Estado actual y desarrollos futuros de la desalación

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Ramon y Cajal fellow

Water scarcity: Need for alternative water sources

1 Population Growth

Rising global populations increase water demand, demand, leading to water scarcity in many regions. regions.

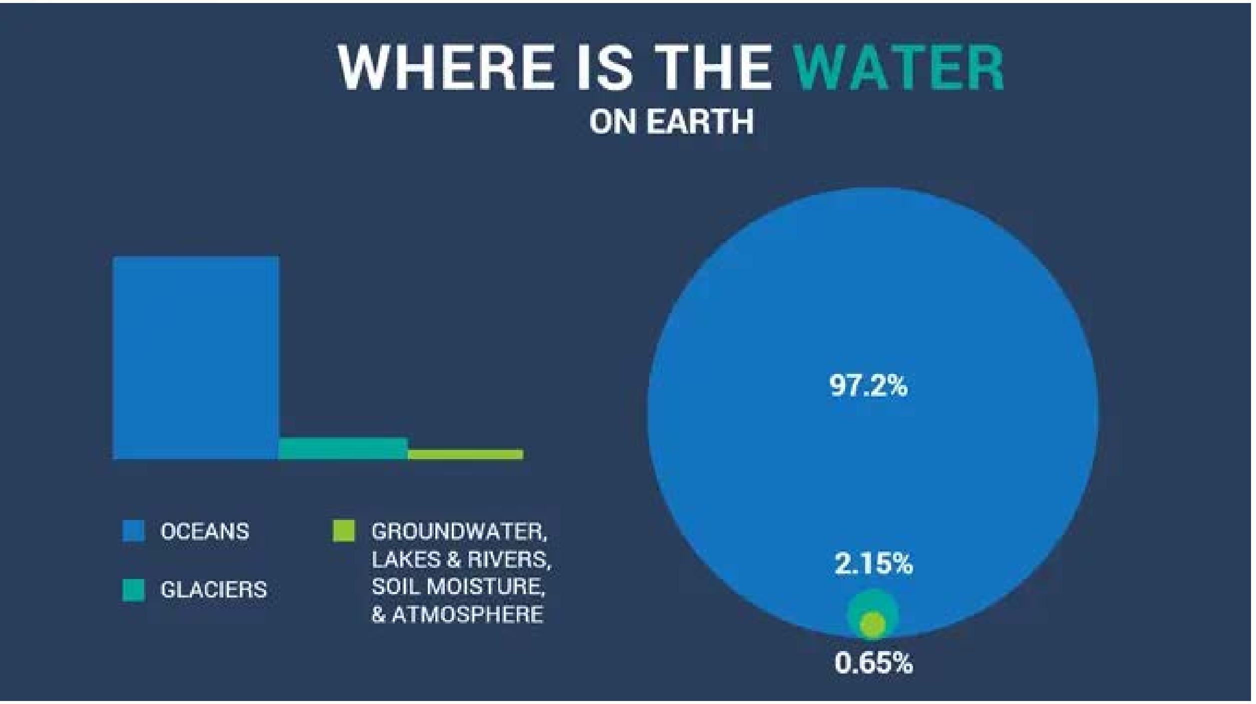
2 Climate Change

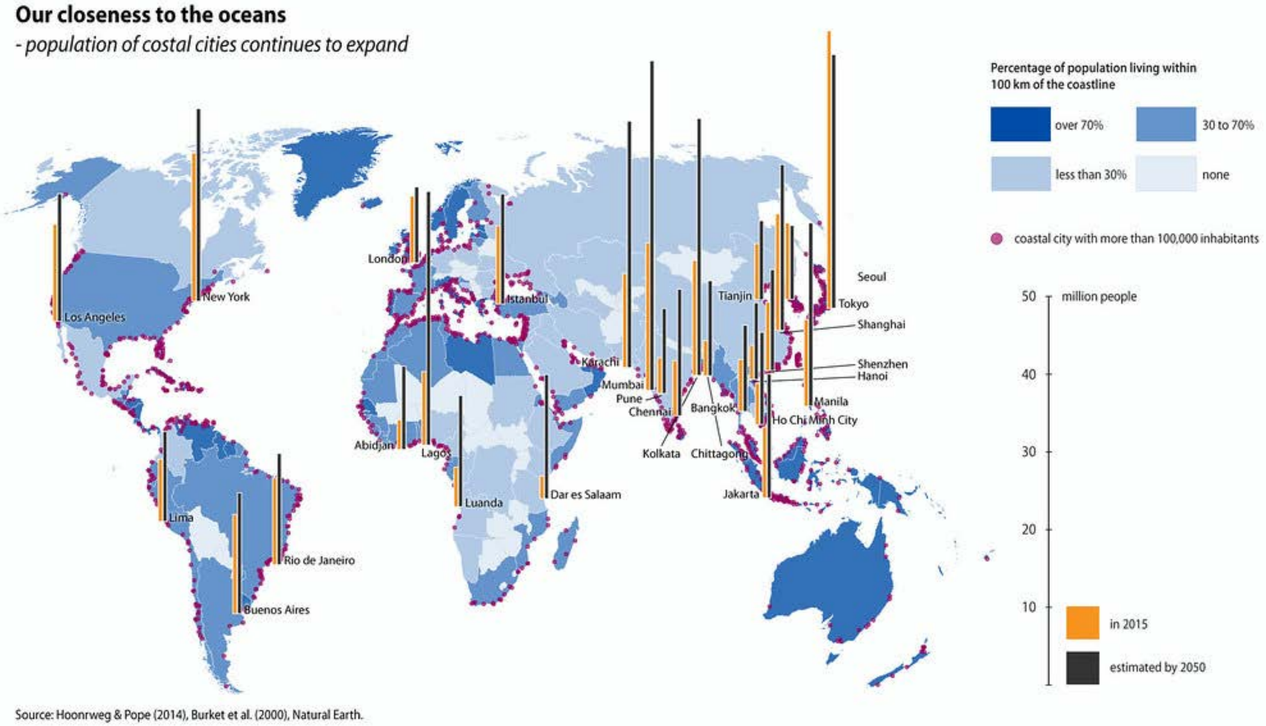
Changing precipitation patterns and increased drought exacerbate water stress.

3 Pollution

Contamination of existing freshwater sources further limits accessible water supplies.

Water is mainly in the oceans!
Most of the population near costal area!





Desalination:

- Process of removing salt and other minerals from seawater
- Is a crucial solution for addressing water scarcity.
- The technology has rapidly evolved, offering a sustainable and reliable source of freshwater for a growing global population.

Milestone Developments in Desalination

1 1950s-1960s

Reverse Osmosis (RO) technology emerged, offering a more efficient and cost-effective method for desalination.

2 1970s-1980s

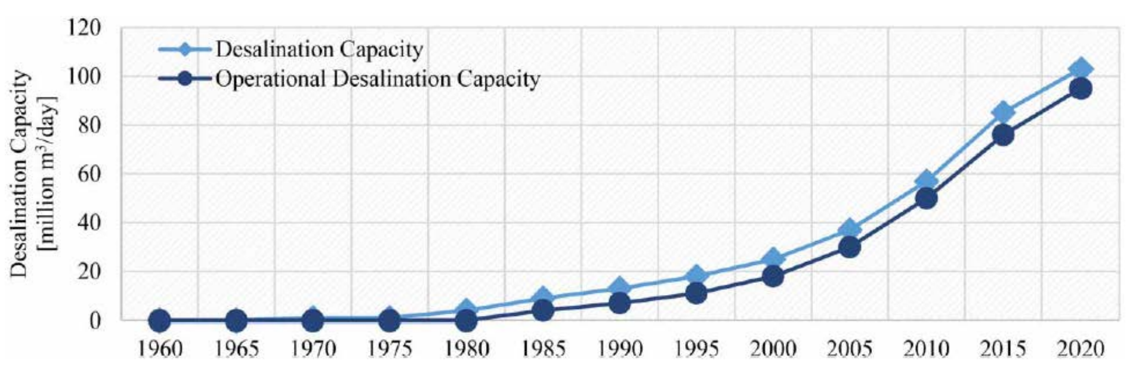
Significant advancements in membrane technology and energy efficiency further improved RO desalination processes.

3 1990s-Present

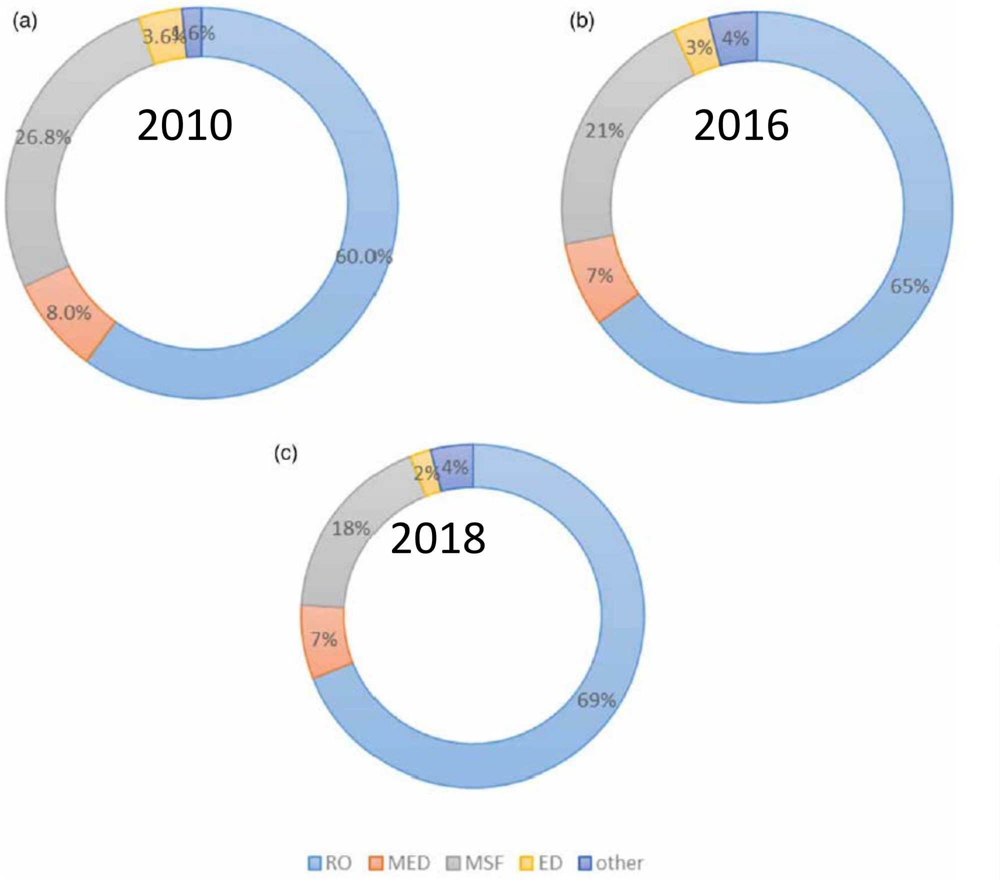
Increased focus on energy conservation and environmental sustainability has led to the development of more environmentally friendly desalination techniques.

