Mitigating Risks to Sustainability in Desalination Technologies via Innovative Materials, Economic Analyses and Environmental Assessment

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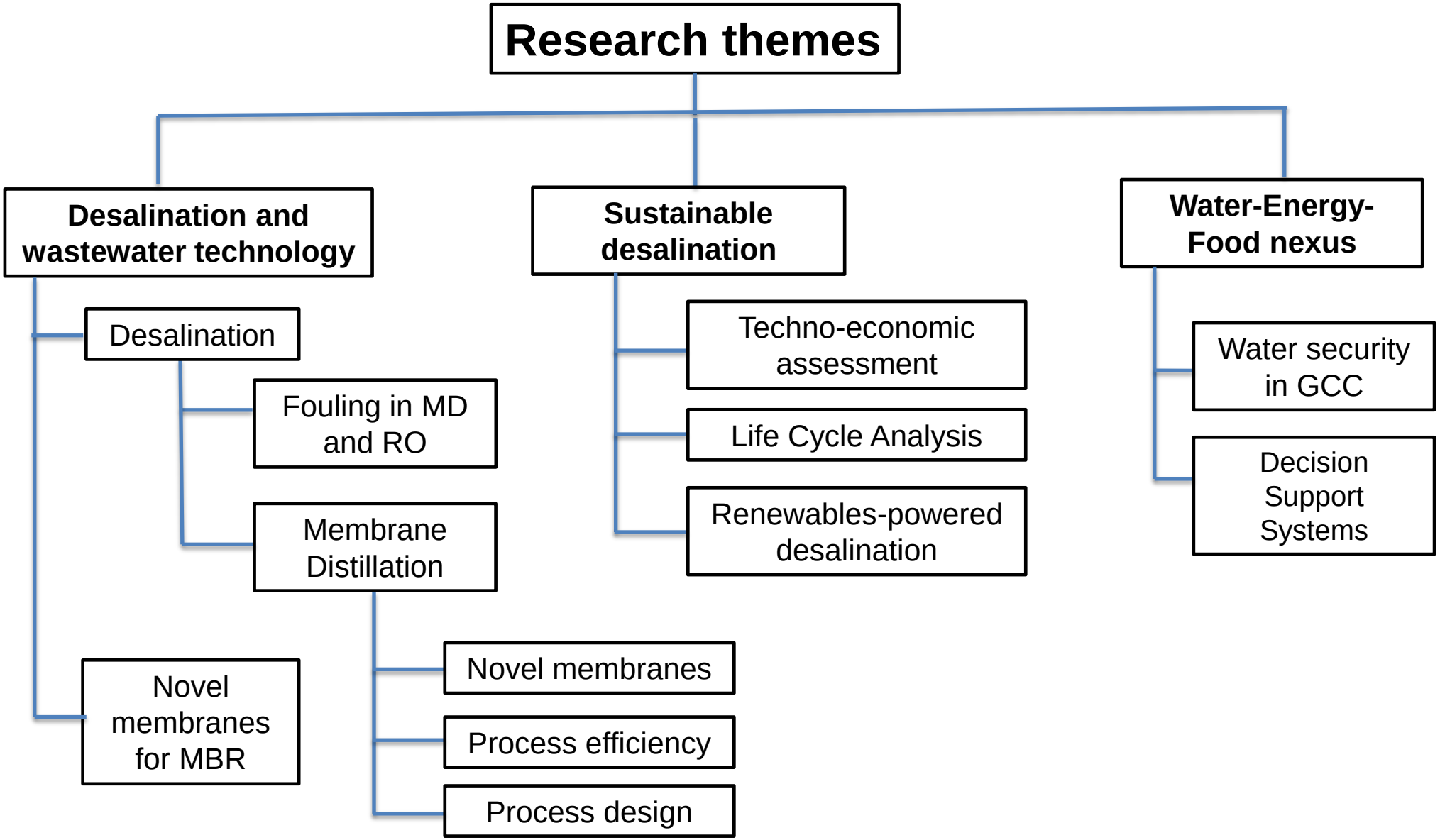
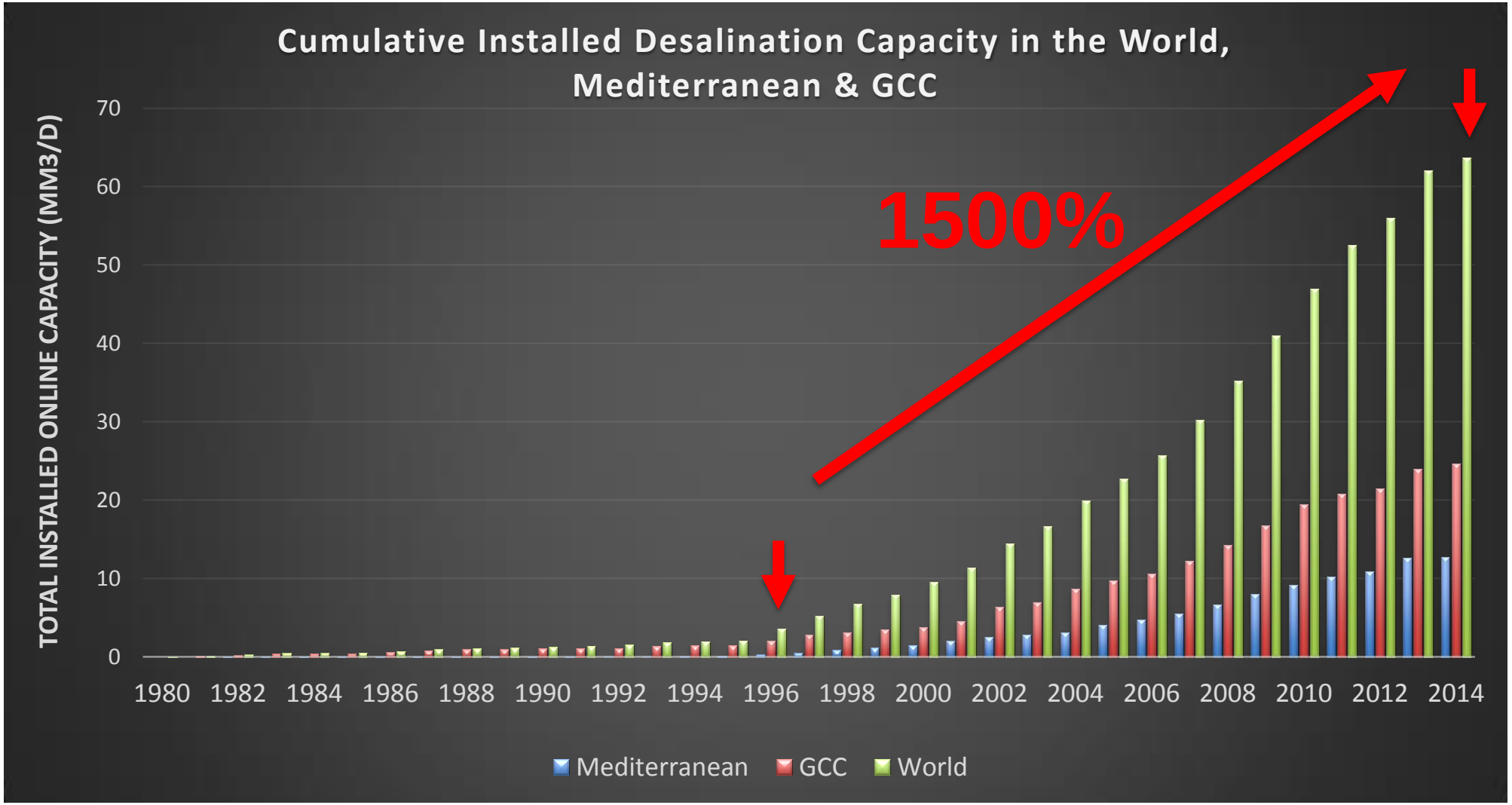
The *Membrane and Sustainable Desalination Research* Group (MSDR) at MI

