The employment of ion exchange membranes in reverse electrodialysis for a closed-loop renewable energy generation process

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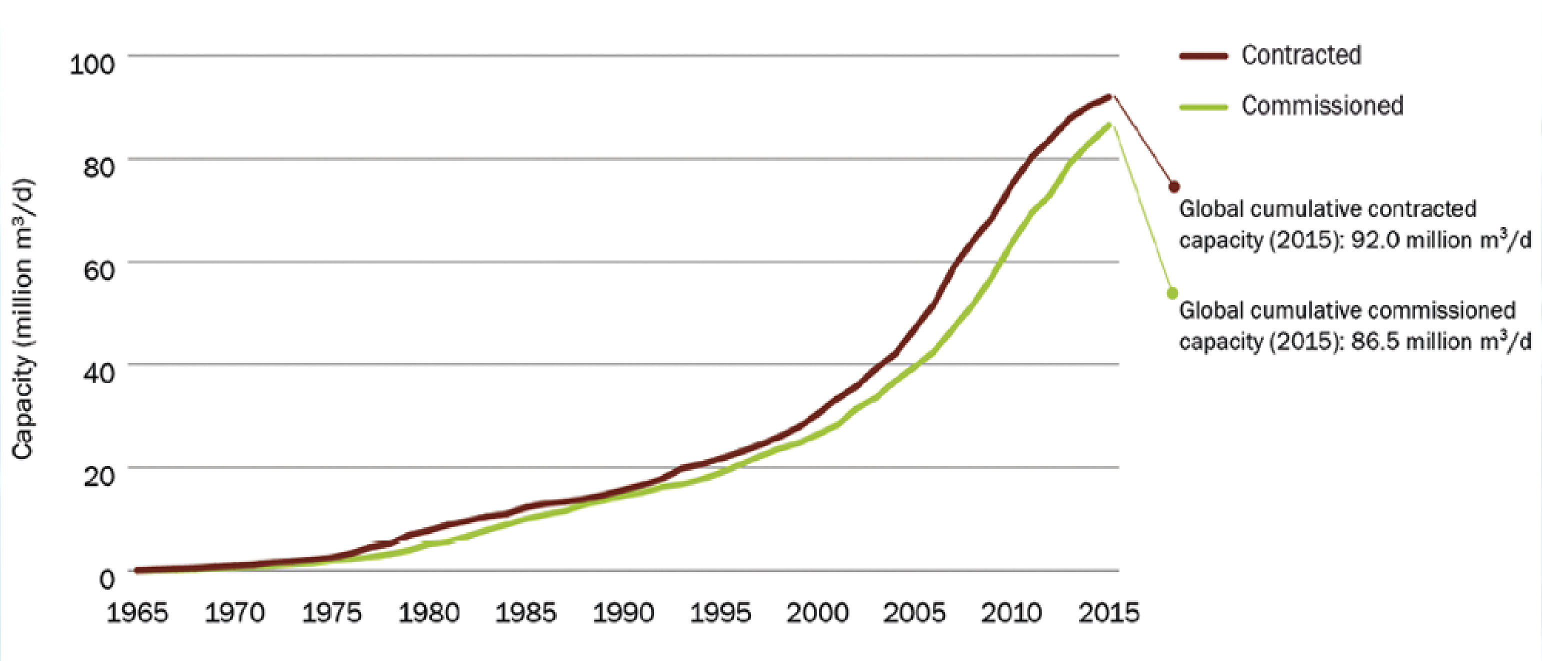
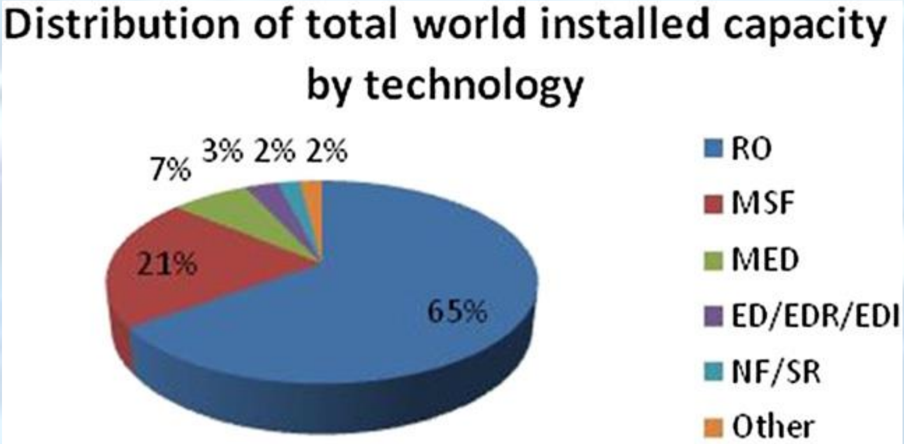
Desalination Technologies

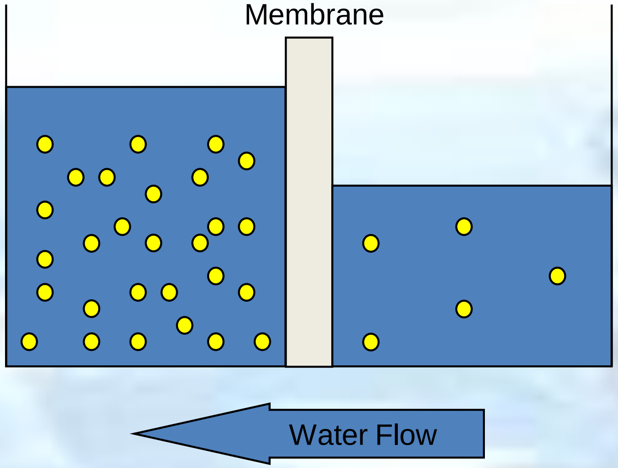




(IDA Desalination Yearbook 2016–2017)

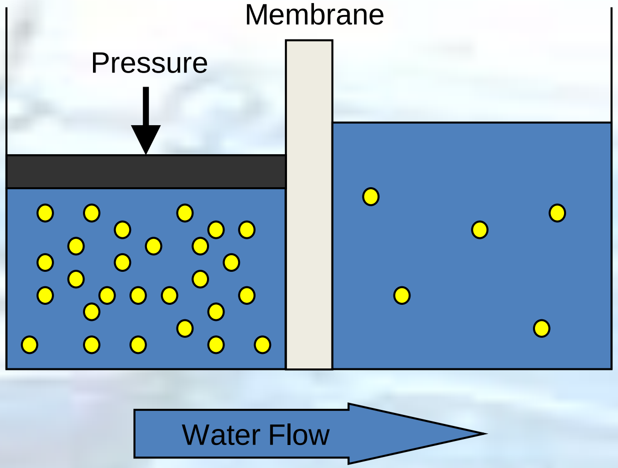
Forward and Reverse Osmosis

Forward Osmosis



Water diffuses naturally through membrane from low concentration side to high concentration side

