Circular Economy in Aruba
Energy, Food and Water and
Tales From a Recovering Engineer

SISSTEM

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University of Aruba

Diego Acevedo

BSc. Mechanical and Engineering – University of Florida (2003)

MSc. Sustainable Energy – TU Delft (2016)

PhD – Engineering Science – KU Leuven Chemical Engineering (Sustainable uses for Reverse Osmosis Brine)

Parallel research/ Areas of Interest:

- Industrial Ecology
- Fresh water production systems
- Wastewater treatment systems
- Ocean Energy
- Tropical food production systems

"People protect what they love, they love what they understand and they understand what they are taught."

- Jacques Yves Cousteau

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- Sustainable Island Solutions through Science, Technology, Engineering and Mathematics

Technology and Engineering

Bioenvironmental Sciences

Information and Data Sciences

Diego Acevedo created using Dall-e

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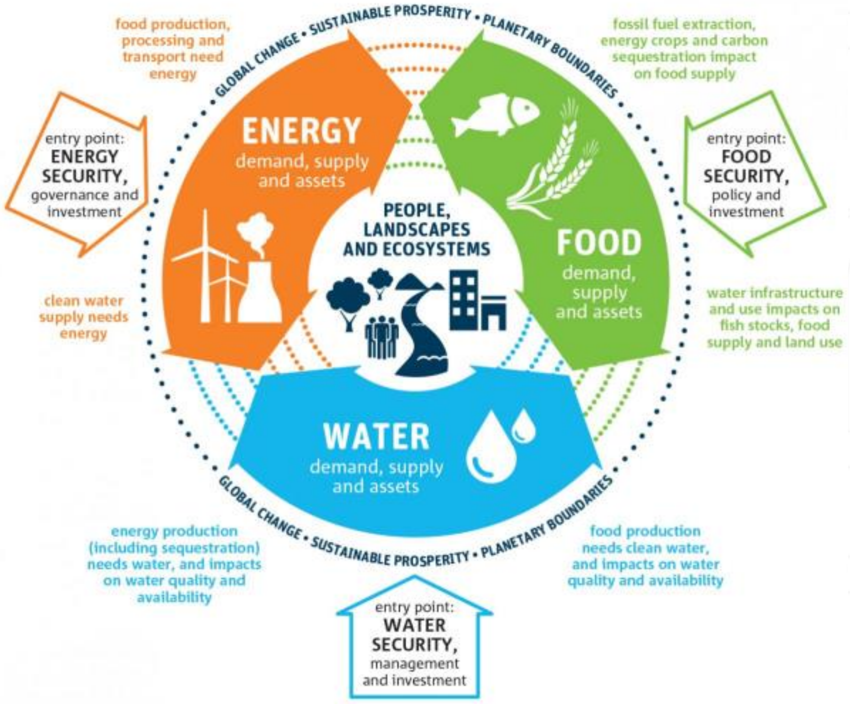
- Islands are the perfect pioneering laboratory



Source: IWA, 2018. Sustainable Development: The Water-Energy-Food Nexus.

