



From Zero to Hero: Adoption of Zero Liquid Discharge across Industries

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The Great Energy Transition
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lux executive summit

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Agenda

- **The problem with liquid discharge**
- Making a case for new technologies
- How it effects the future of industry

The Evolution of Zero Liquid Discharge (ZLD)

- Water management strategy: that no liquid waste leaves the boundary of a facility
- Concept dates back to 1970s
 - Began in the power industry.
 - An increase in salinity of the Colorado river led to new regulations



2017

ZERO (LIQUID) DISCHARGE UNDER CLEAN WATER ACT COMPLIANCE

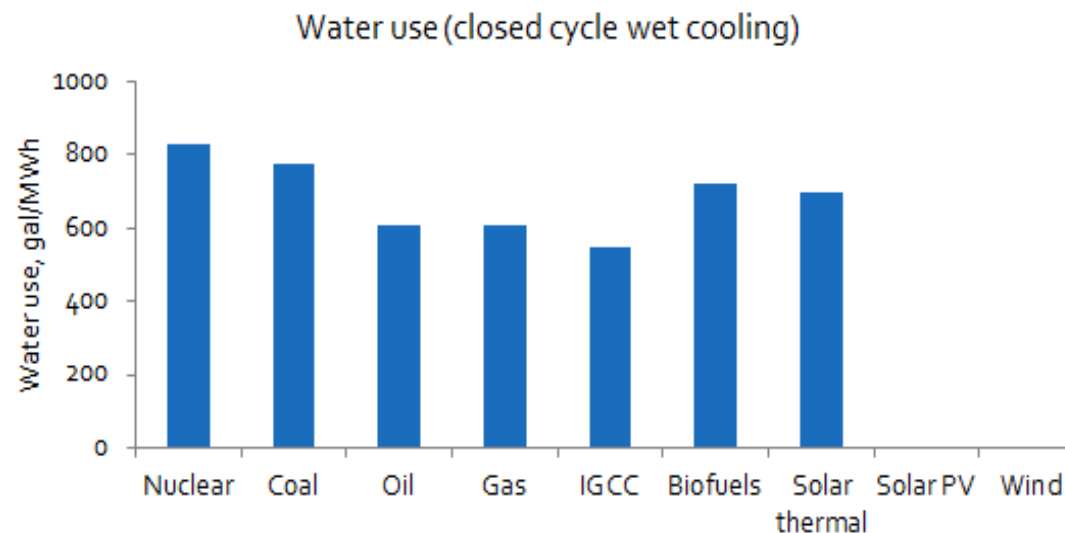
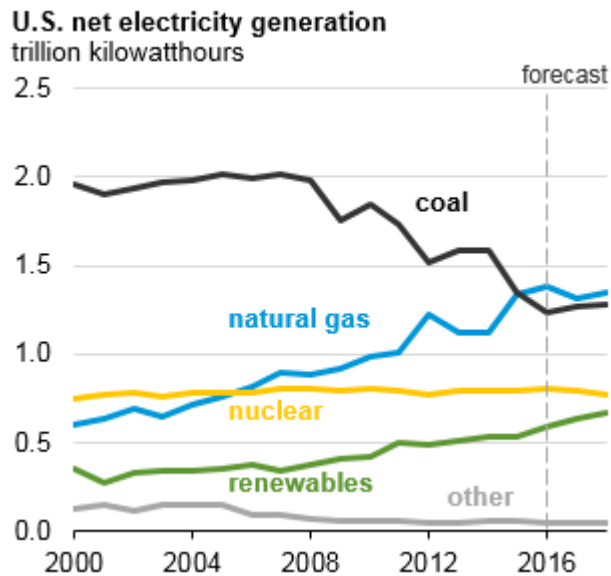
The CWA's long-range goal is to reach zero discharge of pollutants, but the permits do not typically say "no discharge."

JOSEPH COTRUVO APRIL 10, 2017

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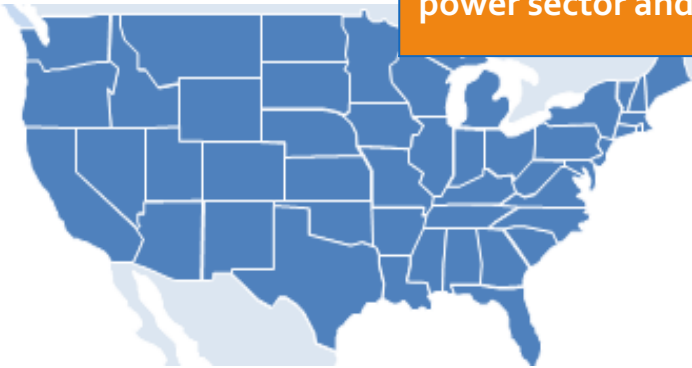
By far the largest water use is in cooling



- Thermoelectric power generation represents 45% of fresh water withdrawal in the U.S
- In Europe, the temperature of water discharge is more important
- Competing with renewables that have a negligible water footprint. Emerging regulations that limit water use through ZLD

Emerging regulations are driving the market for industrial wastewater reuse

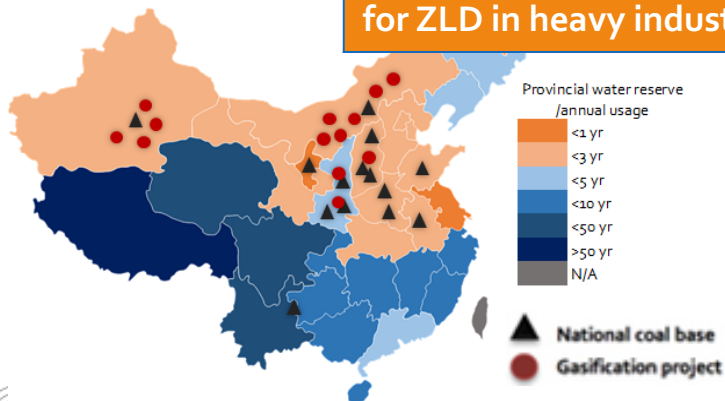
U.S. EPA ELG guidelines for the power sector and oil & gas