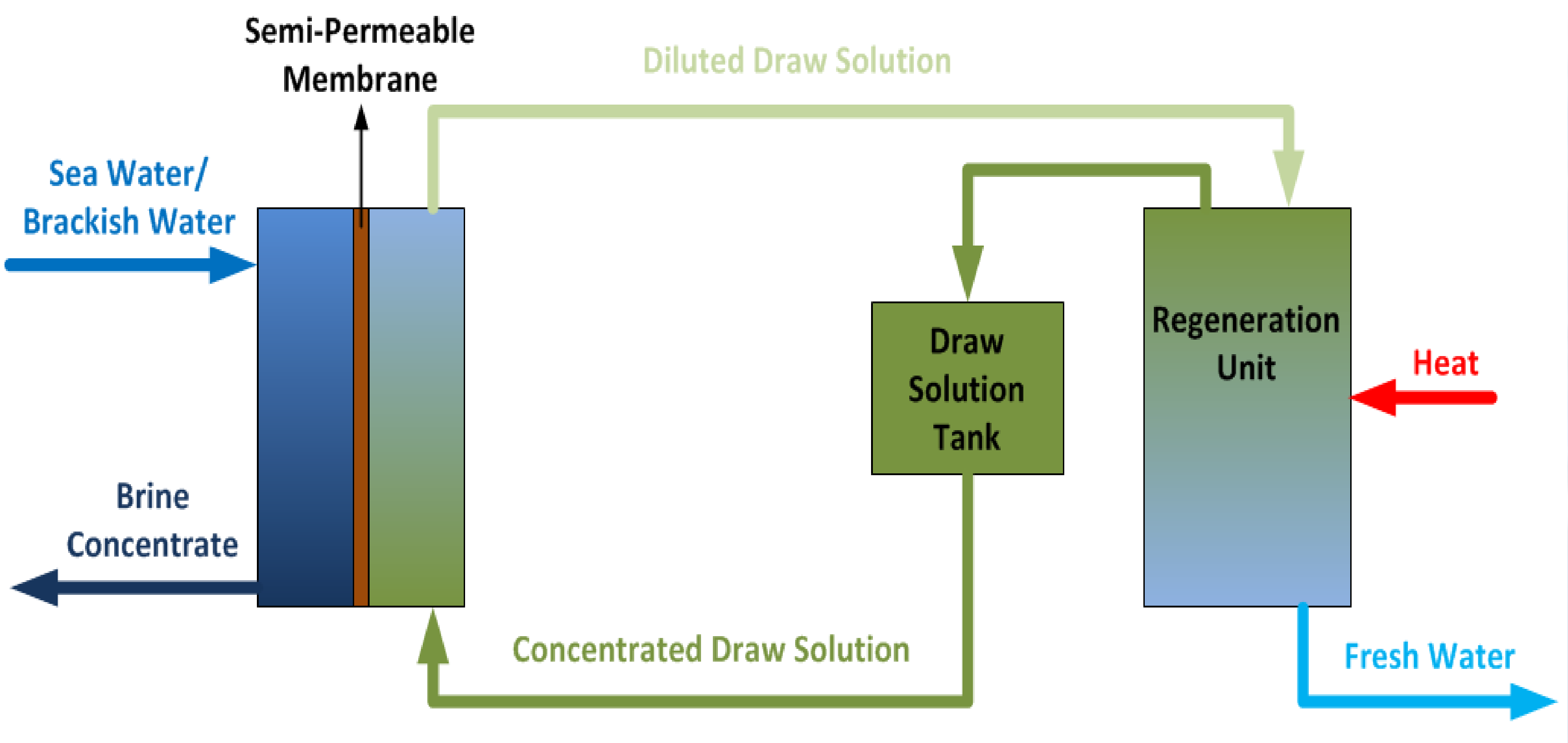
Reverse Osmosis



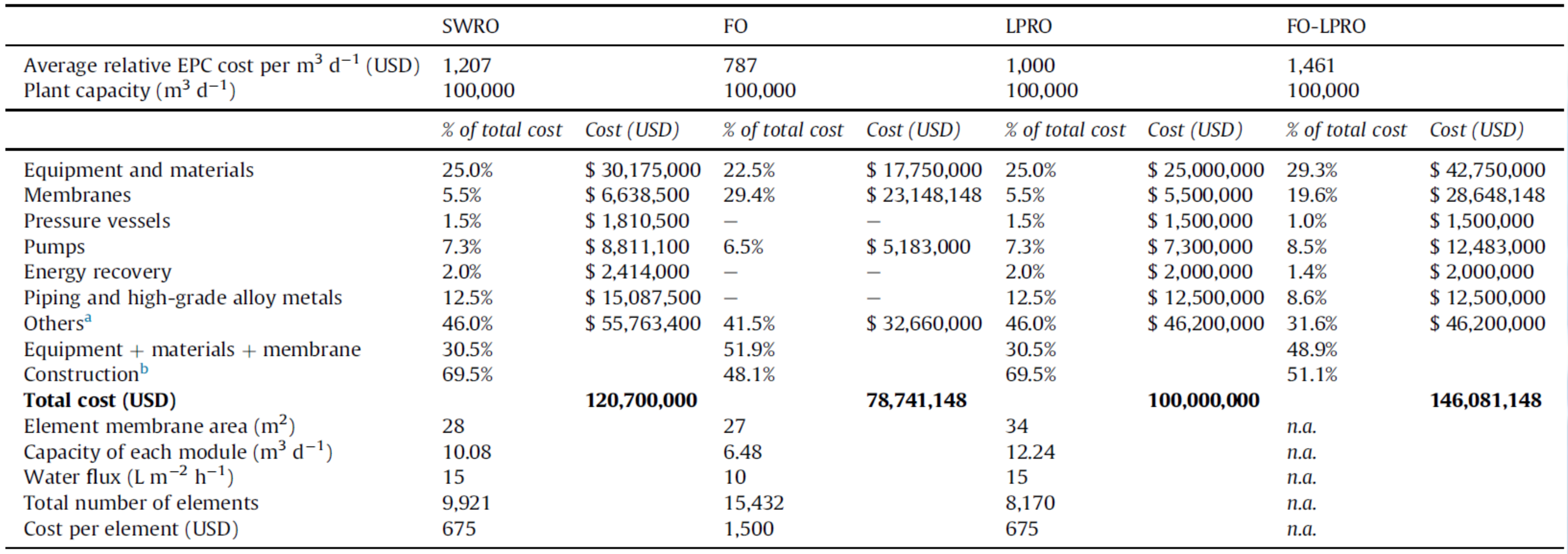
Pressure is applied to concentrated solution to overcome osmotic pressure and force water through the membrane from the high concentration side to the low concentration side

