

Regeneration of Hydrochloric Acid from Liquid Process Streams Containing Iron and Zinc Using Bipolar Electrodialysis

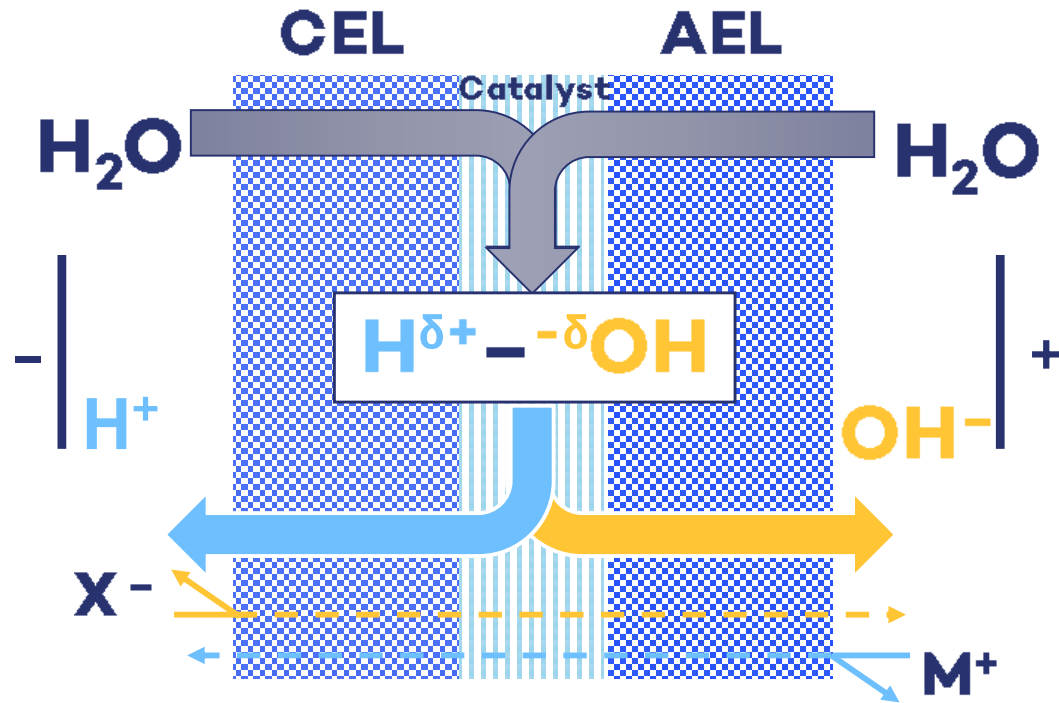
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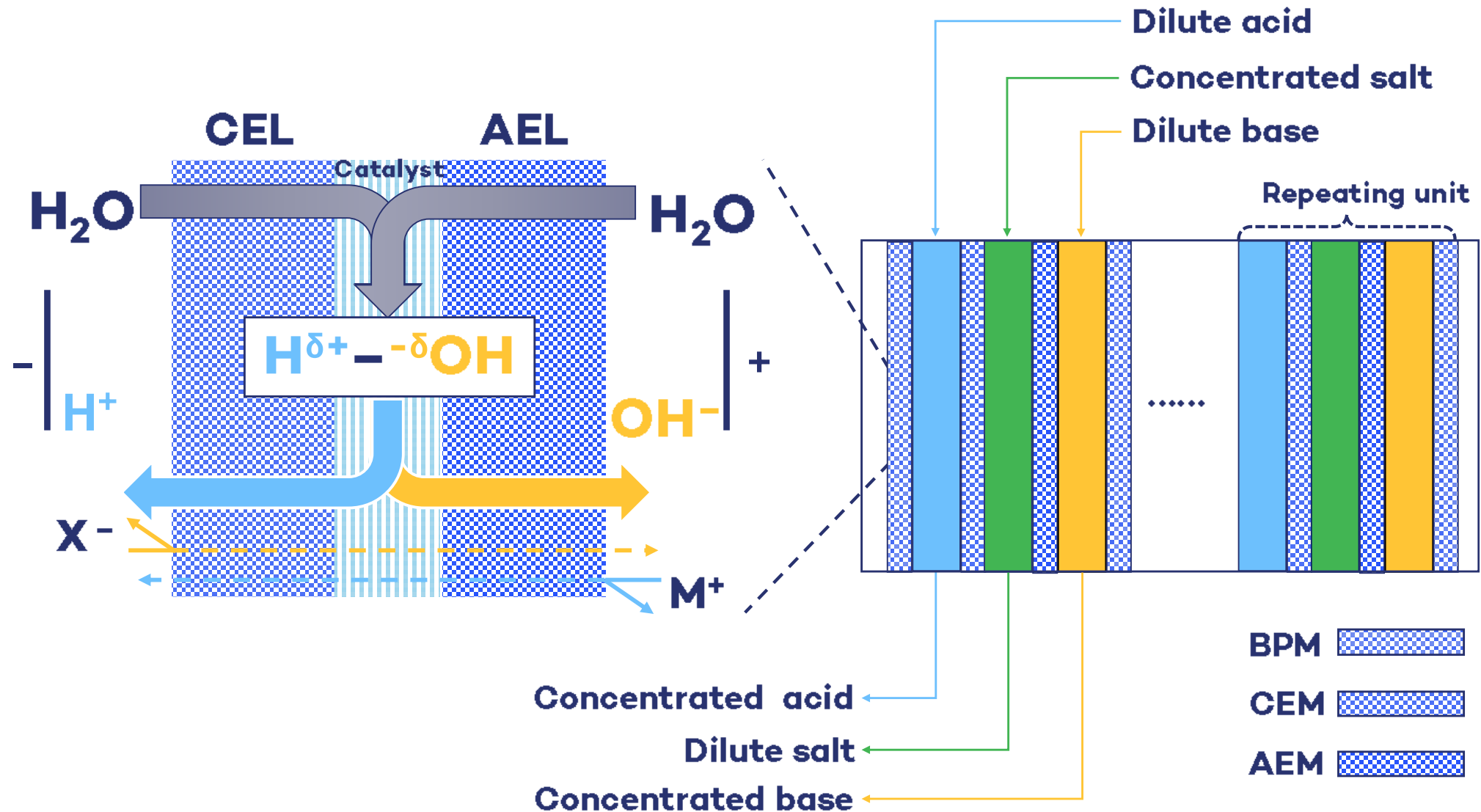
Outline

