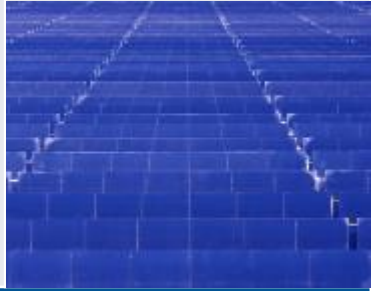
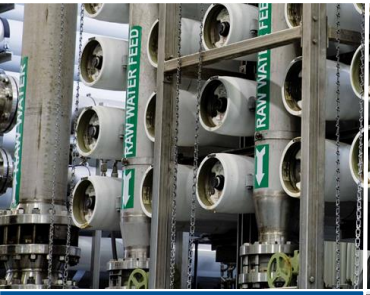








Renewable Desalination

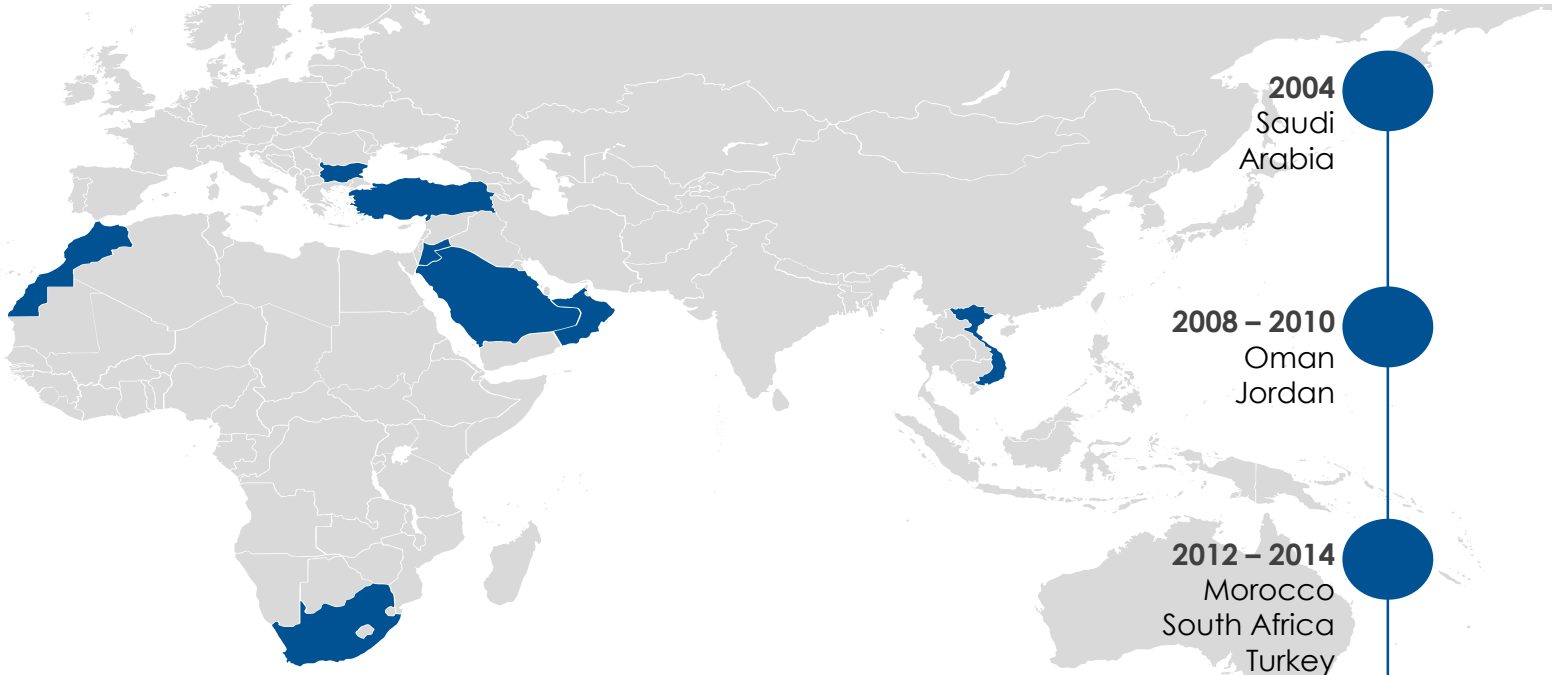
07/11/2018

We develop power and desalination water plants

In over a decade we have become the second largest power & water developer in the GCC region, and a name to contend with internationally.

We have achieved this by **developing**, **investing** in and **operating** a world-class portfolio...

- **35** Assets
- **22+** GW Power
- **3.5** Mm^3 per day Desalinated Water
- **10** Countries
- **30bn** USD of Assets Under Management
- **15%** Portfolio in Renewable Energy
- **2,750+** Employees
- **30+** Nationalities
- **~60%** Local Employment in projects



- **2004** Saudi Arabia
- **2008 – 2010** Oman Jordan
- **2012 – 2014** Morocco South Africa Turkey
- **2015 –** UAE Egypt Vietnam

DEVELOP

We win bids as lead developer, by partnering with the best and focusing on cost leadership.

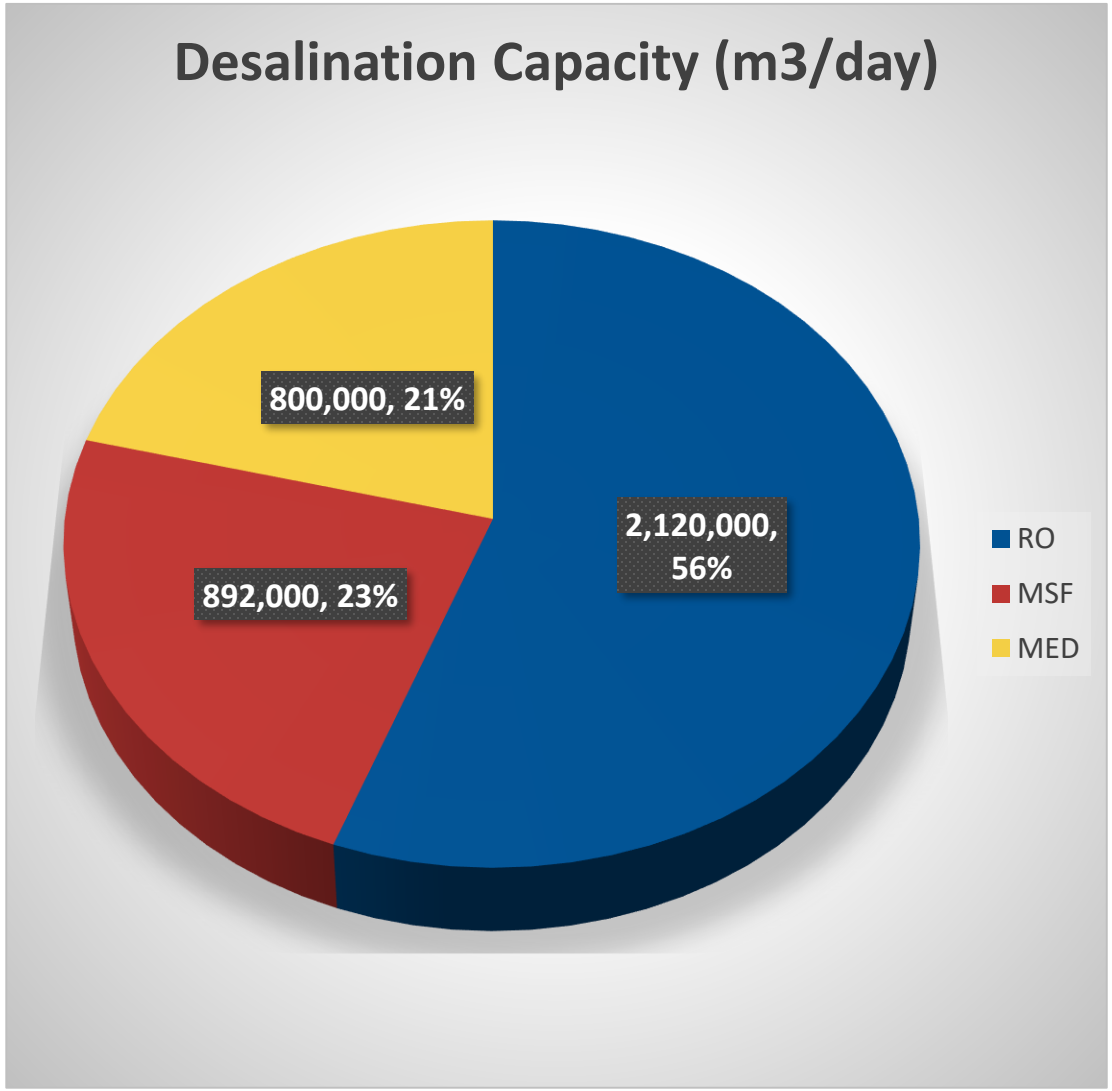
INVEST

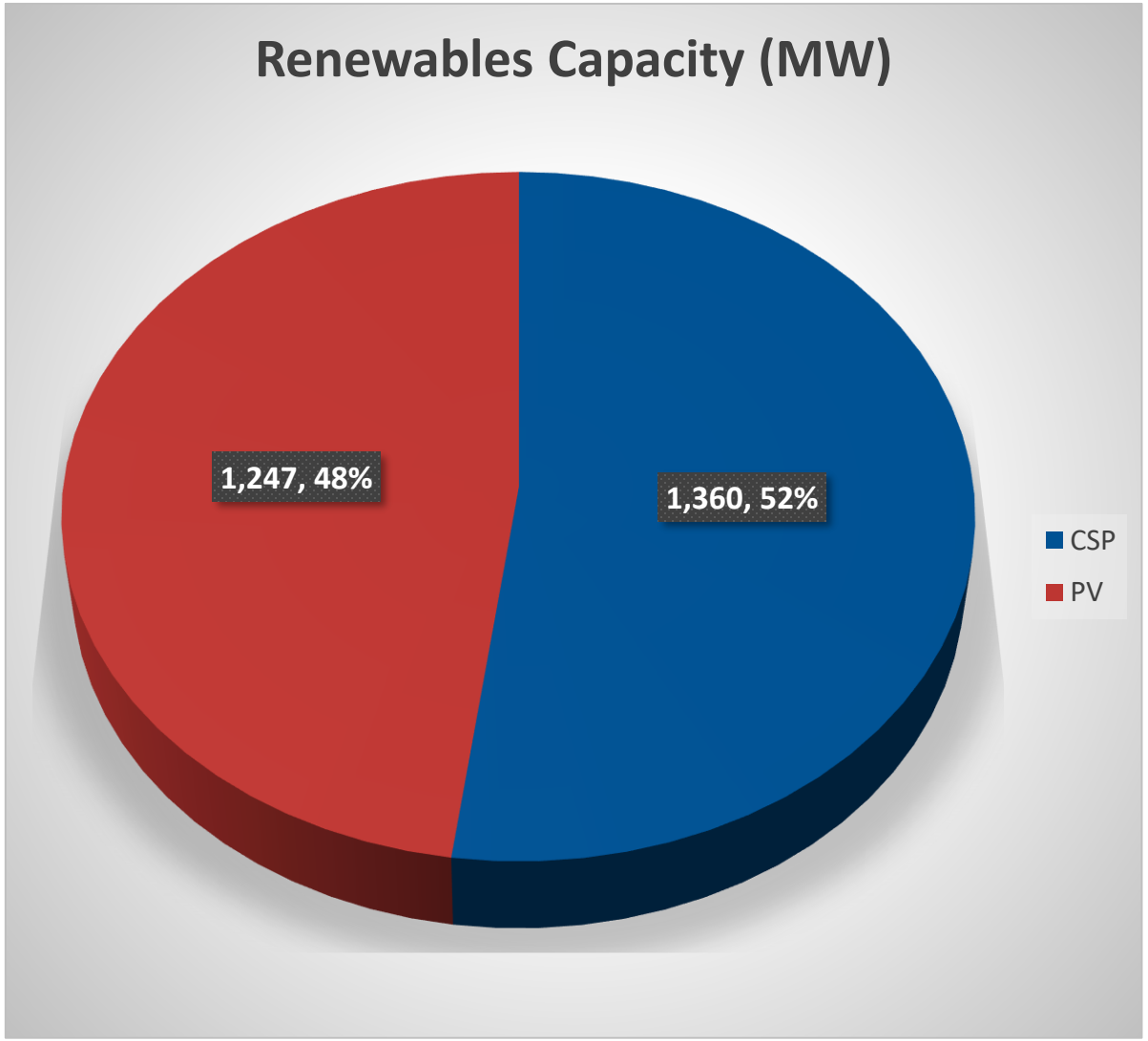
While taking significant, long-term stakes in all our plants