Forward Osmosis Desalination

Two stage process



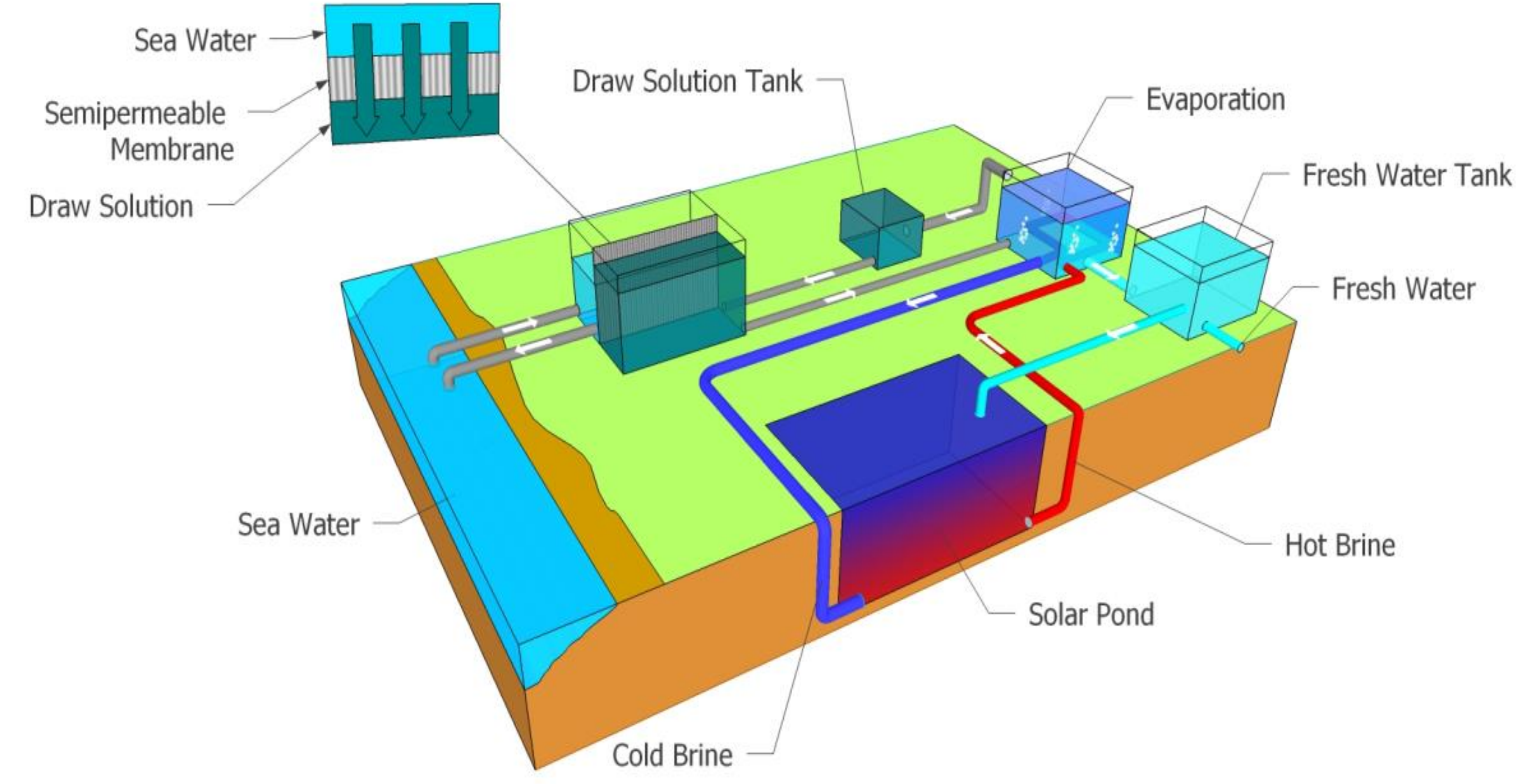
FO Cost Analysis/Comparability



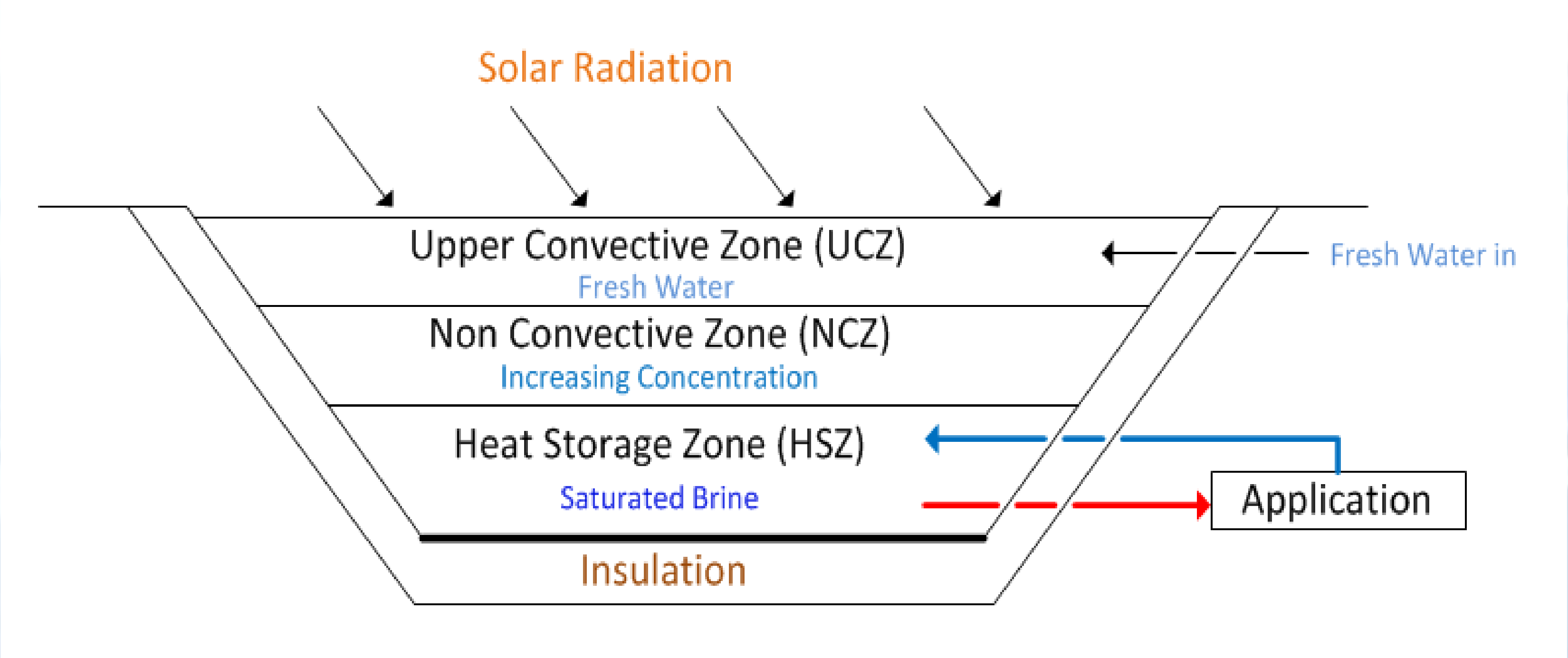
	SWRO		FO		LPRO		FO-LPRO	
Average relative EPC cost per $m^3\ d^{-1}$ (USD)	1,207		787		1,000		1,461	
Plant capacity ($m^3\ d^{-1}$)	100,000		100,000		100,000		100,000	
	% of total cost	*Cost (USD)*	*% of total cost*	*Cost (USD)*	*% of total cost*	*Cost (USD)*	*% of total cost*	*Cost (USD)*
Equipment and materials	25.0%	$ 30,175,000	22.5%	$ 17,750,000	25.0%	$ 25,000,000	29.3%	$ 42,750,000
Membranes	5.5%	$ 6,638,500	29.4%	$ 23,148,148	5.5%	$ 5,500,000	19.6%	$ 28,648,148
Pressure vessels	1.5%	$ 1,810,500	–	–	1.5%	$ 1,500,000	1.0%	$ 1,500,000
Pumps	7.3%	$ 8,811,100	6.5%	$ 5,183,000	7.3%	$ 7,300,000	8.5%	$ 12,483,000
Energy recovery	2.0%	$ 2,414,000	–	–	2.0%	$ 2,000,000	1.4%	$ 2,000,000
Piping and high-grade alloy metals	12.5%	$ 15,087,500	–	–	12.5%	$ 12,500,000	8.6%	$ 12,500,000
Others[a]	46.0%	$ 55,763,400	41.5%	$ 32,660,000	46.0%	$ 46,200,000	31.6%	$ 46,200,000
Equipment + materials + membrane	30.5%		51.9%		30.5%		48.9%	
Construction[b]	69.5%		48.1%		69.5%		51.1%	
Total cost (USD)		**120,700,000**		**78,741,148**		**100,000,000**		**146,081,148**
Element membrane area (m^2)	28		27		34		*n.a.*	
Capacity of each module ($m^3\ d^{-1}$)	10.08		6.48		12.24		*n.a.*	
Water flux ($L\ m^{-2}\ h^{-1}$)	15		10		15		*n.a.*	
Total number of elements	9,921		15,432		8,170		*n.a.*	
Cost per element (USD)	675		1,500		675		*n.a.*	

Valladares Linares et al., Life cycle cost of a hybrid forward osmosis e low pressure reverse osmosis system for seawater desalination and wastewater recover, Water Research 88 (2016) 225–234.

FO – Solar Pond



Solar Pond


Solar Radiation
Upper Convective Zone (UCZ)
Fresh Water
Fresh Water in
Non Convective Zone (NCZ)
Increasing Concentration
Heat Storage Zone (HSZ)
Saturated Brine
Application
Insulation

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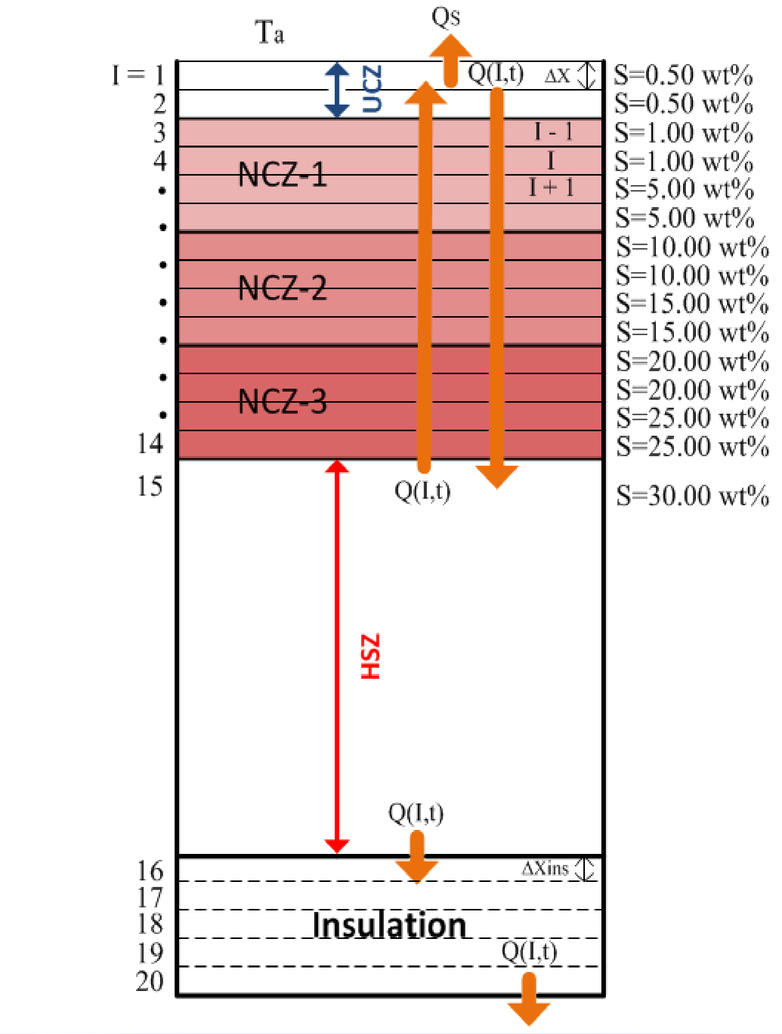
Solar Pond



