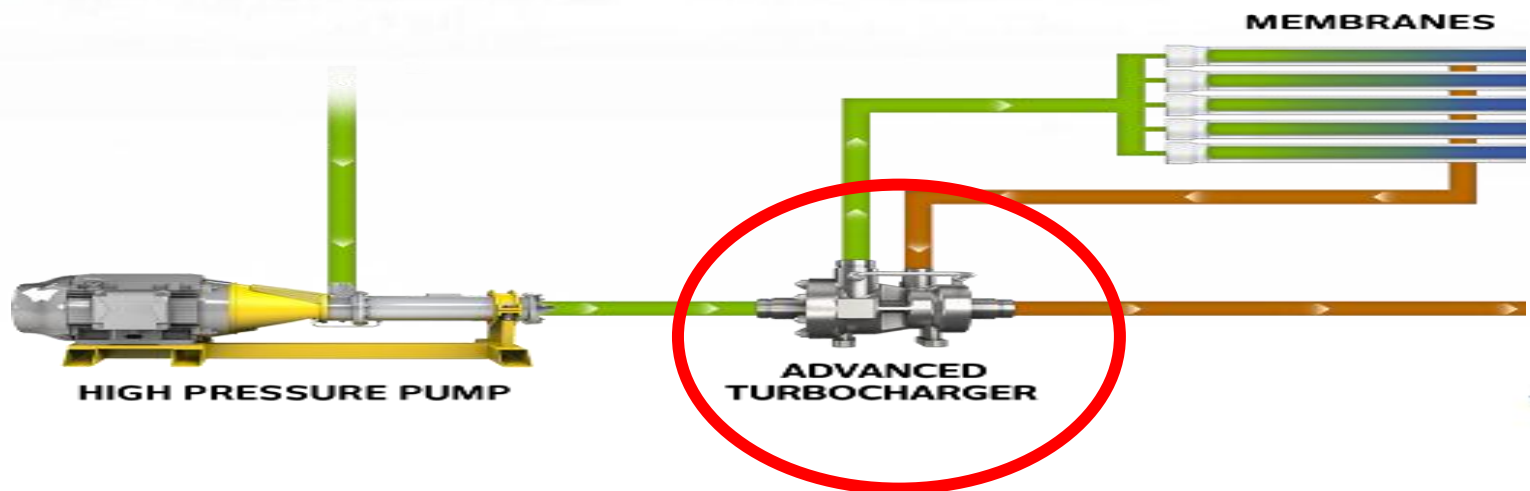
product transfere  
pump, 7%

Second High  
pressure pump,  
4%

Energy consumption of different process stages (Malaeb & Ayoub, 2011).

# Reverse Osmosis (RO)

- **Energy Consumption & Cost:**
- Cost Reduction pathways:
  1. High flux membranes. (Fouling resistant membranes)
  2. More efficient Energy recovery devices.



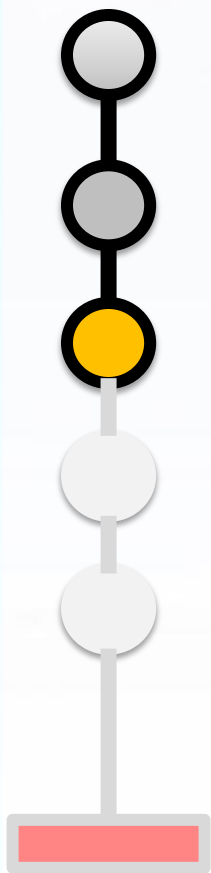


# Reverse Osmosis (RO)

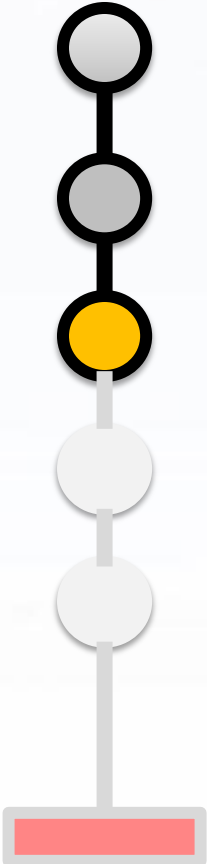
- **Recent Developments :**

Areas of Developments and future researches include:

- Cost Reduction Methodologies.
- Development of high flux membranes.
- Studies in Cost Estimation and Performance Evaluation.

