



Building A More Sustainable CuCMP Process

Selective Copper Removal & Recovery

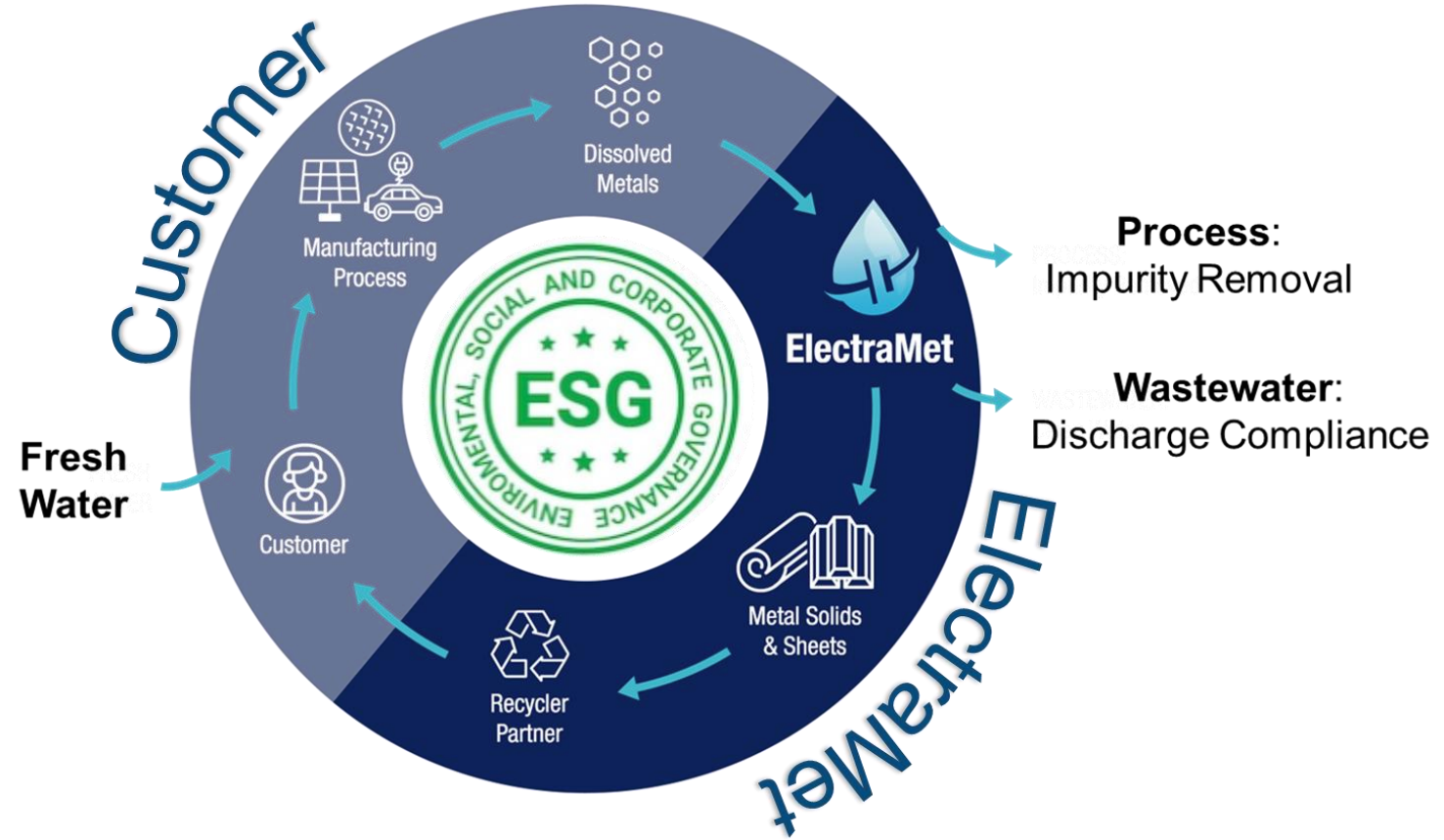


CAMERON LIPPERT, PHD | CO-FOUNDER + CHIEF INNOVATION OFFICER



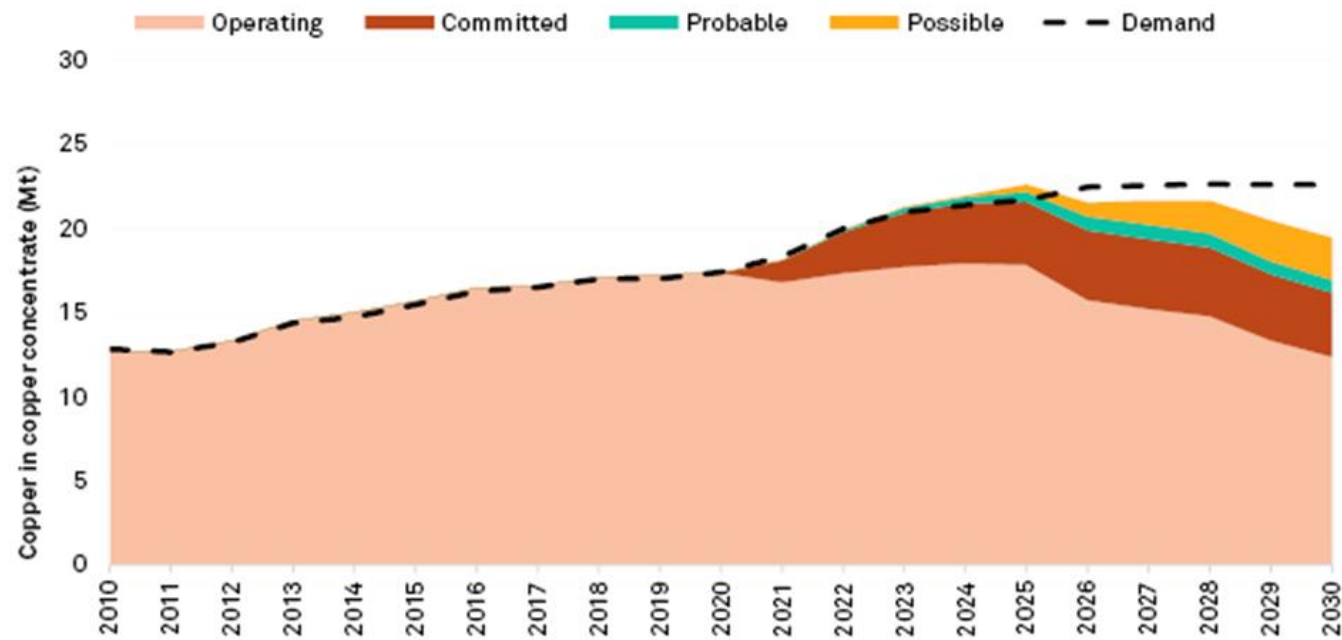
ElectraMet Enables a Circular Economy

ElectraMet is a sustainable solution that uses electrochemistry (chemical and solvent free) to remove and recover dissolved metals from industrial streams. We enable circularity through re-entry of used metals back into the economy.

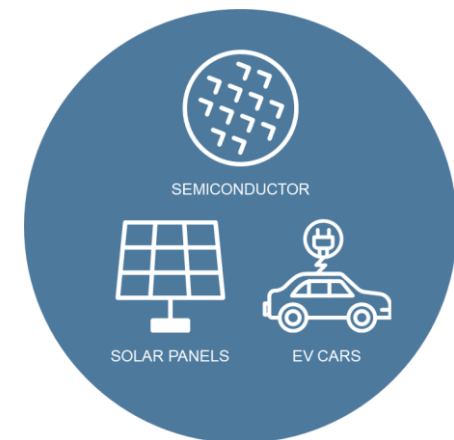


Looming Copper Supply Gap – Metals are Key for the Future

> 2,000,000 lbs of Copper Waste Every Year in US Fabs!



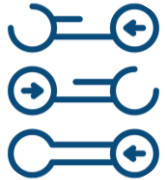
Copper is a **Critical Component** for Electrification



