Reverse Osmosis (RO) Desalination using Renewable Energy Sources

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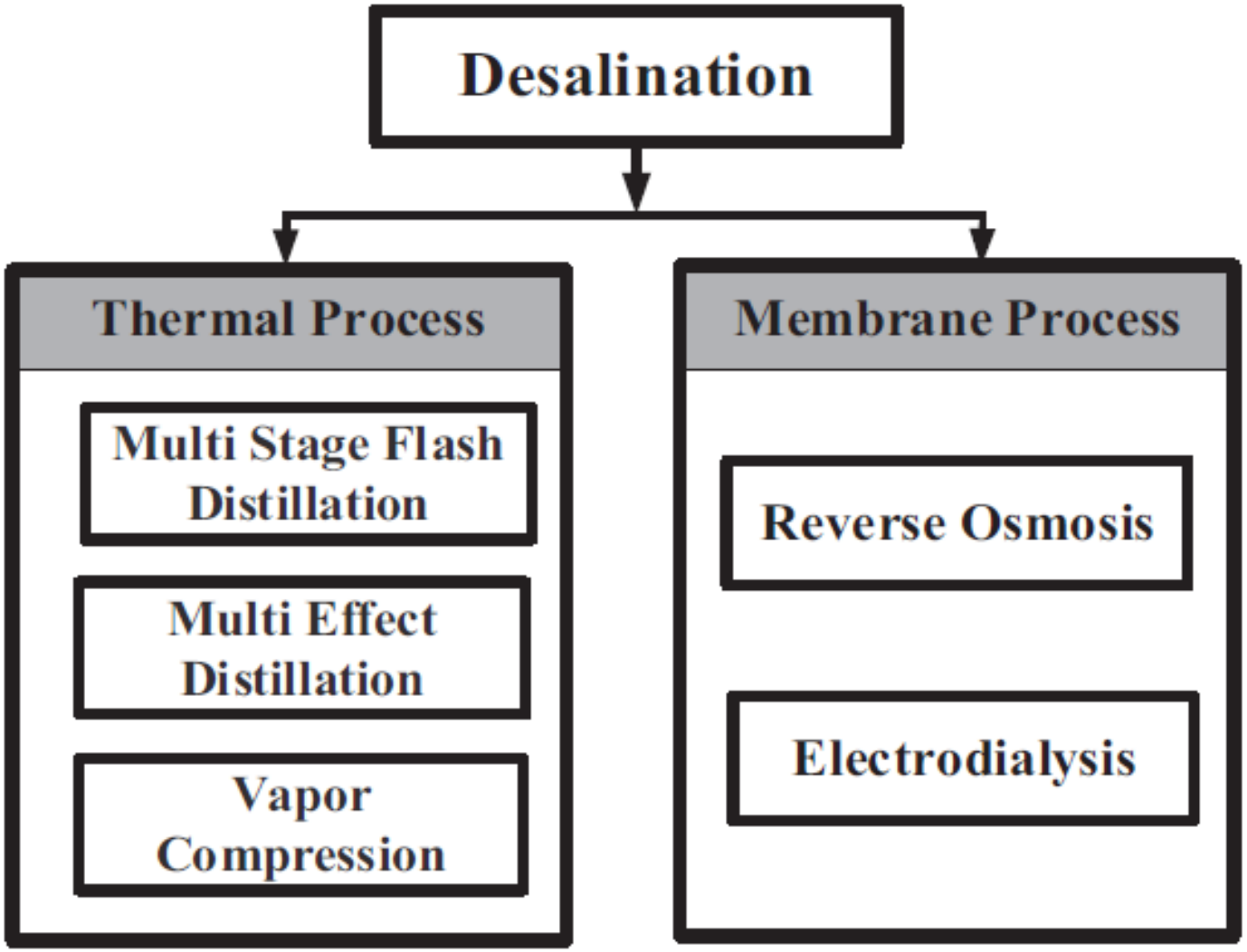
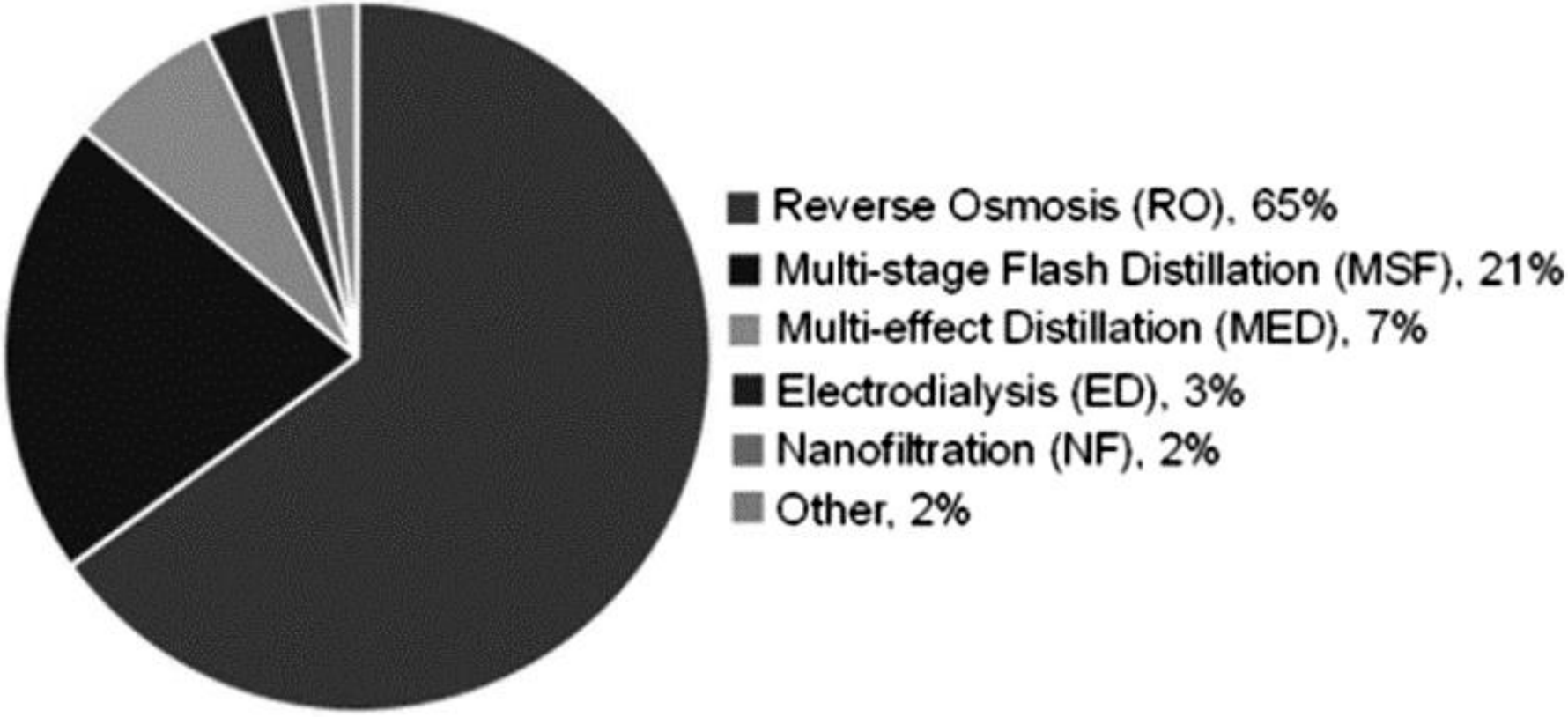
Introduction

Main desalination technologies



Introduction

Commercially available seawater desalination technologies all around the world



Introduction

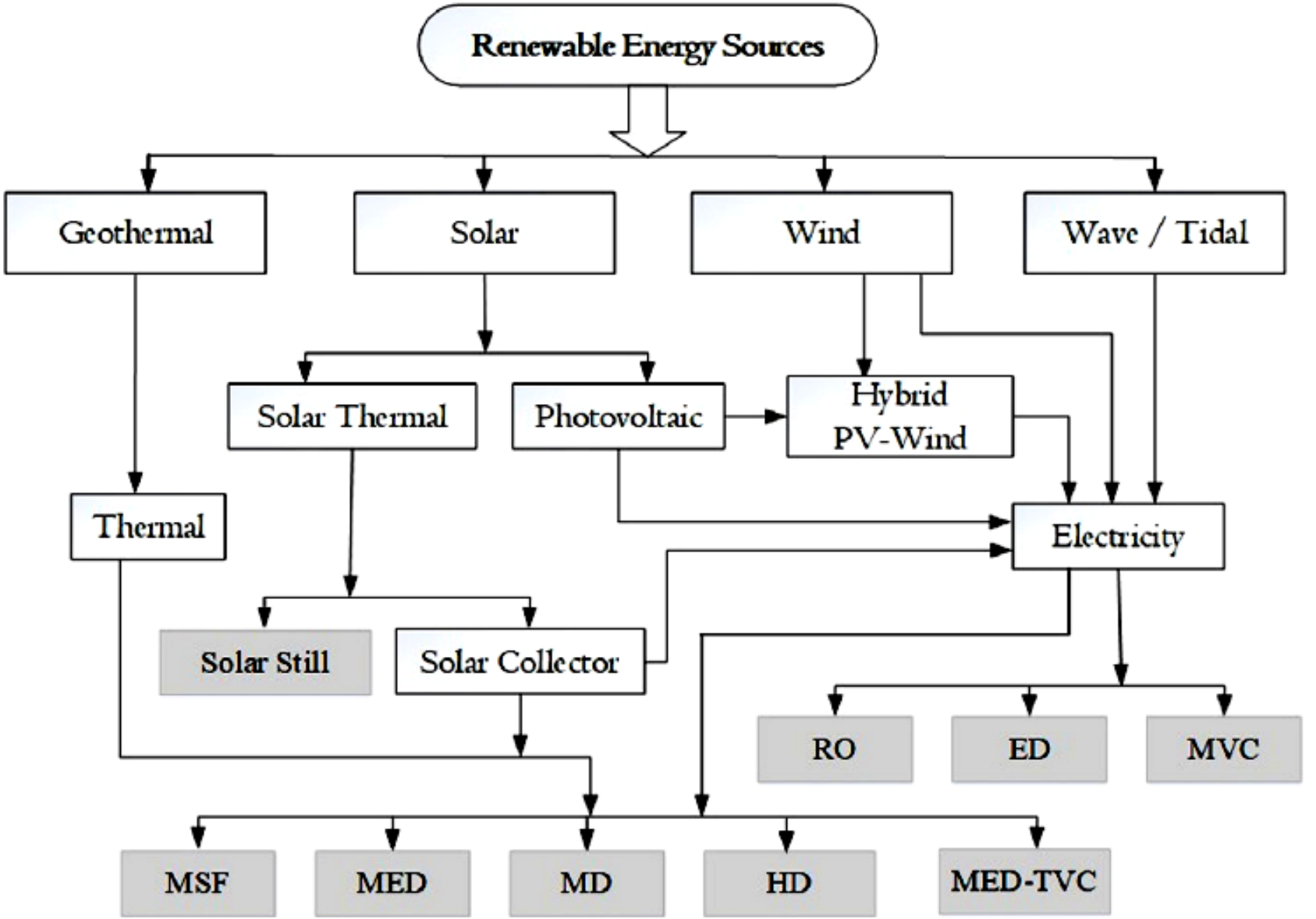
Comparison between the energy consumptions for the water desalination techniques.