OPERATE

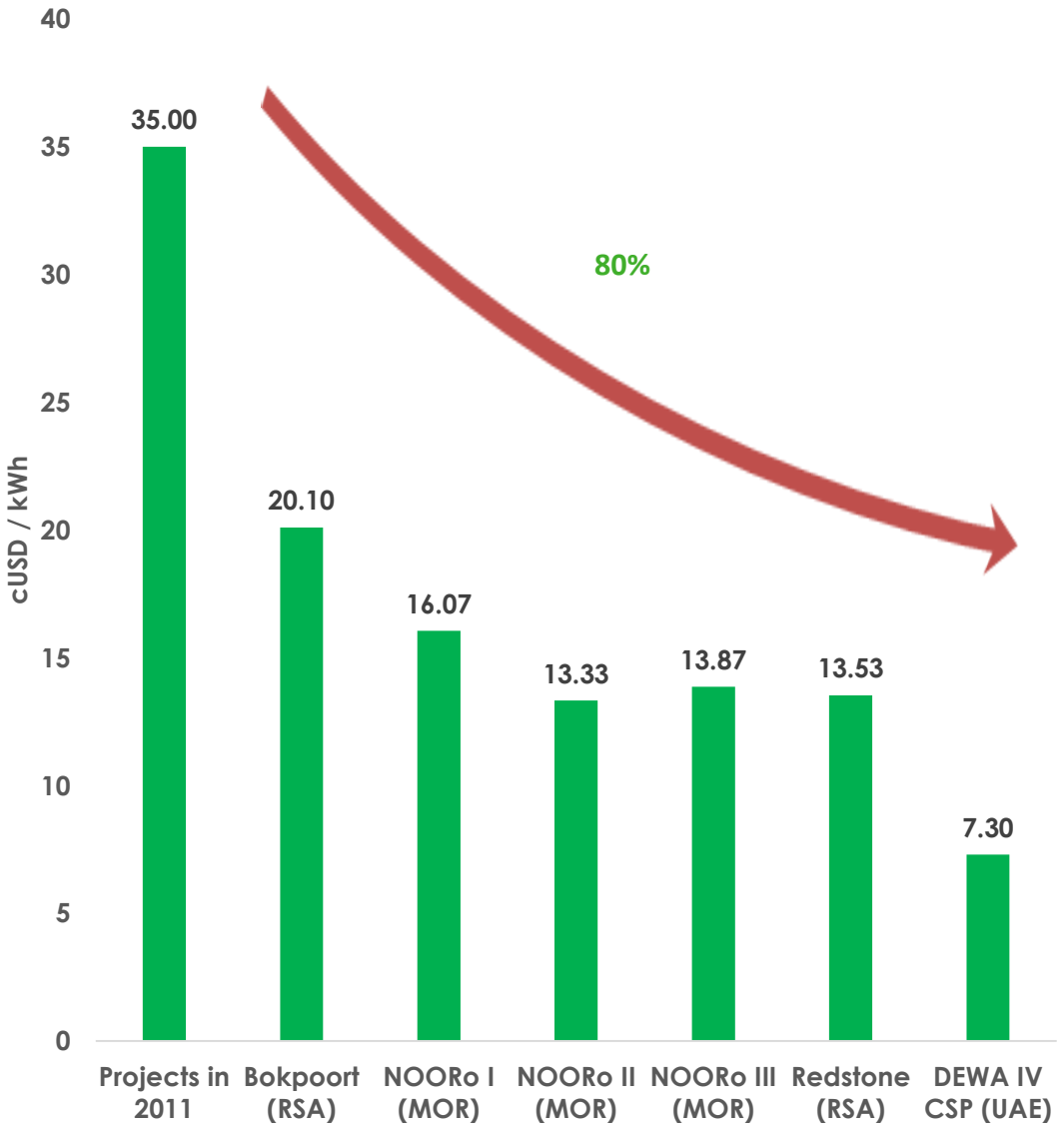
We operate and maintain our plants to the highest global standards

Desalination and Renewable Portfolio





ACWA Power Track Record in CSP



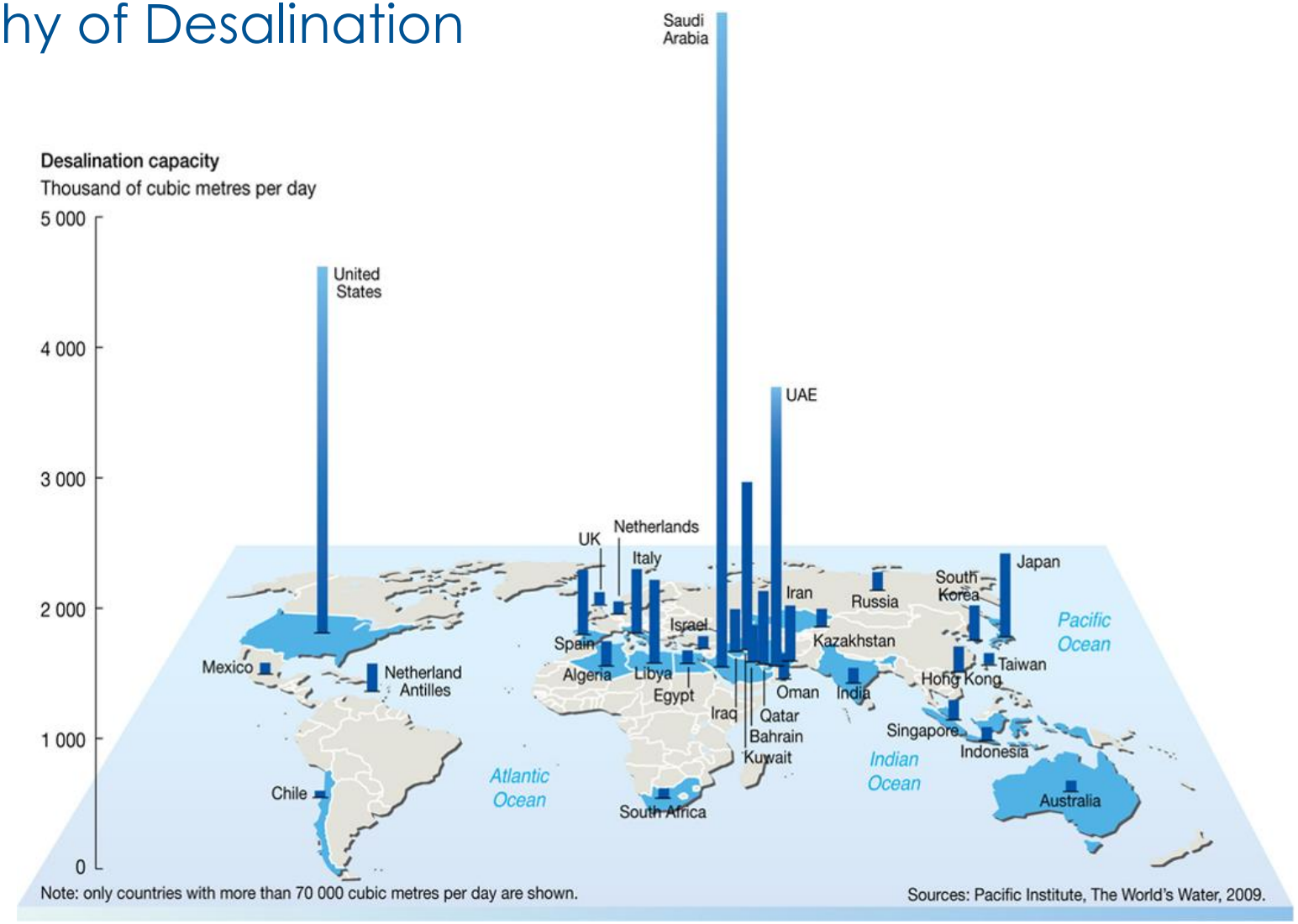
Major contributors to the CSP price decrease

- **Economies of scale** – increase in size of the installed capacity and thermal storage capacity;
- **Technology improvements** – increase in size for the parabolic trough collector
- **Technology shift** – adopting central tower technology
- **Learning curve** – development and in-country experience, faster implementation
- **Supply chain development** – CSP program in China and relevant localization
- **Financing terms** – lenders becoming more comfortable with the technology

CSP Projects	Geography	Status	PCOD (Actual / Expected)	Contracted Power (MW)
Bokpoort CSP IPP 9.3h	South Africa	Operational	Q1 2016	50
NOORo I CSP IPP 3h	Morocco	Operational	Q1 2016	160
NOORo II CSP IPP 7h	Morocco	Under-construction	Q1 2018	200
NOORo III CSP tower IPP 8h	Morocco	Under-construction	Q4 2018	150
Red Stone CSP tower IPP 12h	South Africa	Under Advanced Development	-	100
DEWA IV CSP	UAE	Under Advanced Development	-	700