Unsustainable Treatment Options

Process Water & Wastewater

Incumbent Process



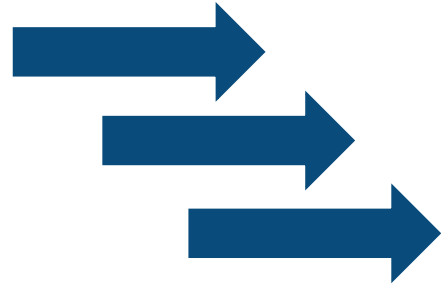
Ion Exchange



Chemicals



Trucking Off-Site



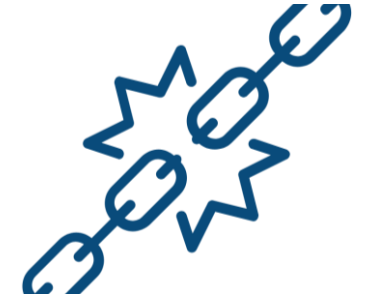
Resulting Problems



Haz Waste
Generation



GHG
Emissions –
Scope 1 & 3

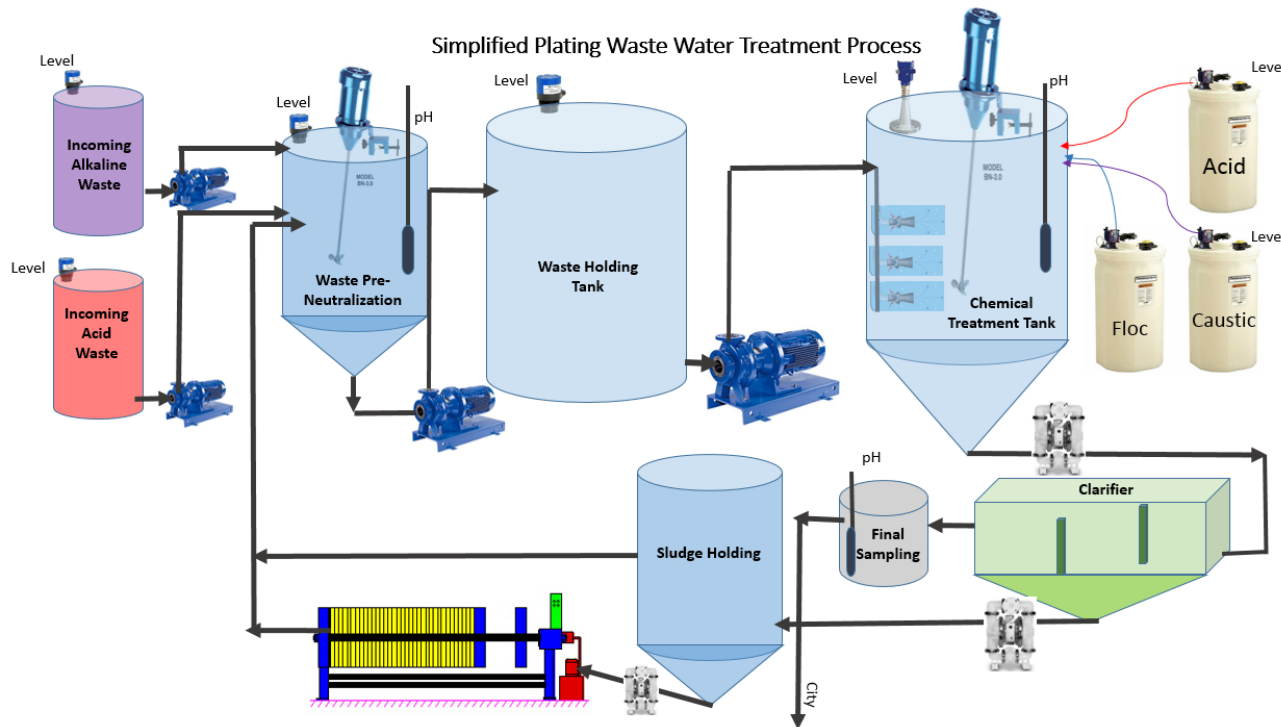


Supply Chain
Risk

Unsustainable Treatment Options

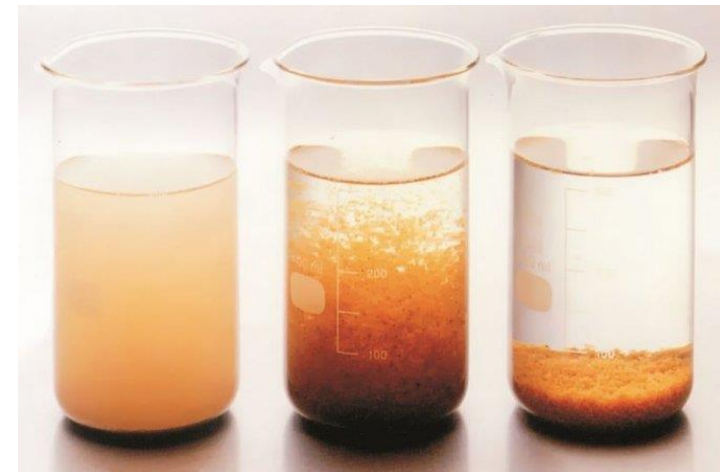
Process Water & Wastewater

Chemical Coagulation



Challenges with Chemistry

- Poor performance with chelators
- Interferences with peroxide
- Highly susceptible to upstream changes

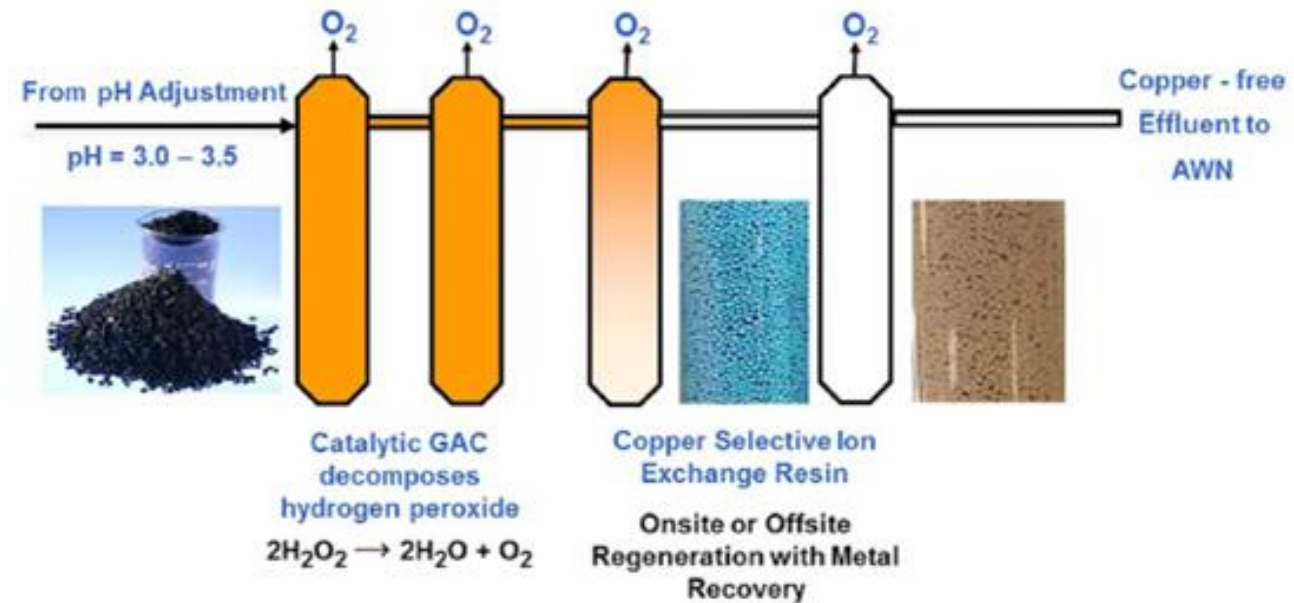


Unsustainable Treatment Options

Process Water & Wastewater

Typical Copper CMP Wastewater Composition

Component	Range
Copper	5 – 100 ppm
Hydrogen Peroxide	50 – 1,000 ppm
Total Solids	500 – 5,000 ppm
Organic Chelators	10 – 50 ppm
TOC	10 – 100 ppm
Triazole(s)	50 – 200 ppm
pH	2 - 6

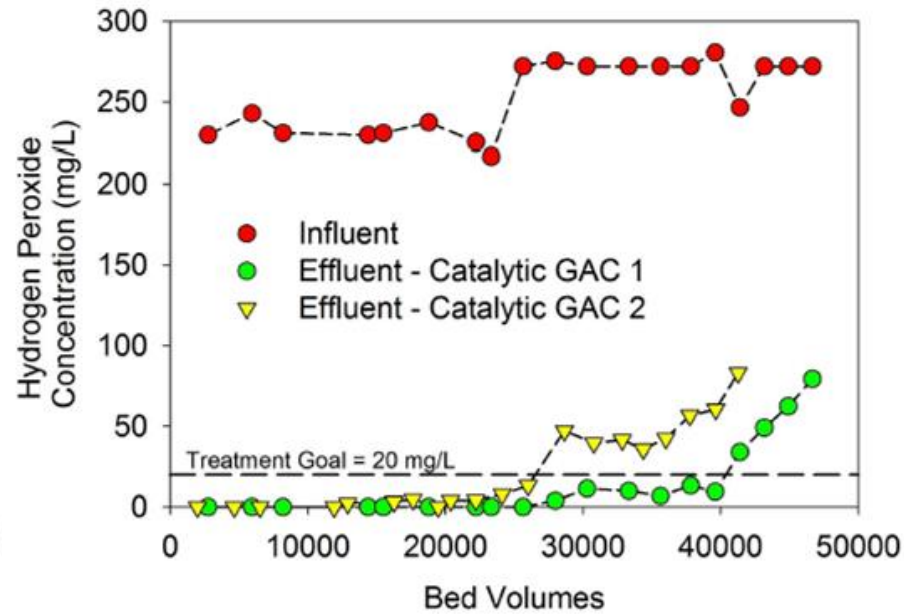
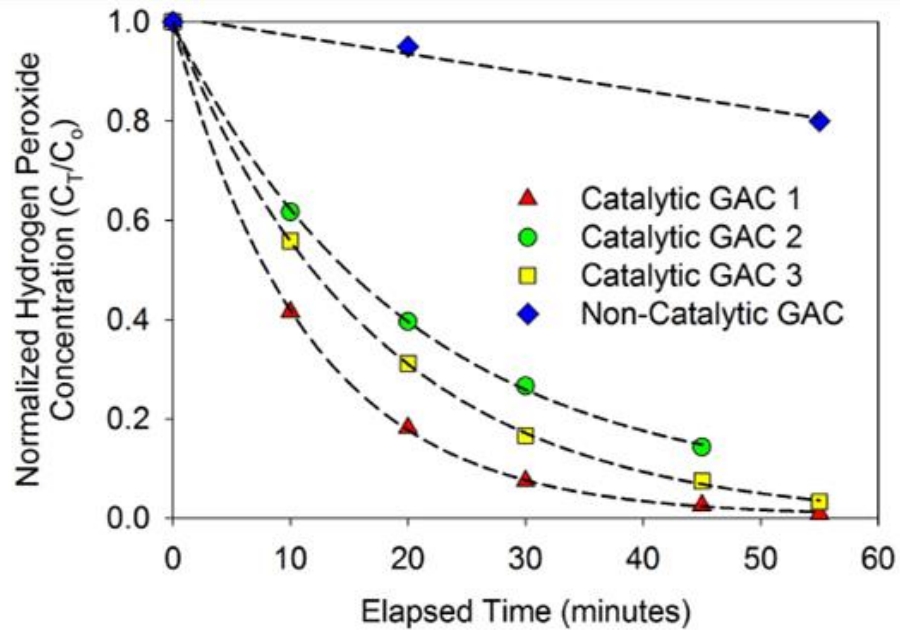


Wismer, M.; Woodling, R. "Copper CMP Treatment Using the Copper Select™ Process", *Semiconductor Fabtech*, 25th ed., pp. 51-55, (2005).

Wismer, M.; Riley, C.; Redding, A "An Approach for Copper and Hydrogen Peroxide Removal from Copper CMP and Solar Cell Wastewater", *Ultrapure Water* (2016).

