Management and valorization of brines from desalination plants in the Gulf

Dr. Philip Davies

Sustainable Environment Research Group,
Aston University, Birmingham, UK

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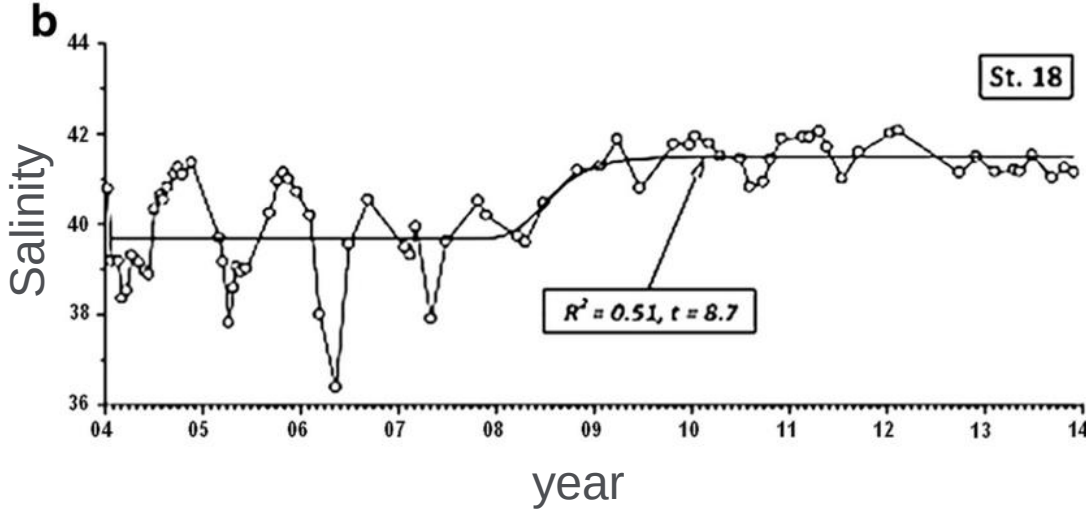
Outline

- Desalination: Challenge of brine disposal
- Approaches to valorising brine
- Water-energy-food nexus
- Conclusions

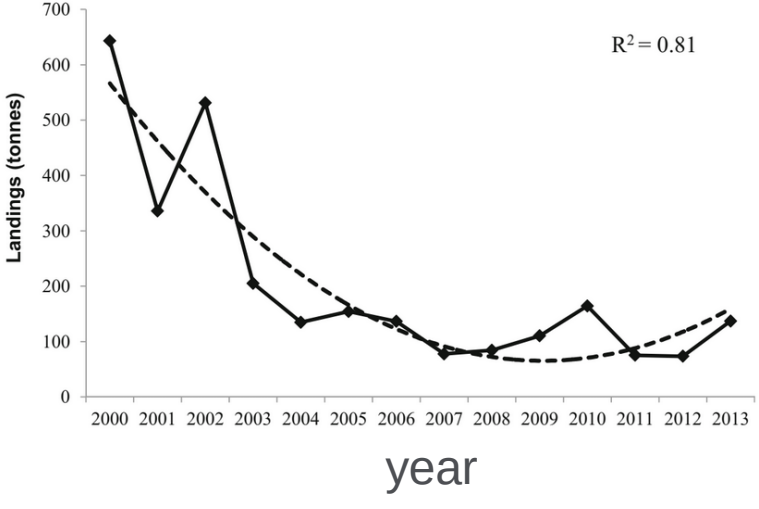
Deterioration in Gulf ecosystems

- Salinity at highest level in 30 years
- Correlates with Shatt Al-Arab river discharge
- Diatom species decreased in coastal waters (92 down from 243)
- Less fish caught

Al-Said et al, Environ Monit Assess, 2017, 189-268



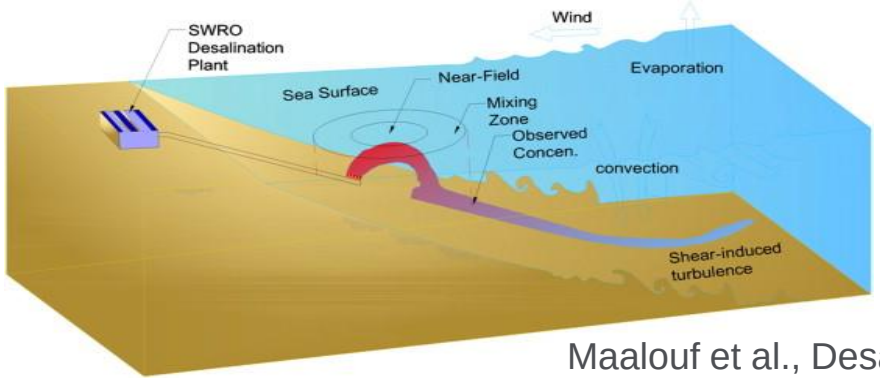
Suboor Landings



Challenge of brine disposal

- Desalination continues to grow
- Water output now 100 million m^3/day
- Brine output equals/exceeds water output:
  - ×1 to ×2 for RO plant
  - ×3 to ×8 for thermal plant
- Elevated:
  - Temperature (+1 to +10°C)
  - Salinity (up ×2)
- No safe limit for concentration of brine not to disturb ocean biota*

constructionweekonline

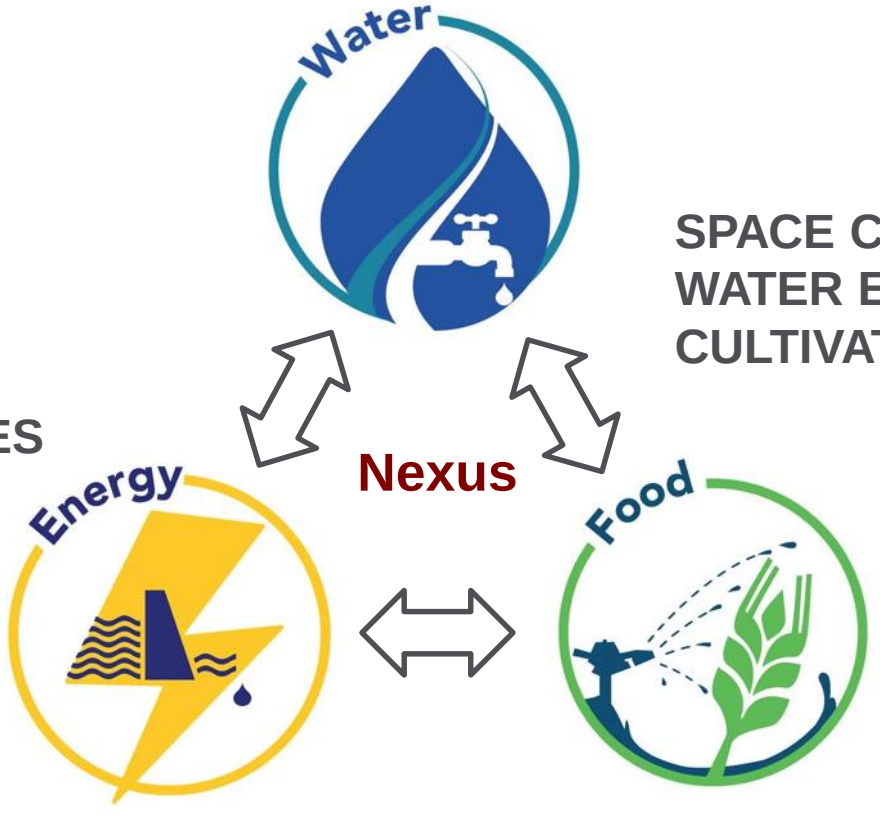


Maalouf et al., Desalination 333(2014)134-

*Falkenberg & Styan, Desalination 368(2015)3-

www.panresearch.com

Valorisation: what can we use brine for?