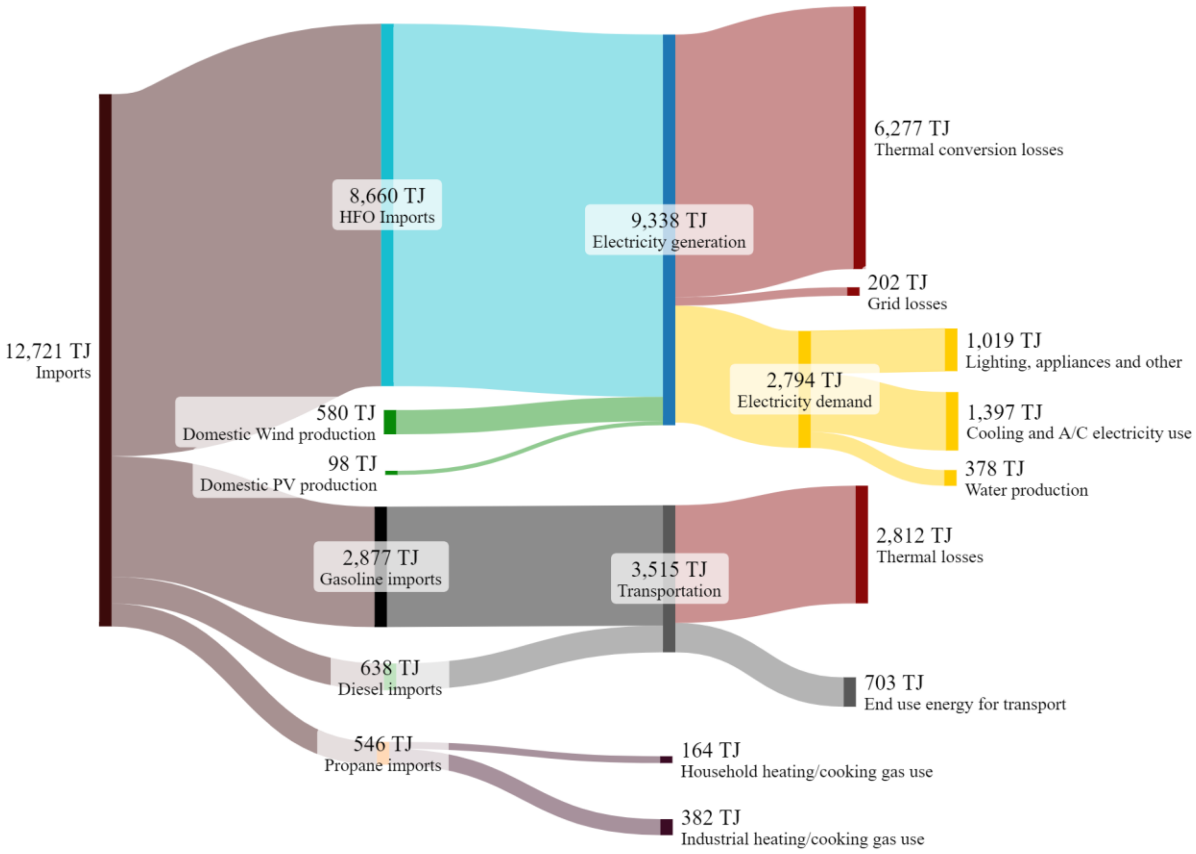

KARLVILLE
BEYOND CONVERTING
UV Open Seam Detector


Nesquik
Lipton
Ice Tea
PERSIL

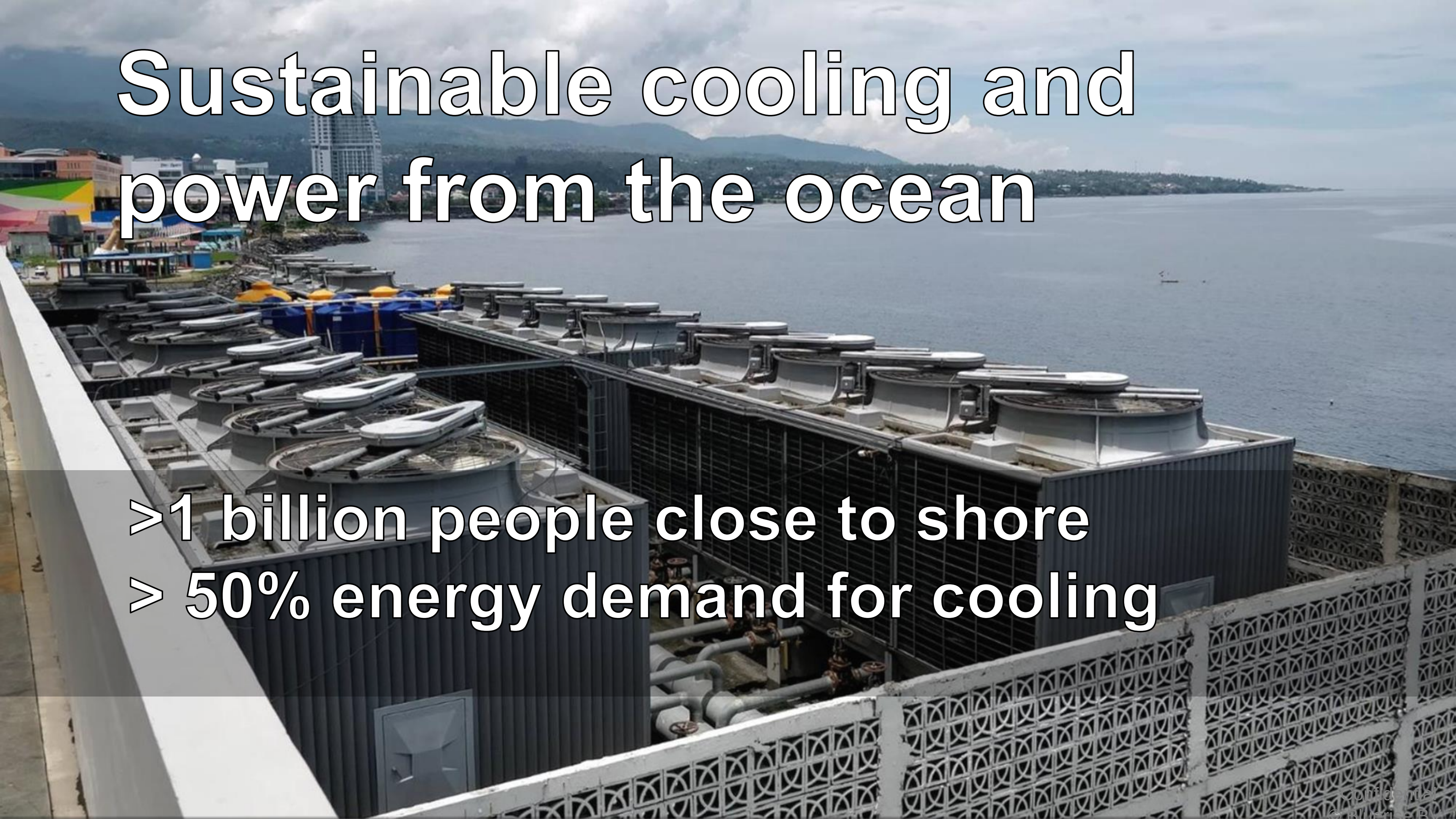

“How inappropriate to call this planet Earth when it is quite clearly Ocean.”
Arthur C. Clarke

Energy

- Water production 100% desalination
- RO processes between ~3.75-4.3 kWh/m^3
- For Aruba: 13% of electricity production for Aruba
- Approximately 13,000,000 m^3/yr
- 378 TJ = 105,000 MWh per year



Energy Flows of Aruba 2018



Sustainable cooling and power from the ocean

>1 billion people close to shore

> 50% energy demand for cooling

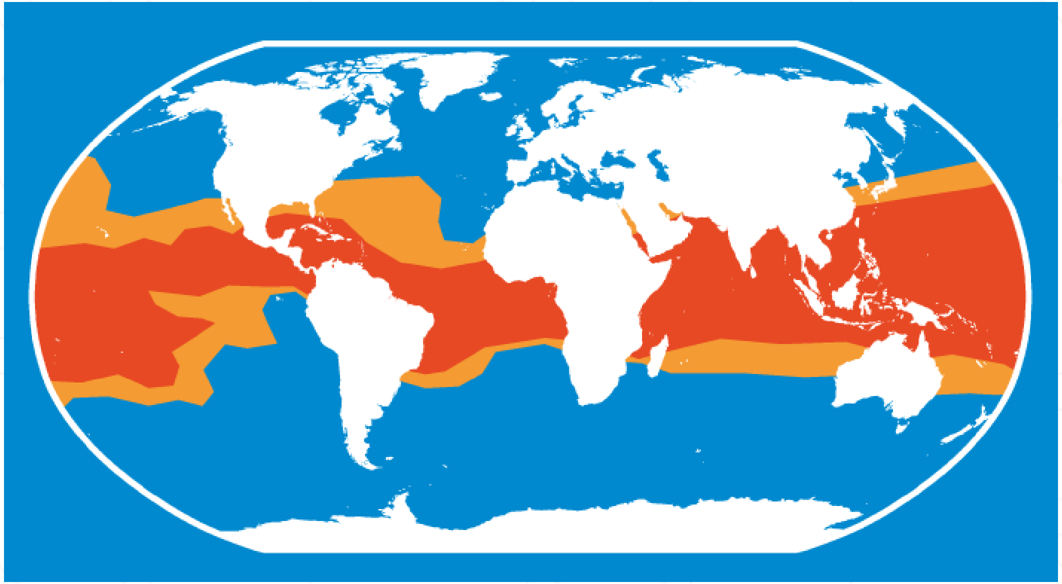
Problem

> Dependent on imported diesel

> Energy price are high > $0.20/kWh

> Current renewables (wind and solar) are intermittent and require significant land use

OTEC Resource



"About 7 terawatts, or three times the global electricity demand can be taken from the ocean without affecting the temperature of the ocean or our environment."

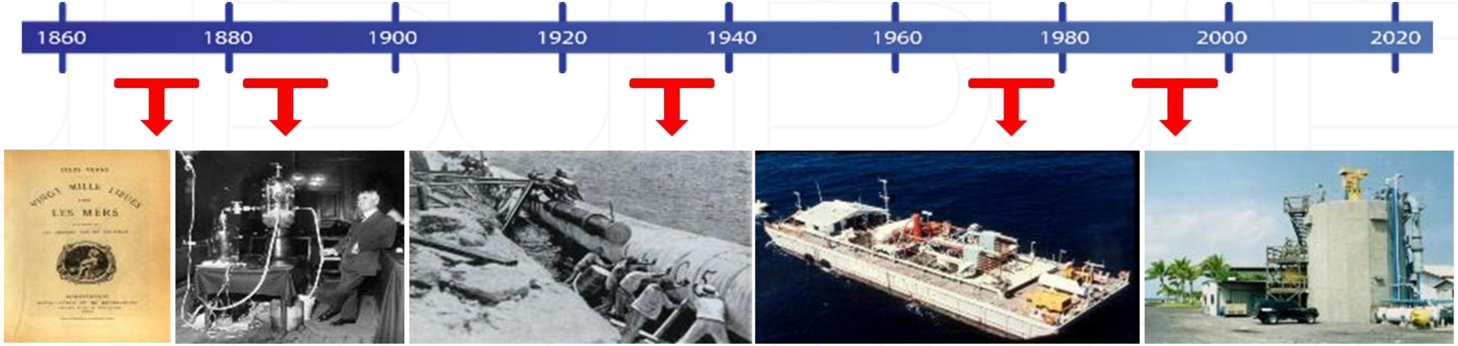
Dr. Gérard Nihous, University of Hawaii

	% global electricity consumption*	Capacity factor
Wave Energy	50-500%	25-40%
Tidal Currents	2%	22-28%
Ocean Currents	5%	26-40%
Ocean Thermal	**200%**	**90-100%**
Salinity Gradient	9%	901-00%

Source: IPCC-SRREN, 2011

Over **100 countries and territories** have access to Ocean Thermal Energy

Where is OTEC now?



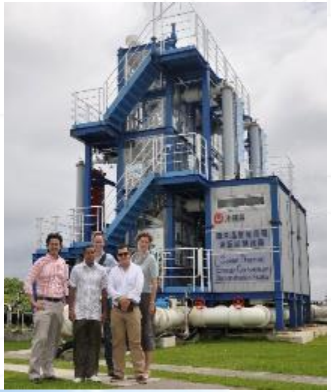
22kW OTEC, Cuba

50kW OTEC, Hawaii

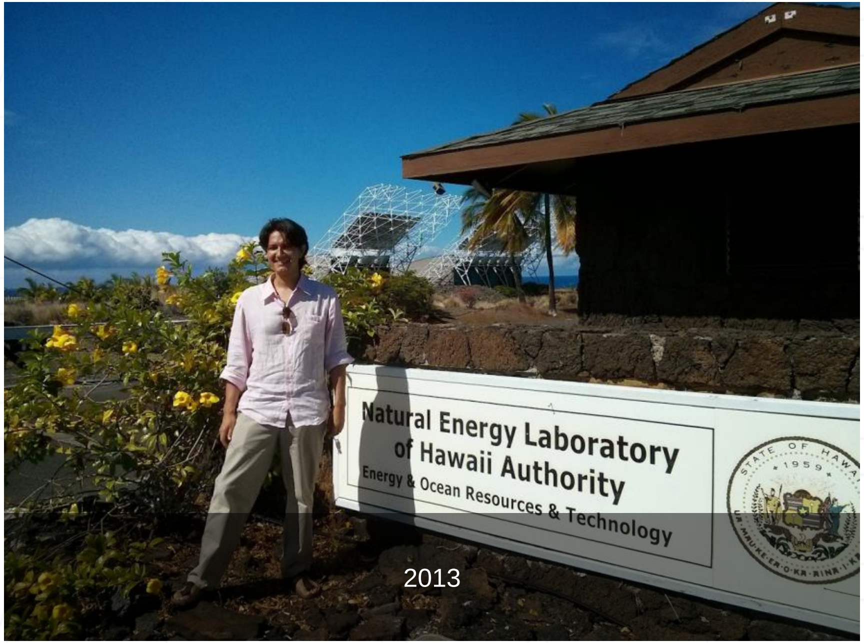
210kW OTEC, Hawaii

Where is OTEC now?

