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

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The Great Energy Transition
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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

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
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**

ELG: Effluent limit guidelines
FGD: Flue gas desulfurization
More deployments... the market is growing
Emerging regulations are driving the market for industrial wastewater reuse

Projected ZLD installation capacity through 2030

- 2015 – Water Ten Action Plan
- 2016 – 13th Five-Year Plan to remove COD and ammonia-nitrogen from industry wastewaters in China
- 2017 – Inland thermal power plants require ZLD in India
- 2017-2022 - Regulations on ELG for power plants in U.S
- Estimated 2022: Future regulations for inland desalination plants to require ZLD

Annual ZLD capacity based on installation data from dominant players

Source: Lux Research, Inc
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Typical treatment vs closed loop to achieve ZLD

Industrial wastewater → Equalization tank: pH softener → Clarified water → Media filtration → Ion exchange → One stage/two stage RO → Brine for deep well injection

Source: Adapted from Oasys Water
Closing the loop lowers brine disposal costs

- 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

Reverse osmosis cost trends

Methods to achieve ZLD are thermal systems and energy intensive
- High salinity feeds cause fouling and scaling directly affecting operational costs
It's 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

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It gets prohibitively expensive at the last mile from brine concentration to crystallization

![Graph showing cost of recovery vs. recovery percentage]

- Primary RO
- High recovery RO
- ZLD
- New ZLD entrants
Summary of the key issues

- Trucking and brine disposal is a pain-point
- Existing systems have their limits
- Energy consumption is extremely high
Identifying the HEROs in ZLD through the Lux Innovation Grid (LIG)

- Pure crystallizer technologies
- Chemical-based salt concentration
- Membrane-based concentrators

L lux executive summit
Low fouling plug-n-play crystallizers

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

![Graph showing cost over time](image)

- Capex
- Electricity
- Maintenance

Offset energy needs

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Ultra Low Temp Adsorption Crystallization

Aqua still

Lesico CleanTech

WAIW – Wind Aided Intensified evaporation

Lux executive summit
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Water management remains a key part for optimizing energy operations

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

Global fresh water scarcity

Emerging regulations

Water and carbon footprint
Stringent discharge regulations

Water management strategy

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Water management strategy
Find methods to optimize the treatment train and recover more value

- 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 into the energy market
Thank you

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