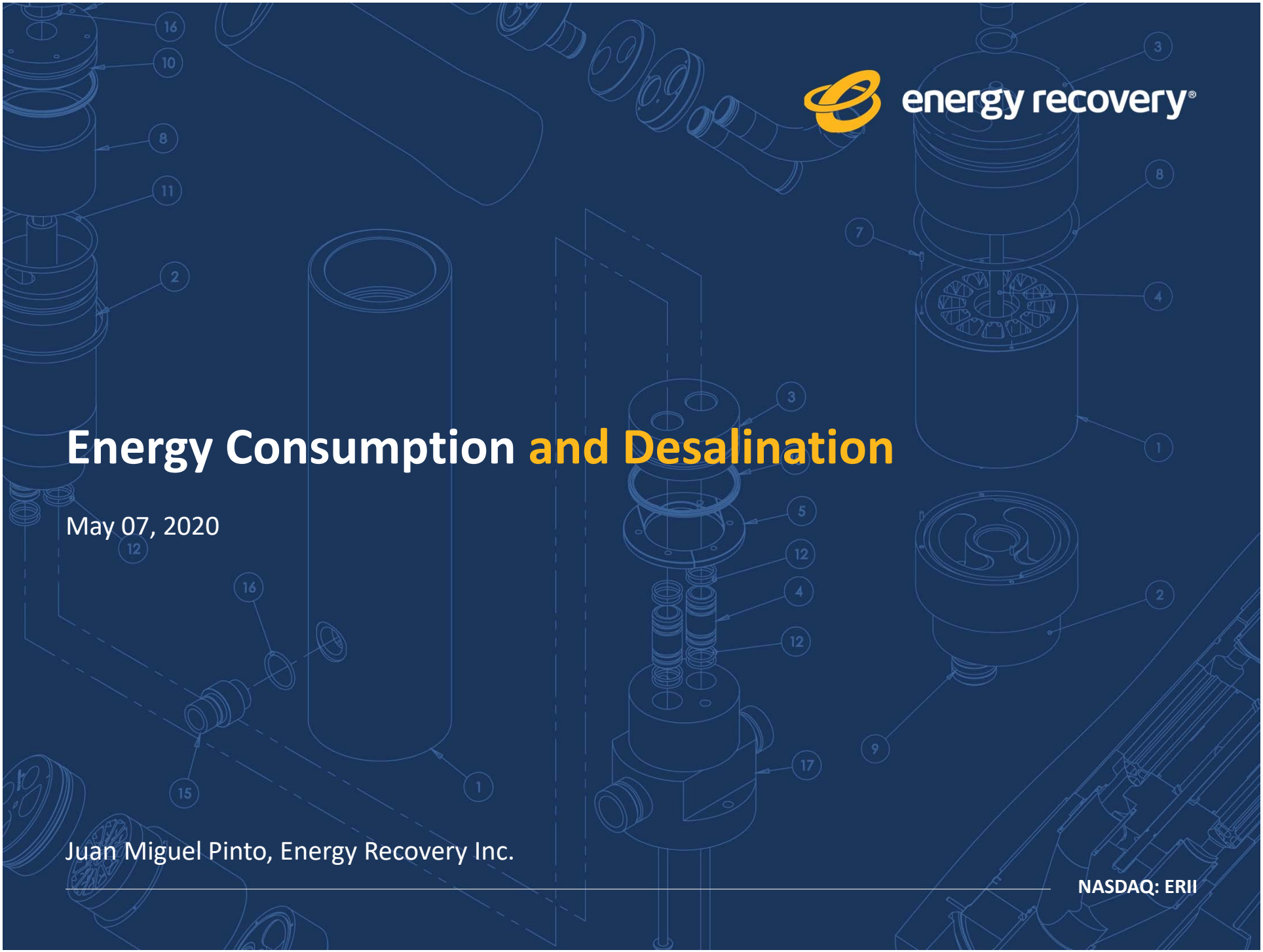

Energy Consumption and Desalination

May 07, 2020

Juan Miguel Pinto, Energy Recovery Inc.

NASDAQ: ERII

AGENDA

1. Introduction
2. Desalination
3. SWRO – Seawater Reverse Osmosis
4. Energy consumption
5. Renewable energy
6. Conclusion

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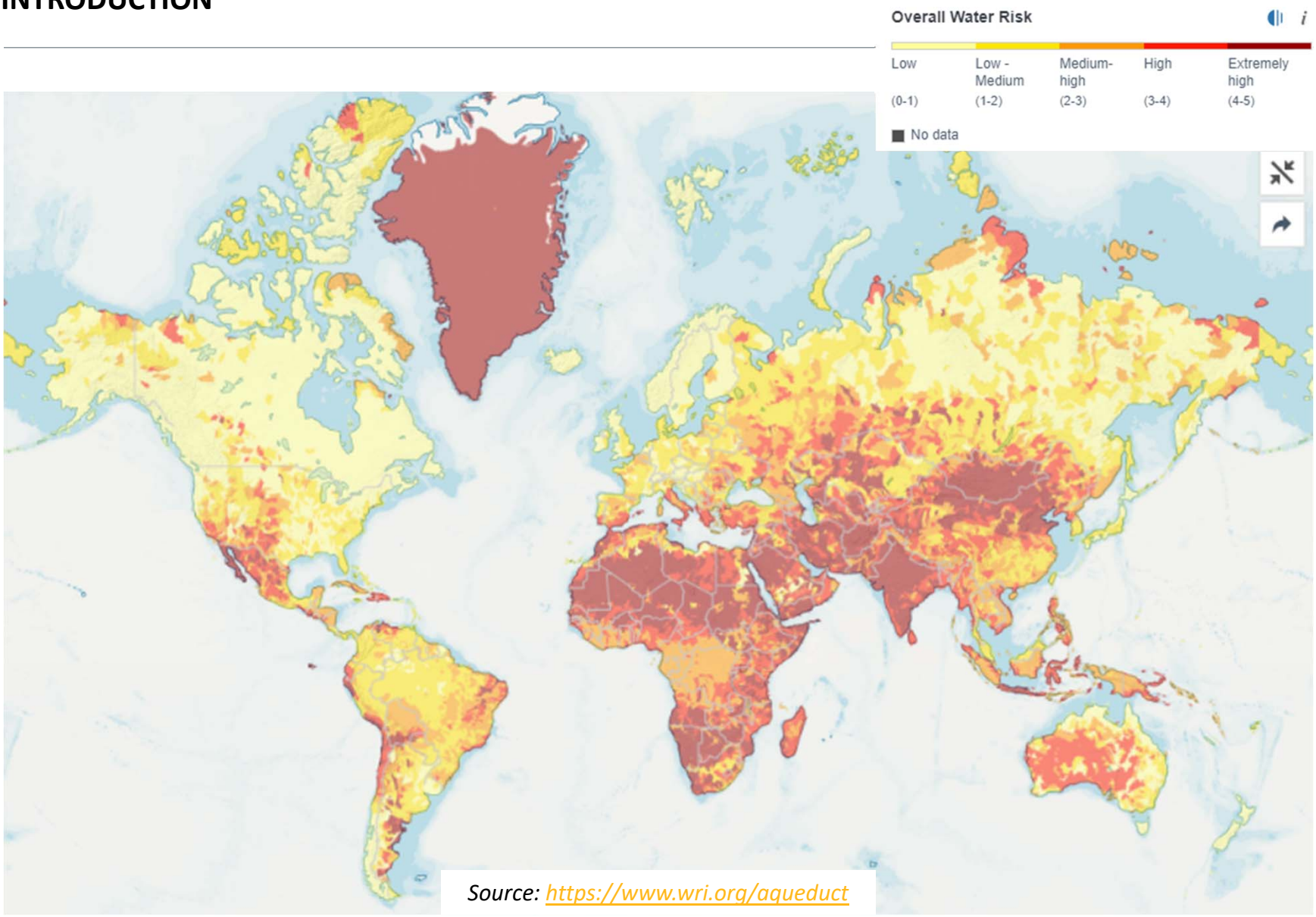
Introduction

INTRODUCTION



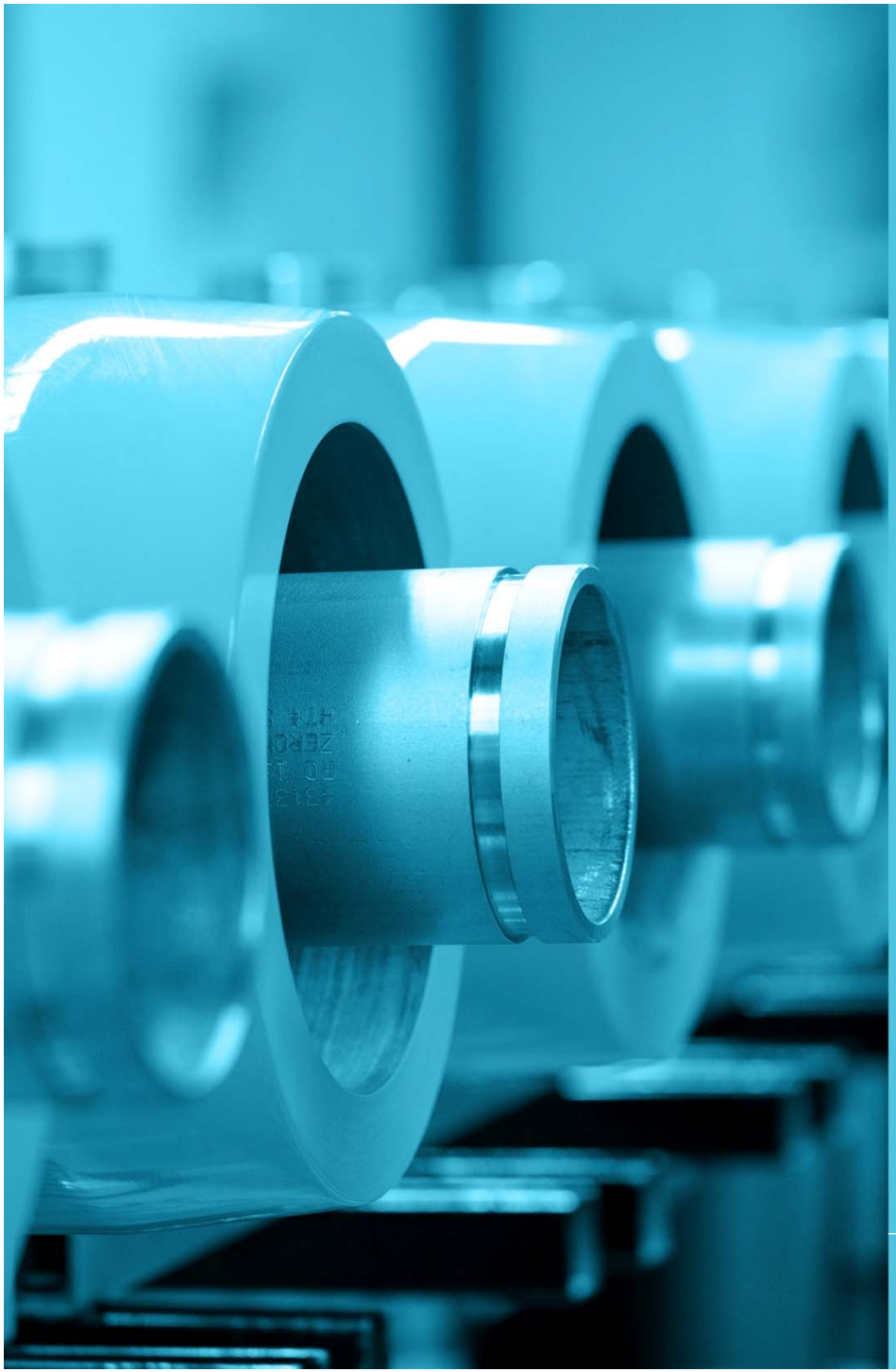
Source: https://www.wri.org/aqueduct

The Impact of Water Scarcity on GDP

Today's Path

A Better Path

Source: https://www.worldbank.org/en/topic/water/publication/high-and-dry-climate-change-water-and-the-economy