Renewable Desalination

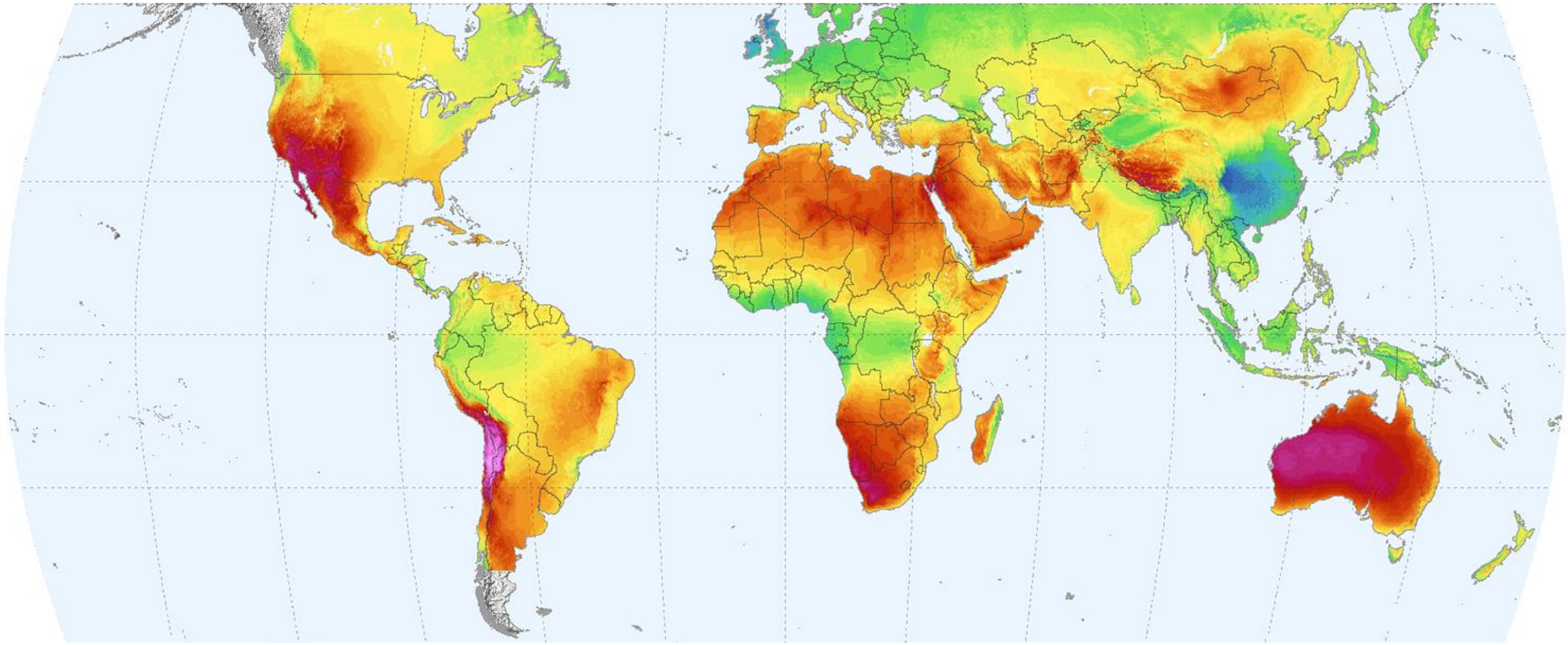
Geography of Desalination



Source: Pacific Institute

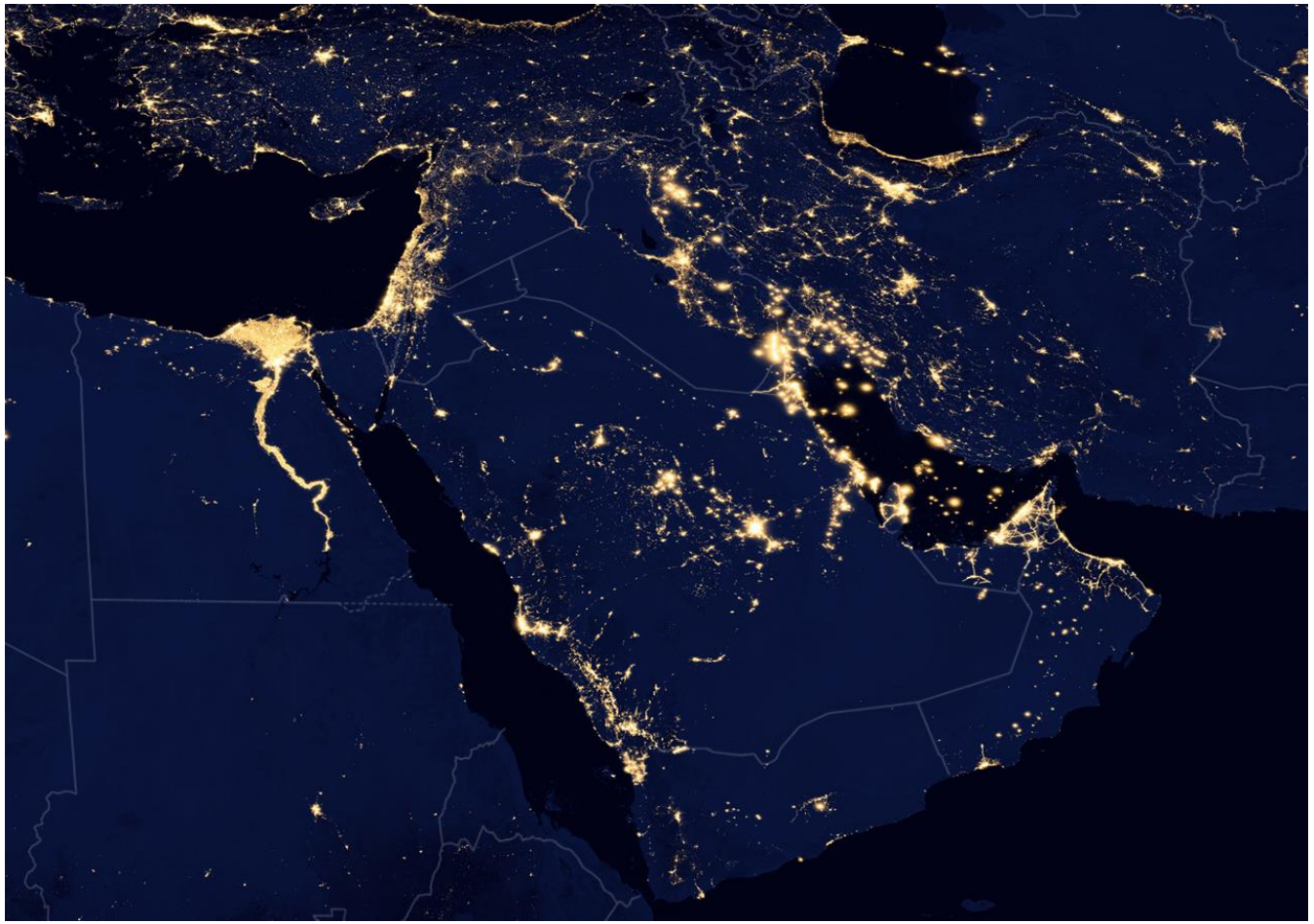
Main desalination activities are concentrated in the MENA Region, Spain and the USA.

Geography of Direct Normal Irradiation (DNI)



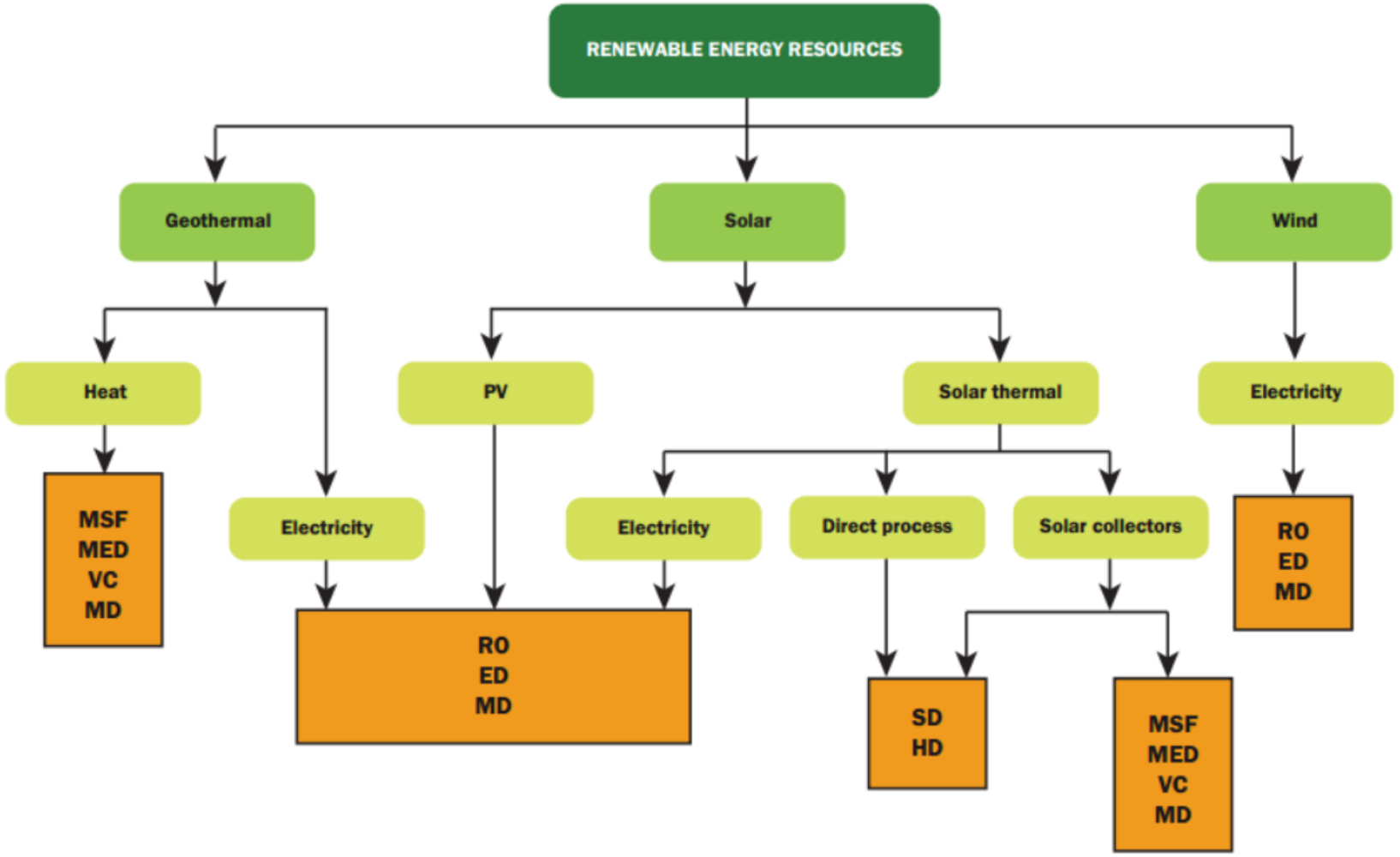
Countries with desalination activities have also high solar potential.

Human activities indicated by night-time light emissions

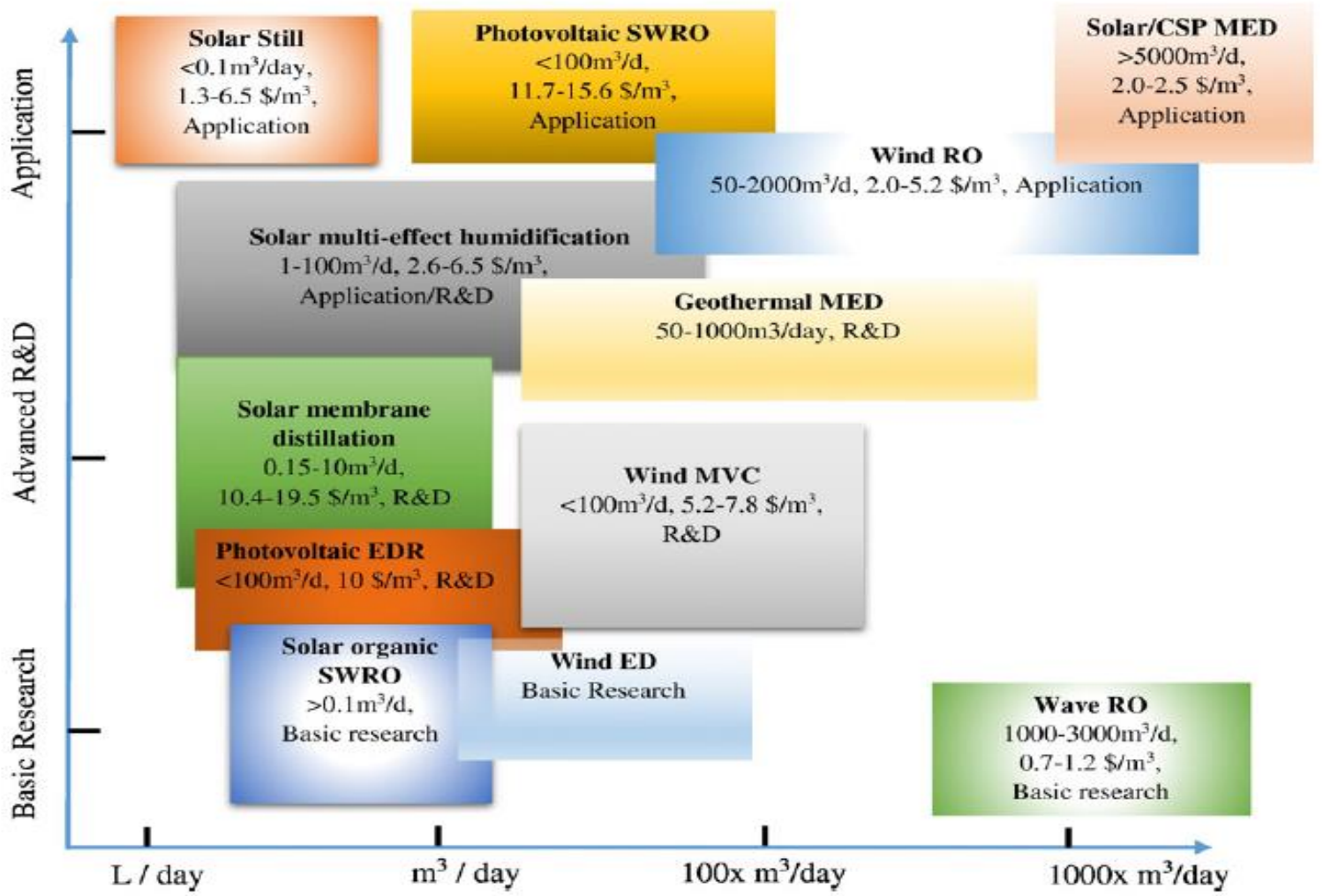


Most highly populated cities in the MENA region are lined up along the coast line.

