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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

11TH WATER DISALINATION CONFERENCE IN THE ARAB COUNTRIES

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جامعة قطر
QATAR UNIVERSITY

INNOVATIVE APPROACHES FOR SUSTAINABLE ENERGY EFFICIENT SWRO DESALINATION

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CAM
مركز المواد المتقدمة
Center for Advanced Materials

بالتعاون مع

Holding Company for Water & Waste Water

وزارة الاسكان والمرافق والمجتمعات العمرانية

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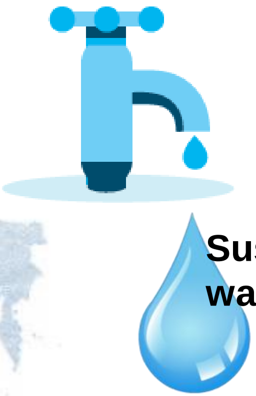
متعاونوا الدورات السابقة

Introduction

Global Needs for Desalination



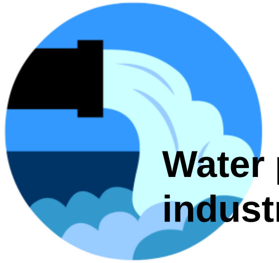
Sustainability of current water resources

Population growth increases potable water demand

Constant exploitation of natural resources by agricultural users

Portable water shortage due to natural disasters (earthquake, flood, etc.)

Climate change-Longer droughts are likely as weather patterns change



Water pollution due to industrial discharge/run off

Introduction-Desalination Facts

- It provides **22.9 billion US gallons**, equivalent of 86.8 million cubic meters per day (as of June 30, 2015)
- Approximately **18,426 desalination plants** worldwide (End of Dec 2015).
- Total installed production capacity of **86.55 million m^3/day** (equivalent to 22,870 million gallons per day (MGD)).
- Around **44%** of this capacity is located in the Middle East and North Africa.
- More than 300 million of people around the world who rely on desalinated water for some or all their daily needs

IDA website, March 2017

Qatar Scenario…

- *Seawater Desalination is strategically important to the State of Qatar*
- *Water stress is rising due to rapidly growing demands from population growth, industrialization, urbanization and agriculture*
- Qatar Nation Vision 2030:*The scarcity of renewable water resources and the escalating competition for water is a major challenge in the sustainable development agenda for Qatar*
- *Innovative desalination technologies that minimize both cost of water production and the environmental impact should be further investigated*
- *QNRS: Energy and Environment Pillar-Water Desalination*
- *Grand Challenges: Water*

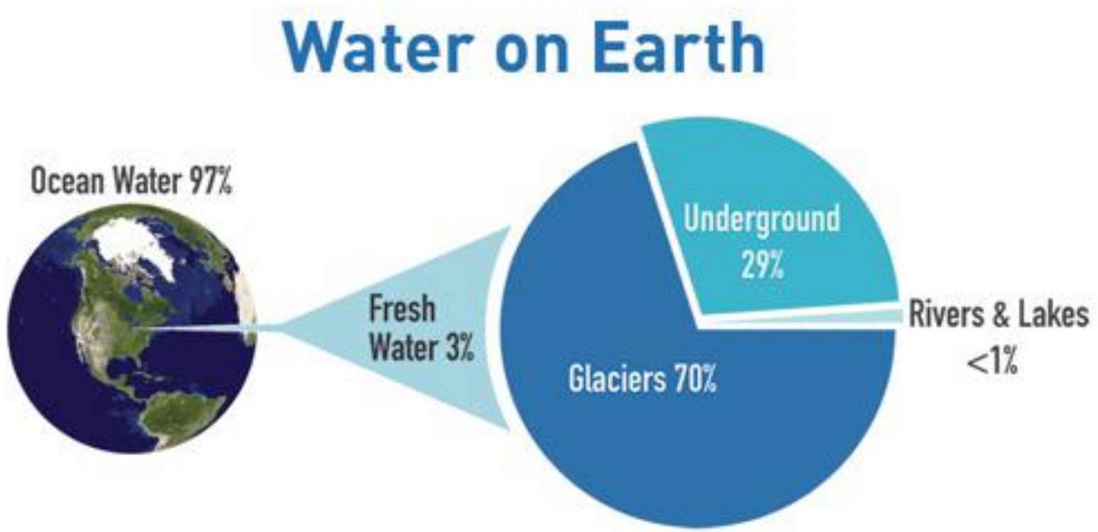
Sources: Qatar Nation Vision 2030

Sustainability in Desalination

Why Desalination is the RIGHT choice?

FACT: Desalination is not cheaper compared to conventional water treatment.

BUT, with all the water we have…



Desalination can provide a sustainable source of freshwater:

- for coastal cities that have either limited or no dependable freshwater sources.
- to ensure an adequate and essentially drought-proof supply of freshwater.

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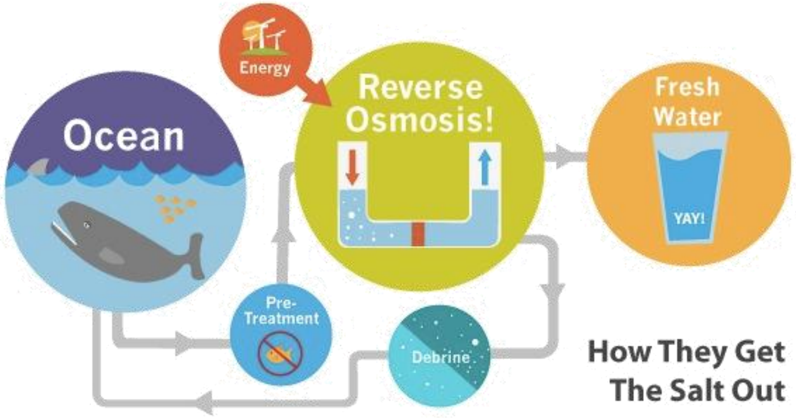
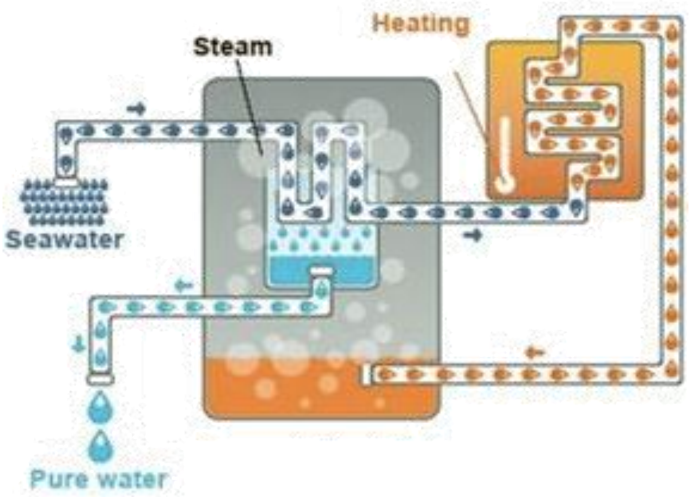
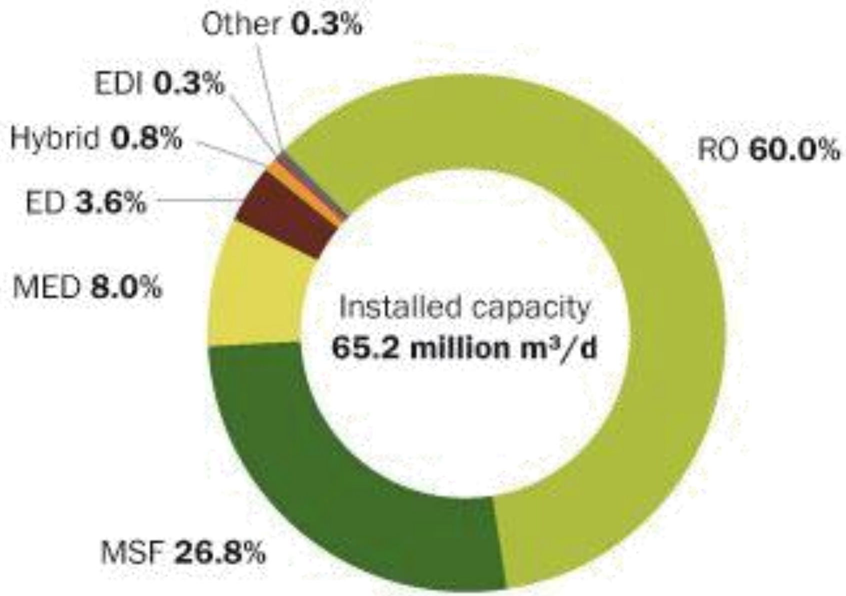
Major Desalination Technology