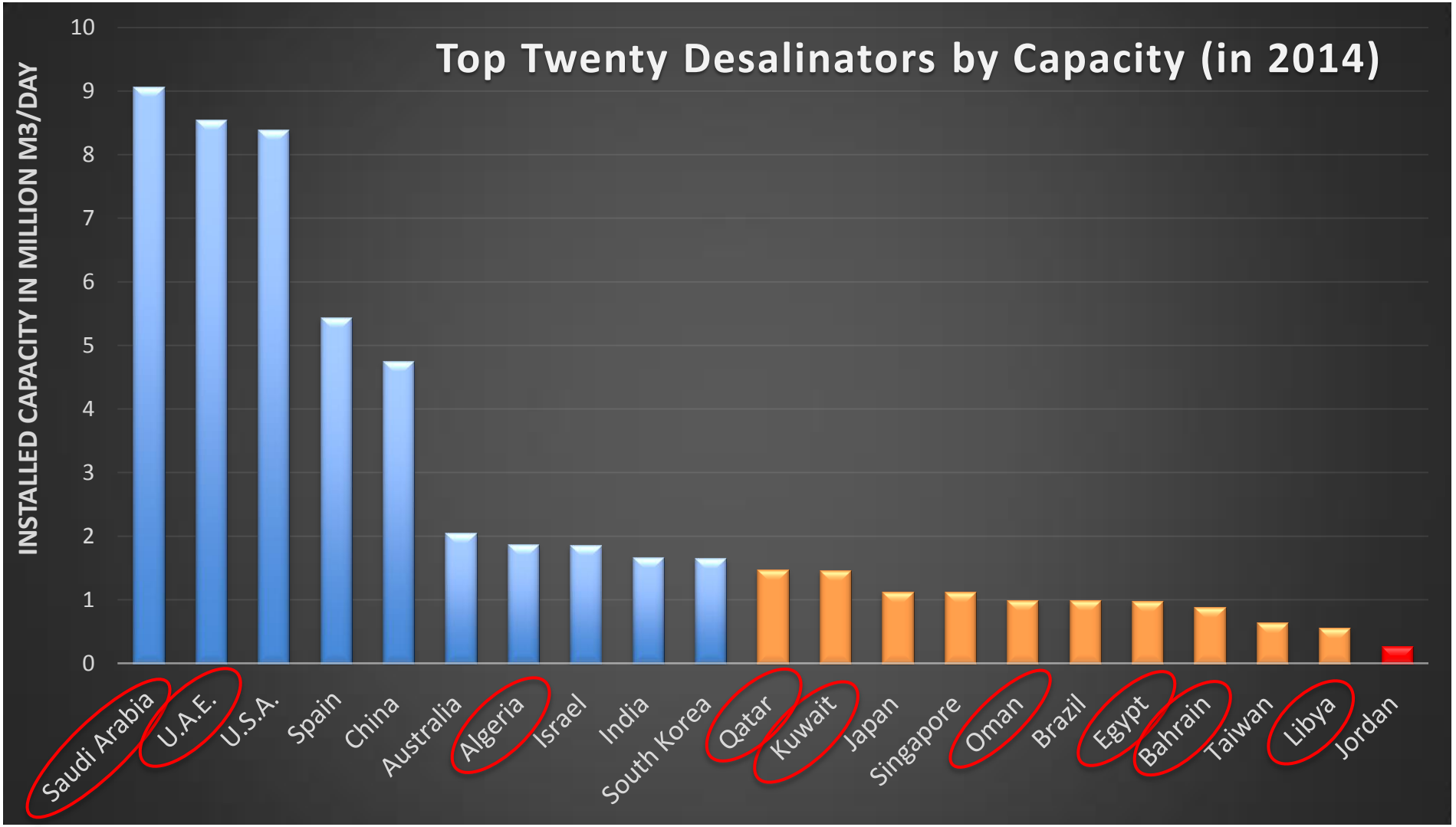


Global desalination market



Data from DesalData.com, 2014

Global installed desalination capacity

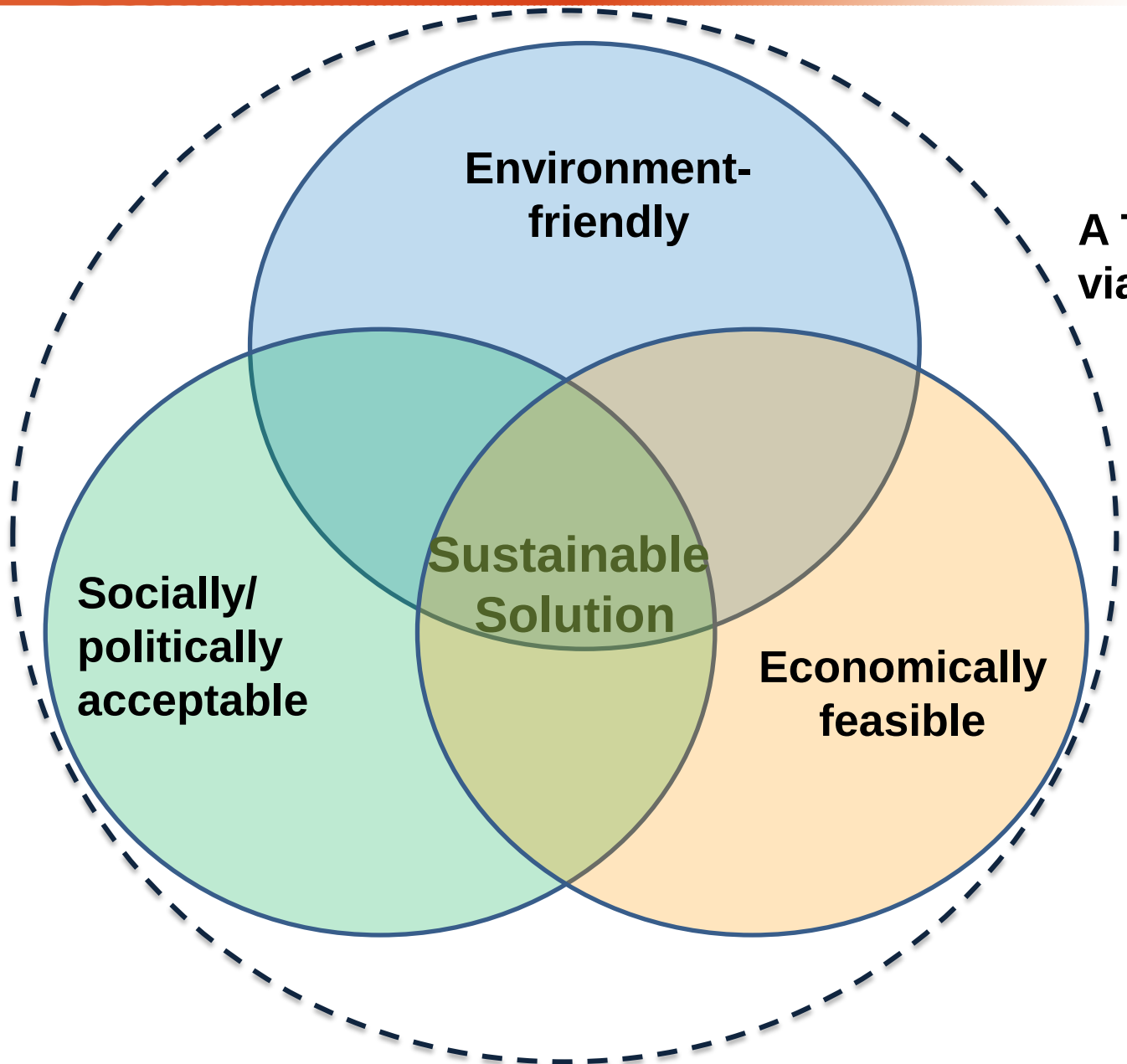


Data from DesalData.com, 2014

The central question:

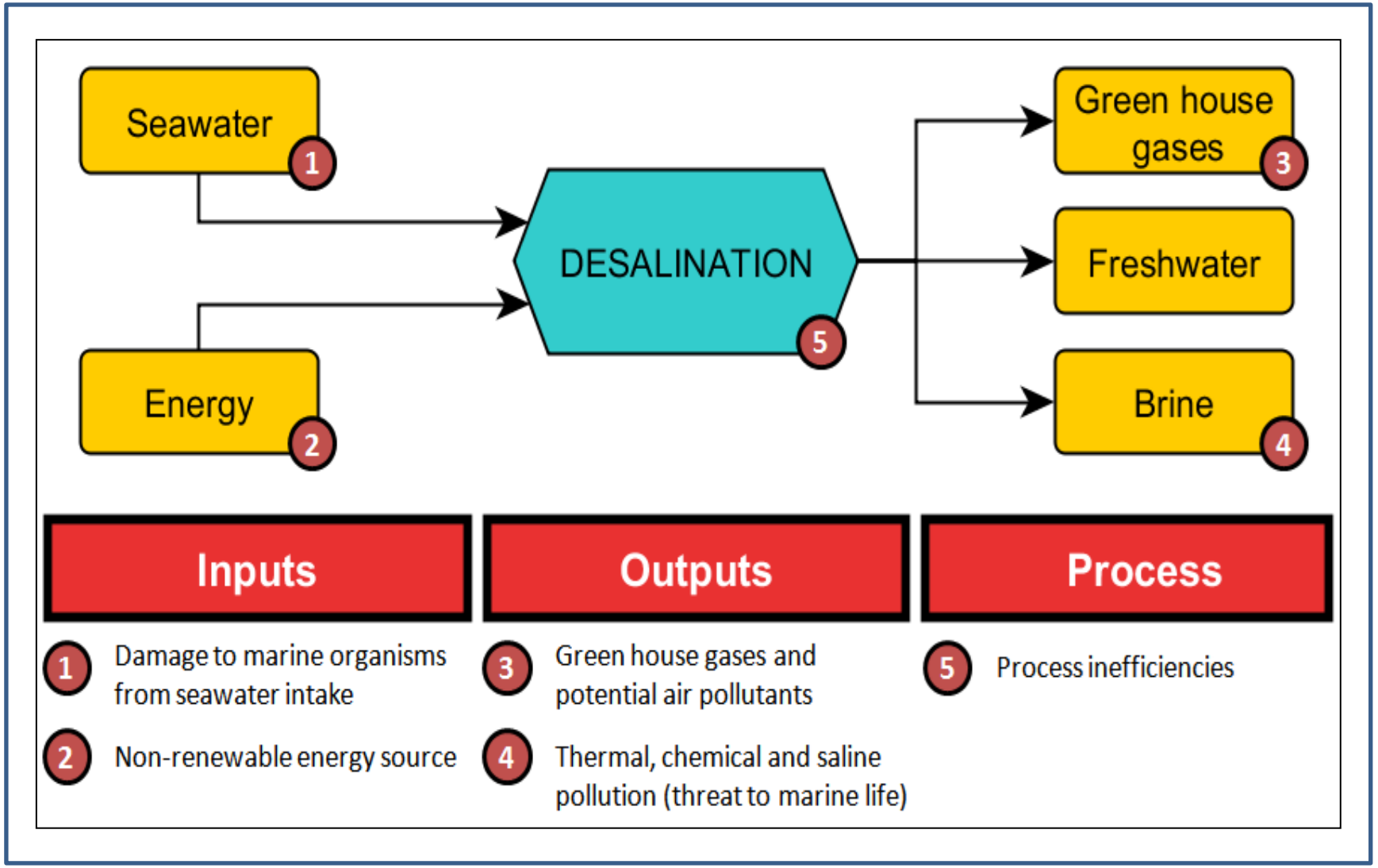
"Given the abundance of seawater and the maturity of desalination technologies, is desalination the solution for the global water scarcity problem?"