Technology Overview



Technology Maturity



Desalination Technologies

Reverse Osmosis

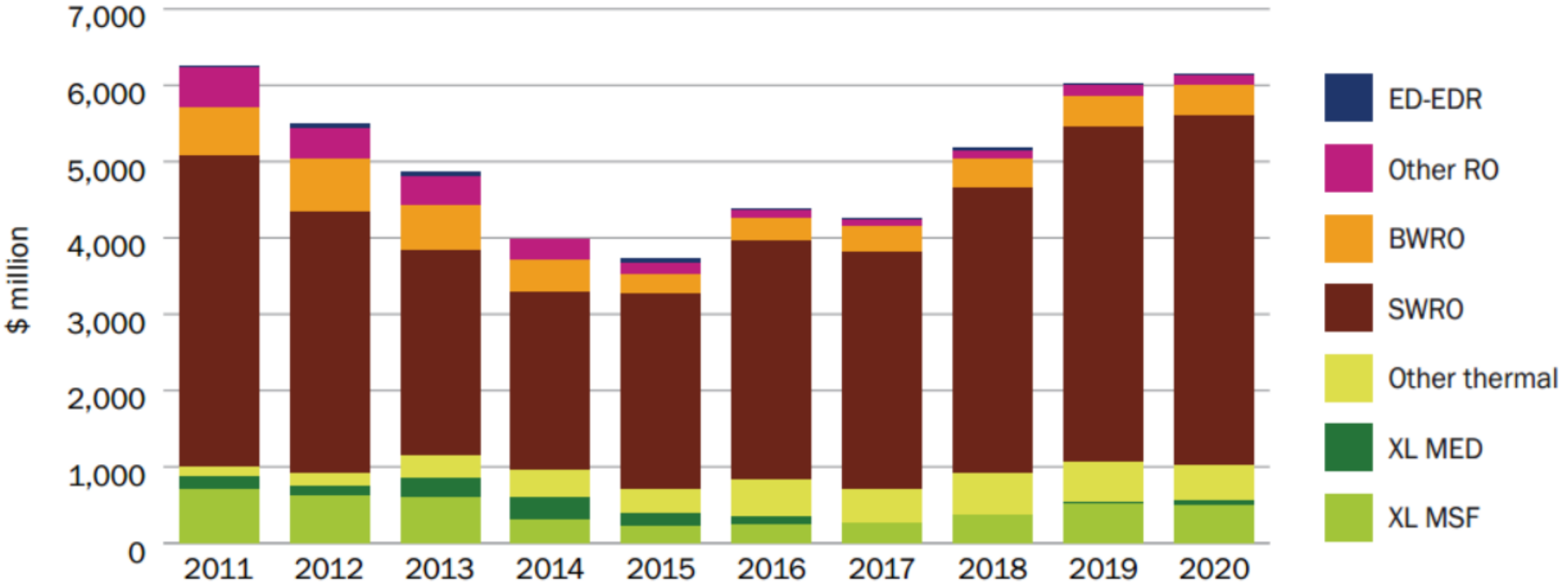
Multi-Effect Distillation

Multi-stage Flash

Average Specific Energy Consumption

Reverse Osmosis		Multi-Effect Distillation		Multi-Stage Desalination	
Electricity (kWh_{el}/m^3)	**4.0**	Electricity (kWh_{el}/m^3)	**1.9**	Electricity (kWh_{el}/m^3)	**3.0**
Thermal Input (kWh_{th}/m^3)	-	Thermal Input (kWh_{th}/m^3 at 60°C)	**78.0**	Thermal Input (kWh_{th}/m^3 at 120°C)	**79.5**