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Desalination

DESALINATION

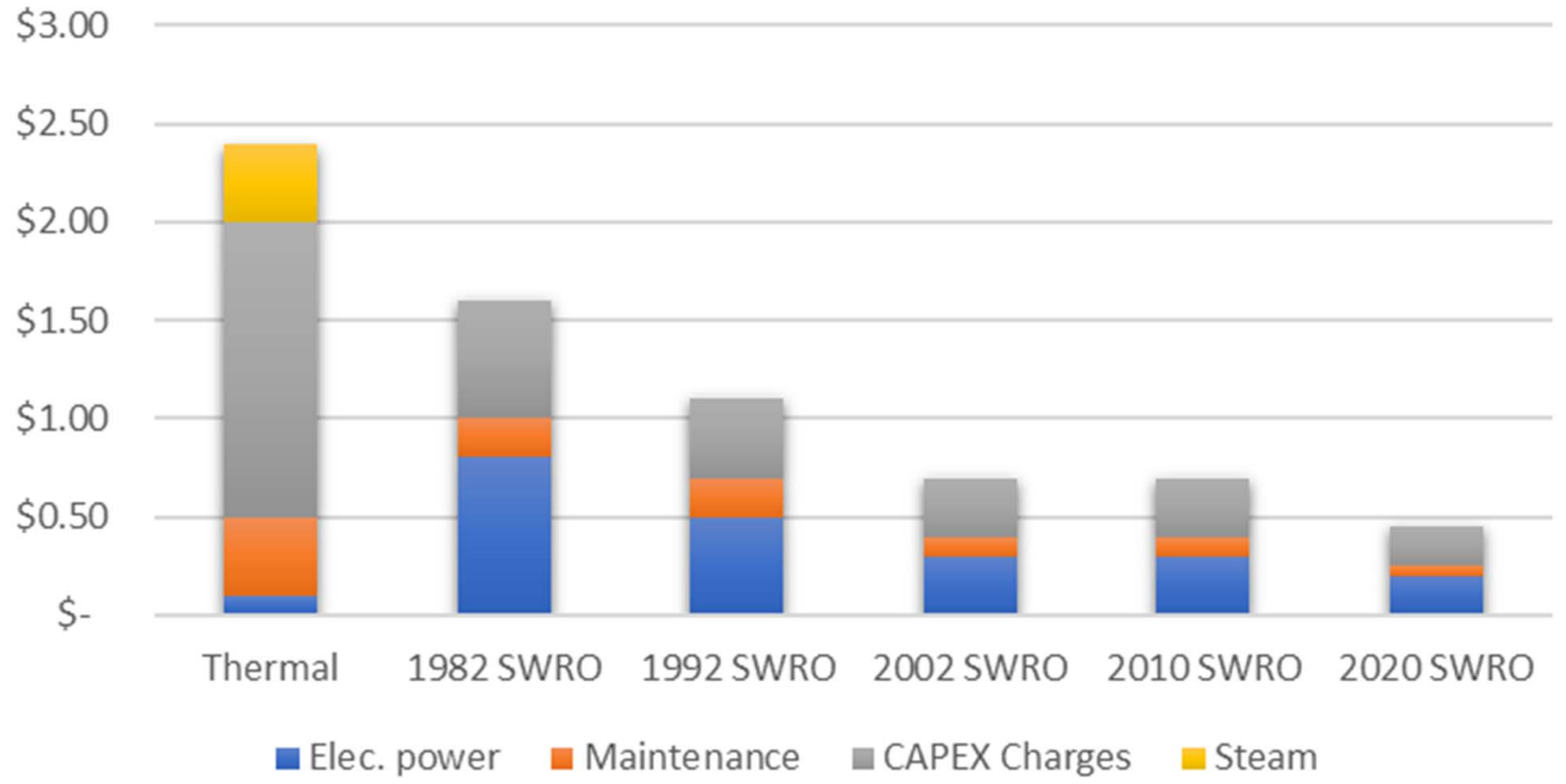
DESALINATION

1970	1982	2002	2005
Multistage Flash	Membrane Technology	Membrane Technology Improvements	Renewable Energies

Source: Multistage picture - Environmental XPRT. Membrane technology - James Grellier / Wikimedia Commons

DESALINATION

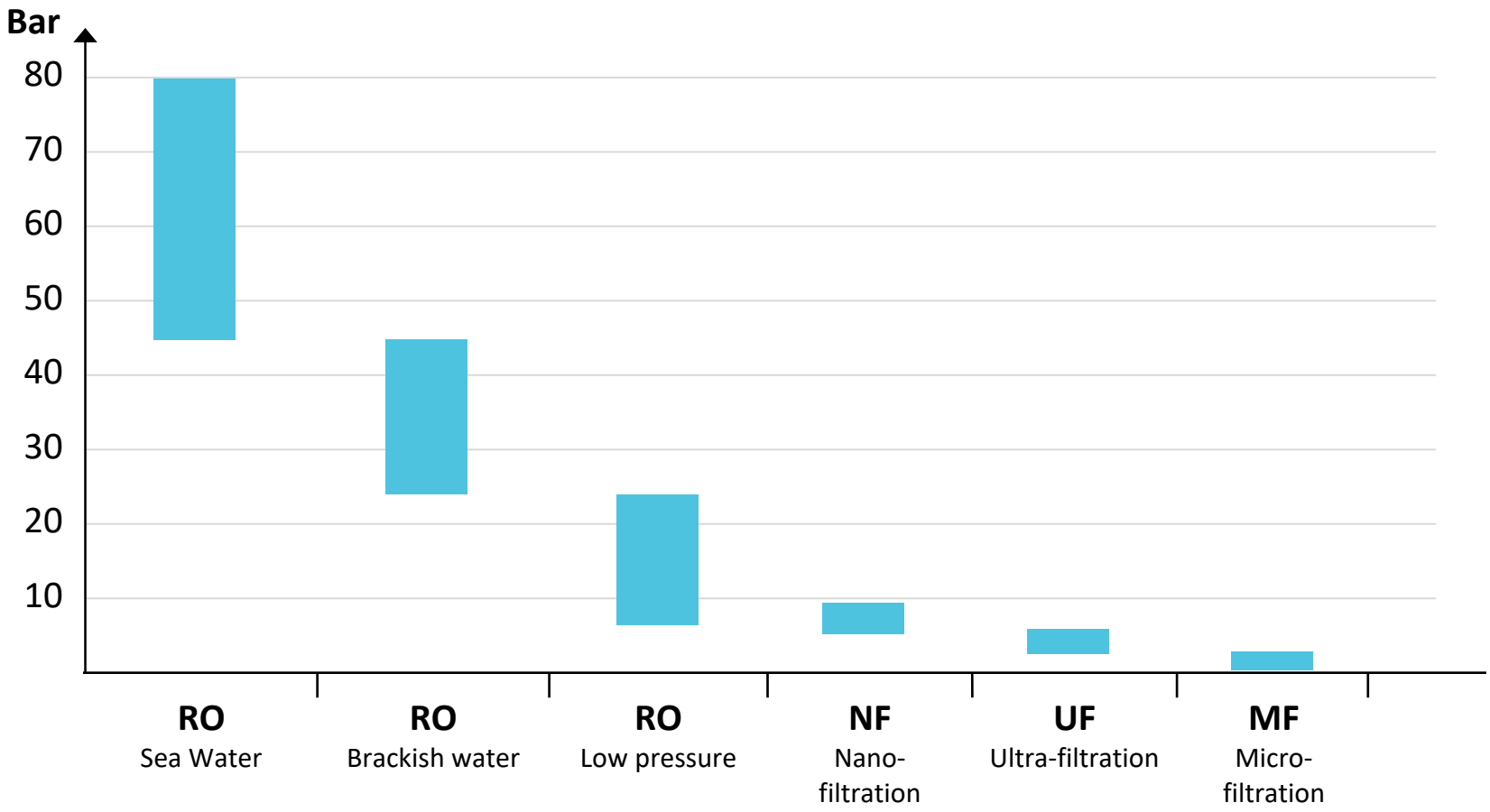
Seawater Reverse Osmosis Cost Trend



Source: Watereuse association – Seawater Desalination Costs 2020 – Estimated cost breakdown.
Jubail SWRO – 0.41 USD/m^3 and Yanbu 4 – 0.47 USD/m^3