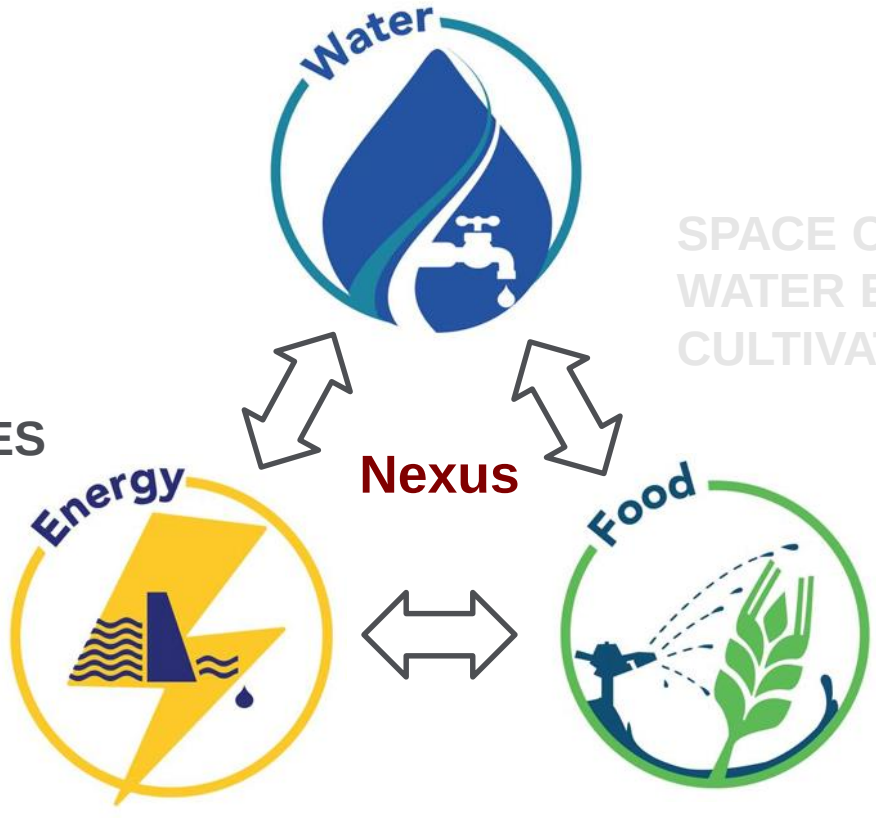
SPACE COOLING for WATER EFFICIENT CULTIVATION

LITHIUM for ELECTRIC BATTERIES

REMOVAL of CO_2

Valorisation: what can we use brine for?

LITHIUM for ELECTRIC BATTERIES



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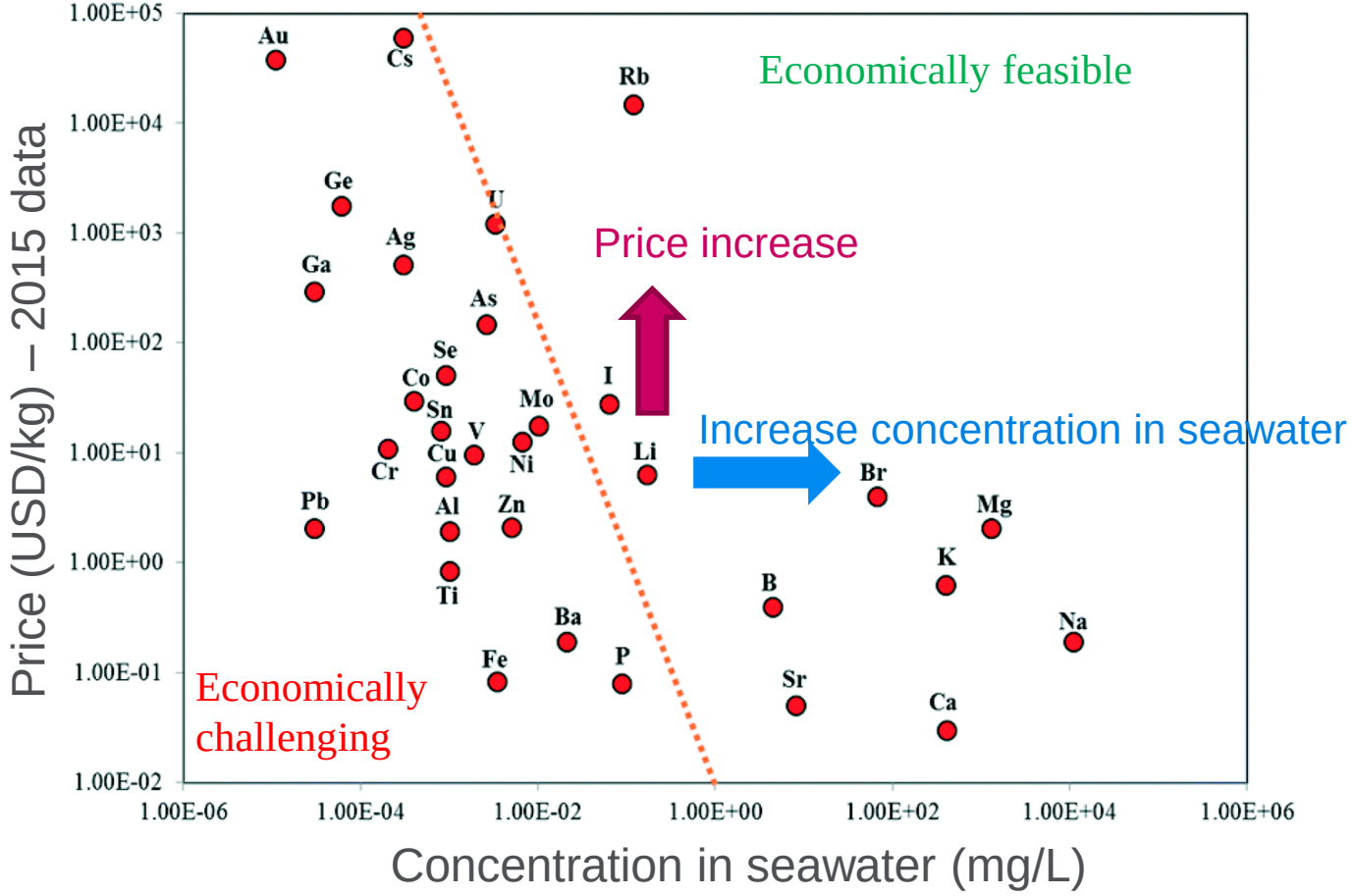
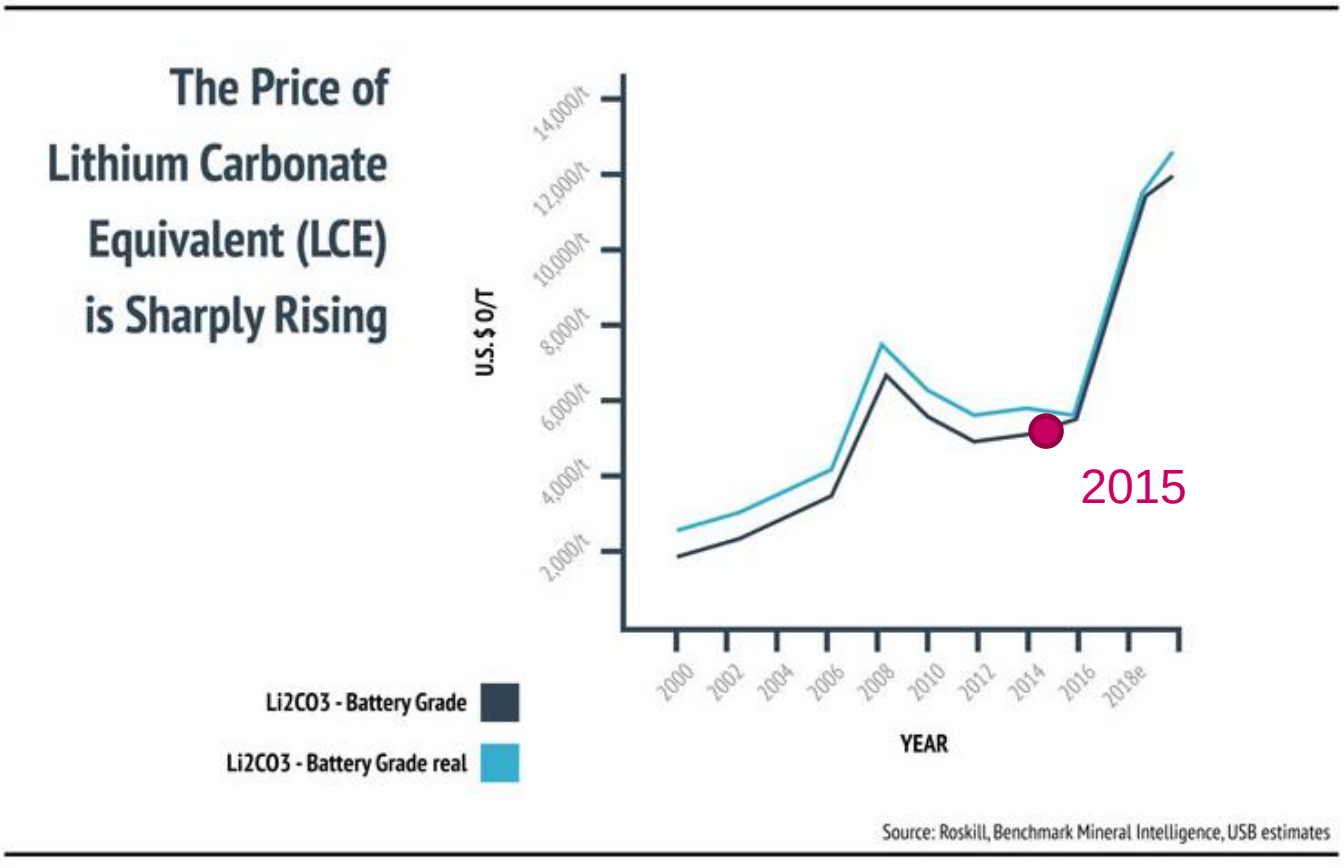
REMOVAL of CO_2