Lab Scale



Grid connected pilots (>200kw)

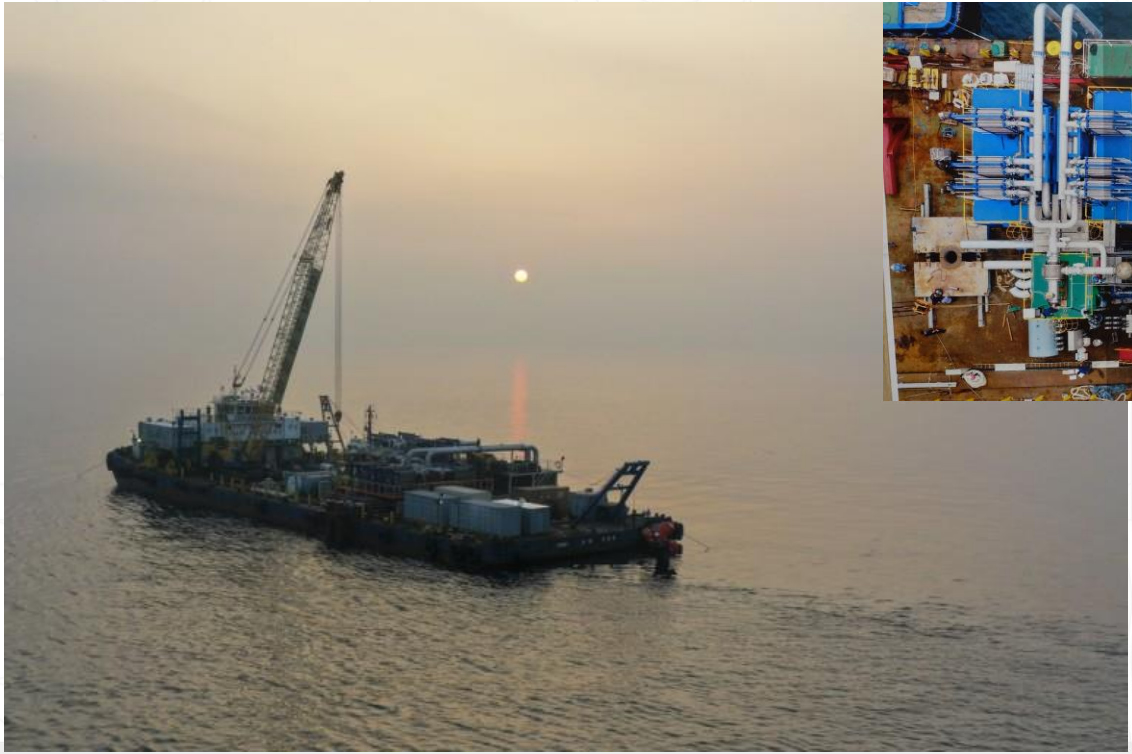

Natural Energy Laboratory
of Hawaii Authority
Energy & Ocean Resources & Technology

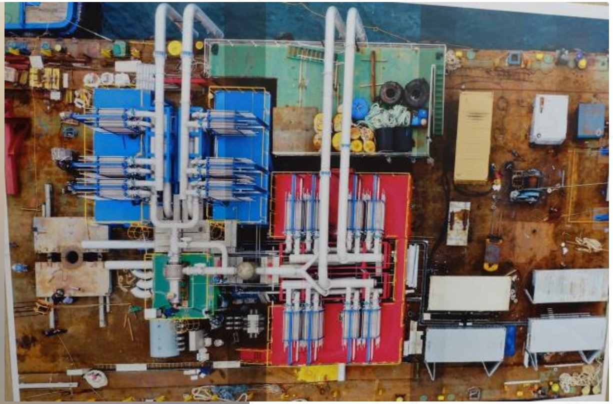
2013


沖縄県
海洋温度差発電
実証試験設備
Ocean Thermal
Energy Conversion
Demonstration Facility

2014

Where is OTEC now?