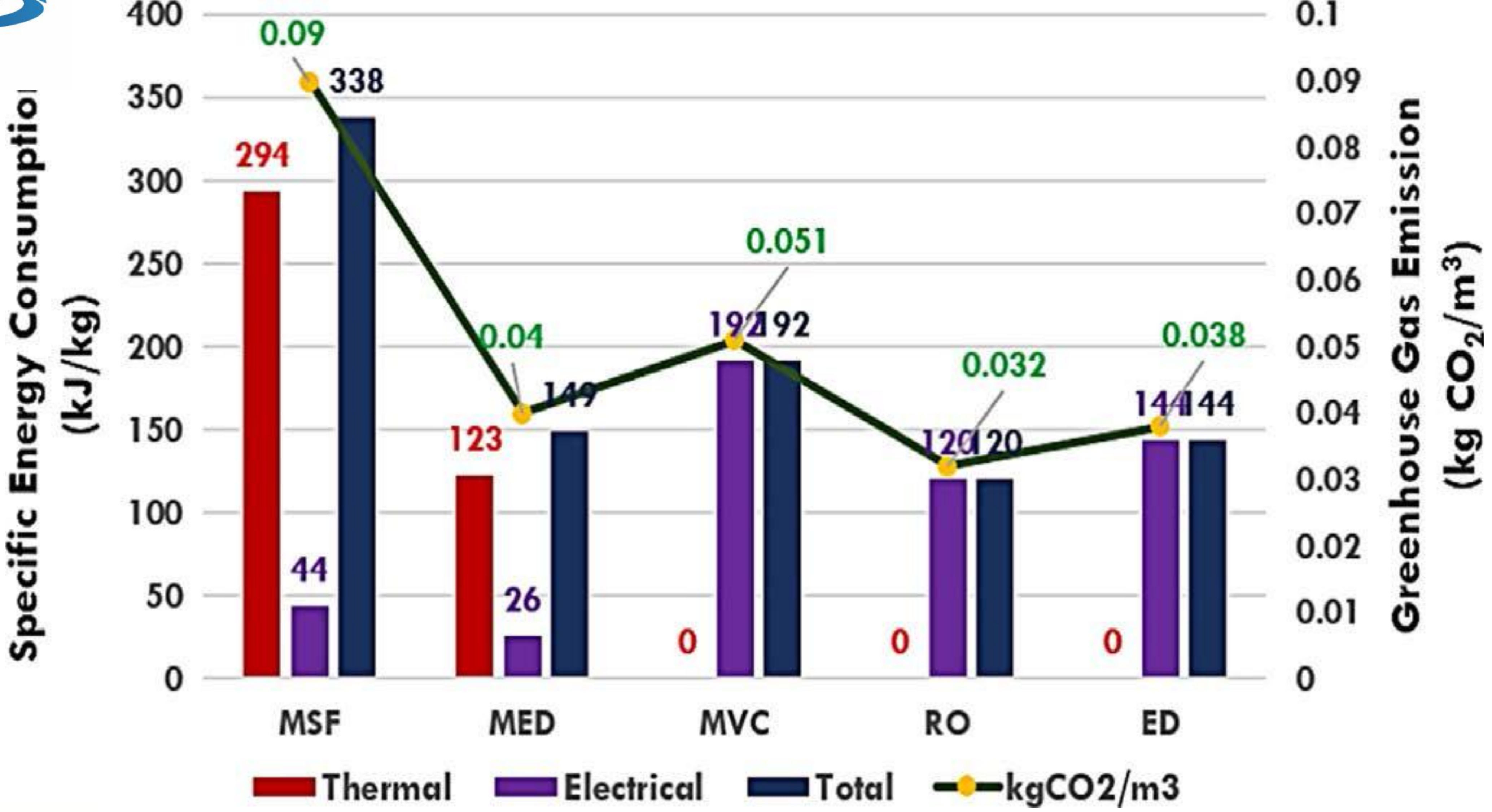
MEMBRANE



DISTILLATION



The specific energy consumption for thermal and membrane desalination processes, SWRO consumes much less energy compared to thermal processes

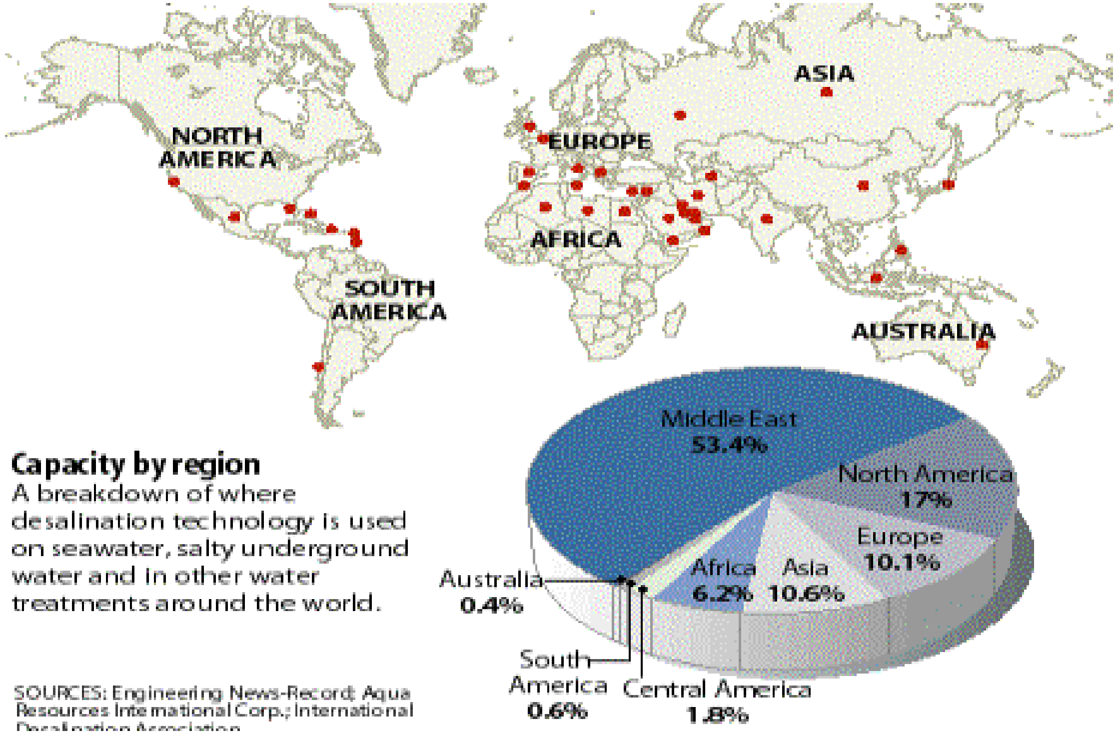


Introduction

SWRO plants installed worldwide in recent years

Location	Capacity (m^3 desalinated water/day)	Start-up Year
Almeria, Spain	~100,000	2015
Carlsbad, United States	~190,000	2015
KAUST, Saudi Arabia	15,000	2014
Oran, Algeria	500,000	2014
Teshi, Ghana	60,000	2014
Al Jubail, Saudi Arabia	58,500	2013
Tuas, Singapore	318,500	2013
Ashdod, Israel	~274,00	2013
Ajman, United Arab Emirates	115,000	2012
Hebei, China	50,000	2012
Tangshan, China	110,000	2012