Sustainability and desalination



The Environmental Impacts of Desalination

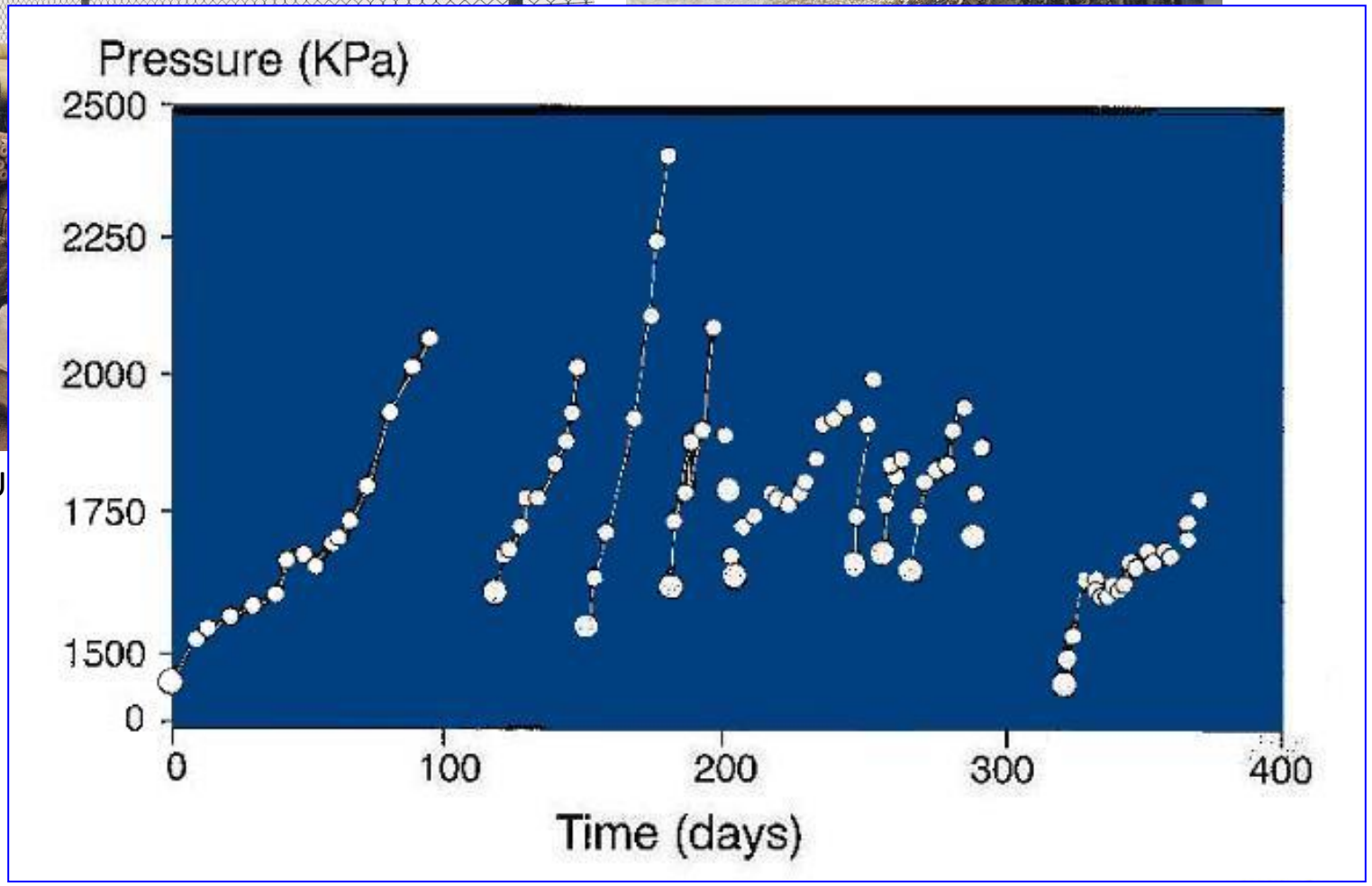
Environmental cost of water



Box model of environmental impacts related to the desalination process

Impacts of membrane fouling

(Source: Prof. Jan Schippers, U



Fouling mitigation: Pre-treatment and intake options

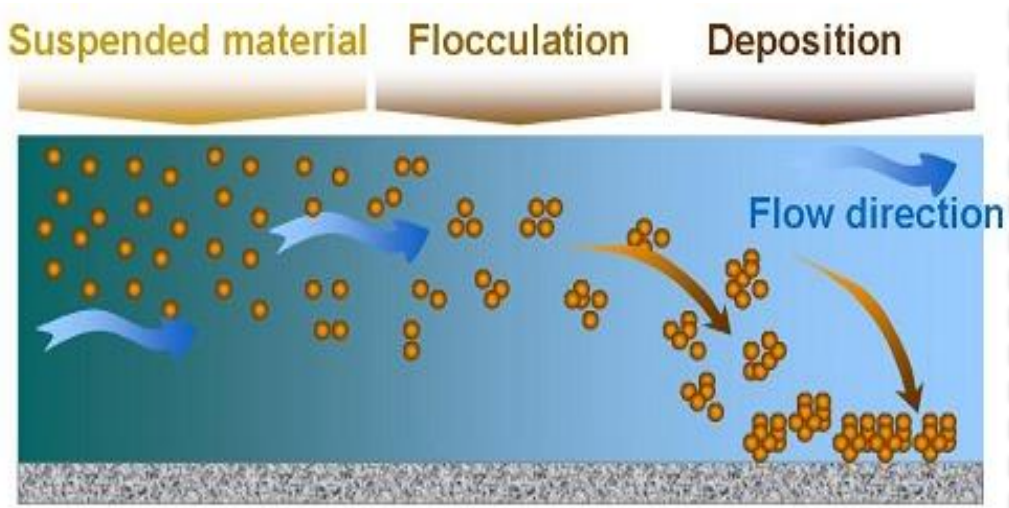
Pre-treatment Options

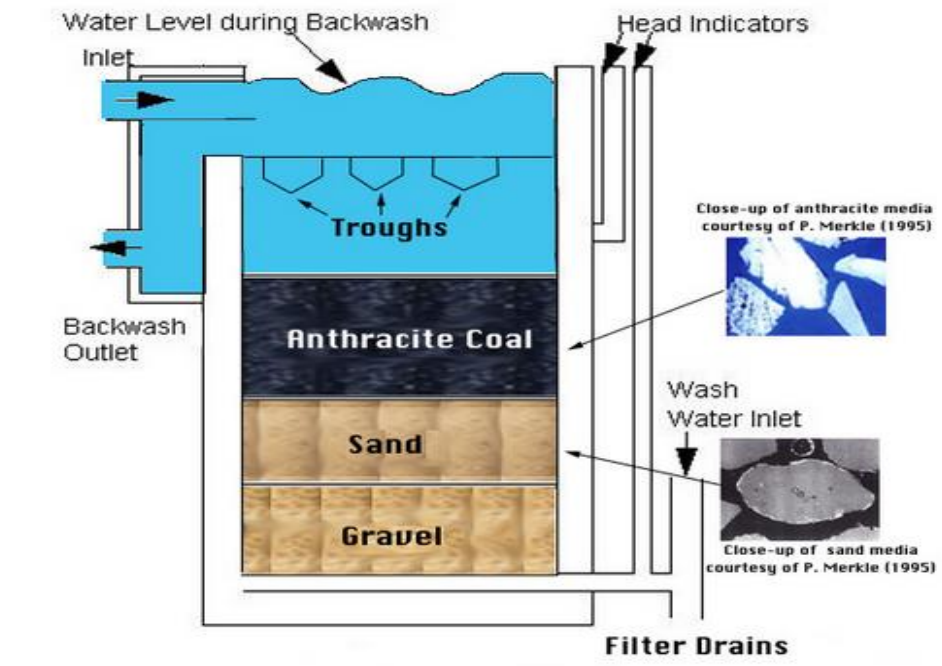
- Coagulation/flocculation/sedimentation of suspended and colloidal solids in the feed water
- Sand filtration (slow or rapid)
- Micro- and ultrafiltration filters

Intake Options

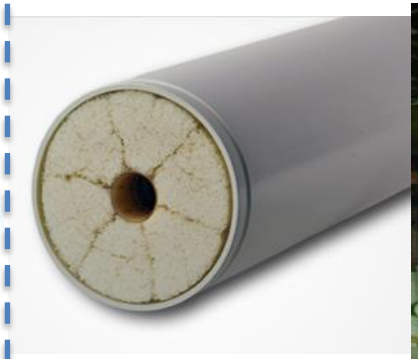
- Conventional (open) intake
- Artificial beach wells or infiltration galleries

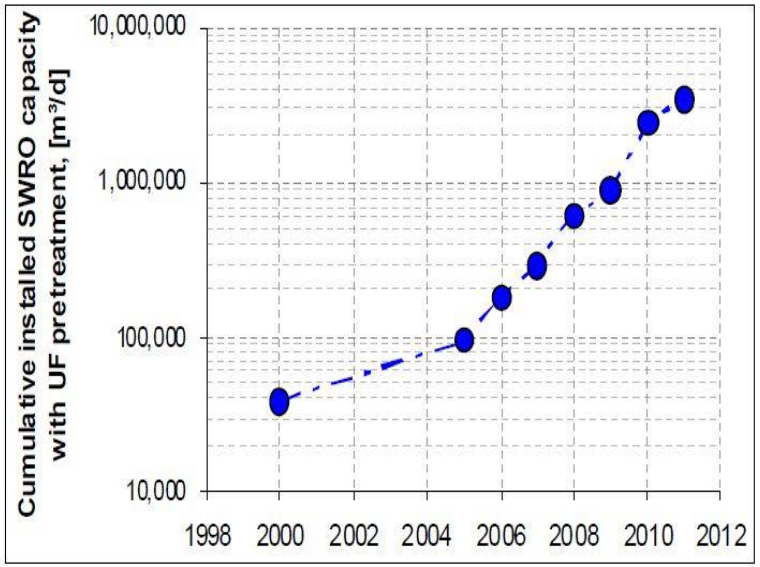
Sedimentation vs. ultrafiltration for pre-treatment





Source: http://www.ewisa.co.za/eWISAWaterworks/misc/WaterTreatment/defaultcoagulation.htm





Study Focus: The Fujairah desalination plant, UAE

- Why Fujairah Desalination plant?
  - Location: United Arab Emirates
  - Largest Hybrid desalination plant
  - Capacity: 454,000 m^3/day (62.5% MSF, 37.5% RO)
  - Operational experience of over 10 years
  - Uses Sedimentation Based Pretreatment for RO desalination

T. Al-Sarkal and H. A. Arafat, *Desalination*, 317, 55-66 (2013)

The proposed pretreatment alternative for Fujairah: X-Flow ultrafiltration

Norit
leading in purification

X-Flow

- Why X-Flow?
  - Expertise in pretreatment using membrane filtration
  - Experience in the gulf region (e.g., The Palm Jumeirah Desalination plant in Dubai, UAE)

T. Al-Sarkal and H. A. Arafat, *Desalination*, 317, 55-66 (2013)

The tool used: Life Cycle Analysis (LCA)

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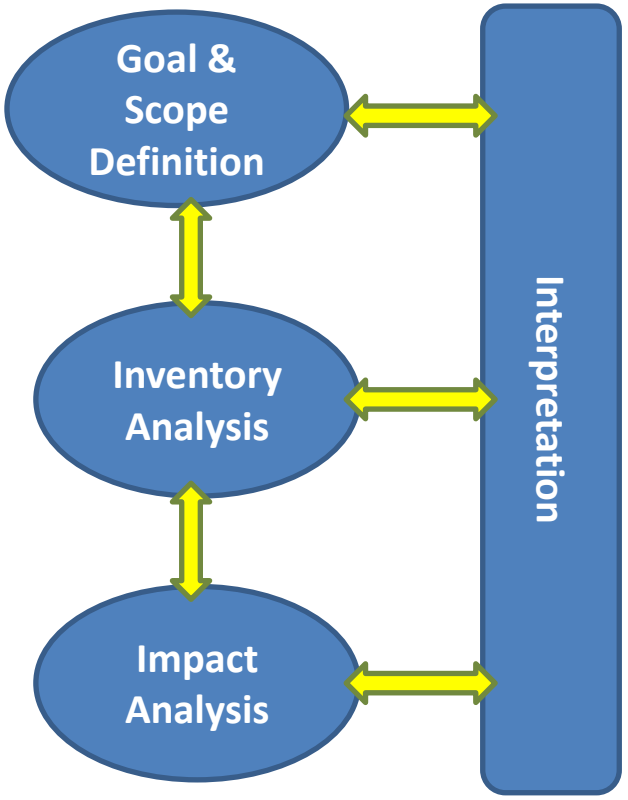
What is an LCA?

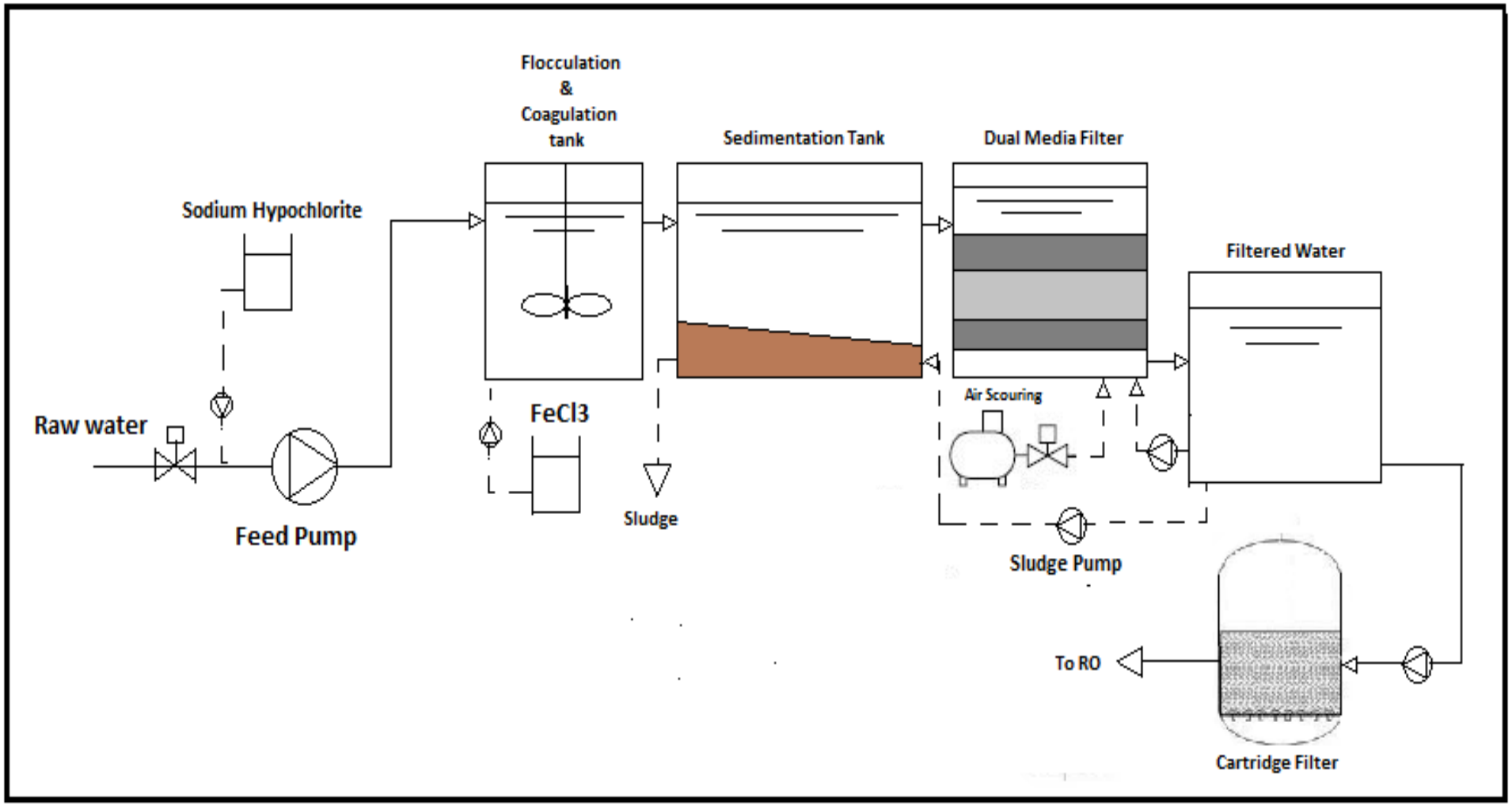
- An environmental accounting tool
- Looks at the environmental impact from conception till disposal (cradle to grave)
- Create an inventory (material inputs and emission outputs) and translate it into an environmental impact