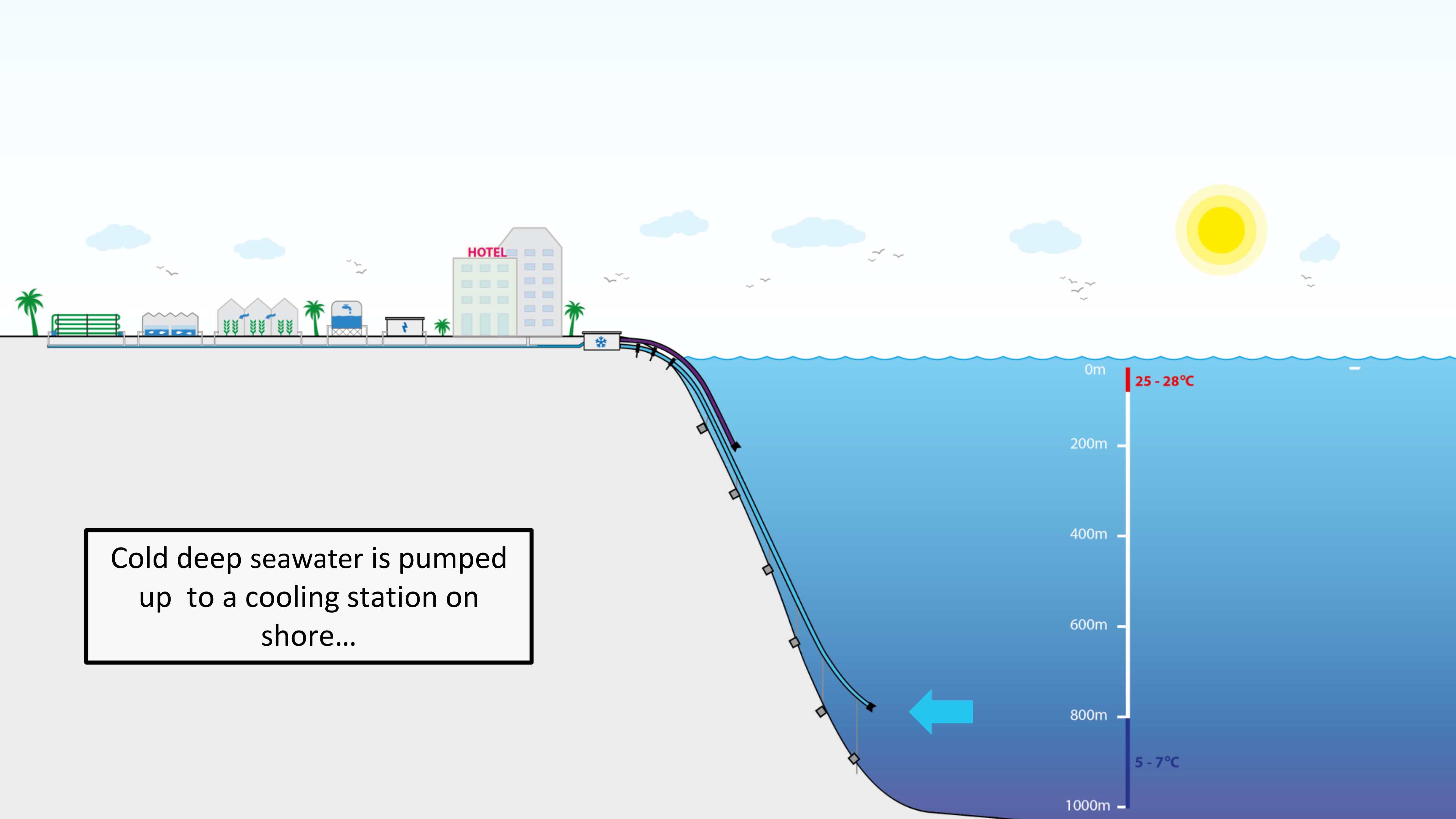


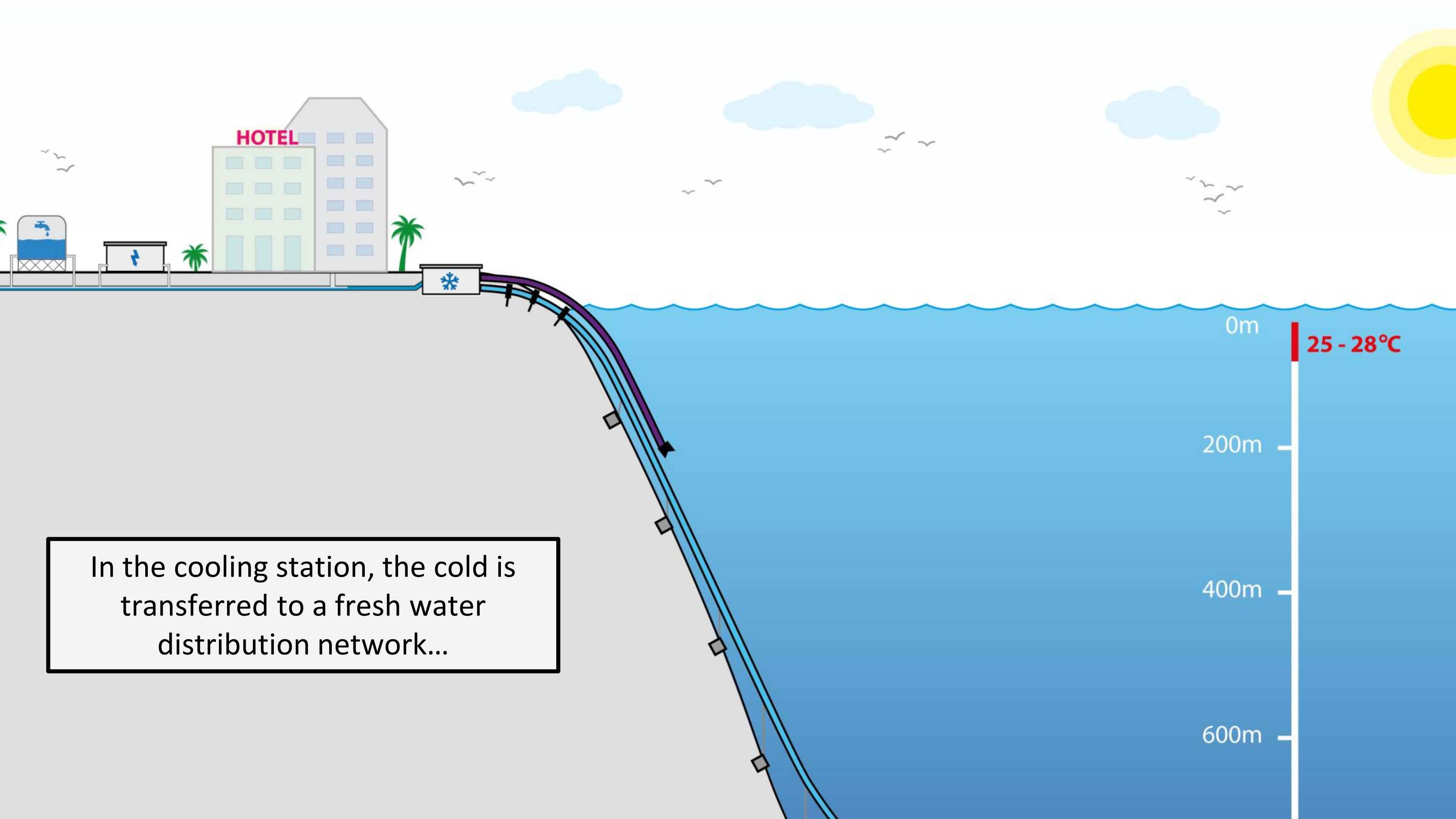


1 MW Gross power – KRISO Source: otecnews.org

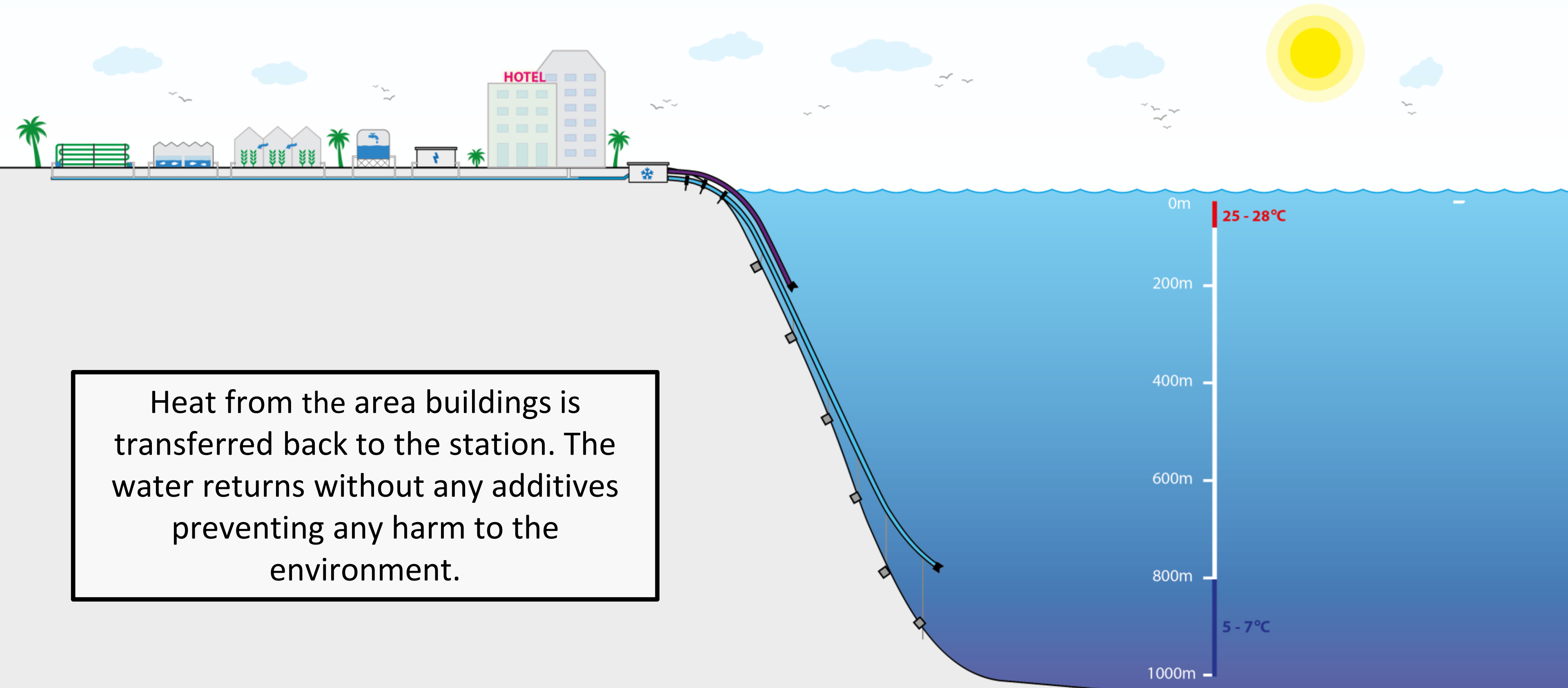
Challenges

- Complexity in Offtake contracts,
- Lack of support mechanisms,
- High Risk + Long Term investments needed
- **Lack of match between need for the technology and ability to develop it (islands vs. continental regions)**


HOTEL
0m
25 - 28°C
200m
400m
600m
800m
5 - 7°C
1000m
Cold deep seawater is pumped up to a cooling station on shore…



In the cooling station, the cold is transferred to a fresh water distribution network…



Heat from the area buildings is transferred back to the station. The water returns without any additives preventing any harm to the environment.

District cooling is not completely new…

Systems like these have matured and are in operation in several countries for decades already

Implementation is expanding all over the world

Examples can be found in the USA, Canada, Sweden, Denmark, Finland and The Netherlands

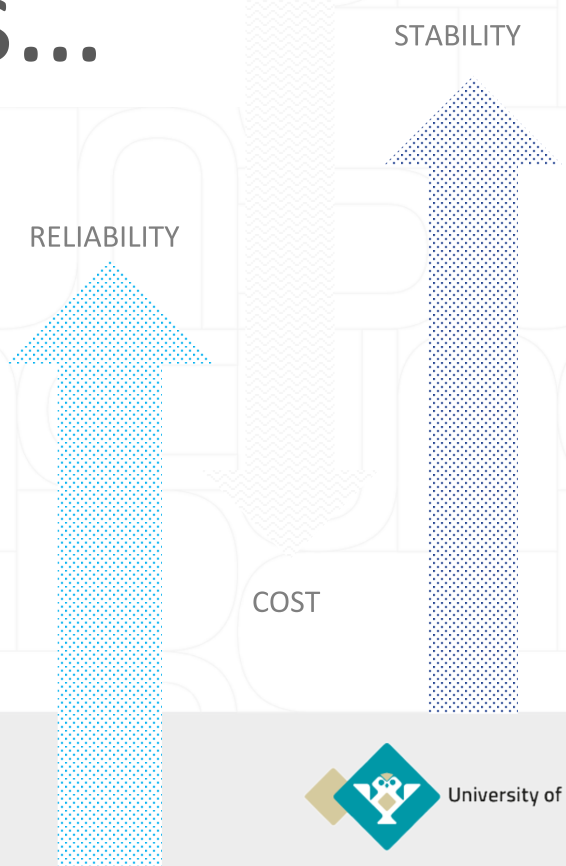
District cooling systems are also operational in relatively harsh and remote environments like the United Arab Emirates, French Polynesia or Qatar

Operational benefits...