Properties	MSF	MED	MVC	TVC
Typical unit size (m^3/day)	50,000–70,000	5000–15,000	100–3000	10,000–30,000
Electrical energy consumption (kW h/m^3)	2.5–5	2–2.5	7–12	1.8–1.6
Thermal energy consumption (MJ/m^3)	190–282	145–230	None	227
Equivalent electrical to thermal energy (kW h/m^3)	15.83–23.5	12.2–19.1	None	14.5
Total electricity consumption (kW h/m^3)	19.58–27.25	14.45–21.35	7–12	16.26
Product water quality (ppm)	≈ 10	≈ 10	≈ 10	≈ 10

Properties	SWRO	BWRO	ED
Typical unit size (m^3/day)	Up to 128,000	Up to 98,000	2–145,000
Electrical energy consumption (kW h/m^3)	4–6 with energy recovery	1.5–2.5	2.64–5.5
Thermal energy consumption (MJ/m^3)	None	None	None
Equivalent electrical to thermal energy (kW h/m^3)	None	None	None
Total electricity consumption (kW h/m^3)	4–6	1.5–2.5	2.64–5.5, 0.7–2.5 at low TDS
Product water quality (ppm)	400–500	200–500	150–500

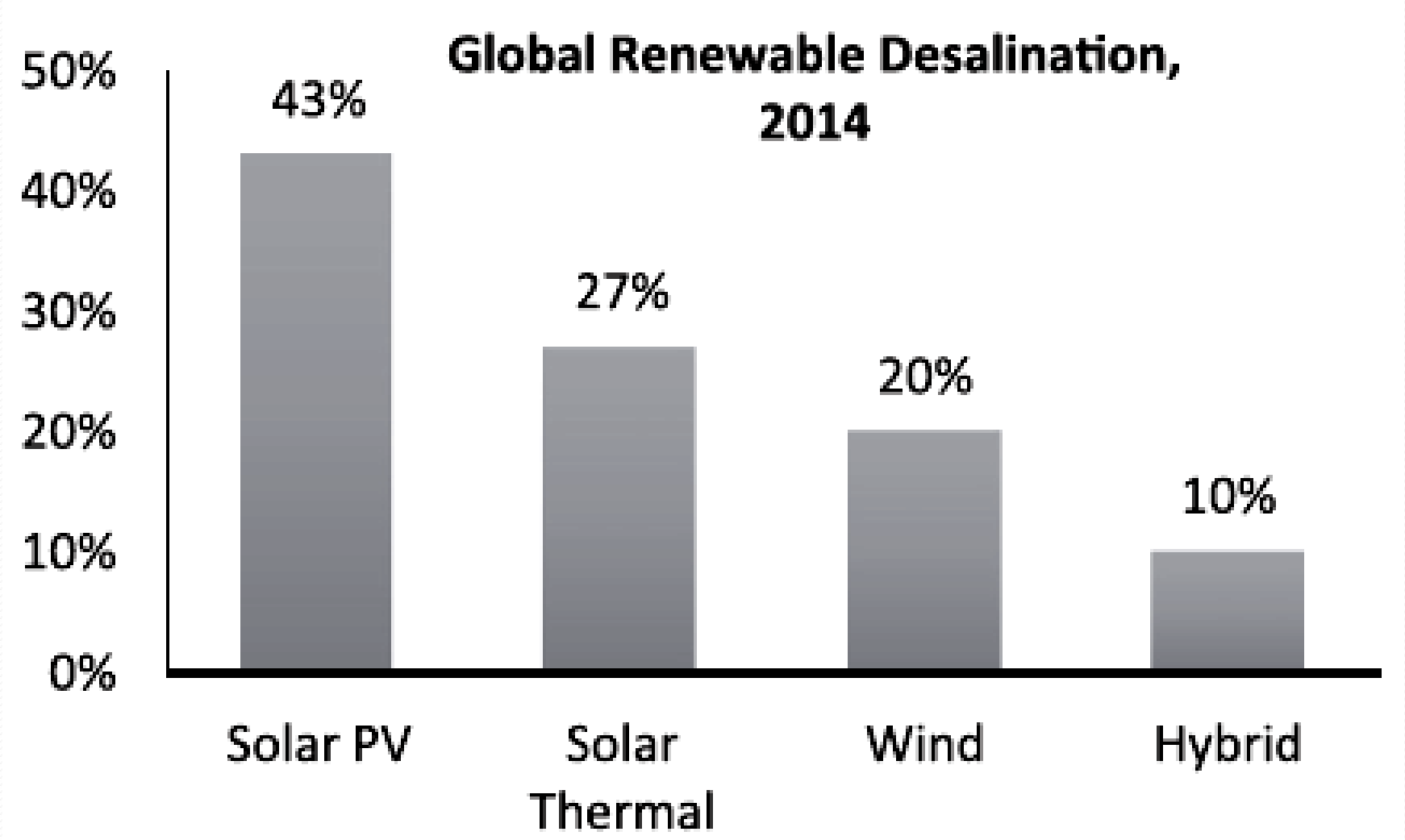
Renewable Energy Sources

Possible options of renewable energy sources for water desalination

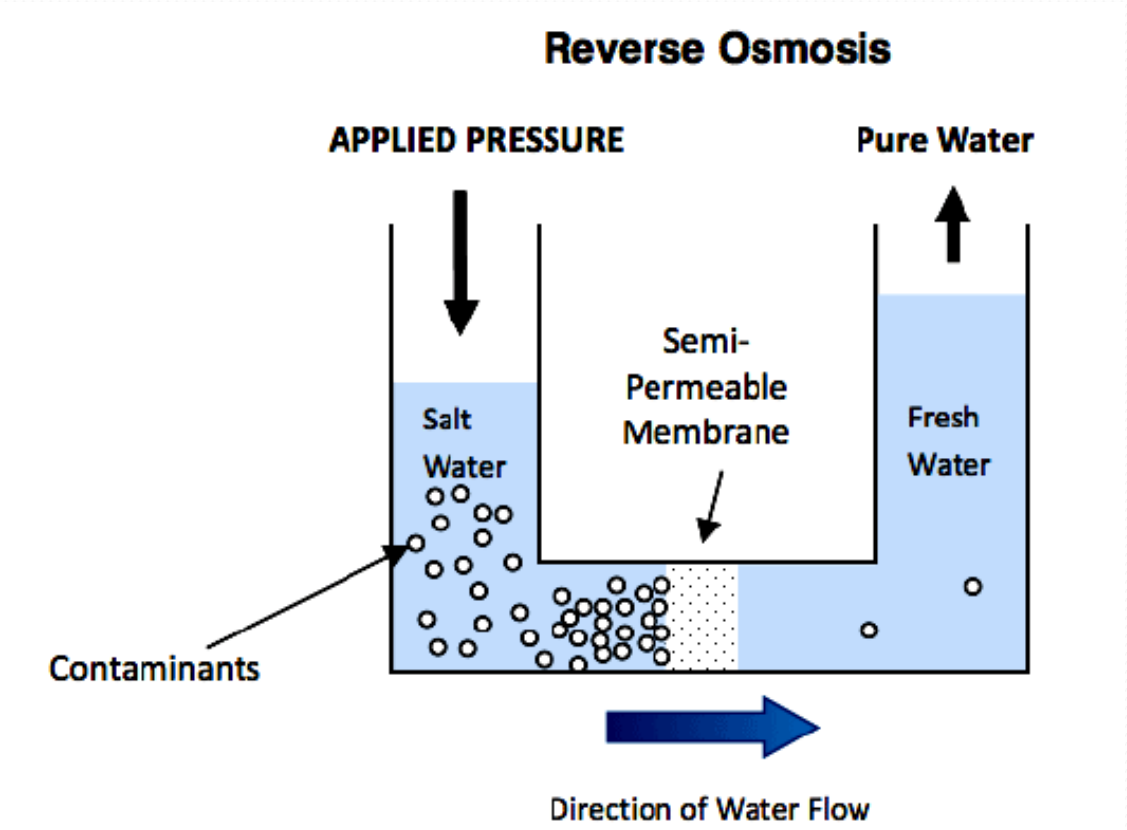


Renewable Energy Sources

Water desalination capacity based on the technology and the type of renewable energy used

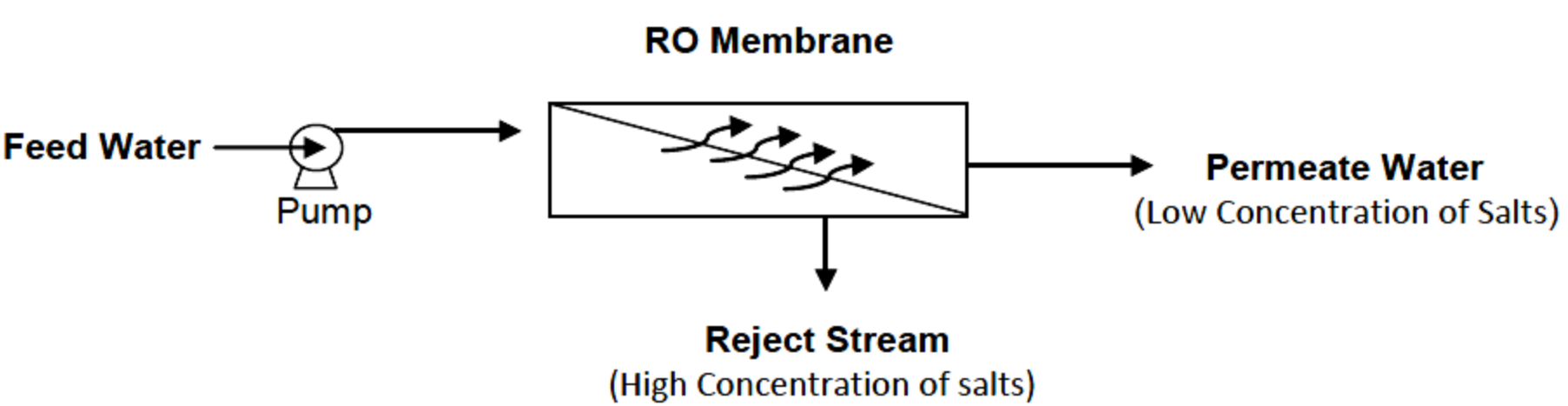


Basics of Reverse Osmosis



When pressure is applied to the concentrated solution, the water molecules are forced through the semi-permeable membrane from concentrated solution to fresh water. The amount of pressure required depends on the salt concentration of the feed water. The more concentrated the feed water, the more pressure is required to overcome the osmotic pressure.

Basics of Reverse Osmosis



As the feed water enters the RO membrane under pressure (enough pressure to overcome osmotic pressure) the water molecules pass through the semi--permeable membrane and the salts and other contaminants are not allowed to pass and are discharged through the concentrate stream, which goes to drain or can be fed back into the feed water supply in some circumstances to be recycled through the RO system to save water. The water that makes it through the RO membrane is called permeate or product water and usually has around 95% to 99% of the dissolved salts removed from it.

Basics of Reverse Osmosis

Energy recovery device

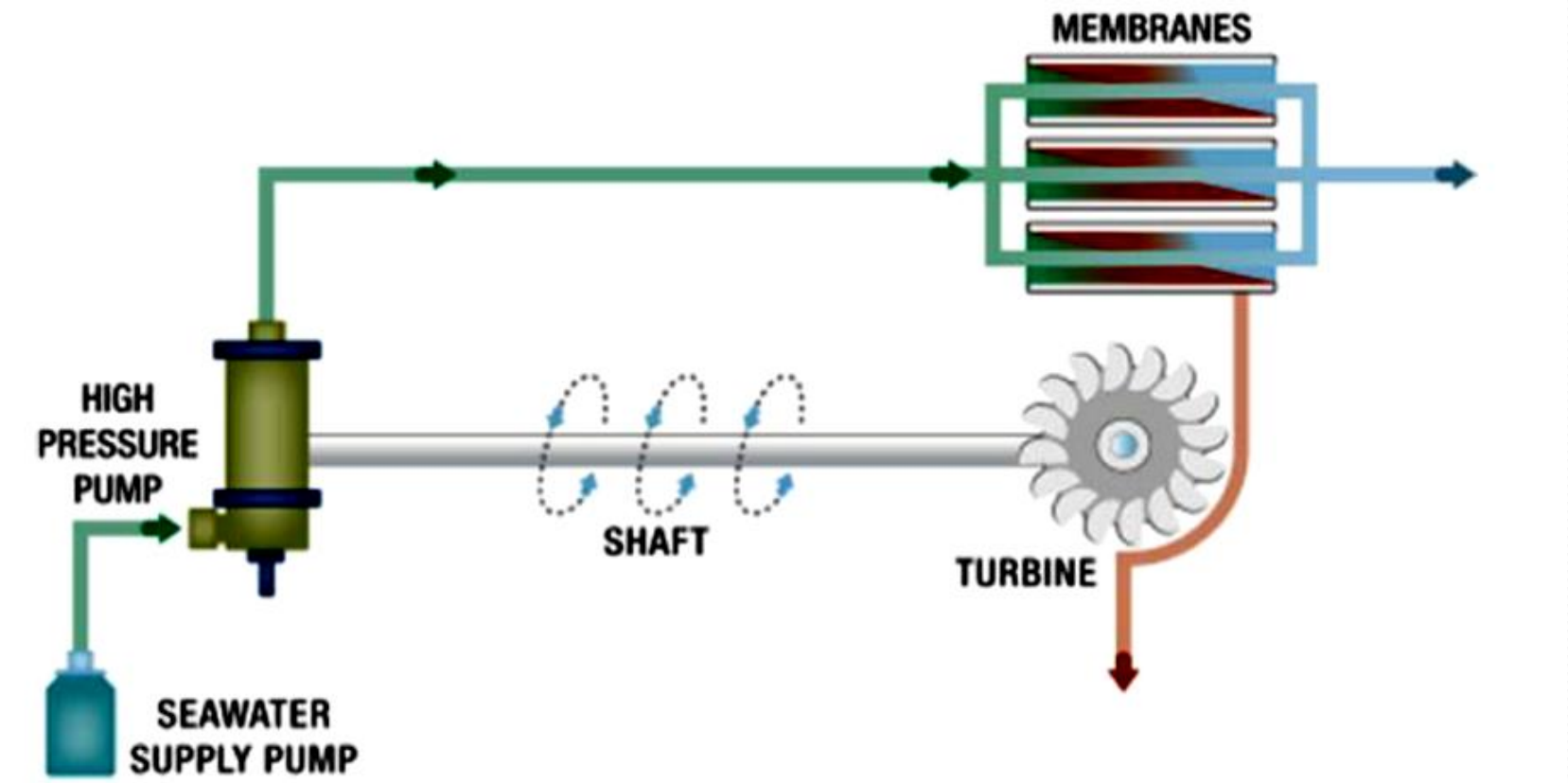
The main function of an energy recovery device would be to improve energy efficiency by harnessing spent energy from the reject and delivering it back to the feed. which are classified as follows:

- **hydraulic to mechanical-assisted pumping**
- **hydraulically driven pumping in series**
- **hydraulically driven pumping in parallel**

Basics of Reverse Osmosis

Energy recovery device

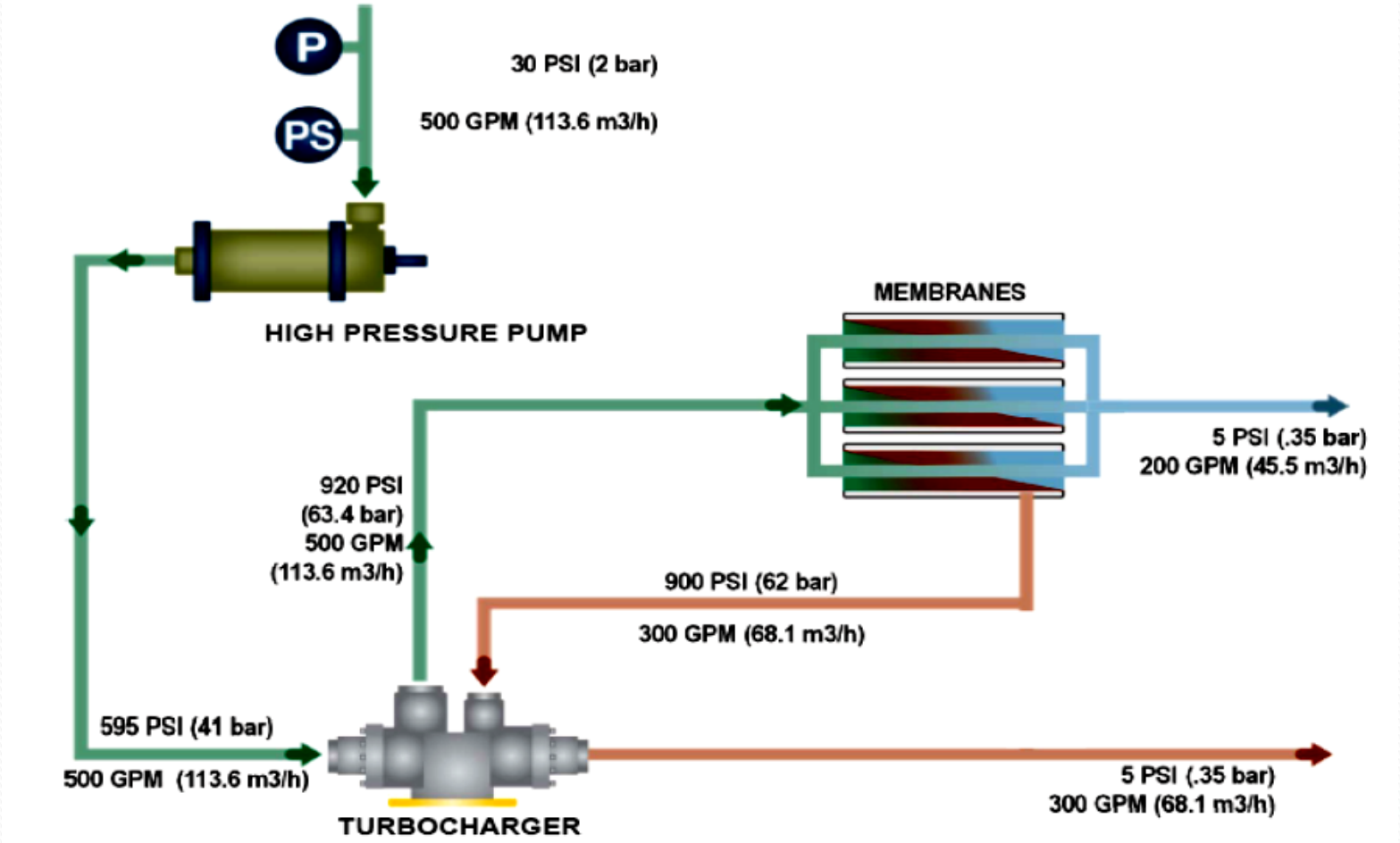
- hydraulic to mechanical-assisted pumping



Basics of Reverse Osmosis

Energy recovery device

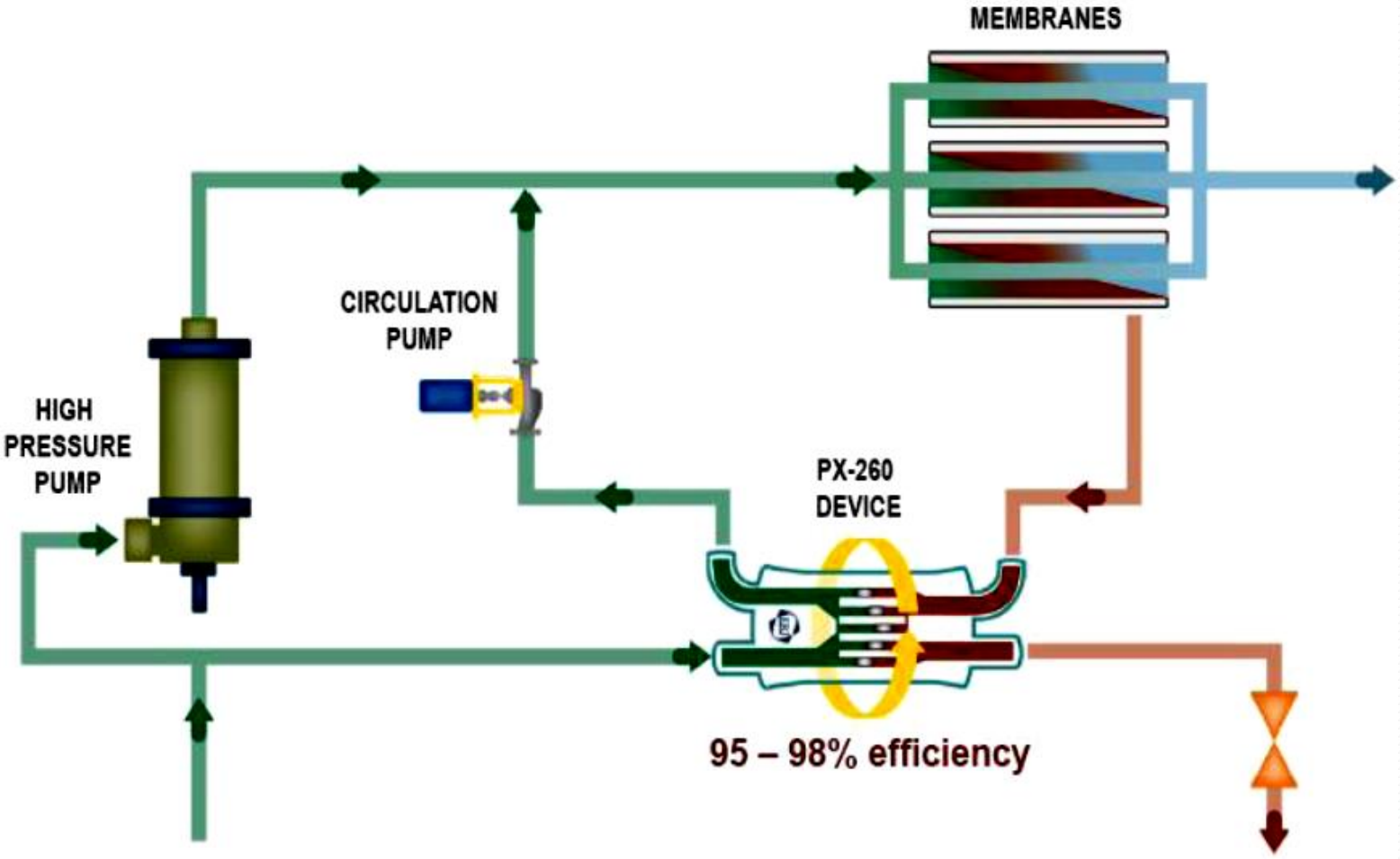
- hydraulically driven pumping in series