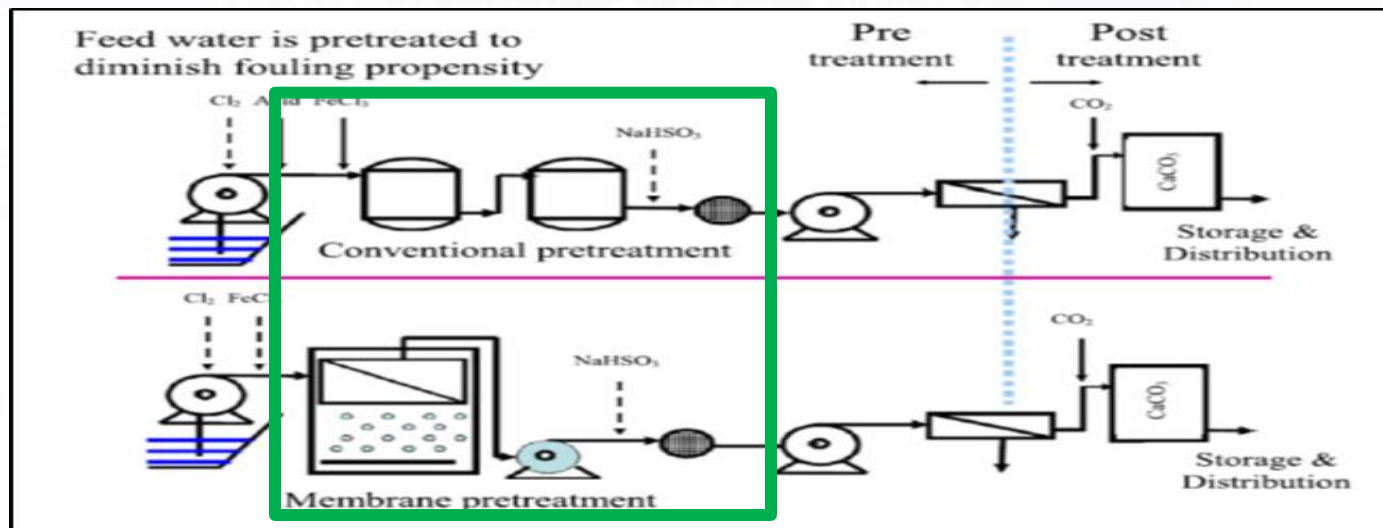


# Reverse Osmosis (RO)

- 
- A vertical decorative bar on the left side of the slide. It consists of a series of circles connected by a vertical line. From top to bottom, the circles are: a white circle with a black outline, a grey circle with a black outline, a yellow circle with a black outline, and three more white circles with black outlines. At the bottom of the bar is a red rectangular block.
- **Future Challenges :**
  - Handling of RO rejected waste.
  - Direct and Indirect costs for brine discharge.
  - Reduction of Membrane Fouling.
  - Evaluation of RO process in pharmaceuticals removal.
  - Studying DBPs removal using RO technology.

# Hybrid Systems (HS)

- Background & Principles.
- Energy Consumption & Cost.
- Recent Developments.
- Future Challenges.



# Hybrid Systems (HS)

- Background & Principles:

**Membrane  
Desalination**

+

**Adsorption**

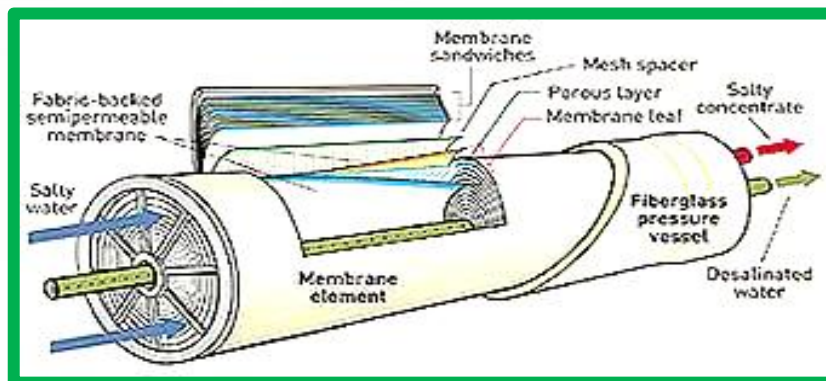
**Coagulation**

**Ion Exchange**

**Nano Filtration**

**Forward Osmosis**

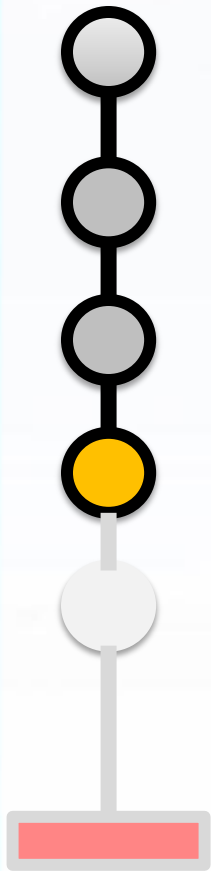
**Other Techniques**



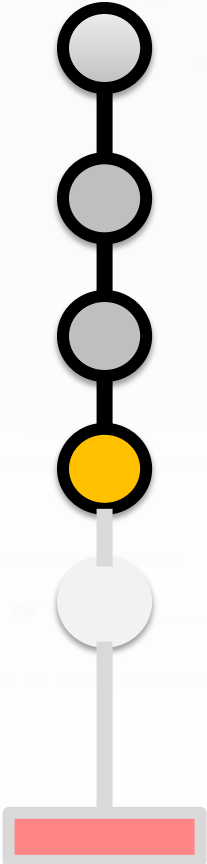
# Hybrid Systems (HS)

- **Energy consumption and Cost:**

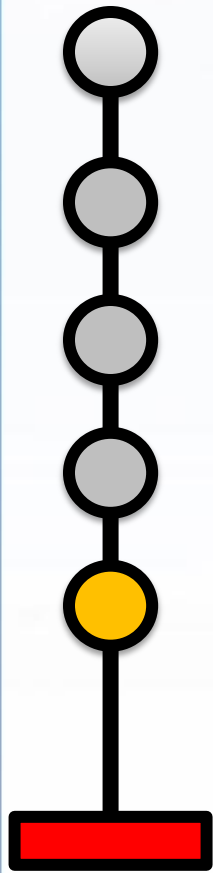
- Energy and cost is very dependent on the design and components of the hybrid system.
- No adequate information on the cost estimate of Hybrid systems.
- Developing membranes, energy reduction and recovery devices will subsequently improve the performance of integrated systems.



# Hybrid Systems (HS)

- 
- A decorative vertical bar on the left side of the slide. It consists of a vertical line with five circles. The top four circles are grey, and the bottom circle is yellow. Below the circles is a red rectangle.
- **Developments and Future challenges:**
  - Economic and Environmental feasibility of different hybrid systems is still unclear.
  - An integrated study for different hybrid systems is crucially needed.
  - Feed water oriented system design should be studied in deep with reference to the financial dimension.

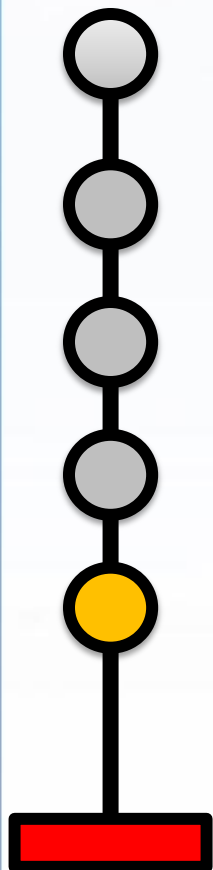
# Recommendations, Remarks & Conclusions



- More research efforts are needed on draw solutes to push FO applications.
- The main two drawbacks regarding RO technology is membrane fouling and Energy consumption.
- New research efforts have added a lot to the development of high flux membranes and cost moderation in RO Systems.

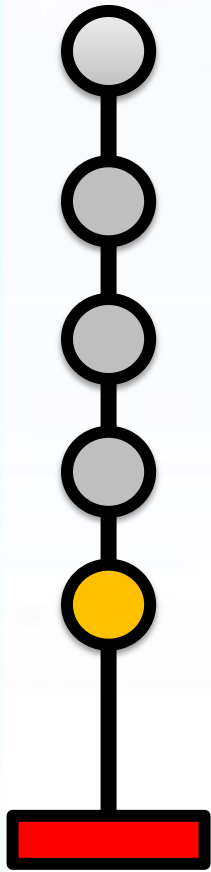


# Recommendations, Remarks & Conclusions

- 
- A decorative vertical bar on the left side of the slide. It consists of a vertical line with five circles stacked on top of each other. The top four circles are grey, and the bottom circle is yellow. Below the circles is a solid red rectangle.
- Developments have been accomplished in Cost estimation and Performance Evaluation of desalination systems.
  - Technical, Economic and Ecological Data analysis programs have introduced a perfect help for decision makers to choose the most suitable system for each case.
  - There is still an information gap in terms of the economic and environmental feasibility of hybrid membrane systems.

# Recommendations, Remarks & Conclusions

- Resources, Needs, and Quality of feed water should be taken into consideration during Hybrid systems designing.
- Hybrid Systems represent the cure for different obstacles faced desalination using conventional methods if used in the right way.





THANK  
YOU