E.U. prevents FGD streams and brine disposal



China 13th five year plan pushes for ZLD in heavy industries



India mandates ZLD to curb surface water pollution



More deployments...the market is growing

Egypt's first ZLD plant is up and running
14 December 2016, source desalination.biz

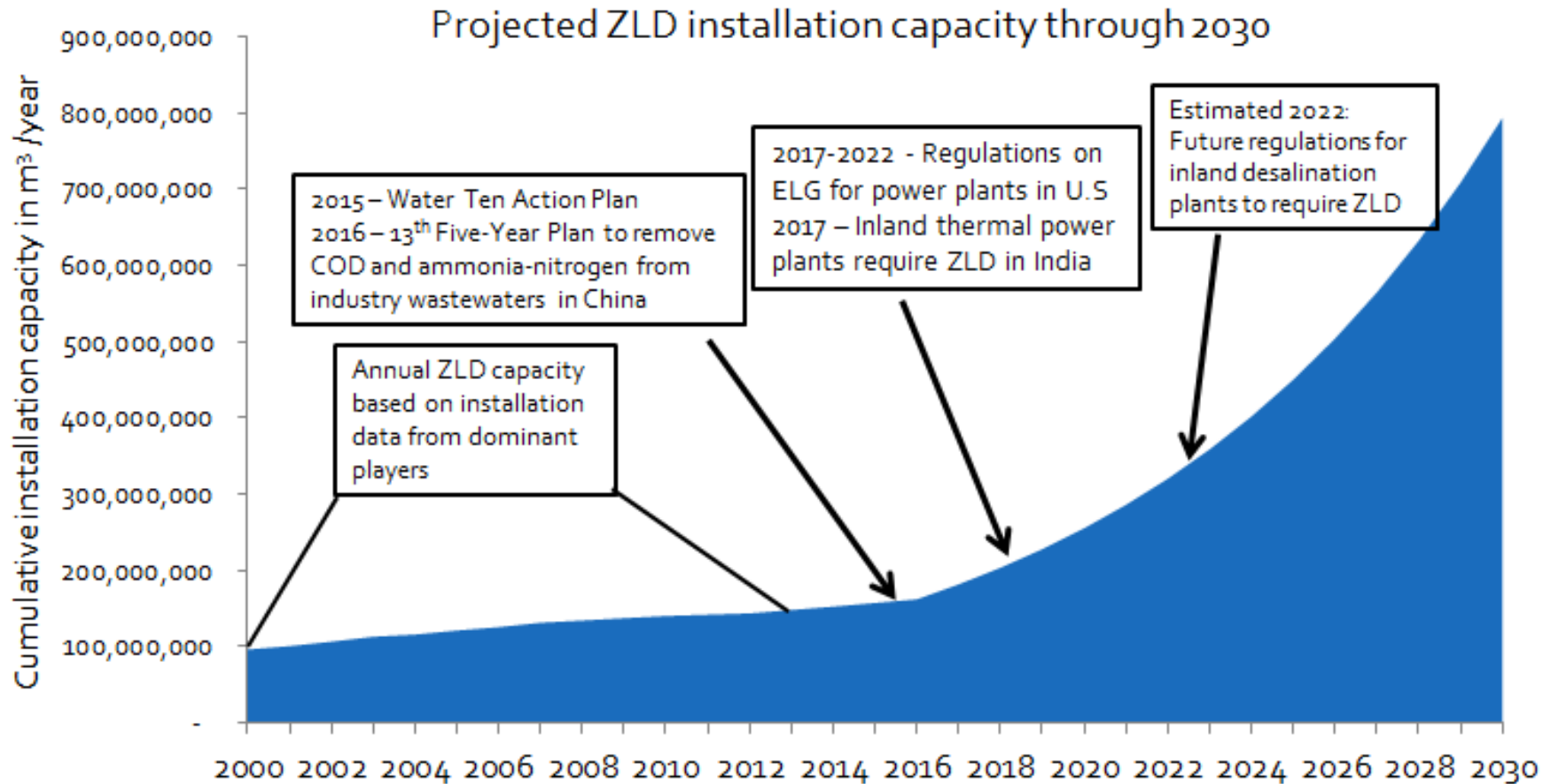
VEOLIA TO PROVIDE WATER REUSE SOLUTIONS FOR QATAR OIL & GAS

GE Wastewater Treatment Enables Oil Refinery to Reuse 100% of Water
August 23, 2016 by Jessica Lyons Hardcastle

SUEZ BAGS FIRST ZLD CONTRACT IN CHINA IN TRIPLE INDUSTRIAL PROJECT WIN
April 14, 2016

China to Develop First Zero-Waste Seawater Desalination Plant in 2017
By Charissa Echavez | Nov 07, 2016 09:02 PM EST