Ion-Exchange is **NOT** Peroxide Tolerant

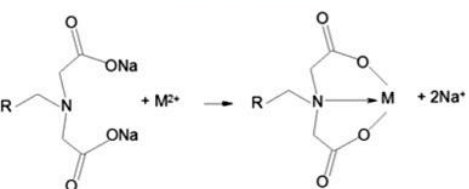
Degradation Yields Unreliable Results



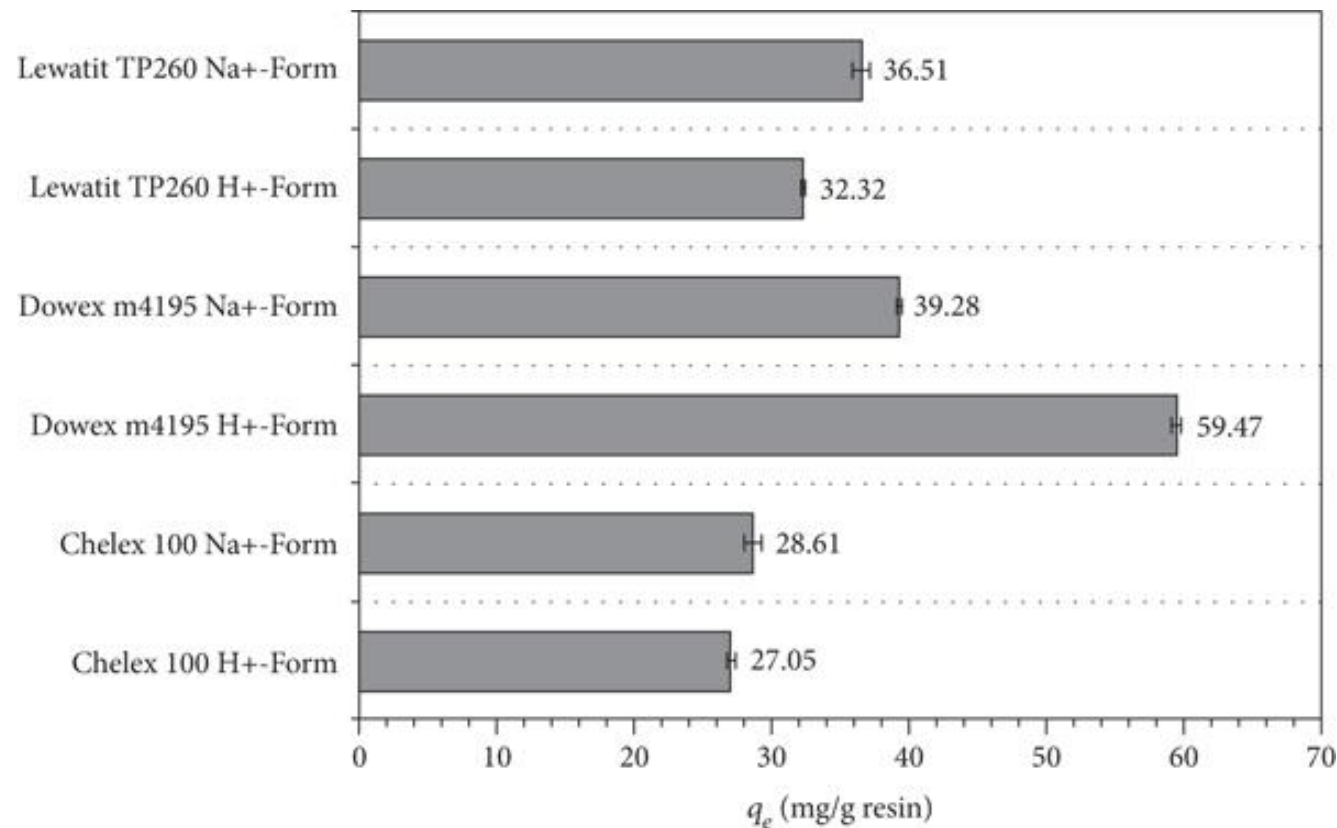
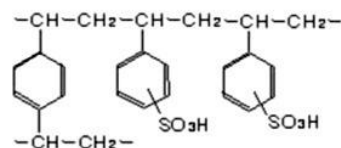
Wisner, M.; Woodling, R. "Copper CMP Treatment Using the Copper Select™ Process", *Semiconductor Fabtech*, 25th ed., pp. 51-55, (2005).

Copper Selective Resins Need Higher Capacity

Low Capacity Yields Large Systems



VS.



Pros & Cons of Ion Exchange



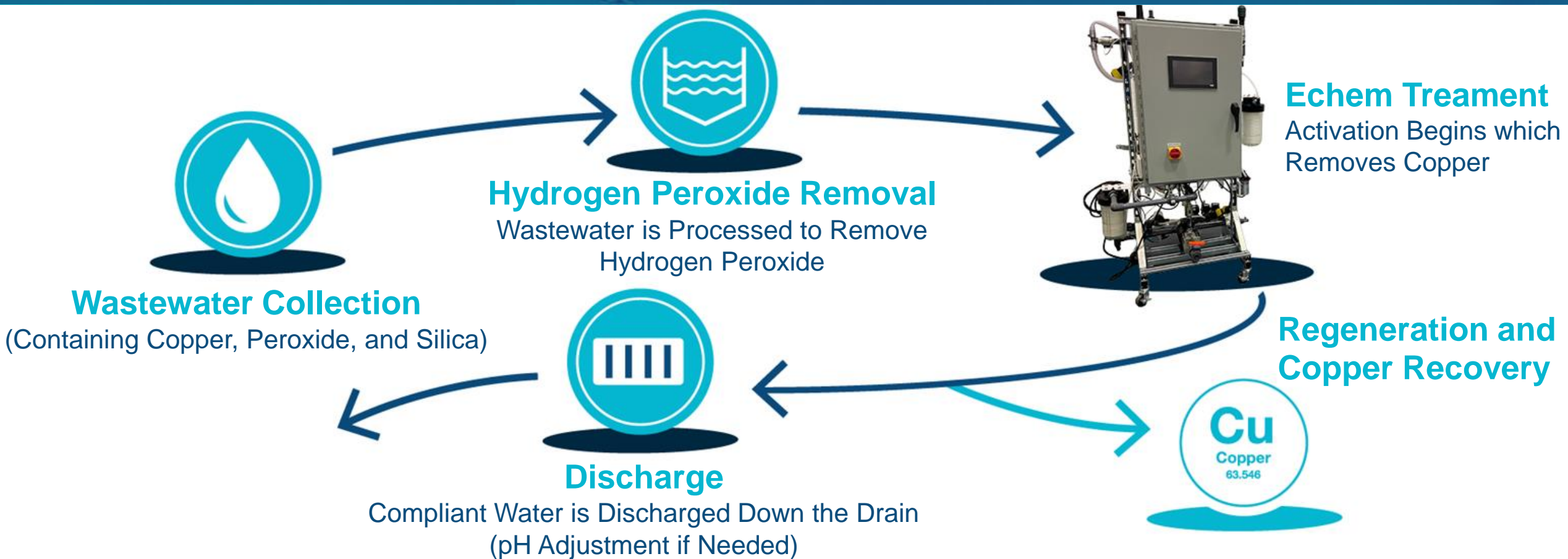
- Excellent copper removal capability (assuming appropriate resin choice and operating conditions)
- Common and familiar unit operation



- Pre-treatment required to prevent resin fouling and degradation (eg, removal of oxidants and organics necessary)
- Expensive regeneration system/OPEX
- Lower system flexibility for subsequent upstream process changes

Electrochemistry: A New Tool – A New Flow Chart

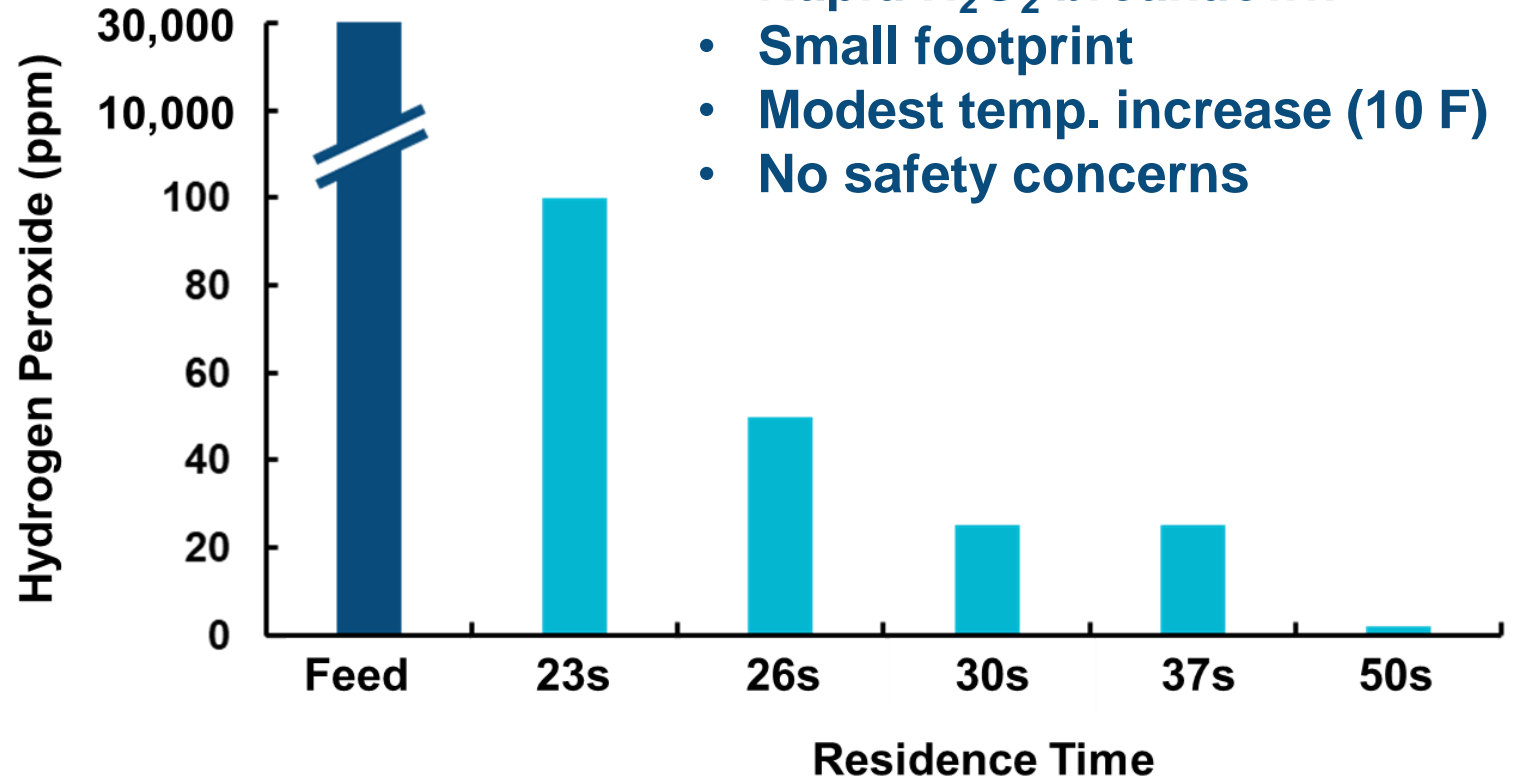
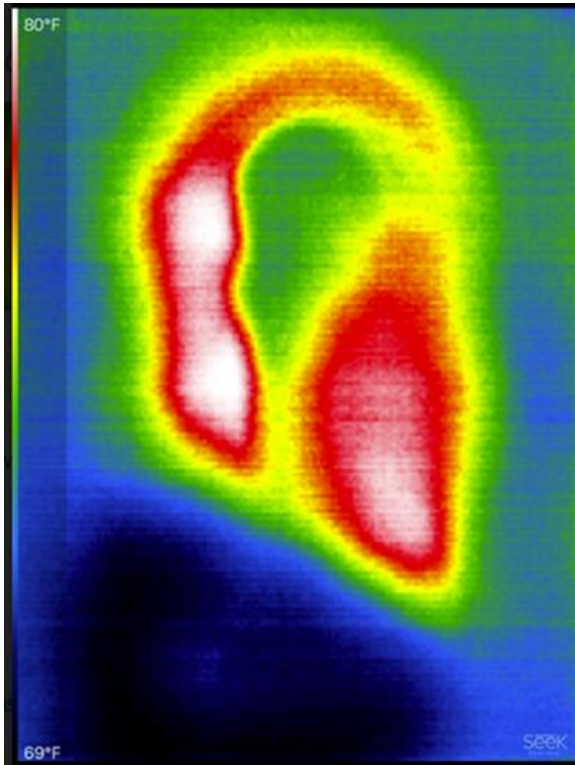
Electrochemical Innovations



