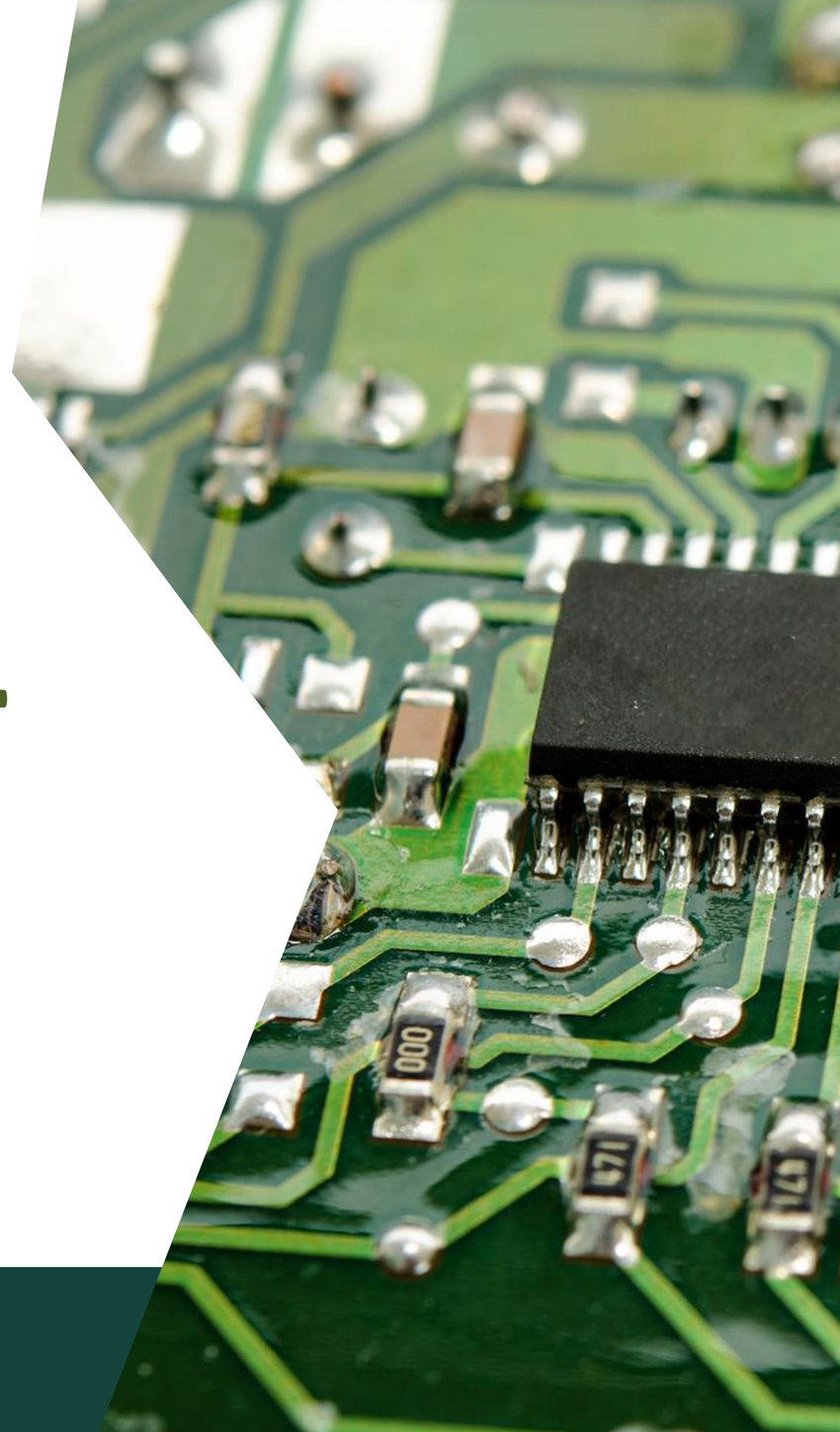
SG MEM Discovery Series
2025-2026

SEMICONDUCTOR WASTE MANAGEMENT

To Establish a Cleaner Future for Semiconductor Industries



MEMBRANE & MICROELECTRONICS

AGENDA

SG MEM Discovery Series 2025-2026

Problem Statement	➢ Semiconductor's manufacturing utilities	**Page 2**
Water Treatment	➢ Current practices in semiconductor sector ➢ SG MEM industry and institutional members' contributions with membrane technologies	**Page 3-7**
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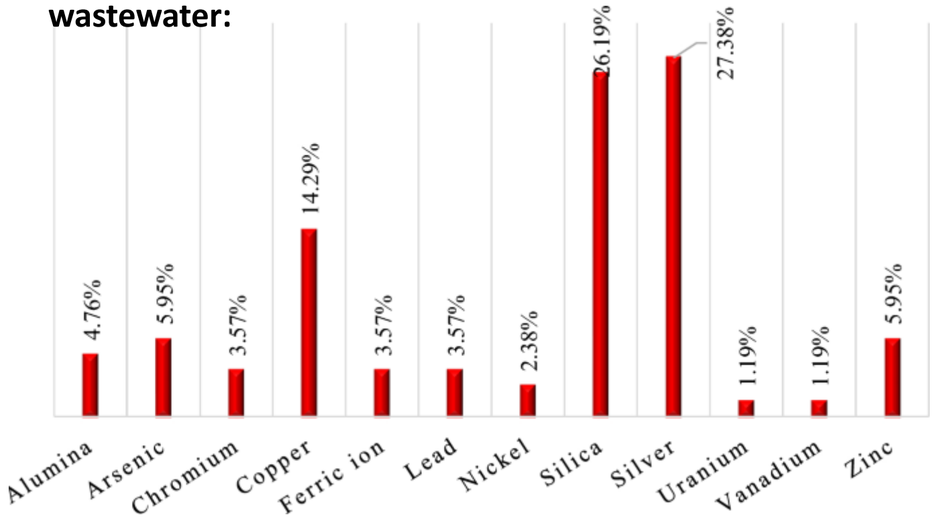