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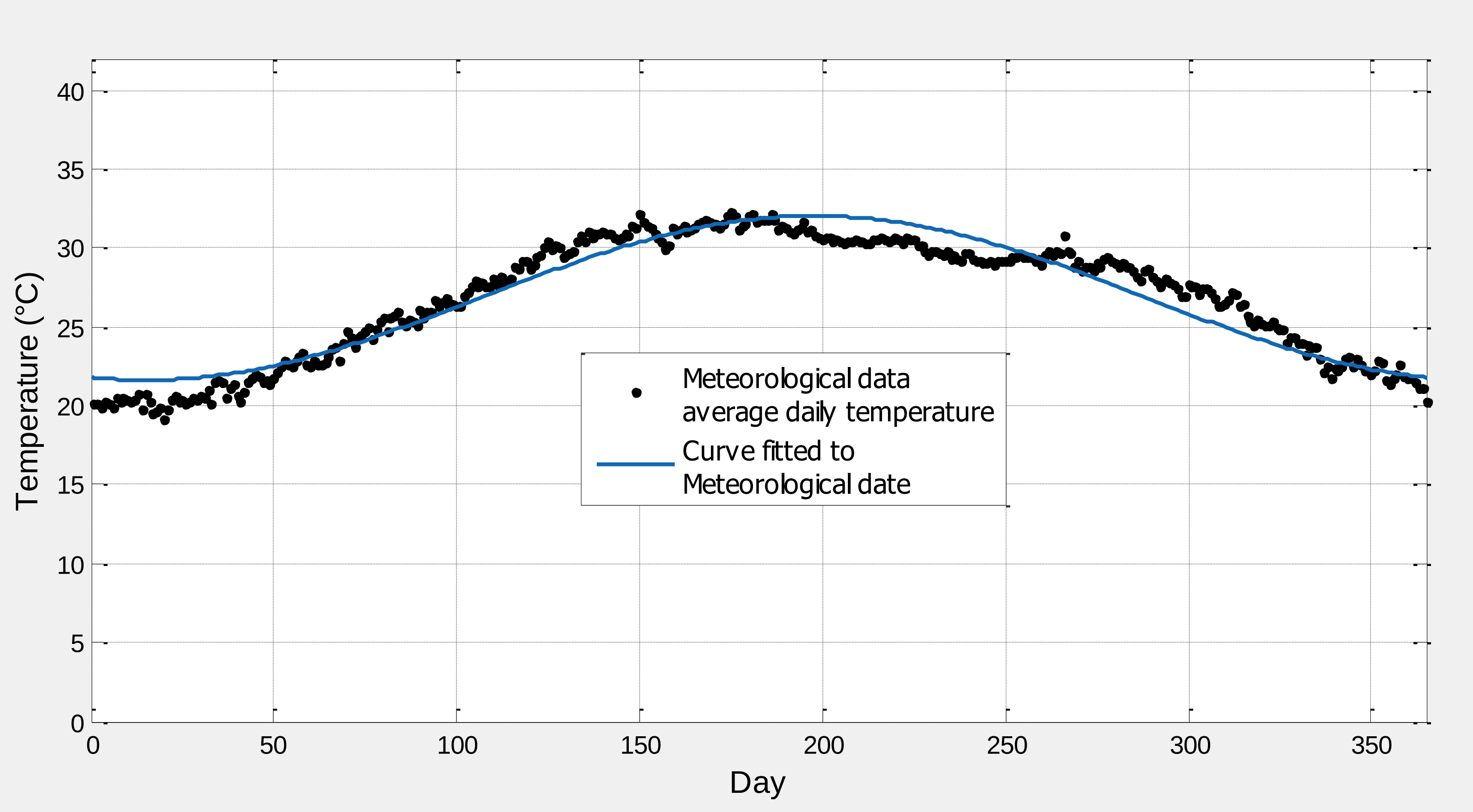
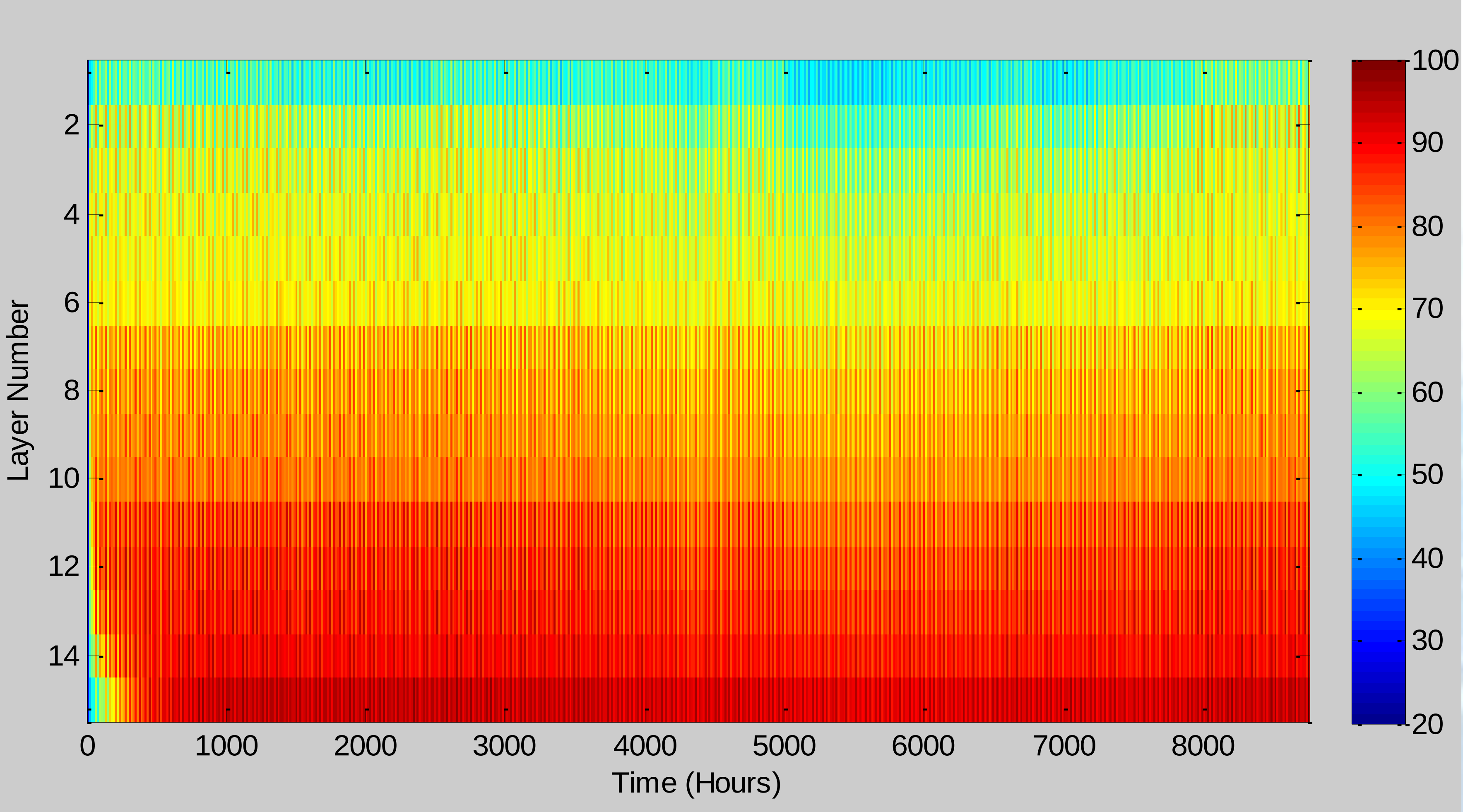
Climatic Data Fitting