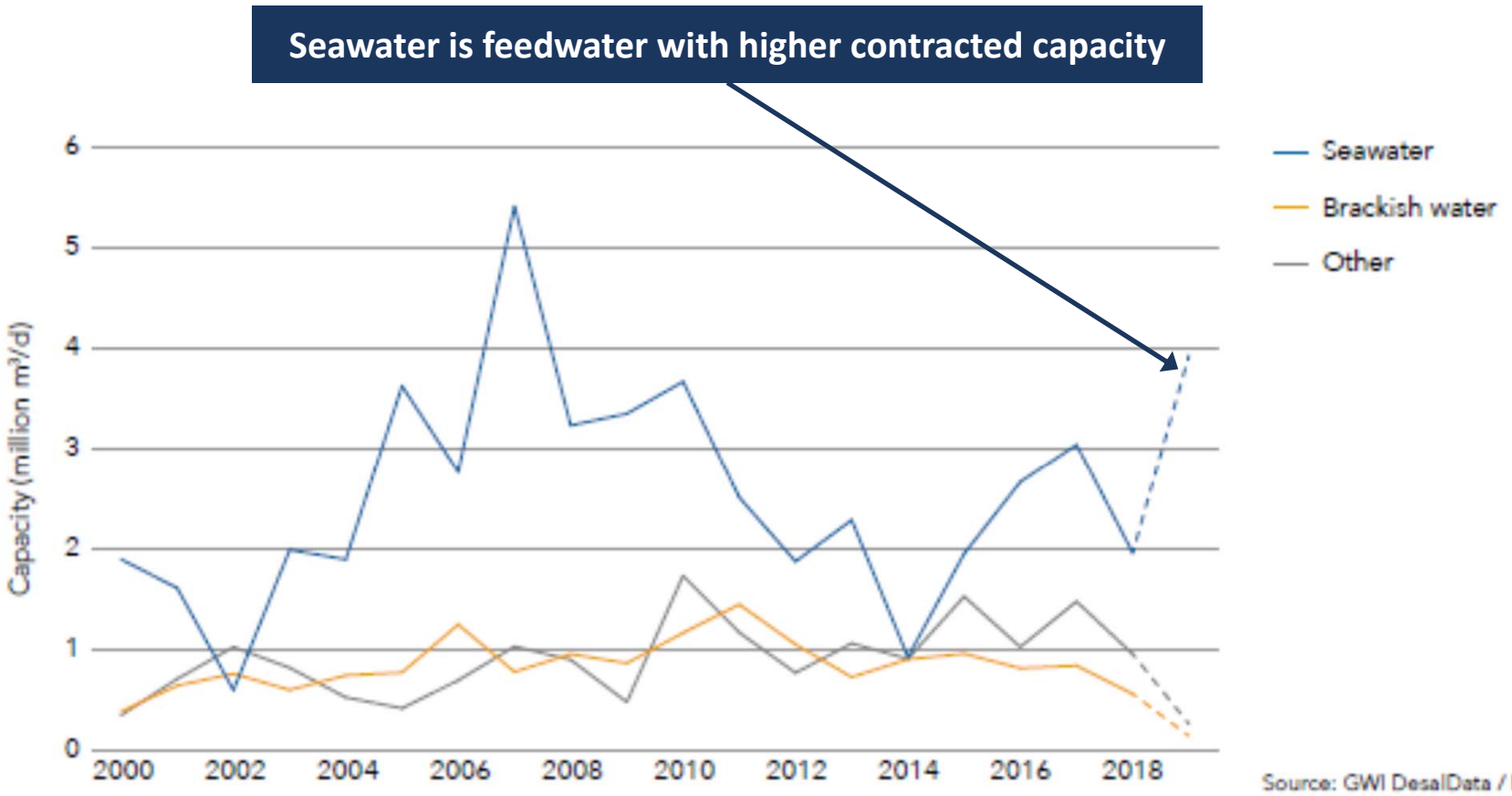
DESALINATION

Membrane Feed Pressure for Feedwater and Membrane Technology



DESALINATION

Annual Contracted Capacity by Feedwater Type, 2000-2019

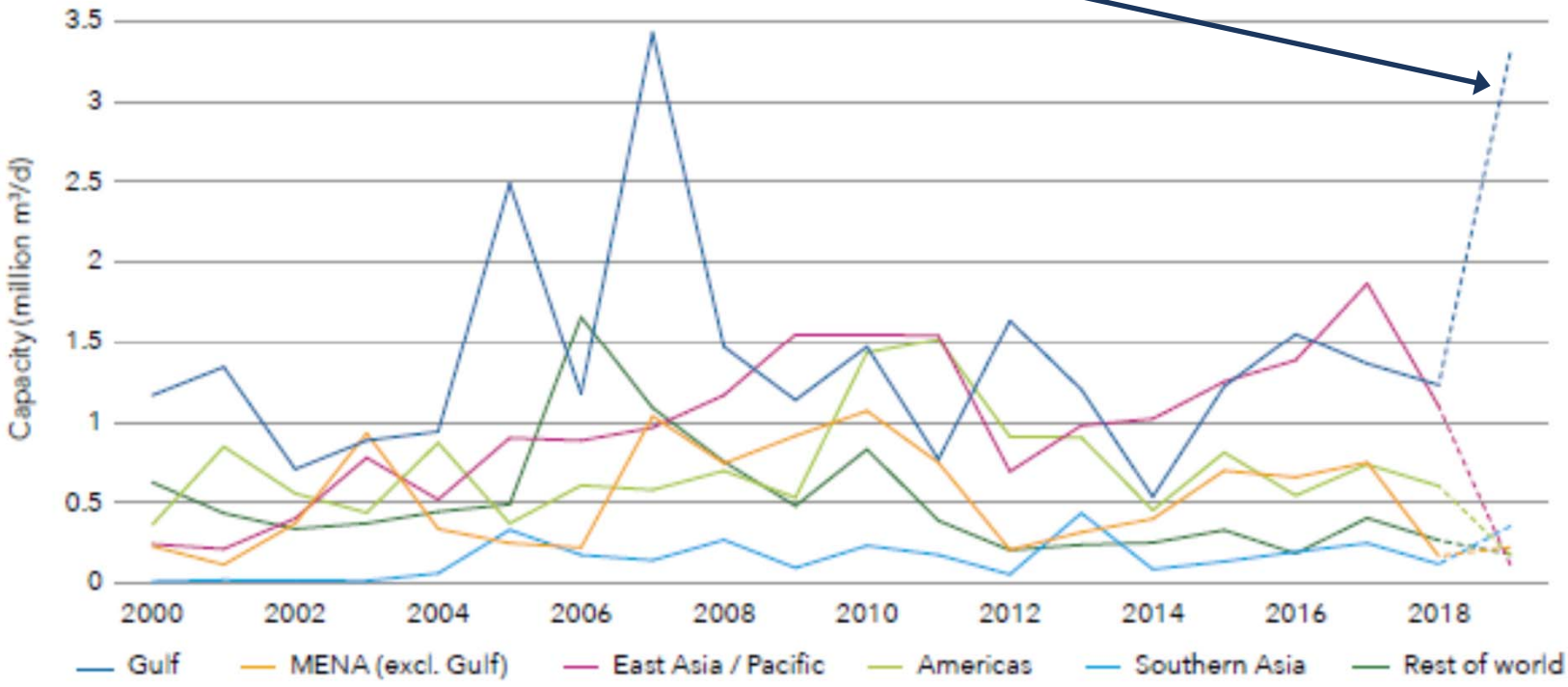


Dotted line indicates values through June 2019; Source: GWI

DESALINATION

Annual Contracted Capacity by Region, 2000-2019

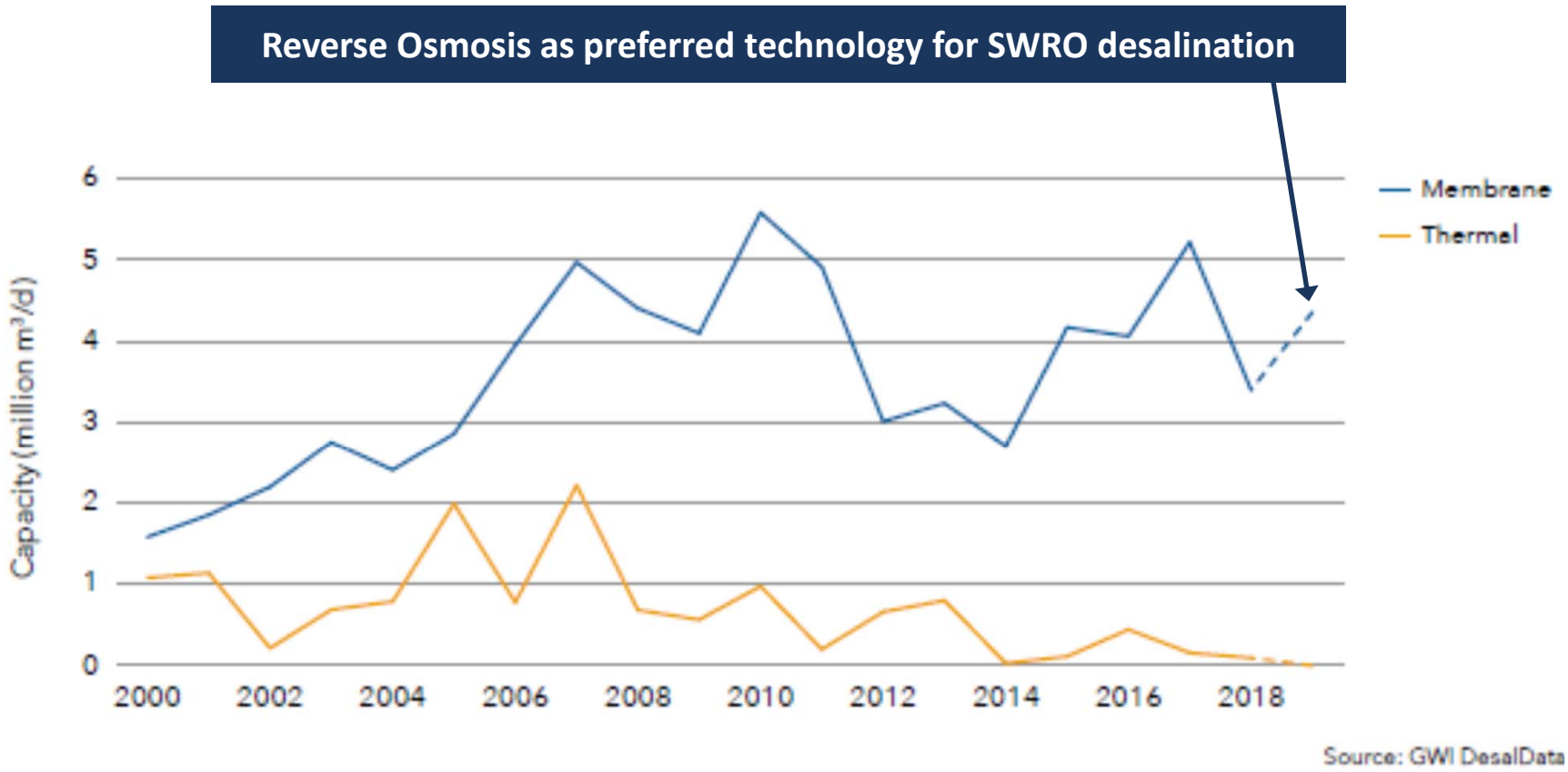
Persian Gulf has the largest demand of SWRO desalination



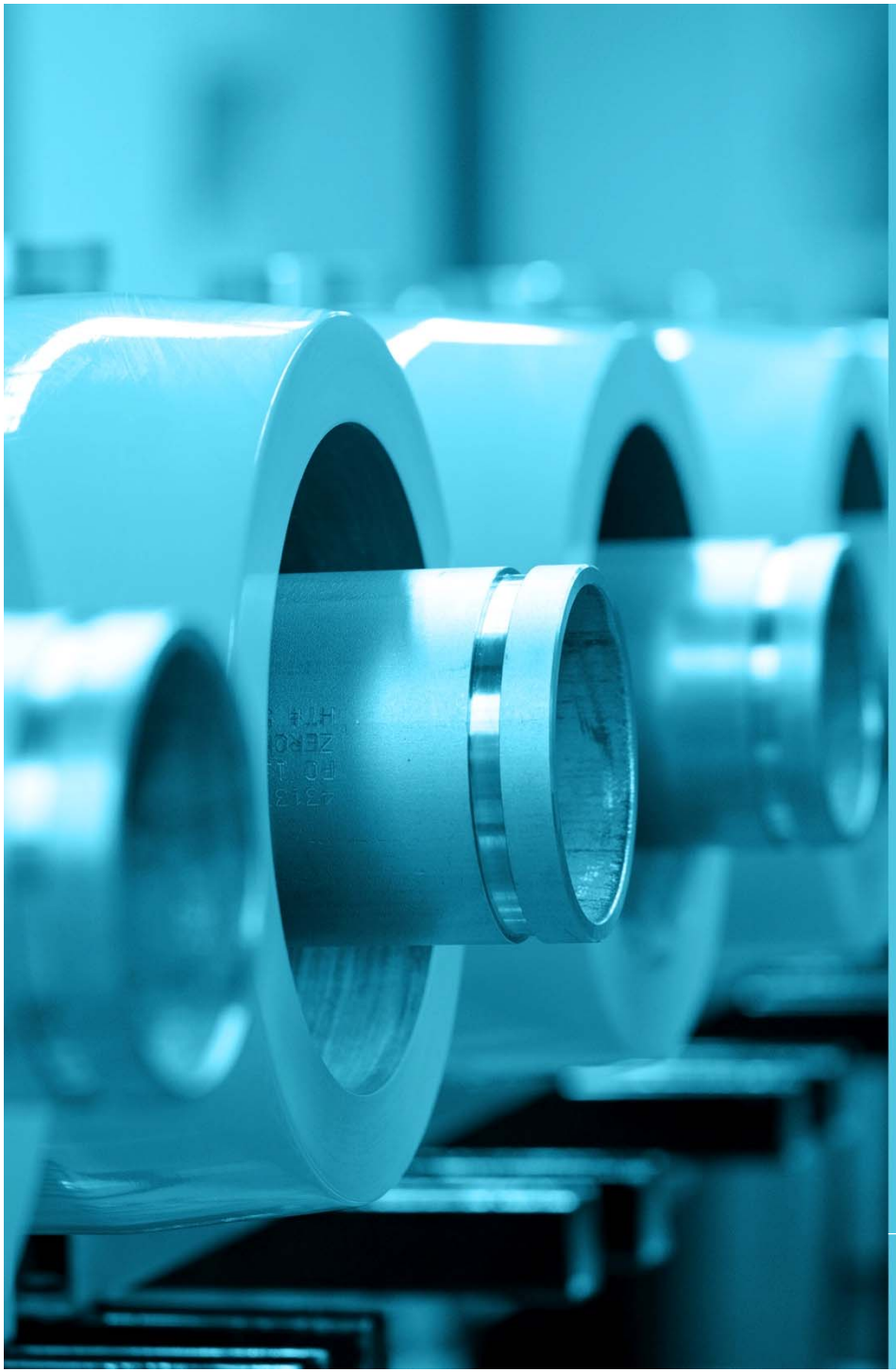
Dotted line indicates values through June 2019; Source: GWI