Recovery of minerals from brine favoured by high price and/or concentration

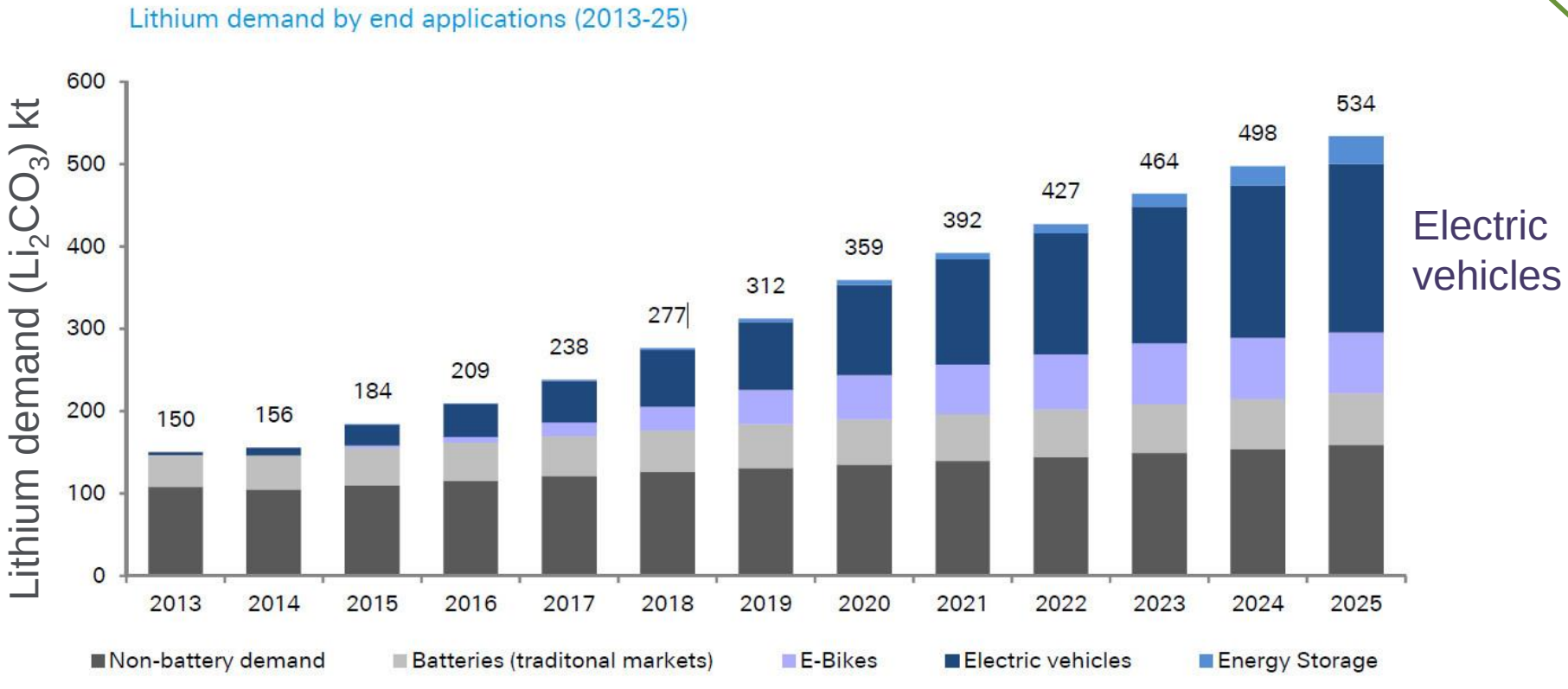


Loganathan et al., Env. Sci – Water Res. & Tech., 2017, 3, 37-53

Lithium price hike



Lithium price hike driven by battery demand



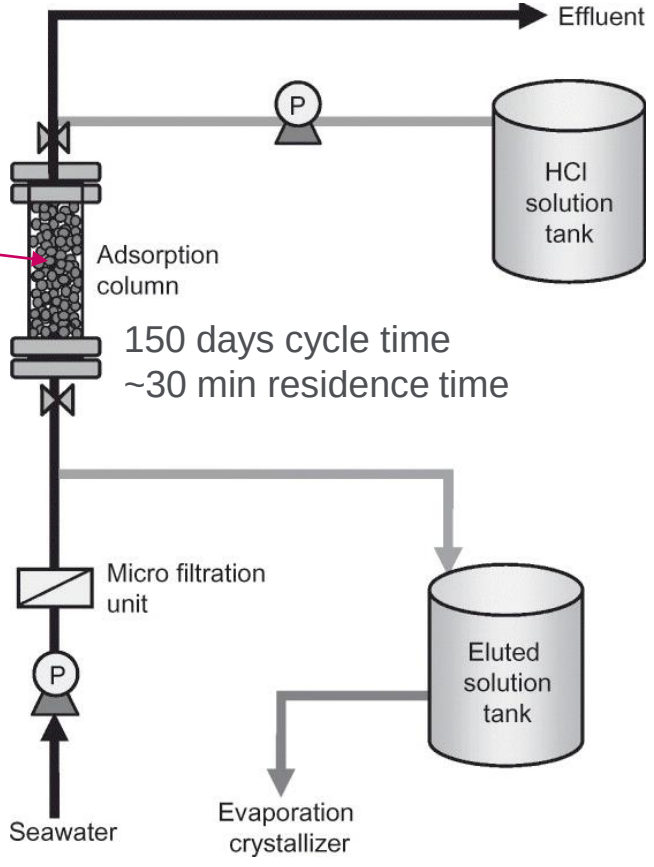
Source: Deutsche Bank; Industry data

Estimated Li availability from Gulf desalination

- Gulf plants estimated to treat ~100 million m^3 of seawater/day
- @ 0.17 g/m^3 and 50% recovery of Li ⟶ **3000** tonnes Li per year
- Compare world production **36 000** tonnes in 2015 (USGS)