Lower energy costs
We guarantee a price lower than the current price for cooling

Stable and predictable price
As a client you pay a fixed rate for cooling, which does not depend on fluctuating fossil fuel prices

Less maintenance / high reliability
No more compressors and refrigerants in house



Commercial benefits…

Environmentally friendly
Exceeding the global trend to provide a environmentally responsible tourism experience

Less maintenance / high reliability
No more compressors and refrigerants in house

Less noise
Due to central system and no more unsightly AC units on outside of buildings

THE COOLING STATION

The place where the cold seawater comes on Shore and is called the Cooling Station

Here, the cold seawater transfers its cold to a fresh water loop which takes the cold to the district cooling customers

The cooling station is equipped with:

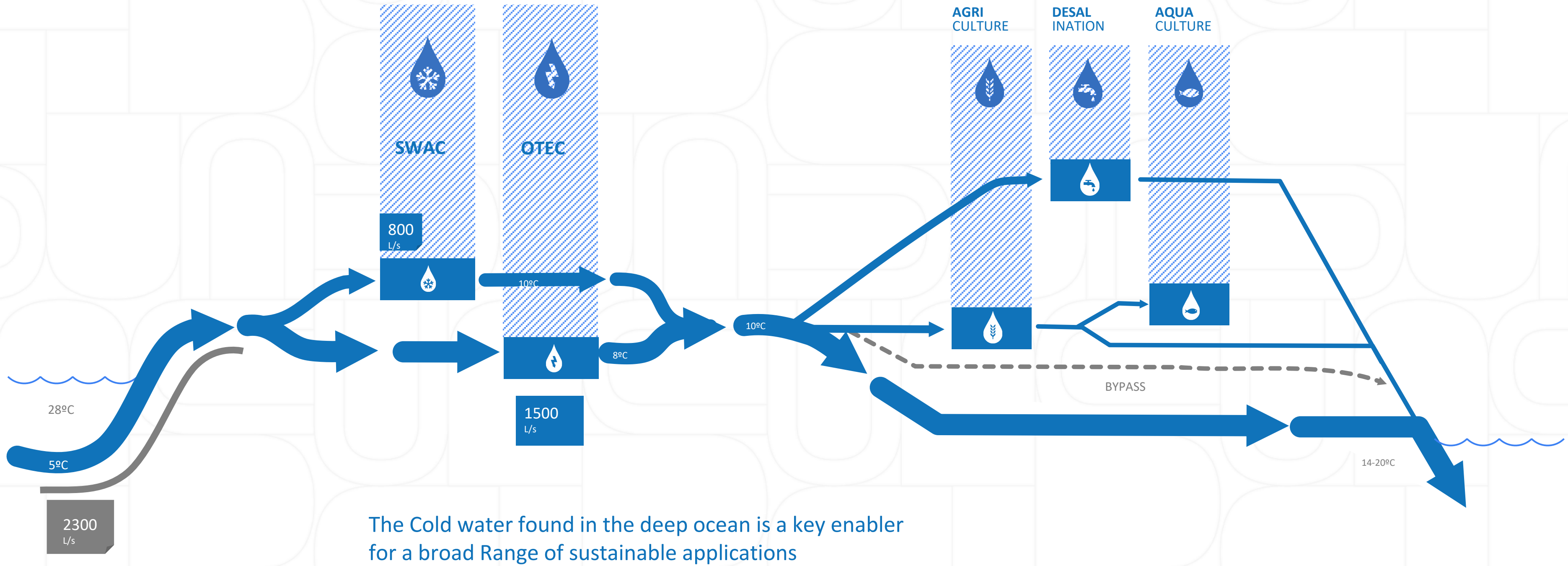
Seawater filters
Titanium heat exchangers
back-up chillers

BONNO
KOBELCO
RK 250
P&H
KOMATSU


DSMC

On-going efforts
Latin America/Caribbean

- Dutch Islands (Aruba, Bonaire, Curacao) - Government policy drafted, OTEC/SWAC seen as strategic importance but no support mechanisms (yet)
- Martinique – Nemo project stopped
- Barbados - IDB supported Ocean energy report – OTEC + offshore wind
- Cayman - OTEC as part of Utilities IRP
- USVI – on-going efforts private development
- Dominican Republic – SWAC development on-going (feasibility supported by USAID)
- Jamaica – On going SWAC development – (CDB support)
- Cuba – University led research
- Colombia – University led research – private proposals
- Mexico – establishment of CEMIE-O, starting Resource assessment



COLD SEA
WATER

The Cold water found in the deep ocean is a key enabler for a broad Range of sustainable applications

What is the ***economic value*** possible from processing of ***Reverse Osmosis Brine*** for ***small islands***?

Diego Acevedo created using Dall-e

Desalination in the ABC islands

- **A**ruba, **B**onaire, **C**uracao: A century of desalination knowledge
- 1903 – desalination of process water for gold mining operations
- As public utility in Aruba since 1932, Curacao since 1928, Bonaire since 1963
- MED → MSF → Reverse Osmosis
- Aruba is 100% dependent on desalination

Globally over 22,000 commercial desalination plants in operation

- ~1,700 seawater systems over 5,000m^3/day (>75% of which are using RO)
- At least 15 islands in the Caribbean with systems over 5,000 m^3/day

Location	Production capacity (m^3/day)	Avg daily Production (m^3)
Aruba	70,000	42,000
Bonaire	33,600	7,200
Curaçao	50,000*	40,000

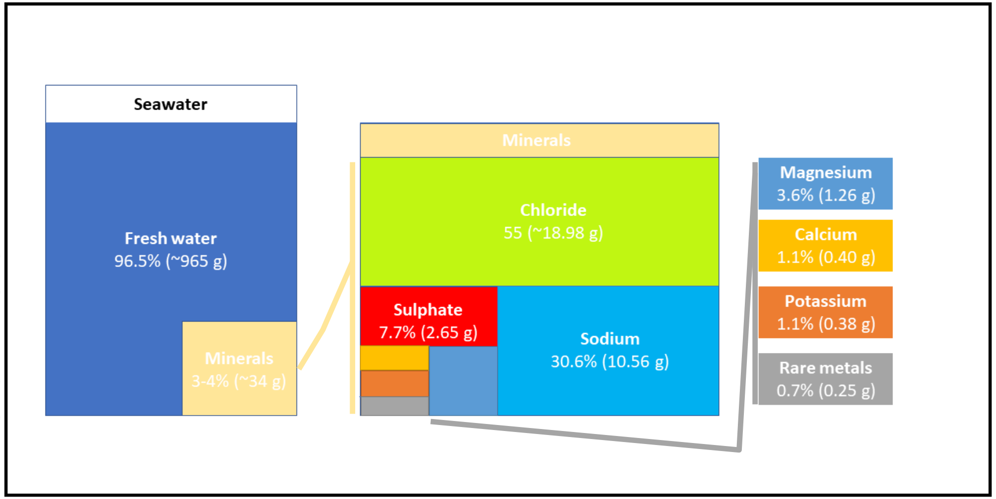
Seawater Composition

	Al	As	Au	B	Ba	Be	Ca	Cd	Ce
Seawater	255.90	-55.32	20.87	145.53	-610.18	-210.45	8781.74	-730.38	-344.55
Brine	257.55	-30.68	15.94	121.29	-610.32	-210.60	8030.37	-730.59	-344.14

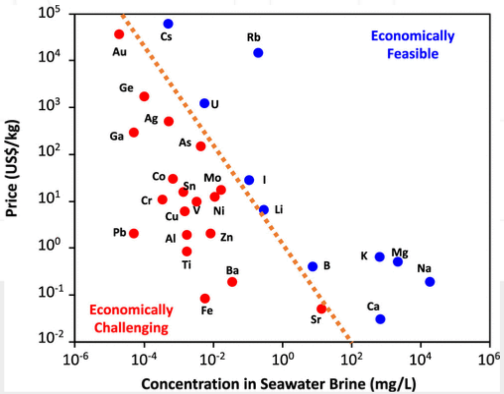
	Co	Cr	Cu	Fe	Ga	K	Li	Mg	Mn
Seawater	-471.57	-363.22	170.65	-579.24	-55.72	1775.61	21.21	4974.39	-817.27
Brine	-471.59	-363.44	150.27	-584.97	-55.37	2290.85	21.91	6808.91	-817.70

	Mo	Na	Ni	Pb	Ru	Se	Sr	V	Zn
Seawater	-535.49	32110.71	-545.73	-478.10	-520.77	-18.92	38.39	-313.40	-307.19
Brine	-535.28	41143.87	-546.27	-475.56	-521.79	-14.07	46.04	-315.11	-310.57

Bonaire desalination samples ICP-MS analysis (conc in mg/l). KU Leuven



Concentration of key minerals in typical seawater. Adapted from: Water Condition & Purification, January 2005



Recoverability potential for different metals in seawater. Kumar et al.