DESALINATION

Additional Contracted Desalination Capacity by Technology, 2000-2019



Dotted line indicates values through June 2019; Source: GWI



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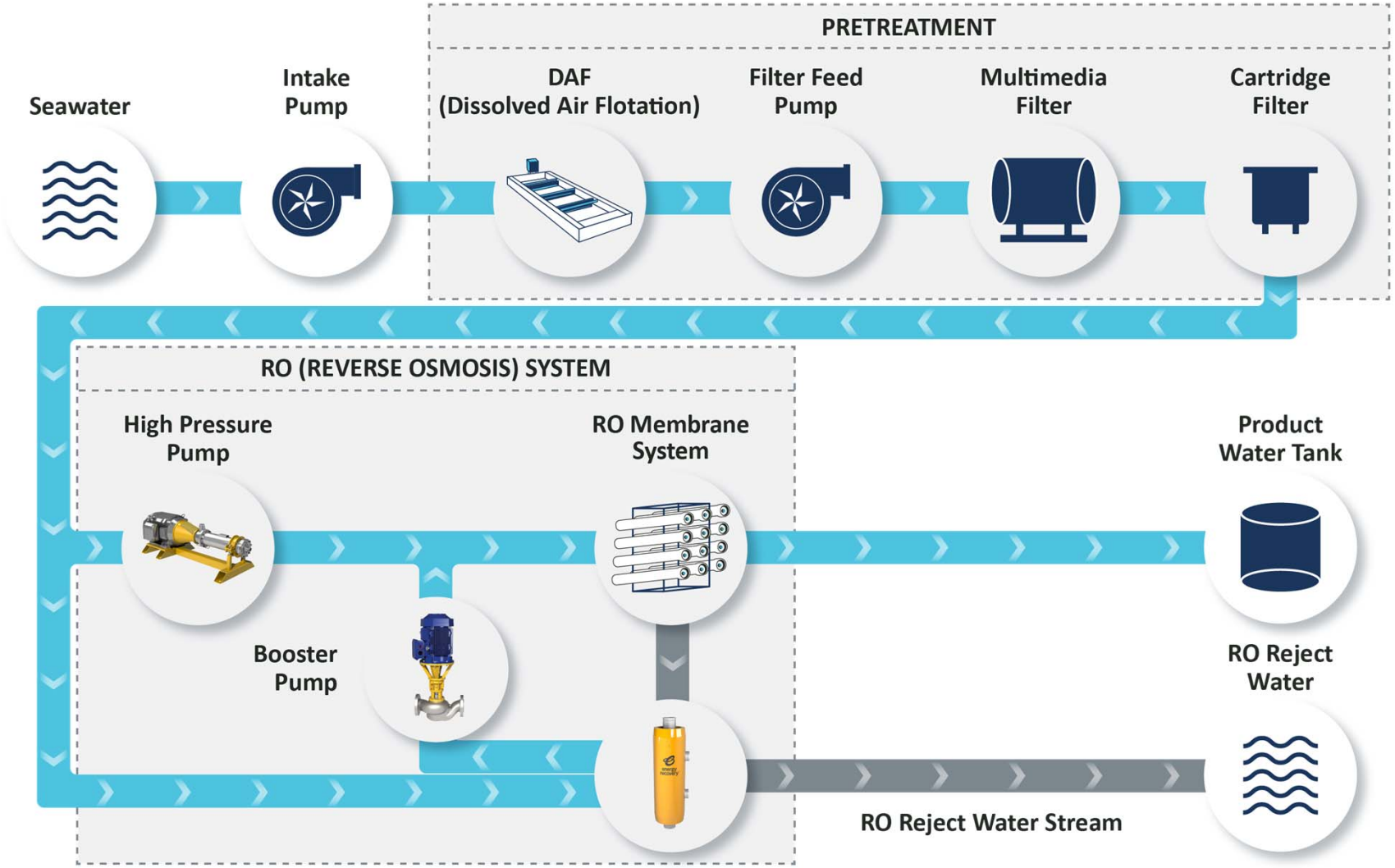
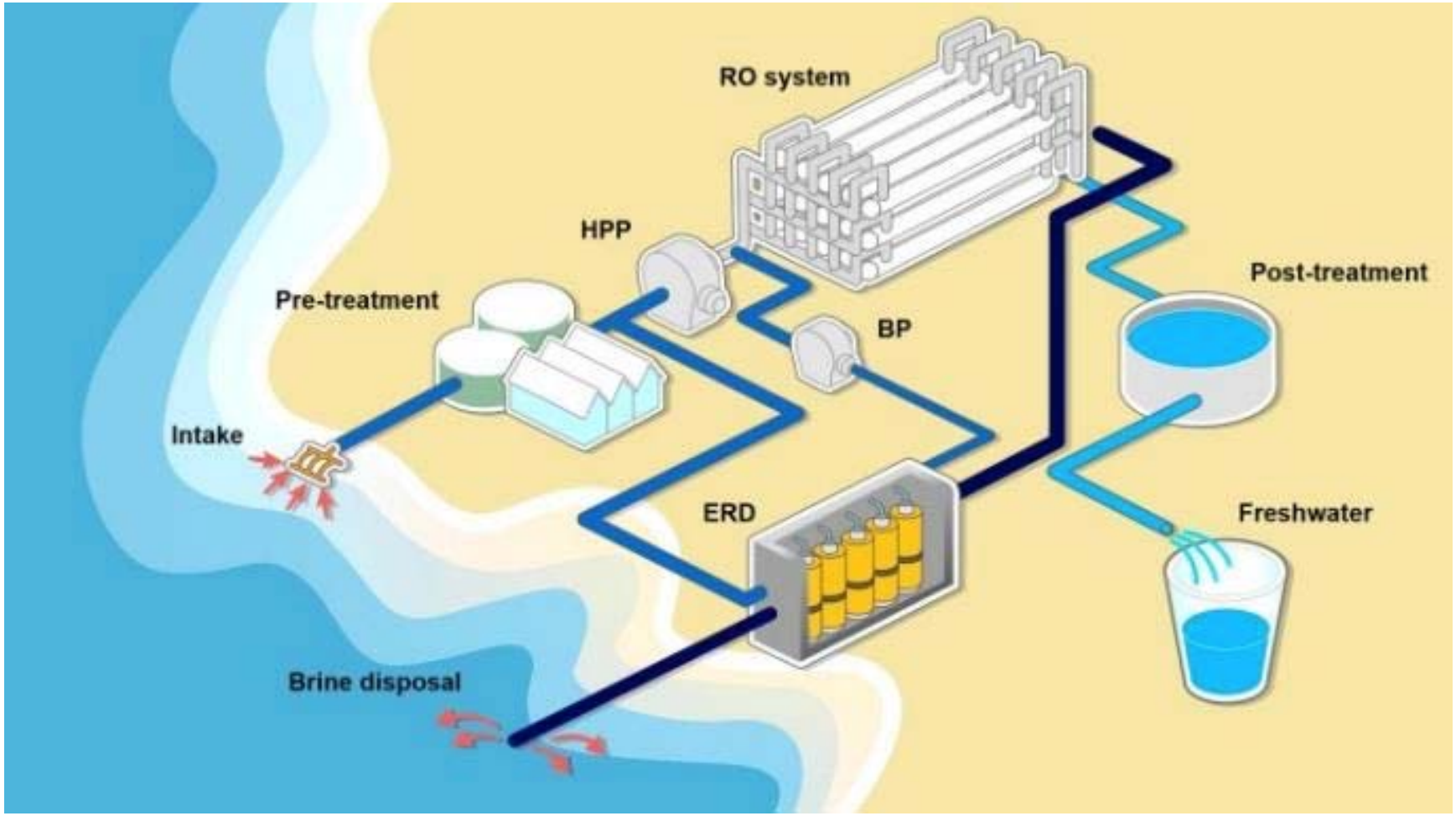
SWRO – Seawater Reverse Osmosis