Technologies to recover Li from seawater

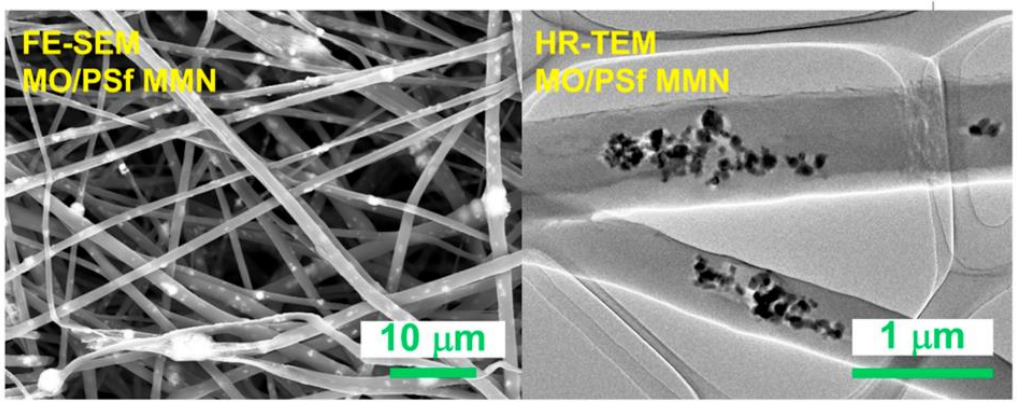
- Li adsorbed on MnO ion-exchange resins, eluted by HCl
- Resin prepared as granules (mm size)
- Slow process: requires large amounts of resin for sufficient residence time



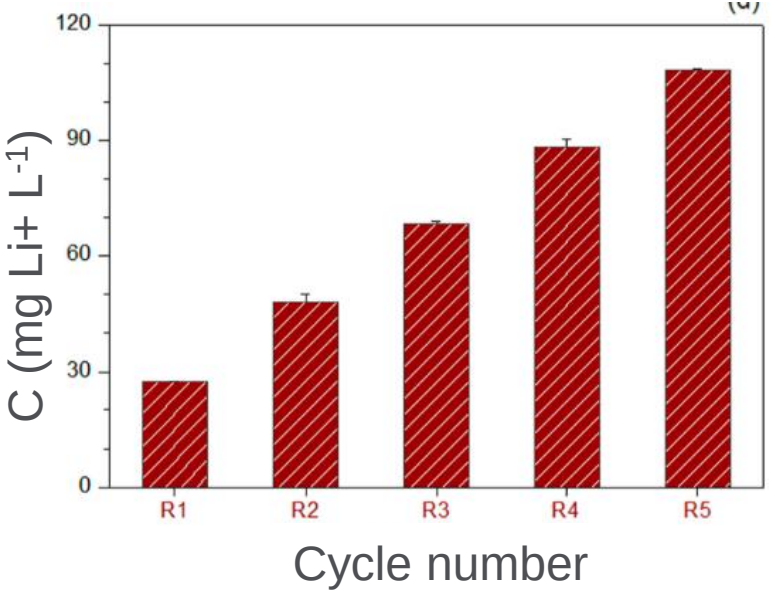
Nishihama et al., Solvent Extraction and Ion Exchange, 29, 421- (2011)

Technologies to recover Li - membranes

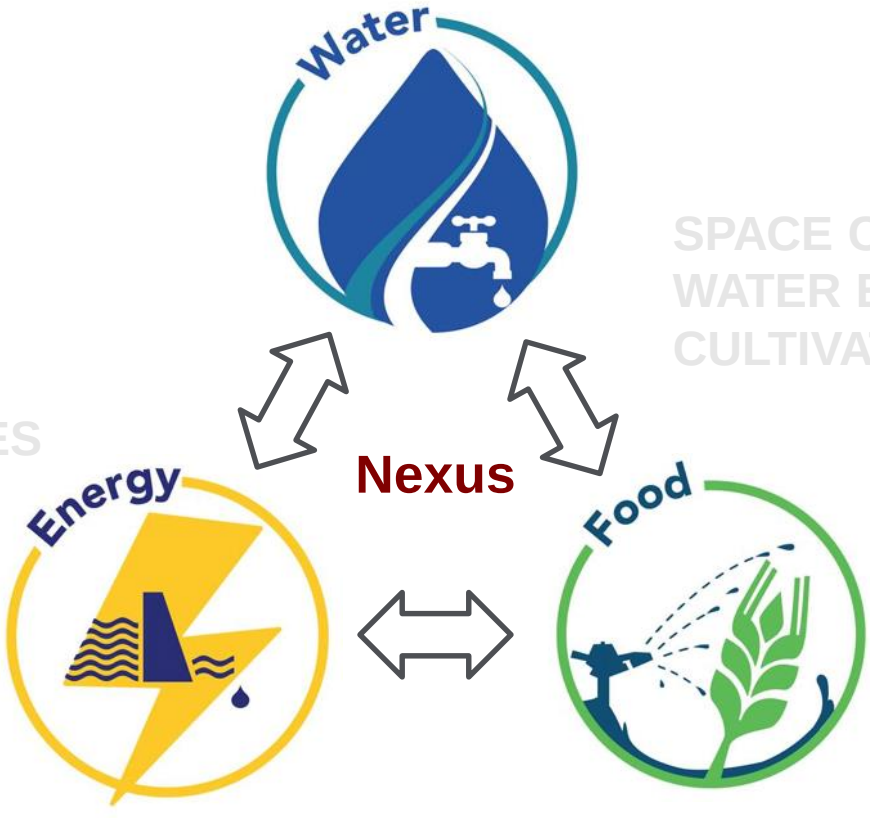
- Electrospun polysulphone mixed-matrix nanofibre dispersed with particulate Li ion sieves
- Residence time only ~2 min, faster cycle time ~ 12 h
- Repeated eluted with HCl to increase Li concentration



Park et al, J. Membrane Science, 510 (2016) 141-



Valorisation: what can we use brine for?