Note: 1 m^3 = 1000 Liters



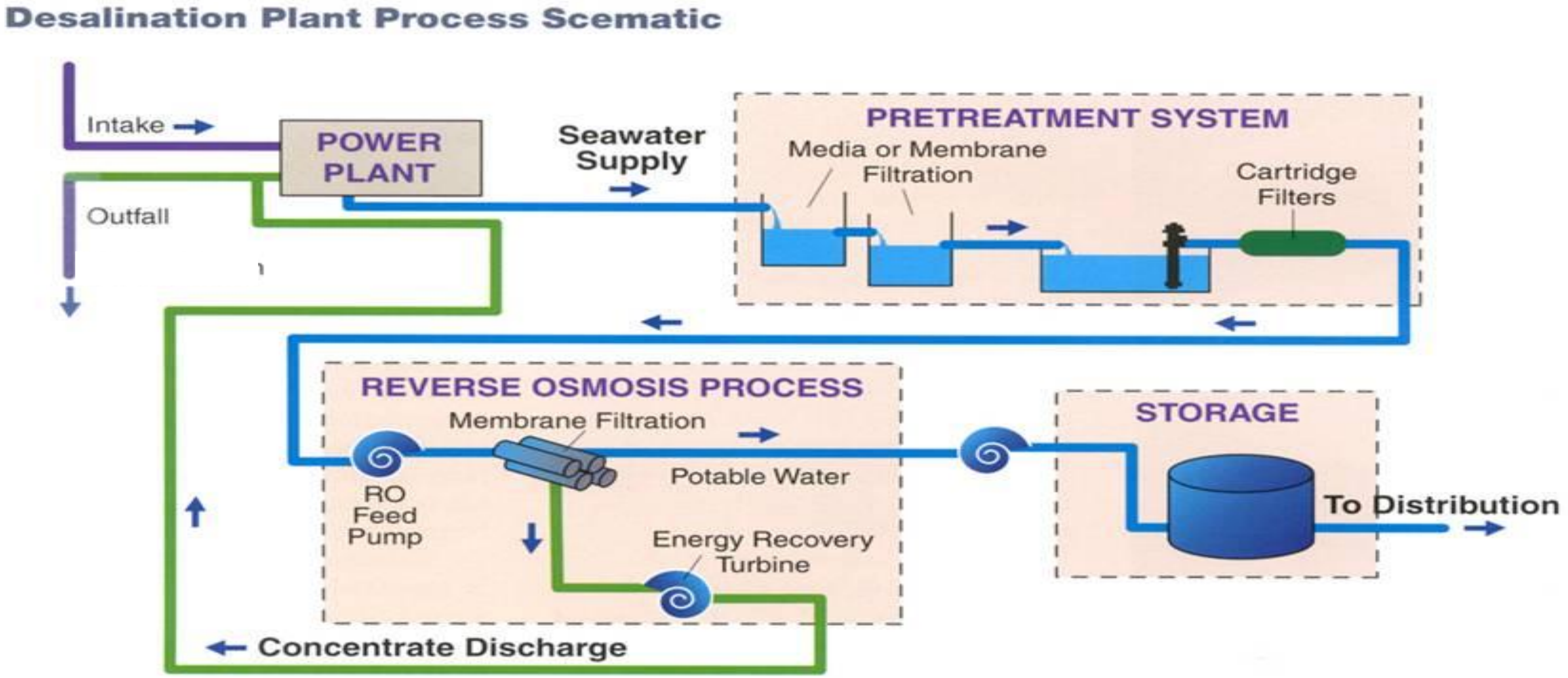
Source: Poseidon Water, San Diego, CA

SWRO Technology

- No phase change- LOW energy consumption.
- Compact, and space requirements are less than with other desalting systems.
- RO equipment is standardized - pumps, motors, valves, flowmeters, pressure gages, etc.
- Many RO systems are fully automated-require little labor.
- Due to their modular design, maintenance is easy.
- The modular design also makes expansion an easy option.

RO system takes small space due to its modularity.