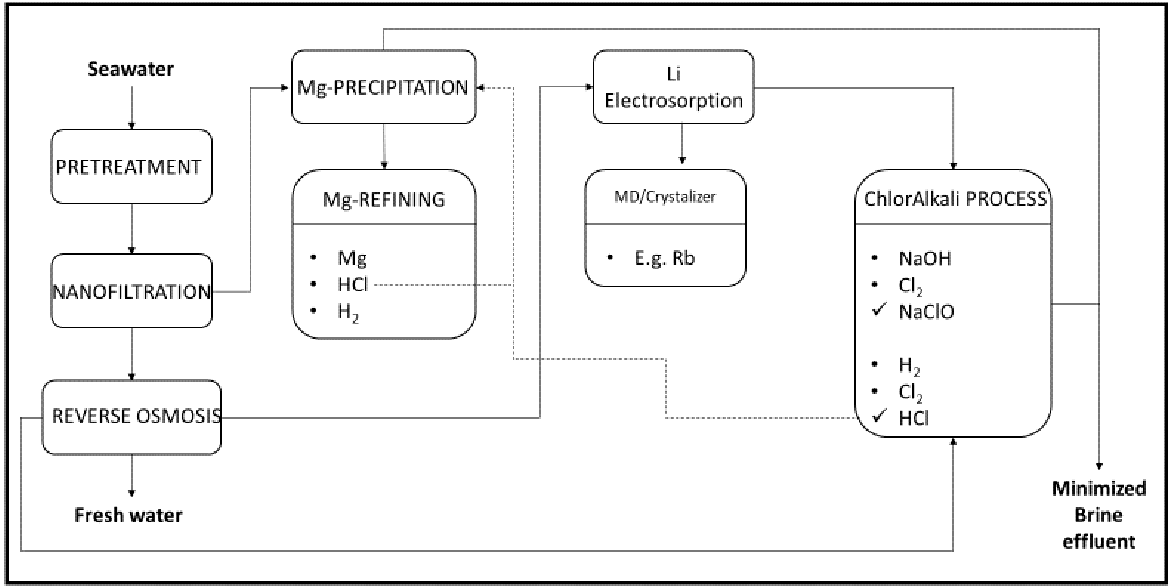
Seawater processing facilities

https://www.dutchcaribbeantv.com/diferente-kompanianan-a-mustra-interes-den-e-area-di-refineria-di-aruba/

Seawater processing facilities

Diego Acevedo created using Dall-e

Seawater processing facilities



Seawater processing facilities

From RO Desalination plants → Sustainable Seawater Refineries

- Minimize direct environmental impact: Lower salinity and amount of effluent
- Increasing economic value of existing infrastructure, maximizing efficiency (affordability of better brine discharge techniques)
- Emissions and impact avoidance from alternate sourcing of recovered materials – LCA as a tool for evaluation

Aruba: 40,000 m^3/day average production
Average cost of water \$4.20/m^3 → ~ \$54 million/yr revenues

Seawater processing facilities

Example estimated extraction potentials:

Magnesium:	**~149,000tons/yr**	**~$372 million/yr**	***export potential***
Rubidium:	**~4 tons/yr**	**~$ 50 million/yr**	***export potential***
Lithium (0.33mg/lt):	**~7.2 ton/yr**	**~$120,000/yr**	***export potential***
Chlorine and Caustic Soda	**(1.5 tons local use)**	***~$2.7 million/yr***	***import reduction***
Energy Recovery	**WWTP/Brine (8,000m^3/day)**	**~$1 million/yr**	***in-house energy use***

Metric that can has been suggested in literature is **LCOWP Levelized Cost of Water Processing** per volume of water but that metric would neglect to take into account the synergetic benefits of co-processing (due to e.g. infrastructure, overhead, efficiency improvement), currently investigating different methodologies.

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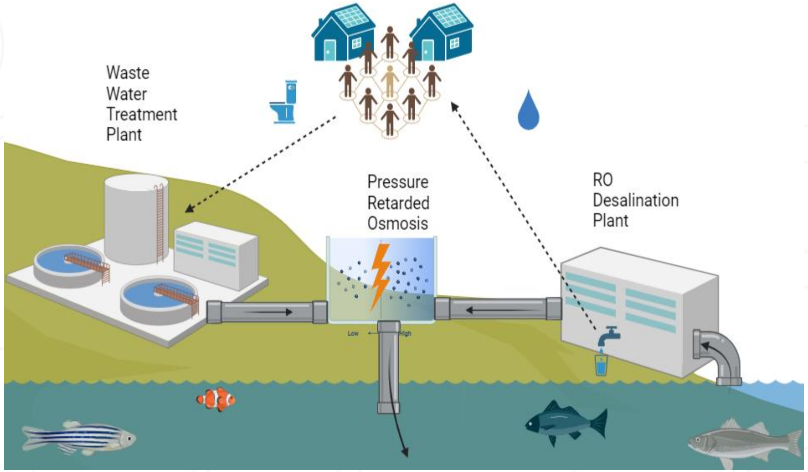
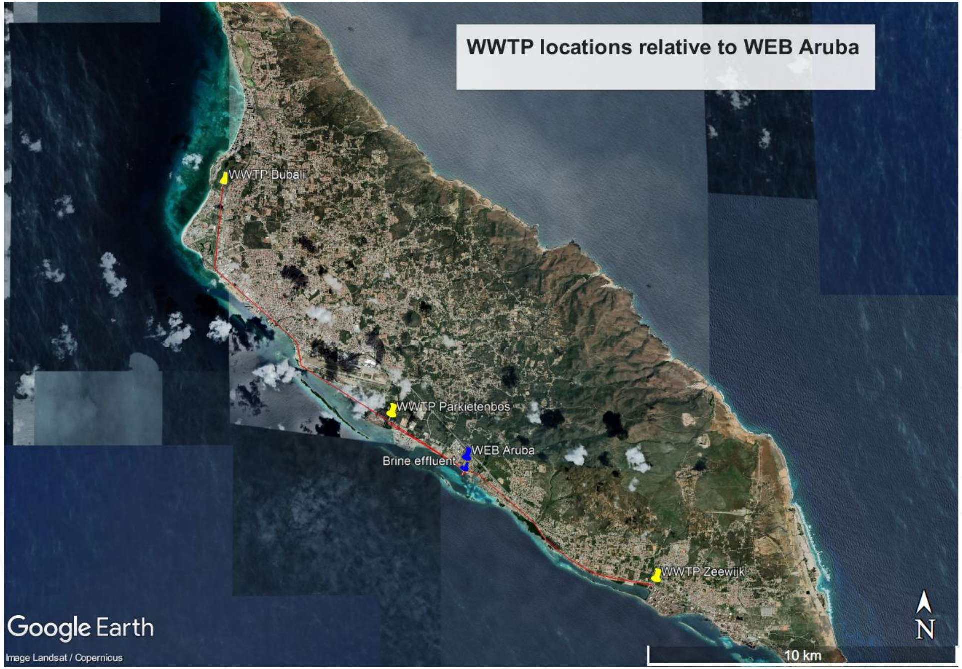
Energy Recovery

- If availability of WWTP near desalination plant, then potential energy through osmotic power technology in the order of 1.5 kWh/m^3 (Aumesquet-Carreto et.al 2022)



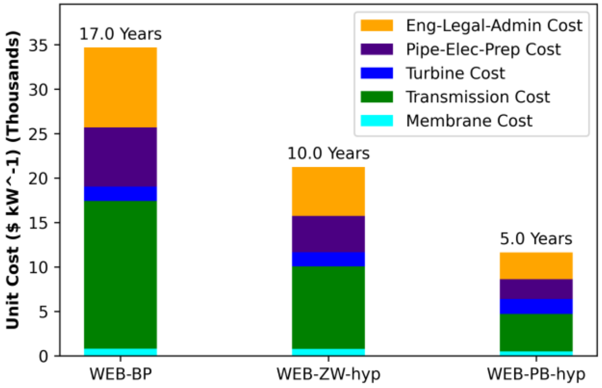
Schematic of RO-WWTP PRO connection (Created with Biorender)



Energy Recovery

- Co-location for future WWTP and desalination plants is promising

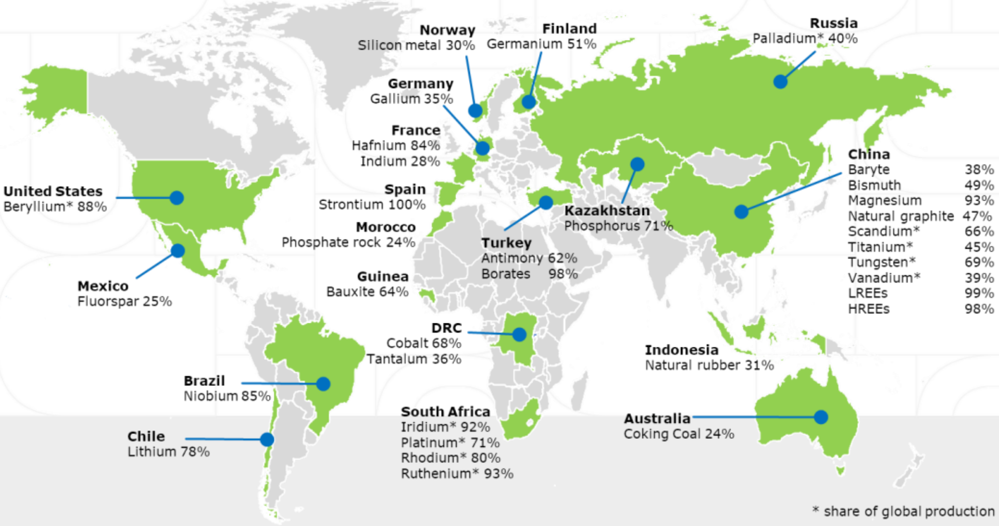
- Hydrogen recovery from electrolytical processes (e.g. chlor-alkali, magnesium production) may support renewable energy fluctuations.