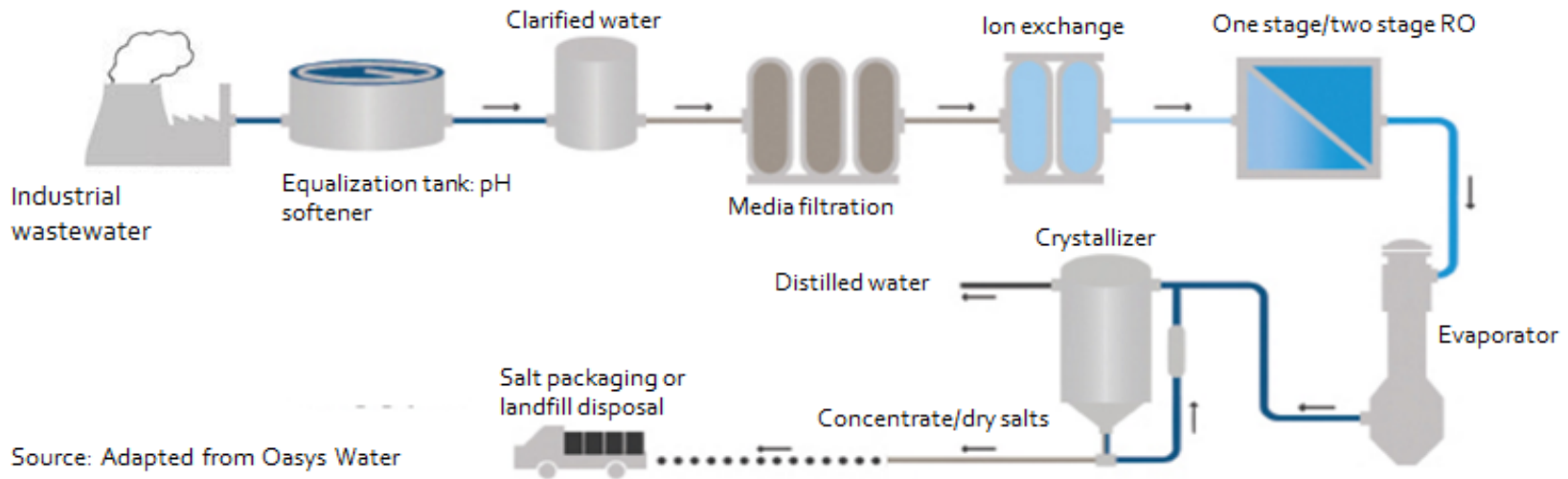
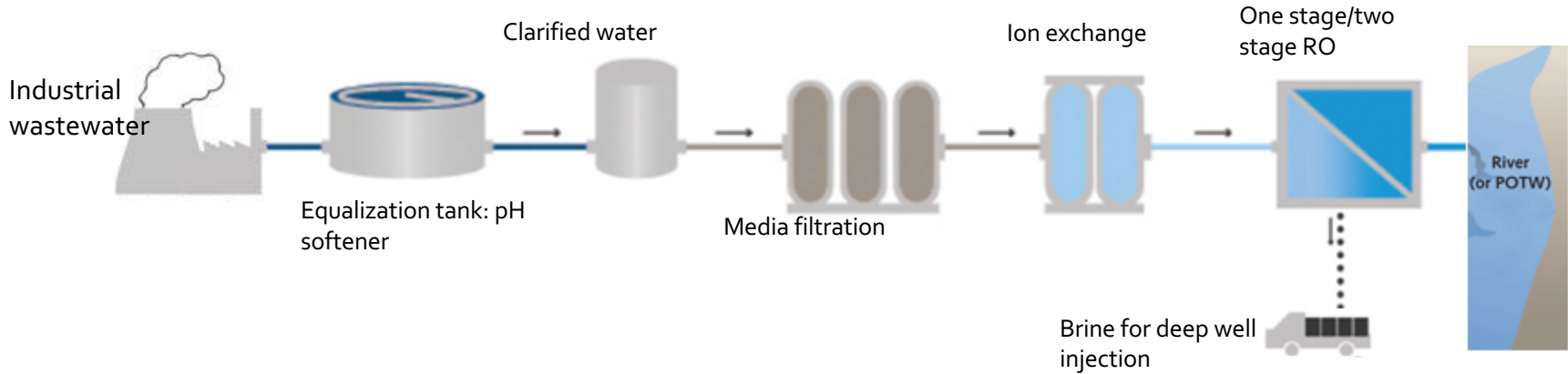
Emerging regulations are driving the market for industrial wastewater reuse



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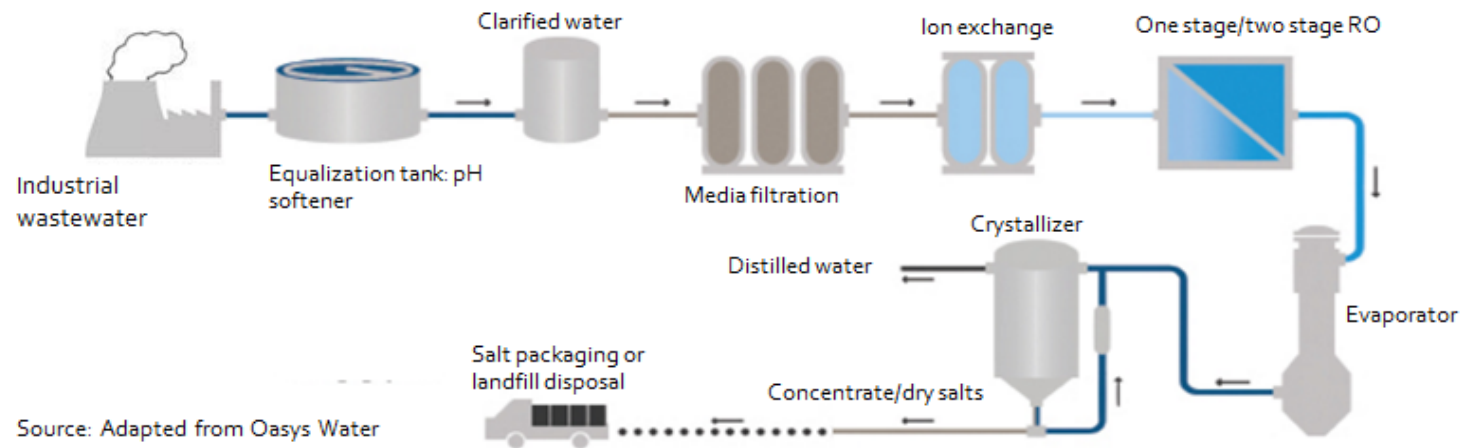
- › The problem with liquid discharge
- › **Making a case for new technologies**
- › How it affects the future of industry