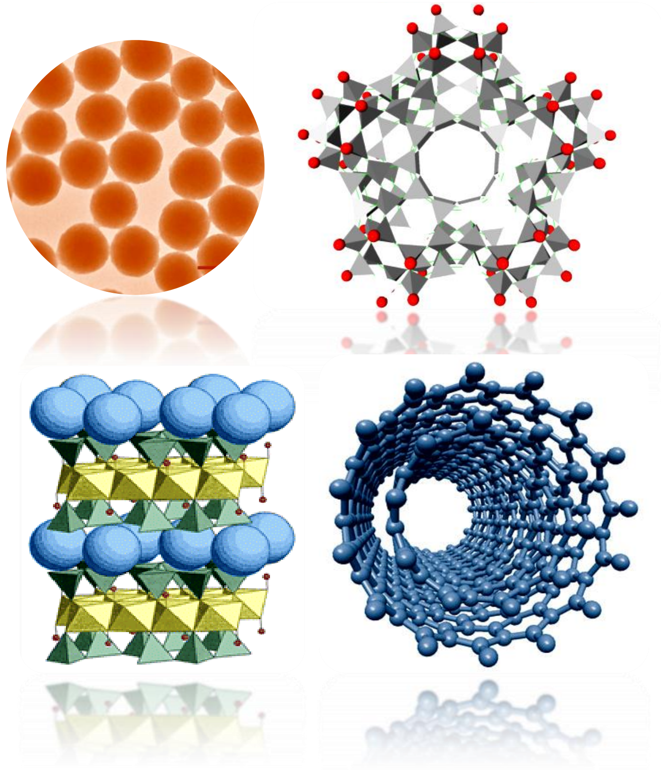
A Typical RO Process

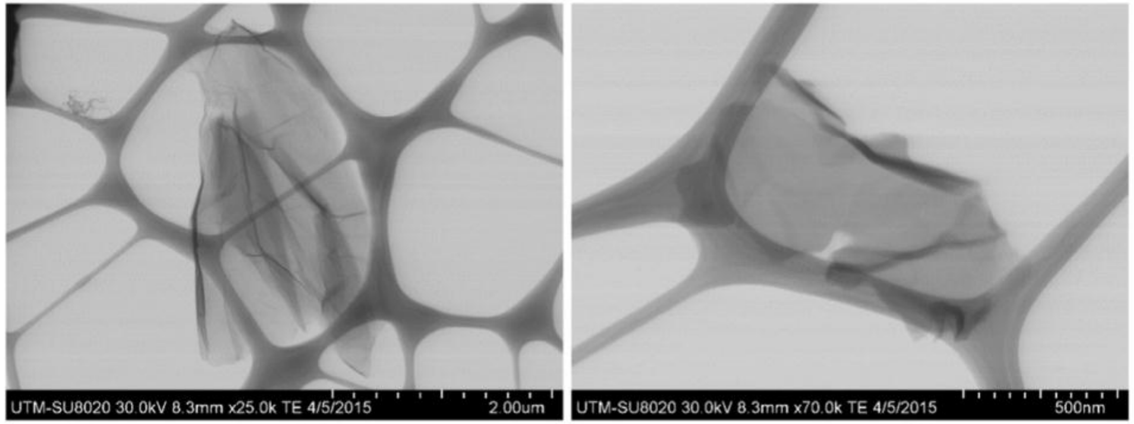


Reverse Osmosis Plant

Roles of Nanomaterials

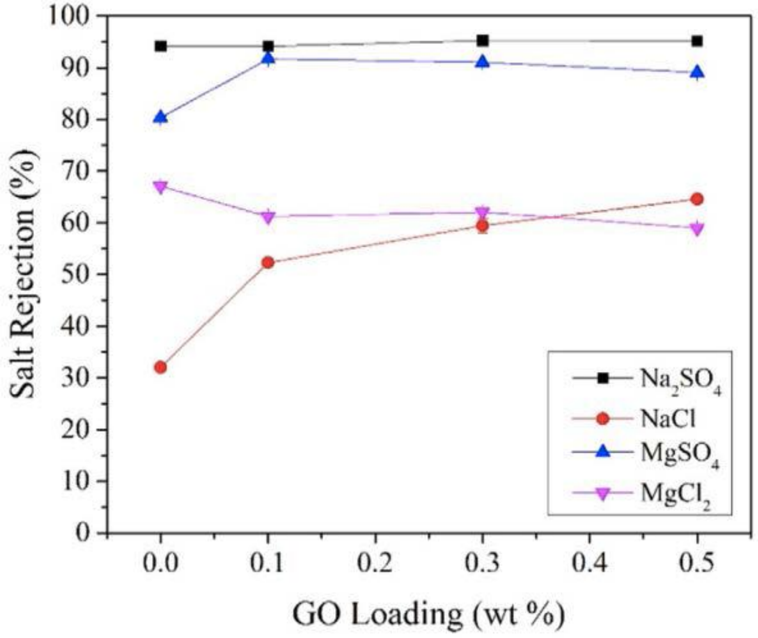
- Nanomaterials are typically defined as materials smaller than 100 nm in at least one dimension.
- At this scale, materials often possess novel size-dependent properties different from their large counterparts.
- Water and wastewater treatment utilize the scalable size-dependent properties of nanomaterials which relate to:
  - High specific surface area and sorption capacity
  - High selectivity and reactivity
  - Fast transport
  - Antimicrobial



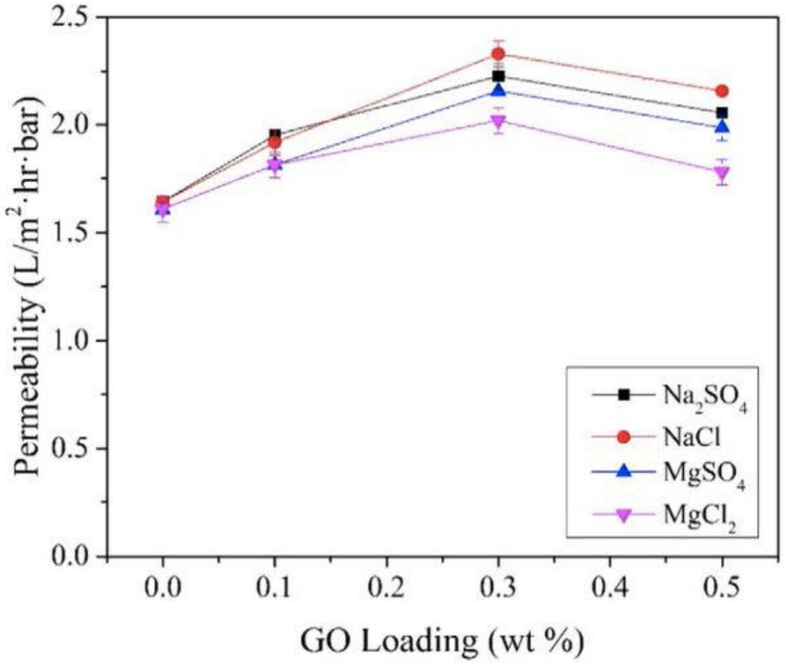


(a) (b)

STEM images of GO nanosheets



(b)



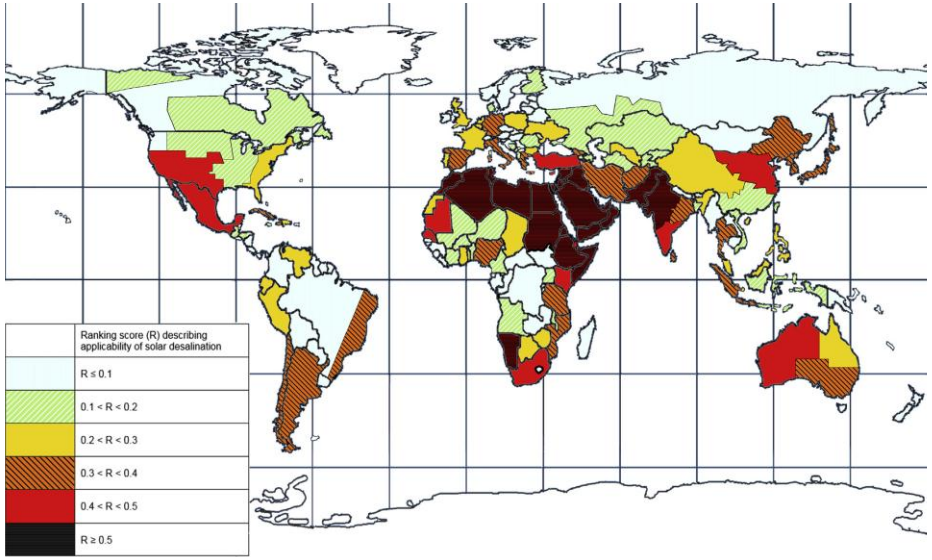
(a)

Filtration performance of membranes made of different types of substrates (a) solute permeability and (b) solute rejection.