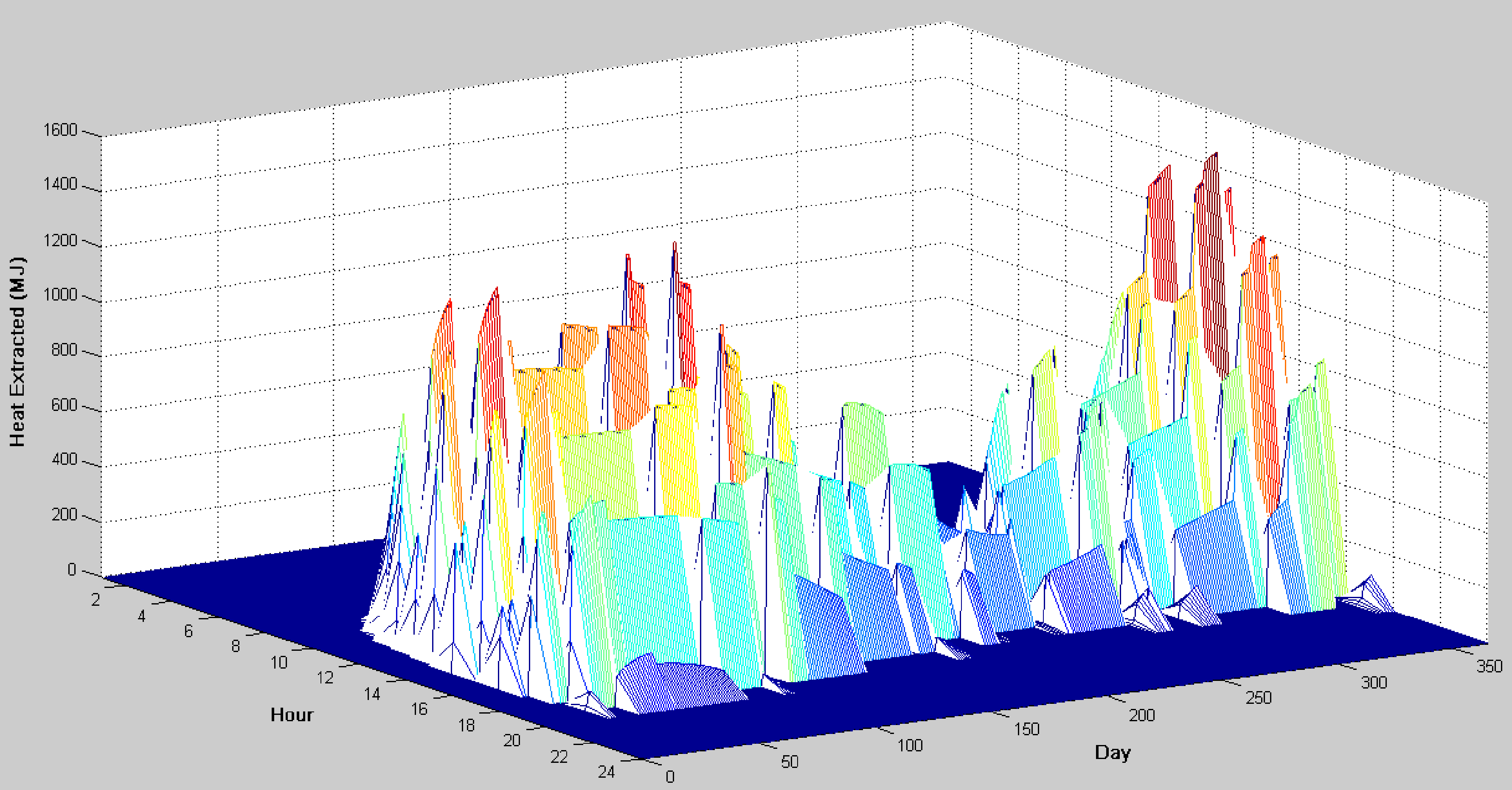


Solar Pond Simulation



A Abbassi Monjezi, AN Campbell, A comprehensive transient model for the prediction of the temperature distribution in a solar pond under Mediterranean conditions, Solar Energy 135 (2016) 297–307.

Solar Pond Simulation



A Abbassi Monjezi, AN Campbell, A comparative study of the performance of solar ponds under Middle Eastern and Mediterranean conditions with batch and continuous heat extraction, Applied Thermal Engineering 120 (2017) 728–740.

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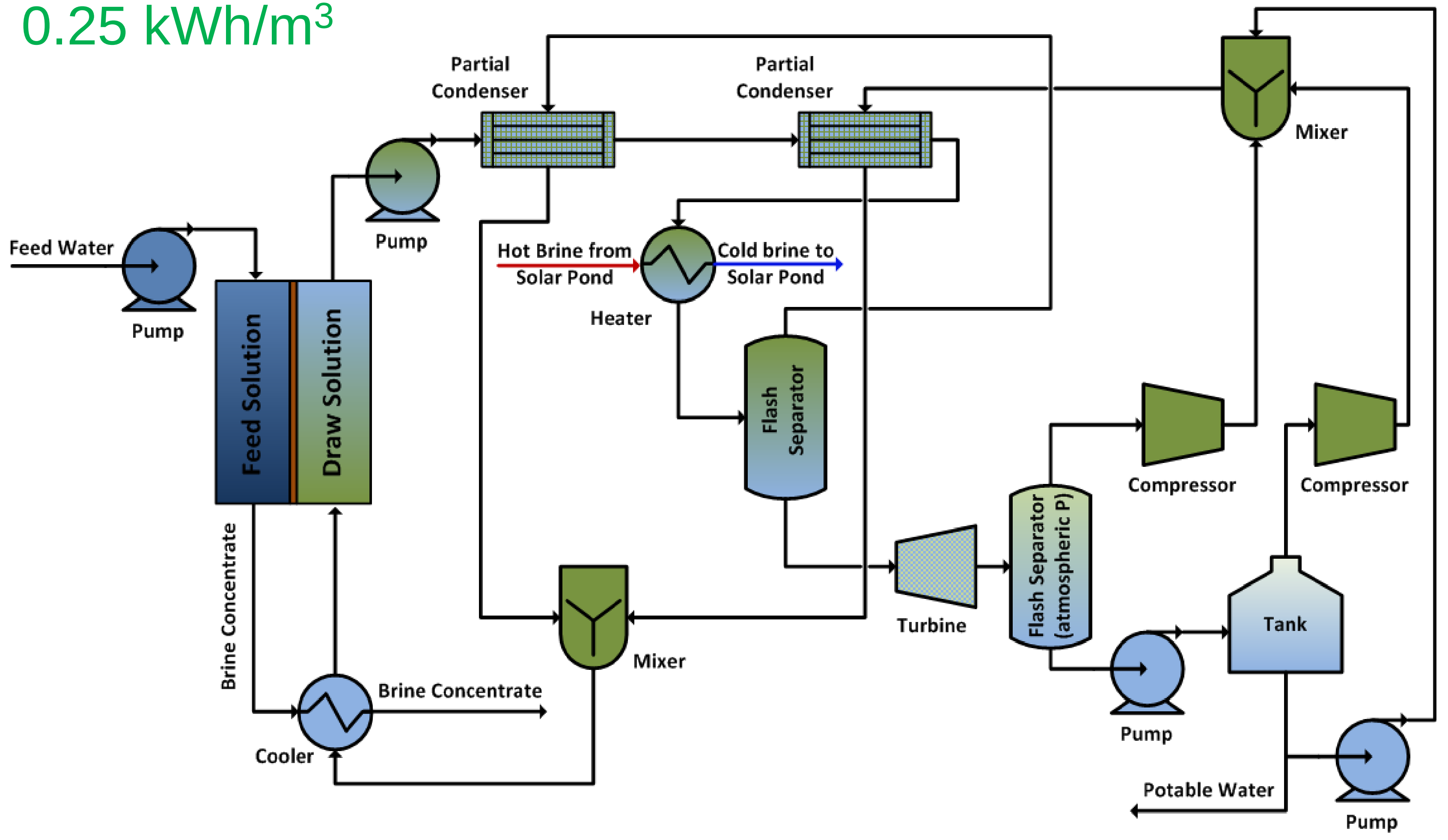
FO Batch Process