Typical treatment vs closed loop to achieve ZLD



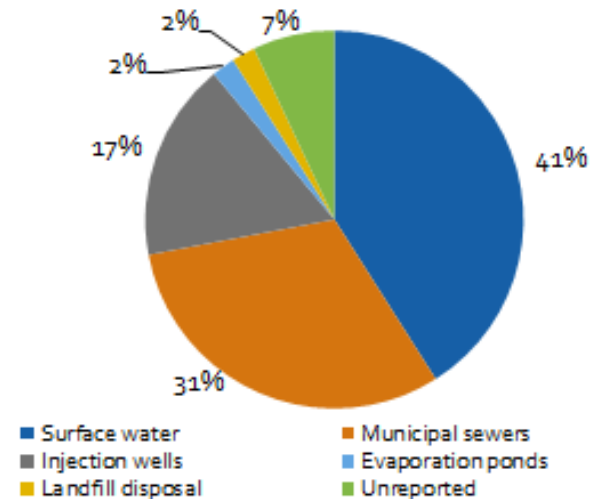
Source: Adapted from Oasis Water

Closing the loop lowers brine disposal costs



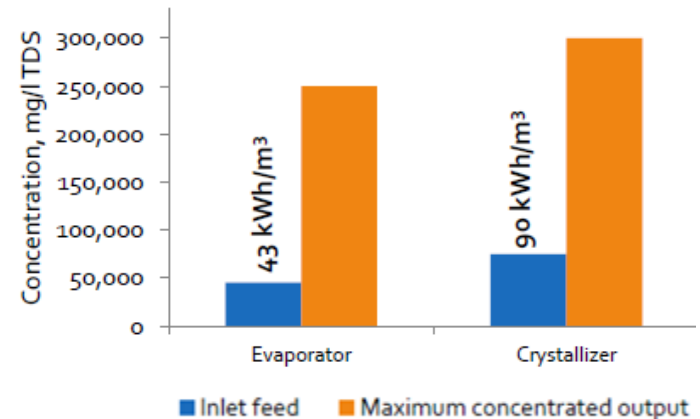
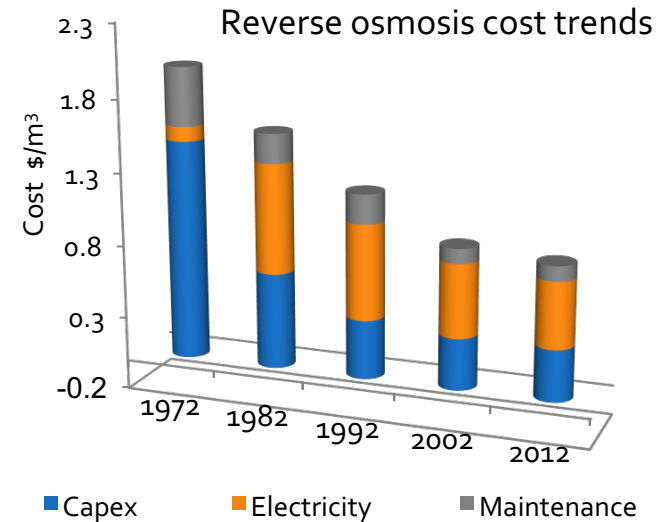
Brine discharge strategies for inland facilities

- Brine disposal is a pain-point for inland facilities and remote industrial applications
- Traditionally, 72% of brine discharge ends up in surface water and at municipal treatment plant



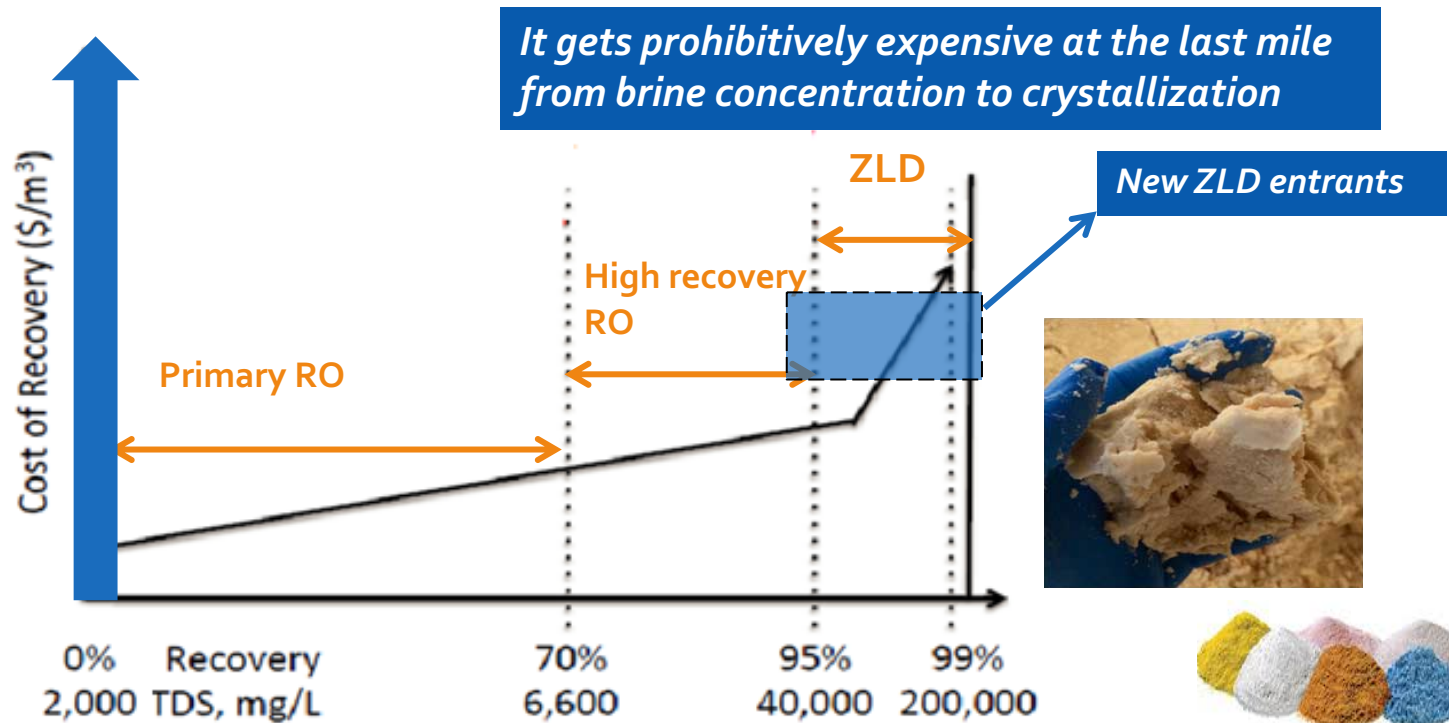
More energy intensive to concentrate brine