Installed capacity

Important growth of installed capacity

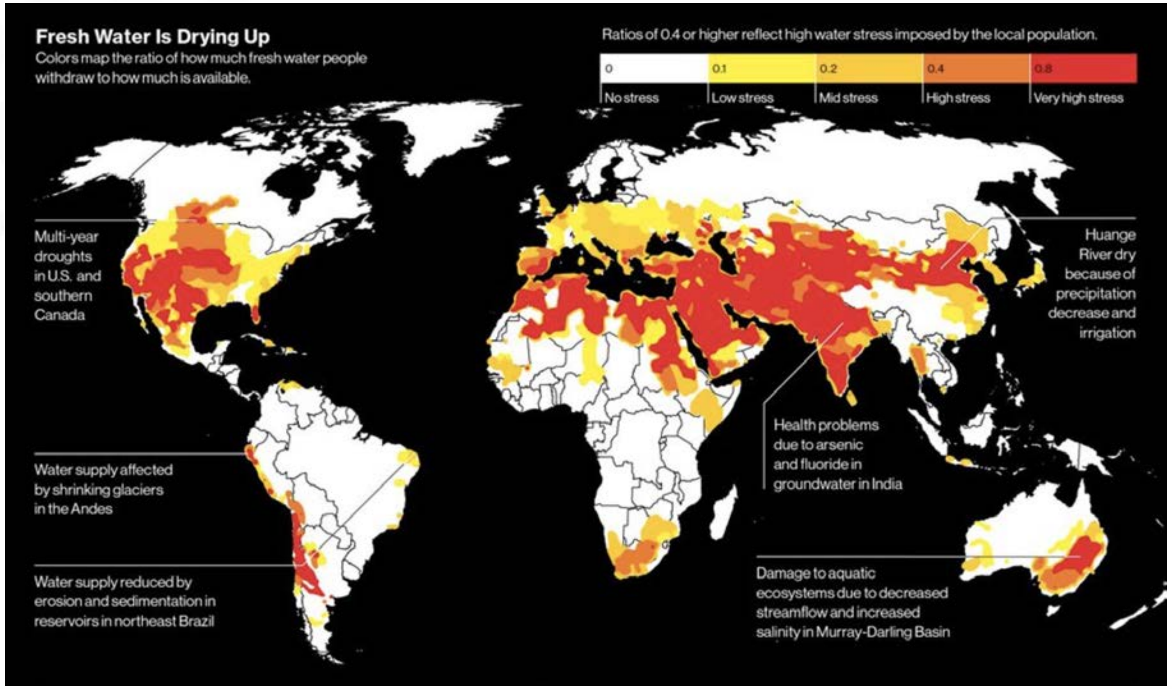


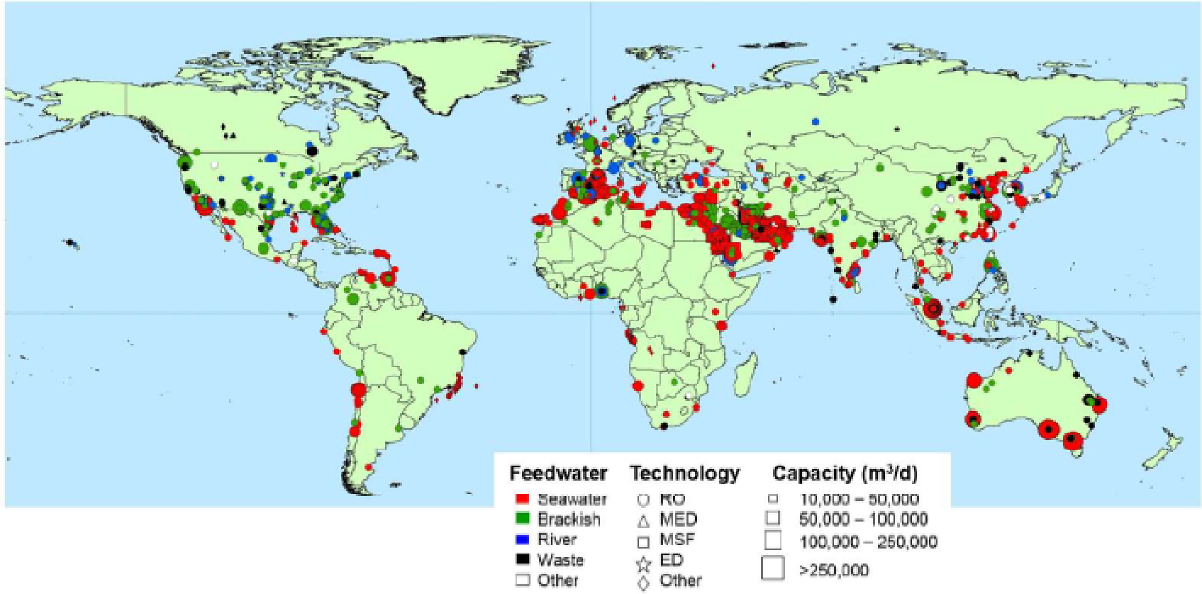
Technologies share of overall installed capacities