RO Thermodynamic limit = 1.53 kWh/m^3

0.25 kWh/m^3



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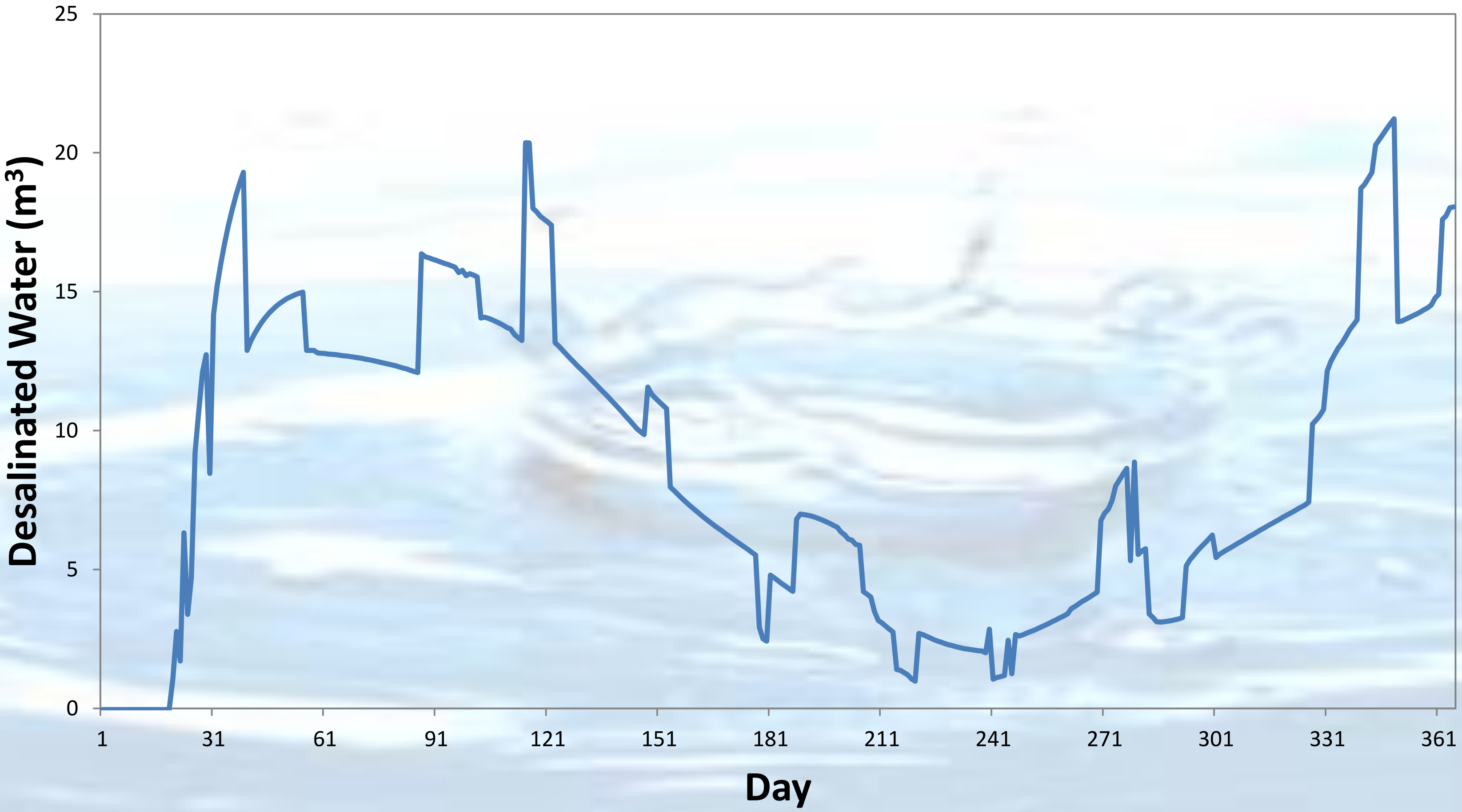
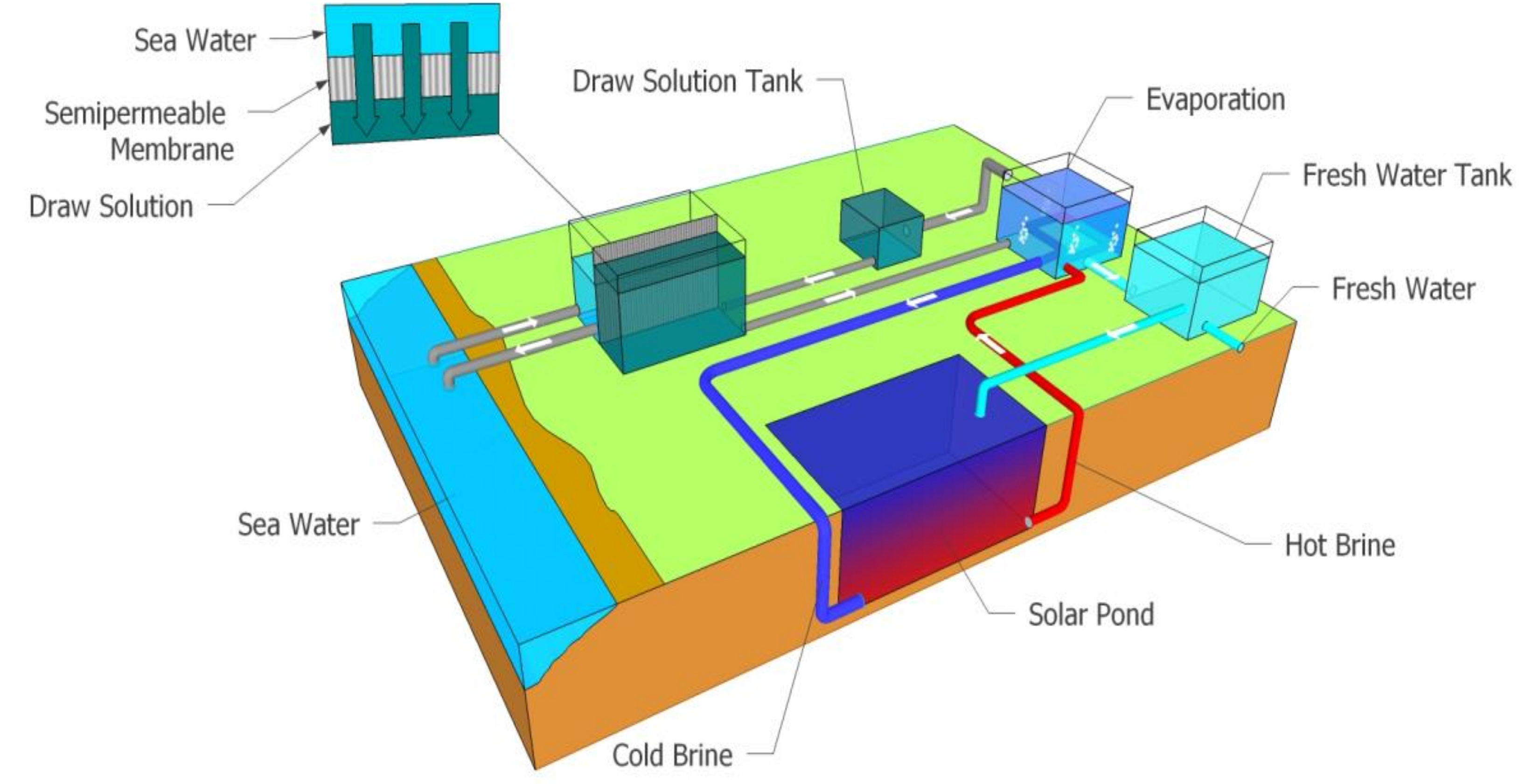
Annual Freshwater Production



FO – Solar Pond



A Abbassi Monjezi, HB Mahood, AN Campbell, Regeneration of dimethyl ether as a draw solution in forward osmosis by using thermal energy from a solar pond, Desalination 415 (2017) 104–114.