Stages of LCA:

- Goal and Scope Definition
- Inventory Analysis
  - Identify and quantify
    - Energy inflows
    - Material inflows
    - Releases
- Impact Analysis
  - Relating inventory to impact on world

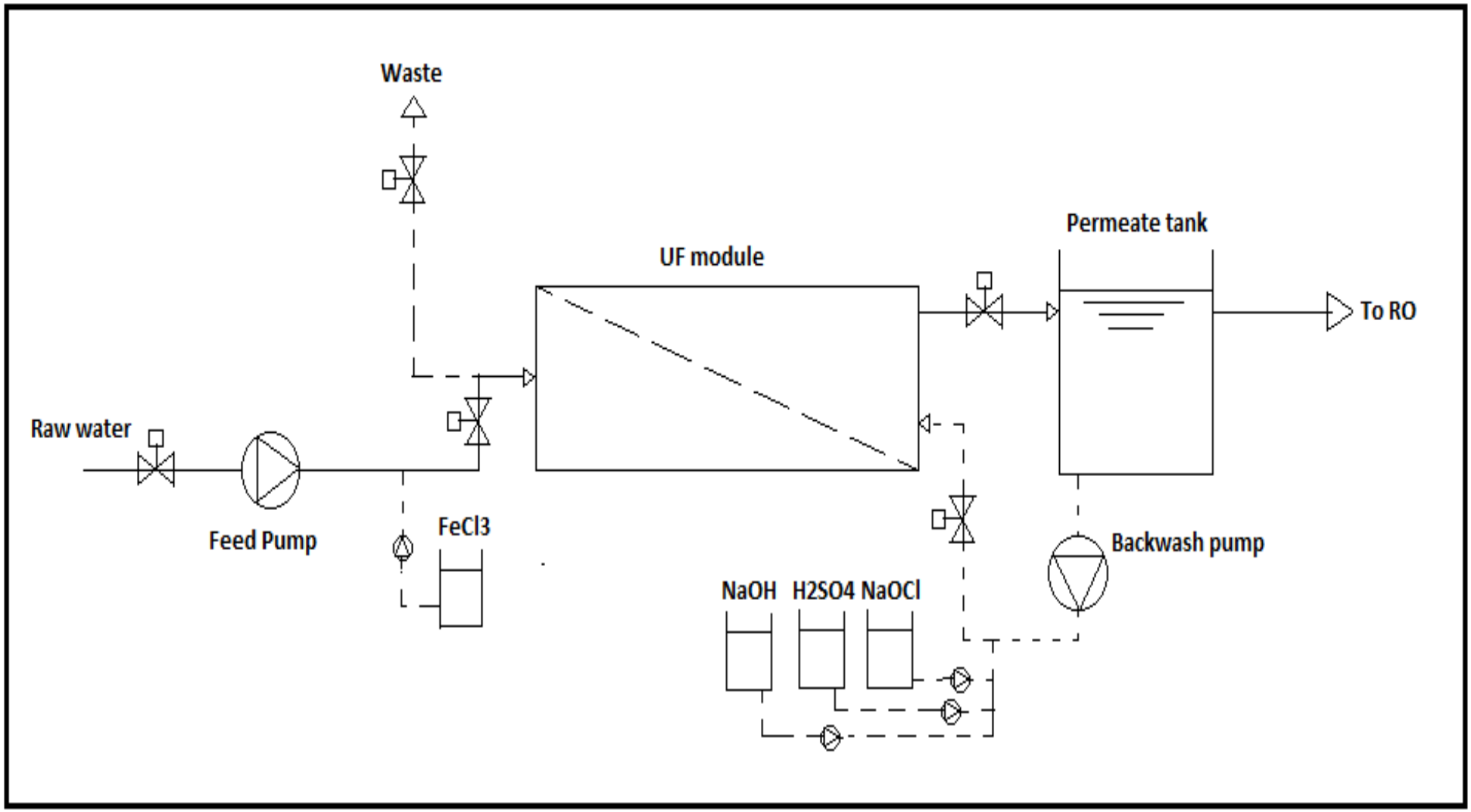


Inventory analysis: Sedimentation-based pre-treatment



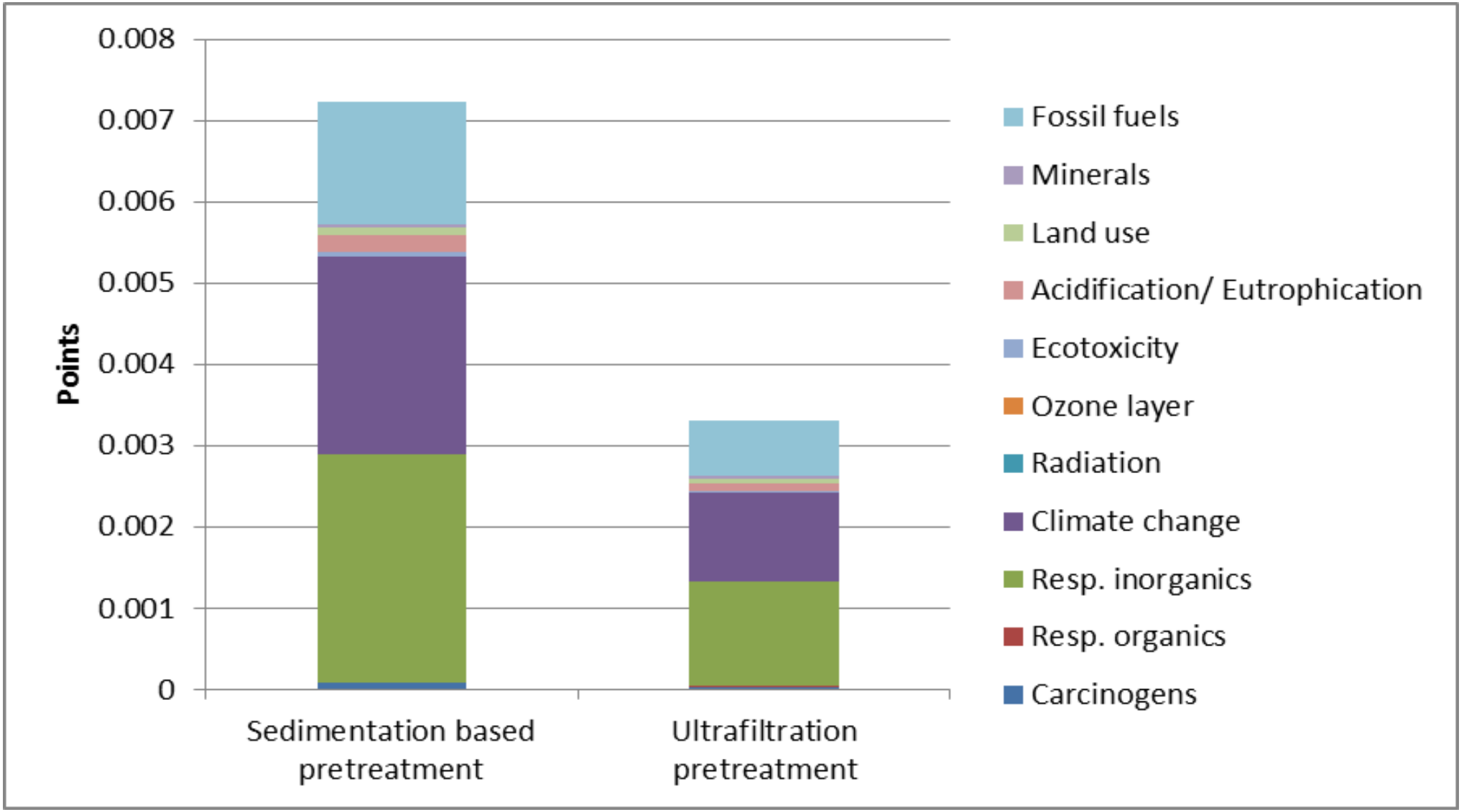
T. Al-Sarkal and H. A. Arafat, *Desalination*, 317, 55-66 (2013)

Inventory analysis: Ultrafiltration-based pre-treatment



T. Al-Sarkal and H. A. Arafat, *Desalination*, 317, 55-66 (2013)

Impact assessment results: SimaPro® Analysis



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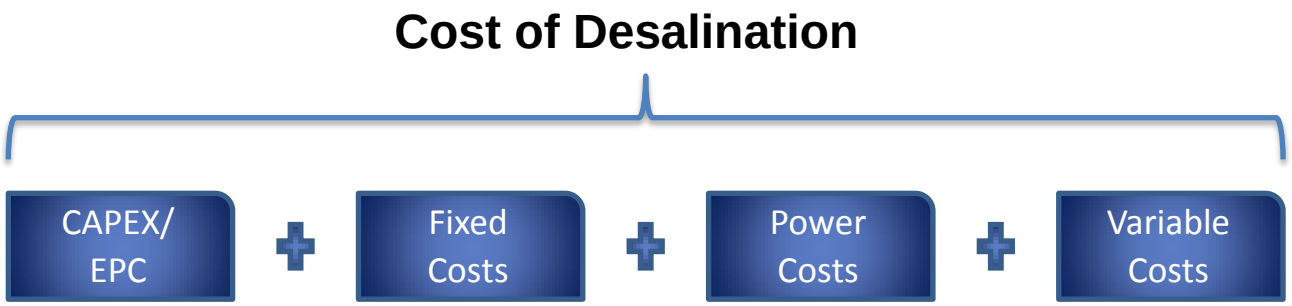
The Economic Impacts of Desalination

Cost of desalination



Cost dependent on:

Location	Technology	Feed water	Energy source	Design

Opportunity: Renewable-energy-powered desalination

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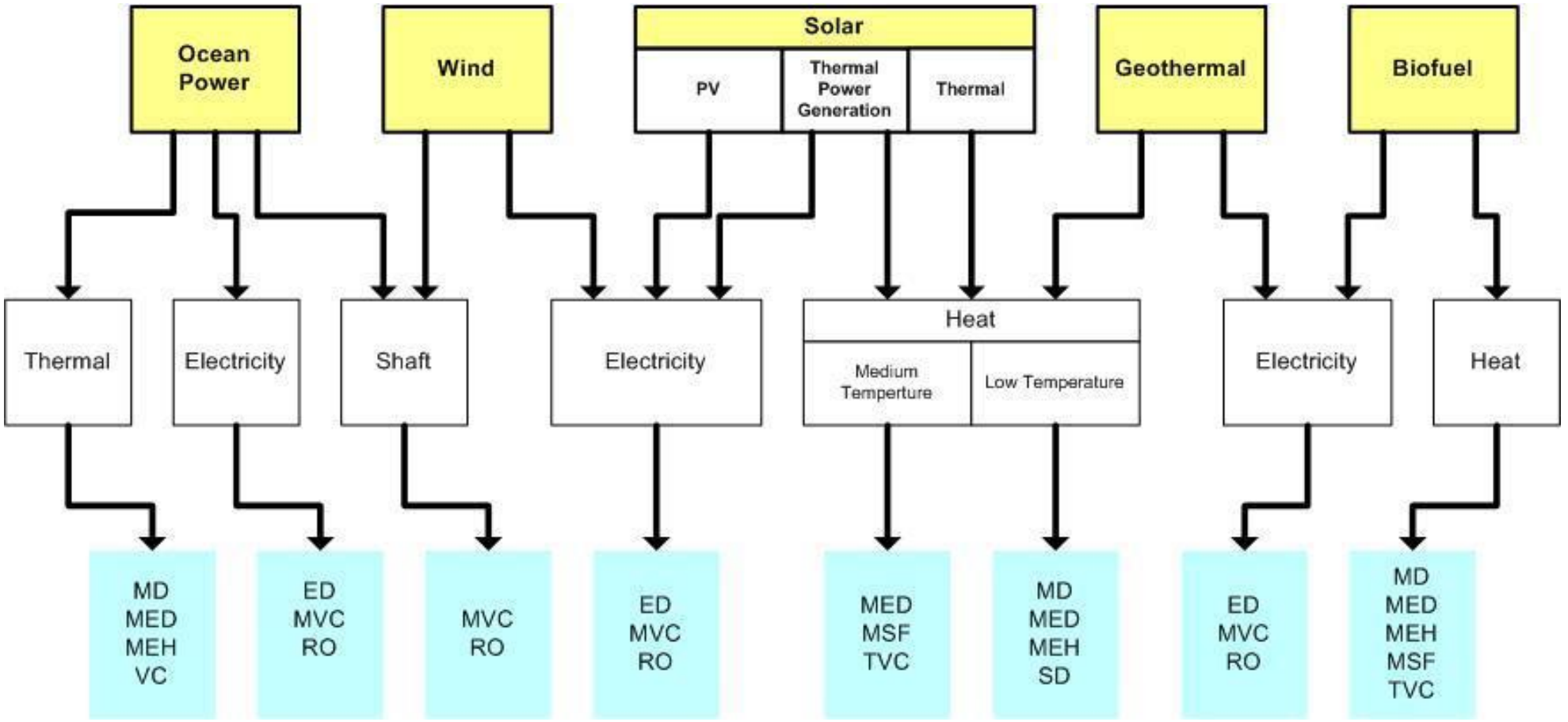
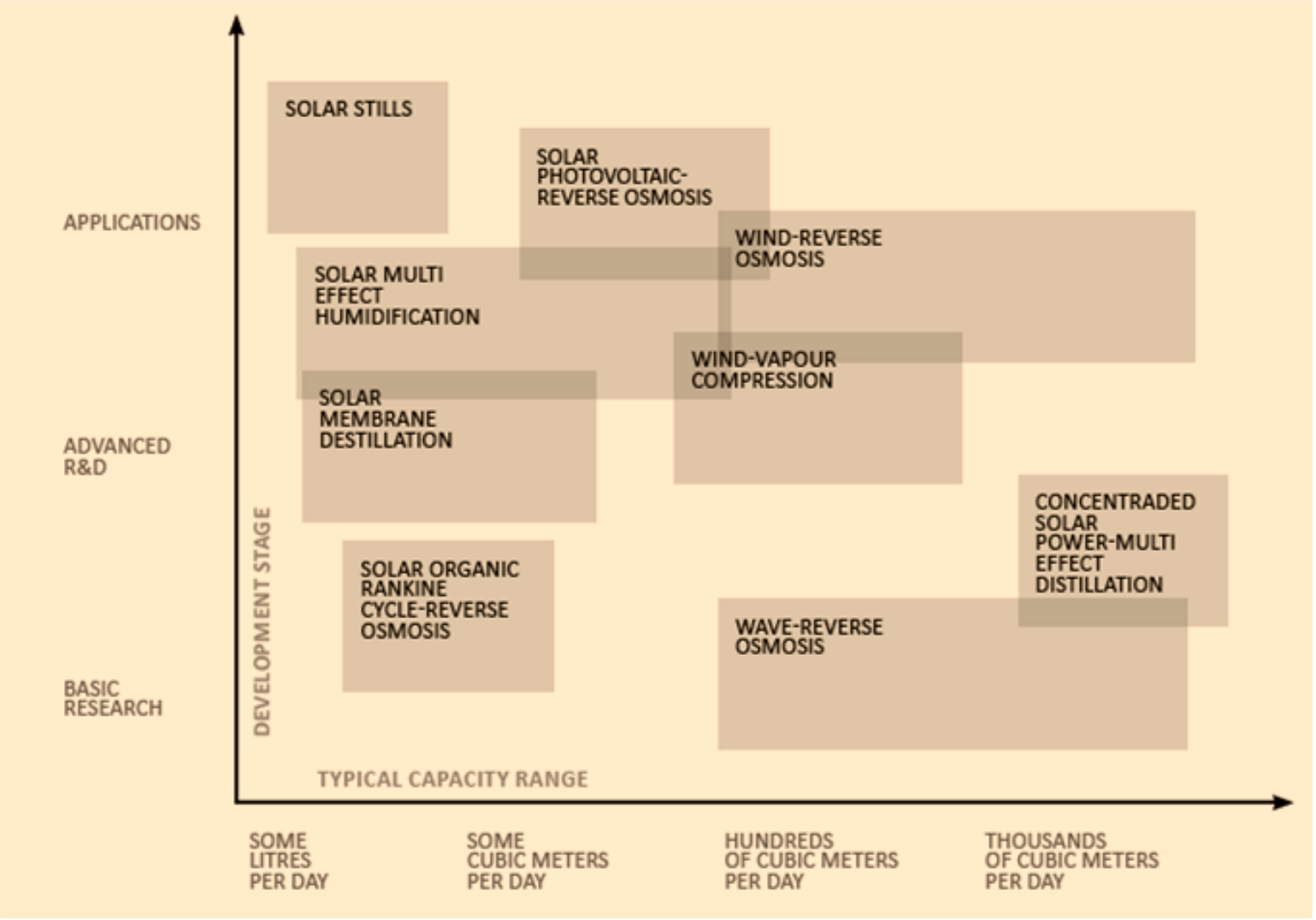


Source: Roadmap for the development of desalination powered by renewable energy, PRODES, http://www.prodes-project.org

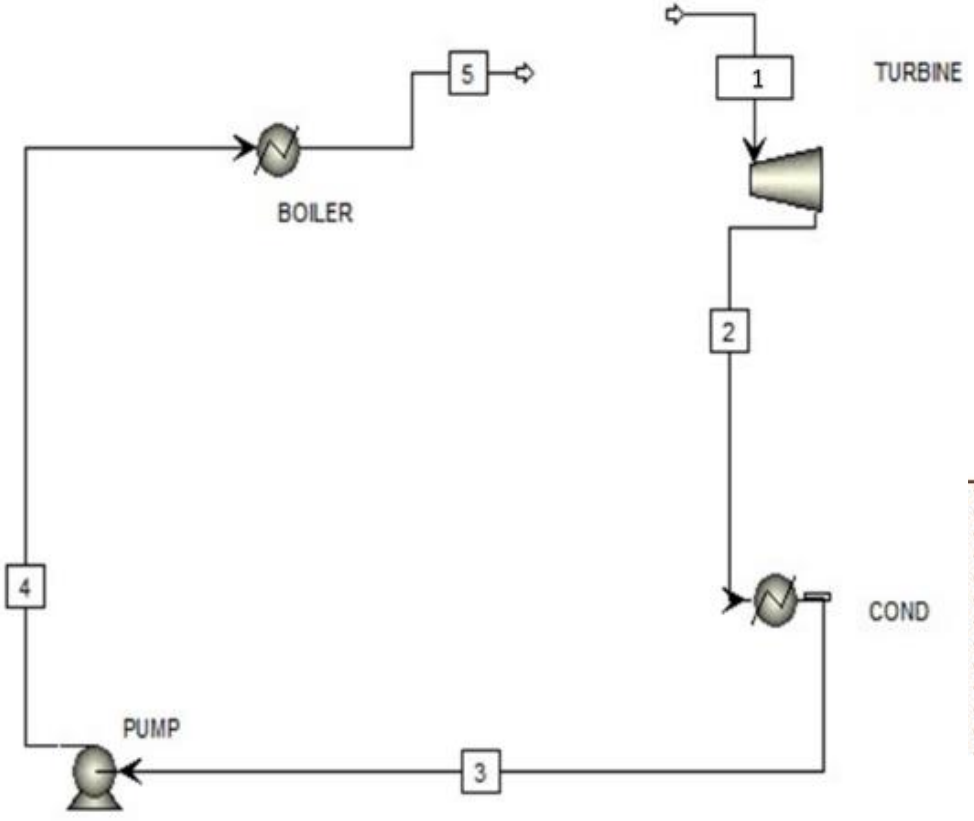
RE-desalination: Maturity versus scale

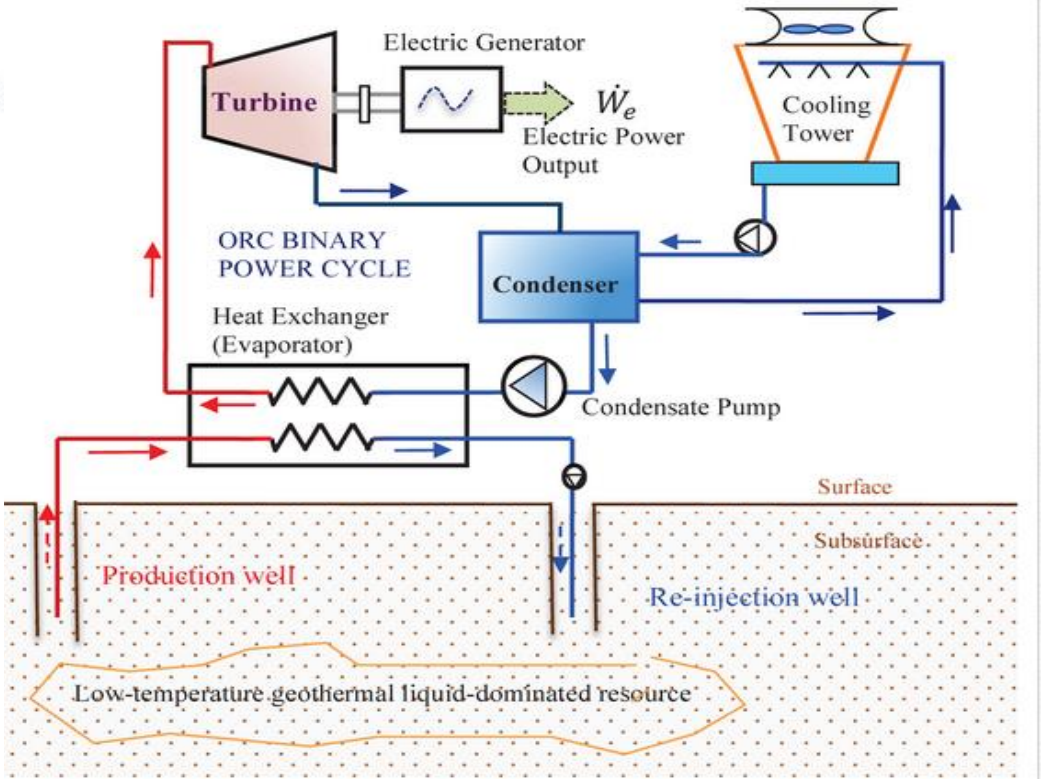


Roadmap for the development of desalination powered by renewable energy, PRODES, http://www.prodes-project.org