Basics of Reverse Osmosis

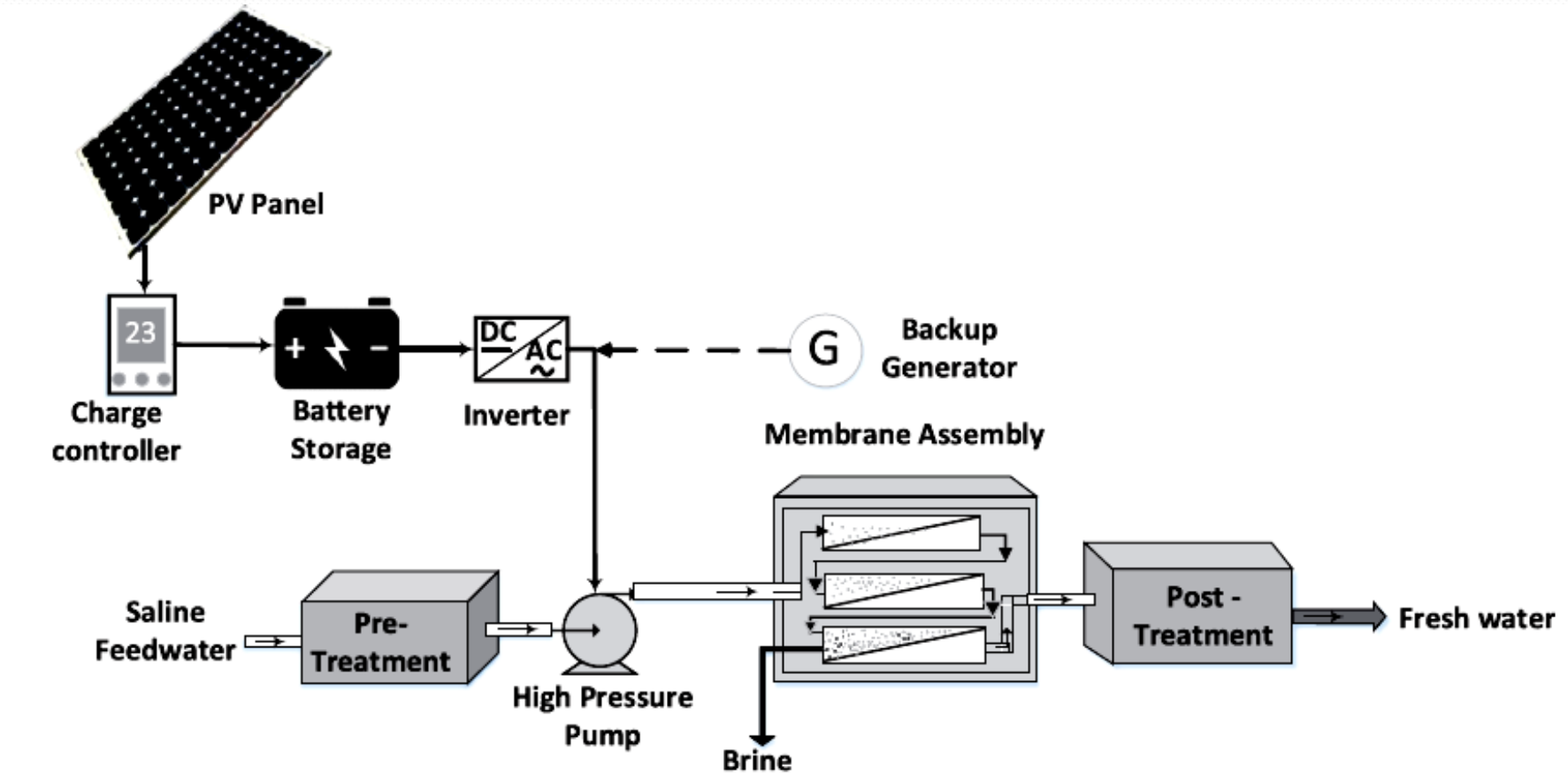
Energy recovery device

- hydraulically driven pumping in parallel



Renewable Energy Sources for RO Desalination

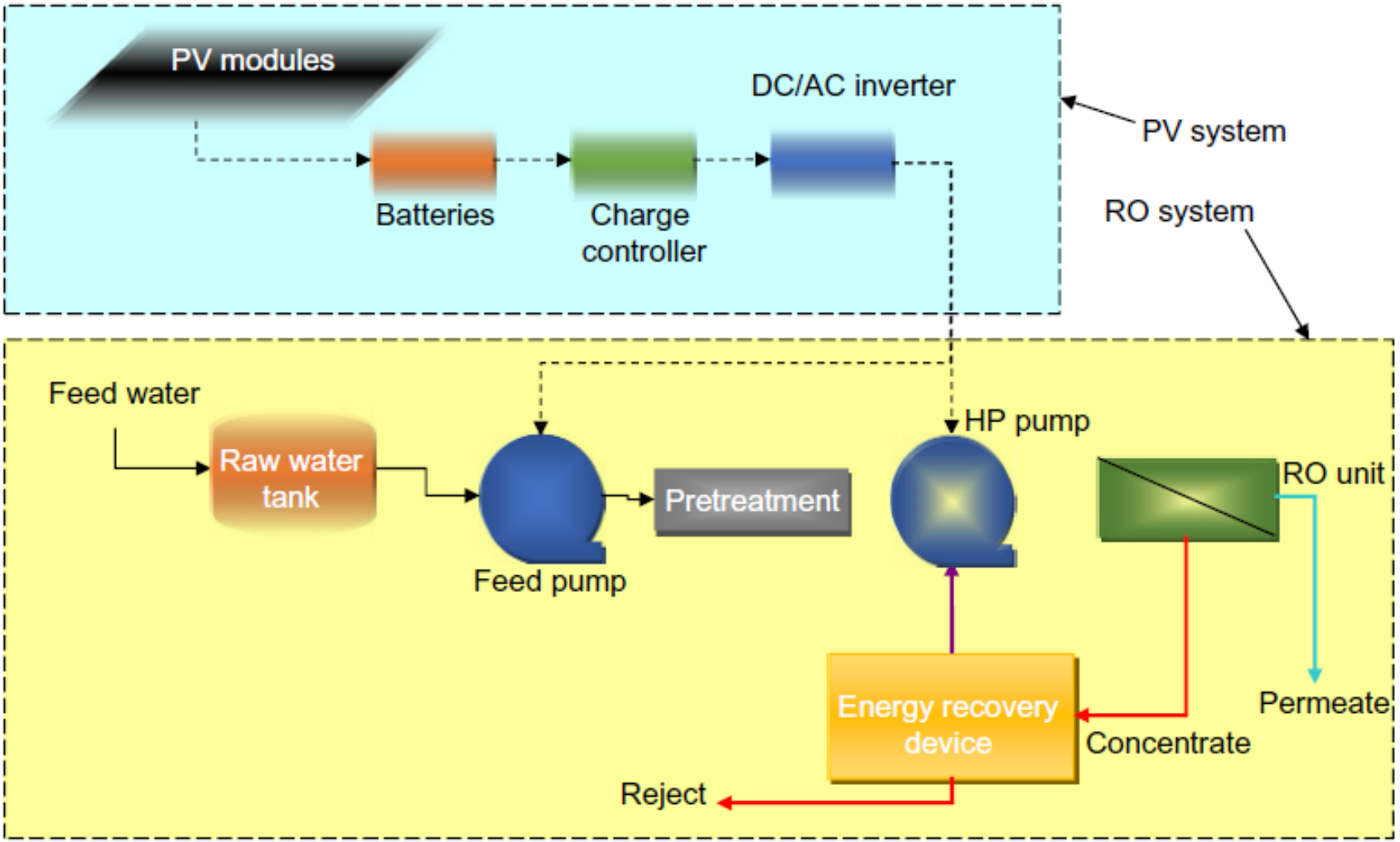
➢Photovoltaic powered RO desalination



A schematic representation of a PV-RO system

Renewable Energy Sources for RO Desalination

➢Photovoltaic powered RO desalination



Basic design model of a RO water desalination system powered by PV.

Renewable Energy Sources for RO Desalination

➢ Photovoltaic powered RO desalination

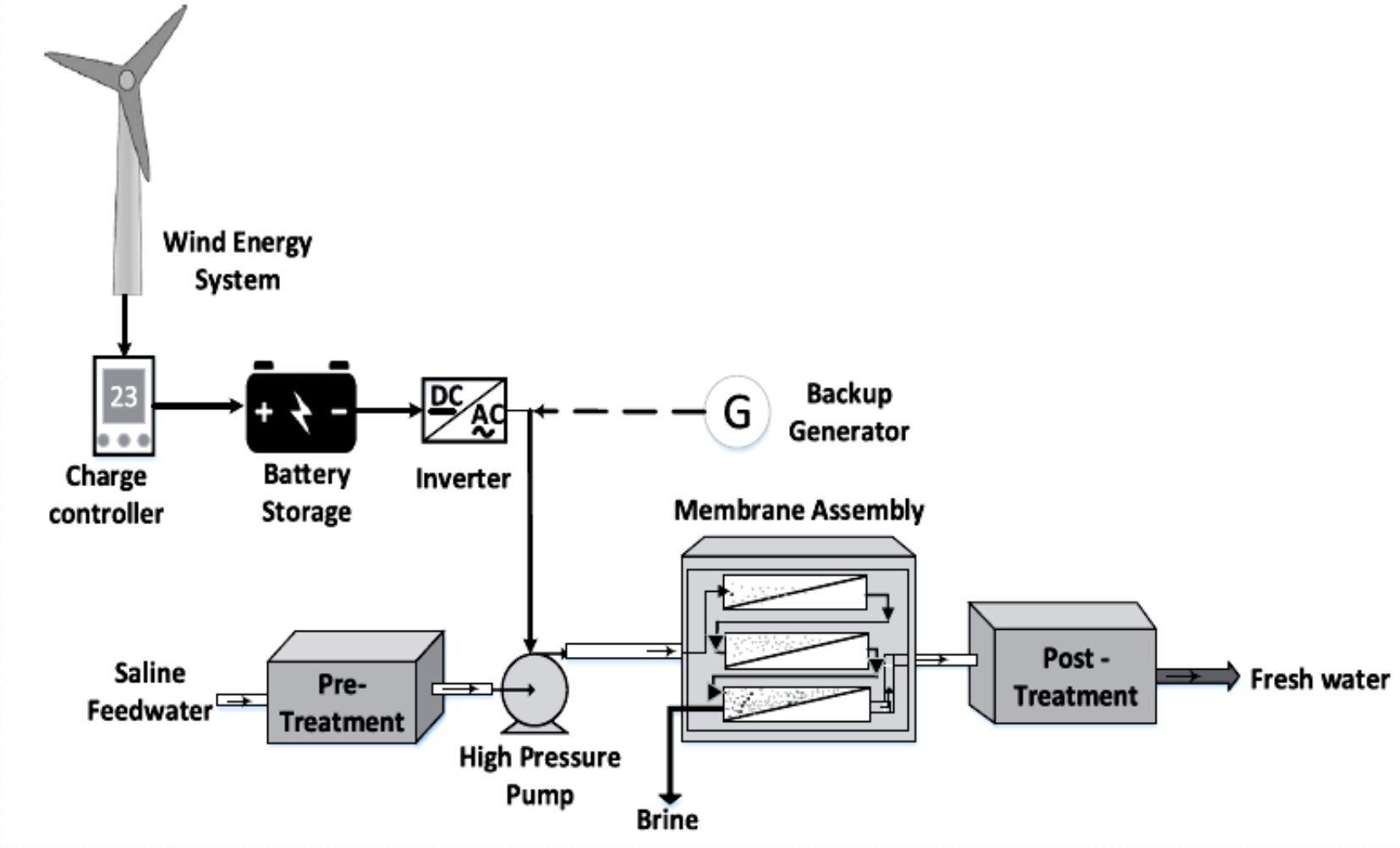
Energy requirements in renewable energy (Photovoltaic) driven RO desalination systems

Renewable water desalination	
Technology variants	PV/RO
Development status	Appl./R&D
Energy input, kWh_e/m^3	0.5–1.5 BW 4.0–5.0 SW
Typical current capacity, m^3/day	< 100
Production cost, USD/m^3	6.5–9.1 BW 11.7–15.6 SW

SW: Seawater, BW: Brackish Water

Renewable Energy Sources for RO Desalination

➢ Wind energy powered RO desalination



Schematic representation of a typical wind-RO desalination system

Renewable Energy Sources for RO Desalination

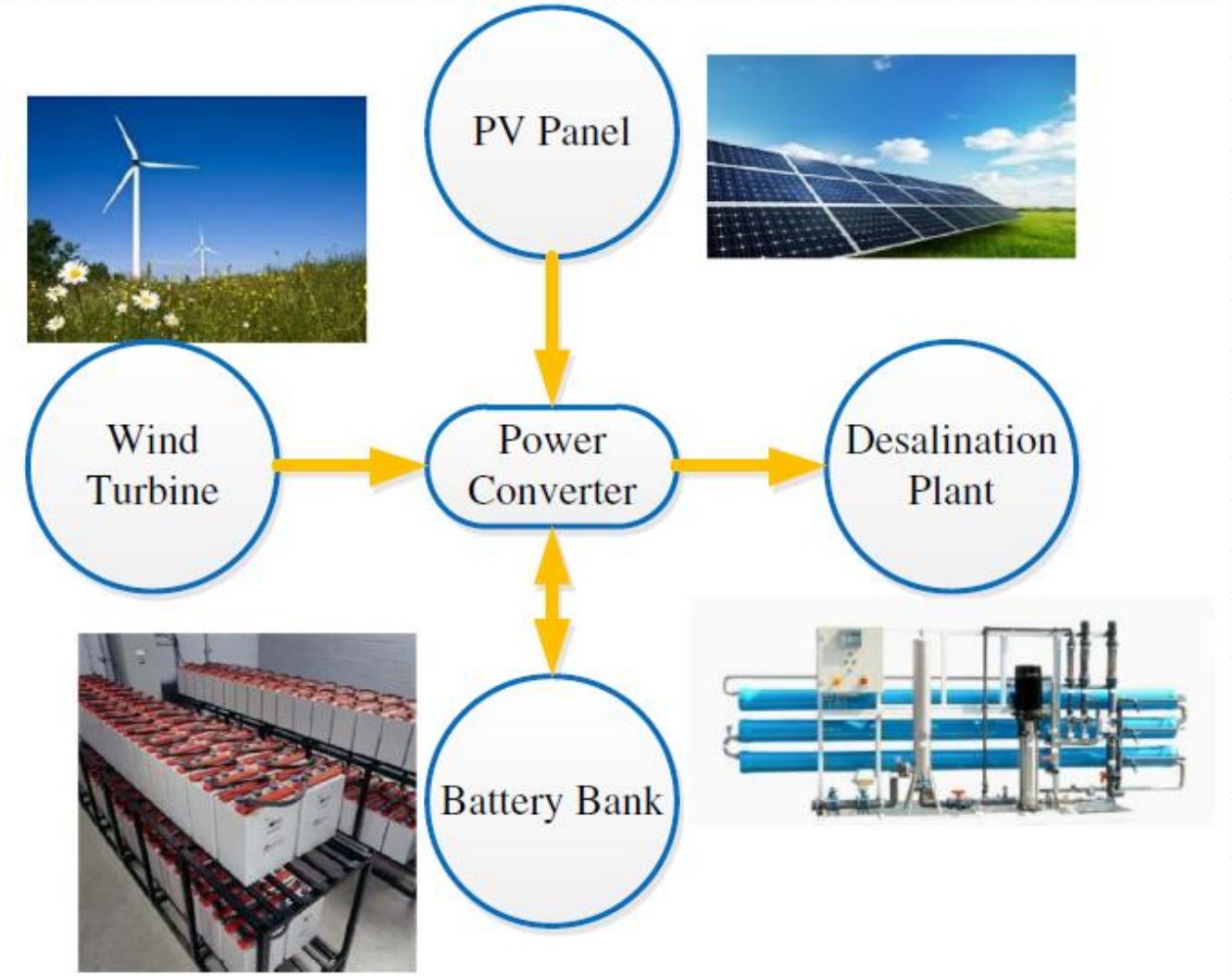
➢ Wind energy powered RO desalination

Energy requirements in renewable energy (Wind energy) driven desalination systems

Renewable water desalination		
Technology variants		Wind/RO
Development status		Appl./R&D
Energy input, kWh_e/ m^3		0.5–1.5 BW 4.0–5.0 SW
Typical current capacity,	m^3/day	50–2000
Production cost, USD/m^3		3.9–6.5 BW 6.5–9.1 SW