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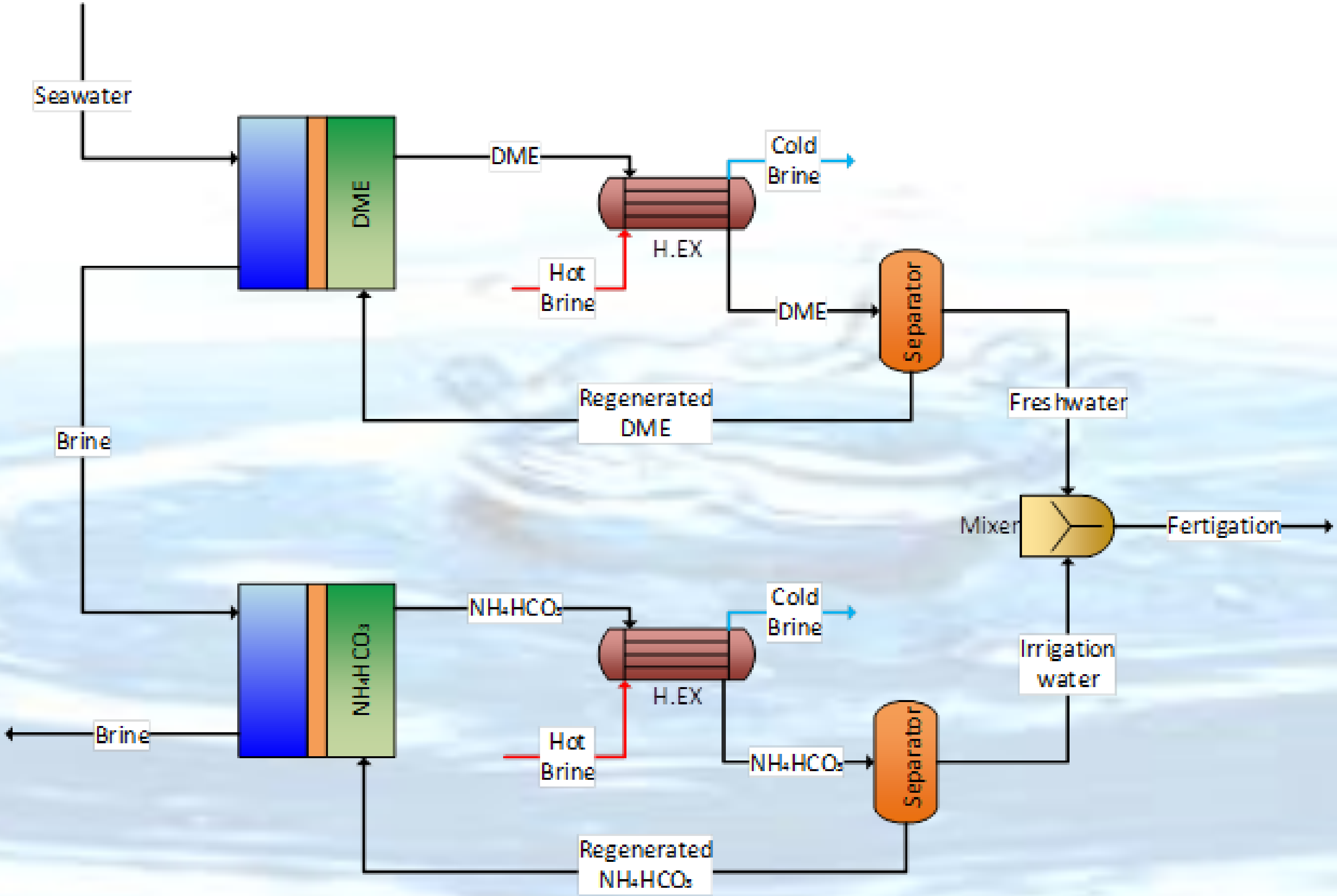
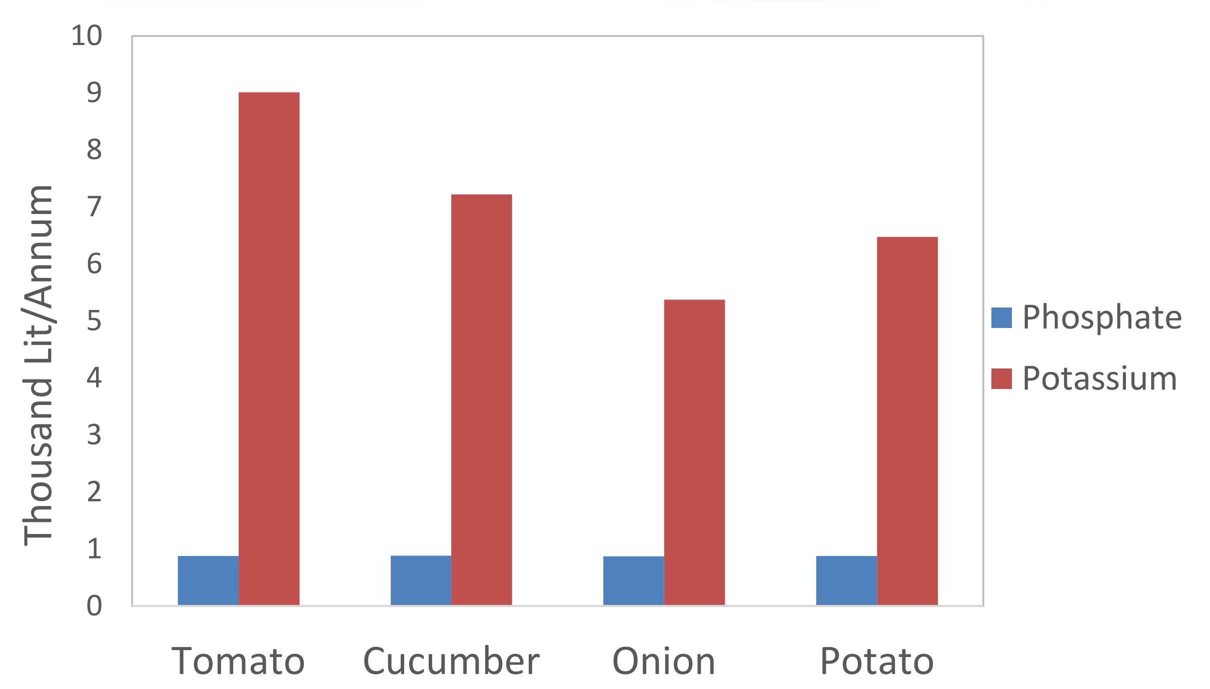
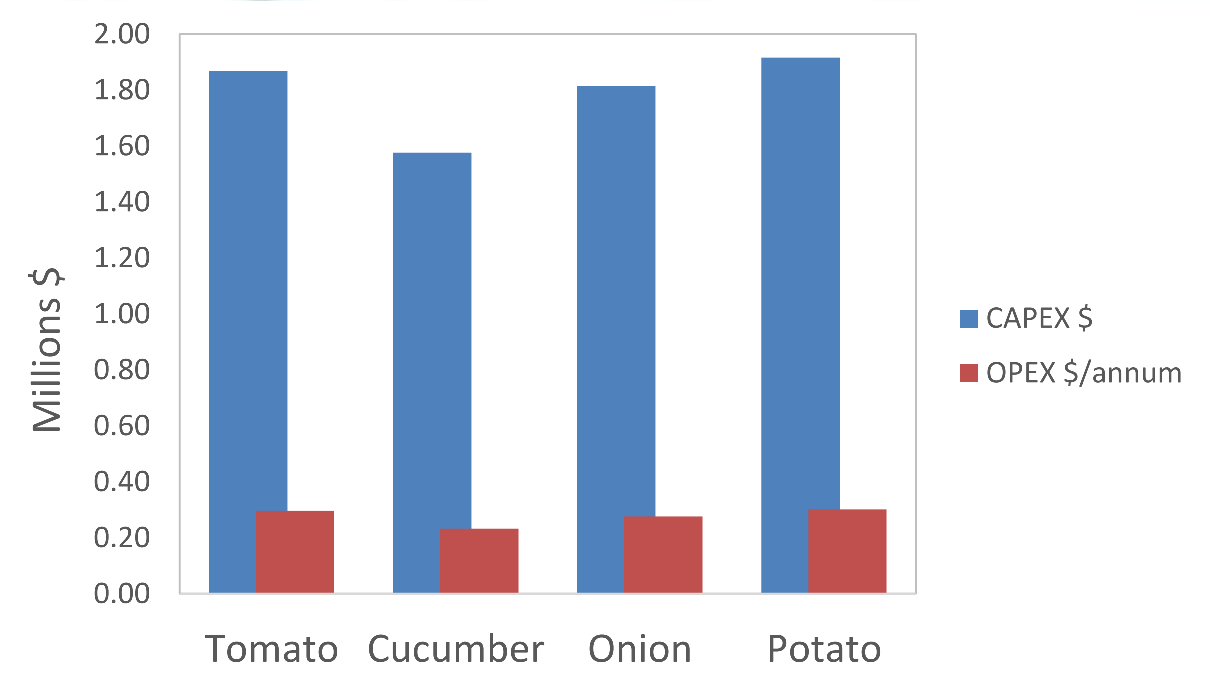
FO - Fertigation