Problem Statement

Semiconductor Waste

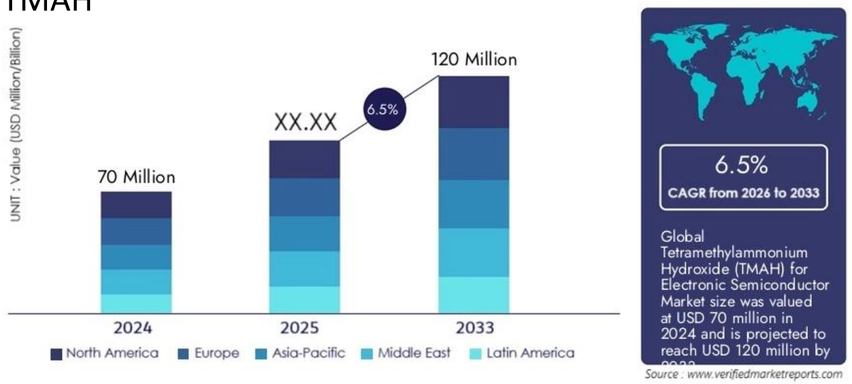
- **Pollution**
  - Heavy metal pollution in wastewater
  - Difficulties of degradability of chemical, organic, and solvent contaminants in wastewater
  - Hazardous materials and CO_2 released from the incineration gas

- **Complexity and Inefficiency of Recycling**
  - Resource-intensive extraction of valuable resources from brine deposits
  - Evaporation ponds to concentrate metals requiring enormous areas of land and processing times

Most common heavy metals in microelectronic wastewater:



Highly problematic compounds generated by photolithography
TMAH

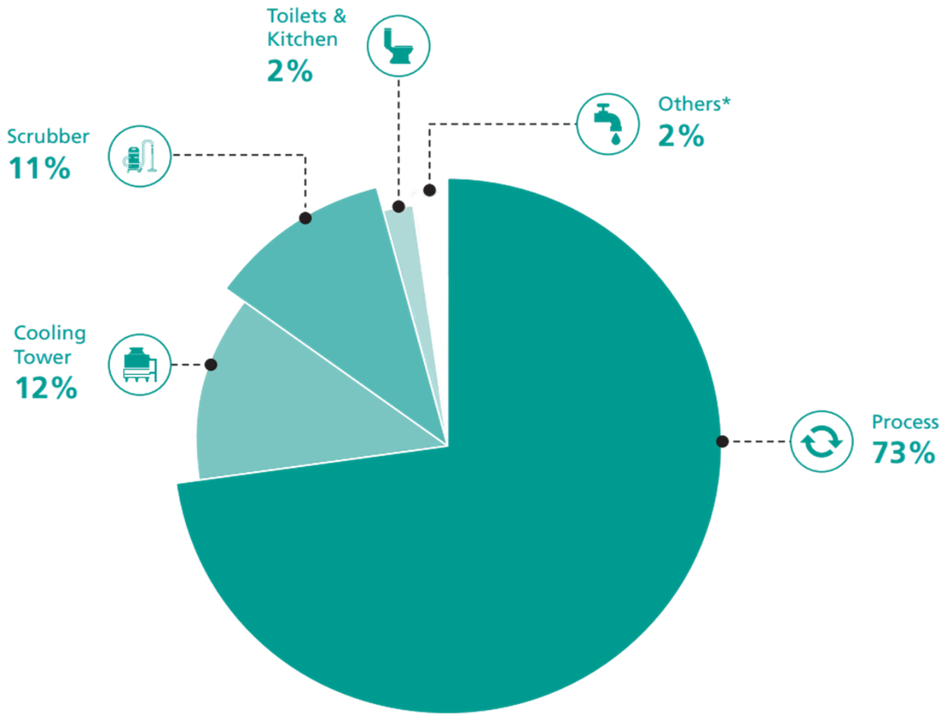


Source: https://link.springer.com/article/10.1007/s13201-024-02104-7

Semiconductor Industrial Water

Recycling Goals

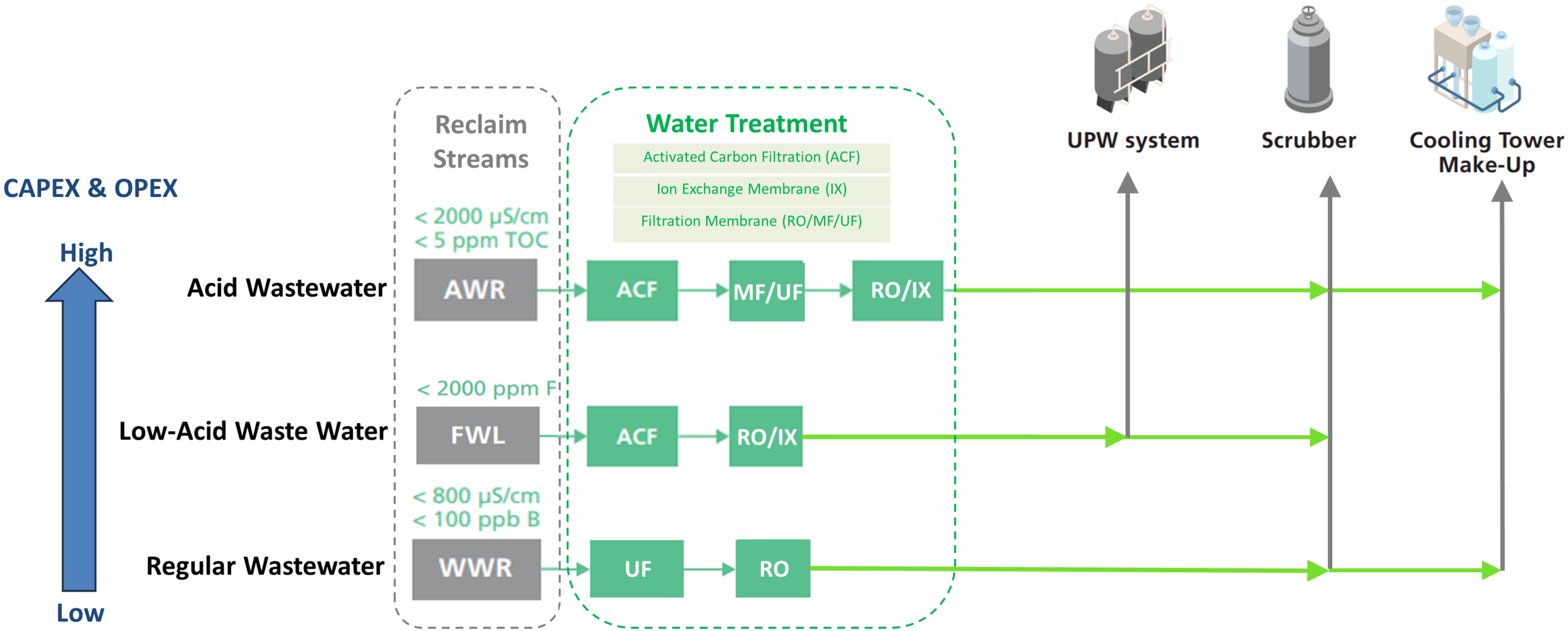
Singapore Front-End Semiconductor Minimum Water Usage: 60,000m³ /year



