Water Energy Nexus

Emerging Technologies

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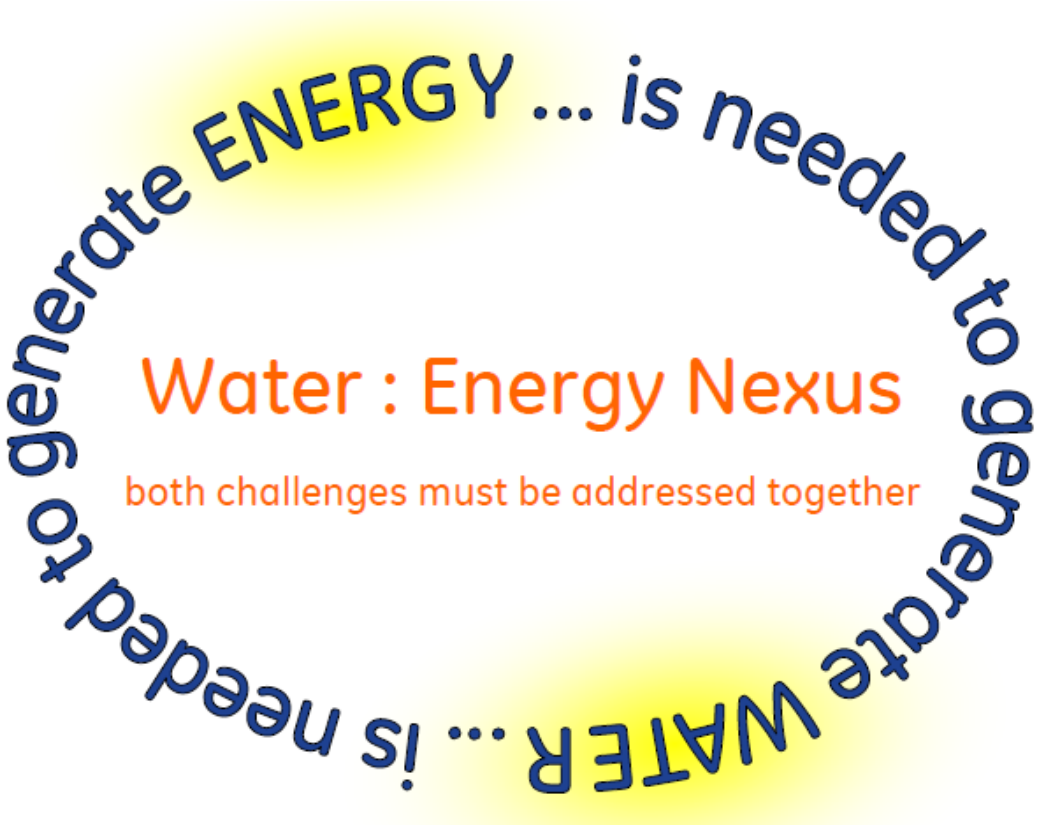
Introduction



Trends driving the future of wastewater treatment

Water Reuse	• Water scarcity drives reuse/reclamation • Tiered criteria (potable, agriculture, industry, etc.)
Effluent Quality	• Increasingly stringent limits for env protection • New parameters – micropollutants, metals
Residuals Management	• Rising costs for residuals treatment & disposal • Regulation of environmental impacts
Energy Reduction & Recovery	• Target energy neutrality • Minimize GHG emissions
Nutrient Recovery	• Nitrogen, Phosphorous, Sulfur • Produce marketable products
Cost	• Attention to CAPEX and LCC • Asset recovery • New business models