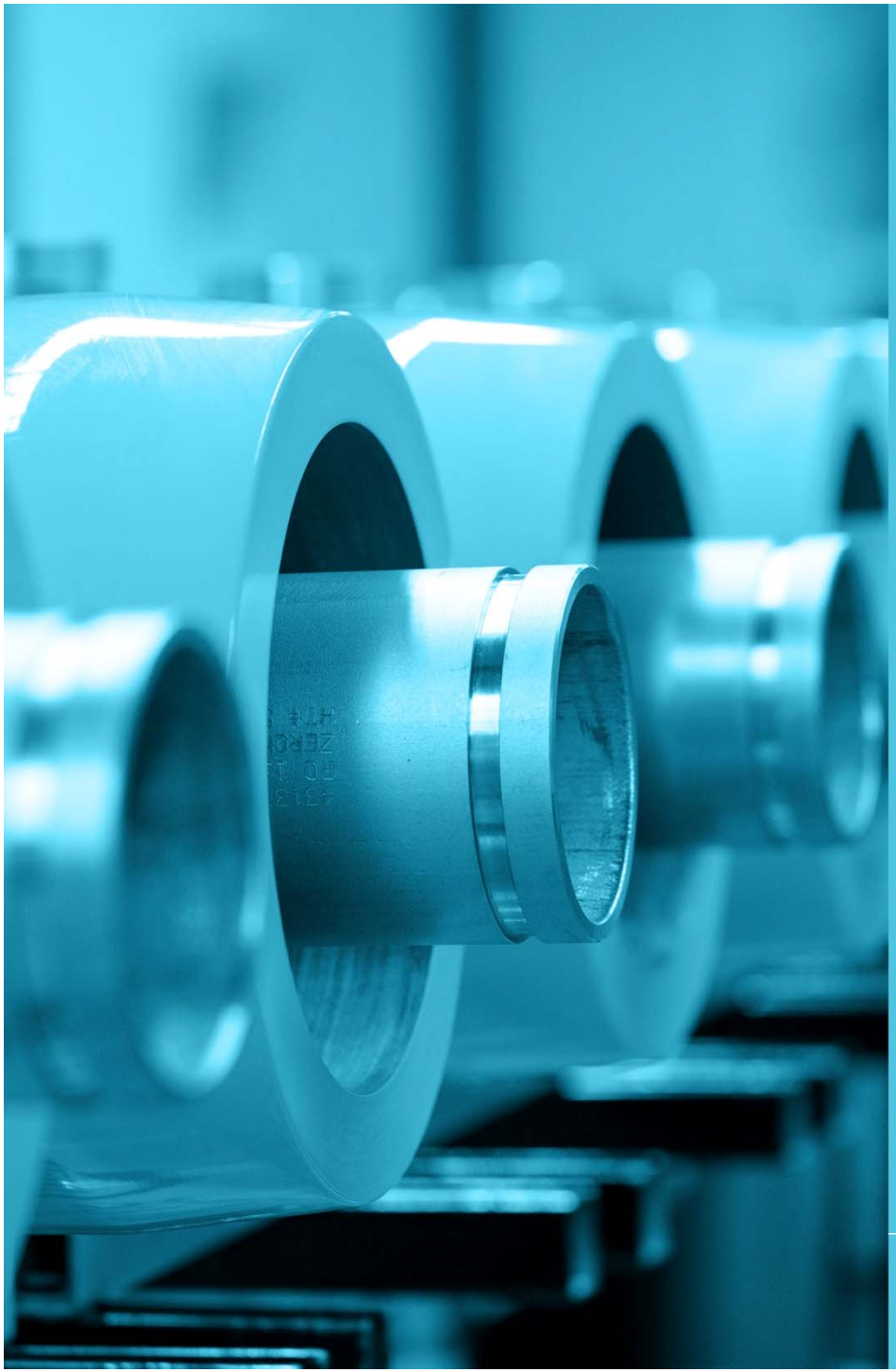
SWRO DESALINATION PROCESS OVERVIEW



SWRO DESALINATION PROCESS OVERVIEW



Source: www.Sciencedirect.com



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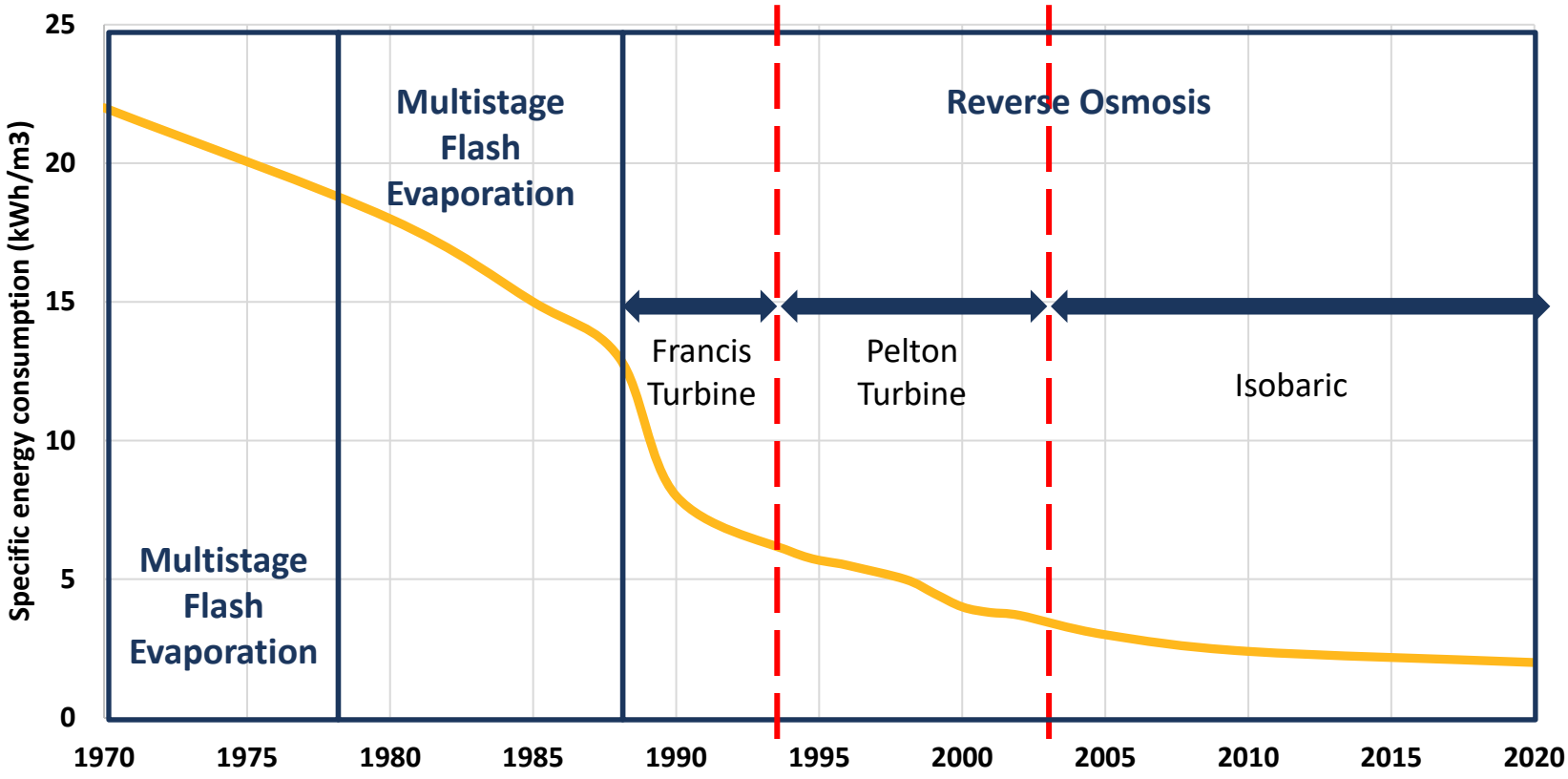
Energy Consumption

ENERGY CONSUMPTION FOR SWRO

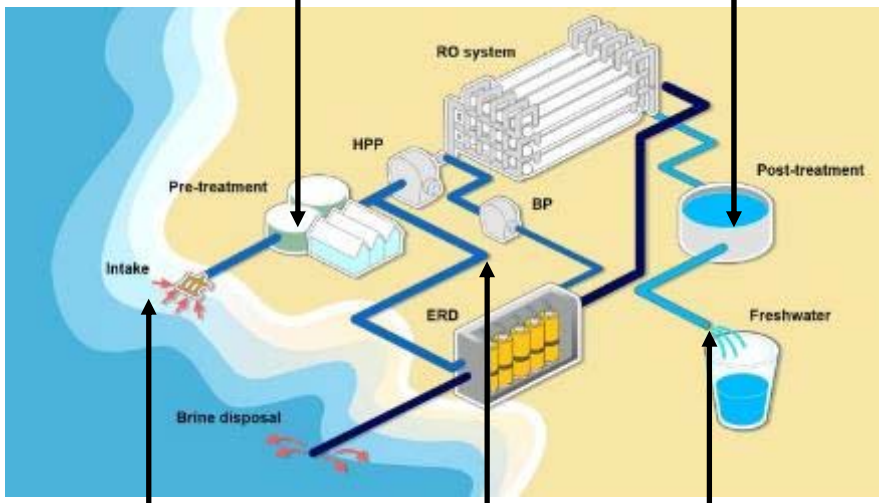
Energy Consumption Over Time



ENERGY CONSUMPTION FOR SWRO

Pre-Filtration
0.24 kWh/m³

Permeate treatment
0.4 kWh/m³



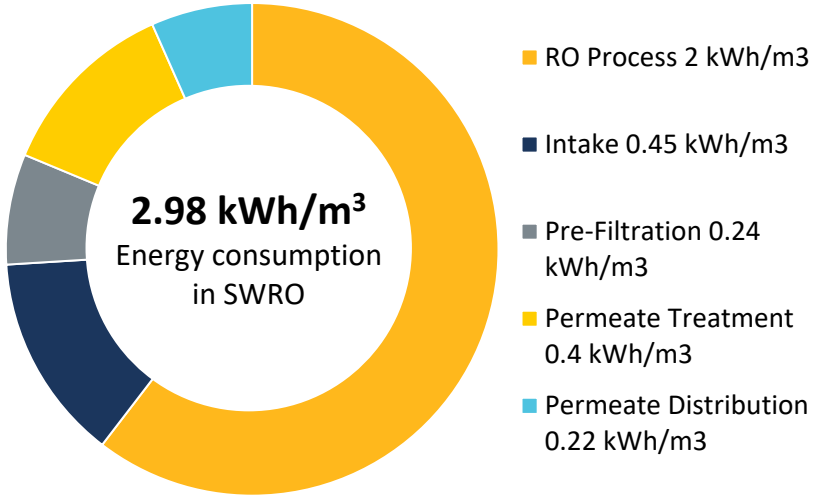
RO process
2 KWh/m³

Intake
0.45 kWh/m³

Permeate distribution
0.22 kWh/m³

Source: www.Sciencedirect.com

Energy Consumption per Process



- RO Process is the most energy intensive process within the SWRO treatment plant
- ERD can reduce energy consumption of RO process up to 60%; therefore, it is a critical component to achieving 2 kWh/m³
- ERD CAPEX only represents 1% of overall plant CAPEX

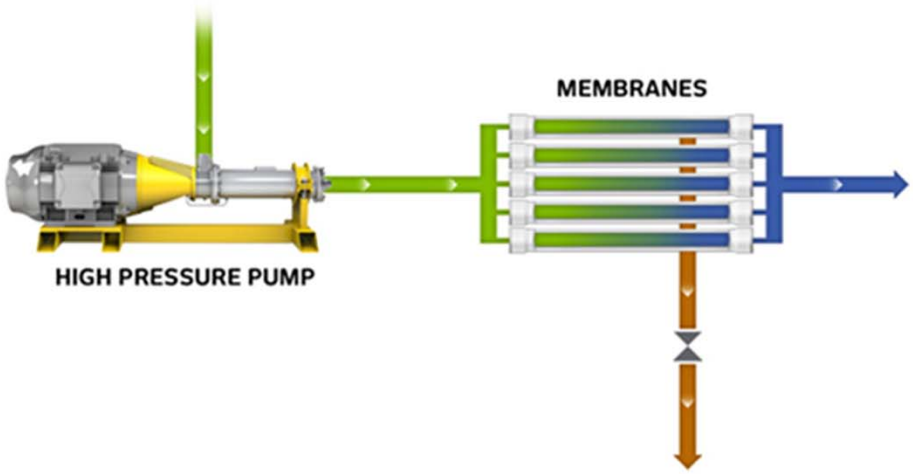
ENERGY CONSUMPTION FOR SWRO

Problem Statements:

- Energy consumption and costs made SWRO uneconomical historically
- Approx. 60% of energy wasted during SWRO prior to implementation of ERDs

HP Pump Provides Full Feed Flow and Pressure to SWRO Membranes

SEC: 8 kwh/m³



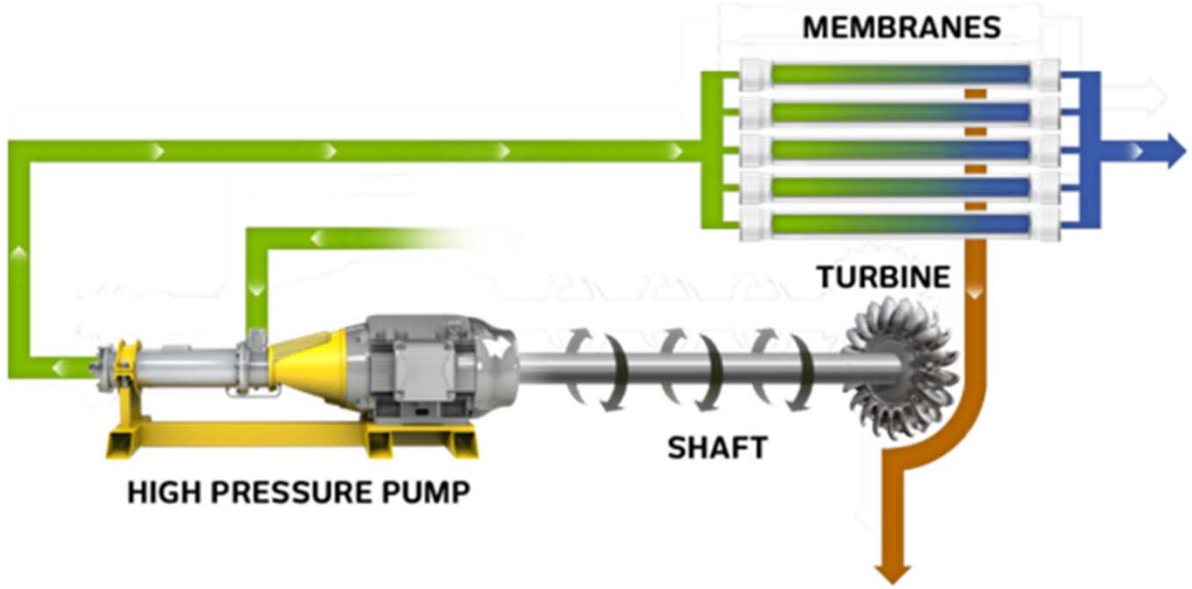
How it Works

A full-size main high-pressure pump is use to supply the membranes with 100% of the feed flow + pressure in order to over come the osmotic pressure of the membranes. Potential energy is "wasted" across the discharge valve.