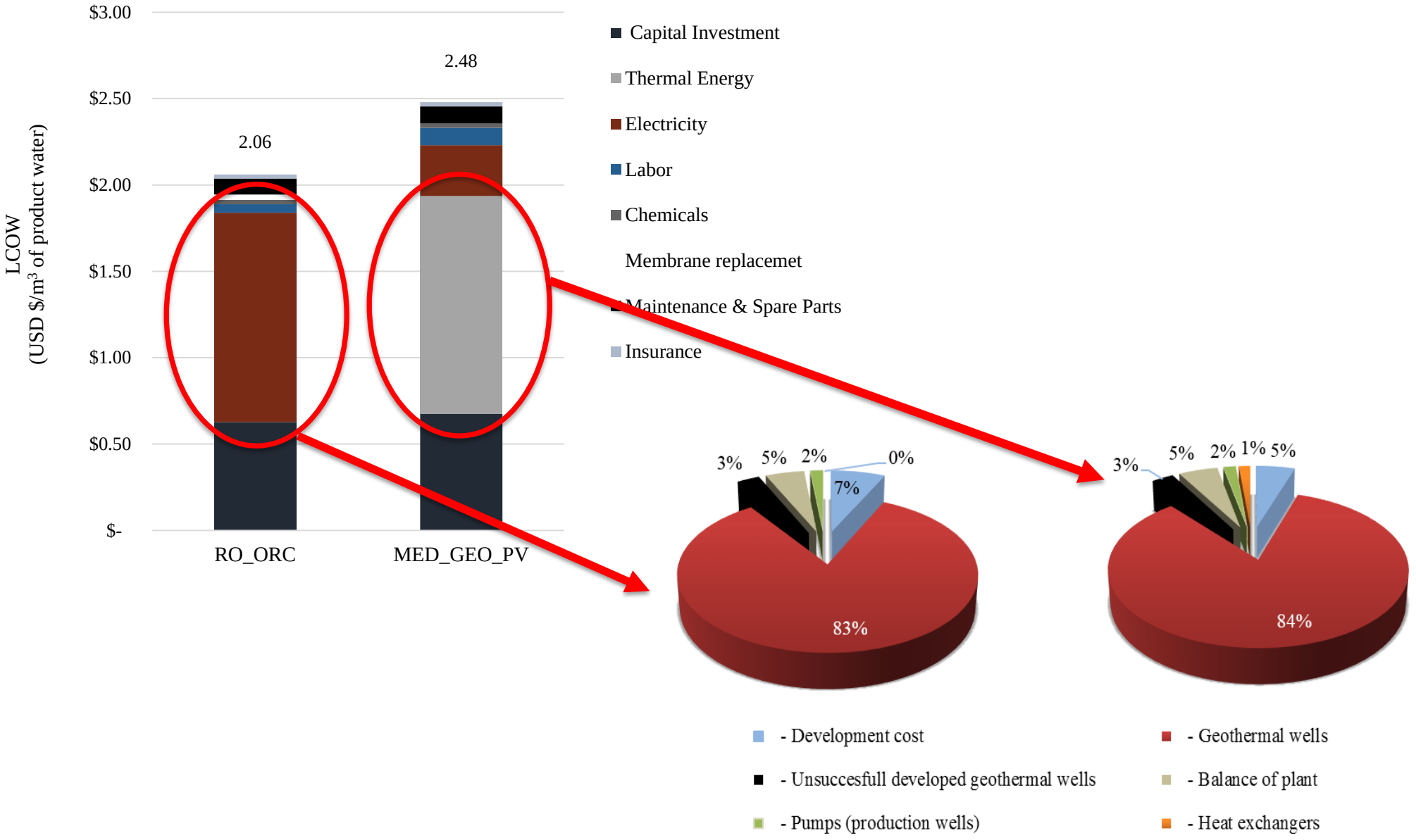
Geothermal desalination

Why geothermal desalination?





Geothermal desalination in UAE: Results



Wind-powered desalination for aquifer storage and recharge

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STORAGE CAPACITY In UAE

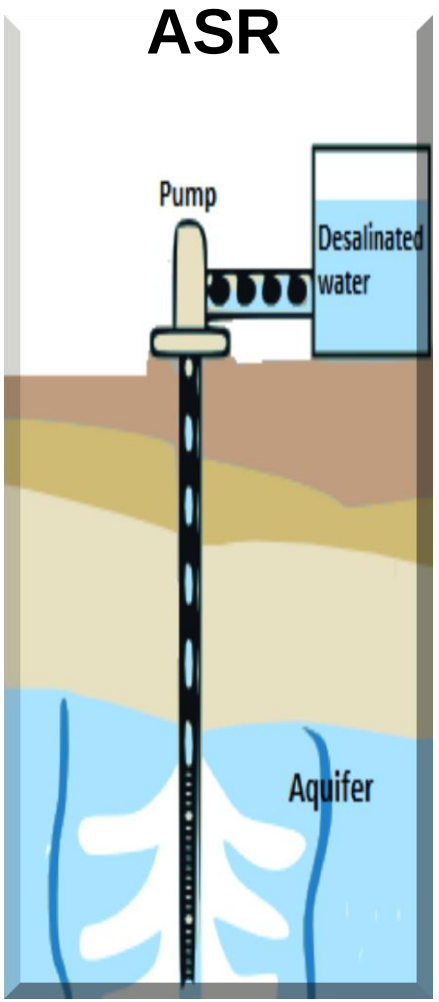
< 2 DAY

WATER

STORAGE CAPACITY

Aquifer Storage & Recovery

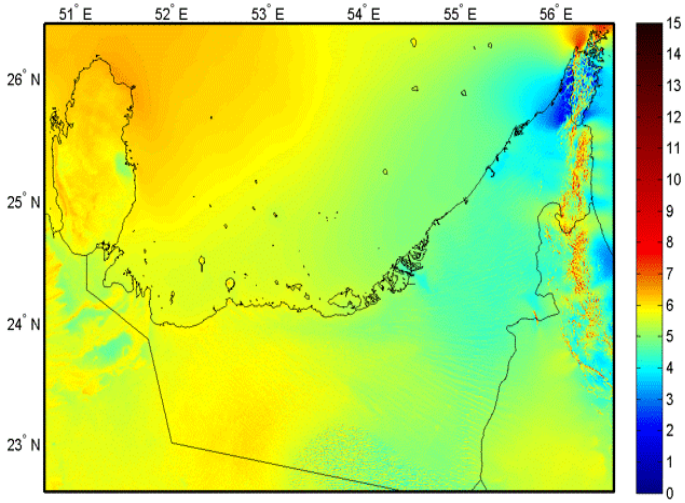
Water Reservoirs



Wind-powered desalination for aquifer storage and recharge

Why wind-desalination?

- Wind energy is the cheapest among renewable energy sources.
- For ASR, RO plant capacity can be allowed to fluctuate per available wind energy
- No need for energy storage



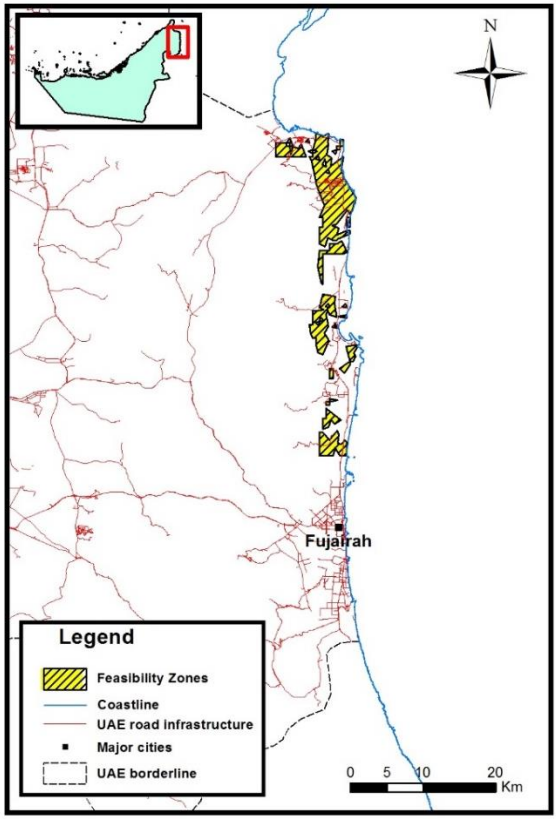
Snapshot of wind speed obtained from Wind Energy Resource Atlas of UAE – developed by Masdar Institute of Science and Technology, Abu Dhabi, UAE

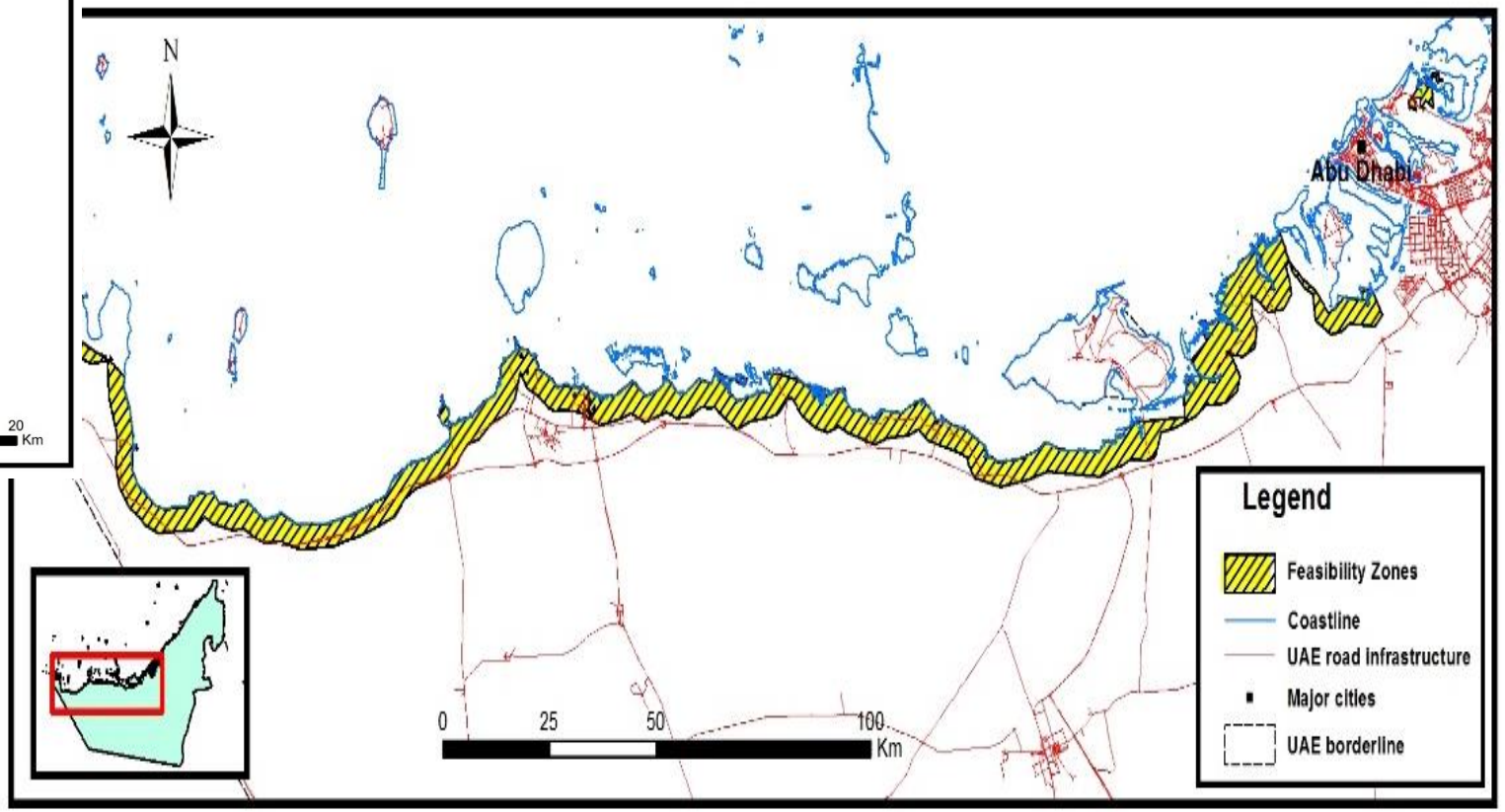
Location of existing pumping stations aimed for the conveyance of desalinated water to the Liwa Aquifer in UAE