Heterogenous Peroxide Destruction Media

New Catalyst for an Improved Operation

Peroxide Destruction Column



- Rapid H₂O₂ breakdown
- Small footprint
- Modest temp. increase (10 F)
- No safety concerns

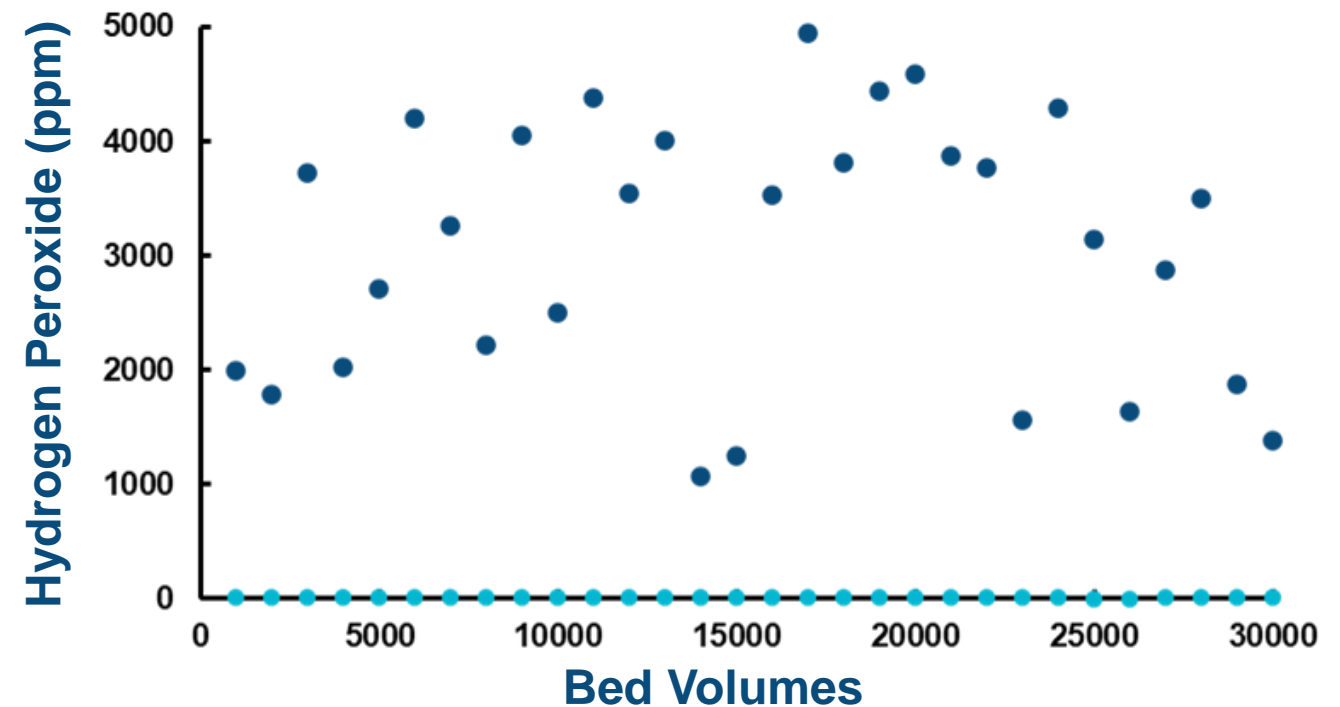
Commercial Peroxide Destruction Installation

New Catalyst for an Improved Operation

Peroxide Destruction Column

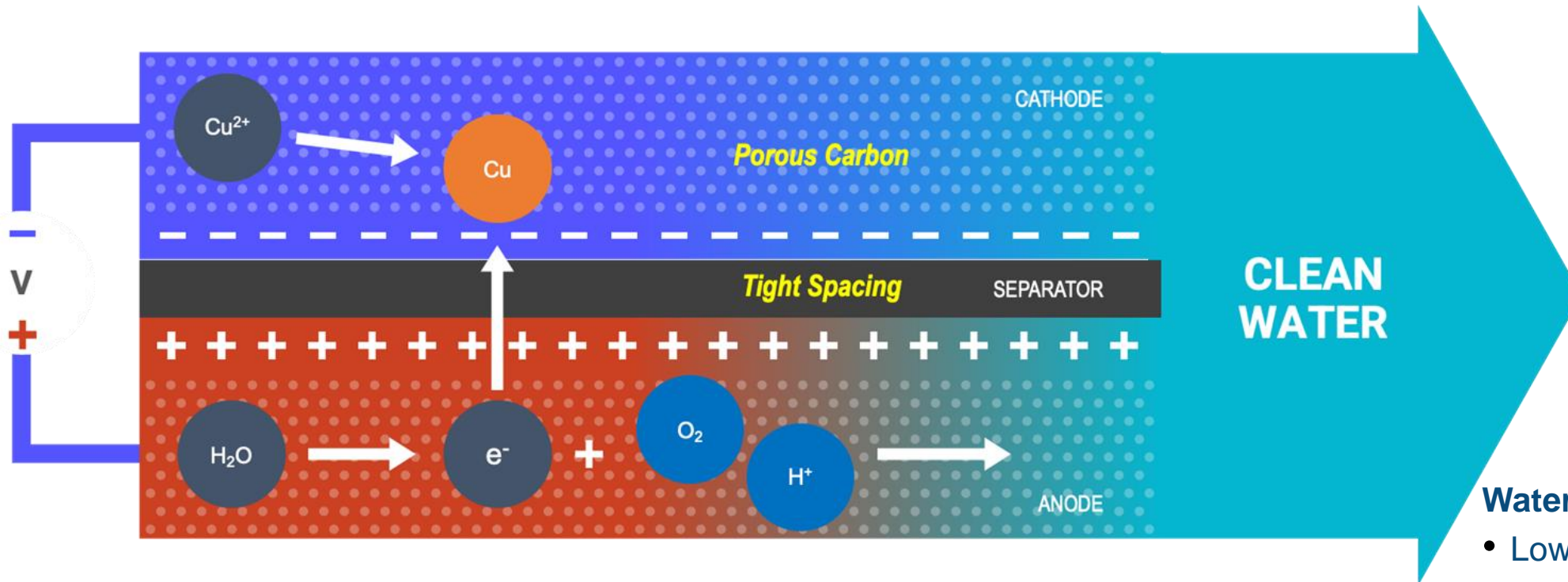


- 3 Years of Commercial Operation
- Highly Dynamic Feed [H_2O_2]