DOI: 10.2166/es.2023.135

Desalination plant in the world



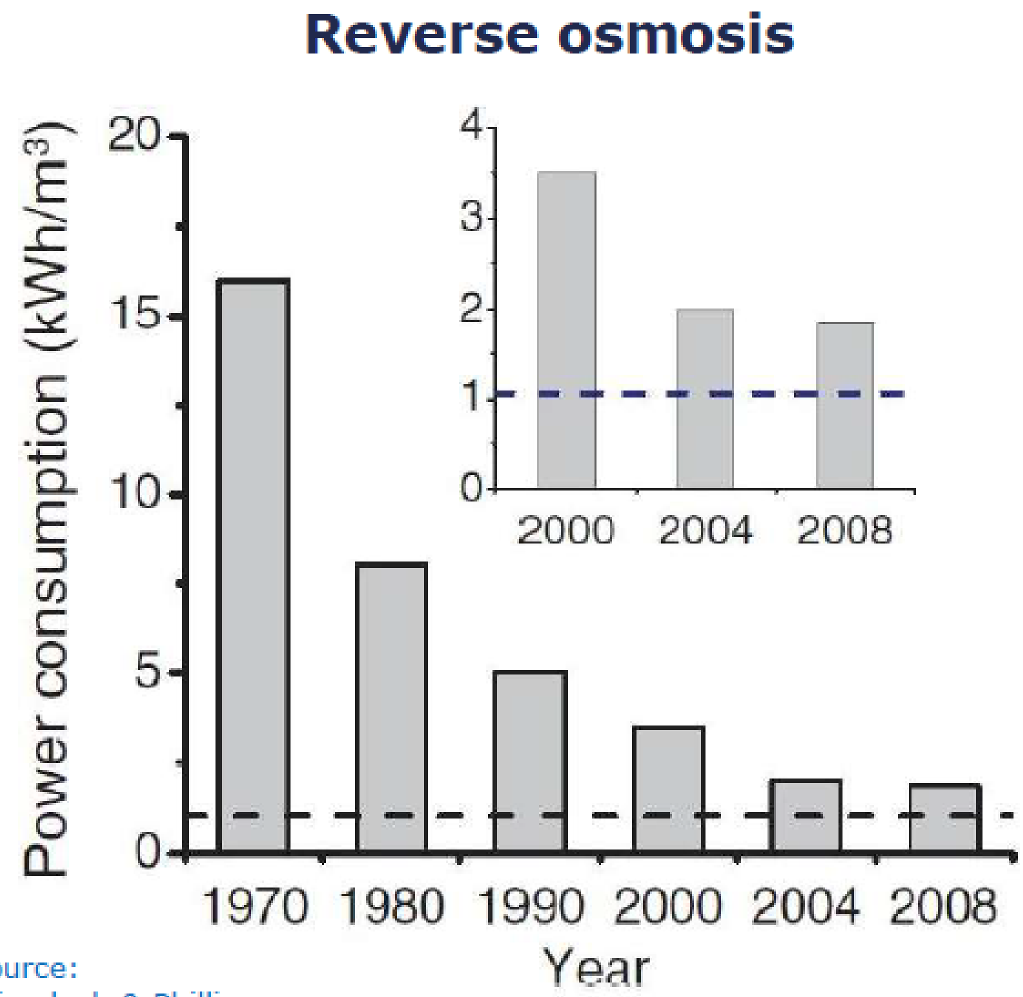


source:
Jones et al, 10.1016/j.scitotenv.2018.12.076

>20.000 desalination plants in operation

50% in the middle east

Evolution of energy consumption



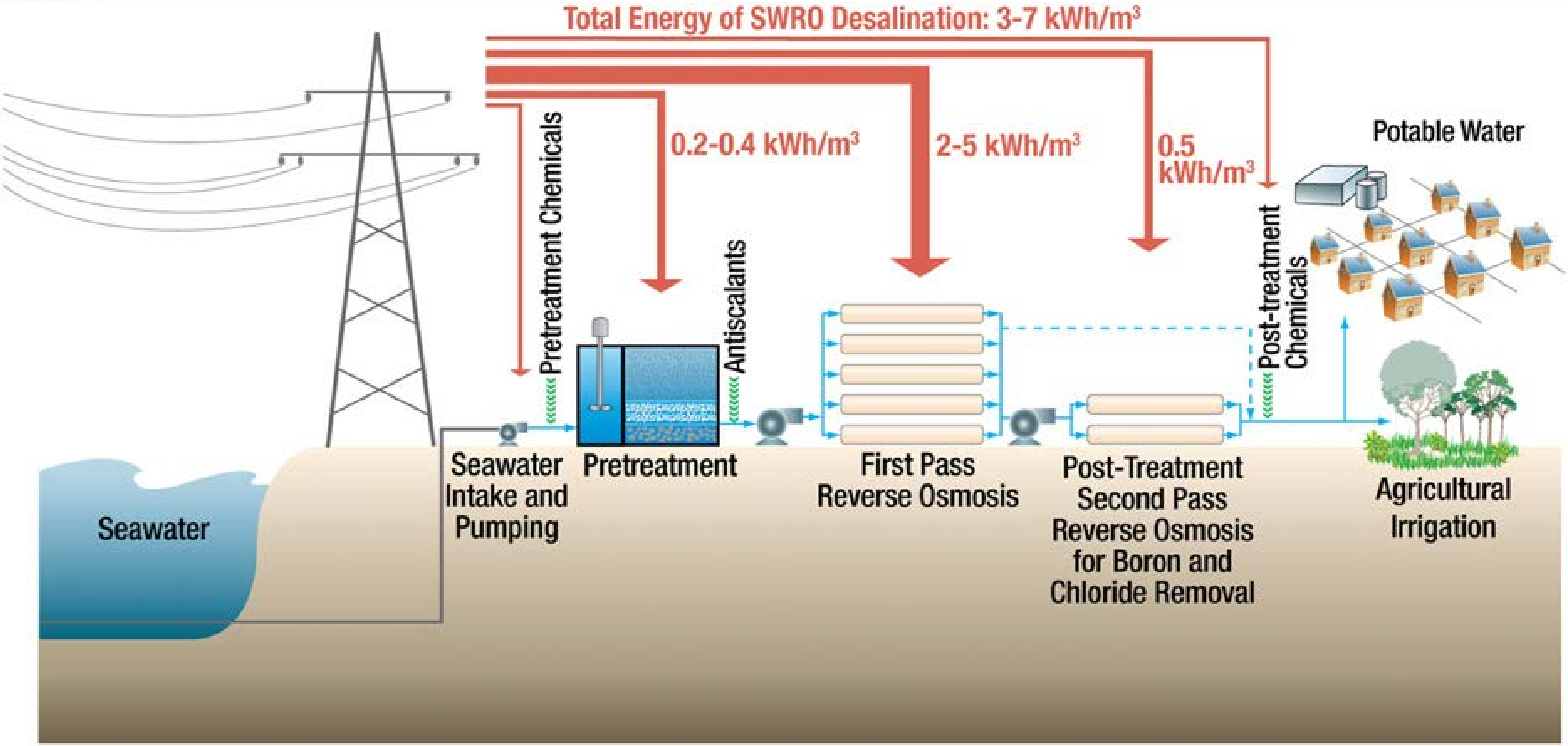
source:
Elimelech & Phillip,
10.1126/science.1200488

Thermal desalination

Reverse osmosis

Energy recovery devices

Desalination plant energy consumption



Shaffer et al. Journal of membrane sicence, 2012

Challenges for desalination?

https://www.arte.tv/en/search/?q=desalination&genre=all

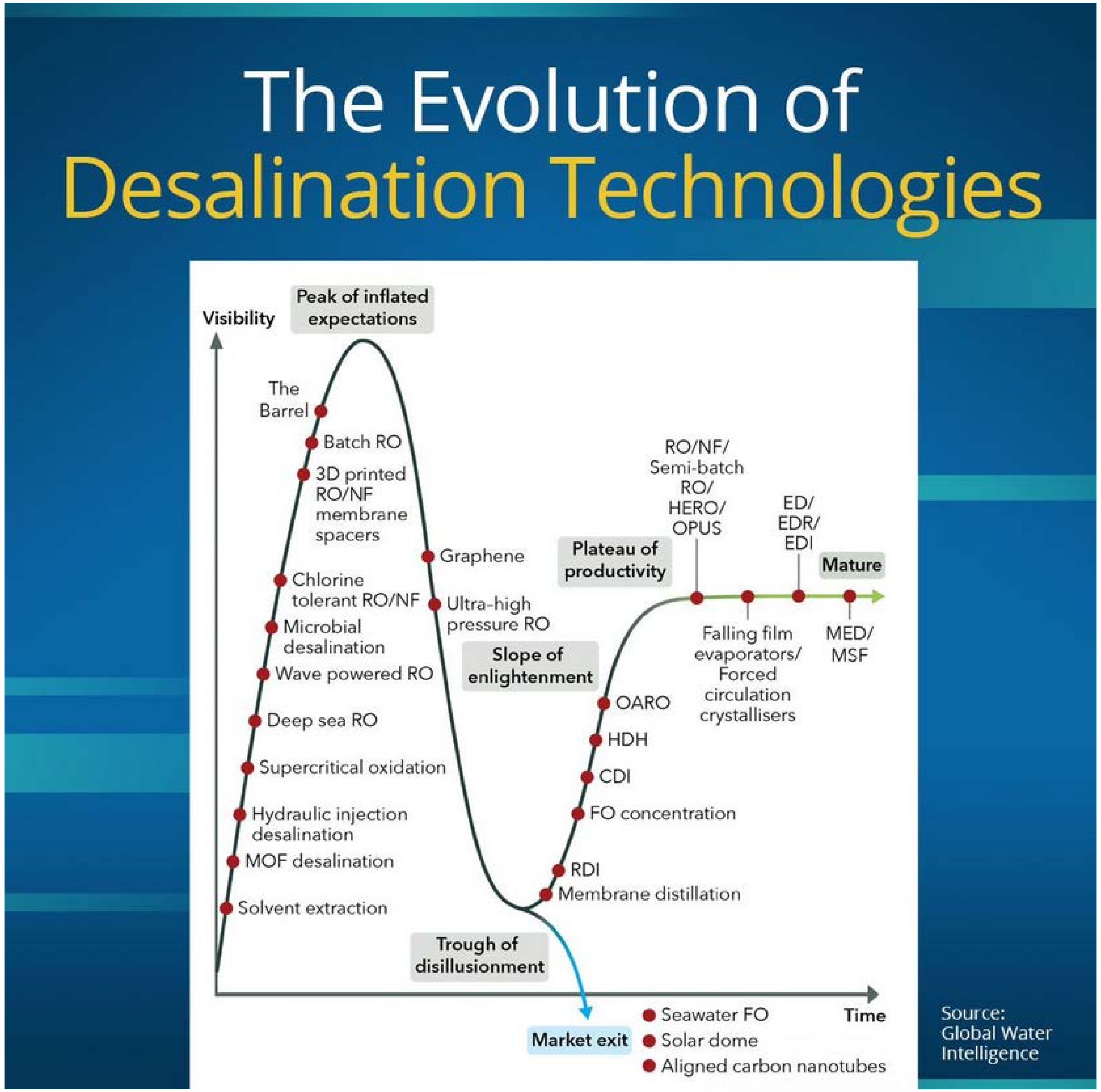
Energy Consumption

Desalination is energy-intensive, so intensive, so reducing energy consumption is vital for sustainability.

Brine Discharge

Managing the discharge of concentrated brine is crucial to minimizing environmental impact. impact.

Mature and emerging desalination technologies



Improved energy efficiency

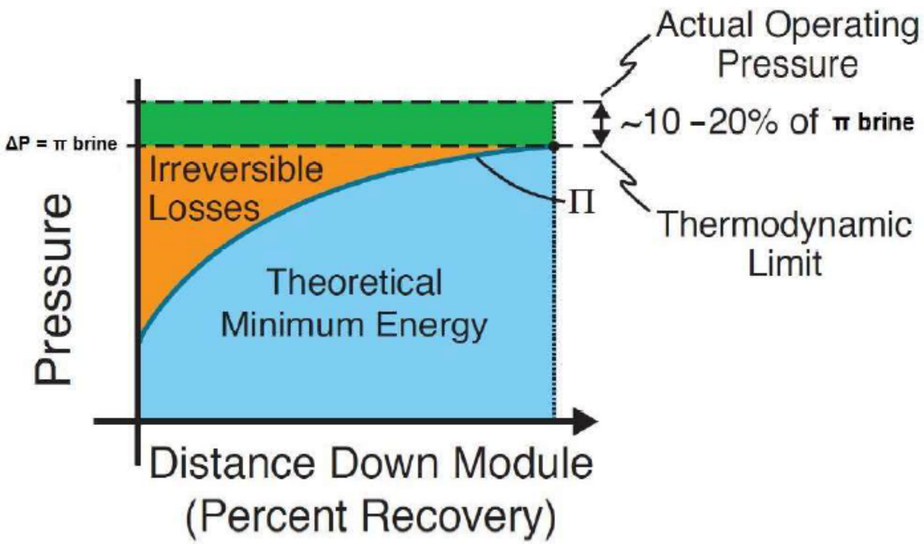
Technological Advancements	Cost Reduction
Improved Membrane Materials	Lower energy consumption
Energy Recovery Systems	Increased efficiency and lower operational costs
Optimized Plant Designs	Reduced capital and operating expenditures

But some thermodynamic límits:

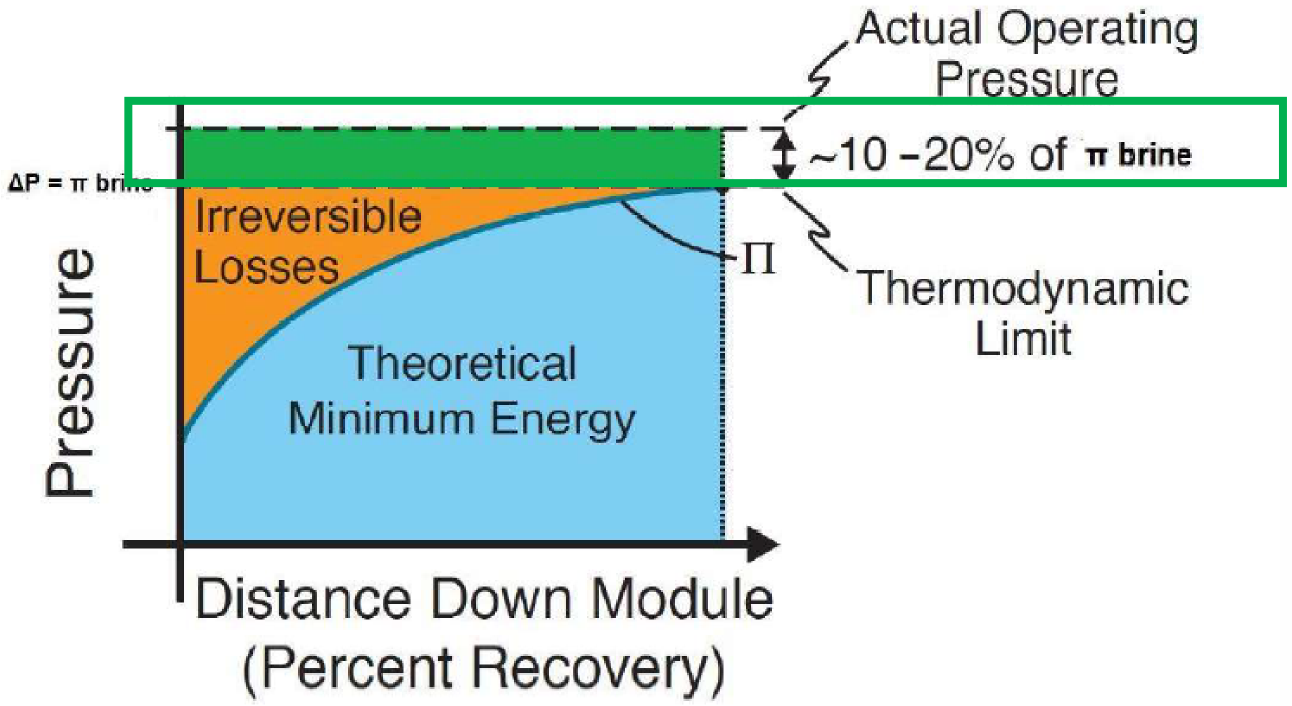
π: 25-30 bar

P: 55-70 bar

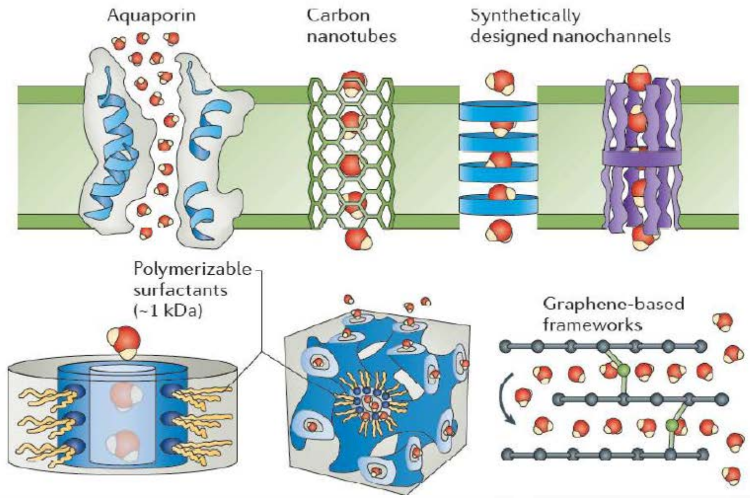
$Energy \sim 2\ \text{kWh/m}^3$



Limiting losses: membrane development



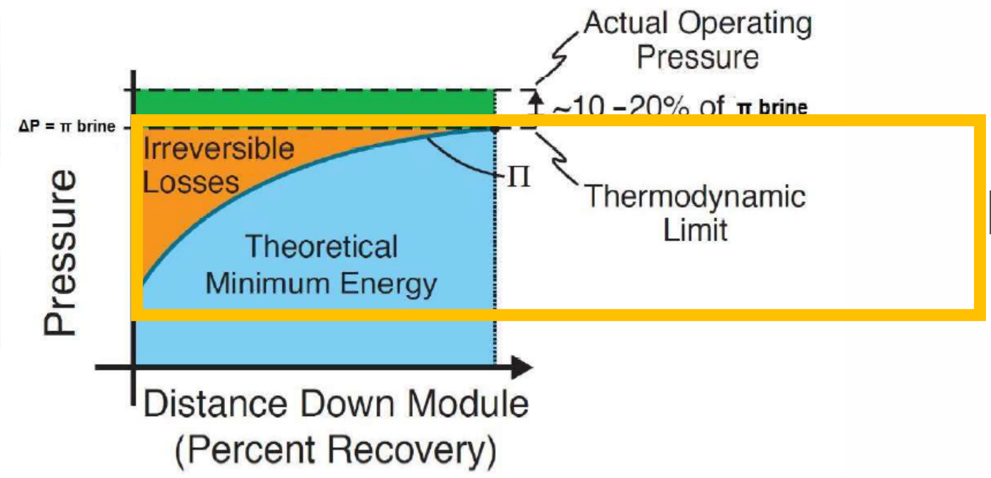
High permeability/ permselectivity membrane to límit pressure losses and membrane surface required



from Werber et al, Nat Rev Mats, 2016

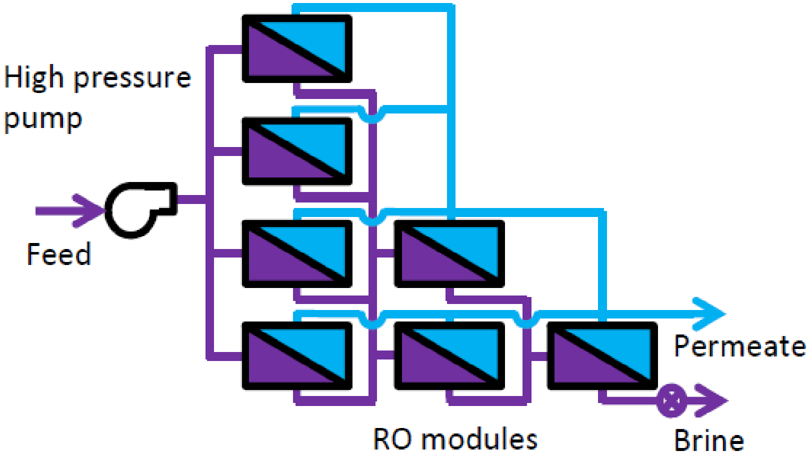
Low fouling /high chlorine tolerant membrane

Limiting irreversible losses



Limiting irreversible losses (closer to theoretical mínimum energy)

Multiple stage RO



Closed-circuit RO

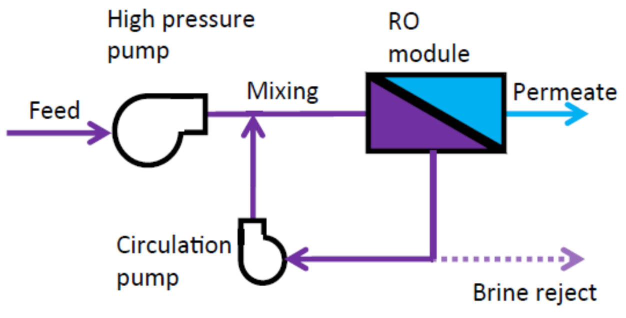


Fig. 2. Schematic diagram of a closed-circuit reverse osmosis system. Feed continu-