Renewable Energy Sources for RO Desalination

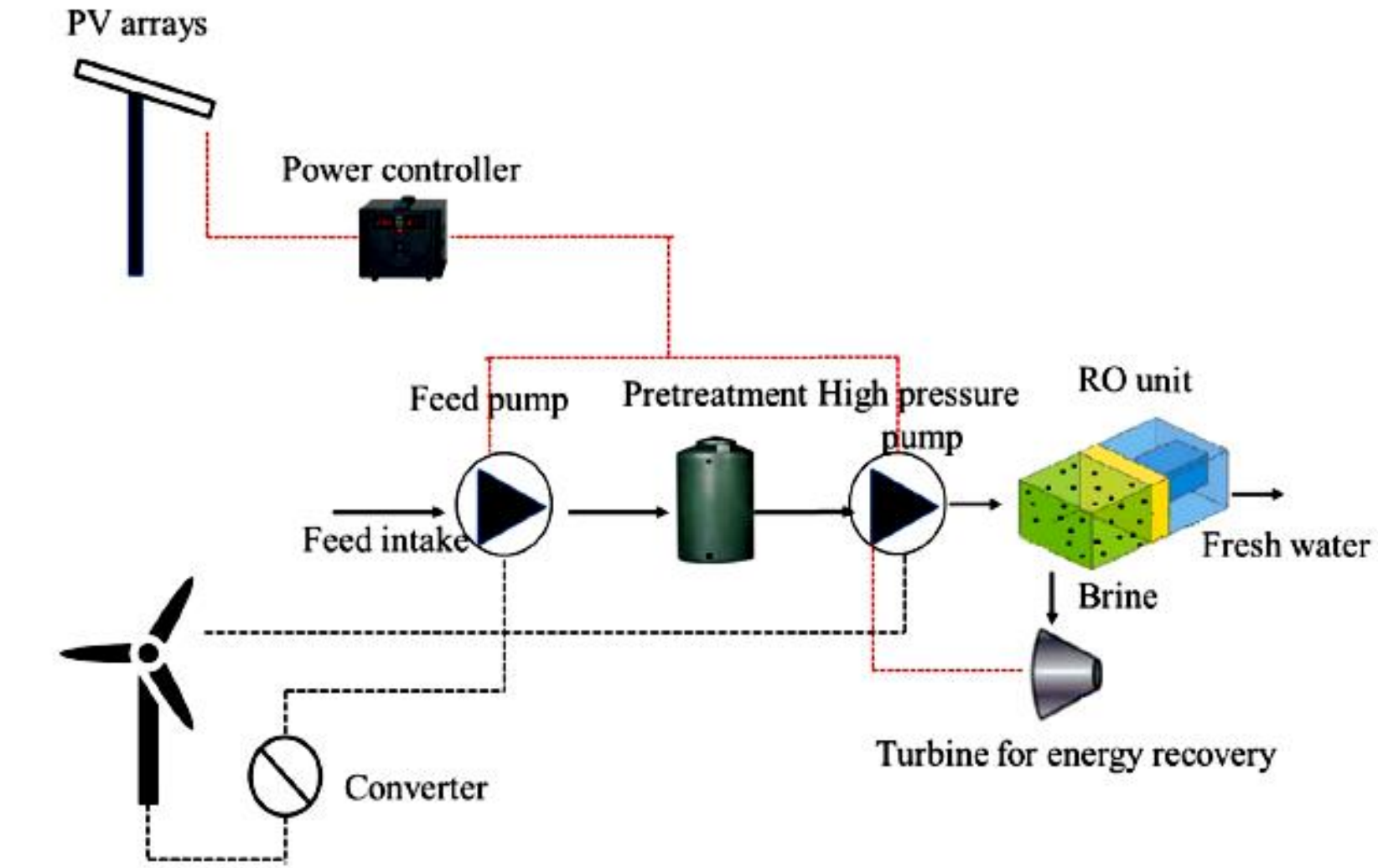
➢ Hybrid PV-wind coupled RO desalination



Schematic of a typical small hybrid solar-wind-powered desalination plant.

Renewable Energy Sources for RO Desalination

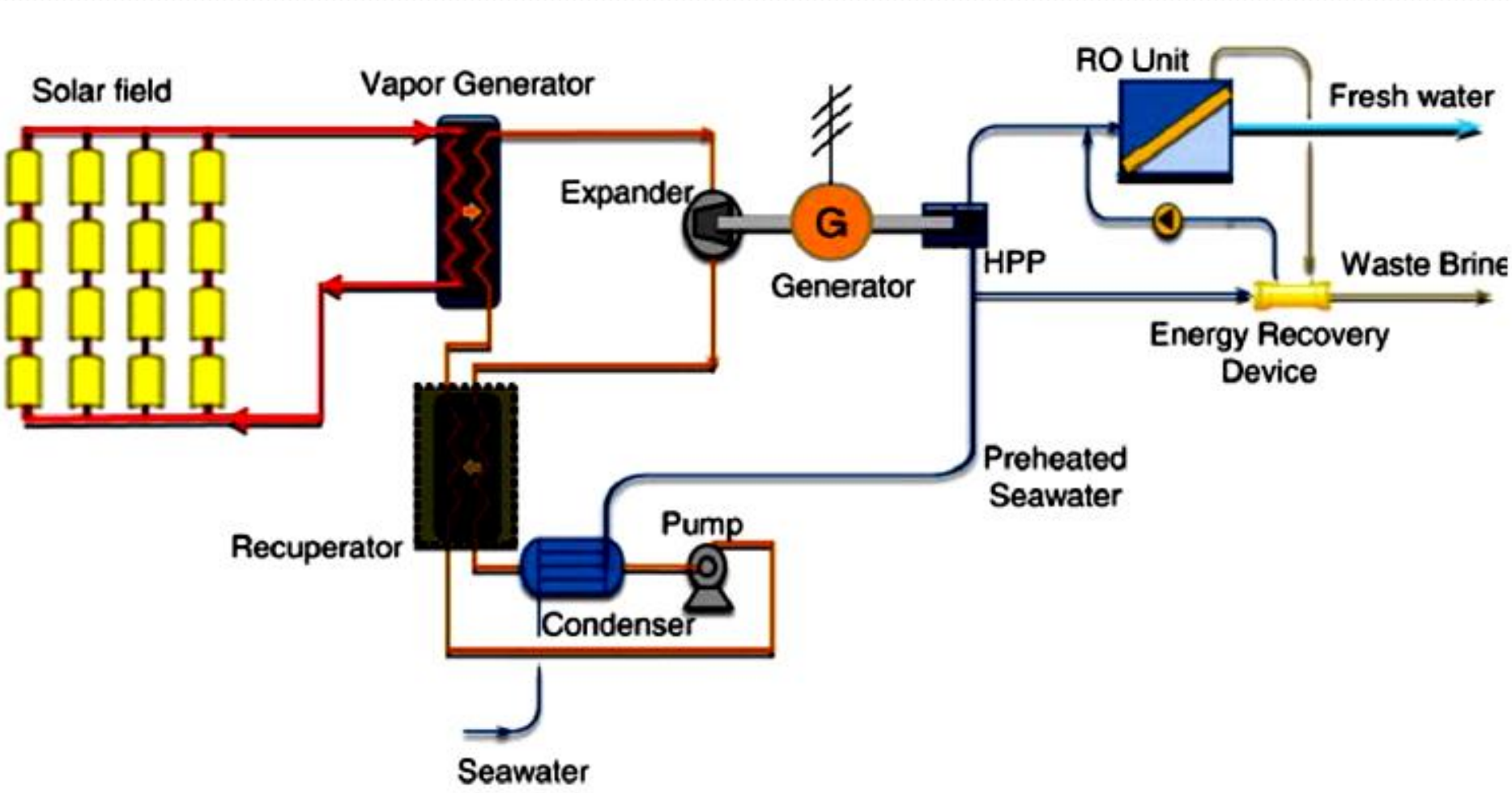
➢Hybrid PV-wind coupled RO desalination



Schematic diagram of solar/wind driven RO system

Renewable Energy Sources for RO Desalination

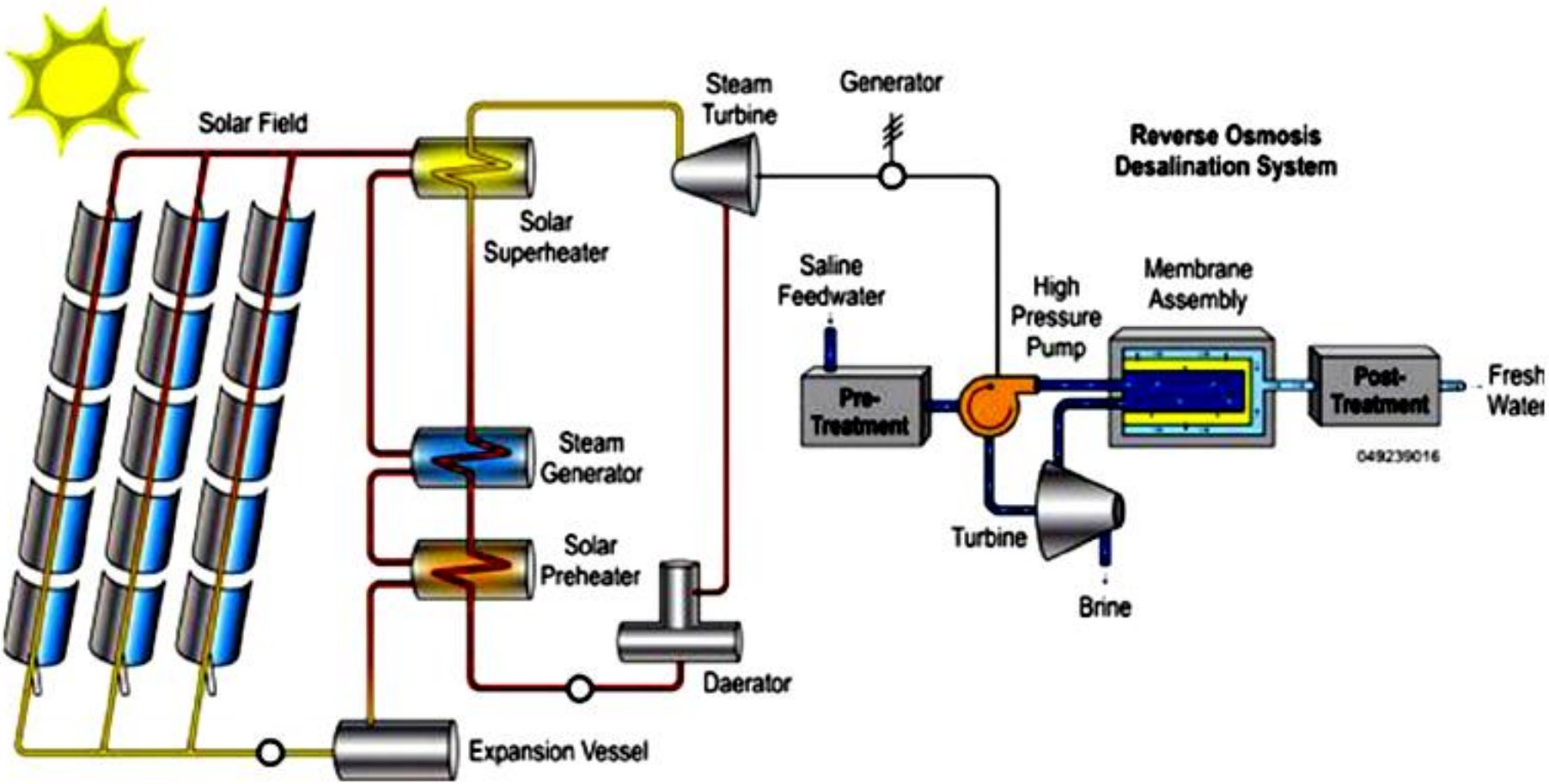
➢Solar thermal Rankine RO unit with energy recovery



Schematic diagram shows the operating principals of Rankine RO unit with energy recovery