Unit capital cost breakdown each comparison of relocation of main WWTP to different locations. Payback period for each case is listed above the bars. (Calculated using Propmod software)

Magnesium

- *Demand:* In 2021, global demand of magnesium was estimated at 1.03Mt of which 88% was supplied by China through Pidgeon process.
- *Environmental impact*: 45 tons of CO_2 eq vs. with current production methods < 10 tons of CO_2 eq. through seawater recovery and, it is estimated that approximately 11 tons of raw material are processed per ton of magnesium produced through Pidgeon process.

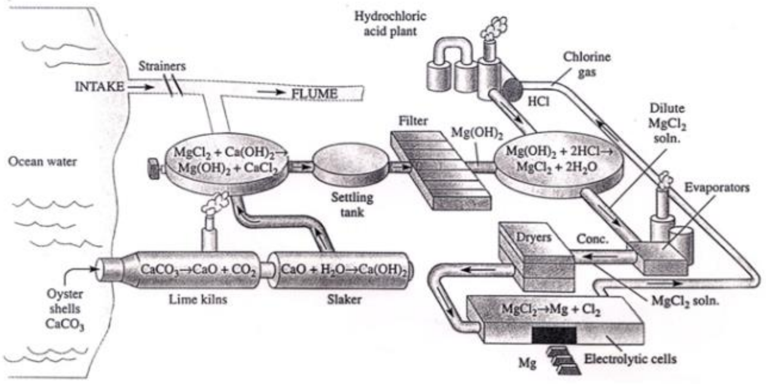


Critical Raw Materials strategy for the EU
Credit: European Commission

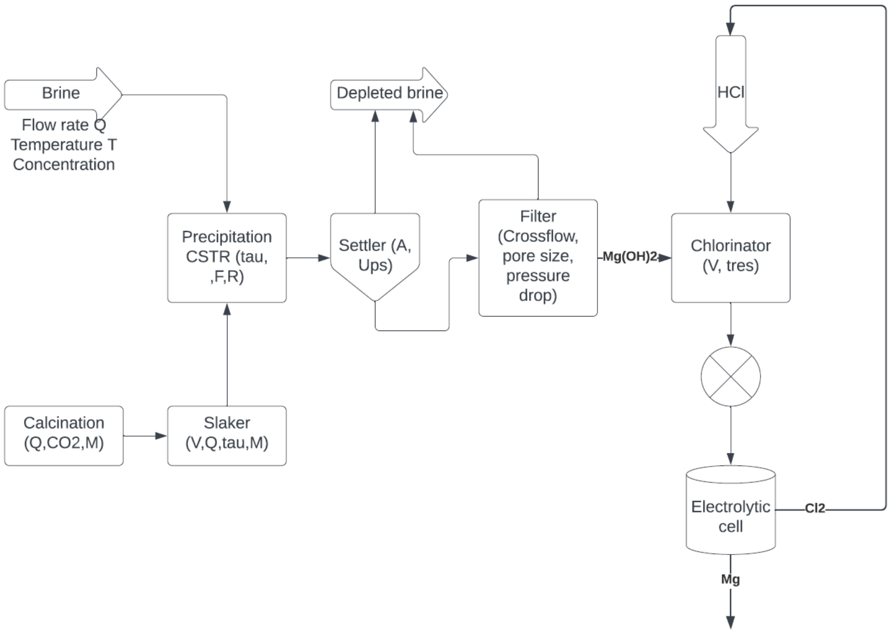
University of Aruba

Magnesium

- Historical precedent (DOW Process)



P. V. Puyvelde. Algemene en technische scheikunde, 2017



Magnesium production flowsheet


OTEC
Bluerise
TUDelft

Reuters

World Business Markets Sustainability Legal Breakingviews Technology Investigations

Commodities

Exclusive: Europe aims to revive magnesium output by 2025 to cut China reliance

By Eric Onstad

May 20, 2022 7:29 AM GMT-4 · Updated 2 years ago

A bulldozer is seen at a magnesium factory near the Dead Sea December 16, 2008. REUTERS/Baz Ratner *Purchase Licensing Rights*

techcrunch.com/2024/09/19/tidal-metals-sees-seawater-as-the-solution-to-a-critical-mineral-shortage/

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Tidal Metals sees seawater as the solution to a critical mineral shortage

Tim De Chant / 7:00 AM PDT • September 19, 2024

Comment

MAGNESIUM

U.S. Department of Defense Forms $28M Partnership with Magrathea for Primary Magnesium Production

February 2, 2024, 1:24 pm

On February 1, 2024, the U.S. Department of Defense (DOD) announced seven awards (totaling $192.5 million) through the Defense Production Act Investments (DPAI) Program to establish domestic

MAGRATHEA SELLS METAL

San Francisco, 12 June 2024 - Magrathea, a company developing innovative technology for the production of carbon neutral light metal from seawater, has sold metal to a customer from the first new electrolytic magnesium smelter designed, built, and operated on American soil in the 21st century.

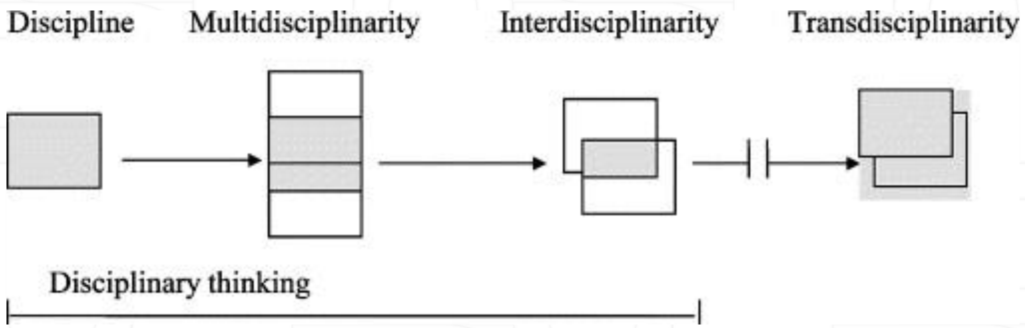
In February 2024, Magrathea announced a $28M public-private partnership with the US Department of Defense to fund the scale-up of the company's technology for producing light metal. In March 2024, Magrathea announced a sustainable brine supply partnership with Cargill who is supplying feedstock to Magrathea's R&D scale-up facilities in the San Francisco Bay Area.

Magrathea is commissioning a two tonne per year R&D pilot and has produced >99.9% pure magnesium metal within the company's first three production campaigns of pilot commissioning. The company's first customer uses magnesium in an unsubstitutable application critical to national security. The customer's uniquely stringent specifications are often considered harder to meet using thermal technologies such as the Pidgeon Process or other inefficient thermal reductions.

"We understand it is uncommon for two-year-old technology companies to sell metal," said Alex Grant, CEO of Magrathea. "Our team is excited to have the chance to solve a real customer's supply chain security problem so early in our journey. This is a significant milestone in our mission to de-risk the supply base of magnesium and other materials for the United States and its allies."

Diego Acevedo created using Dall-e

Transdisciplinarity



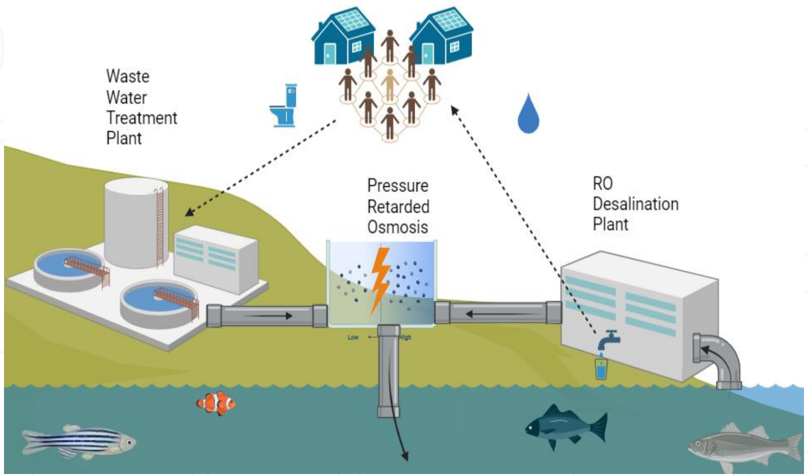
Ramadier, T. (2004). Transdisciplinarity and its challenges: The case of urban studies. *Futures : The Journal of Policy, Planning and Futures Studies, 36*(4), 423-439.