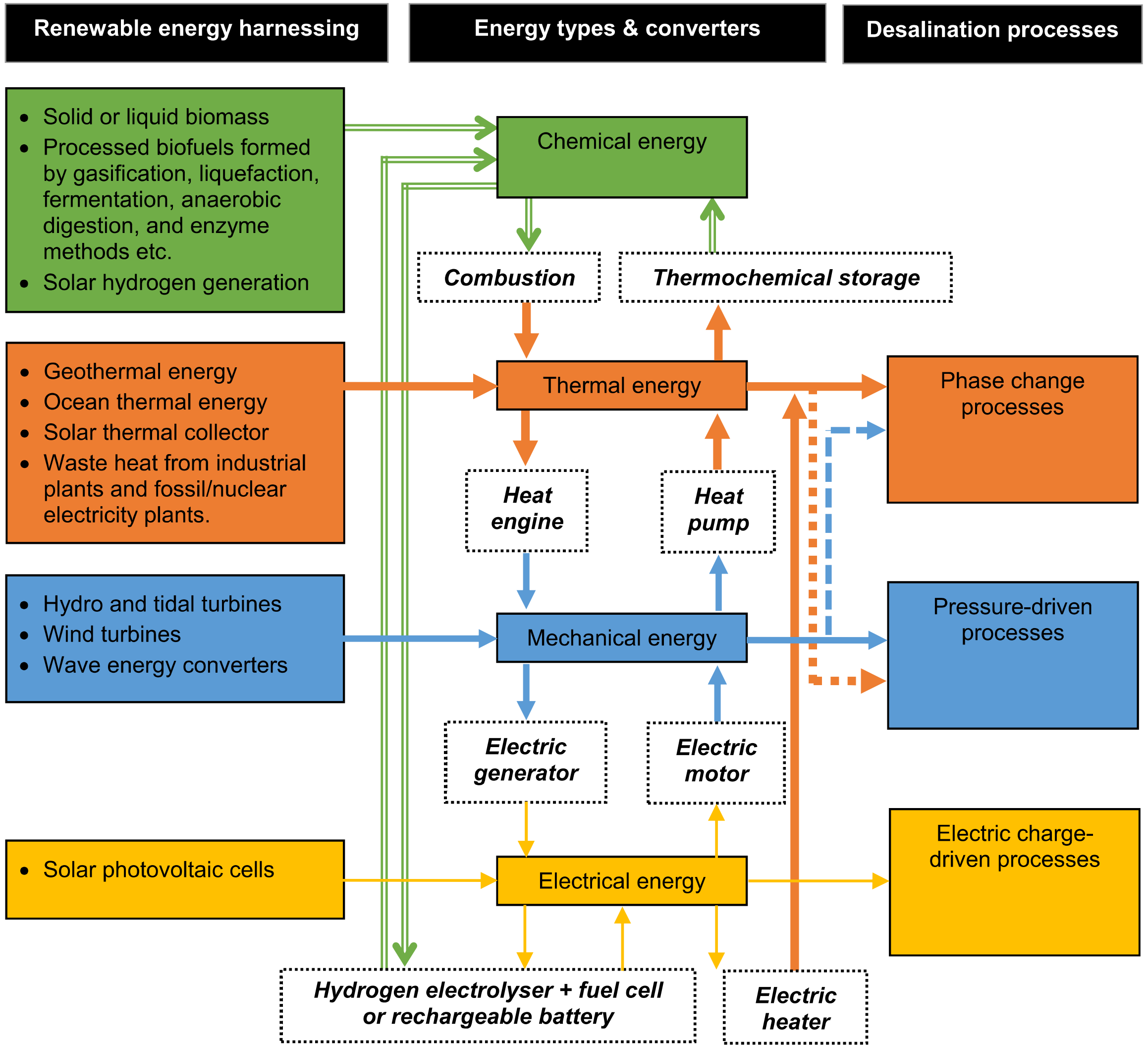
Renewable energy/Solar Powered SWRO Desalination

Examples of solar thermal phase change desalination demonstration plants.

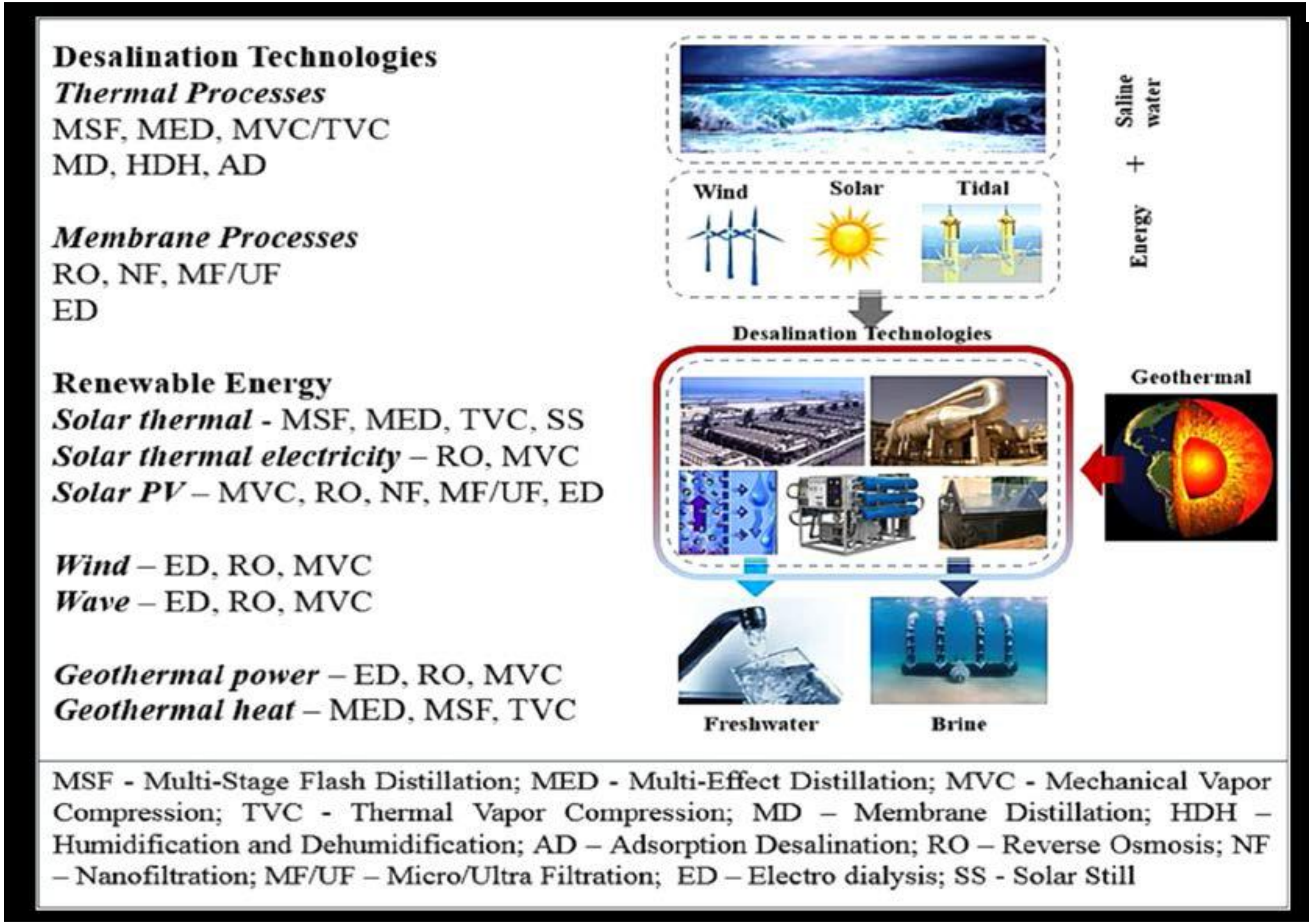
Location	Production capacity (m^3/day)	Type
Gaza, Palestine	0.2	Multi-Effect Boiling
Tunisia	0.5	Humidification-Dehumidification
Northern China	0.8	Multi-Effect Boiling
Dezhou, Shandong, China	1	Humidification-Dehumidification
El Paso, Texas	19	Multi-Stage Flash
Abu Dhabi, UAE	60	Multi-Effect Boiling
Margarita de Savoya, Italy	60	Multi-Stage Flash
Kuwait	100	Multi-Stage Flash
PSA, Almeria, Spain	20	Multi-Effect Boiling



Global applicability of solar desalination based on a rank scoring approach.