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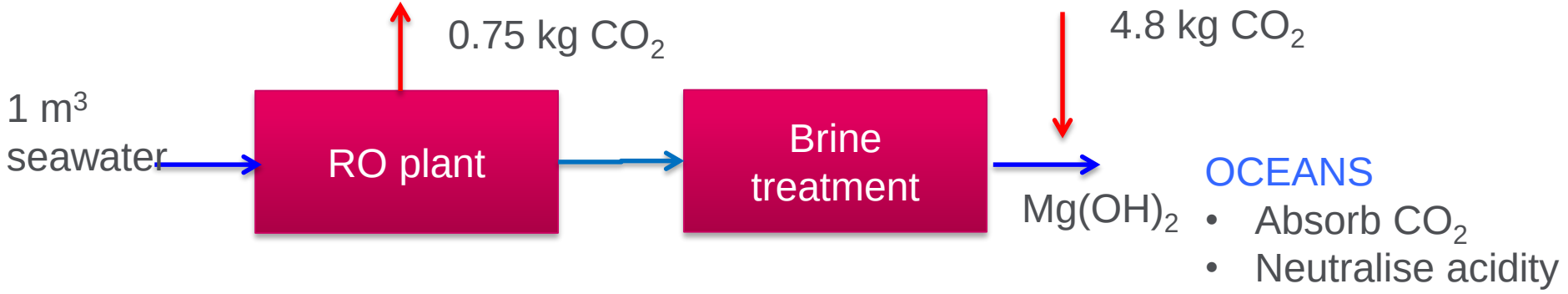
REMOVAL of CO_2

Remove CO_2 and neutralise ocean acidity

- Oceans getting more acidic because of CO_2
- Magnesium in brine can absorb CO_2
- 1 m^3 of seawater can absorb up to 4.8 kg of CO_2

Reactions:

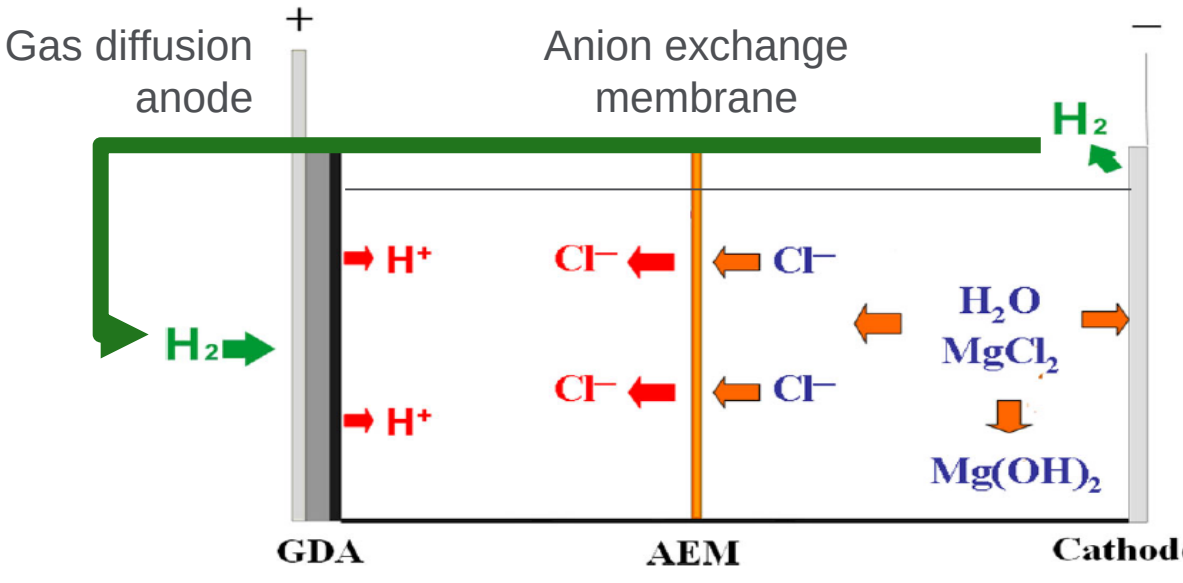
- $MgCl_2\,(aq) + 2H_2O\,(l) \rightarrow Mg(OH)_2\,(s) + 2HCl\,(aq)$
- $Mg(OH)_2\,(s) + 2CO_2(g) \rightarrow Mg(HCO_3)_2\,(aq)$

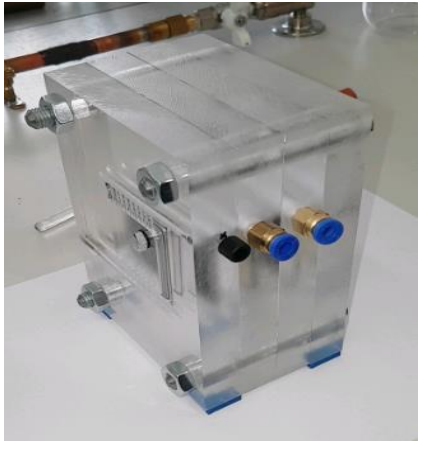


Electrolysis to yield $Mg(OH)_2$

Formation of magnesium hydroxide

$$\Delta E^{o} = -0.50V$$





Prototype at Aston University

$$H_2 + 2Cl^- \rightarrow 2HCl + 2e^-$$

$$H_2 + 2Cl^- \rightarrow 2HCl + 2e^-$$

H. Xie, Y. Wang, W. Chu, Chinese Science Bulletin, 59 (2014) 2882-2889

Electrolysis in flow-through mode

Freshwater input

Brine from desal plant

Electrical power input

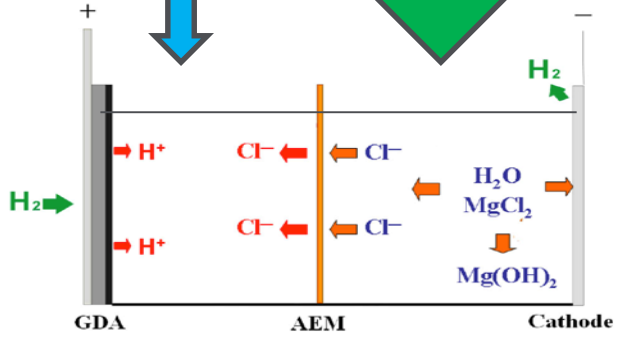
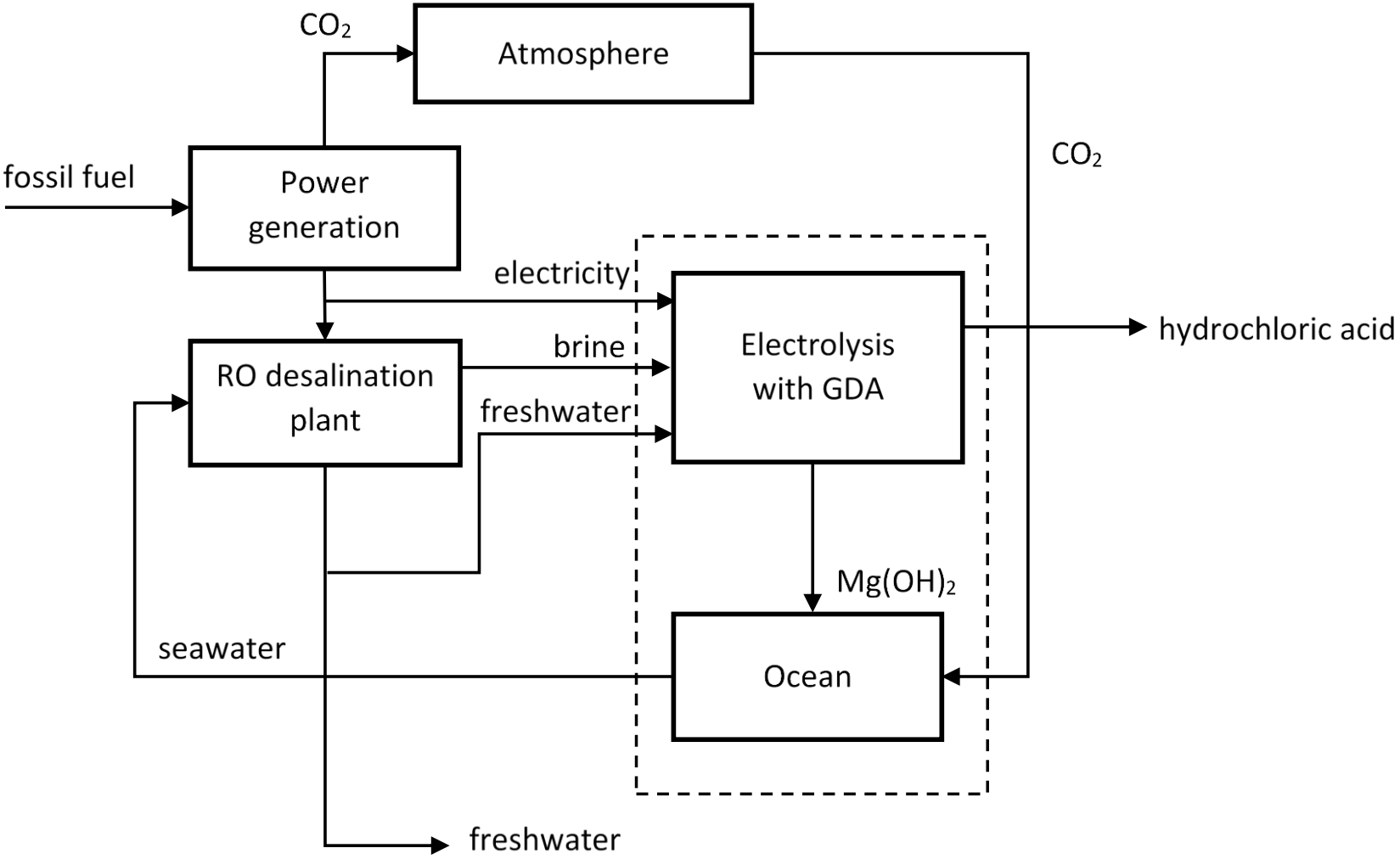