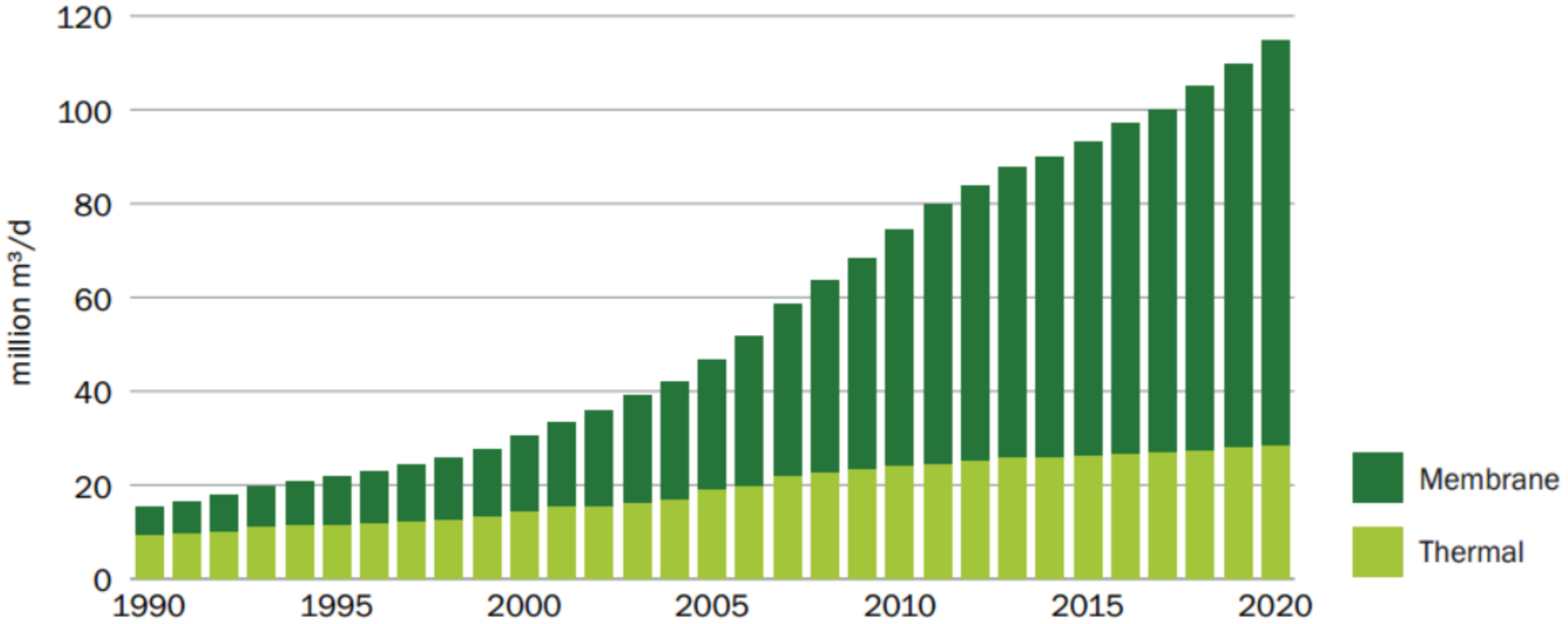
Desalination Investment



Desalination capital expenditure by plant type, 2011–2020

Source: GWI

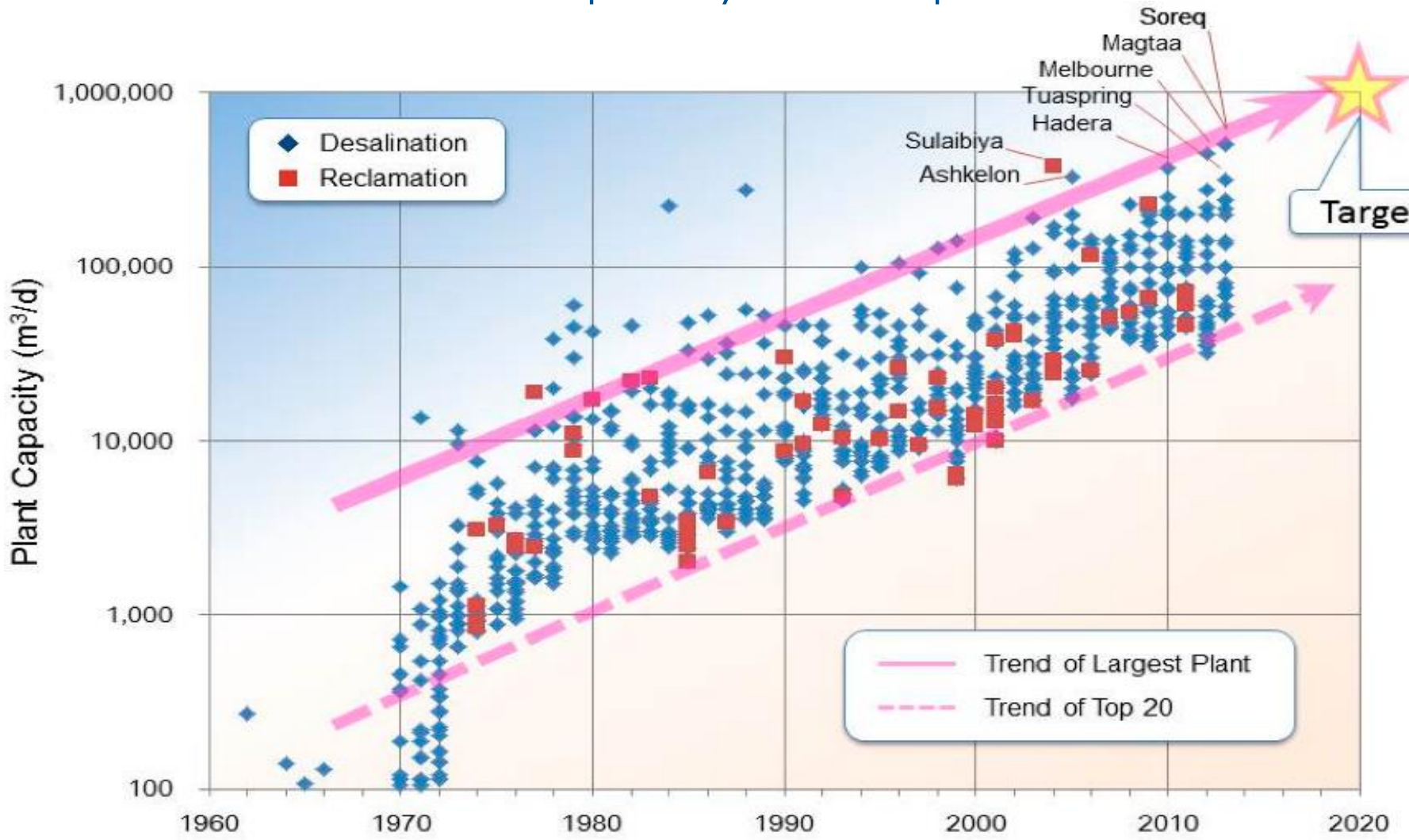
RO – Now the Preferred Technology



Global cumulative contracted capacity by technology, 1990–2020

Source: GWI

RO Desalination Plant Capacity Development

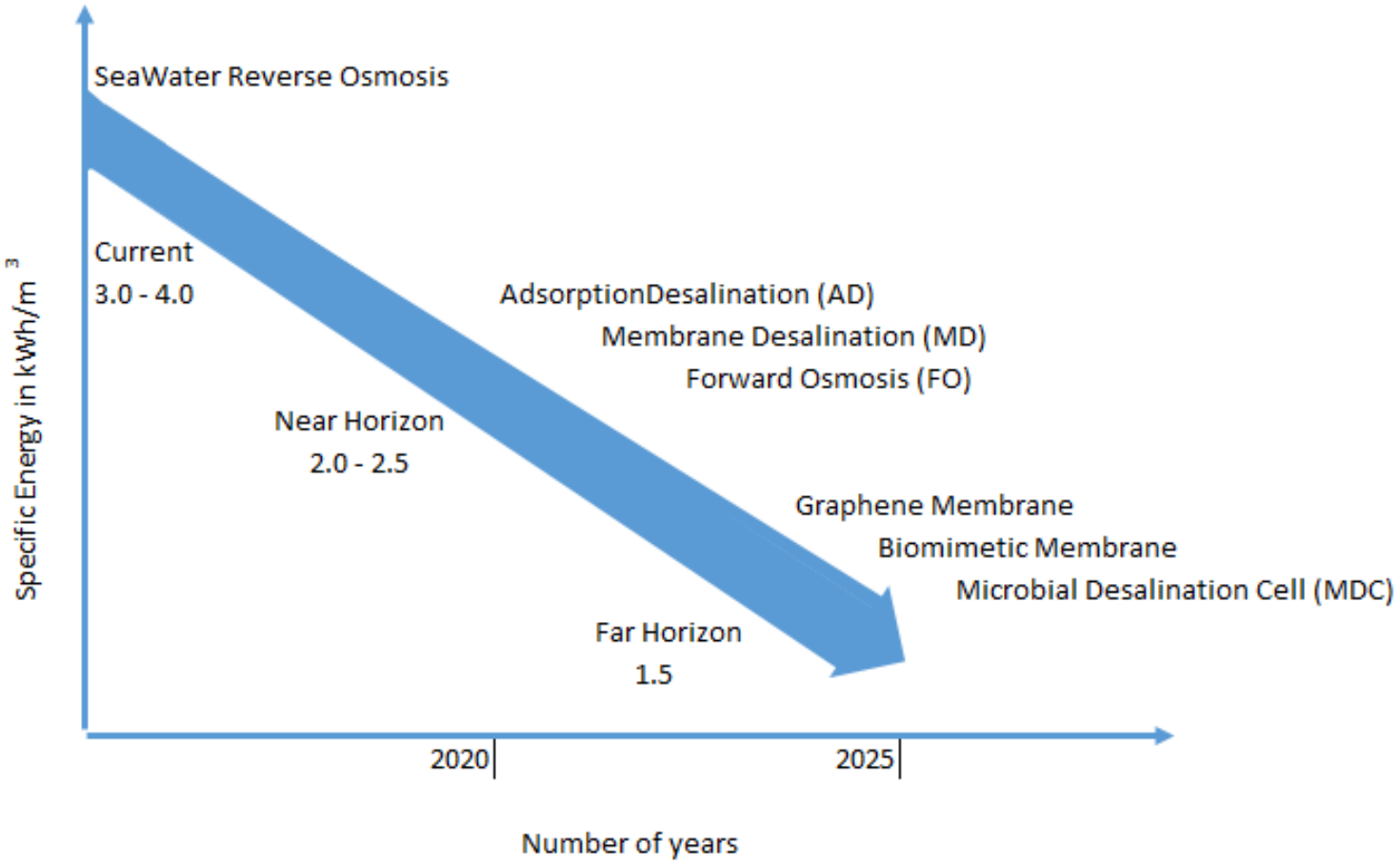


2018 Tenders:

- Al Taweelah RO, 909,200 m3/day
- Al Jubail RO, 700,000 m3/day
- Rabigh 3 RO, 600,000 m3/day
- Shuqaiq RO, 450,000 m3/day
- Yanbu RO, 450,000 m3/day

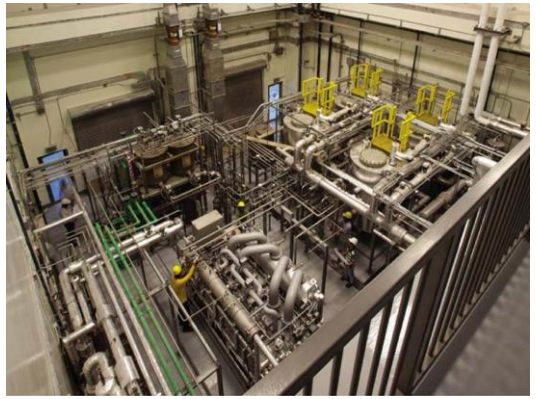
Source: Mega-ton

Desalination Energy Consumption



Emerging Desalination Technologies

Adsorption MED



MED-AD is licensed by KAUST and NUS. Adsorption desalination will increase efficiency of conventional MED from GOR 9-10 to 16-18 at lower product water temperature. A pilot plant is operating at KAUST.

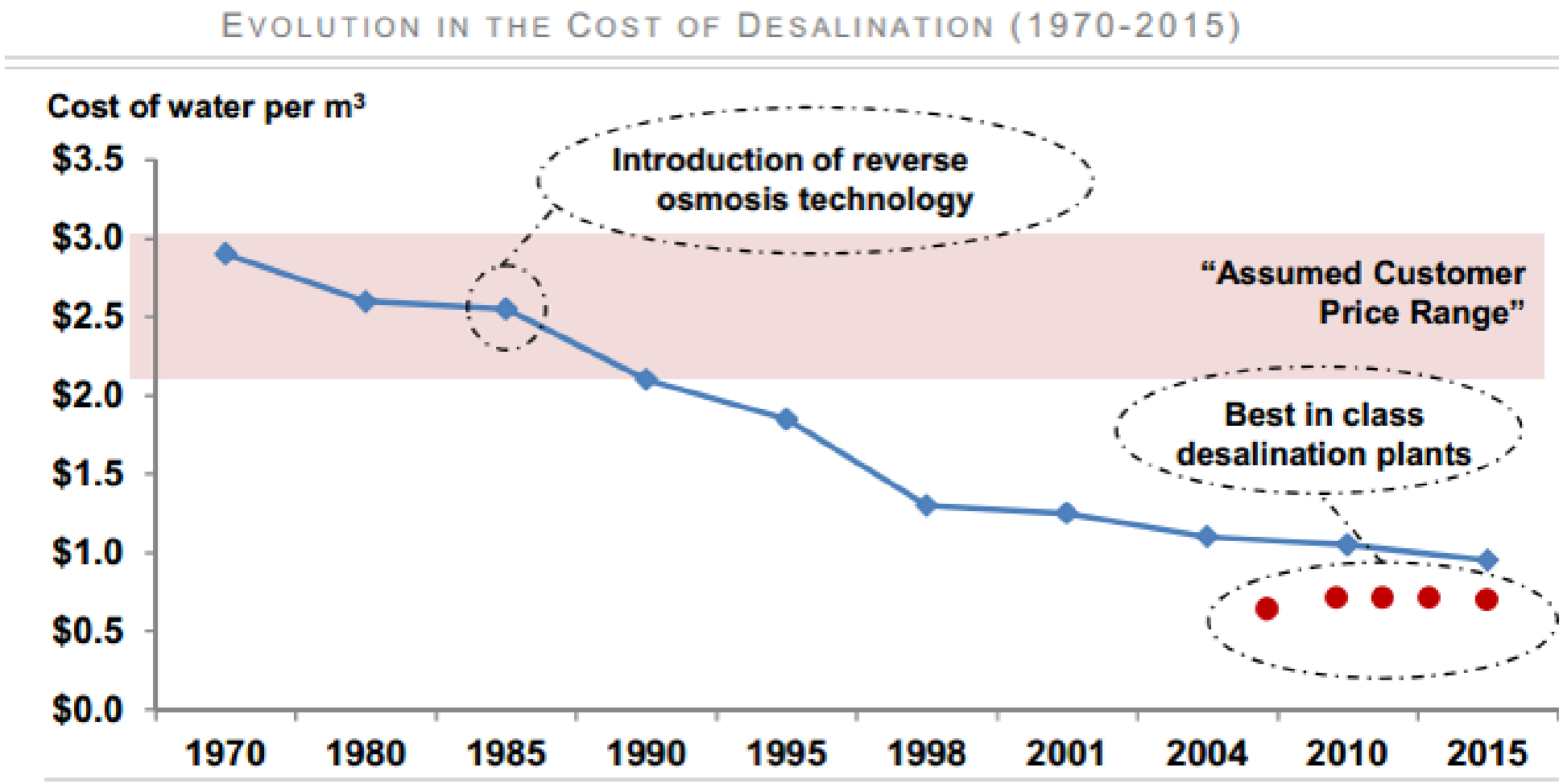
Forward Osmosis

Forward osmosis uses a semi-permeable membrane to effect separation of water from dissolved solutes with significantly lower energy consumption comparted with RO. Pilot plants are operating the UAE and in Oman.

Membrane Distillation

Membrane distillation (MD) is a separation process where a micro-porous hydrophobic membrane separates two aqueous solutions at different temperatures.

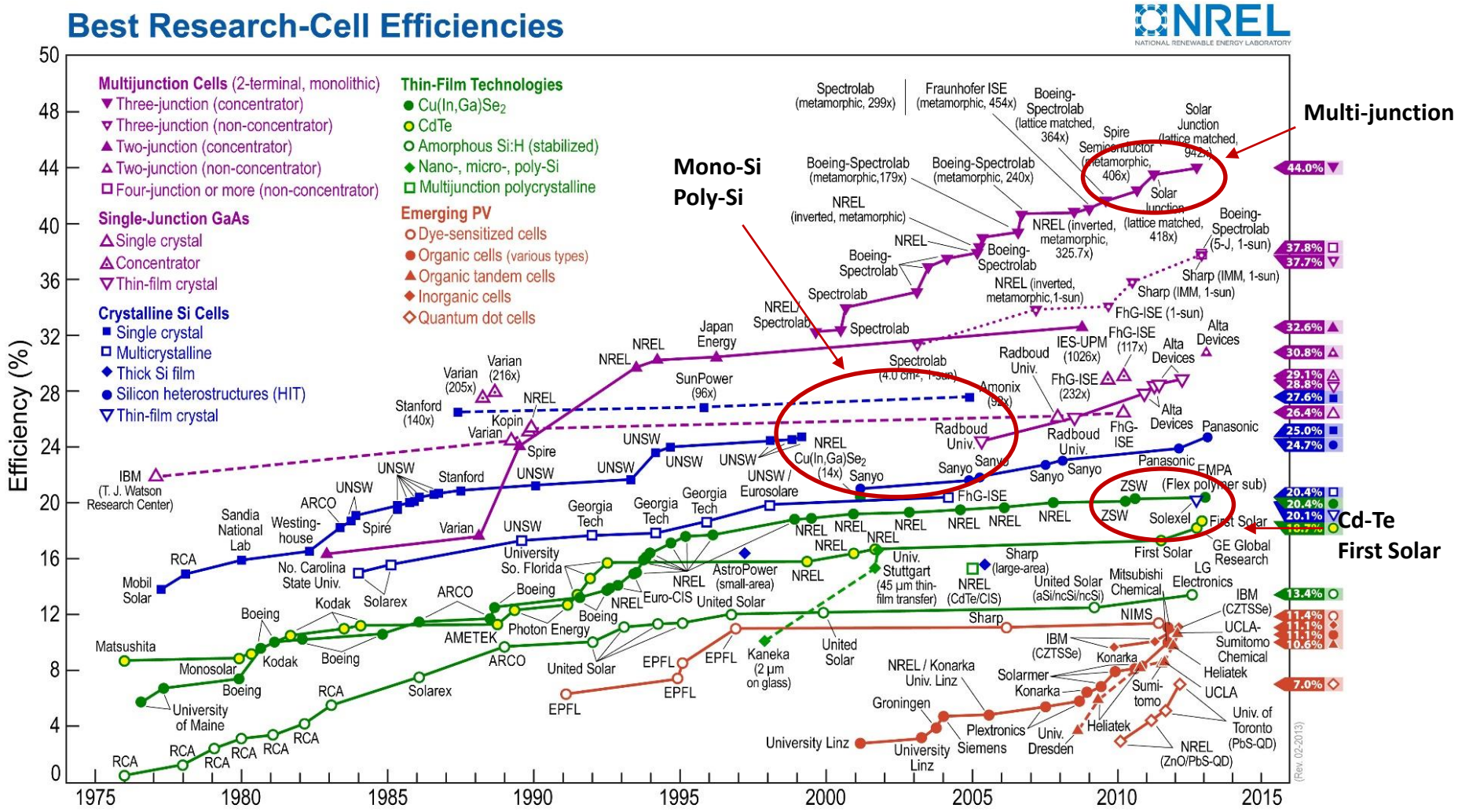
Price Driven Technology Shift



Source: Frost & Sullivan

Photovoltaic (PV)