A. Pugsley et al. / Renewable Energy 88 (2016) 200-219


Desalination Technologies
Thermal Processes
MSF, MED, MVC/TVC
MD, HDH, AD
Membrane Processes
RO, NF, MF/UF
ED
Renewable Energy
Solar thermal - MSF, MED, TVC, SS
Solar thermal electricity – RO, MVC
Solar PV – MVC, RO, NF, MF/UF, ED
Wind – ED, RO, MVC
Wave – ED, RO, MVC
Geothermal power – ED, RO, MVC
Geothermal heat – MED, MSF, TVC
Saline water
+
Energy
Wind
Solar
Tidal
Desalination Technologies
Geothermal
Freshwater
Brine
MSF - Multi-Stage Flash Distillation; MED - Multi-Effect Distillation; MVC - Mechanical Vapor Compression; TVC - Thermal Vapor Compression; MD – Membrane Distillation; HDH – Humidification and Dehumidification; AD – Adsorption Desalination; RO – Reverse Osmosis; NF – Nanofiltration; MF/UF – Micro/Ultra Filtration; ED – Electro dialysis; SS - Solar Still

Energy Recovery Devices

Energy is the **largest variable cost** for Seawater RO (SWRO) plants, varying from **a third to more than a half** the cost of produce water.

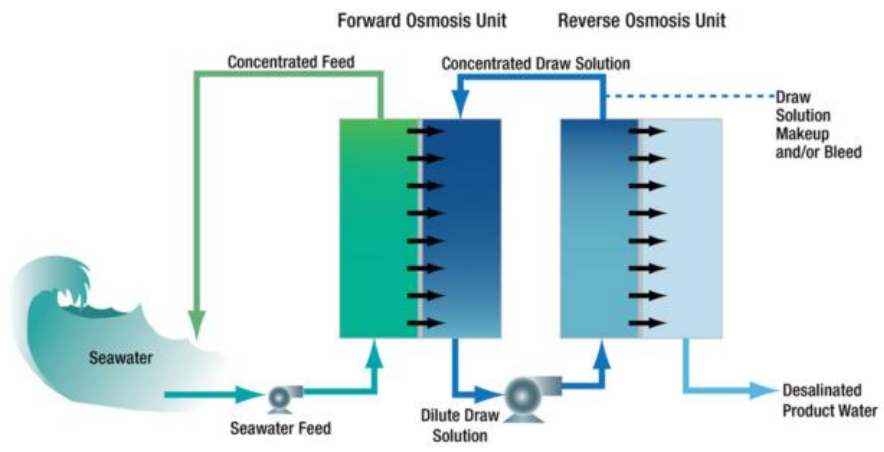
Increased efficiency in **Energy Recovery devices** have achieved substantial energy reductions.

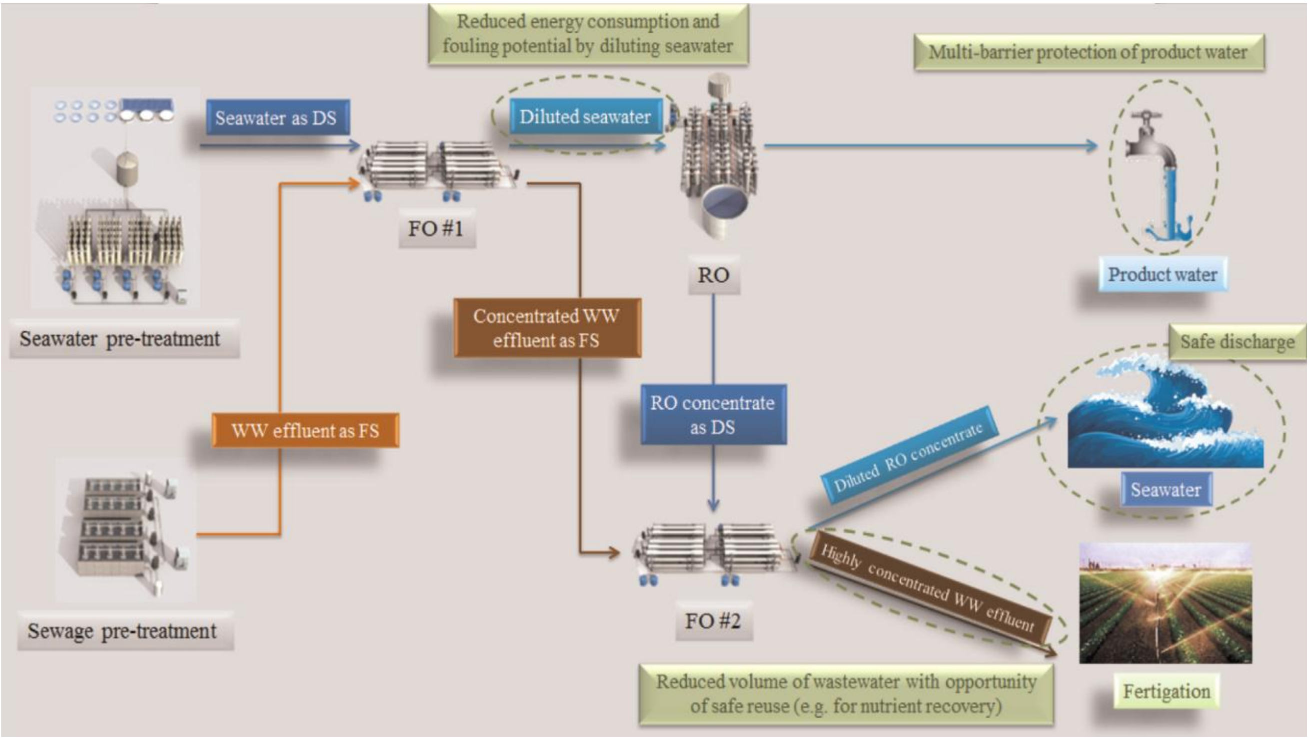
The advances made in the design of ERDs have been beneficial for the desalination industry to reduce the **energy consumption of seawater desalination by more than 50%**

Energy Recovery Devices

- Two types of ERDs, namely **centrifugal and isobaric** have been commonly used in SWRO.
- The utilization of centrifugal ERD is less favored due to its capacity limitation and inefficiency maximum net transfer.
- Isobaric ERDs has much **higher energy recovery efficiency** can transfer energy from a high pressure brine stream to a low pressure incoming feed stream, hence avoid the efficiency losses related to the multiple energy-conversion steps.
- Currently, commercially available ERD consisting of two distinct groups
- **Pressure exchanger (PX)** such as DWEER and ERI that facilitate the transfer of brine pressure directly to feed
- **Equipment** such as Pelton turbine, Francis turbine and back running pumps that transfer brine pressure to mechanical power.

Integrated FO/RO system





Schematic of an FO–RO hybrid process plant for simultaneous treatment of wastewater and seawater desalination (DS: draw solution; FS: feed solution; RO: reverse osmosis; WW: wastewater).

The key benefits include

- Energy saving
- chemical storage and feed systems may be reduced for capital and operations and maintenance cost savings,
- water quality is improved for increased consumer confidence and reduced process piping costs
- the overall sustainability of the desalination process is improved.