Renewable Energy Sources for RO Desalination

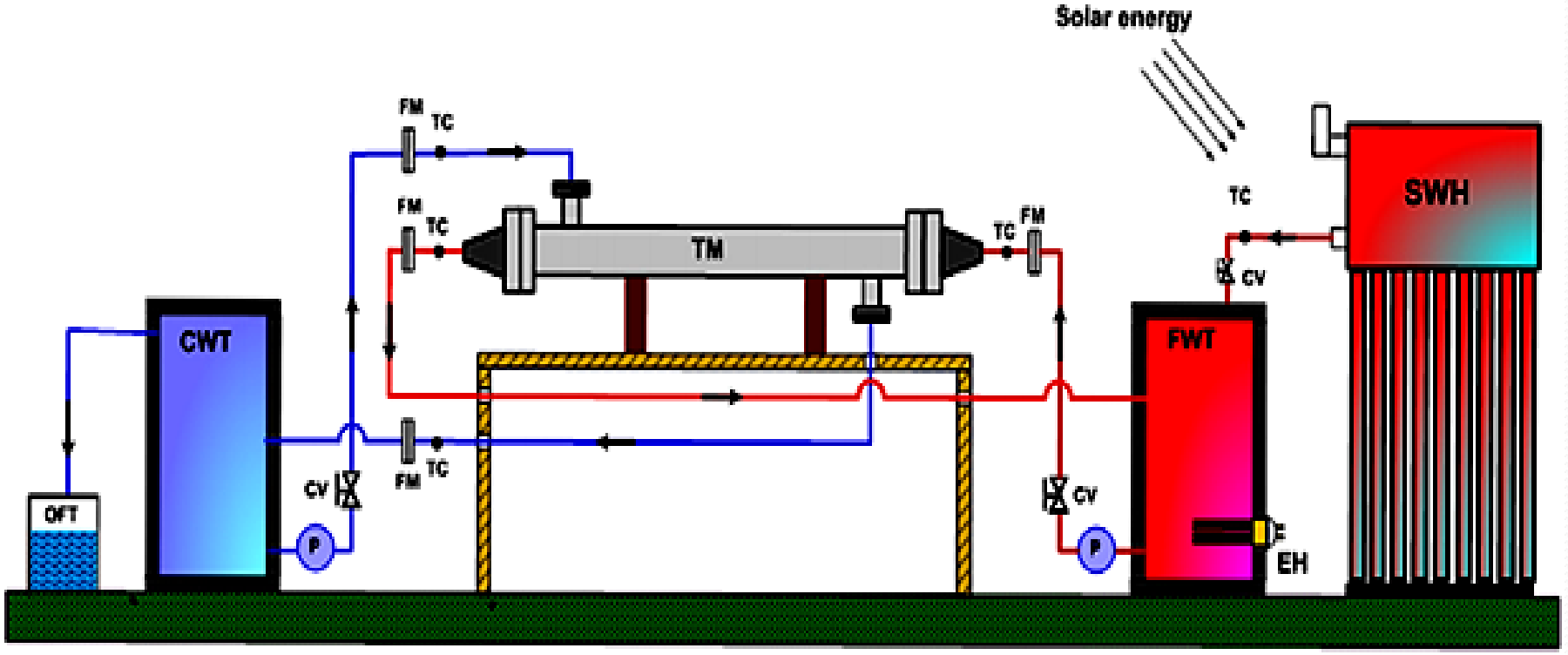
➢Solar thermal Rankine RO unit with energy recovery



Schematic diagram shows the operating principals of Rankine RO unit with energy recovery

Renewable Energy Sources for RO Desalination

➢ Solar thermal energy coupled RO unit

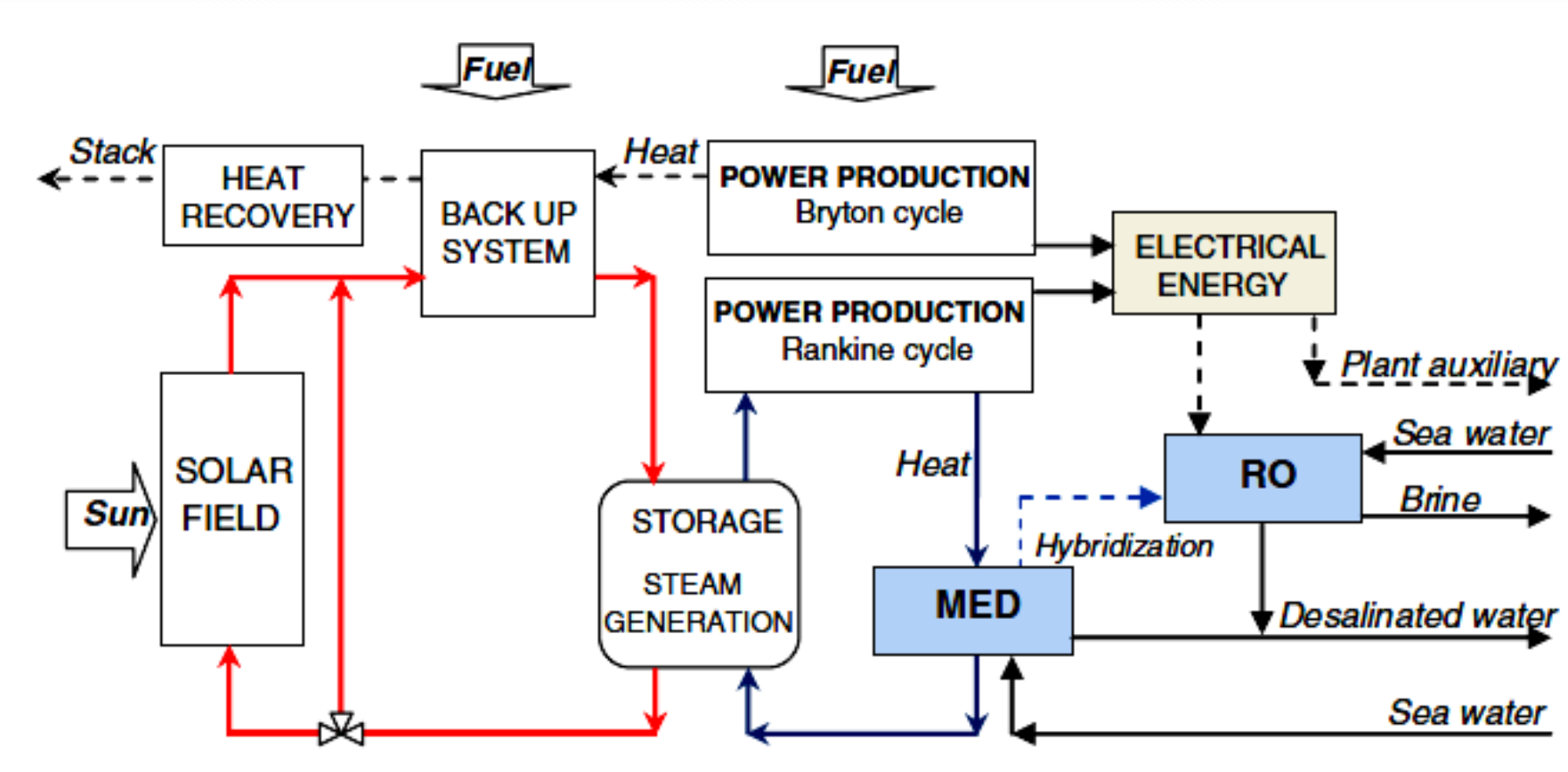


CV	Control Valve	OFT	Overflow Tank	FM	Orifice Flow Meter
CWT	Cooling Water Tank	P	Pump	FWT	Feed Water Tank
EH	Electric Heater	SWH	Solar Water Heater	TC	Thermo Couple
				TM	Tubular Membrane Module

Schematic diagram shows the solar water collector coupled RO desalination unit

Renewable Energy Sources for RO Desalination

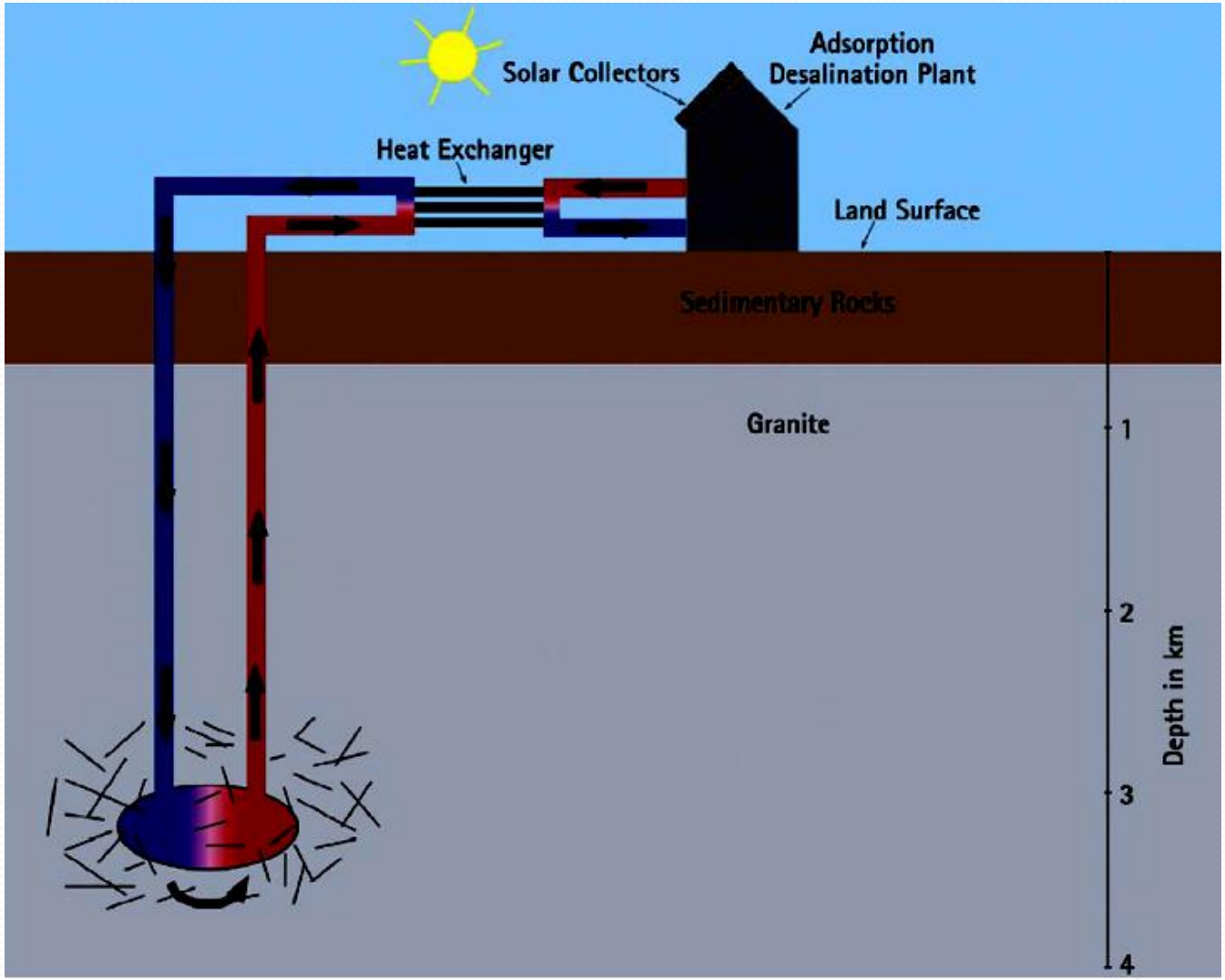
➢Concentrating solar power (CSP) system integrated with MED–RO hybrid desalination



Double scheme for power and fresh water production

Renewable Energy Sources for RO Desalination

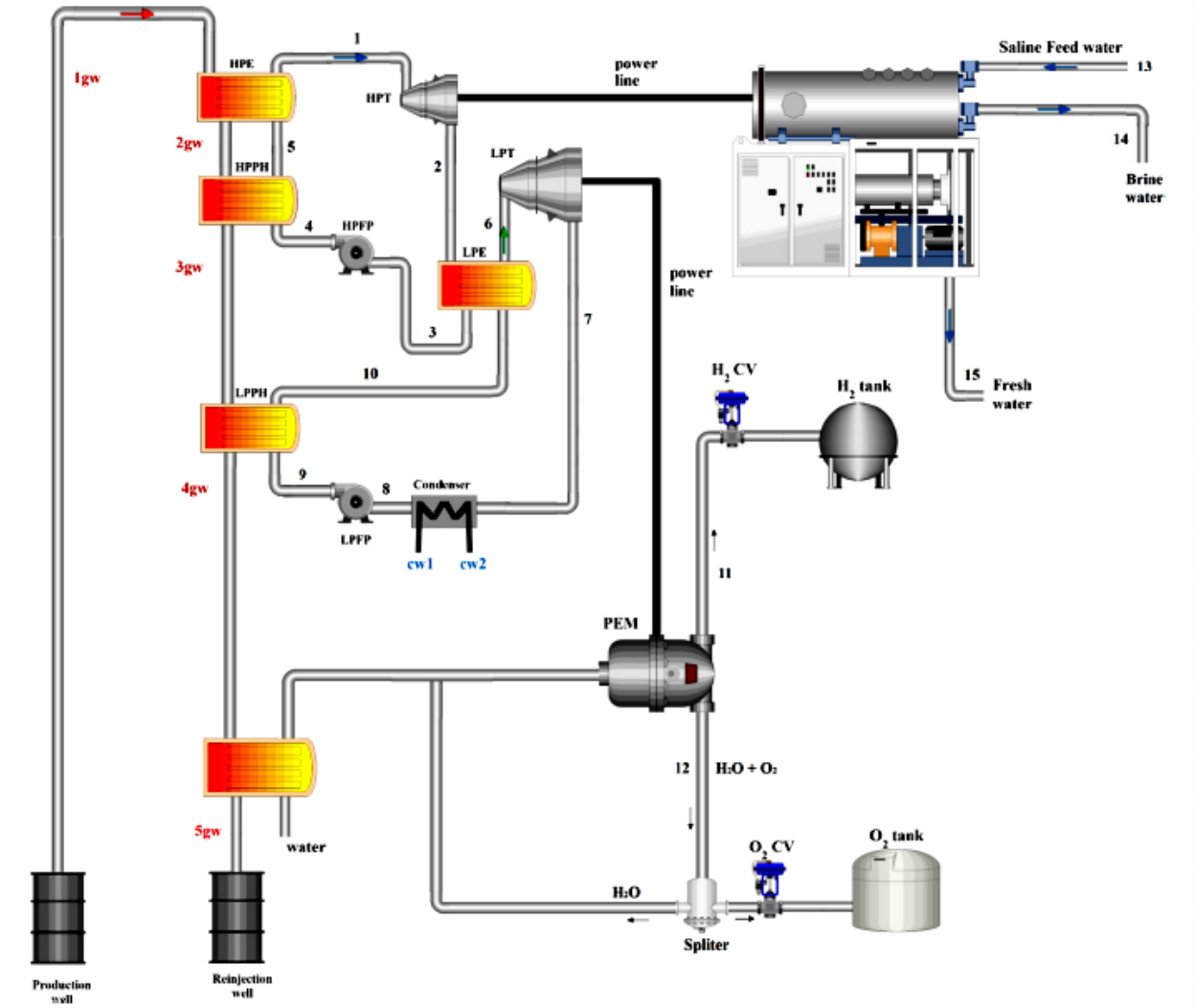
Geothermal energy powered desalination plant