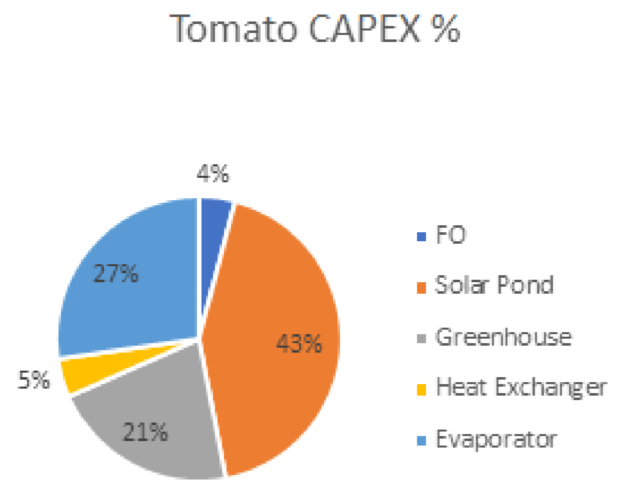


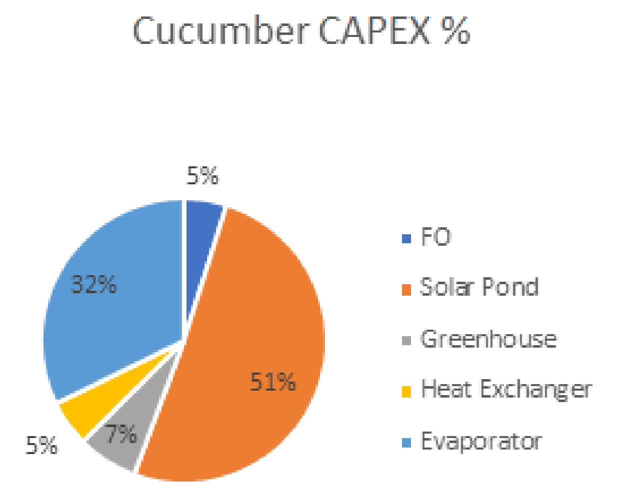
FO – Fertigation – Greenhouse

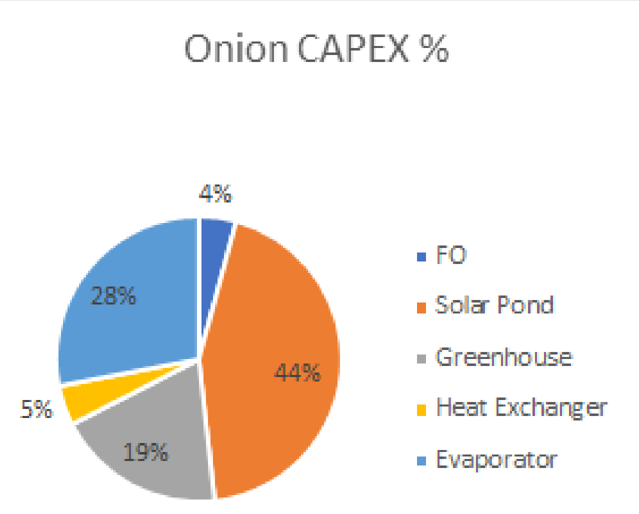


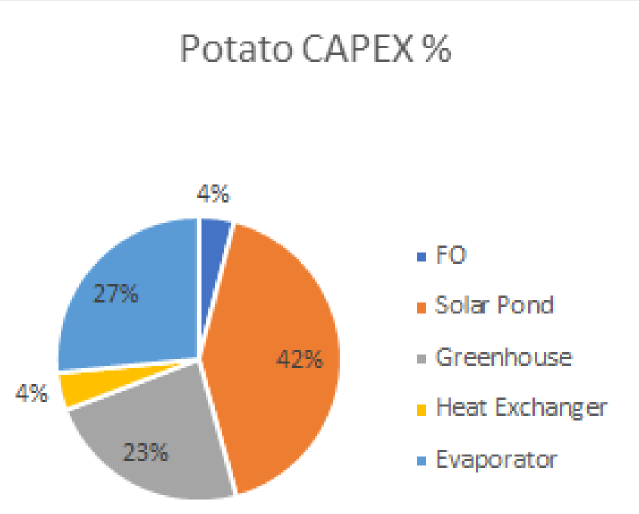


FO – Fertigation – Greenhouse

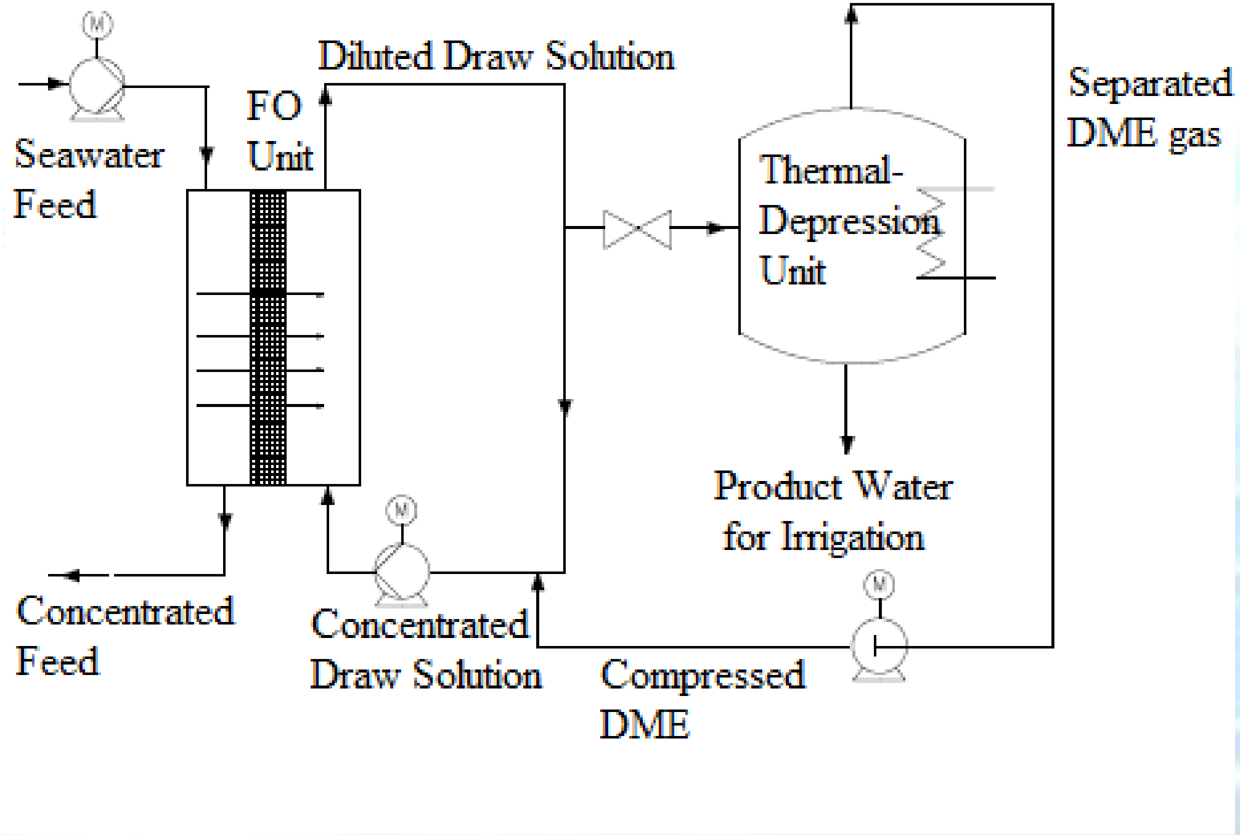

Tomato CAPEX %


Cucumber CAPEX %


Onion CAPEX %


Potato CAPEX %

FO – Irrigation



A Abbassi Monjezi, M Aryafar, AN Campbell, F Cecelja, AO Sharif, 2018, The Capability of Forward Osmosis in Irrigation Water Supply, In: Water Management: Technological and Social Perspectives, Boca Raton: CRC Press.

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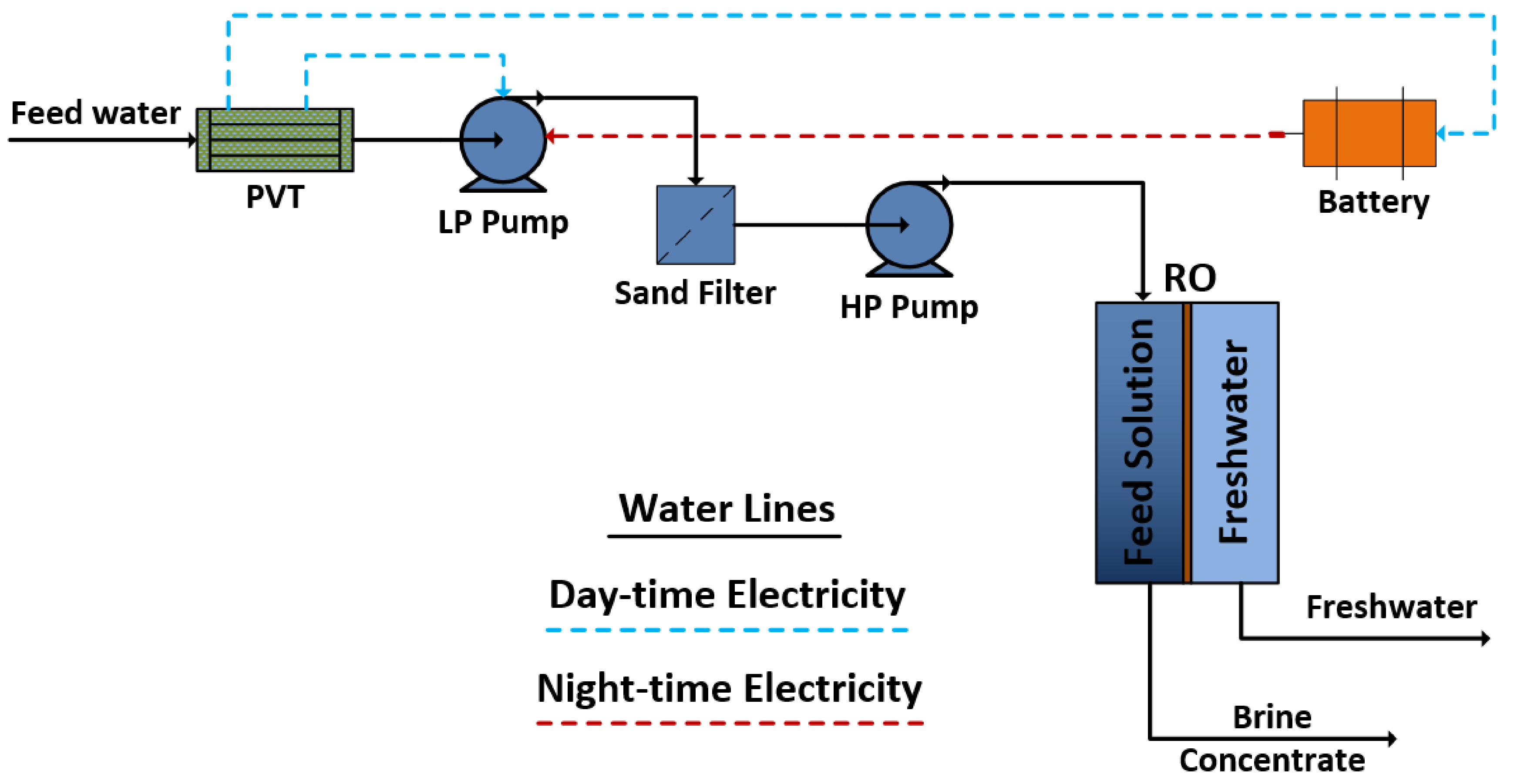
Reverse Osmosis – PVT



Concluding Words

- Forward osmosis offers a process for desalination with a significant reduction in capital and operating costs, and also reduced environmental impact
- Forward Osmosis can be employed to provide fertigation water for greenhouse agricultural development
- Coupling reverse osmosis with PVT modules where seawater is used for cooling can present an efficiency rise in both RO and solar energy generation

Acknowledgements

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