Shift from wastewater treatment to resource recovery

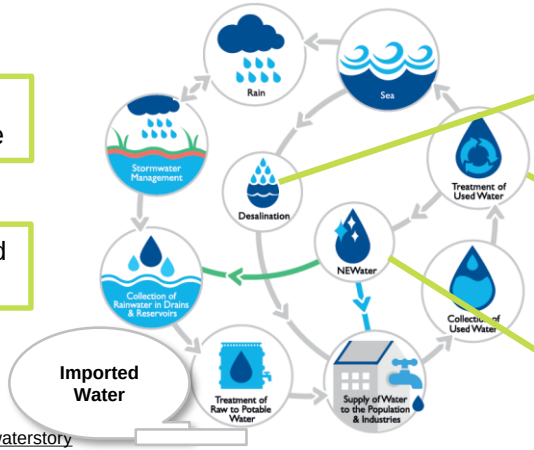
Introduction- Singapore Water Loop

Current Demand:
1863 MLD
430 MGD
40% NEWater
25% Desalted water

Predicted 2060:
~3727 MLD
860 MGD
55% NEWater
30% Desalted water

2060, non-domestic sector will use 70% of water in Singapore

Water import contracts will end year 2061



3.4-4.8 kWh power to produce 1 m^3 of desalted water

The energy content of wastewater is 2-4 times the energy required to treat it

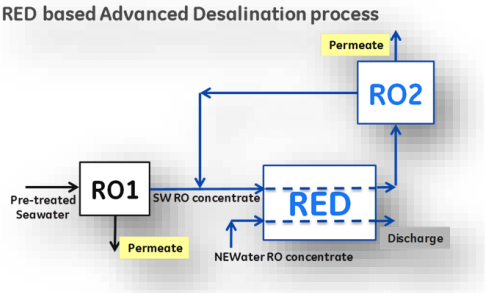
Current NEWater technology has recovery of 75%, increased recovery can displace SWRO energy demands

https://www.pub.gov.sg/watersupply/singaporewaterstory

Technology Driven Approach

- Desalination
- NEWater increased water recovery
- Water Reclamation: Energy Neutral Flow Sheet
- Industrial Water/Wastewater
- Chemical Monitoring and Systems
- Digital tools

1. Reverse Electrodialysis (RED) based Desalination



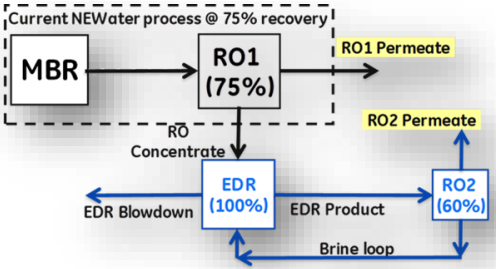
RED for ~100% SWRO recovery

- Leverage salinity gradient to drive higher SWRO recovery
- Cost savings on intake, pretreatment, and outfalls
- Co-located SWRO Desal and WW plants
- Tuas pilot validation in progress, feasibility confirmed at 9” x 10” scale

Benefits

- **Higher water recovery**
- **0.5 kWh/m3 lower energy consumption compared with SWRO**
- Reduced discharge volume

2. Enhanced NEWater recovery using RO-EDR



Technology targets

- **System recovery > 93%**
- **Energy < 0.6 kWh/m3**

Benefits

- Higher water recovery
- Lower energy consumption
- Reduced discharge volume

3. Energy neutral wastewater treatment

Zeelung MABR

Simple installation & Small Footprint:
Nutrient removal and capacity expansion in existing bioreactor volumes, no additional tank required

Low Energy:
Oxygen delivery is 4X greater than fine bubble aeration

Nutrient Removal:
Increase biomass by attached growth

Advanced Anaerobic Digestion

Complete solution:
Pre-treatment | Advanced digestion | Bio-waste digestion | Power generation

Higher energy production:
25-30% more bio-gas yield

Higher capacity/loading:
Patented biological hydrolysis technology to increase feed loading (>2 times) and digestion time (30-50%)