Fig. 2 Illustration of electrolysis cell for conversion of magnesium chloride into magnesium hydroxide

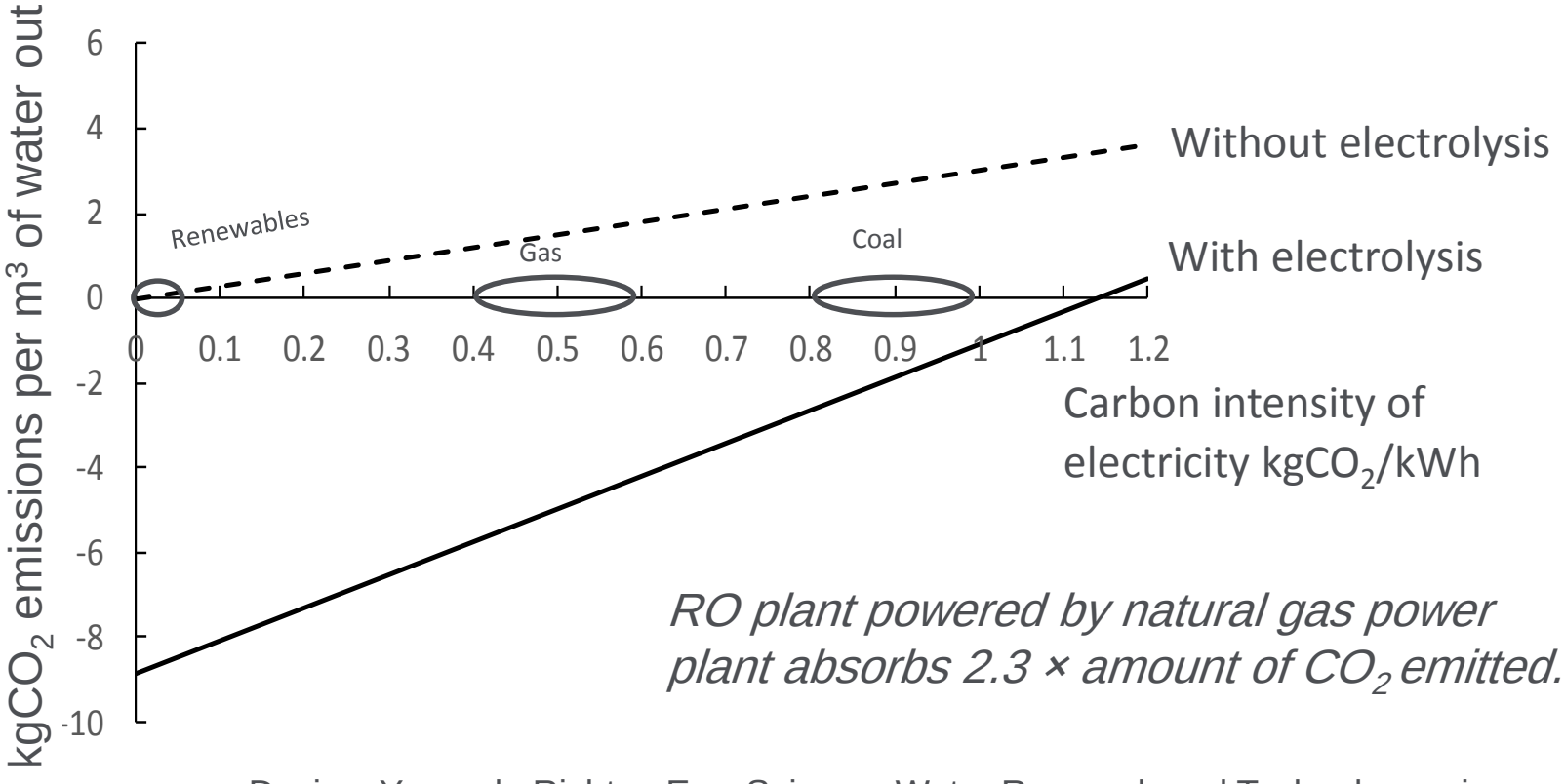
Hydrochloric acid for geological disposal

Brine enriched with $Mg(OH)_2$ to ocean



Davies, Yuan, de Richter, Env. Science: Water Research and Technology – in press

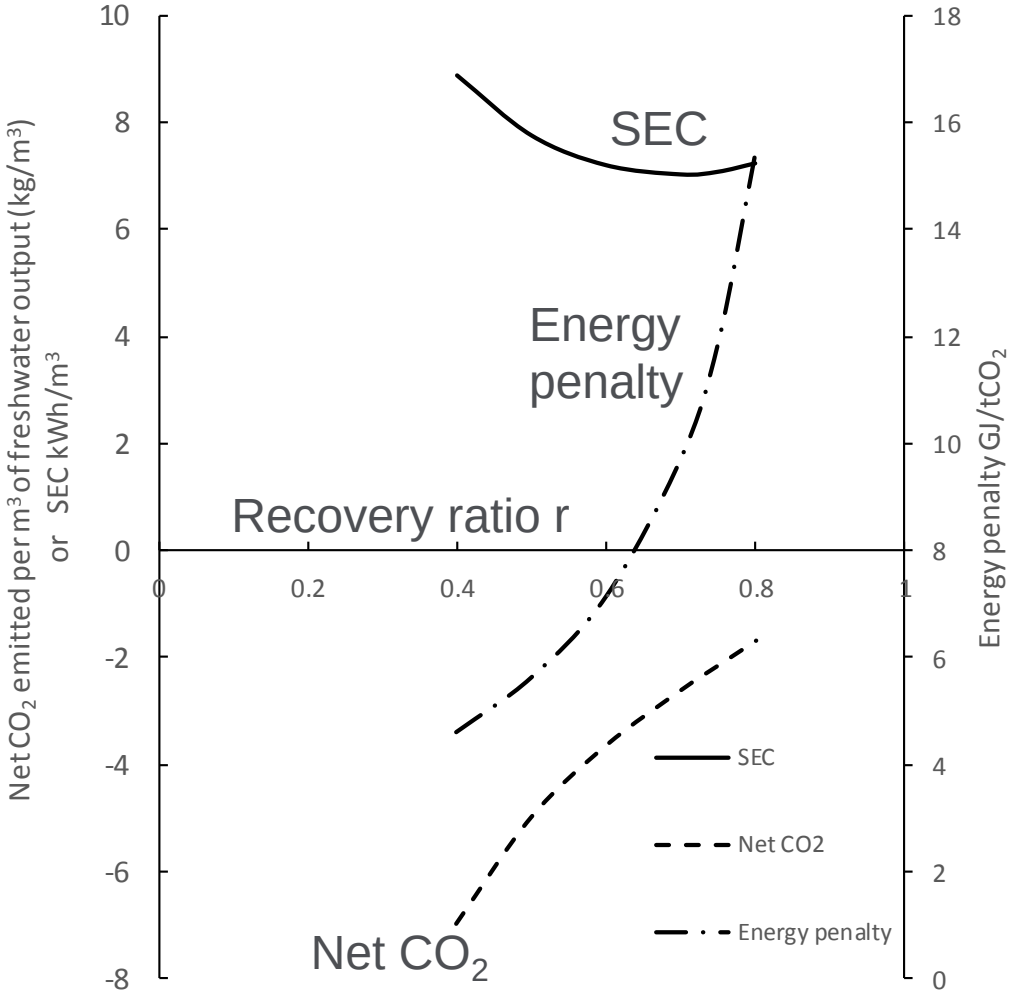
Negative emissions from desalination



Davies, Yuan, de Richter, Env. Science: Water Research and Technology – in press

Specific energy consumption

- SEC increased by electrolysis process
- Recovery ratio around 0.7 minimises SEC