- Membrane technologies are approaching their theoretical energy limit
- Rethinking design can reduce some costs but have a limit for concentrating salts
- Methods to achieve ZLD are thermal systems and energy intensive
 - High salinity feeds cause fouling and scaling directly affecting operational costs



Its expensive to concentrate waste streams

- It comes down to costs. Achieving ZLD is about finding the right economics
 - Reducing operating costs
 - Recovering water for reuse and alternative use of salts byproducts



Summary of the key issues



- Trucking and brine disposal is a pain-point

One stage/two stage RO



- Existing systems have their limits

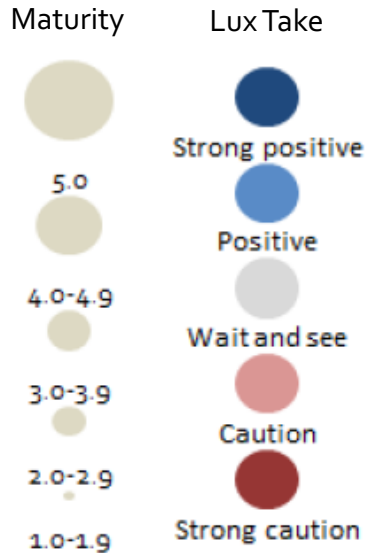


- Energy consumption is extremely high

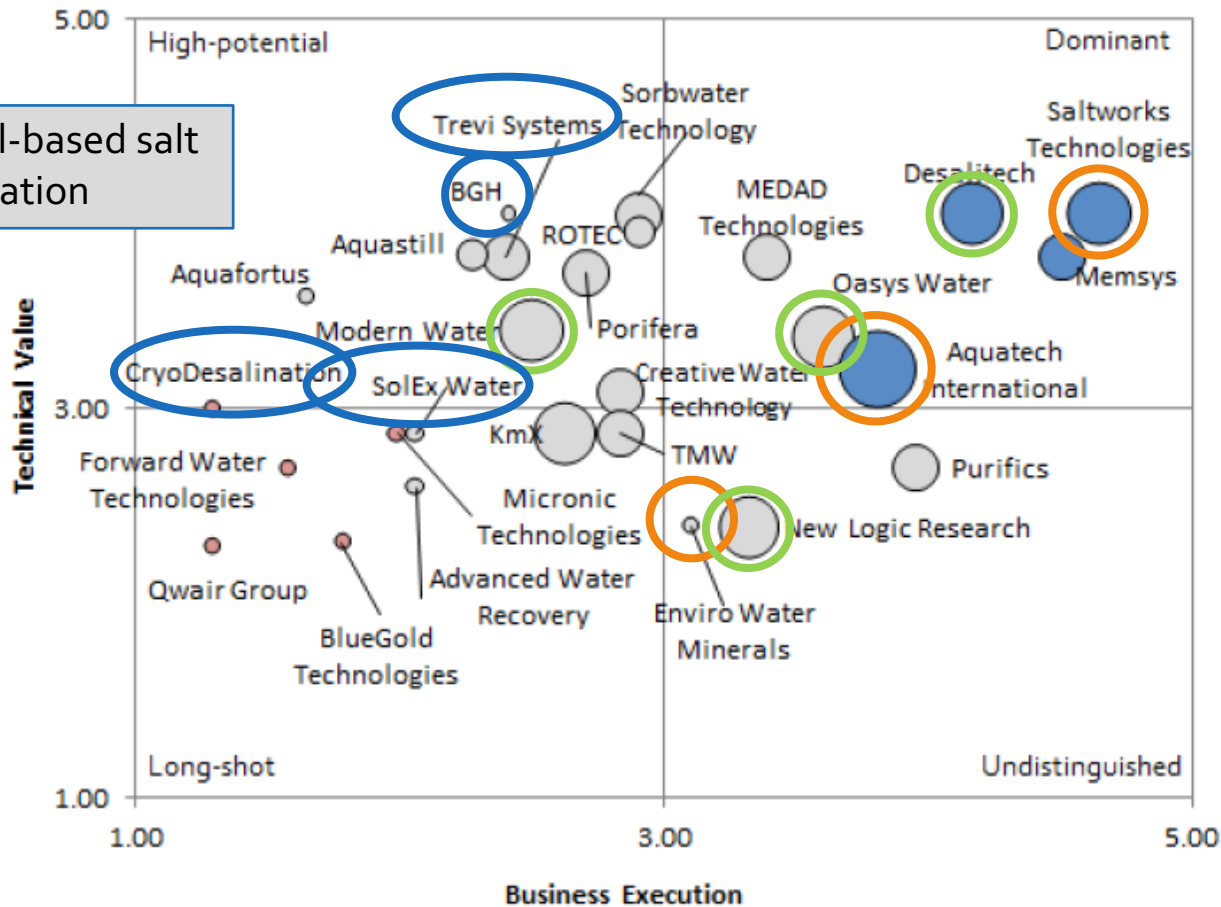
Identifying the HEROs in ZLD through the Lux Innovation Grid (LIG)