Electrochemical Reactor Design for Dilute Copper

Surgical Selectivity

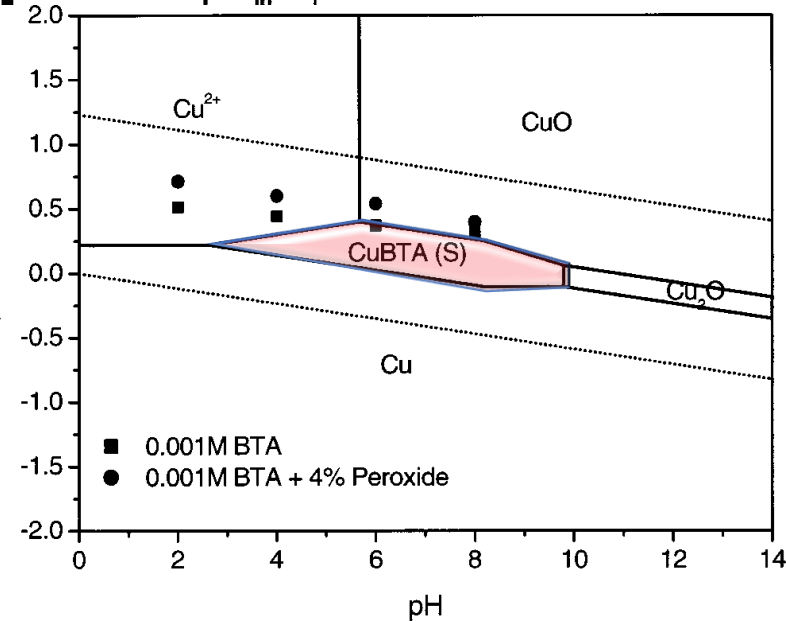
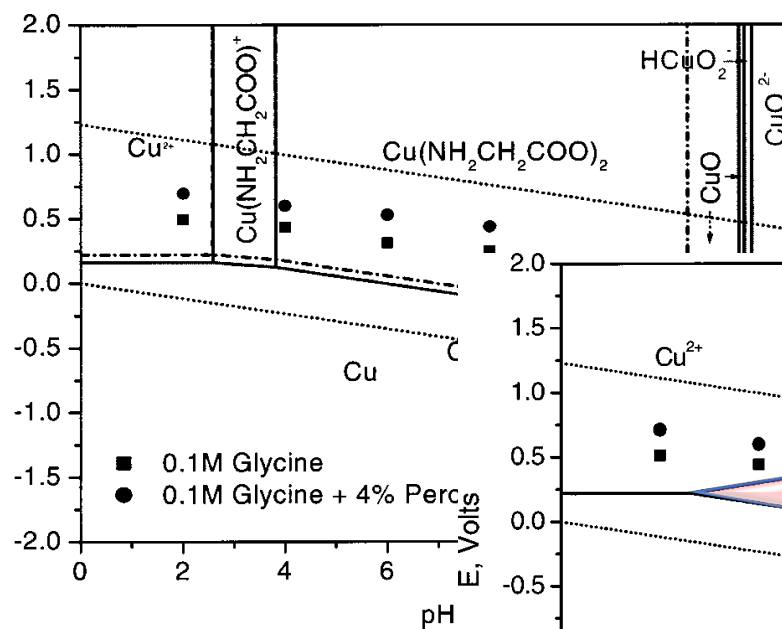
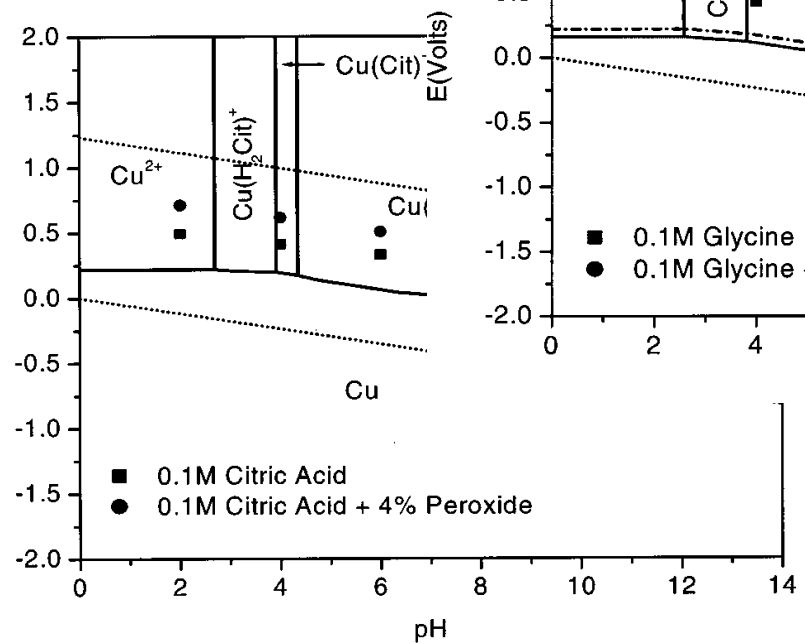
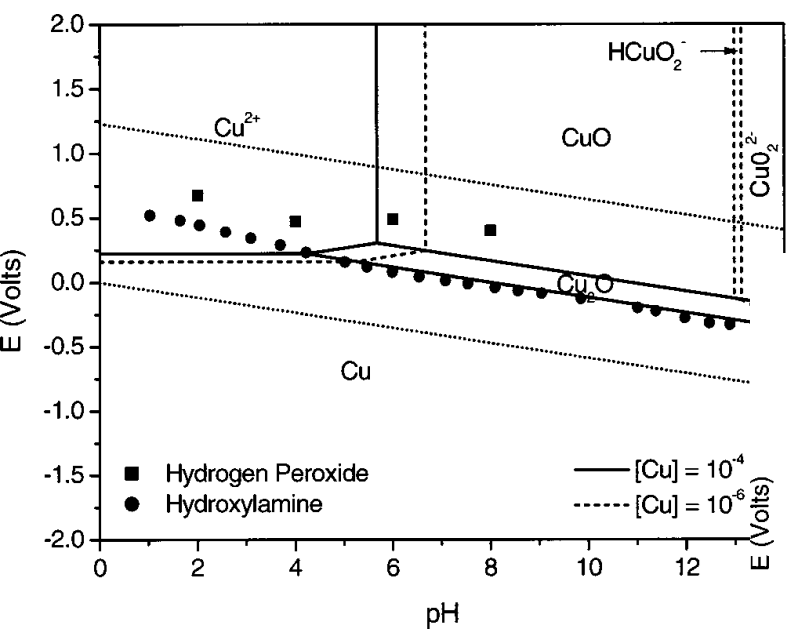


Water Quality Considerations

- Low TSS (< 50 ppm)
- TOC/COD/BOD (< 100 ppm)
- Biological/Microbes (N/A)

Slurry Chemistry is Important

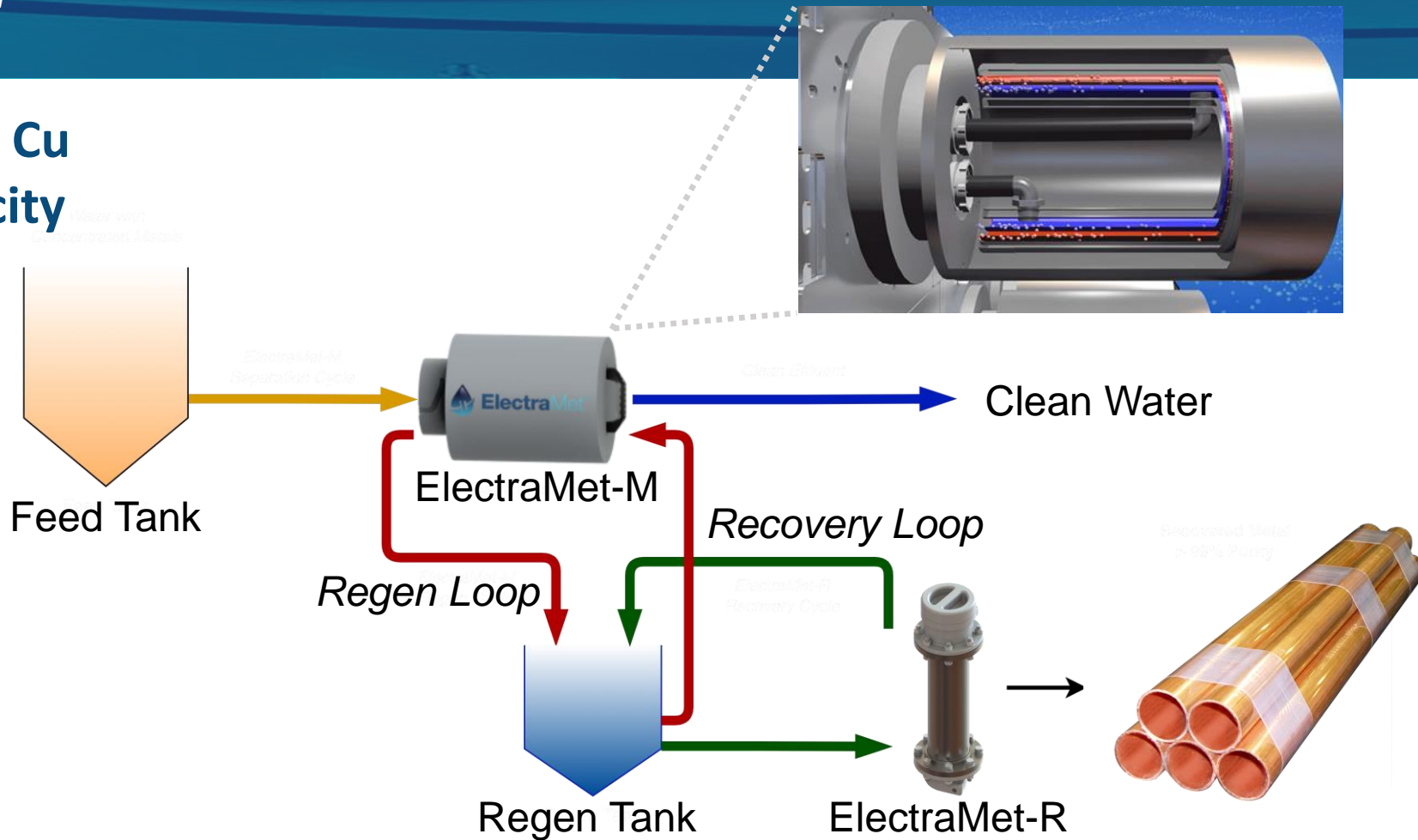
Organic Chelators & Corrosion Inhibitors



Copper Removal & Recovery with Electrochemistry

Closed Loop Process

Up to 900 g/L Cu
loading capacity



Delivering Proven Success – Traditional CuCMP Processes

Reliable and Consistent Discharge Compliance



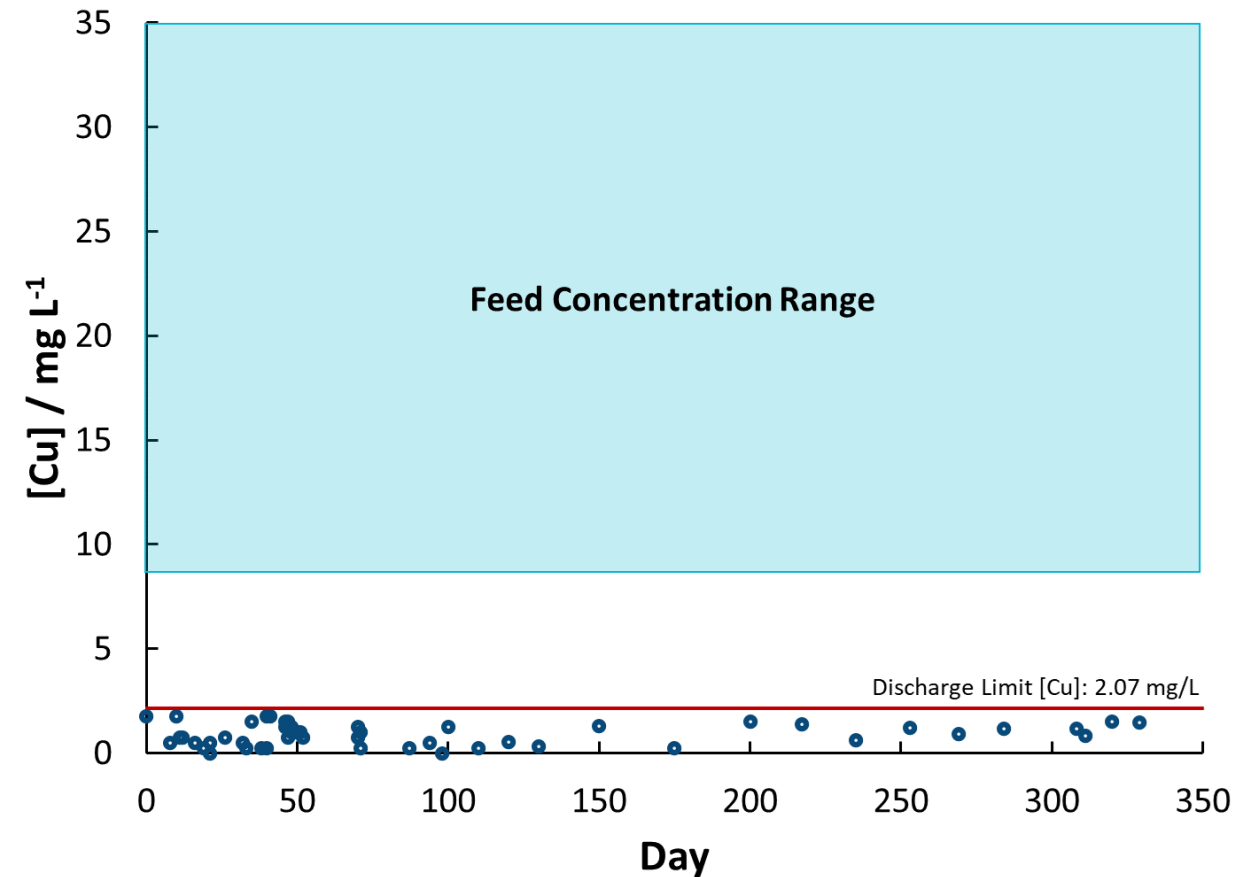
30 Months of Steady Operation

- 100% Planned Uptime
- Consistently and Reliably Met Permit Discharge Limit



Automated Process Adaptation

- Tolerable to Upstream Process Changes
- Adapts to Dynamic Upstream Process Changes Such as Large [Cu] Fluctuations & Peroxide Bleed Through