Source: PUB , Singapore's national water agency

Wastewater Treatment

Water Reclaim Practices



Source: *https://www.pub.gov.sg/-/media/Images/Feature/Content-Pages/Public/Singapore-Water-Loop/Water-Conversation/Resources-on-Water-Efficiency-Measures/Water_Efficiency_Wafer_Fabrication_Semiconductor_v2.pdf*

Wastewater Treatment

PFAS Treatment

PFAS DETOXIFICATION

A broad spectrum of PFAS

- **Longer-Chain Compound Removal**
  - **The MitiGATOR™ Mobile System**
    - **Mobile Carbon Adsorption**
      - 
    - **Ion Exchange Resins**
      - 
- **Long-Chain & Short-Chain Compound Removal**
  - **Filtration System**
    - **Nanofiltration**
      - 

Mobile and filtration system

xylem
Let's Solve Water

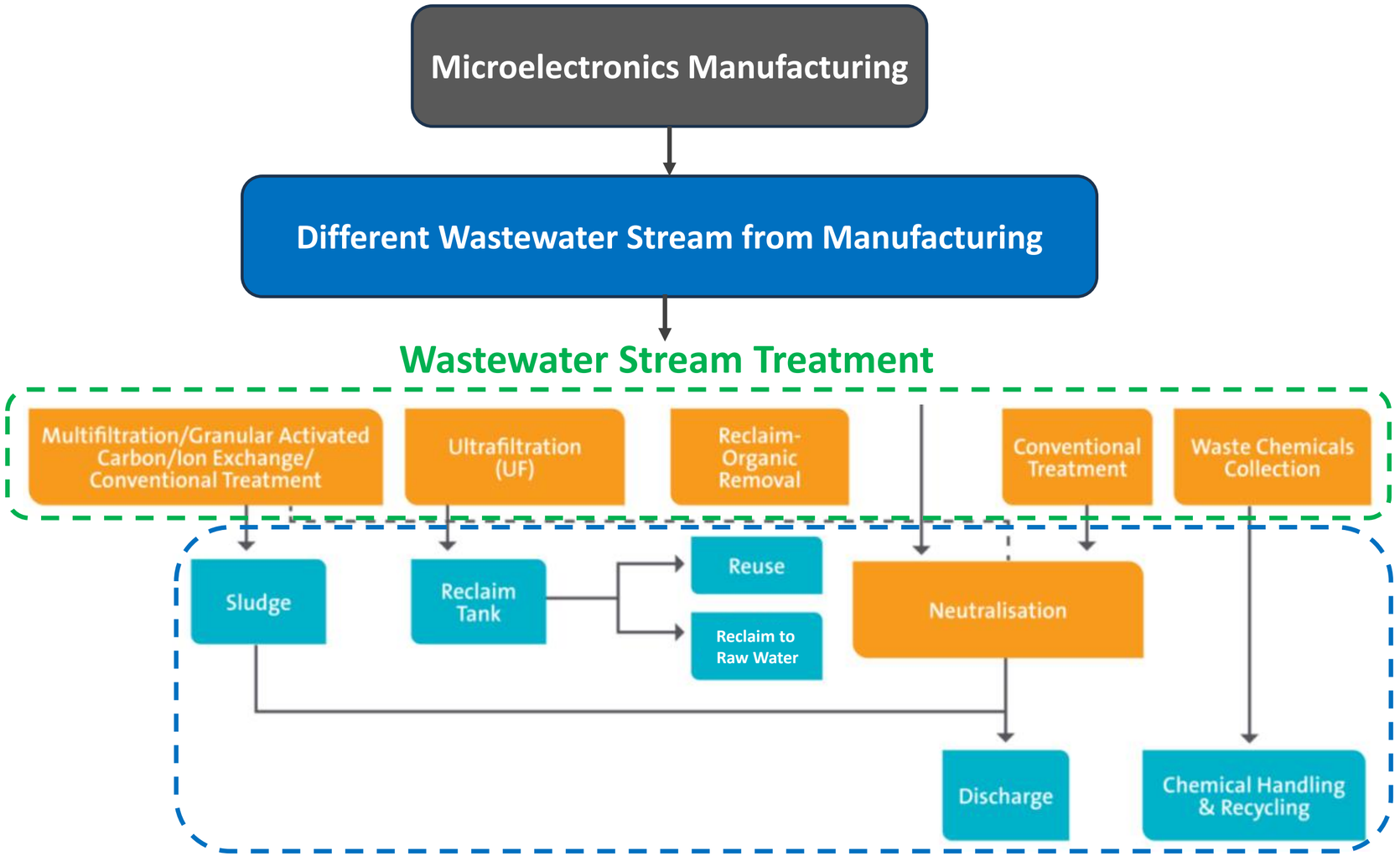
Solution Provider: Xylem