Chemical-based salt concentration

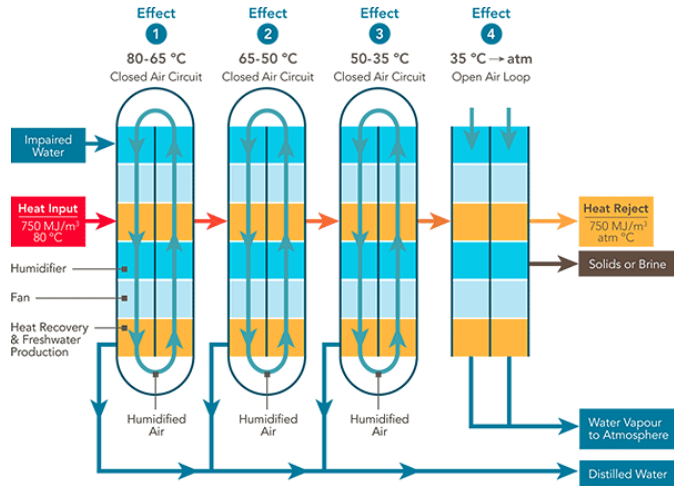
Pure crystallizer technologies



Membrane-based concentrators



Low fouling plug-n-play crystallizers



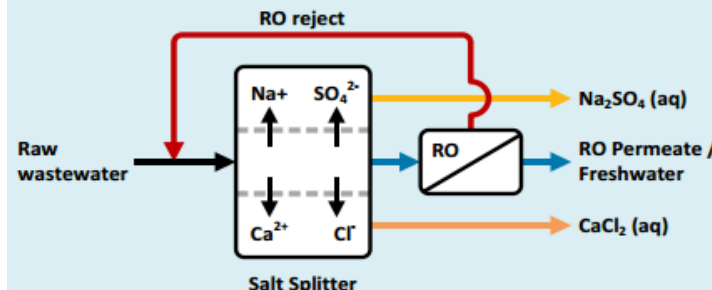
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STAGE OF DEVELOPMENT



Salt Splitter-RO process: split scaling feed into non-scaling streams

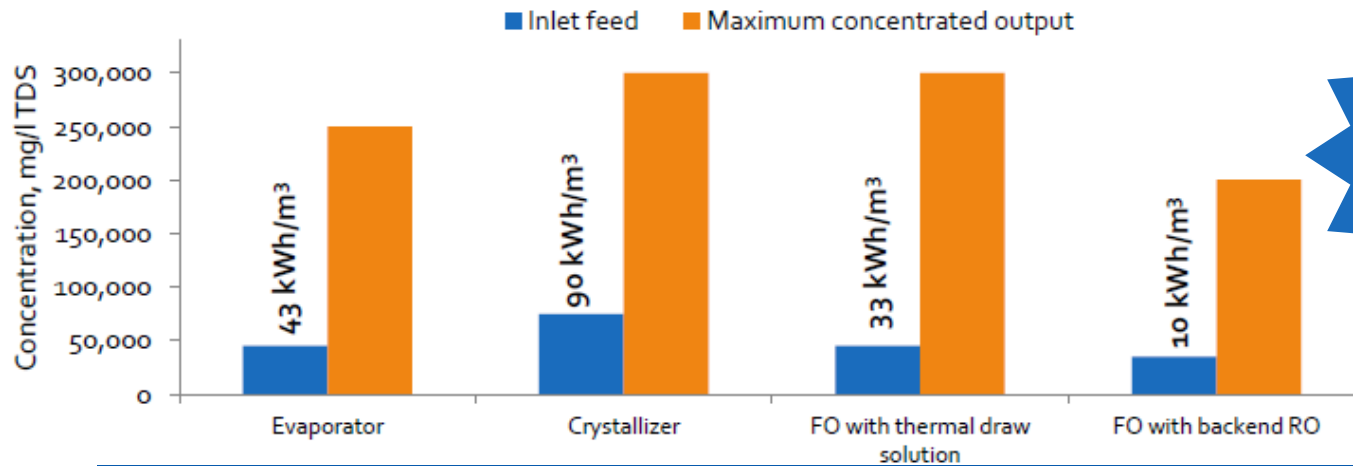


Eliminates the need for soda ash lime softening which can be 10% to 15% of operating cost

Headquarters:	Canada
Founded:	2008
Business Model:	Licenses Technology; Provides Services; Sells Product
Employees:	70
Cash:	\$12 million <i>i</i>
Revenue:	\$16 million <i>i</i>
Website:	www.saltworkstech.com

Italics indicate Lux Research estimated value

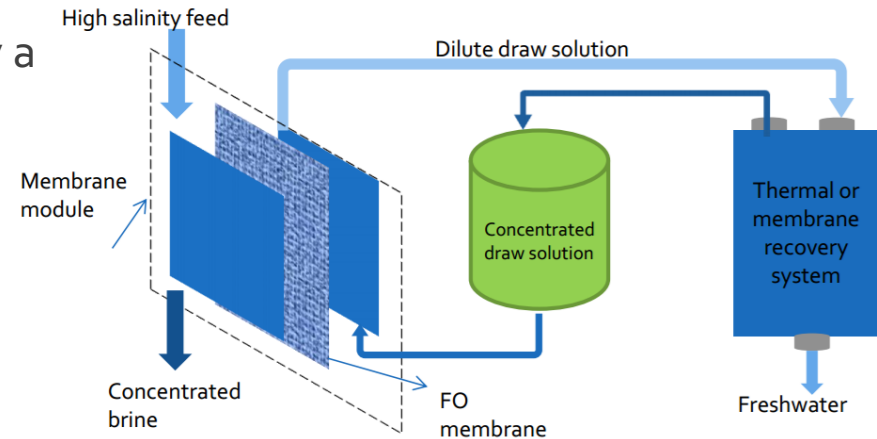
Forward osmosis closes the gap between membrane-based desalination and crystallization