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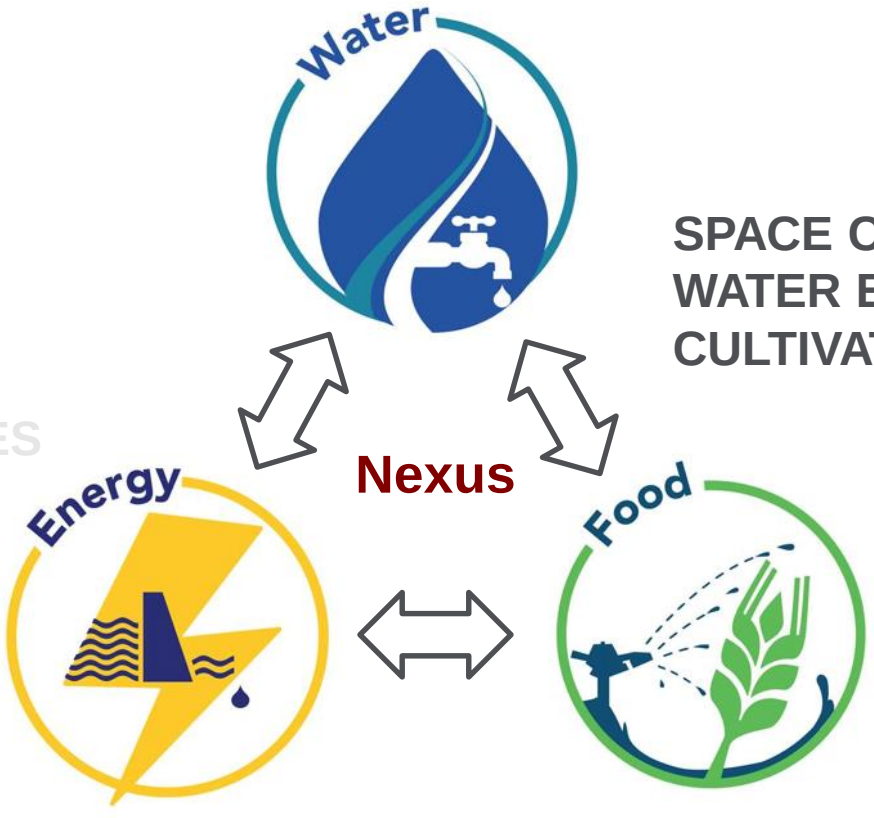
Valorisation: what can we use brine for?



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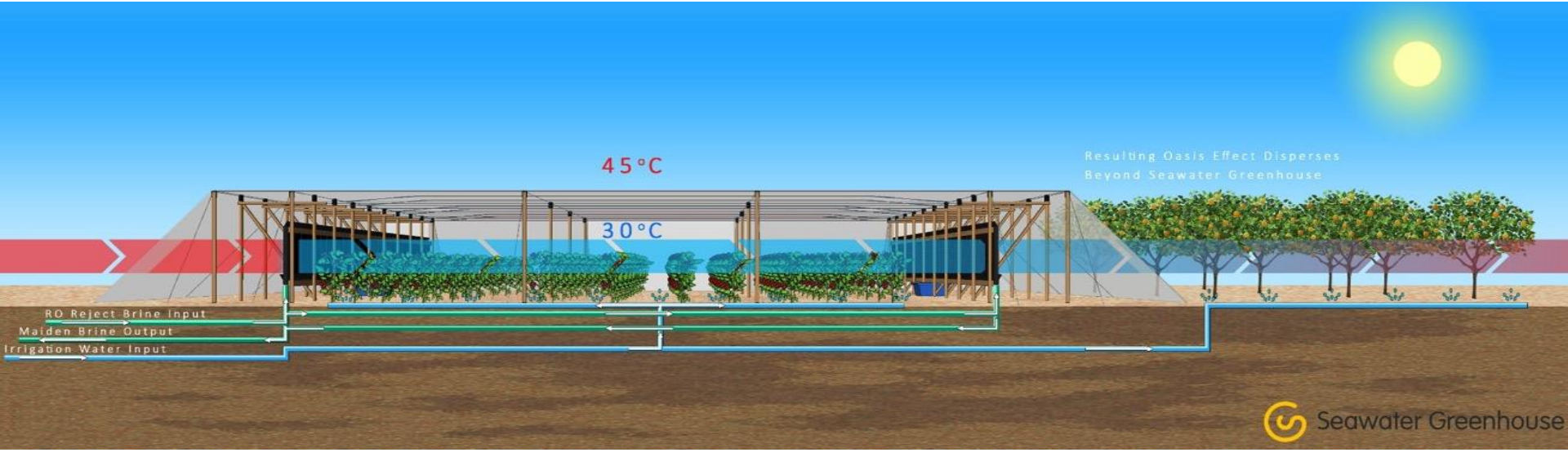
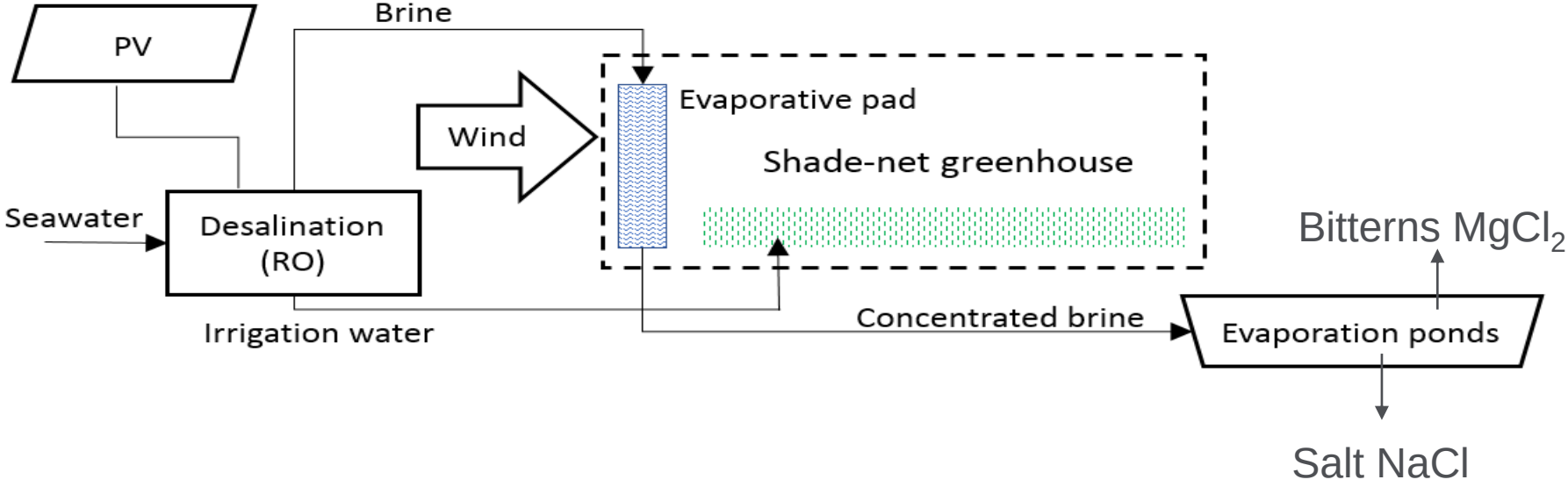
Seawater Greenhouse