ONCE YOU
CARRY YOUR
OWN WATER,
YOU LEARN
THE VALUE
OF EVERY DROP.
Emily's Quotes

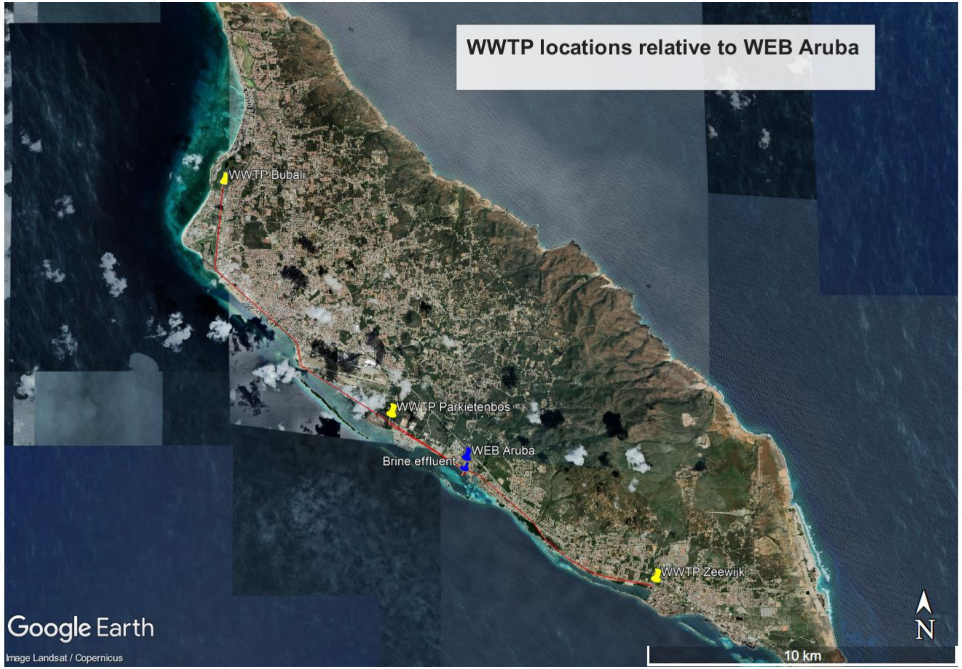
Other research lines

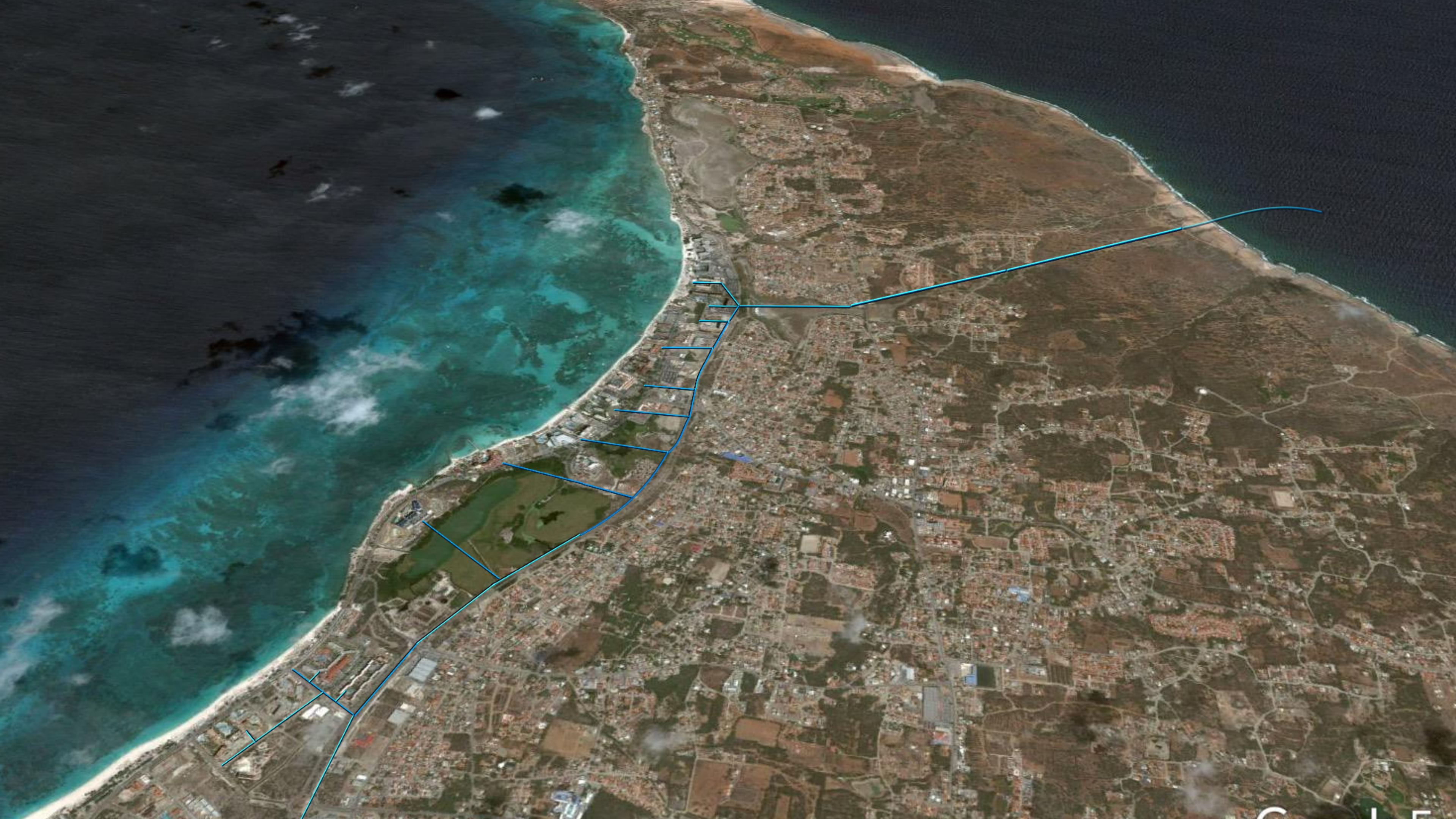
Energy Recovery

- If availability of WWTP near desalination plant, then potential energy through osmotic power technology in the order of 1.5 kWh/m^3 (Aumesquet-Carreto et.al 2022)



Schematic of RO-WWTP PRO connection (Created with Biorender)





Extra Slides

Seawater District Cooling

>10% of electricity of Aruba is being used for cooling the hotels

85% depended on heavy fuels despite all efforts

>USD$20 million used to pay cooling in the hotel area

>700.000 tons CO_2 emission for Aruba each year

+ infra advantage: Most hotels clustered on the north side of the island

Publications and outputs

- Acevedo, D., Mijts, E., John, N., El Bouzidi, M. and van der Bruggen, B. (2023). Perspective in resource recovery from reverse osmosis brines: the case for sustainable seawater refineries for small islands. J Chem Technol Biotechnol. https://doi.org/10.1002/jctb.7469

- Acevedo, D. Kleute, B.J., Kirkenier, J., Dinnissen P., Harmsen B., Blokker, R. (January 23, 2024). Development of Ocean Thermal Energy Conversion in Barranquilla, Colombia at Panamerican Marine Energy Conference. https://pamec.energy/wp-content/uploads/2023/12/68_ACEVEDO_DIEGO_PAMEC2024_Final.pdf
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- Acevedo, D. (April 2023). Transdisciplinary training as part of the PhD training process. at Orpheus Conference. https://orpheus-med.org/conferences/
- Acevedo, D. (March 2023). Valorization of reverse osmosis brines in small islands. at International Conference on Marine Science. https://marinescience.co/on-site-agenda/
- Acevedo, D. (November 30, 2022). Value from the Sea: SISSTEM Research on Valorization of Reverse Osmosis Brines in Small Islands. at Sustainable Island Futures. https://agenda.kuleuven.be/nl/node/90931
- Acevedo, D. (March 31, 2022) “Value from the Sea: SISSTEM Research on Valorization of Reverse Osmosis Brine” at KIVI Kring Caribbean https://www.kivi.nl/afdelingen/kring-caribbean/activiteiten/activiteit/value-from-the-sea-sisstem-research-on-valorization-of-reverse-osmosis-brine
- Acevedo, D. (February 7, 2022) “On the potential for Islands to provide solutions to climate induced energy, water, food and resource challenges” at the UA Climate Change symposium https://www.ua.aw/events/symposium-climate-change/#Agenda

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