ENERGY CONSUMPTION FOR SWRO

Pelton Wheel

SEC: 4 kwh/m^3



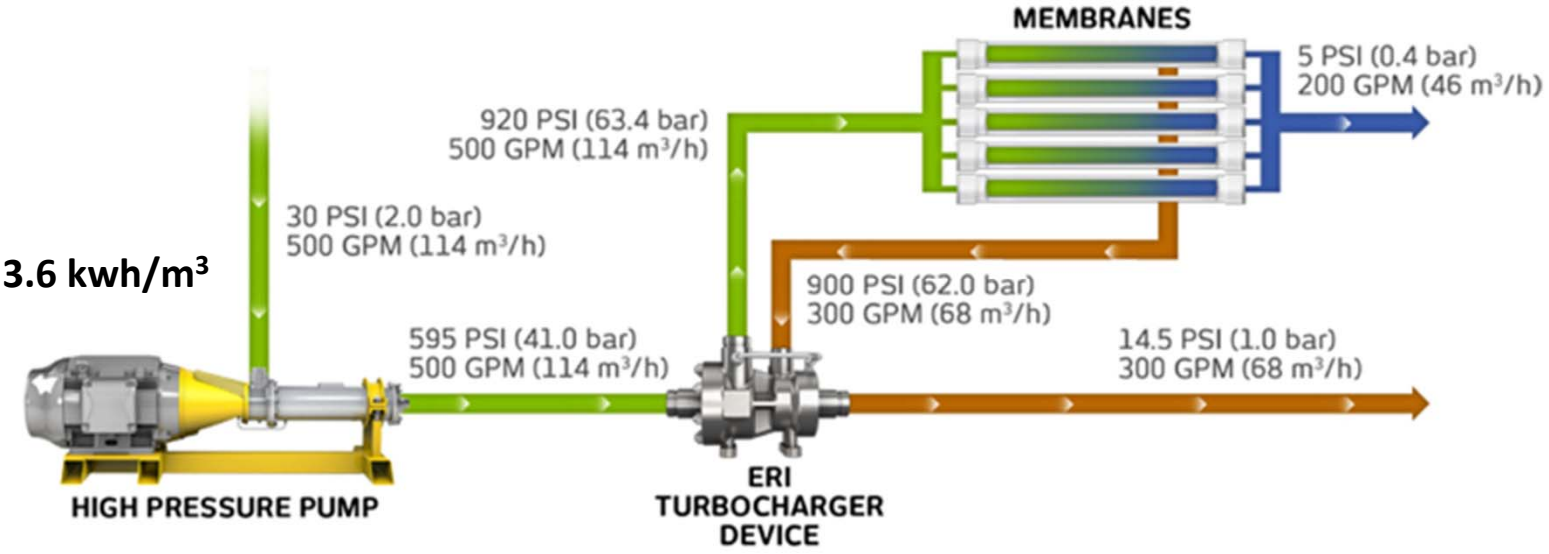
How it Works

The Pelton Wheel converts hydraulic energy into mechanical energy to offload the work done by the high-pressure pump's motor. The Pelton Wheel's shaft is directly connected to a dual-shafted motor and must rotate at the pump's design speed. The high-pressure pump must be sized for the full flow and head required by the membranes.

ENERGY CONSUMPTION FOR SWRO

Turbocharger

SEC: 3.6 kwh/m³



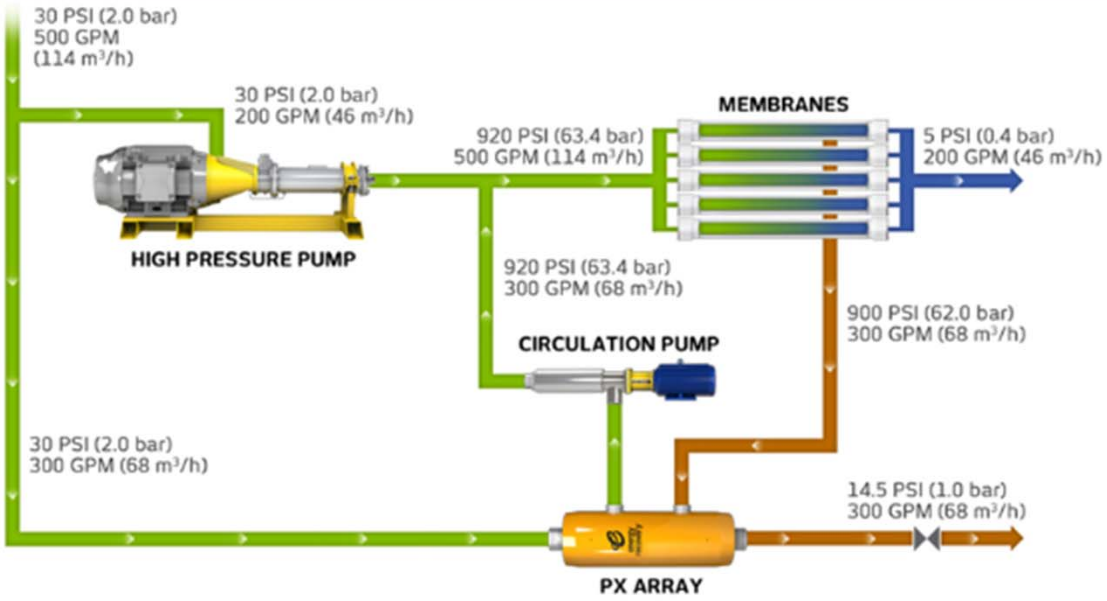
How it Works

Turbochargers convert hydraulic energy in the brine stream into mechanical energy reducing the amount of head required by the main high-pressure pump. The turbine drives the pump section “boosting” the discharge of the high-pressure pump to membrane feed pressure. The Turbocharger “decouples” the ERD from the pump and motor, allowing it to run at higher speeds and higher efficiency than the Pelton Wheel.

ENERGY CONSUMPTION FOR SWRO

PX

SEC: 2.98 kwh/m³

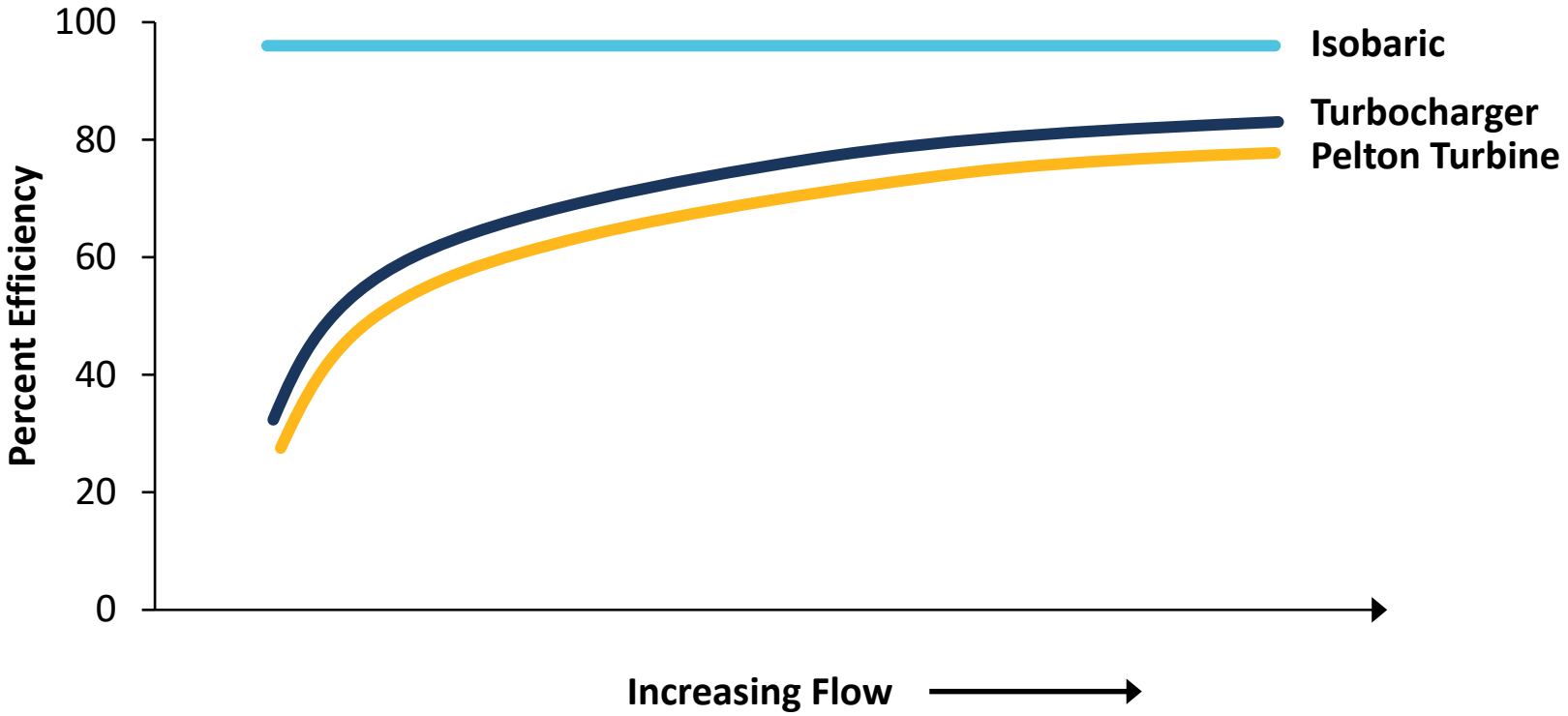


How it Works

The PX Pressure Exchanger converts hydraulic energy in the concentrated brine stream into hydraulic energy that supplements the flow from the main high-pressure feed pump which feeds the membranes. This is done via direct contact between the concentrated brine and filtered seawater feed stream.