Schematic representation of a geothermal energy powered desalination plant

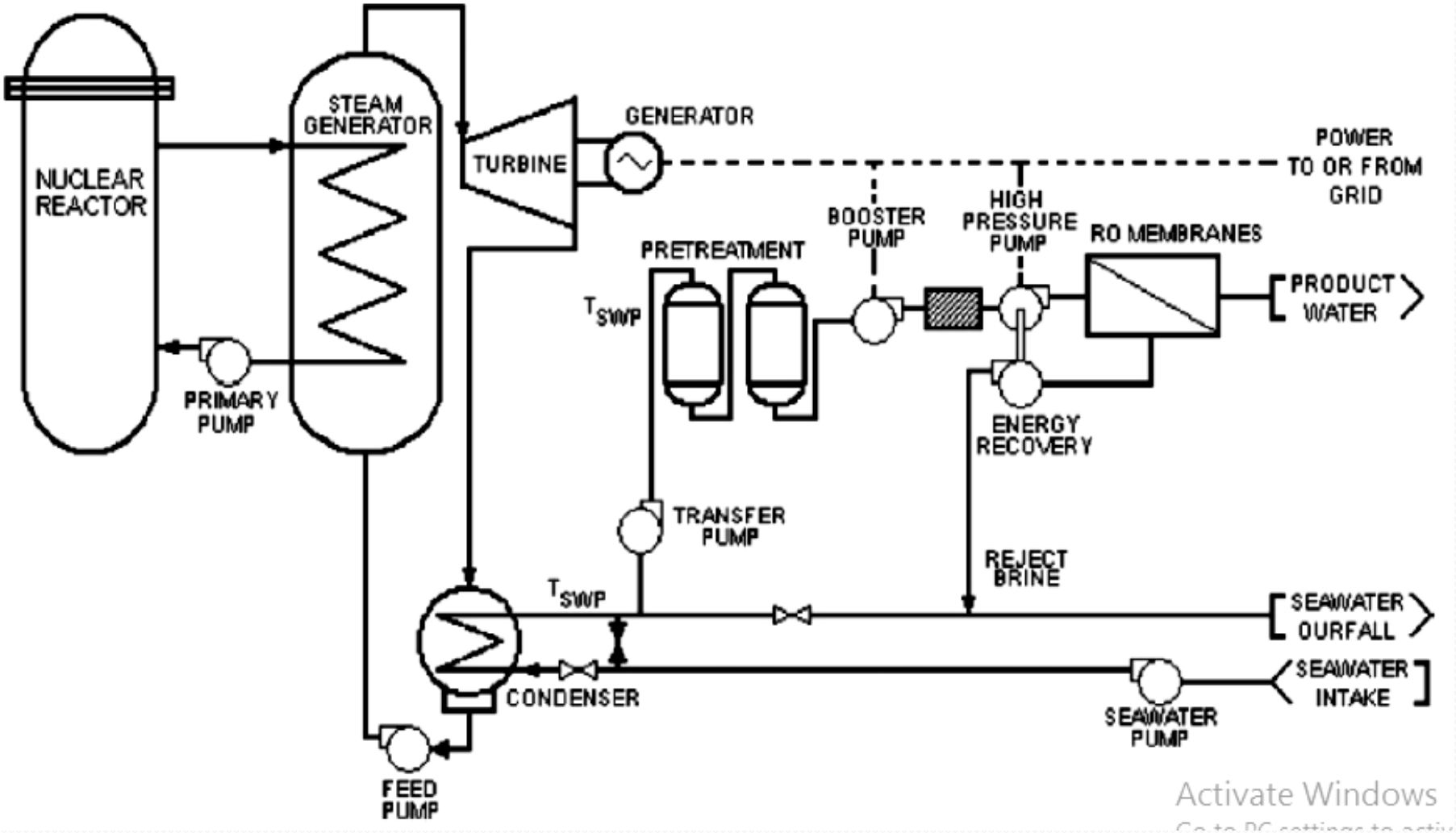
Renewable Energy Sources for RO Desalination

- Combination of geothermal driven dual fluid organic Rankine cycle (ORC), proton exchange membrane (PEM) and reverse osmosis (RO) desalination unit.



Renewable Energy Sources for RO Desalination

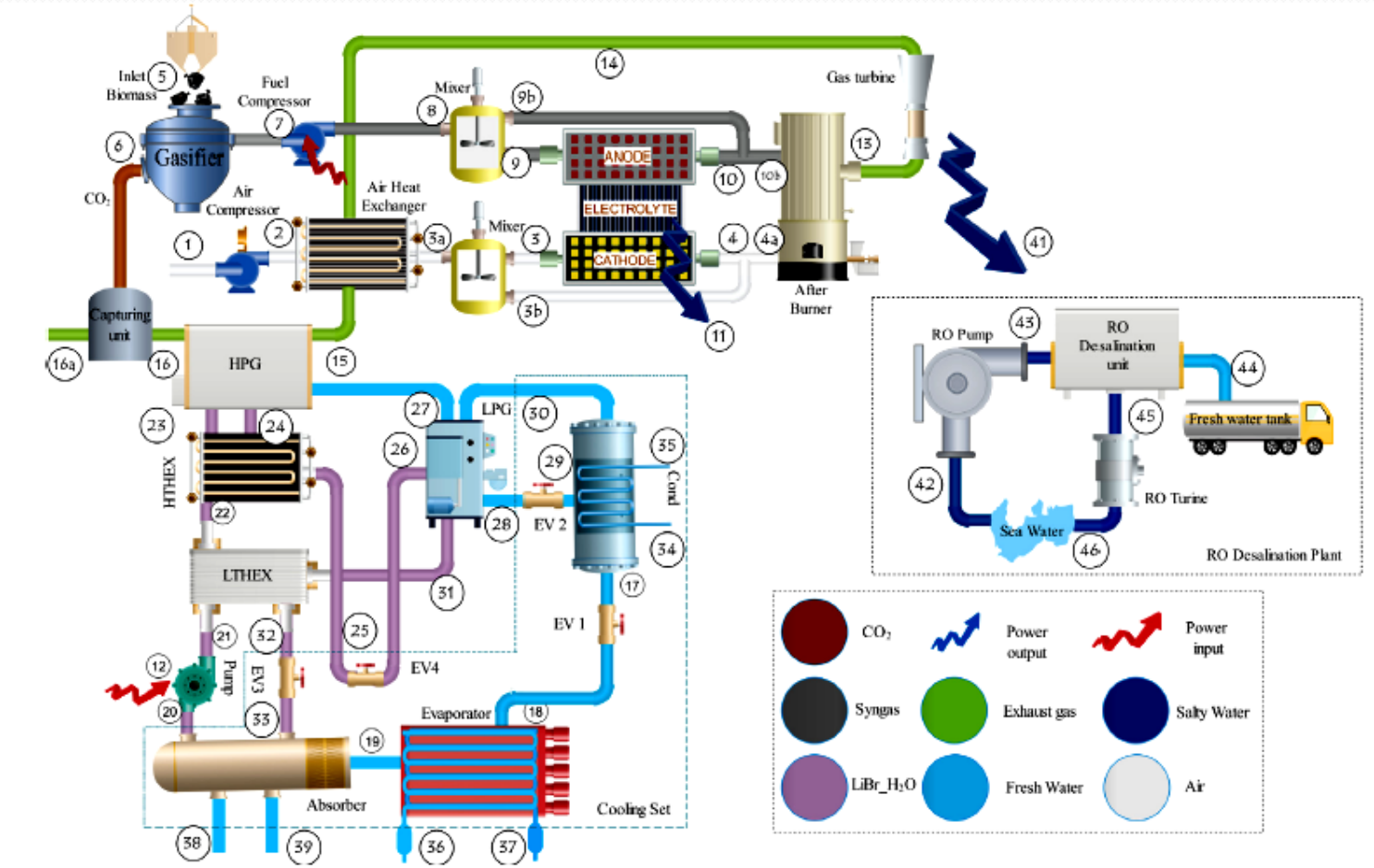
➢Nuclear desalination coupling with RO



Schematic representation of nuclear power plant powered RO desalination plant

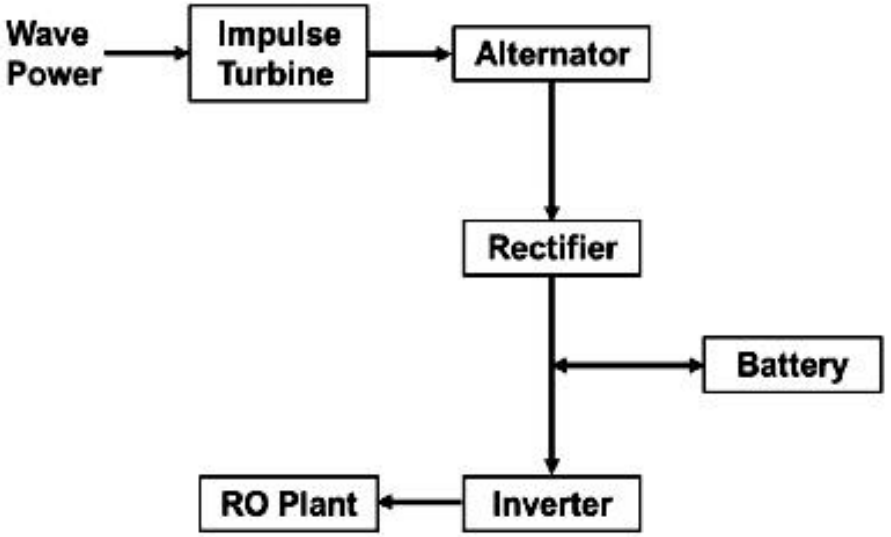
Renewable Energy Sources for RO Desalination

In this study, a biomass-based solid oxide fuel cell integrated with a gas turbine, a reverse osmosis desalination unit, and double-effect absorption chiller is proposed for power generation, cooling and freshwater production.