- Treated 21 million gallons of water and reintroduced clean water back into the sanitary sewer system.

Source: [Construction site removes PFAS with mobile filtration solution | Xylem Singapore]

Wastewater Treatment

Differentiated Wastewater Stream Treatment



Outcome: Water Reclaim & Discharge and Resource Recycle

Solution Provider:
Veolia

- Integrated water treatment system for microelectronics industry

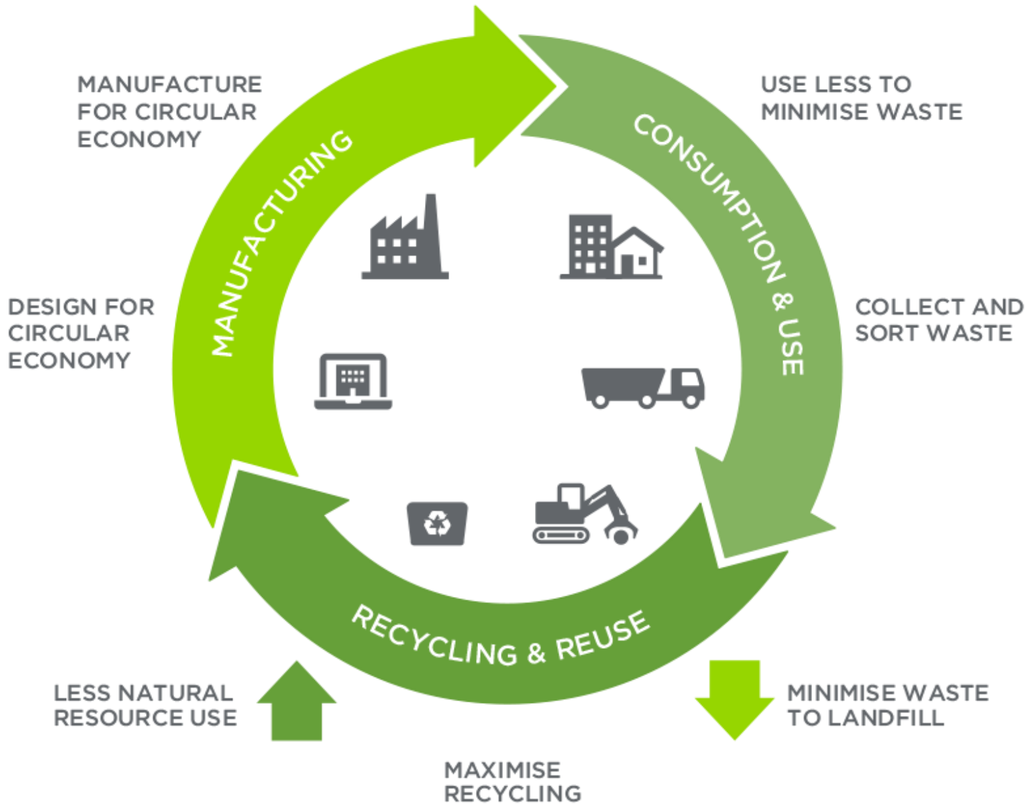
Source:
https://www.watertechnologies.com/industries/microelectronics

Resource Recovery

Aims

- Circular Economy
  - Valuable component recovery from wet etching, photolithography, backgrinding, and dicing processes

- Sustainability
  - Zero liquid discharge
  - Low energy/carbon consumption
  - Recycling >90% useful resources (e.g., metals, solvents, etc.)