Batch RO

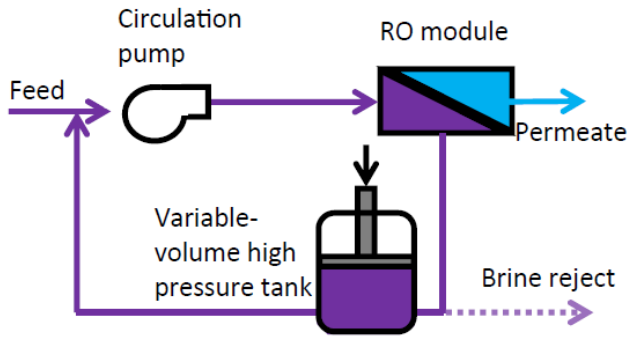
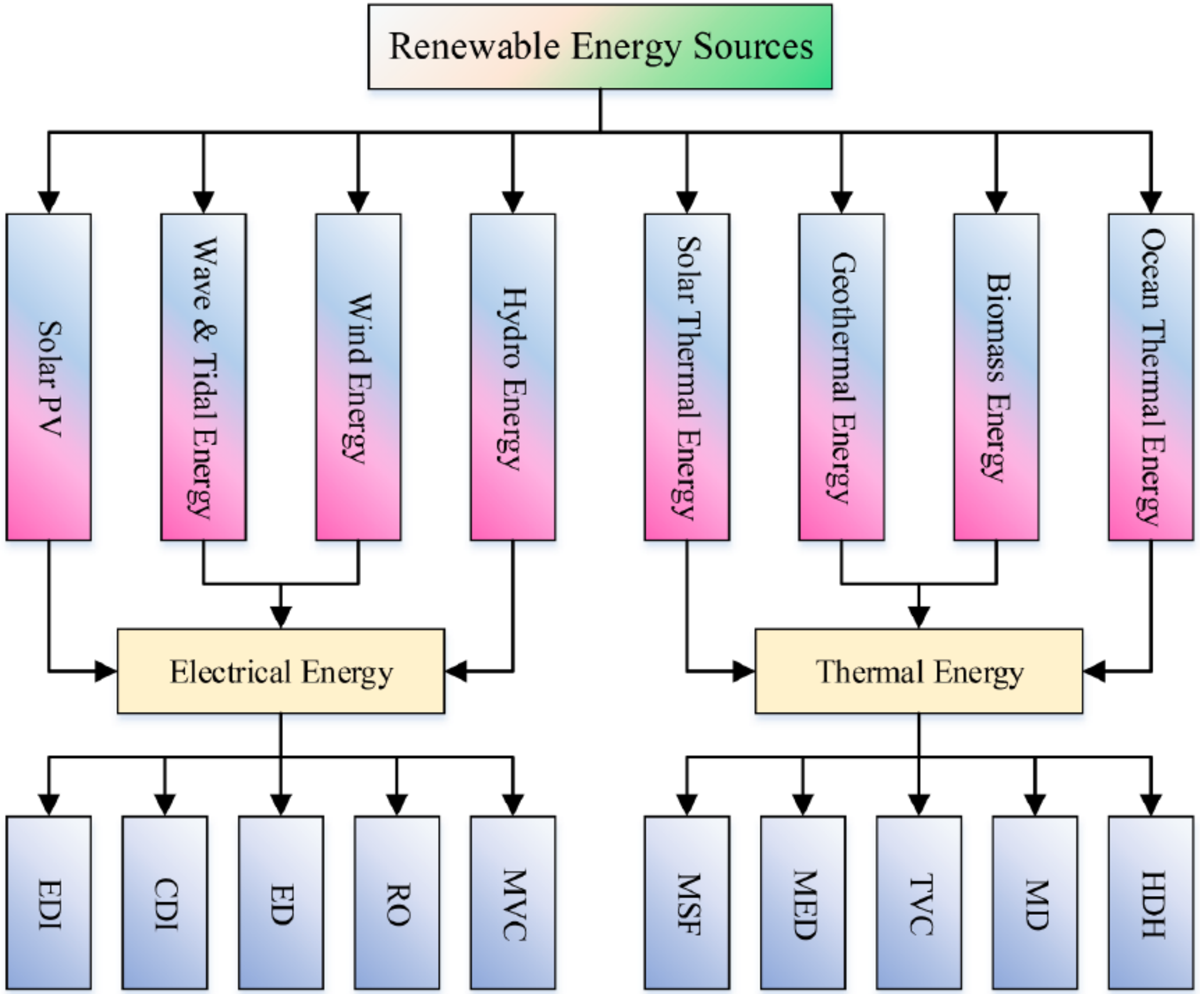
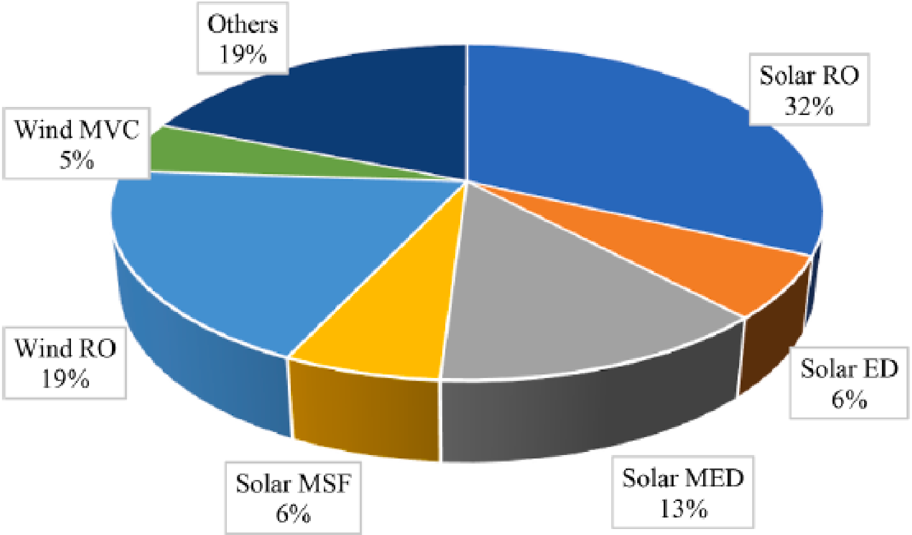


Fig. 3. Schematic diagram of a batch RO system with a high pressure, variable-volume