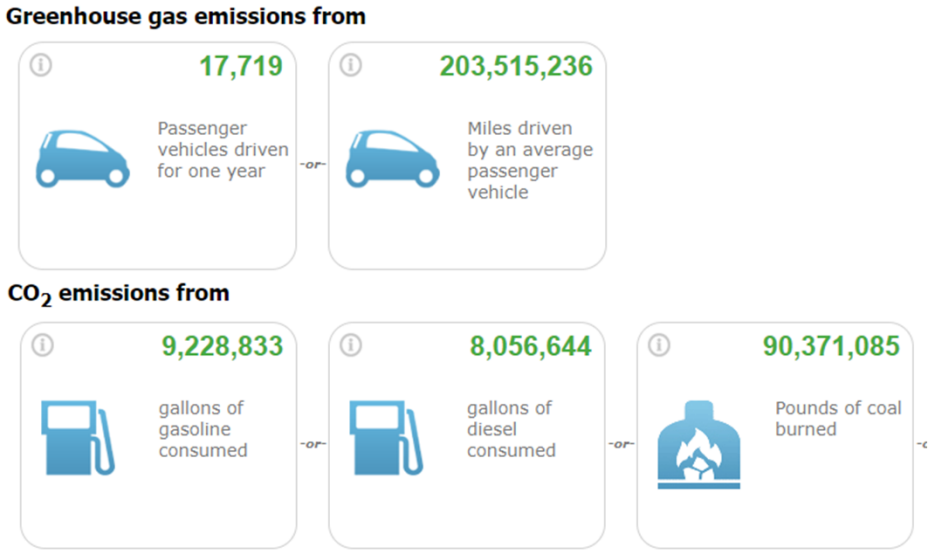
ENERGY CONSUMPTION FOR SWRO

Isobaric energy recovery systems have high efficiency regardless of system size



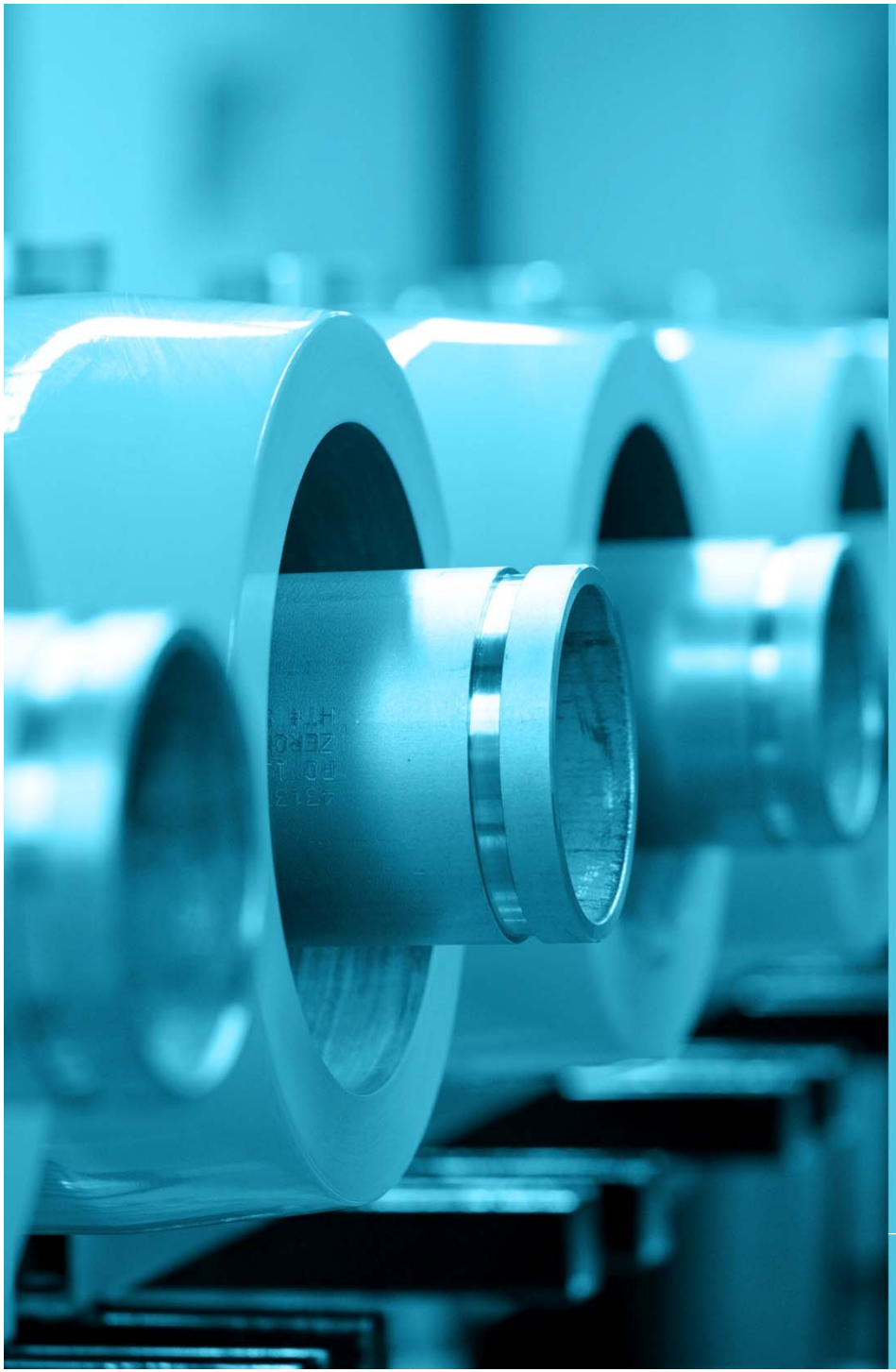
ENERGY CONSUMPTION FOR SWRO

- **Carlsbad SWRO**
  - **Location**: California
  - **Capacity**: 189,250 m^3/day (50 MGD)
  - **Energy recovery device**: Isobaric – PX devices
    - ✓ 116 million kWh (kilowatt-hours)
    - ✓ Equivalent to 82,107 metrics tons per year of CO_2
    - ✓ Equivalent to 12 million dollar in electricity cost



https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Photo courtesy of Poseidon Water



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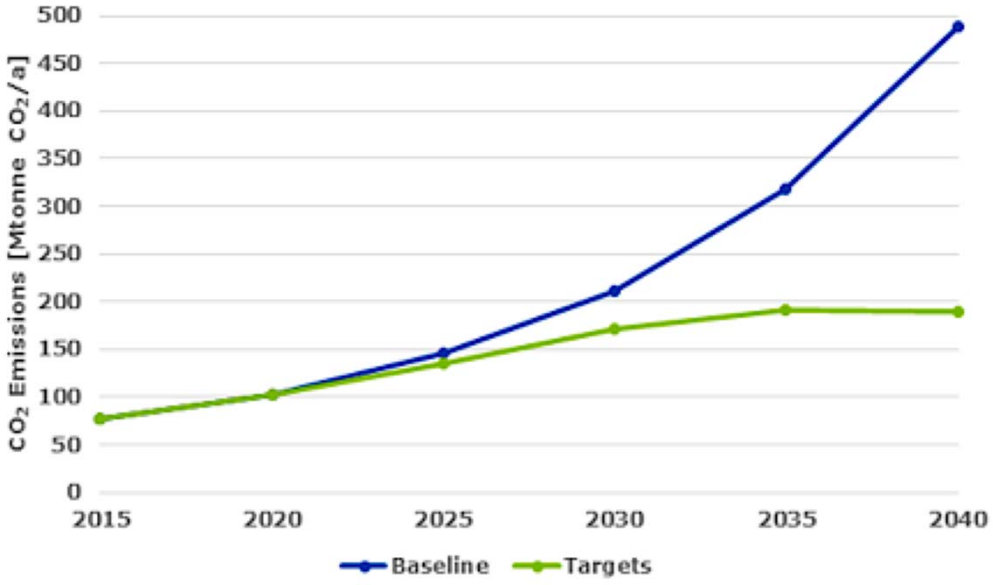
Renewable Energy

RENEWABLE ENERGY POWERED DESALINATION

- The energy consumption of seawater desalination is higher than traditional water supply solutions (groundwater, rain catchment, rivers, lakes, etc.)
- This is a sustainable and cost effective solution thanks to decreasing cost of renewable energy systems

Estimated CO_2 Emissions of Global Water Desalination Plants



- Baseline scenario assumes compounded growth rate of water desalination of 10% per year
- Target scenario assumes gradual introduction of fully renewable powered desalination until 2040

Source: Global Clean Water Desalination Alliance

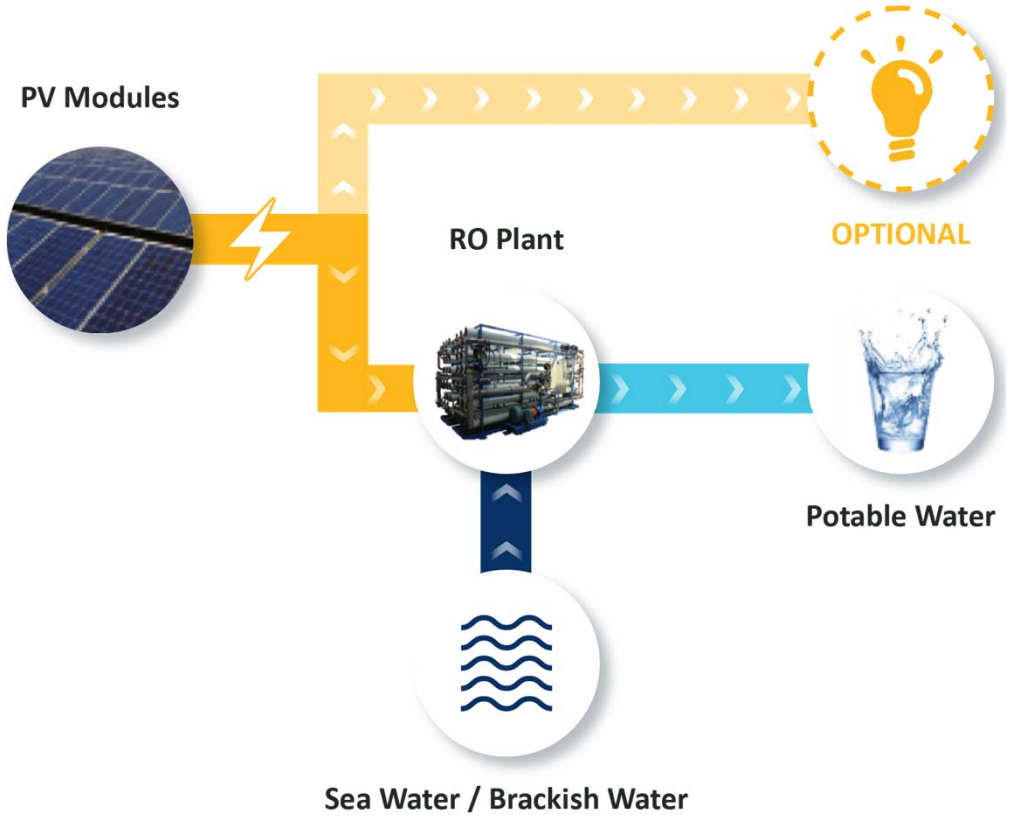
SMALL-SCALE RENEWABLE ENERGY POWERED DESALINATION

- Suitable option for remote locations and small islands where the reliable and safe provision of drinking water is a constraint and expensive
- Electric grid and water networks are often inadequate
- Small-scale renewable energy powered desalination can be the optimal solution to address the water constraints

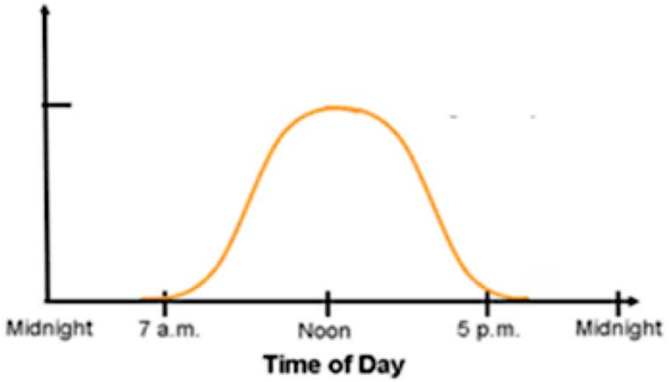
Source: Global Clean Water Desalination Alliance

TECHNOLOGY BRIEF: SMALL SCALE SOLAR SEAWATER DESALINATION – DIRECT COUPLING (OFF-GRID), NO STORAGE

- This configuration is ideally suited for very remote locations with limited access to a reliable electricity grid and service personnel
- The configuration avoids using batteries and uses water storage instead to allow a water supply during day and night



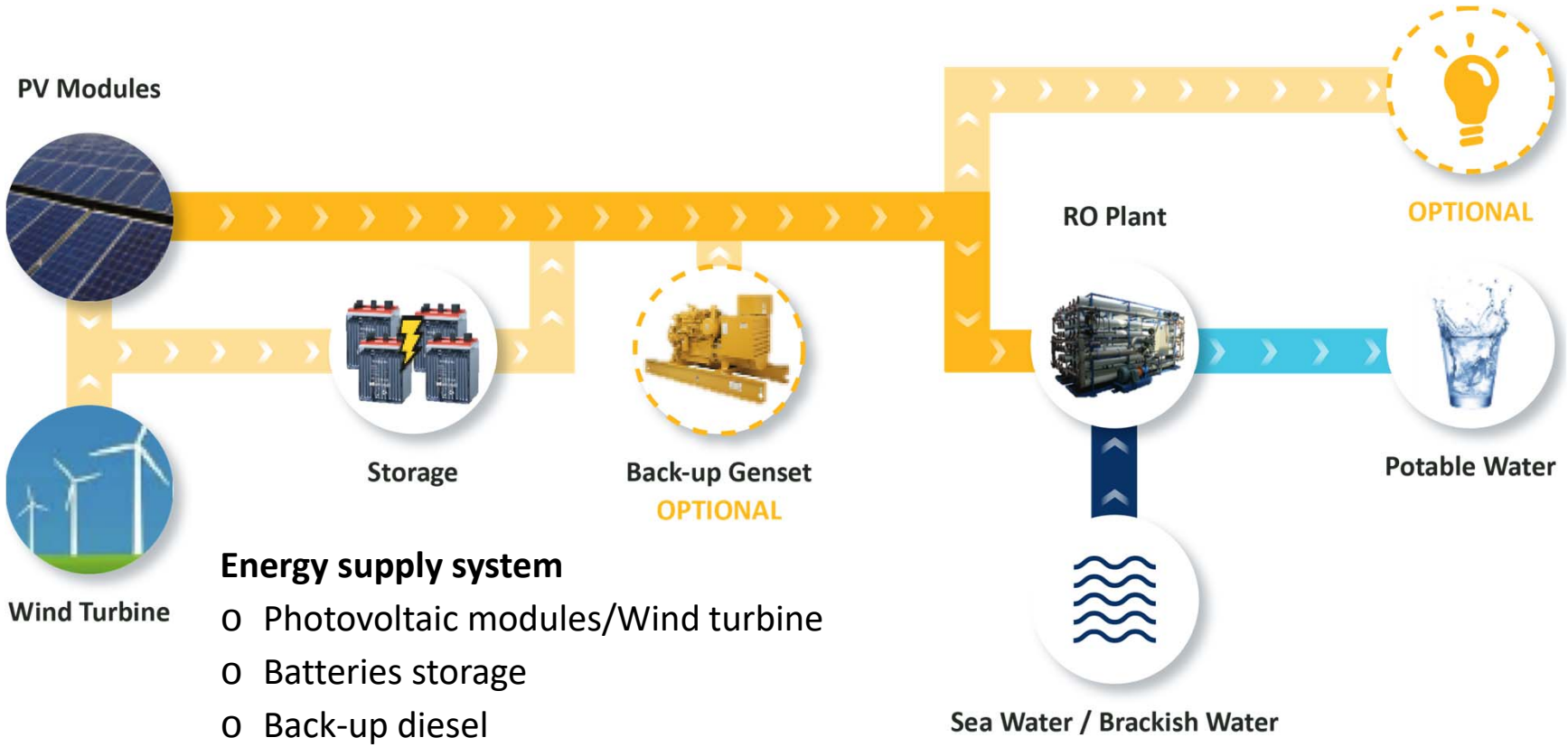
Daily Water Production



Source: Global Clean Water Desalination Alliance

TECHNOLOGY BRIEF: SMALL SCALE SOLAR SEAWATER DESALINATION – DIRECT COUPLING (OFF-GRID) WITH STORAGE OR BACKUP GENERATION

- Good option for locations with inadequate grid supply but access to service personnel for batteries or back-up generators
- Distributed solution obviating the need for costly water transmission and distribution systems