Source: https://futurerecycling.com.au/sustainability/circular-economy/

Commercial Solutions for Resource Recovery

Resource Recovery By gradiant alkaLi 3 Spin-off powered by Gradiant START

Metal, Solvent and Acid Recovery (Commercially Available)

Extraction, Concentration and Conversion

Targeted Metal Recovery:

Lithium (**≥ 90%**)

Selective Chemical Extraction

Targeted Chemical Recovery:

IPA and Ammonium Hydroxide **(up to 90%)**

Phosphoric acid

RO Infinity Membranes (Counter Flow Reverse Osmosis*, Nanofiltration, etc)

Targeted Chemical Recovery:

Sulphuric acid, Phosphoric acid, Sulphate, Ammonia, Cobalt, Nickel, etc.

Customizable integration or combined with other applications such as Electrodialysis Reversal, etc.

*: Translated by START

Source: Home | alkali & Selective Contaminant Extraction for Industrial Water Treatment

Resource Recovery By MEMSIFT INNOVATIONS

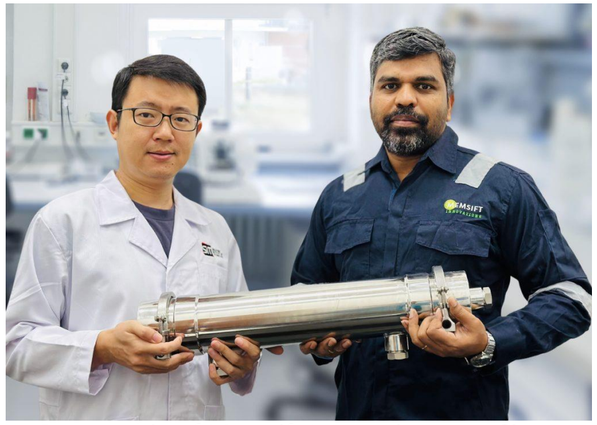
Metal and Acid Recovery (Commercially available)

Industrial implementation at Microelectronics manufacturer Linxens

Membrane Distillation

Targeted Metal Recovery:

Metal: Nickel, Copper, Zinc, Lithium
(Recovered metal concentration: **26.8 tons/1,460,000L/year**)



Partnership of Memsift Innovations and Singapore Institute of Technology to tackle higher concentration wastewater (up to 90% chemicals)

Membrane Distillation + Nanofiltration

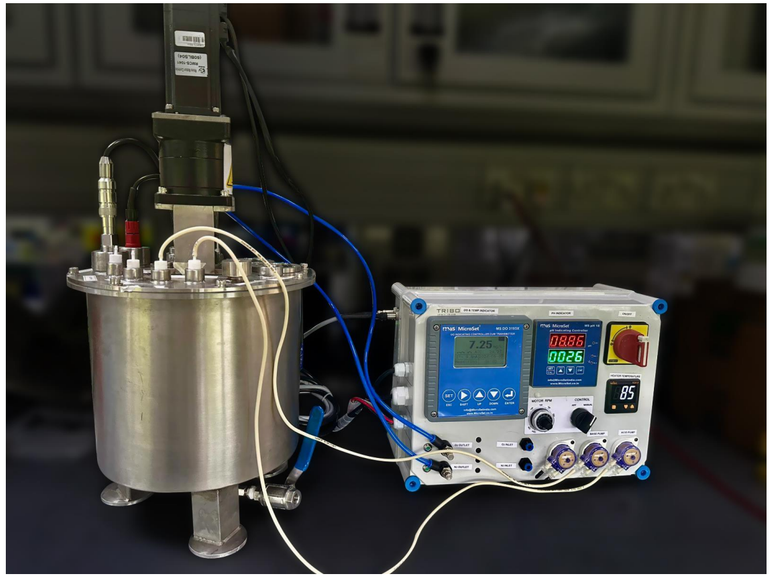
Targeted Chemical Recovery:

MD: NaOH, HCl, H_2SO_4, Na_2CO_3, $CuSO_4$, $CuCl_2$, $ZnSO_4$, Li_2SO_4, $NiCl_2$, IPA
NF: H_2SO_4, $(NH_4)_2SO_4$, Na_2CO_3, NaOH, NH_4Cl, NH_4OH, IPA
(Applicable to chemical concentration at **10-20%;** Recovery rate: **>95%**)

Source: Linxens and Memsift Innovations use membrane distillation technology for world's first sustainable nickel recovery system | Water & Wastewater Asia

Resource Recovery By BIOMETALLICA

Valuable Metal Recovery



Biomimicry Solution (bioleaching, separation, etc.)