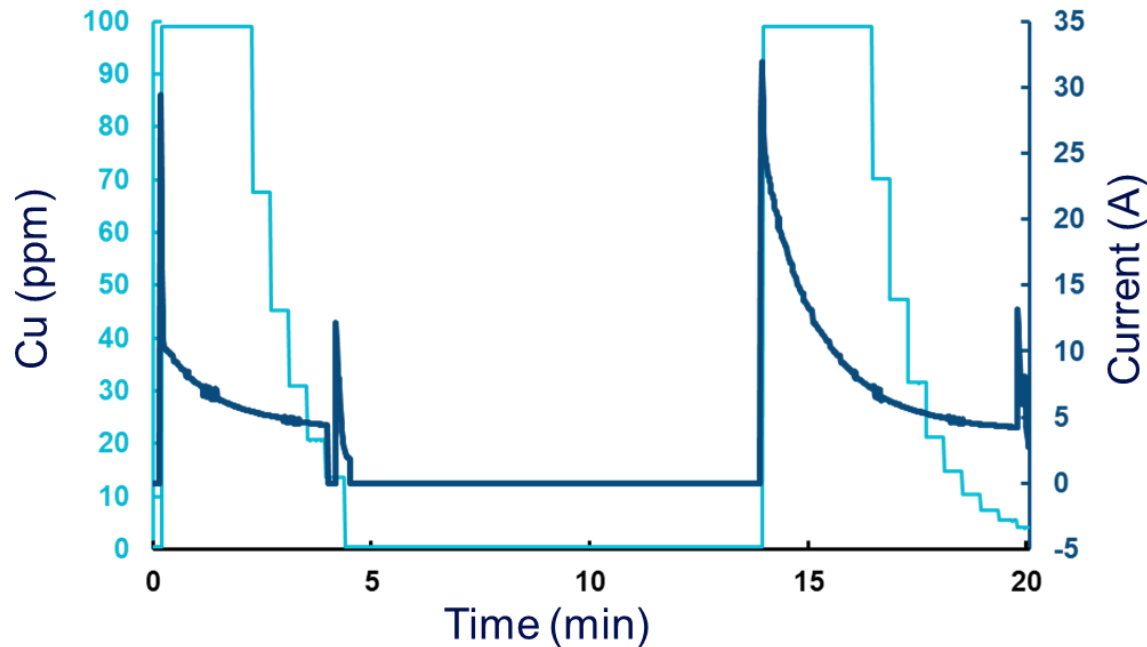
Delivering Proven Success – Traditional CuCMP Processes

Reliable and Consistent Discharge Compliance



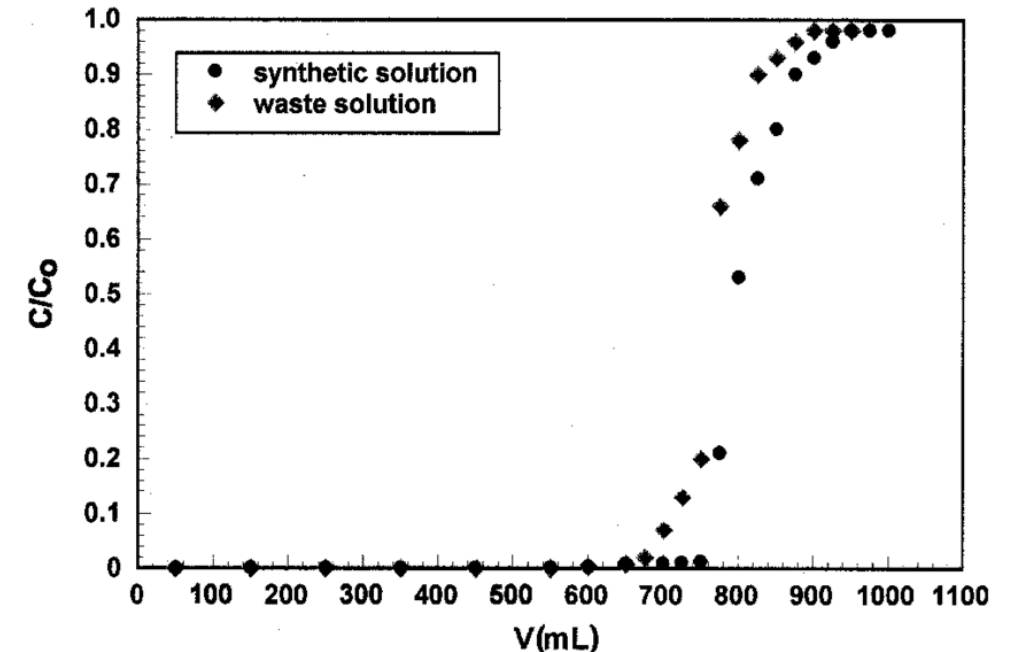
Echem: Inherent Feedback Signal

- Floating current (amps) matches [Cu] levels
- Automated dynamic operation



Phys. Chem: Blind Breakthrough

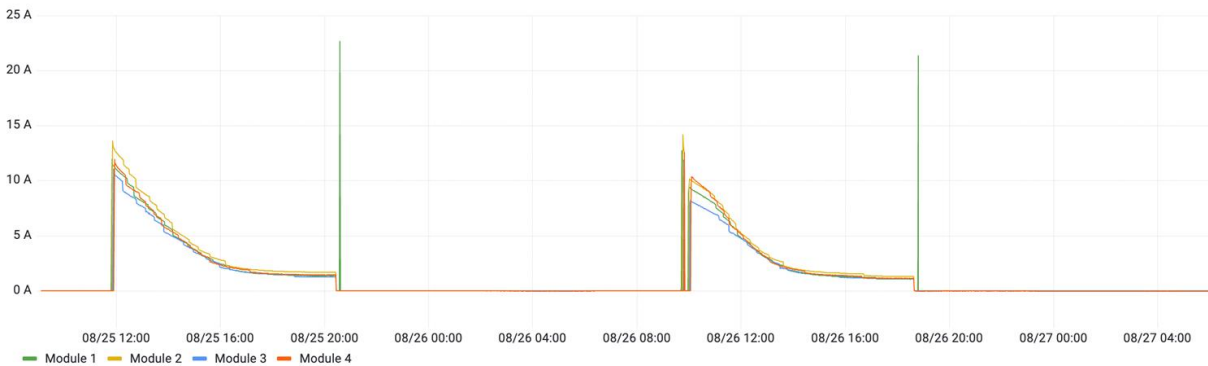
- No real-time insights
- Need second system in case of breakthrough



ElectraMet Includes Advanced Digitization

Actionable Intelligence

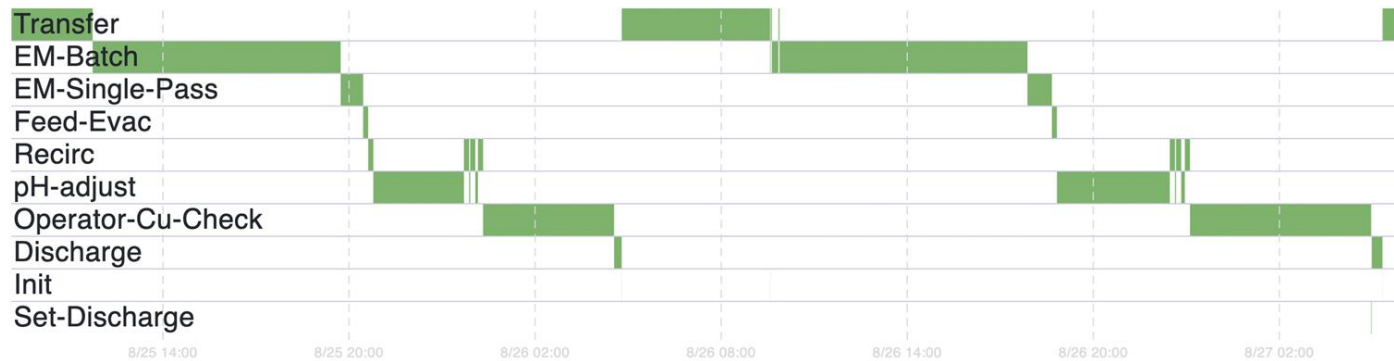
Current



Pressure



Process Timing Diagram



Trackable Parameters

- pH
- Temperature
- Flow
- TDS
- ORP
- Tank Levels

ElectraMet Includes Advanced Automation

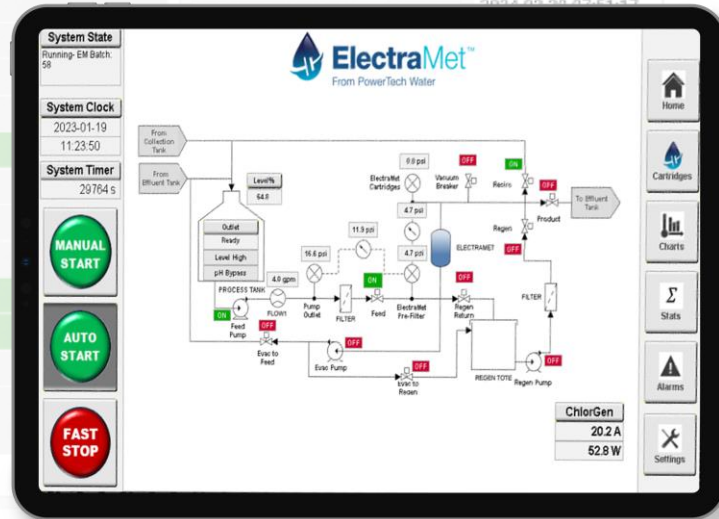
Actionable Intelligence

Remote Operation

- Reduced labor requirements
- Simple controls
- Tie into existing SCADA systems

Actionable Intelligence

- Real-time display
- AI supported diagnostics & analytics
- Increased plant uptime