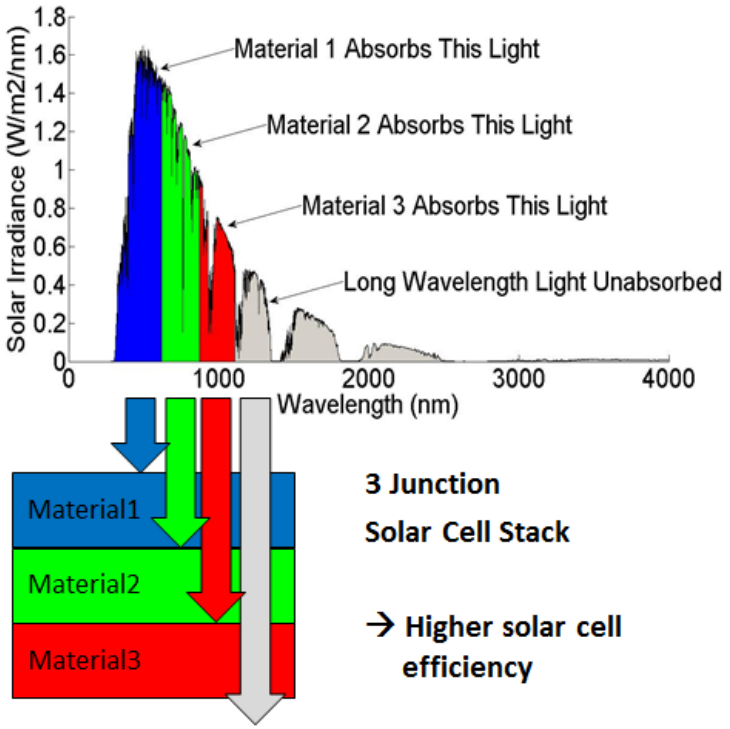
Renewables: Photovoltaic (PV) Roadmap



New PV modules technologies

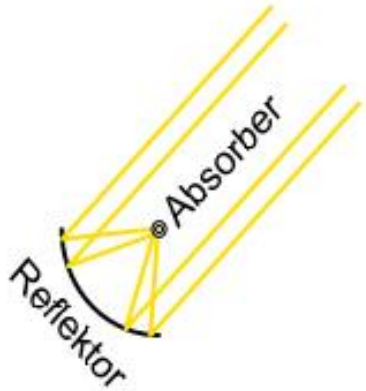
- Mature technologies as Poly-Si, Mono-Si with efficiencies close to 20% can still improve slightly but it is not expected a big jump in efficiencies

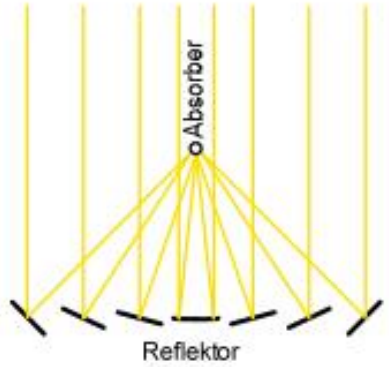
- Disruptive technologies, e.g. multi-junction solar cells have reached efficiencies of 45% and are expected to reach 50%

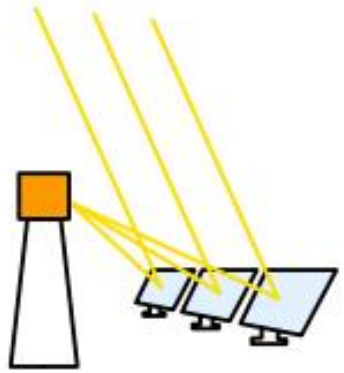


Concentrated Solar Power (CSP)

Solar-thermal (CSP) Technologies







Parabolic Trough

Linear Fresnel

Solar Tower

CSP Technology Comparison

MS Central Tower

Synthetic Oil Parabolic Trough

Pros	Cons
- Higher storage capability - Higher efficiency (gross 45%)	- Lower efficiency in a place with low visibility - Less mature technology than trough technology – higher technology risk
- Not impacted by the visibility and attenuation - Mature technology and more competitive market	- Less cost-effective storage - Lower efficiency (gross 40%)

Optimal technology choice is very project specific

Single Tower

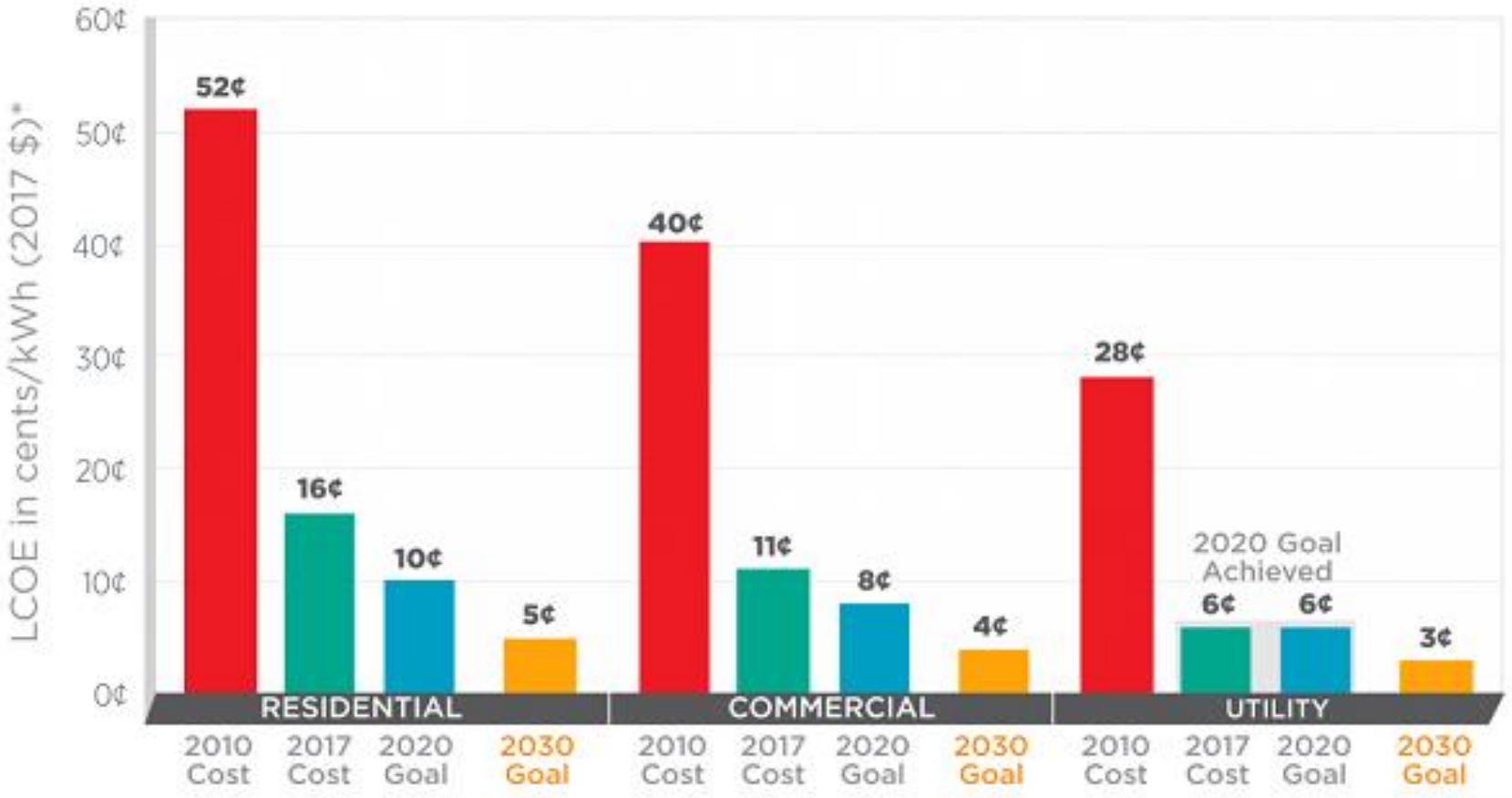
Multi-towers

Pros	Cons
- Easy to store energy. Compact solution. The process is located in a reduced area. Cost savings due to the scaling factor in key equipment (i.e. receiver) - Small and big heliostats can be used	- Lower efficiency in the solar field due to atmospheric attenuation losses - More difficult to build the tower and receiver assembly
- Better performance in places with low visibility and high attenuation - Modular concept. Easier construction	- More difficult to store energy: not compact solution, pipes needed between towers, pumping and thermal losses, freezing risk - Only small heliostats can be used

CSP technology. Emerging concepts

	Pros	Cons
Parabolic Trough Typical Thermal Oil	- Mature technology - More competitive market	- Limited delta T (100 degrees C). Larger storage system - Limited maximum temperature 400 degrees C. - Lower steam cycle efficiency - Indirect storage system. Storage with other fluid (Molten Salts)
Parabolic Trough Enhanced Thermal oil (Helisol)	- Higher maximum temperature (425 degrees c) - Higher steam cycle efficiency - Higher delta T. Smaller storage system for same capacity	- Under testing. Not commercial projects yet. - One supplier and exclusive product. - Higher vapor pressure. Higher pressure in the system (40bars) - Carbon steel in the limit to be used (425 degrees C)
Parabolic Trough Molten Salts	- Higher maximum temperature (550 degrees C) - Higher steam cycle efficiency - Higher delta T. Smaller storage system for same capacity (similar to tower)	- Under testing. Not commercial projects yet. - Risk: Frozen issues in the solar field - Higher thermal losses (pipes in the solar field at 550 C
Parabolic Trough Direct Steam	- Higher maximum temperature (550 degrees C) - Higher steam cycle efficiency - Direct steam generation	- Under testing. Not commercial projects yet. - Steam storage issues - Higher pressure in the system - More complex operation

SunShot Progress and Goals

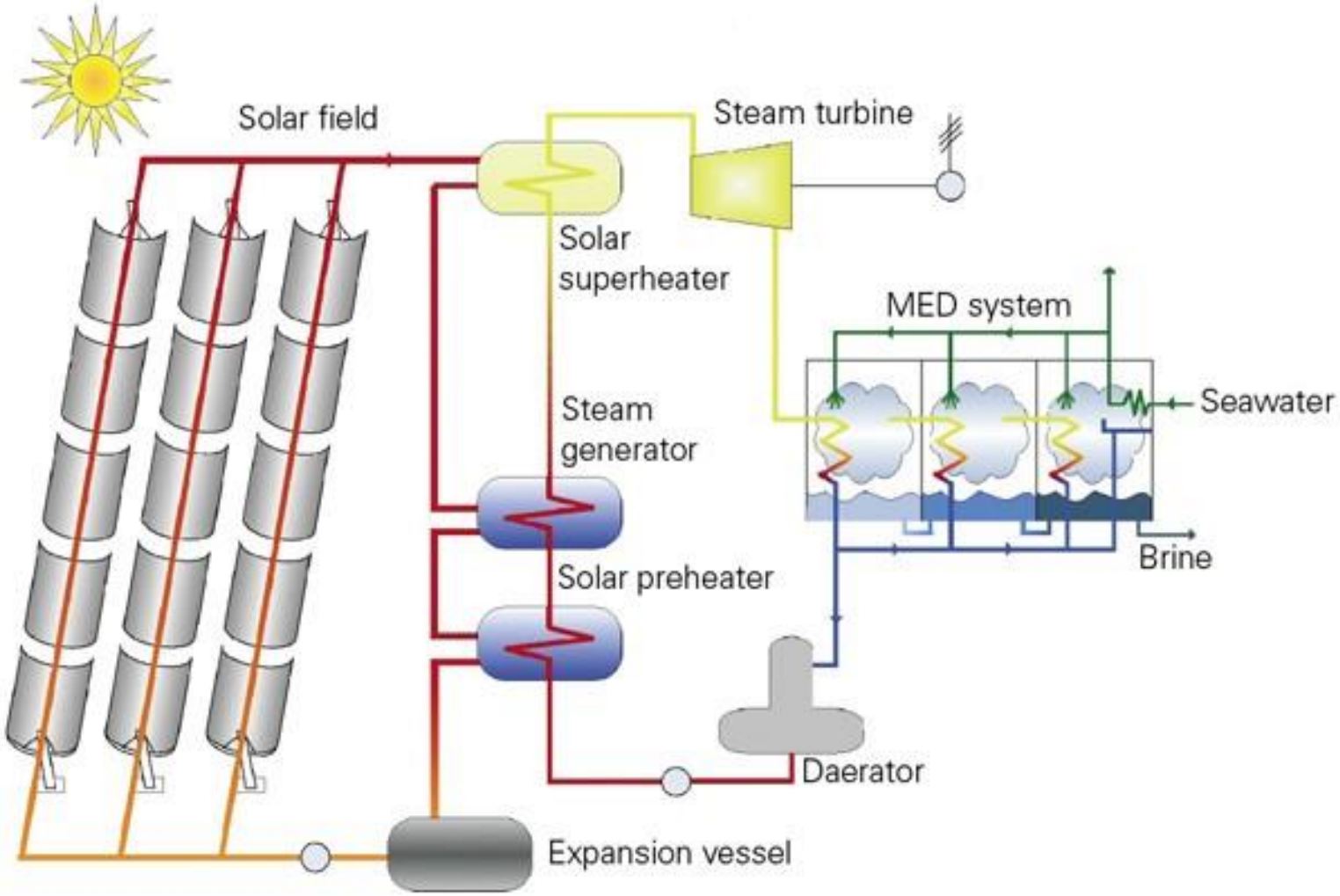


*Levelized cost of electricity (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010–17.