Wind-powered desalination for aquifer storage and recharge

Objective	Criterion	Reason
Environmental	areas of ecological value are excluded	Minimization of Wind-RO impact
Social	Minimum distance from towns at 2.5 km	Acceptable in terms of safety and aesthetics for town centers
Techno-economic	Minimum distance from airports at 2.5 km	Acceptable in terms of safety and aesthetics for airports
	Maximum distance from the coast at 3.5 km	Acceptable distance between the desalination plant and the wind farm is set at 2 km. The desalination plant is assumed to have a minimum distance from the coast of 1.5 km
	Maximum ground slope up to 30%	Slope affects the cost of construction and maintenance
	Maximum distance from major roads at 10 km	The distance from road infrastructure affects the costs for construction, operation and maintenance of the wind farm
	Minimum wind speed at 5 m/s at 80 m hub-height	Economically feasible potential for wind energy generation

Wind-powered desalination for aquifer storage and recharge





The Social and Political Impacts of Desalination

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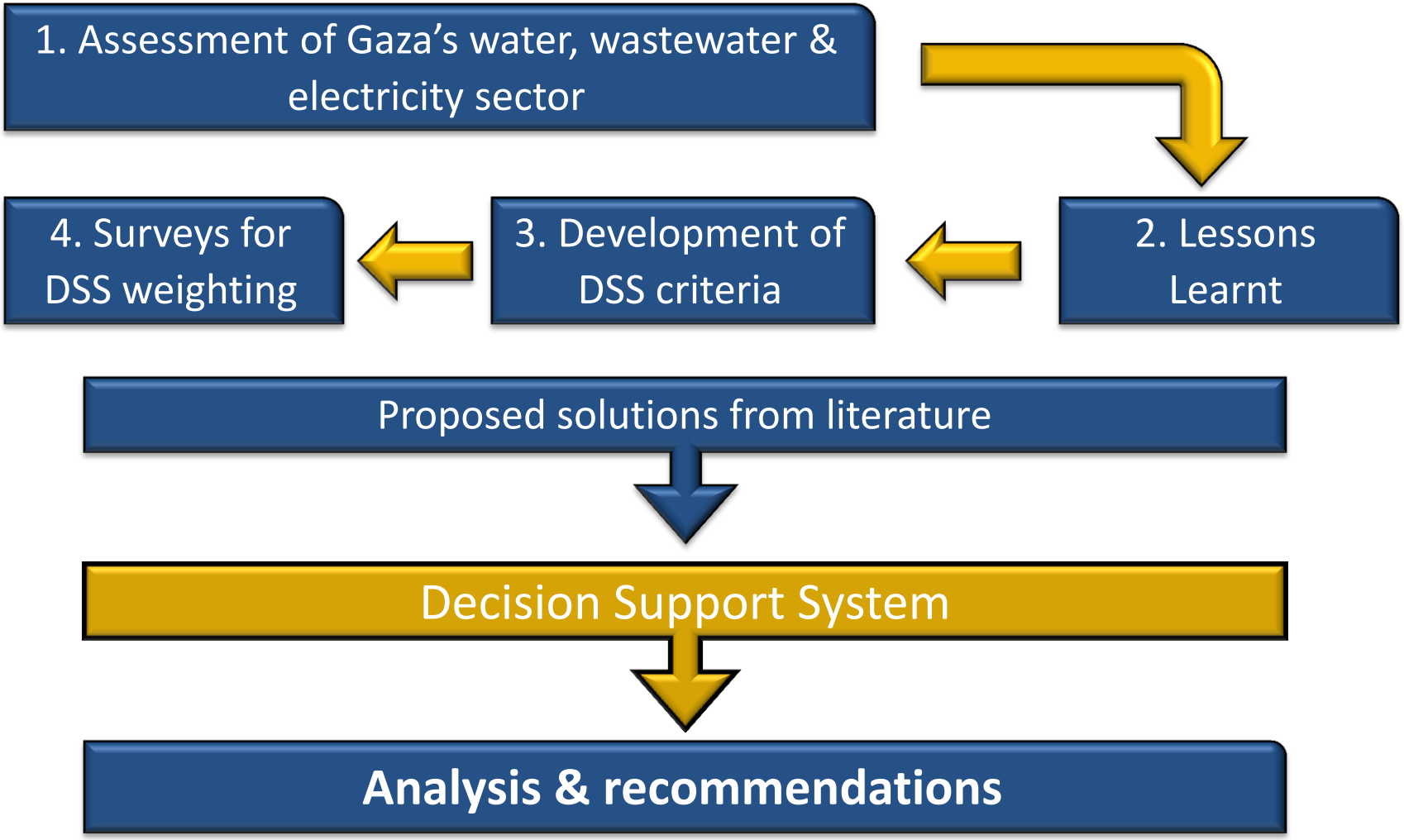
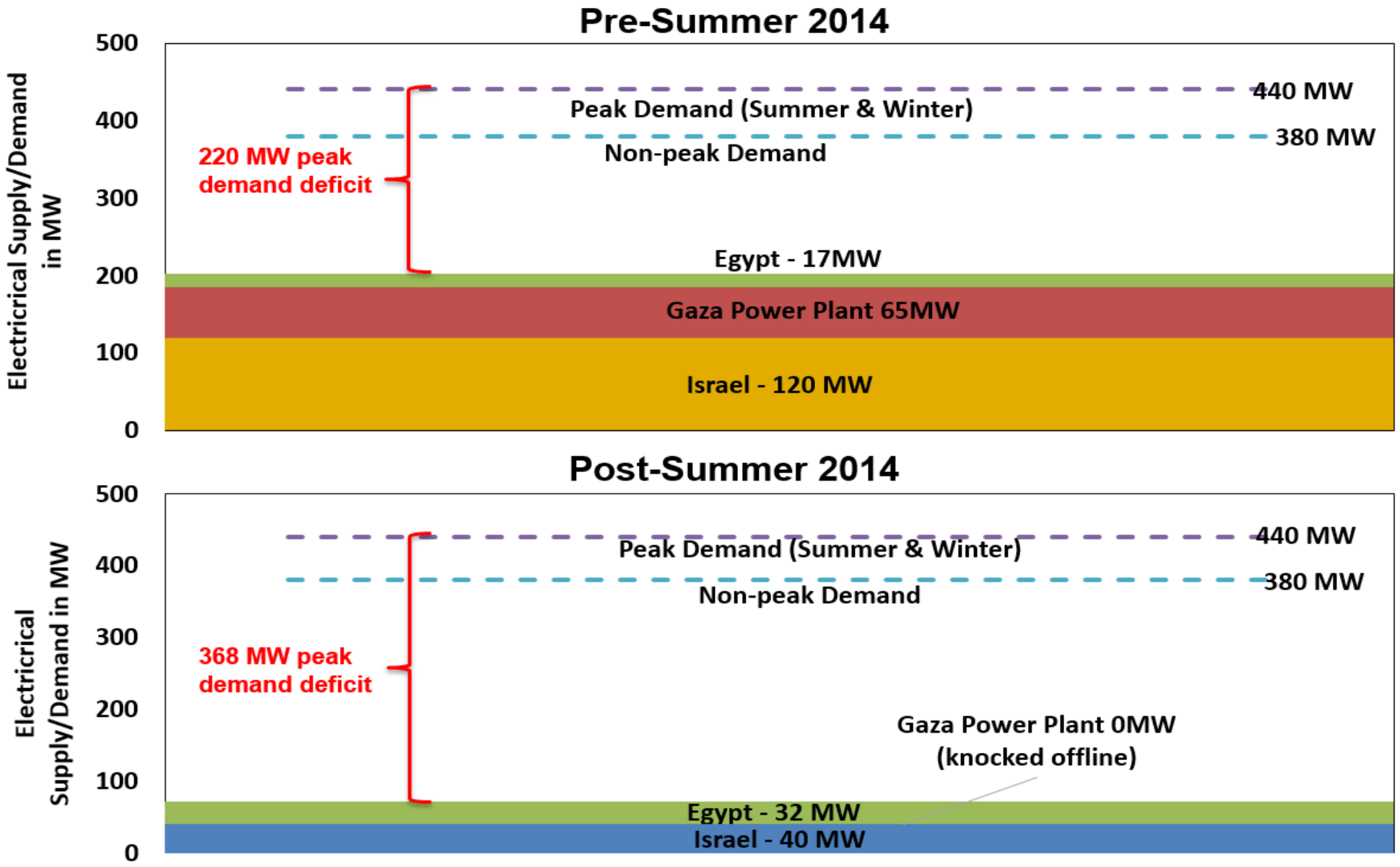
Is Desalination the solution for Gaza?