Targeted Recovery:
Nano-particles of Platinum **(92%),** Palladium **(95%),** Rhodium **(99%),** Gold and Silver

Achievements of sustainability:

- Environmentally friendly
- 6x more energy-efficient
- 3x more cost-effective than traditional methods
- A reduction of 44 tonnes of CO_2 equivalent

Source: https://www.biometallica.com/#solution

Emerging Solutions for Resource Recovery

Resource Recovery

Carbon Capture

Translational Project for Flue Gas Separation:

Technology

Thin-film composite (TFC) hollow fiber membranes with
- High packing density
- High permeability
- Preliminary CO_2 capture system design with stages and configurations

Techno-Economic Performance
- CO_2 permeance ≥1500 GPU
- CO_2/N_2 selectivity ≥20
- **Captured carbon for valuable resource and reduced CO_2 footprints**

Targets:

✓ Upscaled CO_2 Capture cost at < 50 USD per ton

✓ Carbon application to graphene, silicon carbide, electrode

Grant: LCER COORDINATING OFFICE

Background IP: NUS National University of Singapore

Translational centre: Start Separation Technologies Applied Research and Translation

Test-bedding at NEWRI's Waste-to-Energy Research Facility

Industrial collaborators: Chevron, SJ SURBANA JURONG

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Nanyang Environment and Water Research Institute

Cost-Effective Resource Recovery

Commercial Applications

- 01 Biomimicry application
- 02 Counterflow reverse osmosis
- 03 Crystallization and distillation
- 04 Membrane distillation

Membranes can be integrated in the system

≥ 90%

Emerging Recovery Areas

- 05 High-concentration (90%) solution for chemical recovery
- 06 Gas Separation and carbon capture

Future Green Aspirations

Net zero

Net zero emissions by 2050

100% carbon-free electricity

100% carbon-free electricity globally, where available

Water

Water conservation through reduce, reuse, recycle and restore

Zero waste to landfill

Zero waste to landfill through reduce, recycle and recovery

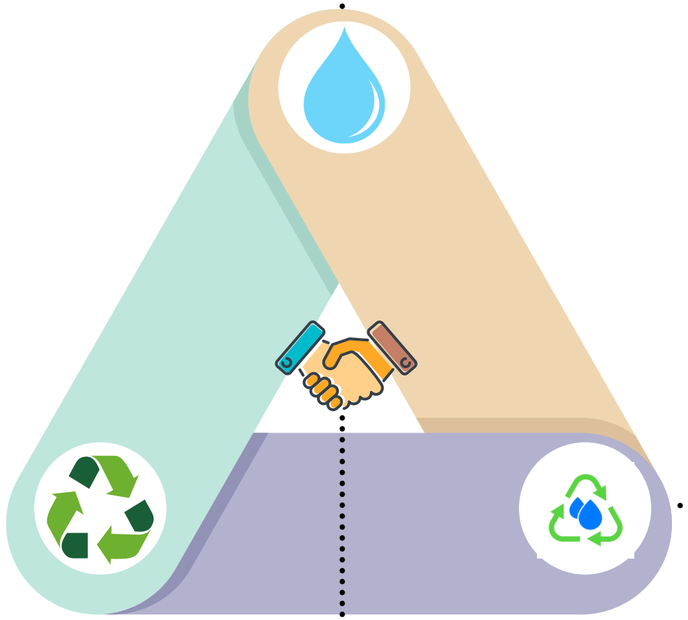
Source: Micron Technology Singapore

Conclusion

Zero Liquid Discharge
- Multi-filtration membranes

Water Recycle
- Multi-filtration membranes
- Ion exchange membrane
- Carbon adsorption
- Conventional treatment (for debris, suspended solids, disinfection, etc.)

Resource Recovery of Valuable Chemicals & Metals
- Membrane distillation
- Enhanced NF membrane



Through Academia & Industry Collaboration
- Demonstration on the industrial facility
- Hands-on experience for local students for future roles in sustainability practices