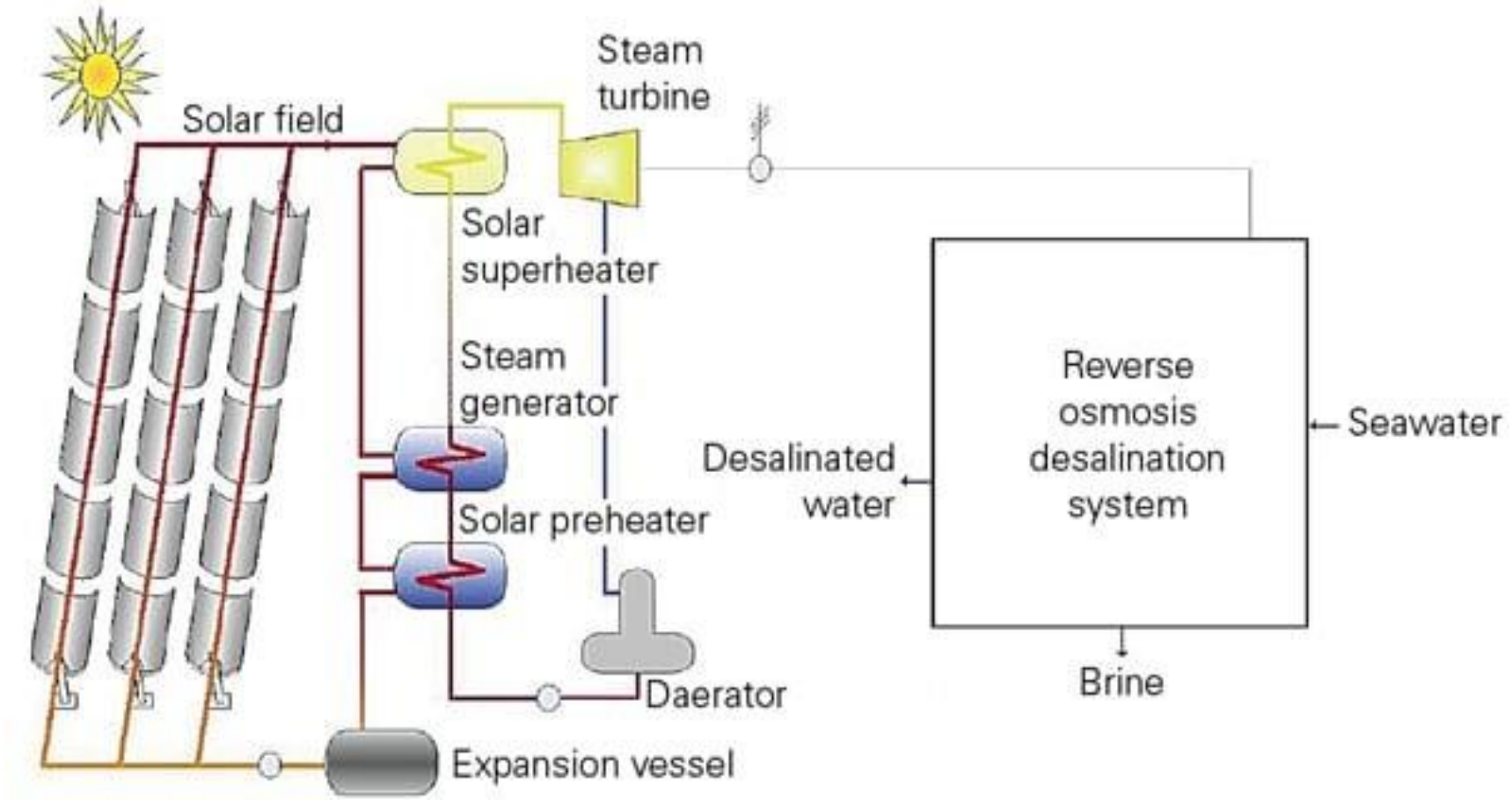
Solar Desalination Methods

Two basic methods of achieving desalination using this technique; direct and indirect

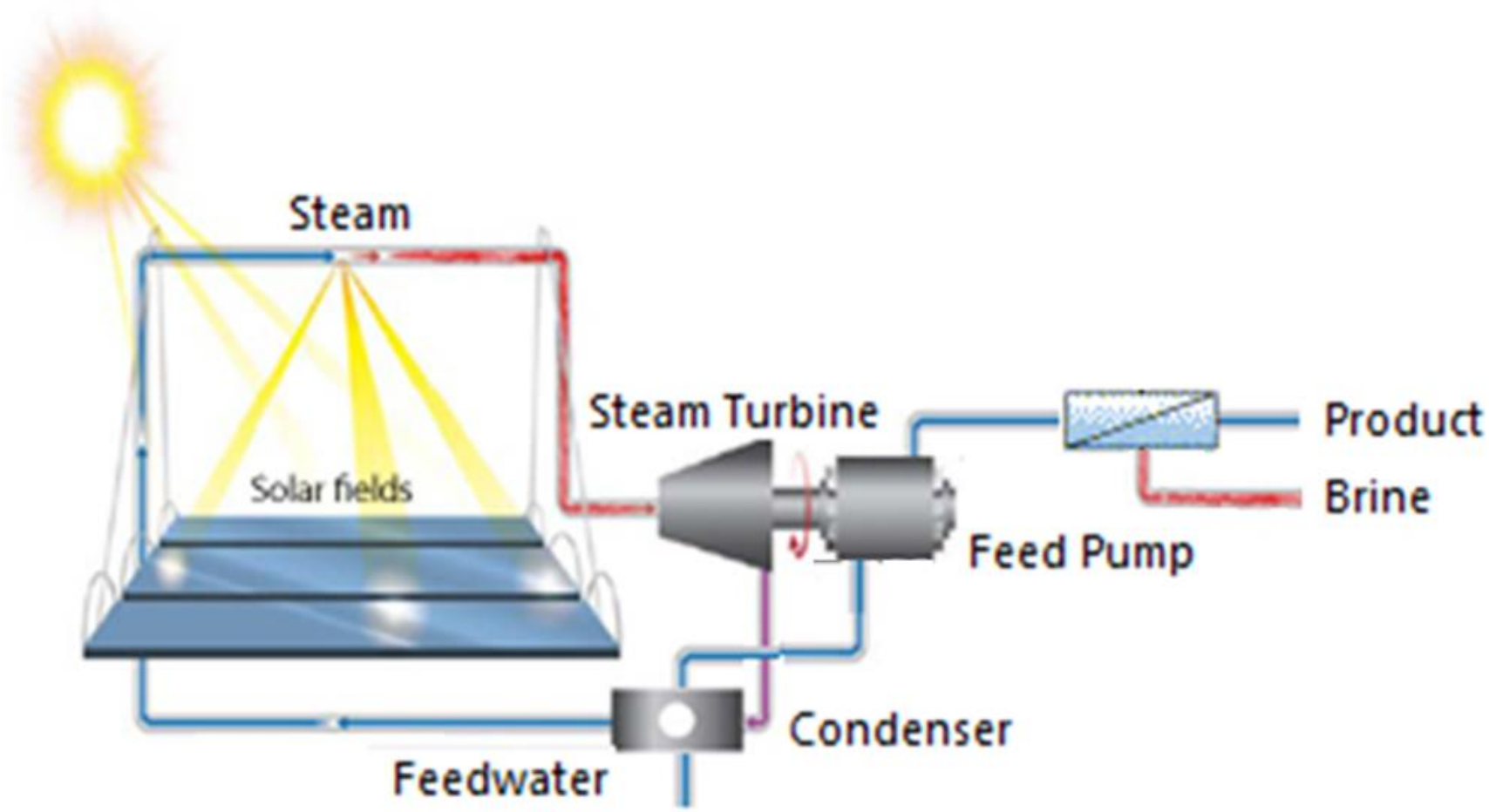
1) Sunlight provides heat for evaporative desalination processes



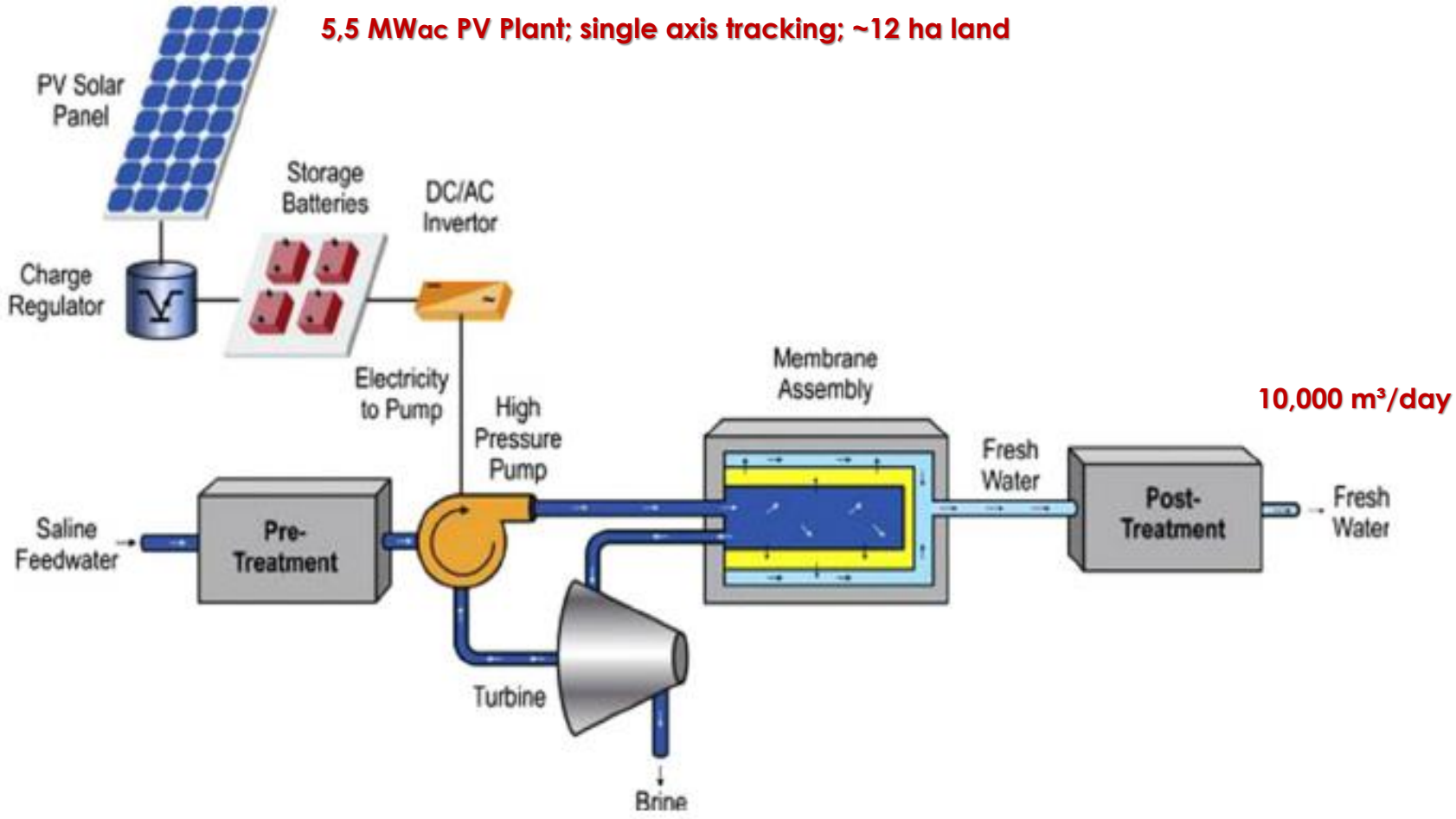
2) Sunlight is converted to electricity (CSP) to power a membrane process