https://doi.org/10.1016/j.watres.2016.09.029

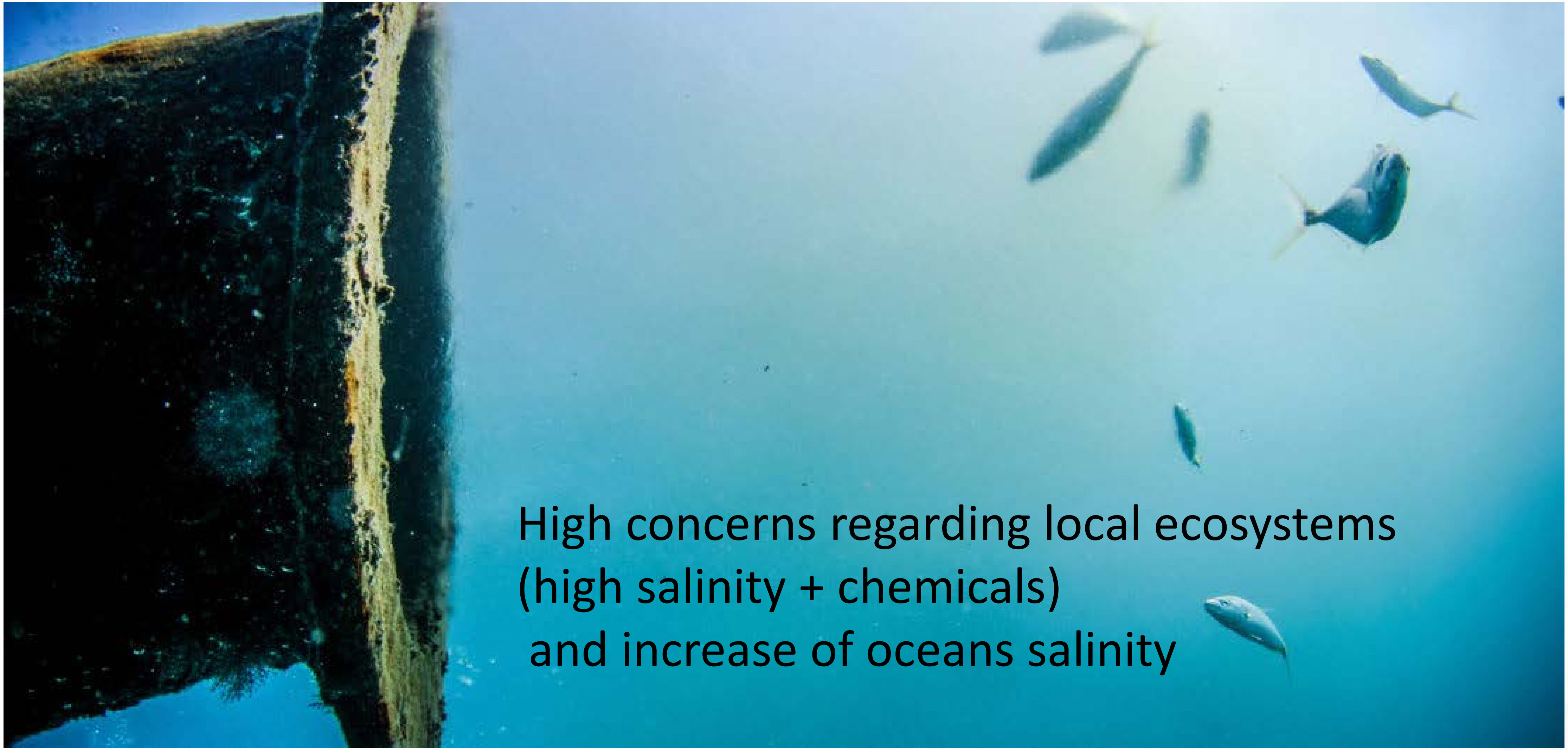
Renewable energy





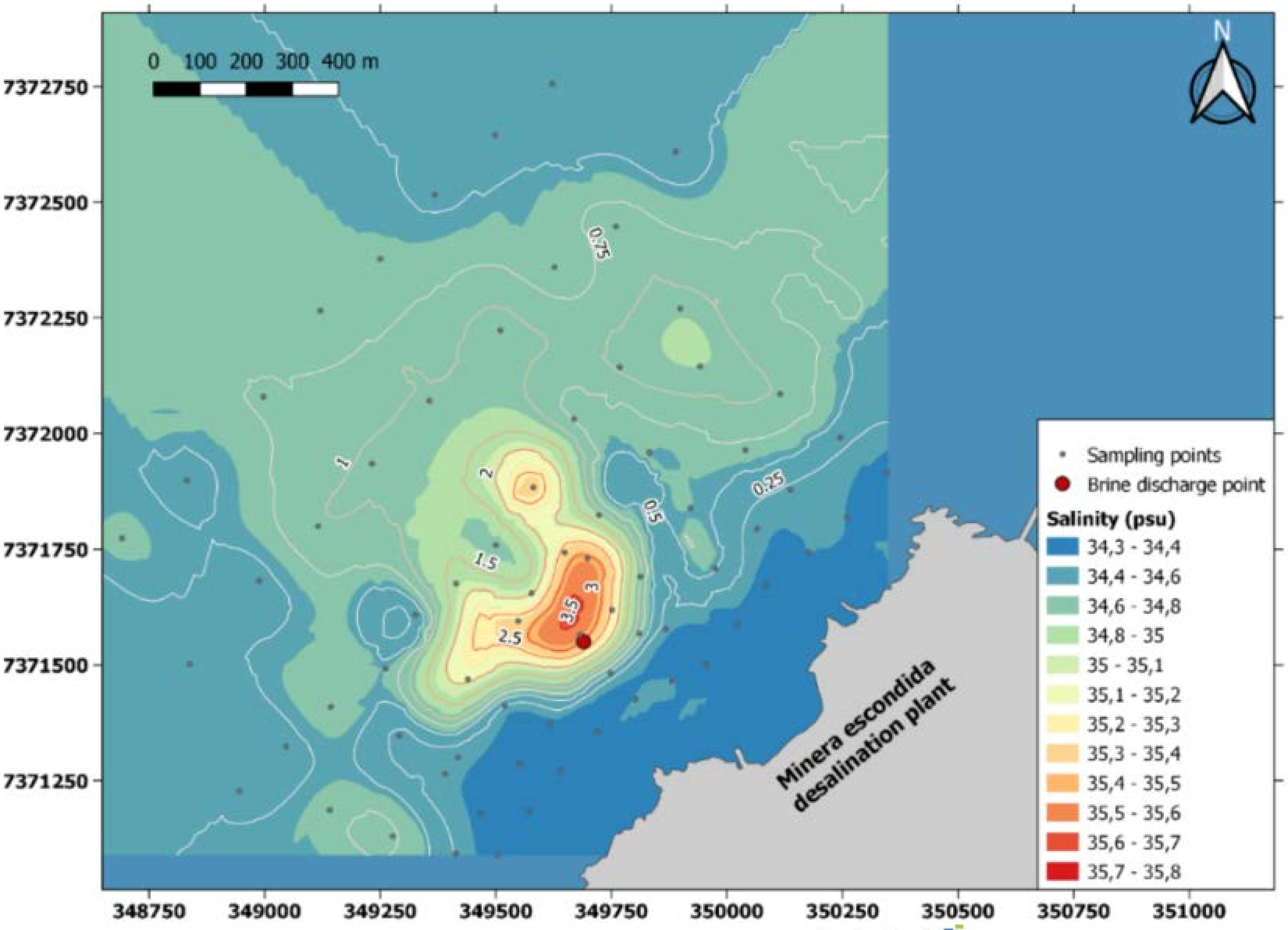
https://doi.org/10.1016/j.enconman.2023.117035

Brine discharge and valorization



High concerns regarding local ecosystems
(high salinity + chemicals)
and increase of oceans salinity

Brine discharge:



Hot topic!

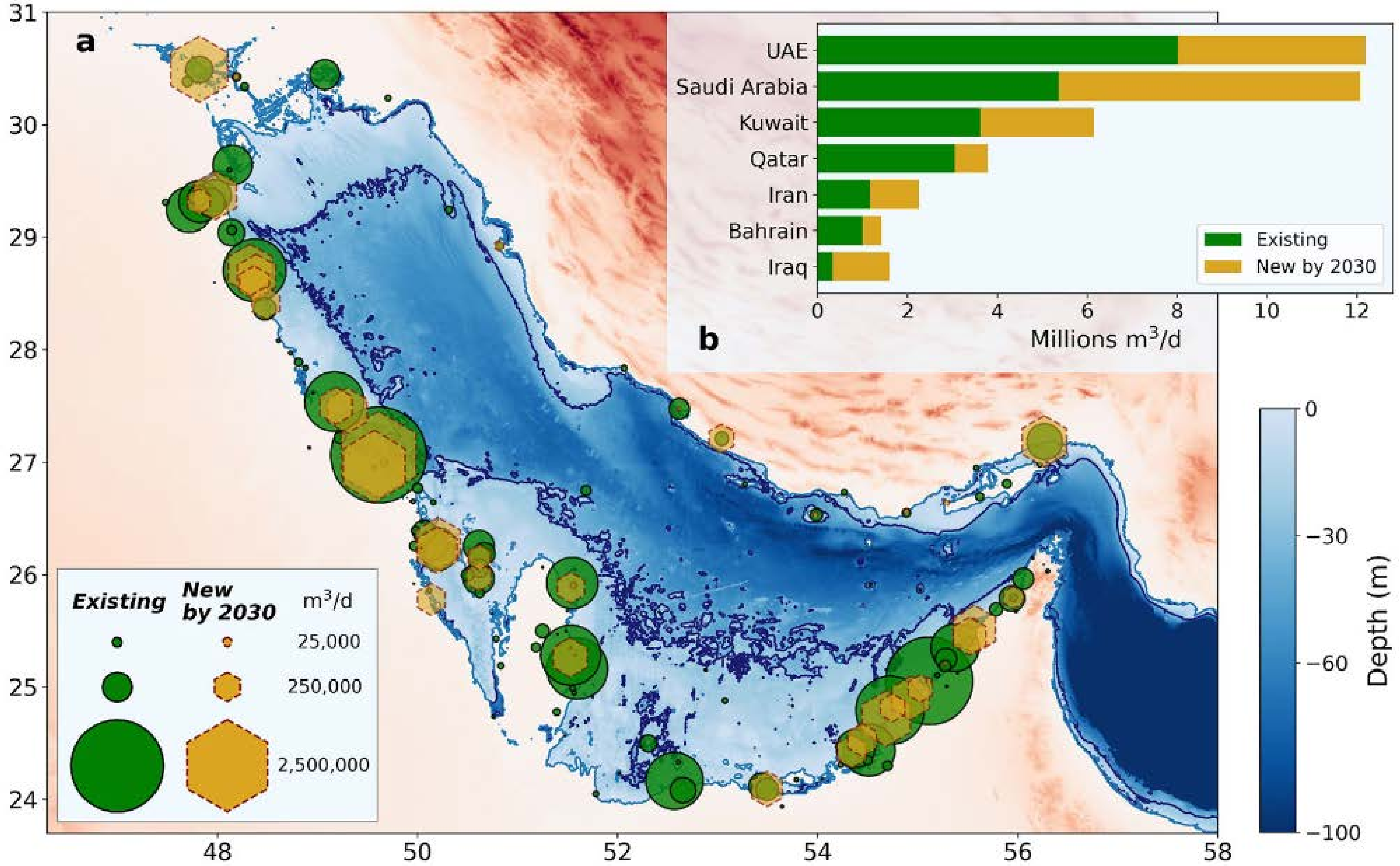
Mainly local impact

Controversial statements on ecosystems

Can be limited through predilution, difusors, etc...

https://doi.org/10.1016/j.marpolbul.2024.116905

Brine discharge: salinity increase, case of arabian/persian gulf



https://doi.org/10.1038/s41598-022-25167-5

Worst case scenario: by 2050, increase of salinity likely below 0.5g/L

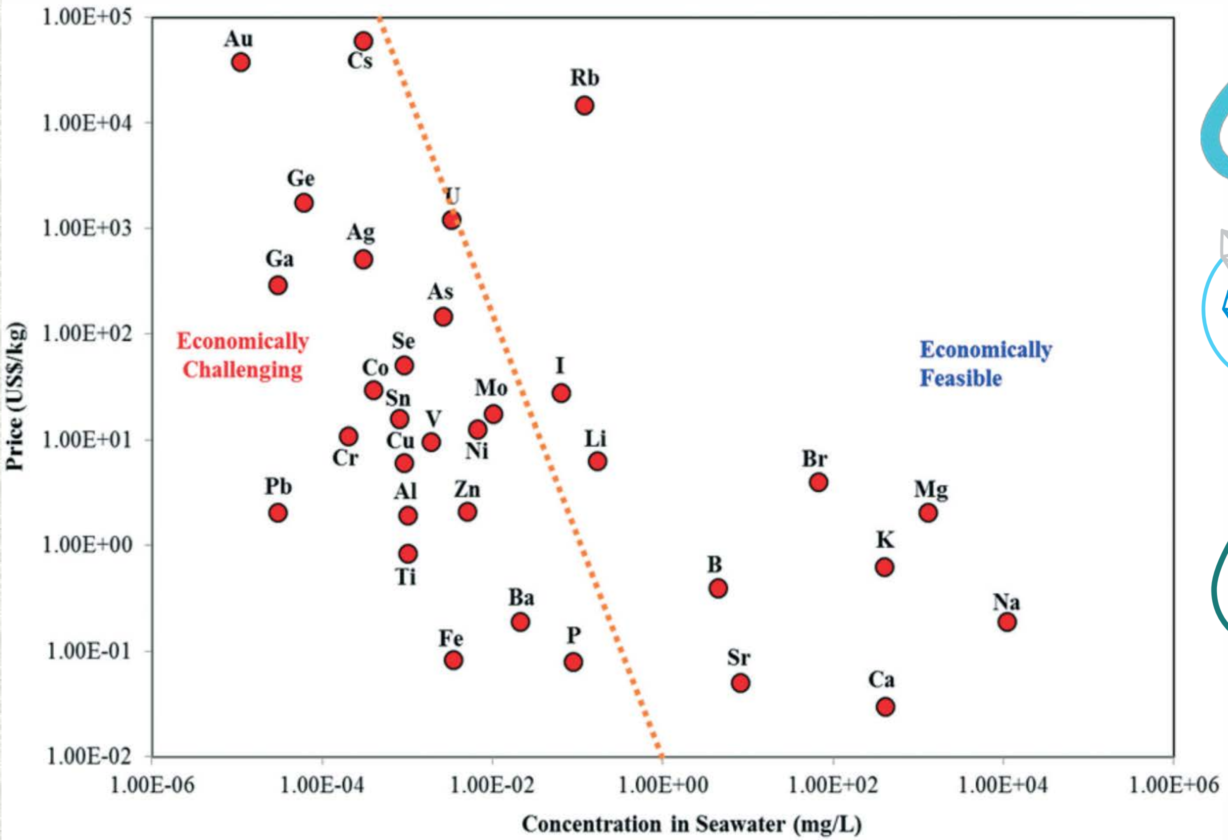
Main concern for inland desalination: brine management!