The DSS approach

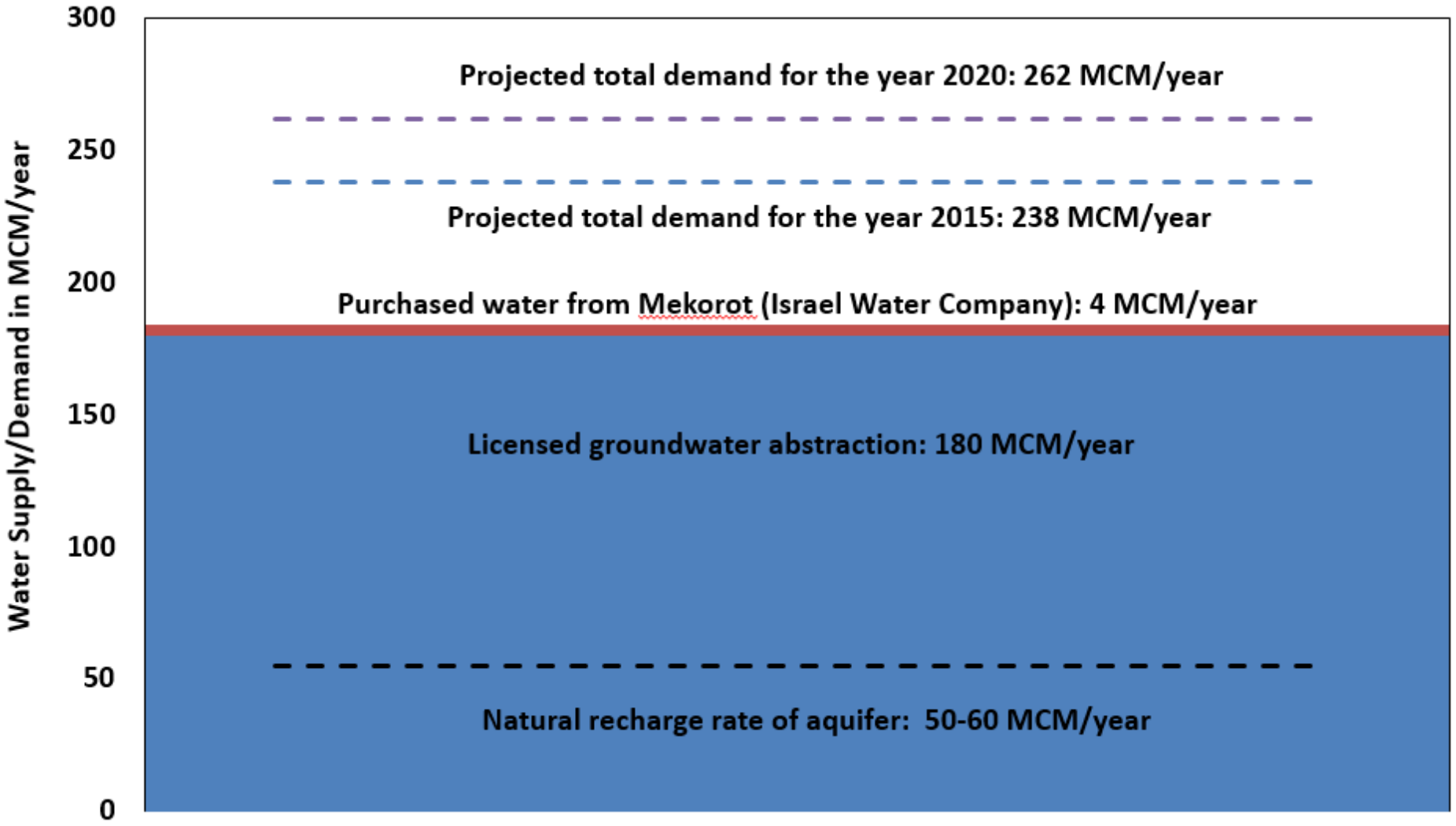


Gaza's electricity supply-demand gap



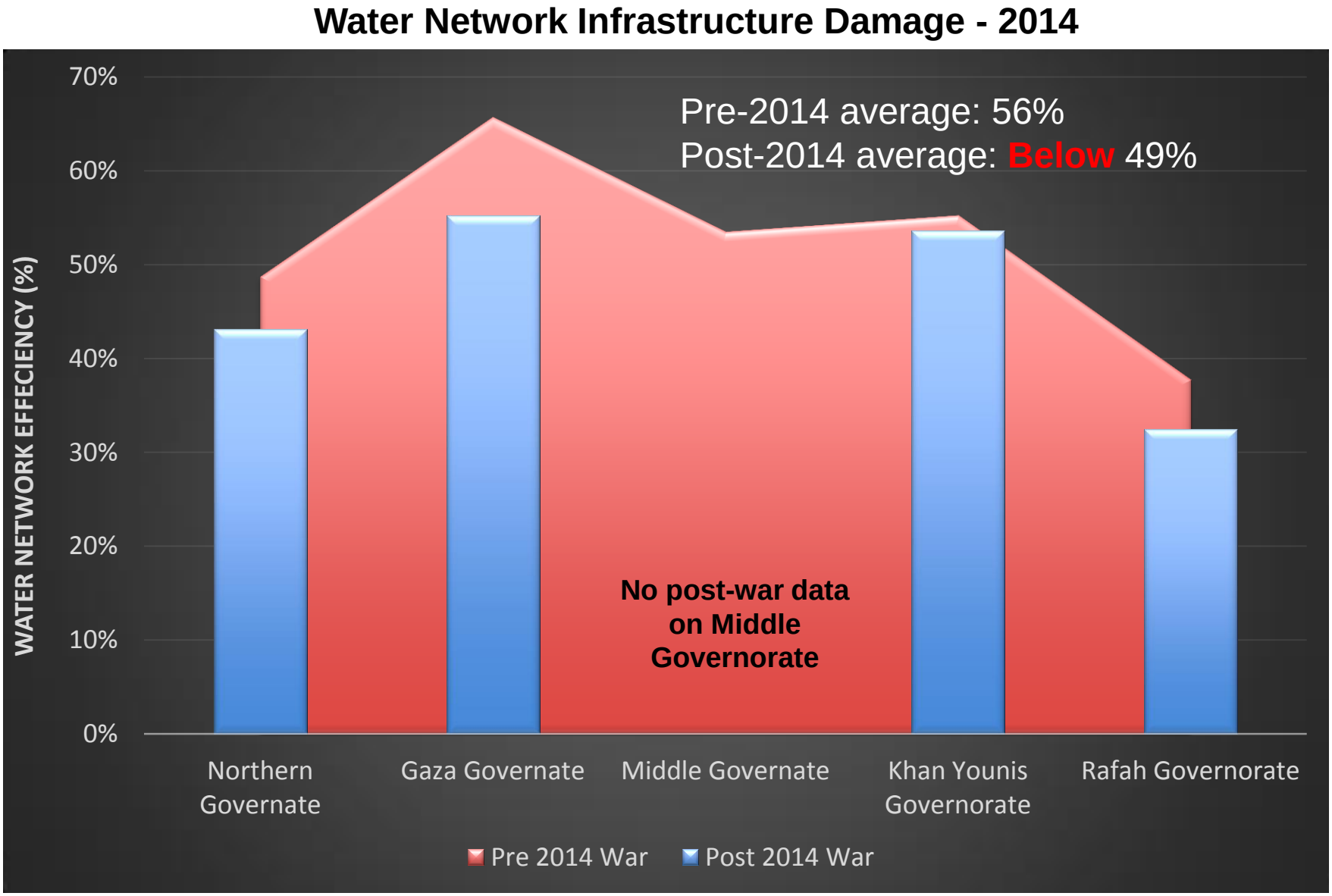
Adapted from MAS, 2013

Gaza's Water Supply-Demand Gap



Adapted from E. Van R, 2012

Gaza's water network



Gaza Decision Support System (DSS)

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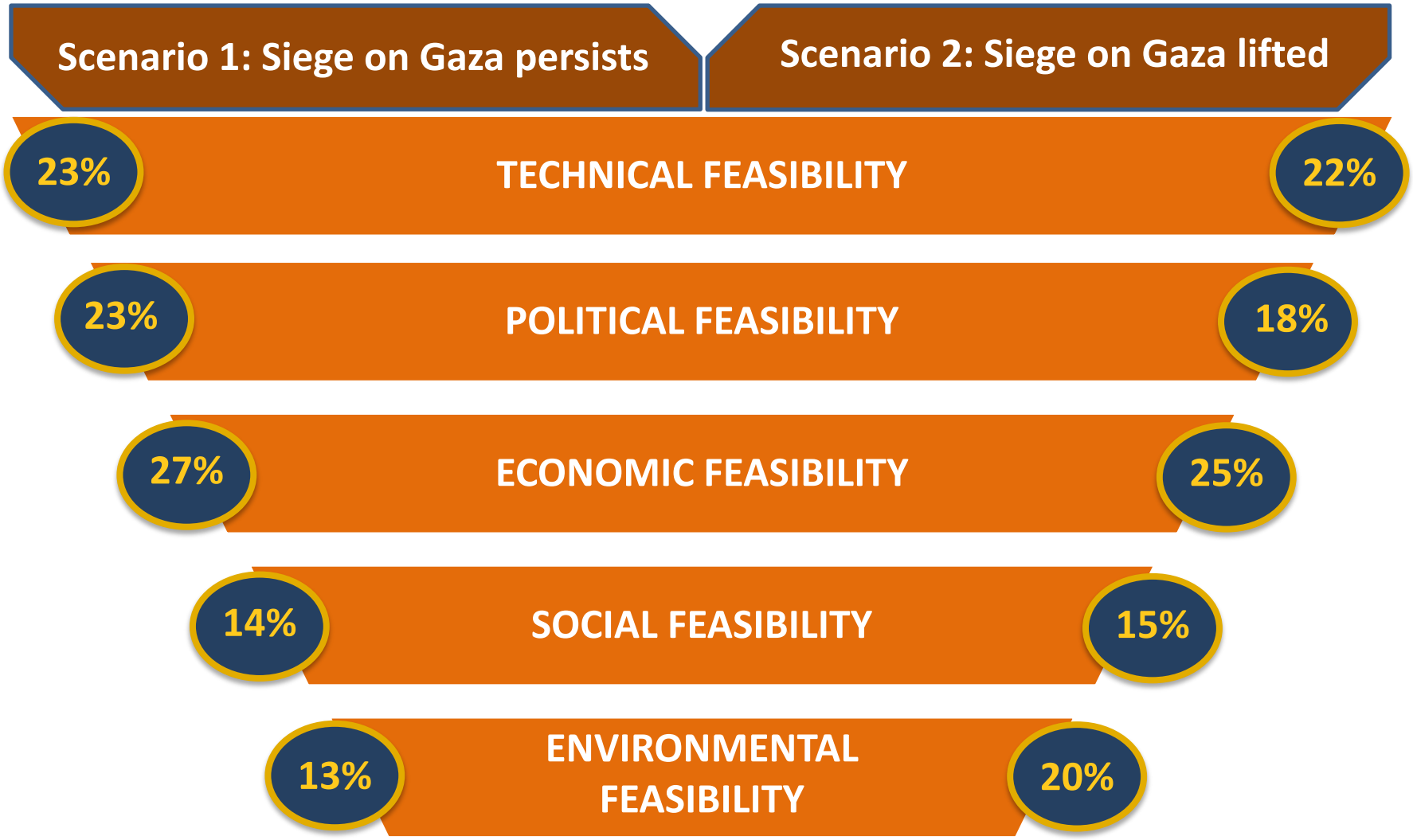
20+ water experts surveyed from Gaza and abroad



Proposed solutions for Gaza

#	Proposed Solution	Period	Description
1	**Demand side management (DSM)**	SHORT-TERM	The modification of consumer demand for water through various methods such as Economic instruments, Behavioral tools, and Technical tools.
2	**Network repair**	MEDIUM-TERM	Improving the efficiency of the water network that represent the majority of assets of water utility.
3	**Constructed wetlands**	MEDIUM-TERM	The construction artificial wetlands that require little to no power input and can be used for irrigation or to recharge the depleted aquifer.
4	**Rain water harvesting (RWH)**	SHORT to MEDIUM-TERM	Rainwater Harvesting: proposed as a feasible solution to mitigate Gaza's water crisis, given its general technical simplicity, low cost and decentralized nature which limits risk.
5	**SWRO Sinai**	LONG-TERM	Centralized Sea Water Reverse Osmosis Plant in Sinai that serves both Sinai and Gaza, minimizing the risk of infrastructural attacks or damage.
6	**SWRO Gaza**	LONG-TERM	The proposal of decentralized SWRO plants in Gaza to fill the rapidly increasing water demand-supply gap while minimizing the risk of centralized infrastructure.
7	**BWRO Gaza**	LONG-TERM	The proposal of constructing brackish water reverse osmosis plants in Gaza to address the water quality and affordability challenge as well as to fill the demand-supply gap while minimizing risk at a lower price.

Gaza's DSS Outcome

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Scenario 1 (Siege persists)

Rank	Solution	Value
1	DSM	69.3%
2	Network repair	68.7%
3	RWH	68.7%
4	SWRO Sinai	64.4%
5	Constructed wetlands	62.2%
6	SWRO Gaza Multiple	53.7%
7	BWRO Gaza Multiple	49.8%

Scenario 2 (Siege is lifted)

Rank	Solution	Value
1	Network repair	72.8%
2	DSM	68.2%
3	RWH	67.4%
4	SWRO Sinai	65.7%
5	SWRO Gaza Multiple	65.7%
6	Constructed wetlands	61.8%
7	BWRO Gaza Multiple	55.6%

So, is desalination the solution to the global water scarcity problem?

Concluding remarks

- Desalination can be a lucrative choice, especially with abundance of seawater
- However, it is a process with consequences:
  - Cost (not affordable by everyone!)
  - Multiple environmental impacts (GHG, marine life impacts, etc)
  - Social and political impacts
- Many of these impacts can be mitigated or minimized but often at a cost
- Desalination should be one tool in a box containing many other water management tools.
  - If Desalination proves to be the best tool,.. Use it!

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THANK YOU

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