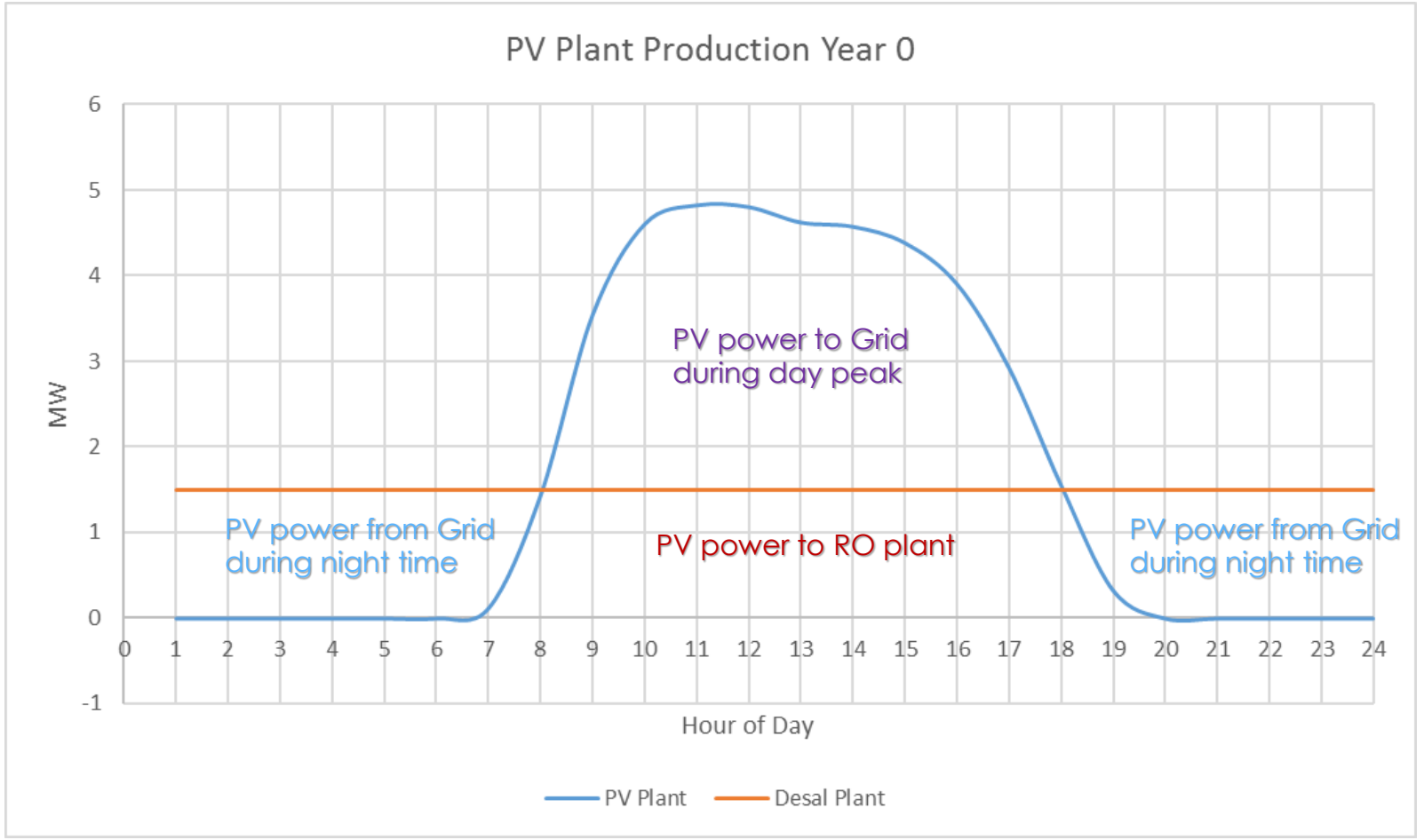
Solar-CSP with direct steam RO plant (Turbo pump)



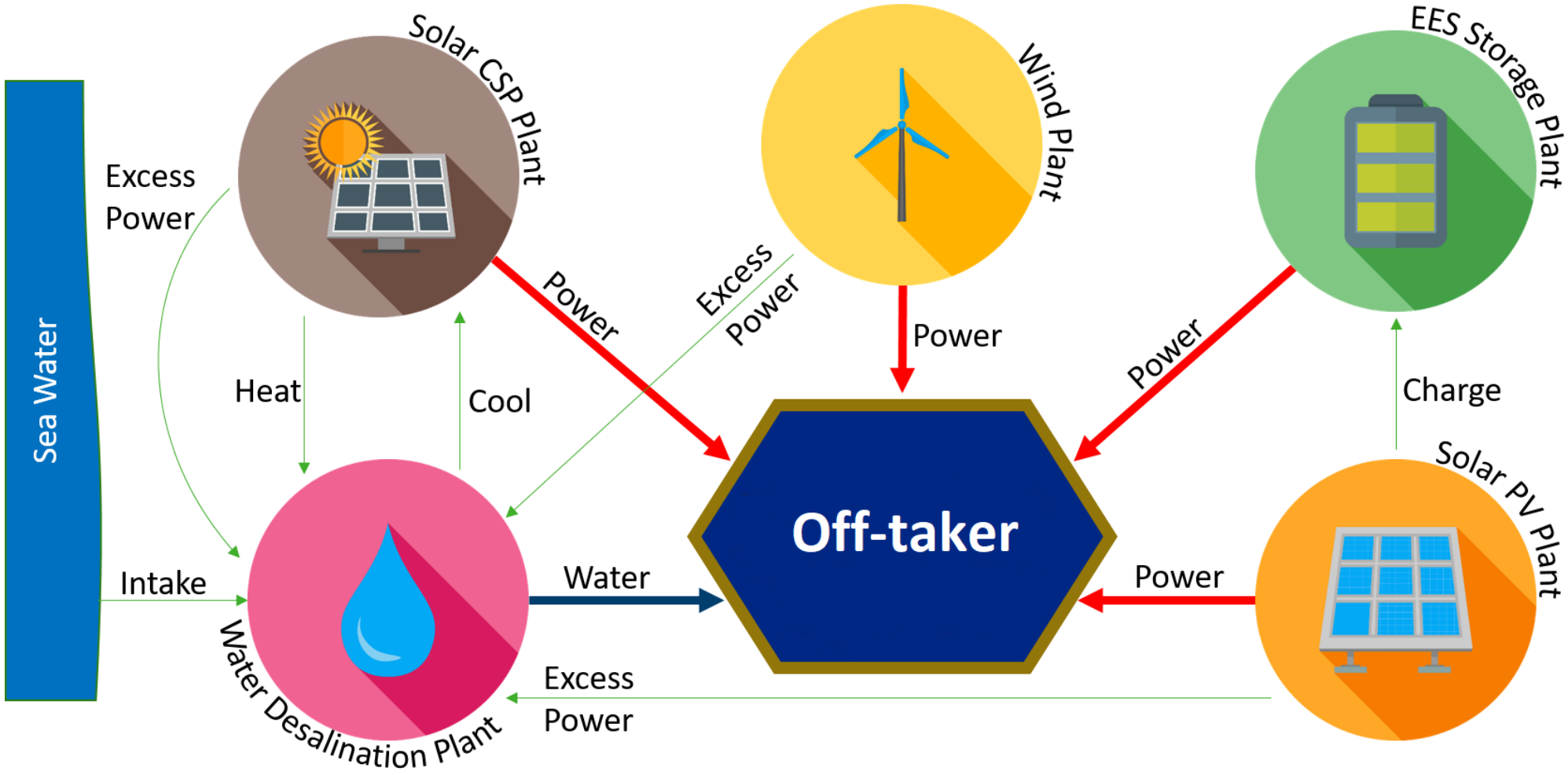
Sunlight is converted to electricity (PV) to power a membrane process



3) Solar-PV driven Reverse Osmosis Plant



Integrated Renewable Desalination System with Energy Storage



Conclusion

- Water and energy are inextricably linked, especially for seawater desalination, and desalination plays a vital role in the GCC in providing reliable, sustainable, and resilient water supplies.
- Solar and desalination technologies are commercially available to be deployed at large-scale.
- Reducing specific energy consumption of the desalination process is a key prerequisite for the deployment of utility-scale renewable driven desalination plants in the GCC, hence, less Capex for Solar Plant and Energy Storage.
- CSP systems as heat supply for desalination can be designed for lower temperatures to avoid expensive materials resulting in significant cost savings compared to CSP for power generation.
- Contrary to CCGT plants the CSP peak generation occurs in Summer.
- Water can be stored more economically at utility scale than for example electricity in a battery.
- Gravity and Hydrogen storage are emerging technologies to store excess generation from PV and Wind plants.
- Demonstration project in GCC required to path the way and to accelerate deployment of large-scale projects.

ACWA POWER
أكوا باور

Thomas Altmann
VP-Innovation & Technology
taltmann@acwapower.com
www.ACWAPower.com

Saudi Arabia

Building 1,
Ground Floor,
Business Gate
Office Complex,
Airport Road
P.O. Box 22616
Riyadh 11416
T: +966 1 2835555
F: +966 1 2835500

Saudi Arabia

King Abdulaziz
Branch Rd,
Ash Shati,
Jeddah,
23613
T: +966 12 618 9000

UAE

The One Tower, 41st
Floor, Barsha Heights,
Sheikh Zayed Road,
P.O. Box 30582
Dubai
T: +971 4 5090555
F: +971 4 3859625

China

2101 Tower B,
Ping An International
Financial Center,
No. 1-3,
Xin Yuan Nan Lu,
Chao Yang District,
P.O. Box 10027,
Beijing
T: +86 10 5979 2330
F: +86 10 8438 1078

Egypt

Plot 176,
Second Sector,
City Center Giza
Systems Building,
New Cairo,
Cairo
T: +202 23 225 500

Jordan

Amman-Khelda,
Al Khalideen Suburb,
Al Hakam Bin
Amro Street -
Bldg No. 22
P.O. Box: 2564
Amman 11953
T: +962 (6) 534 0008
F: +962 (6) 535 7210

Morocco

Villa 6-G-7,
Angle Avenue
Mehdi Ben Barka
et Atthuya,
Hay Riad,
Rabat 10100
T: +212537714164
F: +212537714165

Oman

South Lobby Roof
Top,
Grand Mall,
P.O.Box: 163,
PC: 136,
Al Khwair,
Muscat

South Africa

7th Floor,
90 Grayston Drive,
Sandton,
Johanesburg,
2196
T: +27 117224100

Spain

Empresarios
Agrupados
Calle Magallanes 3,
28015
Madrid

Turkey

Barbaros Plaza,
Emirhan Caddessi,
No.113 Kat.19,
Dikilitas,
Besiktas
Istanbul
T: +90 212 259 3396
F: +90 212 259 3397

Vietnam

11th floor,
BIDV Tower 194,
Tran Quang Khai St.,
Hoan Kiem District,
Hanoi
T: +84 43 935 2966
F: +84 43 935 2969