60% less energy required

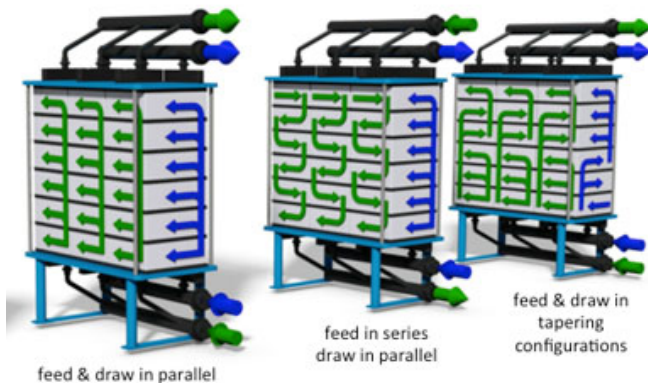
Reduces operational costs by replacing a secondary RO and evaporator

- Semipermeable membrane separated by a concentrated draw solution
- Companies are exploring low fouling membranes with a tolerance to high salinity feeds



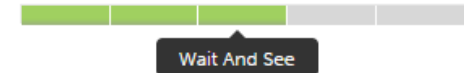
Trevi Systems

- Membrane and polymer based draw solution to generate a high osmotic pressure
- Concentrates brine up to 250,000 ppm using only 10 kWh/m³ of electricity
- Reliance on “waste heat” to run the process at low energy



TREVI SYSTEMS

LUX TAKE



STAGE OF DEVELOPMENT



Headquarters:	United States of America
Founded:	2011
Employees:	30
Cash:	\$3 million
Revenue:	\$5 million

Italics indicate Lux Research estimated value

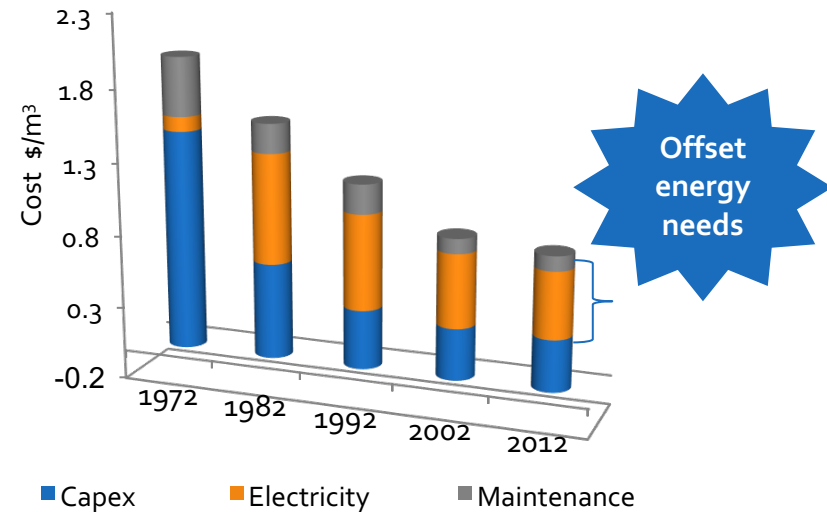
Several new developers build FO-ZLD



Moving away from thermal systems to reduce energy consumption is not the answer

- Energy represent about a third to one-half of the operating cost

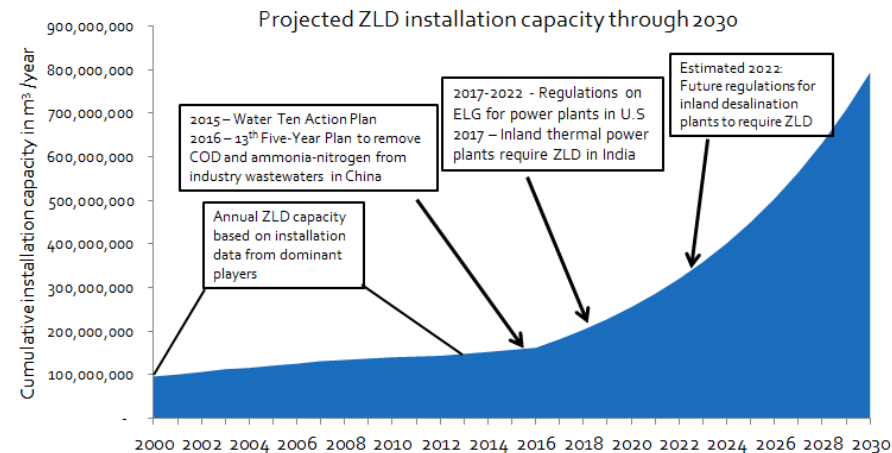
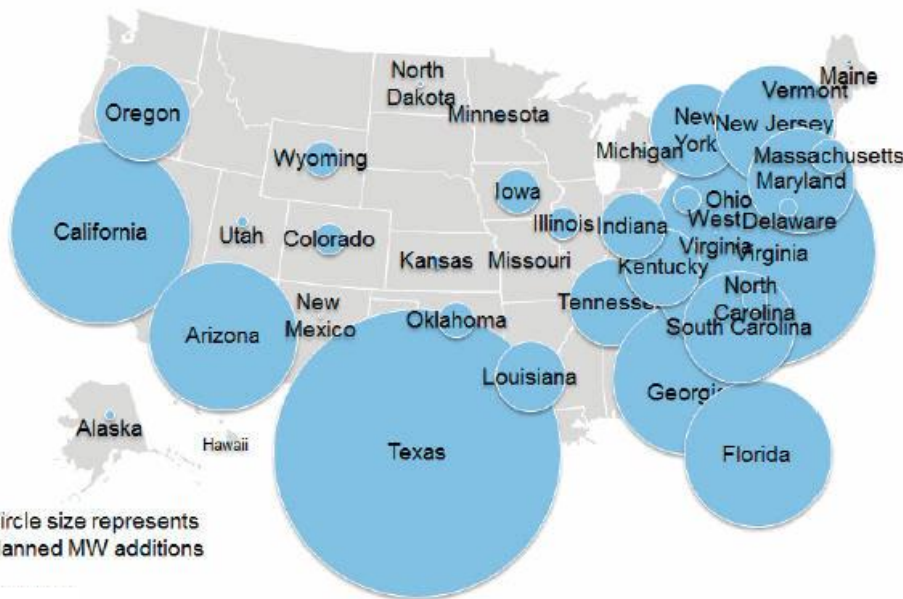
Coupling systems with renewables or accessing waste heat will drive costs down