Brine as a resource: brine valorization

MINERAL MAKEUP OF SEAWATER

In order of most to least:

ELEMENT	MOLECULAR WEIGHT	PPM IN SEAWATER	MOLAR CONCENTRATION
Chloride	35.4	18980	0.536158
Sodium	23	10561	0.459174
Magnesium	24.3	1272	0.052346
Sulfur	32	884	0.027625
Calcium	40	400	0.01
Potassium	39.1	380	0.009719
Bromine	79.9	65	0.000814
Carbon(inorganic)	12	28	0.002333
Strontium	87.6	13	0.000148
Boron	10.8	4.6	0.000426
Silicon	28.1	4	0.000142
Carbon (organic)	12	3	0.00025
Aluminum	27	1.9	0.00007
Fluorine	19	1.4	0.000074
N as nitrate	14	0.7	0.00005
Nitrogen (organic)	14	0.2	0.000014
Rubidium	85	0.2	0.0000024
Lithium	6.9	0.1	0.000015



Challenges of seawater brine mining

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Energy Consumption

The energy required to process brine can be substantial, leading to high operational costs and environmental concerns: one key issue is concentration

Mineral Separation

Separating valuable minerals from the highly concentrated brine solution

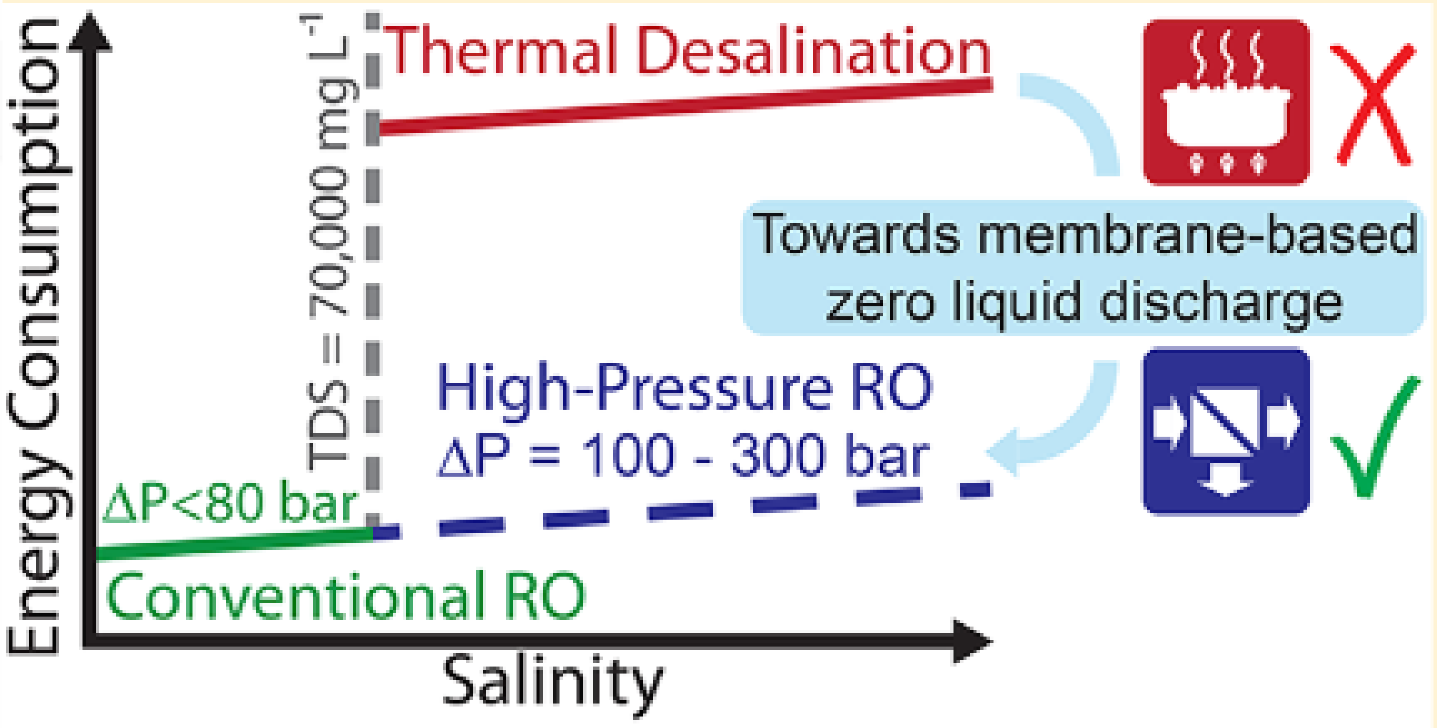
Valorization of ''products''

Value of recovered products should compensate costs of extraction

What to do with the remaining NaCl?

Technology for brine concentration

Limitations of RO (pressure) for further concentrating brines:

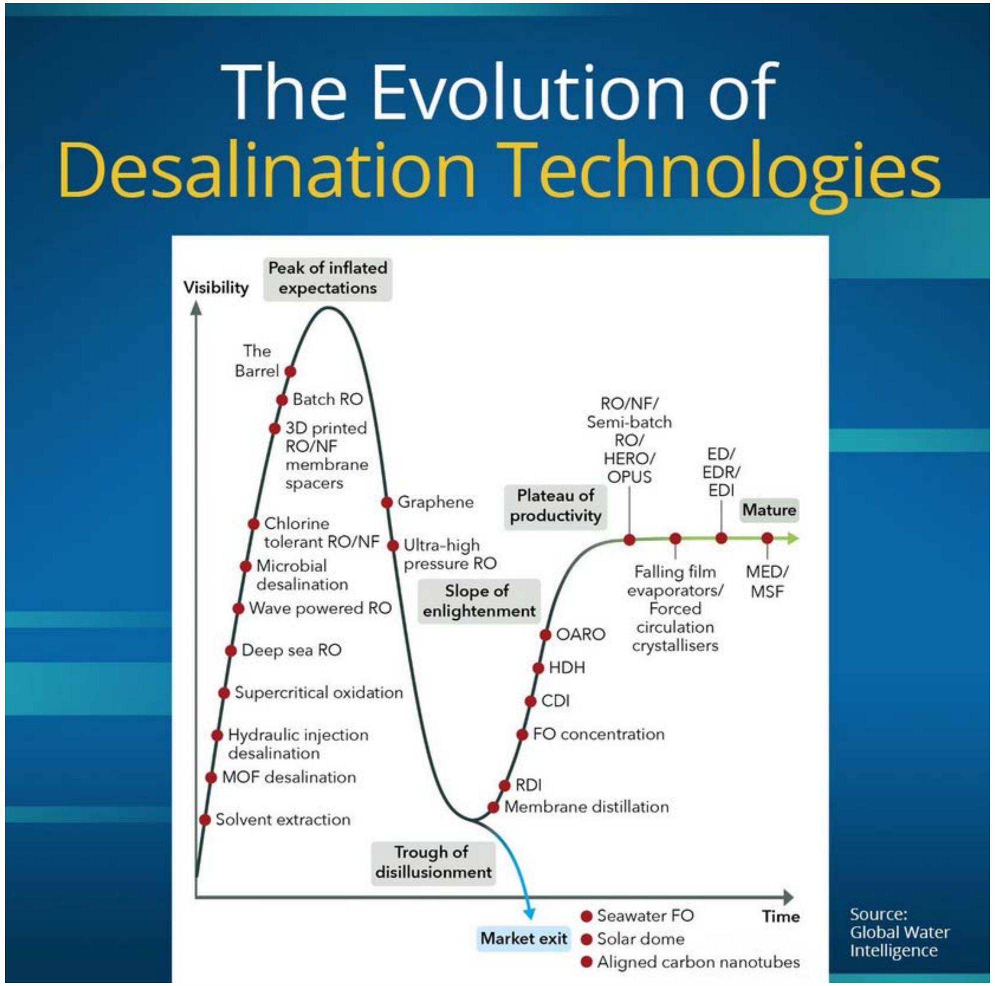


DOI: 10.1021/acs.estlett.8b00274

Technology for brine concentration

Limitations of RO (pressure) for further concentrating brines:

Space for alternatives membrane technologies which can reach higher osmotic pressure



Osmotically assisted RO

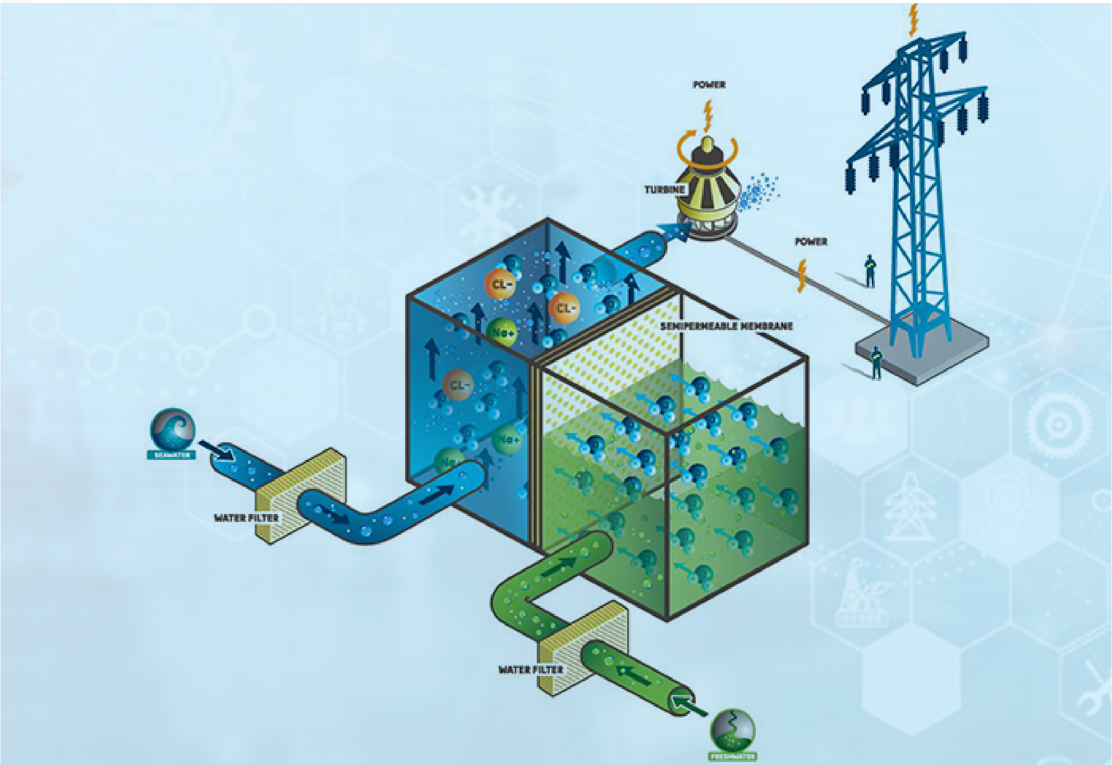
Membrane distillation

Forward osmosis

Electrodialysis

Seawater (desalination) and energy!