Class A/B bio-waste:
Valuable by-product

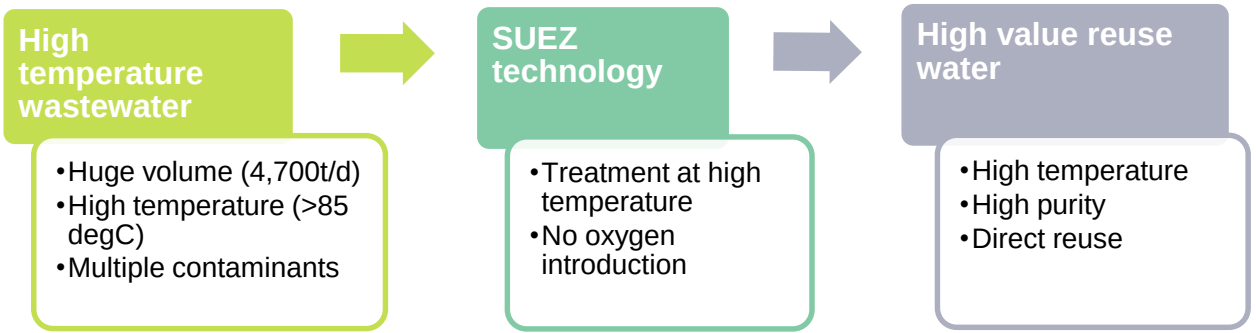
Anaerobic MBR

Reduced energy consumption & waste:
No aeration needed
80% less sludge waste

Bio-gas production:
Methane-rich bio-gas production as energy

Reliable & superior effluent quality:
ZeeWeed* 500 reinforced hollow fiber membrane

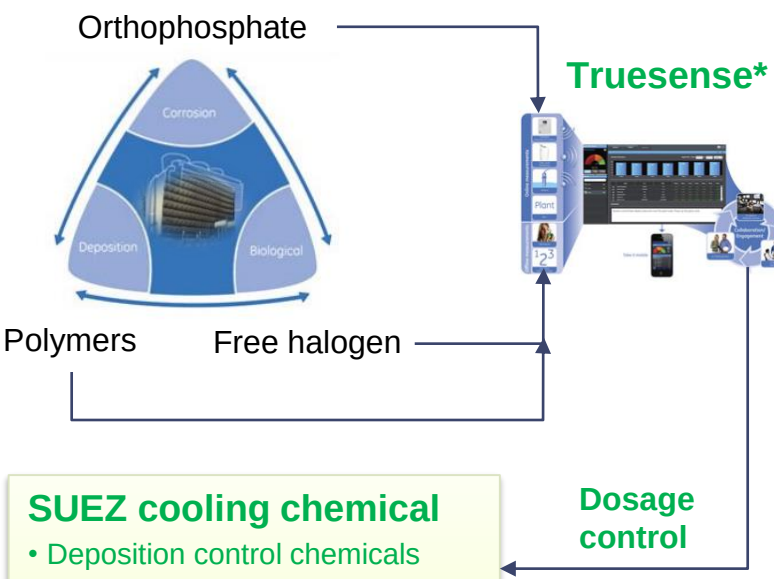
4. Industrial hot wastewater reuse: advanced membrane technology



Benefits

- Applicable to most high temperature industrial wastewater streams
- Saving on water intake (E.g., company A: **33% saving, 2,300 t/d**)
- Saving on cooling and heating energy (85 degC)
- Saving on feed water pre-treatment

5. Cooling water treatment and optimization



Highlights

- All-in-one measurement
- Accuracy
- Low maintenance
- Insights* connection
- Chemical dosage control

Benefits

- Save water
- Cut water cost
- Reduce manpower

6. Digital solutions for remote monitoring and diagnostics, water and energy usage optimization

- Asset/productivity optimization
- Early detection
- Wireless connection
- Safety

Plant operation parameters

Off-line analysis reports

- Loading of off-line reports

Insight* Server

- Collaboration
- Security
- Cloud

Remote monitoring & control

- Graphics and Reports
- Mobile & computer access
- Performance analytics

: Simplicity : Mobility : Security : Reliability :

Summary

Treatment	Technologies
Desalination	RED Technology: Reducing 0.5kWh/m3
Water Reclamation	Development of Energy Neutral Flowsheet • Zeelung • Advanced Biological Hydrolysis • Anaerobic MBR
NEWater	Increase water recovery from 75% to greater than 90% using EDR technology, thereby reducing reliance on Seawater
Industrial Wastewater	High end technologies for hot water recycling
Digital and Chemical Monitoring	Enhanced capabilities to monitor and optimize energy-water efficiencies

Quote….

"I never believed it would be impossible forever; I thought sometime, some place, technology will be found that would make it nearly possible."

Lee Kuan Yew, former Prime Minister of Singapore, on the prospect of Singapore achieving water self-sufficiency.