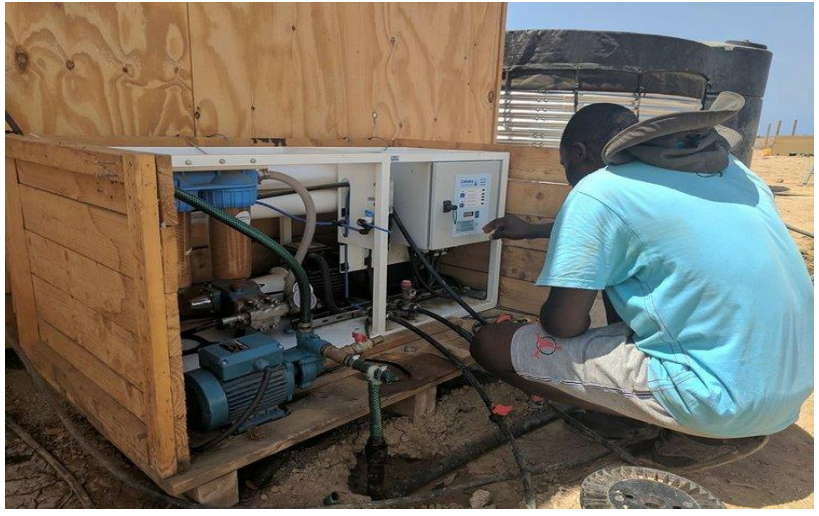
- Brine is used to cool a greenhouse for crop production
- Demonstrated in: Tenerife, UAE, Oman, Australia and Somaliland



Seawater Greenhouse: Somaliland, 2017

- Desalination by Reverse Osmosis (RO) + photovoltaics
- Wind ventilation
- Low cost 1000 m^2 shade net
- Reject brine for cooling then salt production





Seawater Greenhouse

Seawater Greenhouse

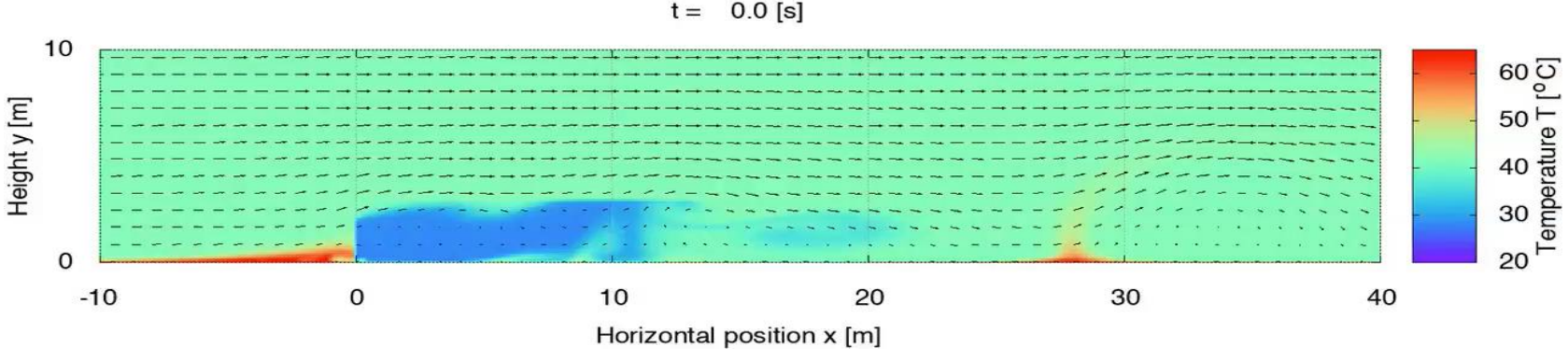
Evaporative cooling pad

Cucumbers

Seawater Greenhouse: modelling & design

Summary findings:

- Modelling using Computational Fluid Dynamics
- 8-58% reduction in land usage for brine disposal vs. evaporation ponds
- Cool air 10-15 m downstream of pad
- Validation against satellite data



Akinaga et al, Desalination 426(2018)135-

Key conclusions

Brines mostly dumped today – harmful not valuable

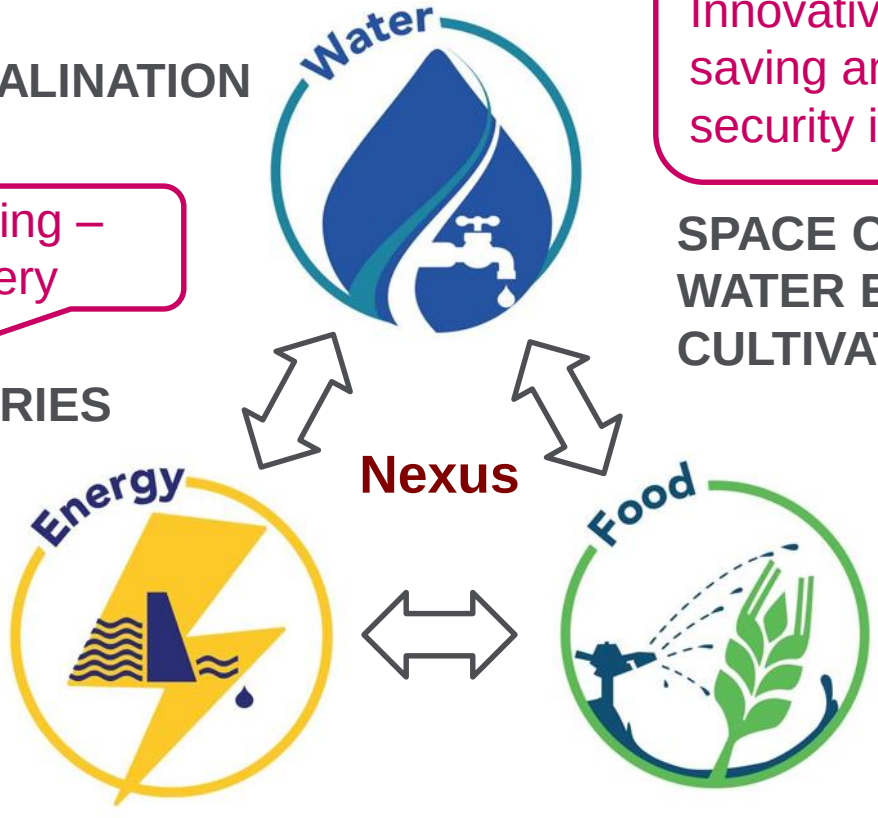
DESALINATION

Increasingly promising – membrane recovery

LITHIUM for ELECTRIC BATTERIES

Negative emissons but high SEC

REMOVAL of CO_2



Seawater Greenhouse: Innovative approach for water saving and improved food security in arid countries.

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High-recovery desalination complementary to brine valorisation

Acknowledgements

- Innovate-UK and Department for International Development (Agri-Tech Catalyst Programme)
- Seawater Greenhouse Ltd
- University of Bahrain

Thank you for listening!

Department for International Development

Innovate UK
Technology Strategy Board

Seawater Greenhouse

University of Bahrain
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