Osmotic energy: controlled mixing of seawater and river water to produce energy



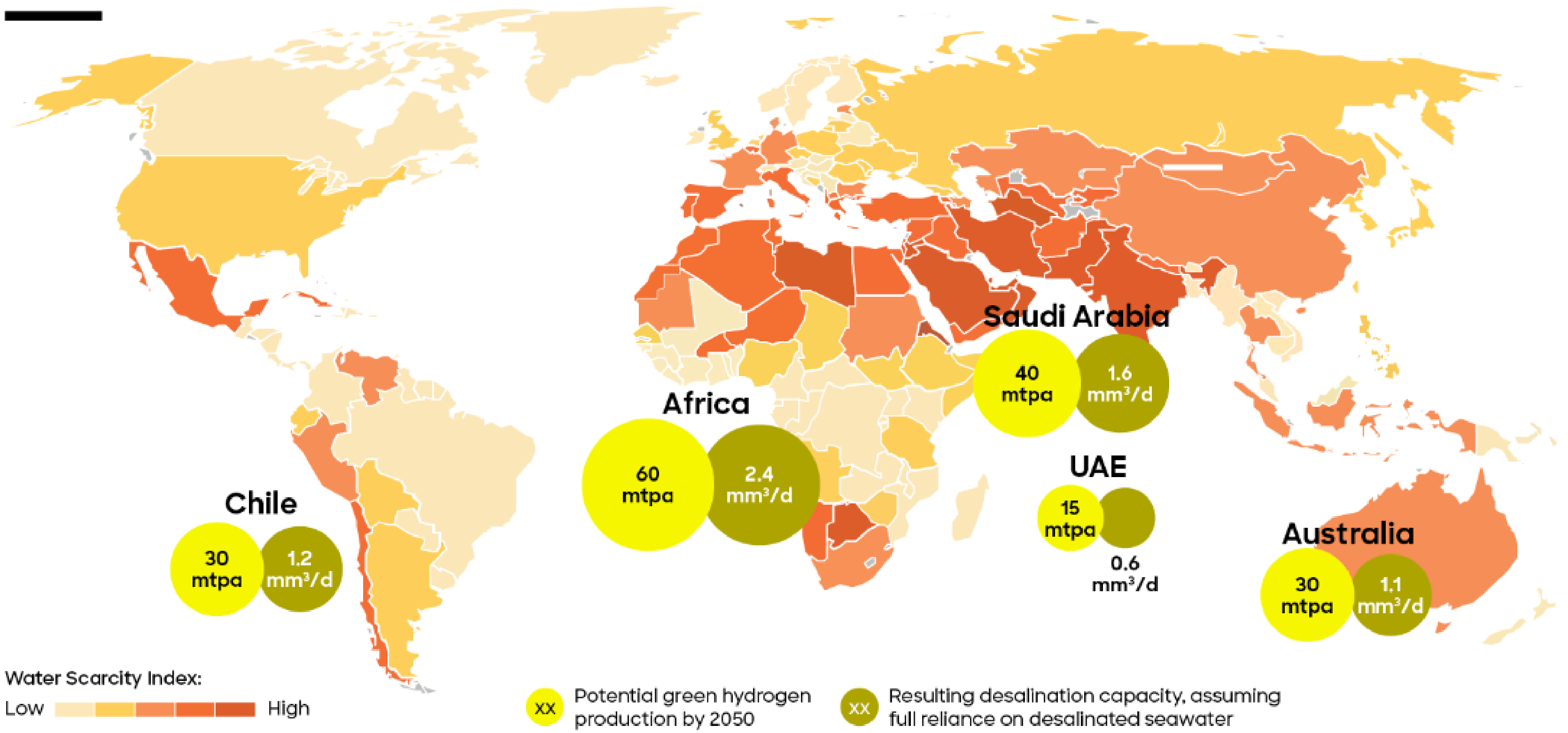
Presssure retarded osmosis

Reverse electrodialysis

Desalination to provide water for "green" hydrogen production

Projected green hydrogen production and desalination capacity requirements

Selected regions, 2050



Source Green hydrogen production figures: for UAE, National Hydrogen Strategy; for Saudi Arabia, Deloitte 2023 Global Green Hydrogen Outlook; for Africa, AGHA 2022 Africa's Green Hydrogen Potential; for Australia, BloombergNEF's latest New Energy Outlook on Australia (covering only exported green hydrogen); for Chile, Chilean 2020 National Green Hydrogen Strategy

Roland Berger

Desalination or water reuse?

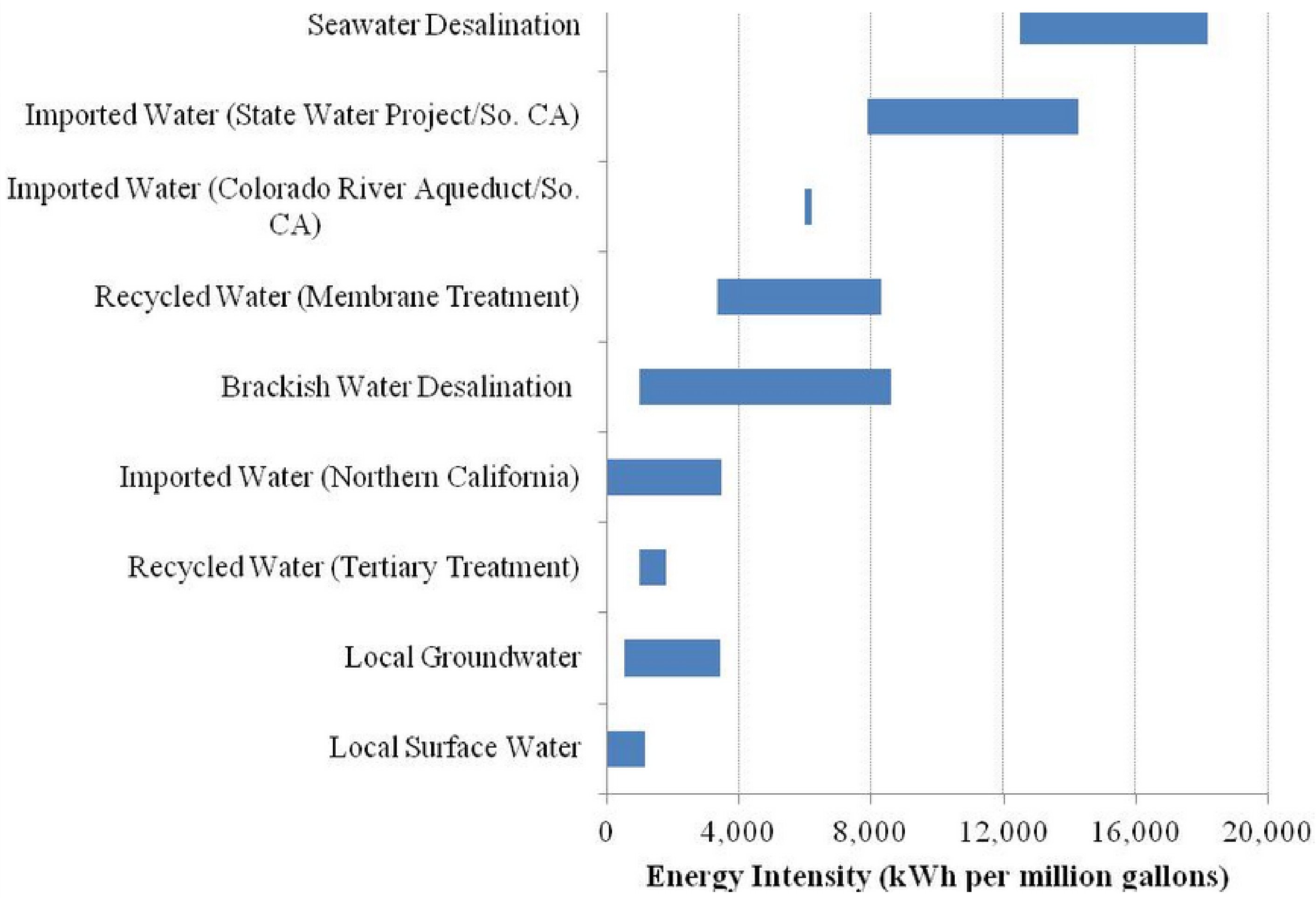


Figure 1. Comparison of the Energy Intensity of California Water Supplies

Water reuse (including with RO polishing step requires lower energy than desalination.

Current push for water reuse

Possible to reach several quality of water through reuse depending on needs!

Conclusions

- Desalination is a key component in water supply and will continue to grow
- Energy/costs limitations will most likely be incremental given the current state of development and thermodynamic límits
- Environmental impact of desalination still to be further studied
- Seawater/ Desalination plants are more and more seen as platform for other resources
  - Brine recovery
  - Energy production

Thanks!

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