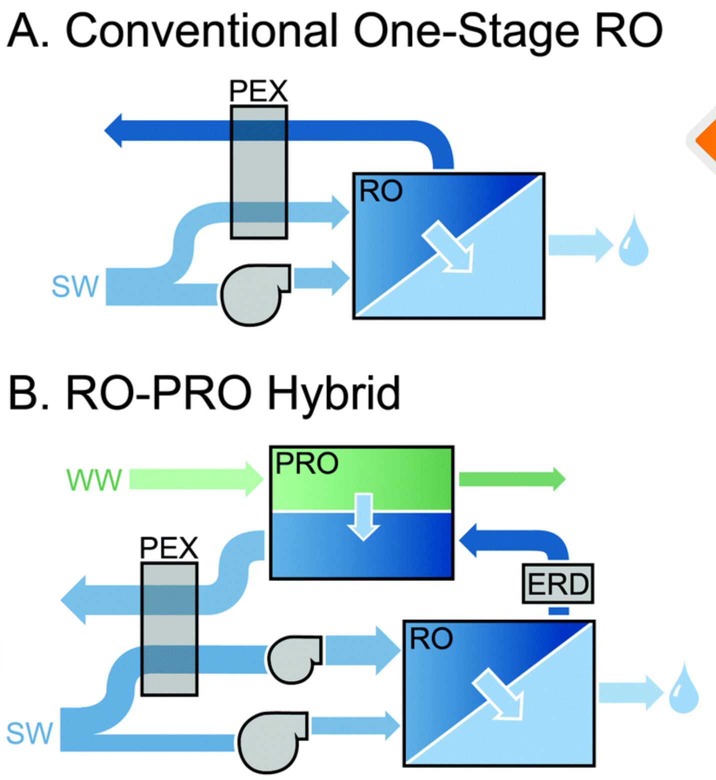
L. Chekli et al. / Journal of Membrane Science 497 (2016) 430–449

Integrated PRO/RO system

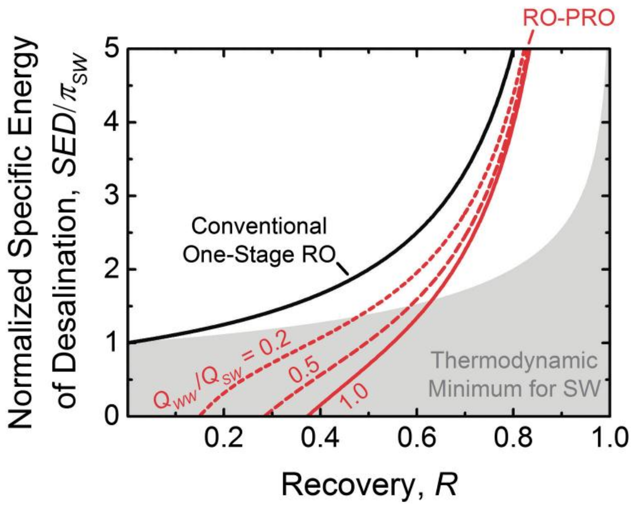
An opposite process of RO, called pressure retarded osmosis (PRO), utilizes the salinity gradient between a relatively fresh impaired water source and seawater to produce pressure and hence, energy

Benefits of RO-PRO hybrid system:

The energy generated by PRO would reduce the specific energy consumption in the RO-PRO hybrid system

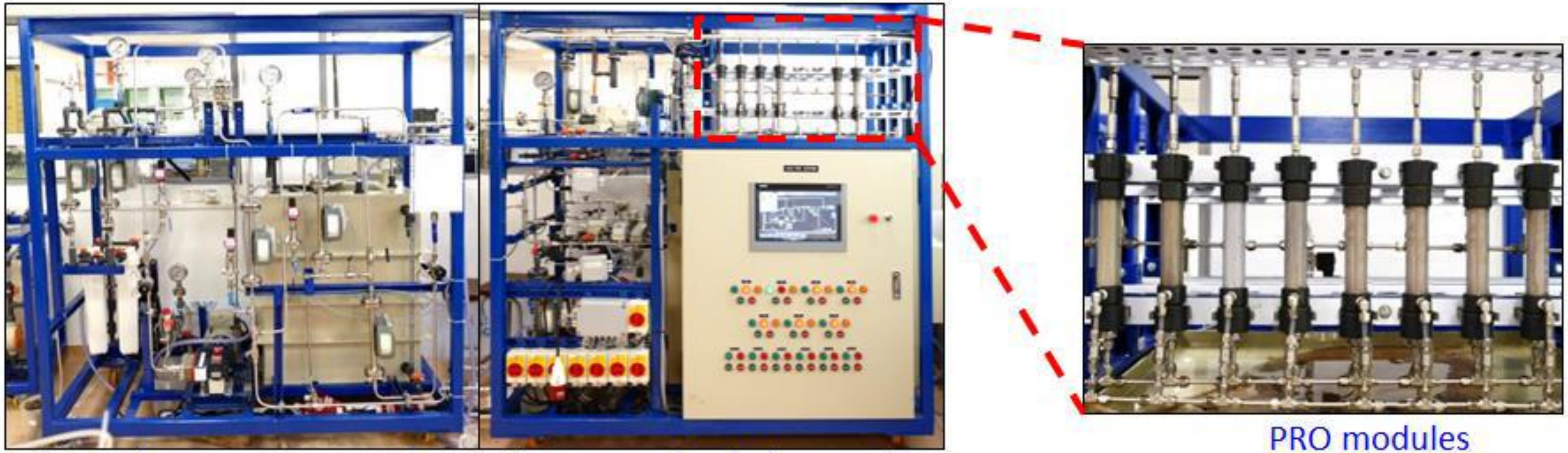


The retentate coming from RO via pressure exchanger is used as the draw solution, while the impaired water (like municipal wastewater, industrial wastewater or brackish) is used as the feed solution in the subsequent PRO system to generate osmotic energy .



Normalized specific energy consumption of seawater desalination, SED, as a function of water recovery, R, for a one-stage reverse osmosis (RO) system (black line) and a hybrid RO and pressure-retarded osmosis (PRO) system (red lines).