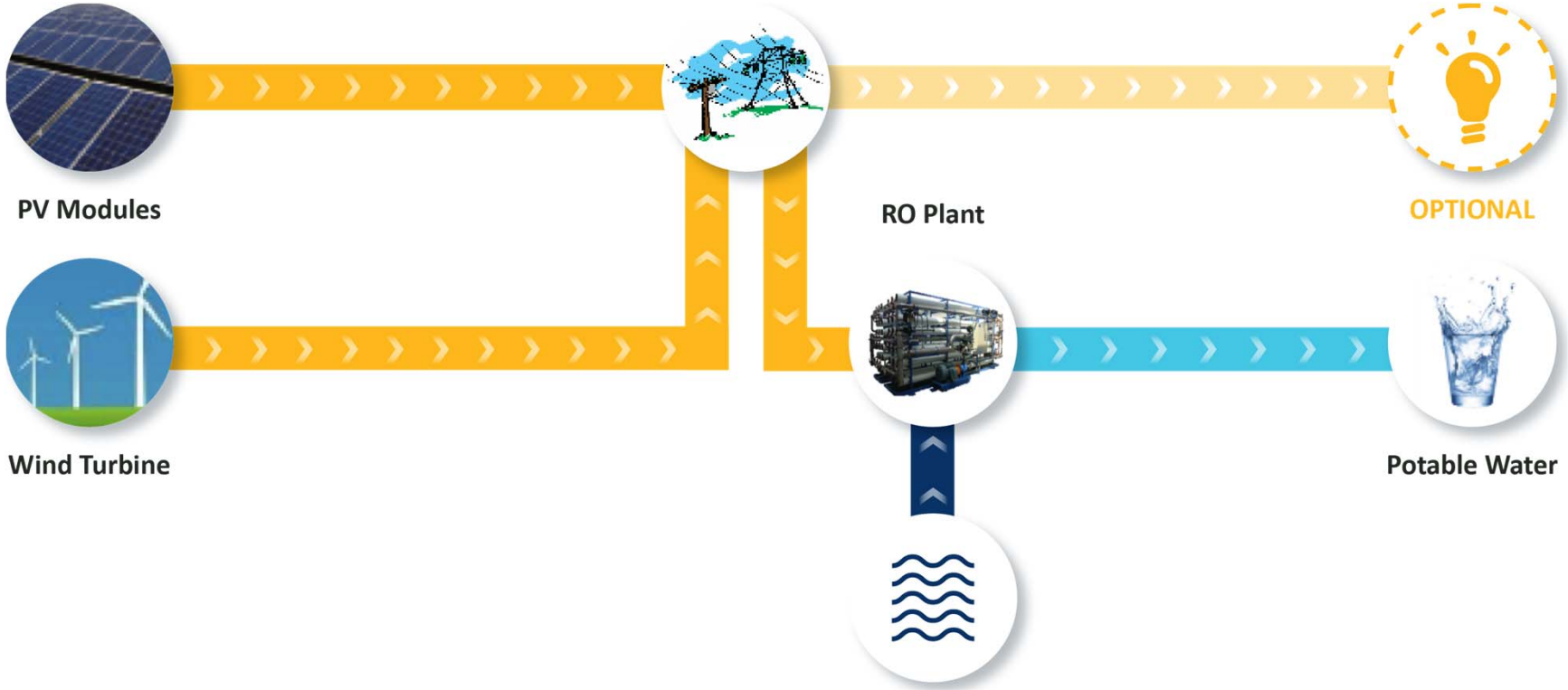
Energy supply system

- Photovoltaic modules/Wind turbine
- Batteries storage
- Back-up diesel

Source: Global Clean Water Desalination Alliance

TECHNOLOGY BRIEF: SMALL SCALE SOLAR SEAWATER DESALINATION – GRID CONNECTED

- Good option for locations with access to a reliable electric grid
- The renewable energy supply system can be sized to completely offset the CO_2 emissions of the desalination plant
- Reduced maintenance requirements due to absence of storage and backup generators



Source: Global Clean Water Desalination Alliance

TECHNOLOGY BRIEF: UTILITY-SCALE RENEWABLE DESALINATION – GRID CONNECTED WITH VIRTUAL NET METERING

- The Desalination Plant and the Renewable Power Plant are connected to the grid and don't need to be co-located
- The Renewable Power Plant is sized to completely offset the CO_2 emissions of the Desalination Plant (over the lifetime of the plant)

Desalination Plant

- Operates 24h per day
- Connected to the grid, using existing infrastructure to supply electricity 24h per day

Electricity Grid

Renewable Power Plant

- Operates only during certain hours of the day producing electricity from sunlight or wind
- Connected to the grid, using existing infrastructure

Source: Global Clean Water Desalination Alliance

REFERENCES: SMALL-SCALE SOLAR DESALINATION (OFF-GRID) – PHILIPPINES

General Information

Item	Description
Owner/promoter	Elemental Water Makers
Location of SWRO Plant	La Union, Luzon, Philippines
Year of construction	2018
Capacity of SWRO Plant	11 m^3/d
Type of RE Plant	PV plant
Capacity of RE Plant	4 kWp

11 m^3/d PV powered RO system from Elemental Water Makers, Philippines

Source: https://www.elementalwatermakers.com/project-philippines/

REFERENCES: MEDIUM-SCALE WIND AND SOLAR-POWERED DESALINATION – CHINA

An independent grid was designed to support the desalination of 10,000 m^3/day of sea water a day. The current production line has a capacity of 5,000 m^3/day.

Item	Description
Owner/promoter	Dafeng Plant
Location of SWRO Plant	Jiangsu province, China
Year of construction	2014
Capacity of SWRO Plant	5,000 m^3/d
Type of RE Plant	Wind power
Capacity of RE Plant	2.5 MW turbine

Containerized system

Source: http://en.fhned.com/product/equipments/

REFERENCES: UTILITY-SCALE RENEWABLE POWERED DESALINATION – PERTH, AUSTRALIA

General Information

Item	Description
Owner/promoter	Water Corporation
Location of SWRO Plant	Kwinana, Perth Western Australia
Year of construction	2006
Capacity of SWRO Plant	144,000 m^3/d
TDS (design)	35,000 – 37,000 mg/l
Specific Energy Consumption	4 - 6 kWh/m^3
Power requirement of SWRO Plant	24 MW
D&C Joint Venture	Suez-Degrémont/ Multiplex/Worley Parsons/Water Corporation

It is the first large-scale seawater RO plant in the world powered by renewable energy using green electricity procured from an Australian wind farm.

Kwinana SWRO Plant – Perth

Emu Downs Wind Farm

- The green electricity consumed by the desalination plant is provided by the 80 MW Emu Downs Wind Farm.
- The wind farm comprises 48 wind turbines and is located in a distance of 200 km from the desalination plant.

Source: Global Clean Water Desalination Alliance

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Conclusion

CONCLUSION

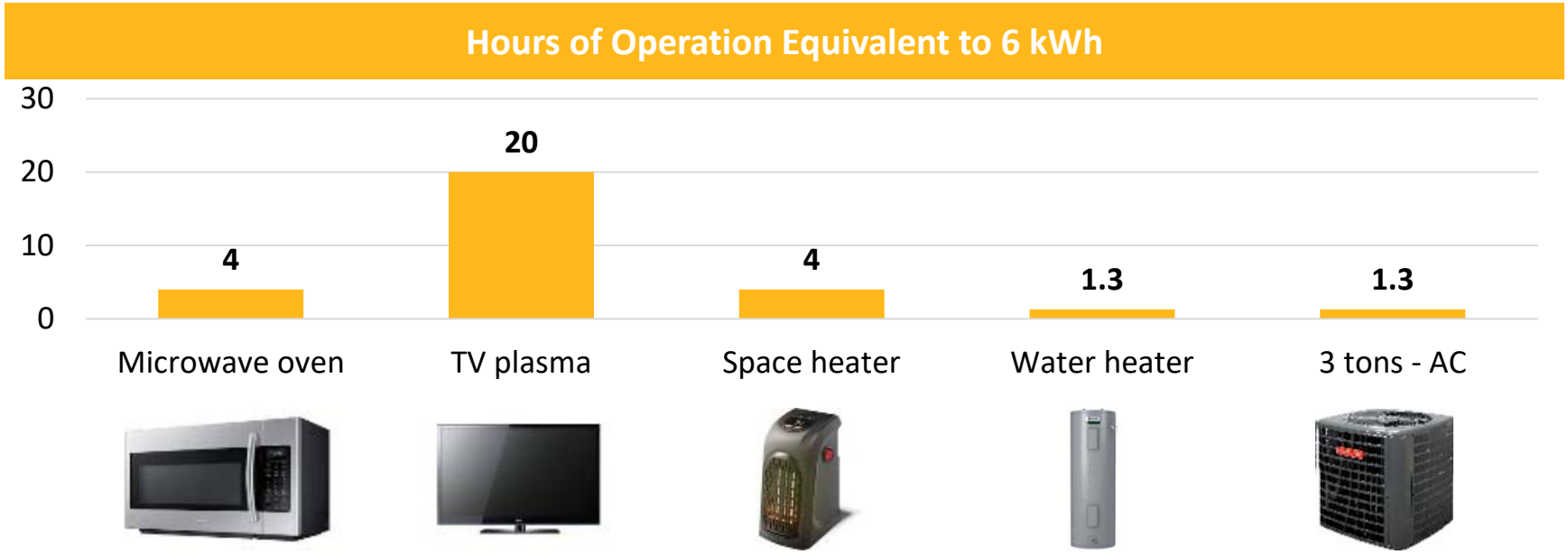
- Seawater Reverse Osmosis (SWRO) is a feasible option to increase water availability for isolate locations, cities, industrial applications or others
- Reverse Osmosis is the preferred technology for desalination
- If the SWRO plant uses the correct technology, the SWRO design will reduce energy consumption and operational cost

- Energy renewable + SWRO are a good match to reduce water cost, and environmental impact
  - Wind power
  - Wave power
    - ✓ DOE Announces Prize Competition for Wave Energy Water Desalination
  - Solar Power
  - Other options

CONCLUSION

SWRO energy consumption to produce water for a family of four for one day is equivalent to:

- 1 m^3 of desalinated water requires 2.98 kwh
- 1 family of 4 persons – 100 gallons per person per day [1] – 400 gallons (1.5 m^3) per family
  - Equivalent to 4.5 kwh to produce desalinated water + 1.5 kwh for distribution
- 6 kwh is the same energy consumption for the following appliances [2]:
  - Equivalent to 3 tons of air conditioning capacity running for 1.3 hour (covers 1,200-1,500 sf) [3]



[1]source: USCG, [2] Source: energy.gov, [3] Source: hvac.com

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