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Water management remains a key part for optimizing energy operations



Thermal power capacity addition through 2025

- U.S. thermal power sector is evolving toward greater adoption of combined-cycle gas plants that all need cooling water
- There are incumbents, but the market continues to grow and there is space for innovation

Today ZLD affects every industry

Increasing cost of sourcing water and disposal
 Sourcing billions of gallons of freshwater in drought affected areas



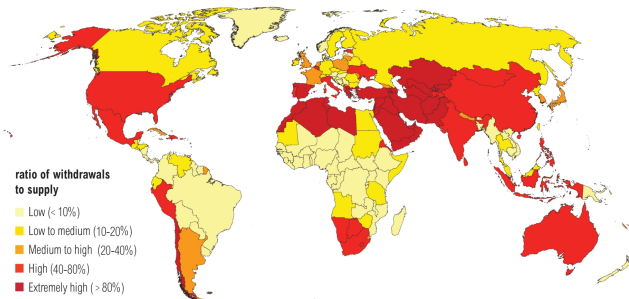
Water and carbon footprint
 Stringent discharge regulations

Global fresh water scarcity

Emerging regulations



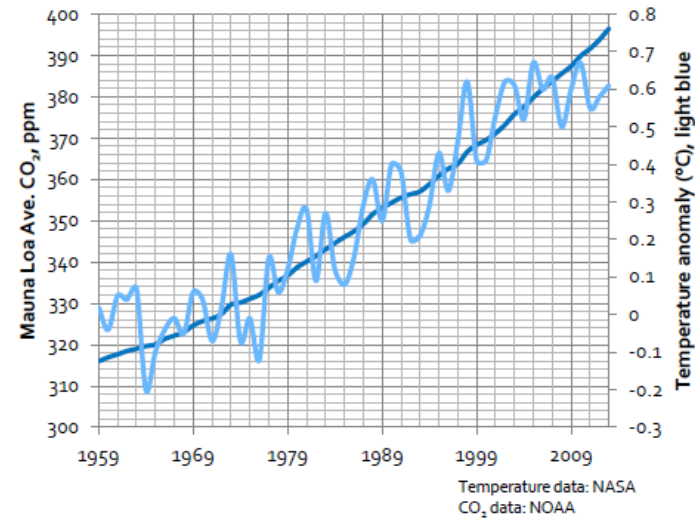
Water Stress by Country: 2040



NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.

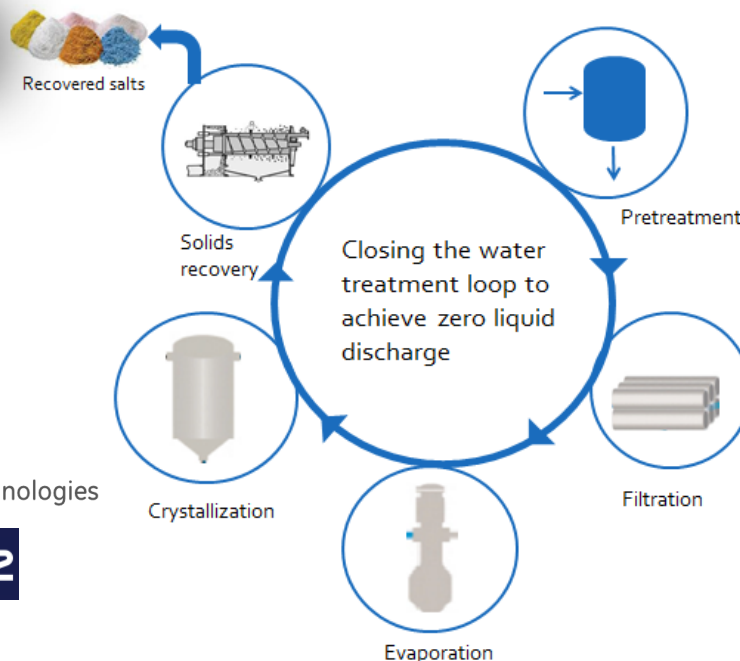
For more: ow.ly/RlWop

WORLD RESOURCES INSTITUTE



Find methods to optimize the treatment train and recover more value

Petrolithium: Extracting Minerals From Petroleum Brine



- Part of the value chain? Improvements in upstream brine concentration can go a long way
- Finding new markets for recovery byproducts
 - Mining for salts made easier
 - Recovery of rare earth and trace metals feeds back in to energy market

Thank you



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