Delivering Proven Success – Emerging Slurry Technologies

Electrochemistry Adapts to New Chemistries



Removes Copper from Stronger Chelates



Recover Cu as High Purity Sheets



Potential to Reuse Slurry



Before CMP



After CMP



1,310 ppm



After Treatment



1.64 ppm

Delivering Proven Success – Emerging Slurry Technologies

Electrochemistry Adapts to New Chemistries



Removes Copper from Stronger Chelates



Recover Cu as High Purity Sheets



Potential to Reuse Slurry



Electrochemical Systems Allow for a **Smaller Footprint**

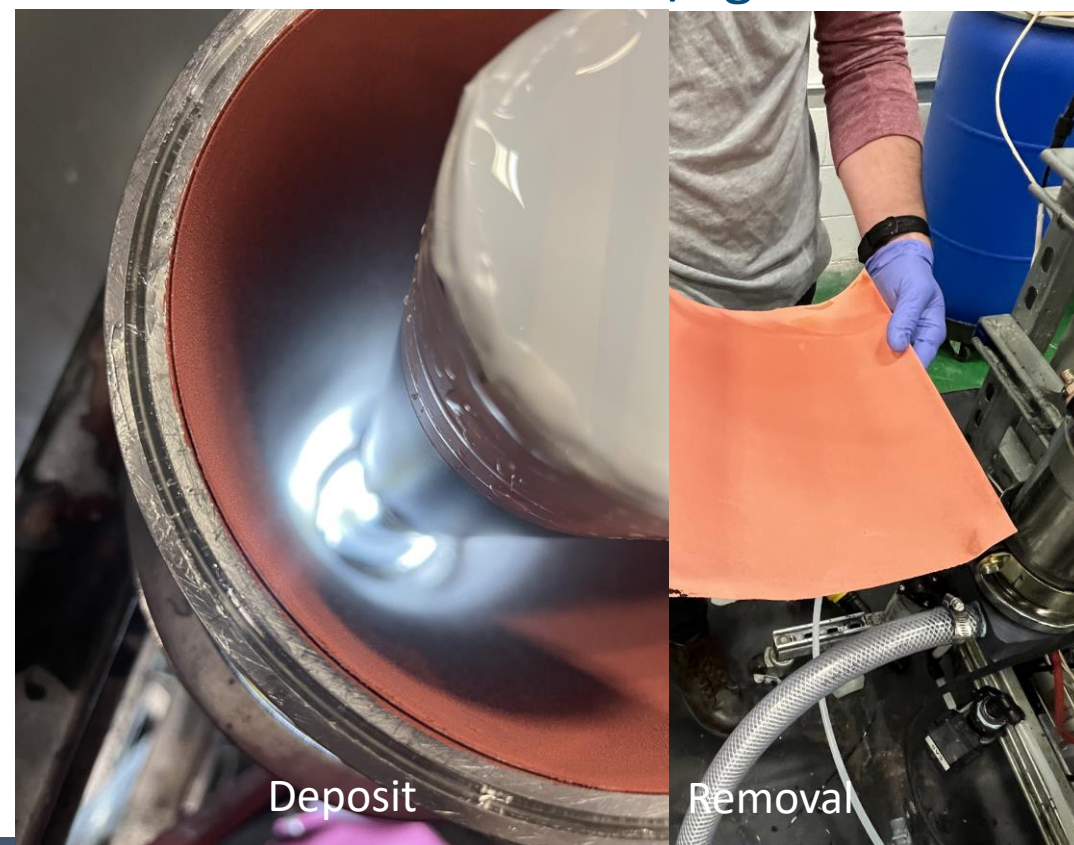
Modular Systems for Improved Operations

Power – 0.6 kWh/m³ Treated



4.5ft D x 17ft L x 7ft H

Power – 0.8 kWh/kg Cu

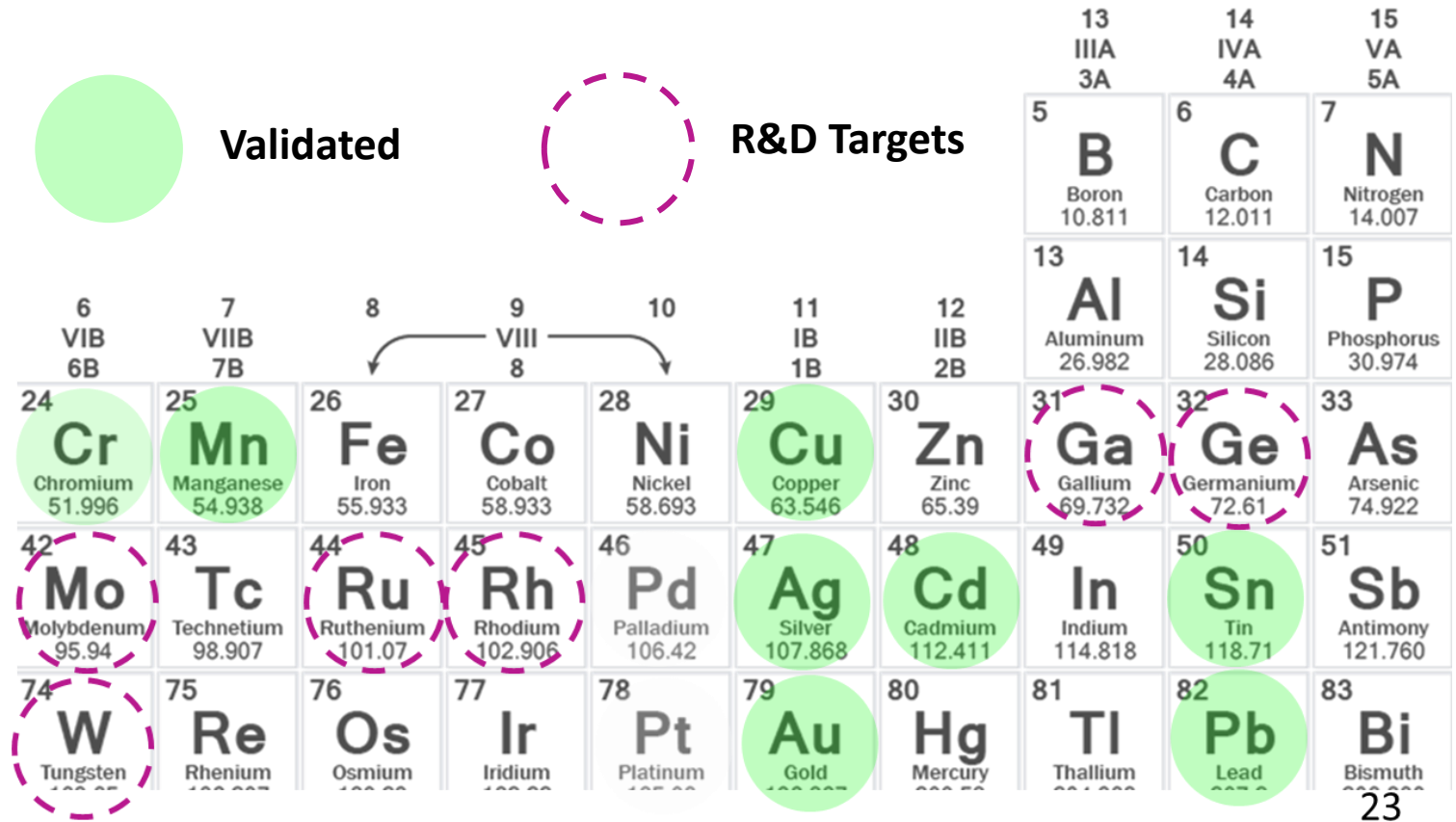


Smart Reactor Design Imparts Surgical Selectivity

Proven Success with Multiple Metals

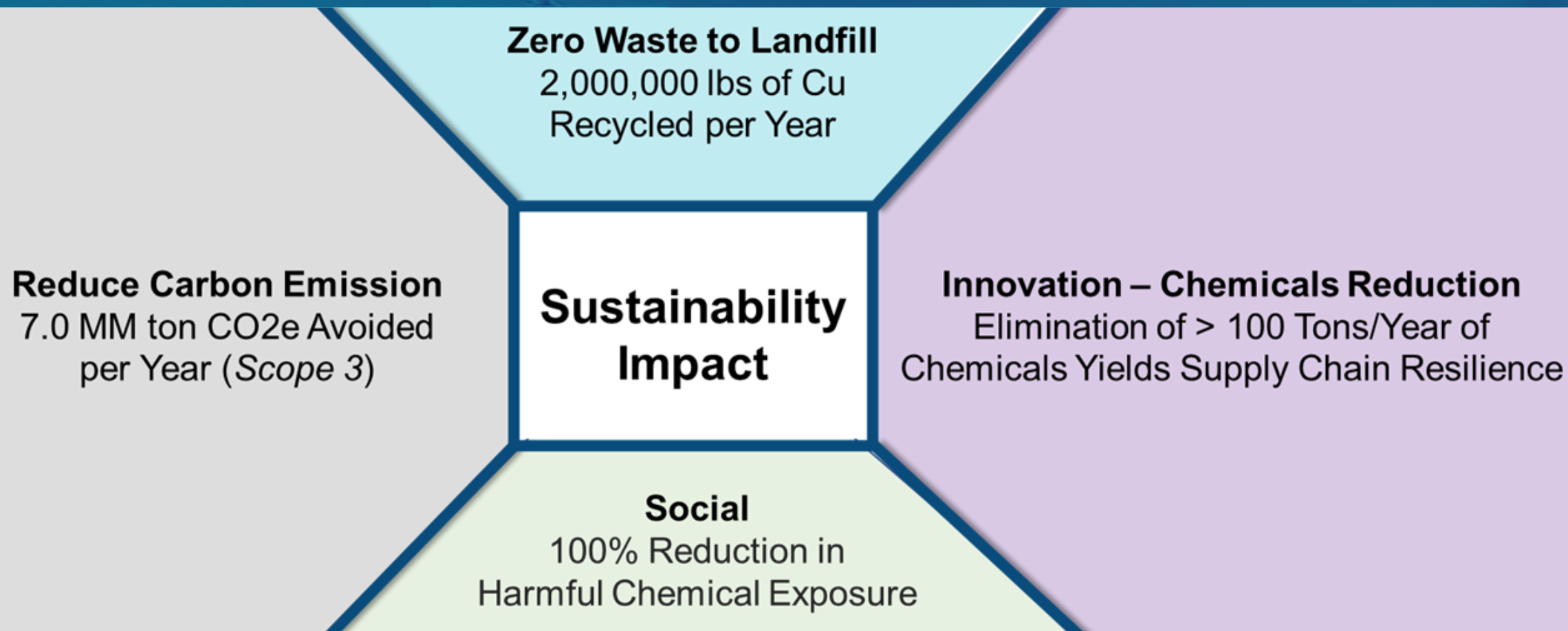
Electrochemistry Can:

- 1) Selectively Target Specific Metals
- 1) Target Multiple Metals for an Improved Process to Meet Compliance



Electrochemistry Delivers Sustainability

Broad Sustainability Impacts



Thank You | Q&A

Cameron Lippert

✉ Cameron.Lippert@electramet.com

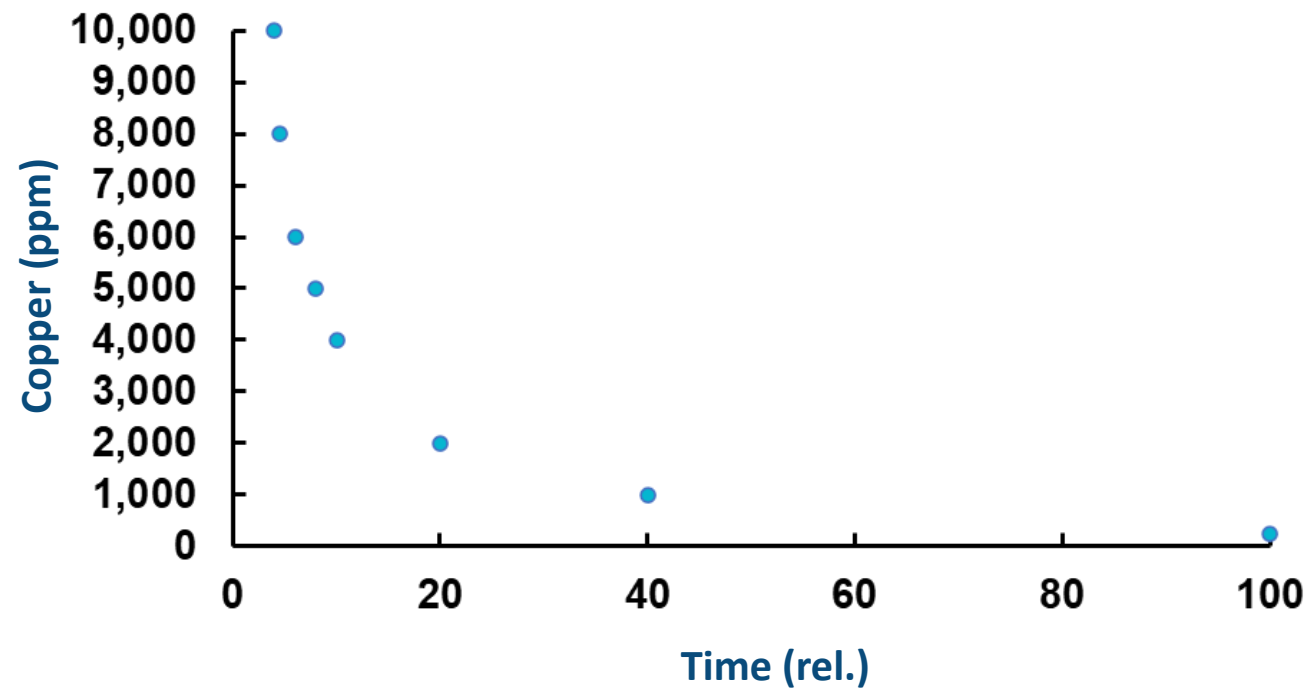
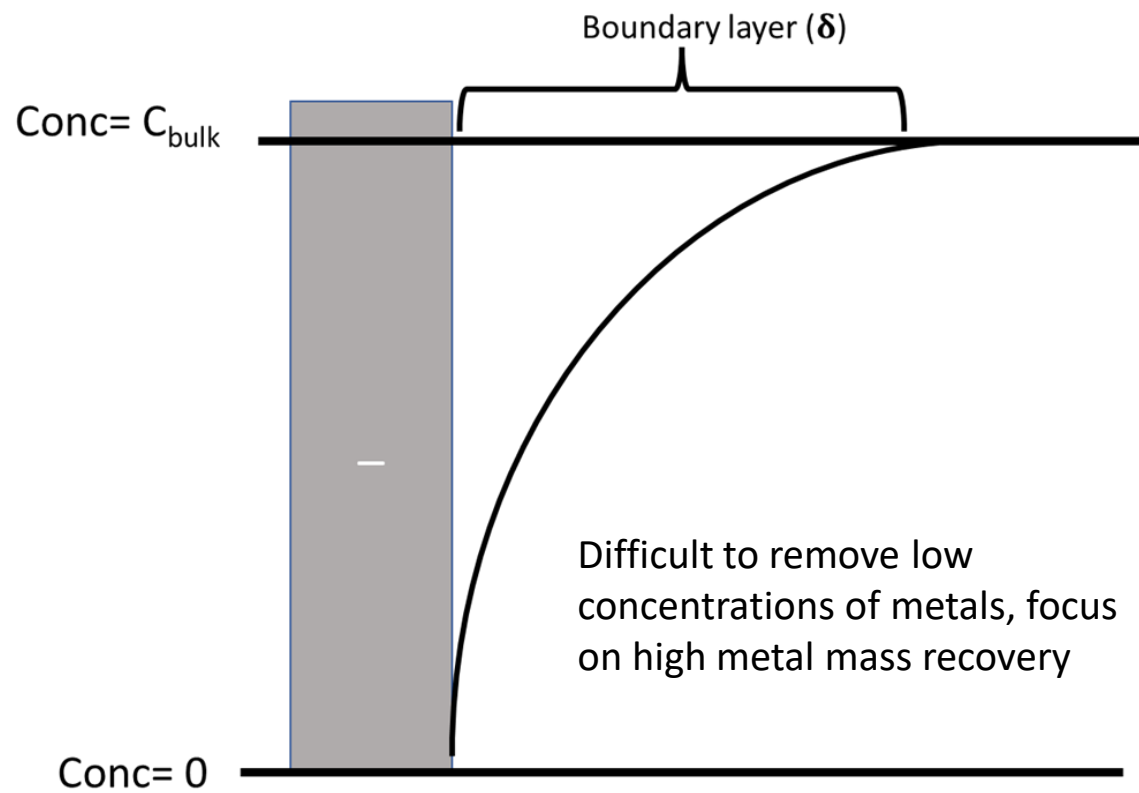
📱 859.437.4823

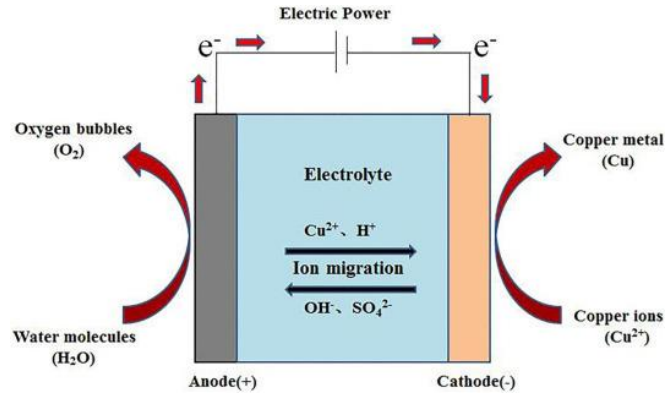
ElectraMet.com

✉ Info@electramet.com

📱 859.600.1857

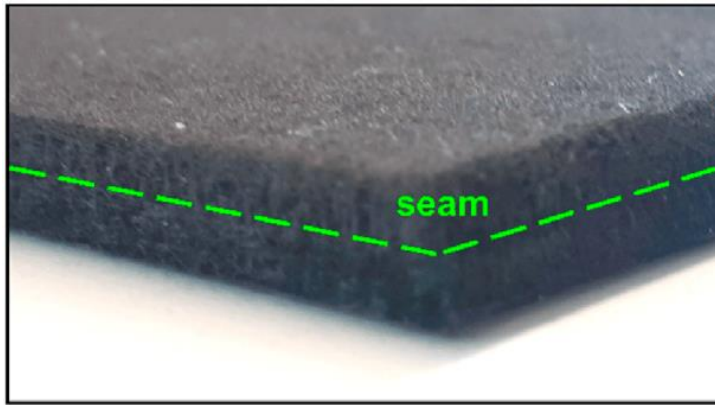




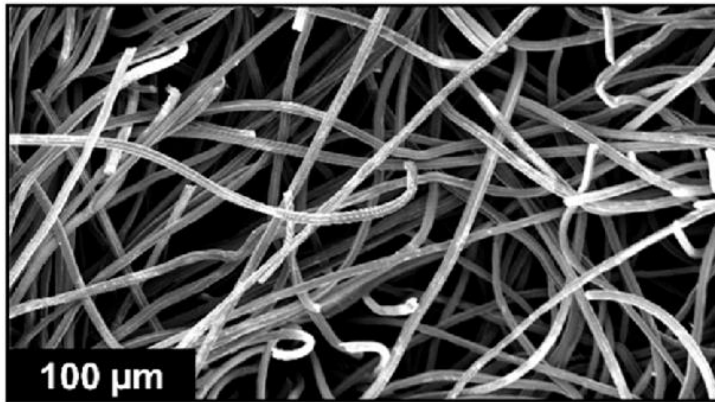


Parameters	Electrowinning
[Cu] (ppm)	> 10,000
pH	0
Conductivity	Very High (> 10,000 uS/cm)
Impurities	None

Parameters	Industrial Wastewater
[Cu] (ppm)	5 - 100
pH	4 - 9
Conductivity	Med (2,000 uS/cm)
Impurities	TSS, Organics



(b)



Gap between carbon pieces $\sim \delta$
Low concentration removal possible