Renewable Energy Sources for RO Desalination

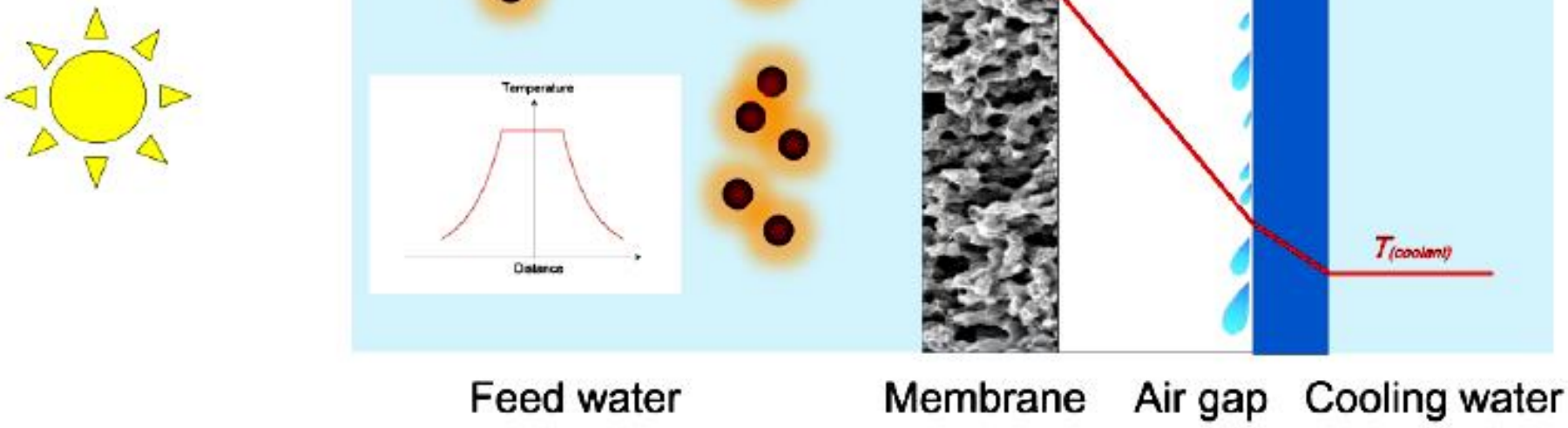
- **Wave energy converter system powered RO seawater desalination**



Application of nanofluid for desalination system

Application of nanofluid for desalination system

Enhancement of energy utilization using nanofluid in solar powered membrane distillation

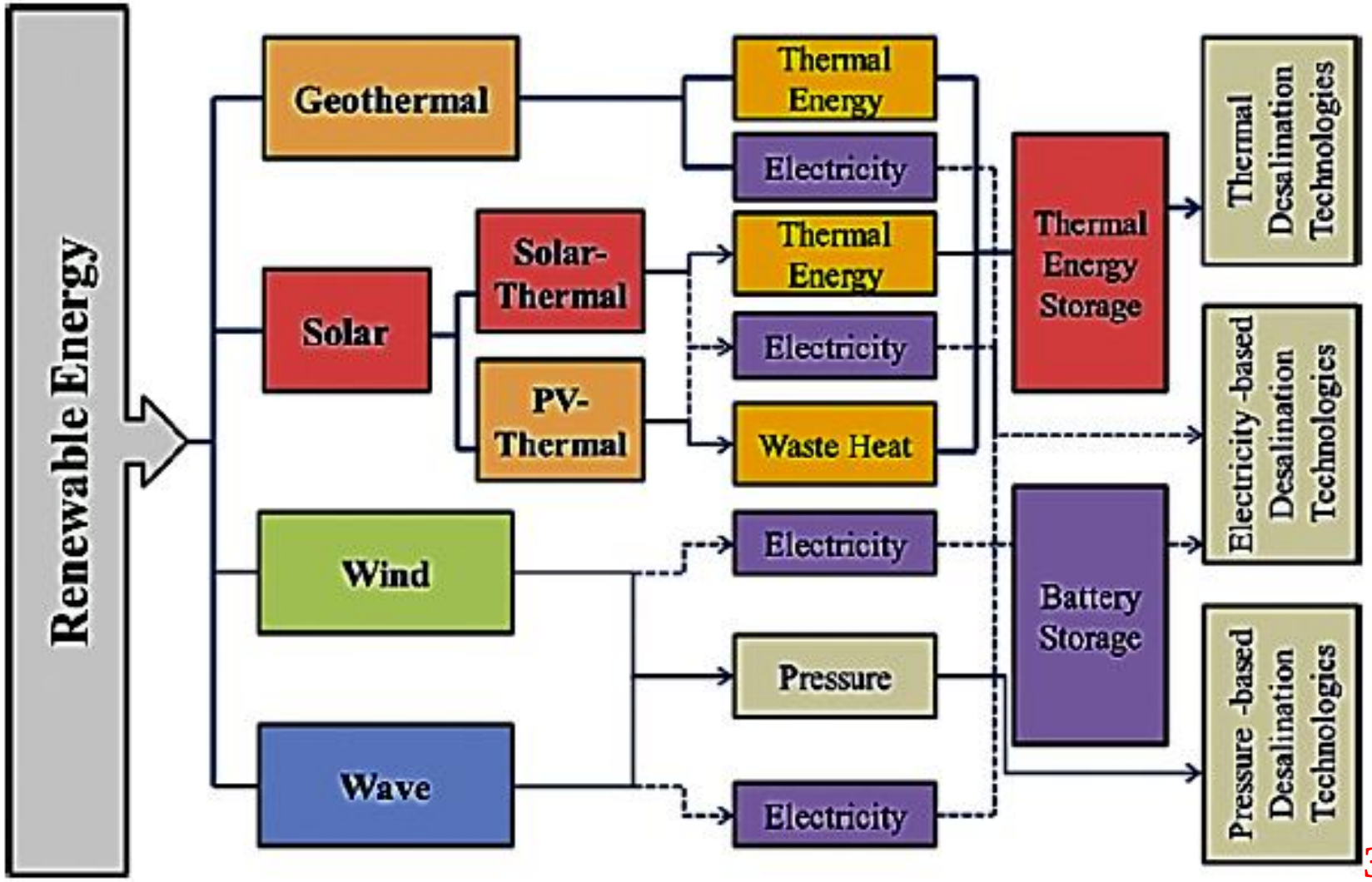


The nanofluid enhanced solar-powered membrane distillation represents a promising perspective for better solar energy utilization.

Energy storage systems for RO desalination unit

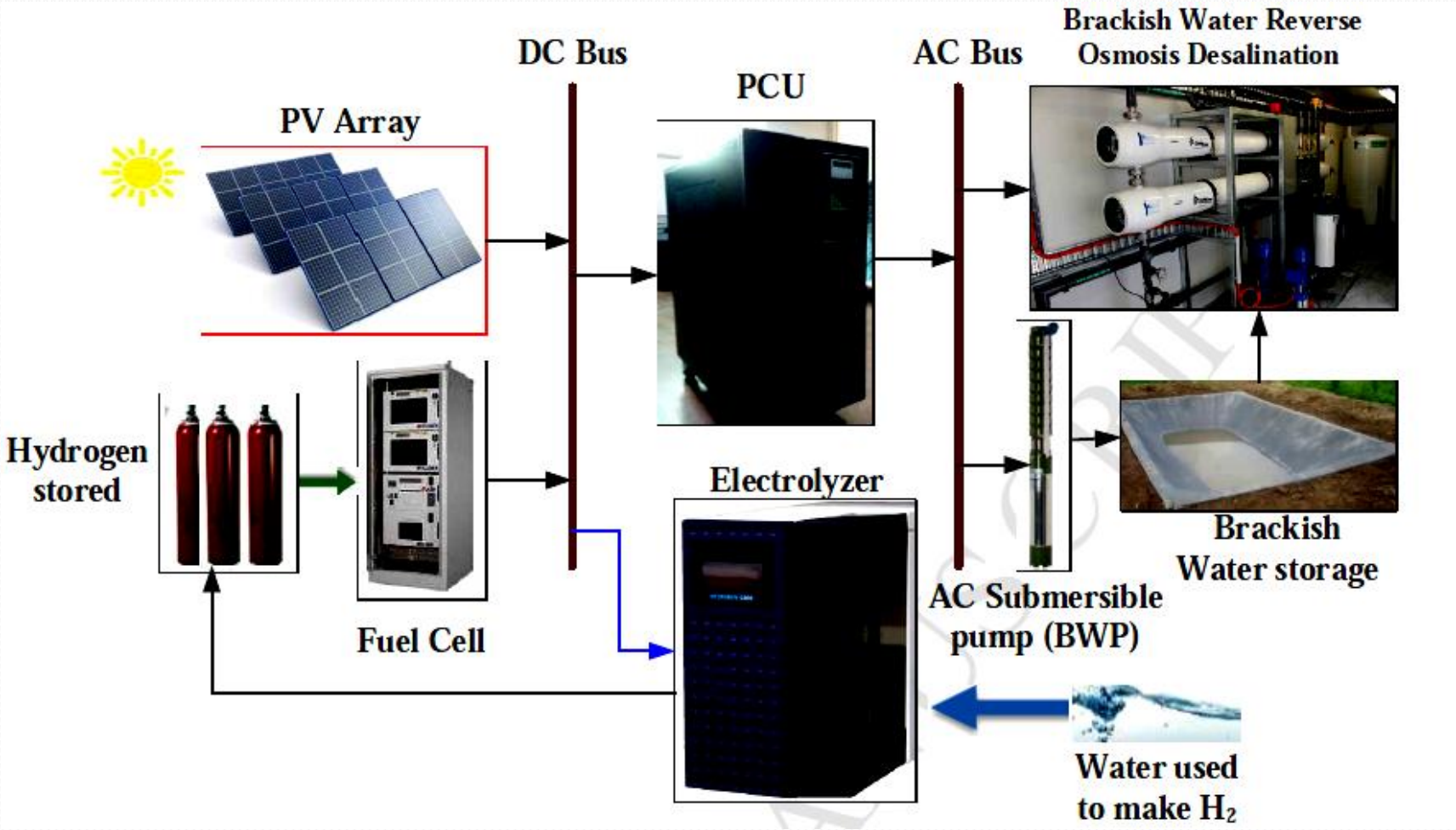
Energy storage systems for RO desalination unit

- **Desalination technologies coupled with renewable energy and storage systems.**



Energy storage systems for RO desalination unit

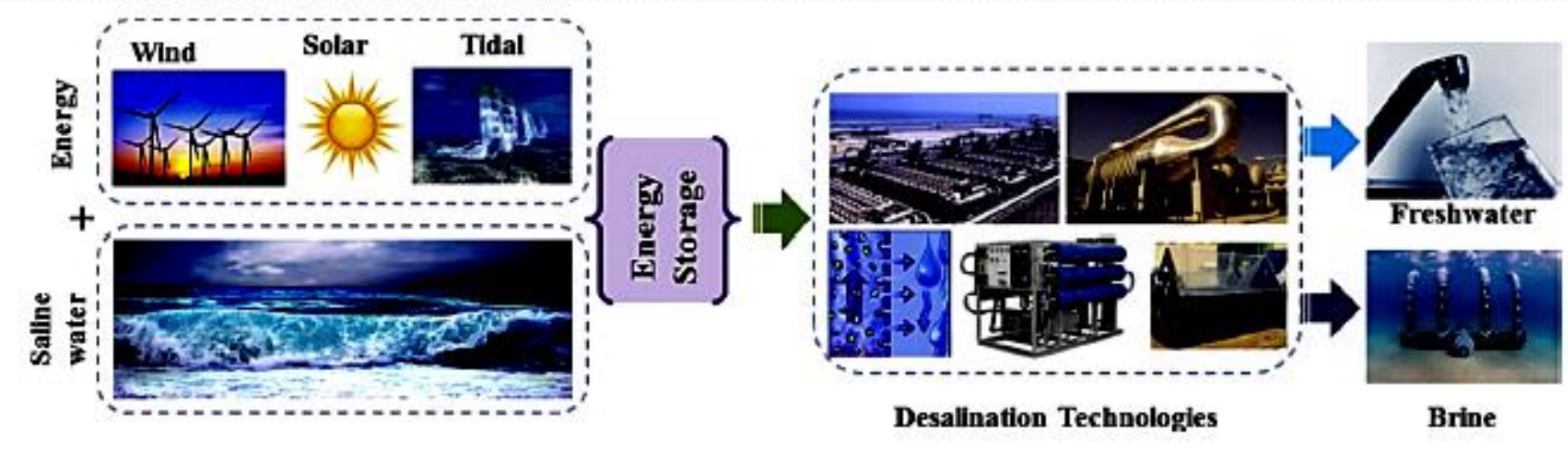
- **Fuel cell as an effective energy storage in reverse osmosis desalination plant powered by photovoltaic system**



The system consists of PV array, self-charging fuel cell, electrolyzer, power conditioning unit (PCU) and hydrogen storage tank.

Energy storage systems for RO desalination unit

➢ **Energy storage for desalination processes powered by renewable energy and waste heat sources**



Thermal energy storage (TES) requires a suitable medium for storage and circulation while the photovoltaic/wind generated electricity needs to be stored in batteries for later use.

Conclusions

- **The PV energy based desalination systems in use are available in different sizes ranging from 0.8m3/d to 60,000m3/d with an approximate cost of US$ 6.5/m3 to 15.7/m3.**

- **Wind energy based desalination plants are available in sizes ranging from 1m3/d to 250,000m3/d with an approximate cost of US$ 3.9/m3 to 9.1/m3.**

- **Desalination systems based on wind-PV hybrid energy have been implemented in many countries with the size ranging from 3m3/d to 83,000m3/d. The cost of water from systems varies from US$ 6.12/m3 to 1.4 $/m3.**

- **Tidal energy-RO desalination using hydraulic turbine could reduce water desalination cost by 31%–41.7% compared with conventional RO system at the optimum feed pressure (5.6 MPa) and at water recovery rate of 40%.**

Recommendations for future work

- **Energy storage systems need to be integrated with intermittent renewable energy sources such as wind, solar and the ocean to smooth the power fluctuations caused by the intermittence.**

- **The existing storage systems, such as batteries, resulting in higher water desalination costs due to their short operation life and high cost. Therefore, economical, long-lasting energy storage solutions are needed.**

- **The geothermal energy, where available, could be used to eliminate the need for energy storage and to provide continuous energy during the periods of intermittence.**

Recommendations for future work

- **More research on optimization of hybrid energy sources-desalination systems is needed to identify methods that can minimize the cost of fresh water production.**

- **More research on study the effect of nanofluid on the performance of RO desalination system.**

- **More research on study the effect of lattent storage materials on the performance of RO desalination system.**

The End