Straub et al. Energy Environ. Sci., 2016,9, 31-48

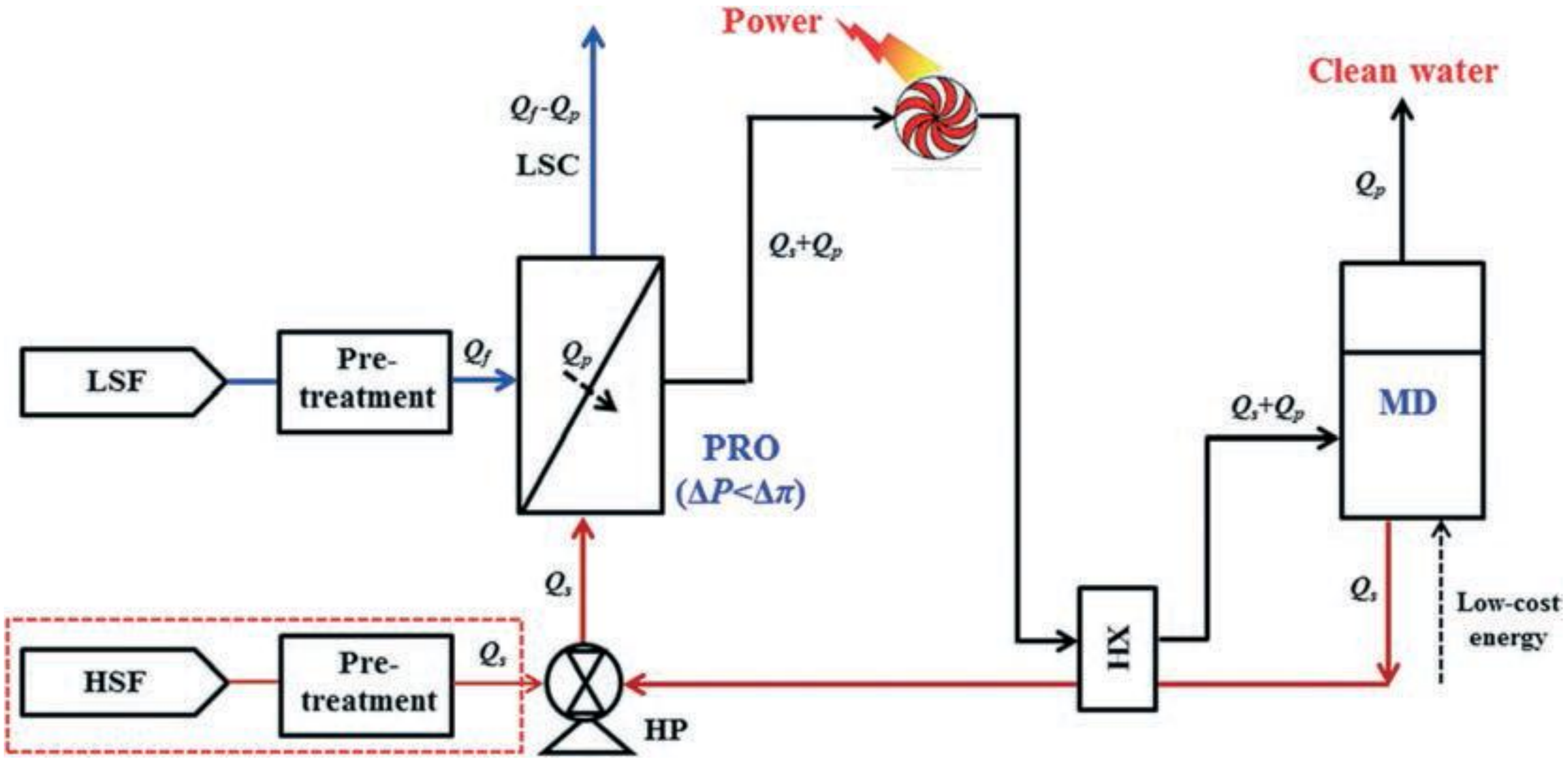


Seawater reverse osmosis (SWRO)

Pressure retarded osmosis (PRO)

PRO modules

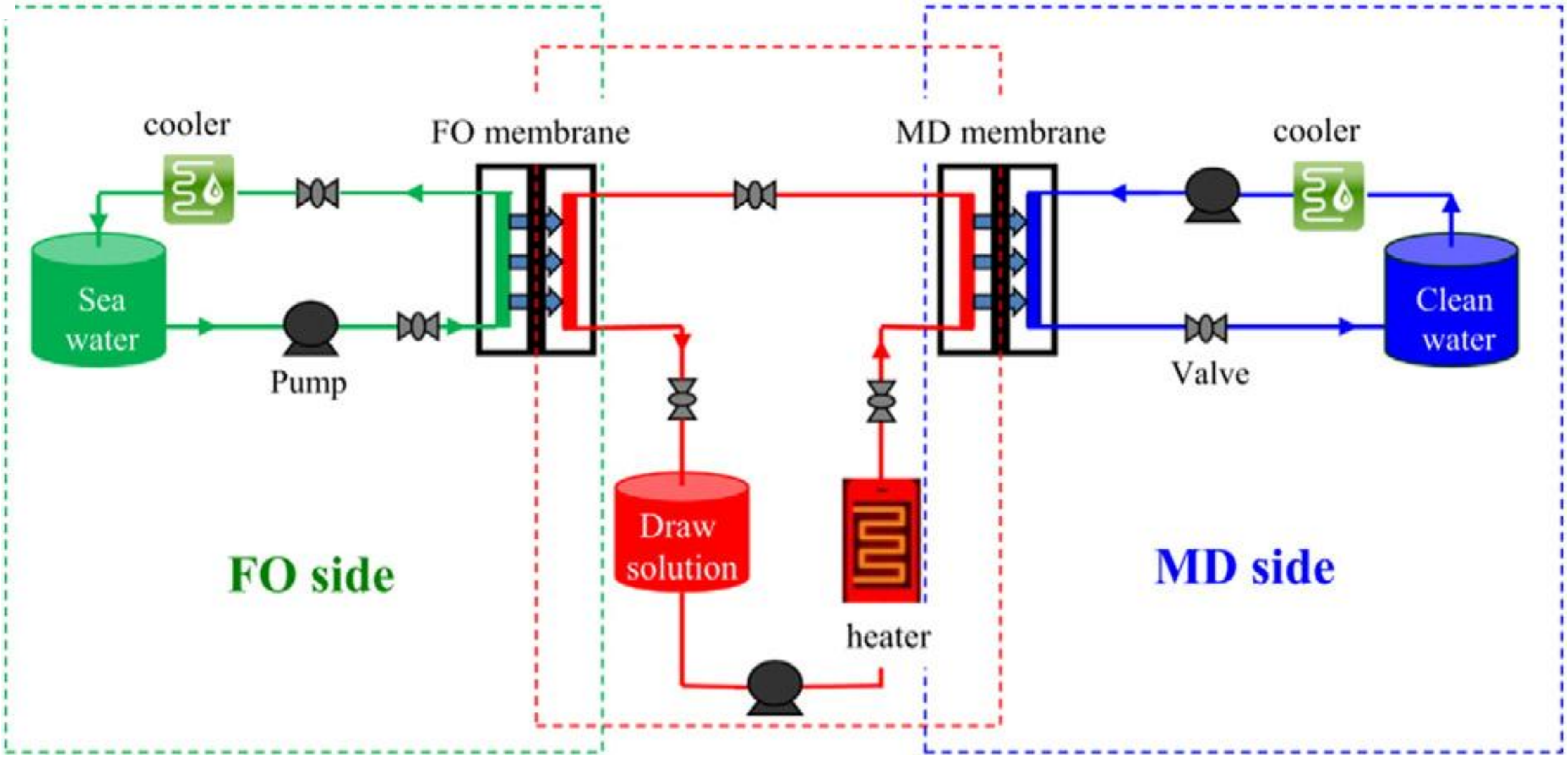
Integrated PRO/MD system



Schematic diagram of the PRO–MD hybrid system for osmotic power and clean water generation
PRO: Pressure retared osmosis; MD: Membrane Distillation

Environ. Sci.: Water Res. Technol., 2015, 1, 507–515

Integrated FO–MD system



An integrated FO–MD system which allows the FO process serves to draw clean water from the feed solution to the draw solution side, meanwhile the MD process is utilized to reconcentrate the diluted draw solution.

Conclusions

- Increased efficiency in Energy Recovery devices have achieved substantial energy reductions, which resulted in energy consumption of seawater desalination by more than 50%
- The integration of several promising approaches may provide radical solutions and attractive.
- Some of the innovative solutions for energy efficient desalination are ongoing in lab, prototype, and pilot plant scale.
- The large investments that sustain nanotech has provided certain level of confidence that this existing field will impart an economic impact on the next generation desalination.
- ERDs can significantly reduce the energy consumption.

Concluding Remarks

- Desalination and wastewater treatments are promising approaches to tackle alarming water shortage issues.
- The advancement of nanotechnology offer tremendous opportunities to heighten the performance of current existing technology for desalination and wastewater treatments.
- Nano-enabled membrane is an emerging material which holds potential to move from laboratory to industry.
- The key drivers for commercialization of this technology need to be identified in order to expedite the industry adoption in near future

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Thank You