1. Intro to bipolar electrodialysis (BPED) applied to galvanizing
2. Lab bench data processing Fe-rich acid from galvanizing plant
3. Technoeconomic analysis
4. Plant workflow

Bipolar membrane (BPM)



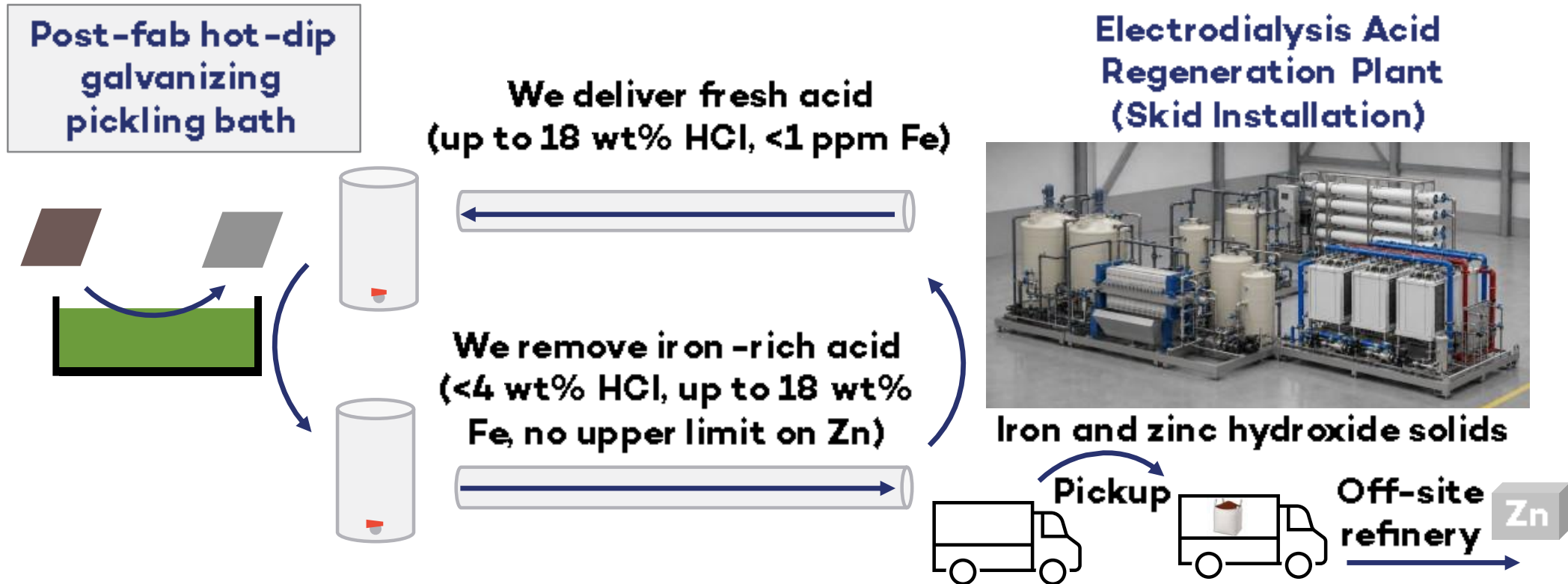
Bipolar electro dialysis (BPED)



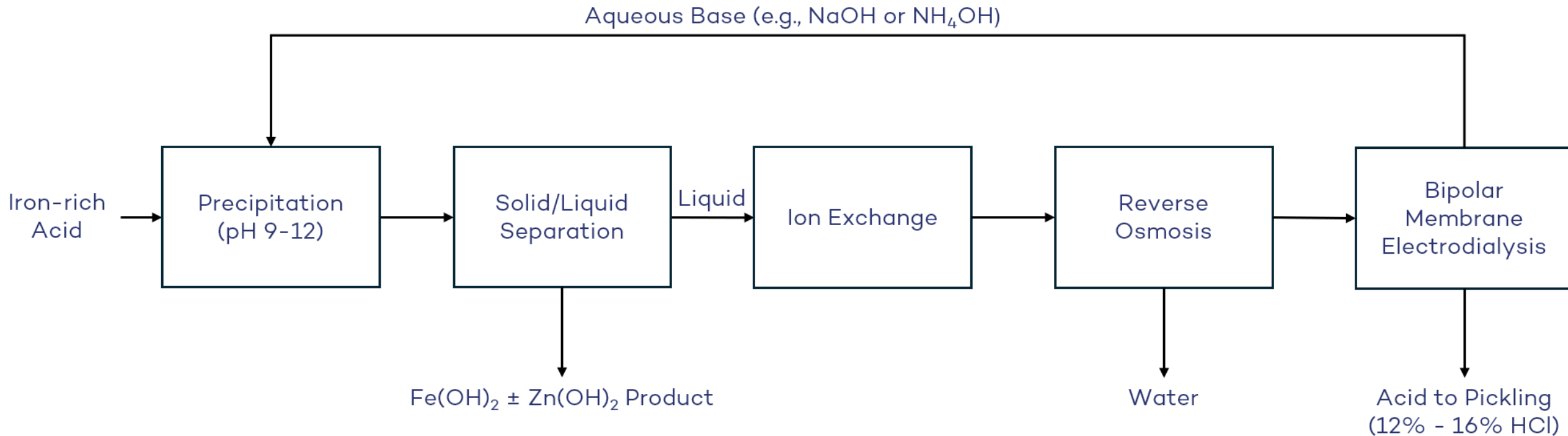
BPED features

- Safe
 - Ambient P and T
 - Minimal gas generation (H_2 and O_2)
- Feed flexibility
 - Na^+ , NH_4^+ , Cl^- , SO_4^{2-} , NO_3^-

BPED applied to pickling acid regeneration



Flow sheet for iron-rich hydrochloric acid

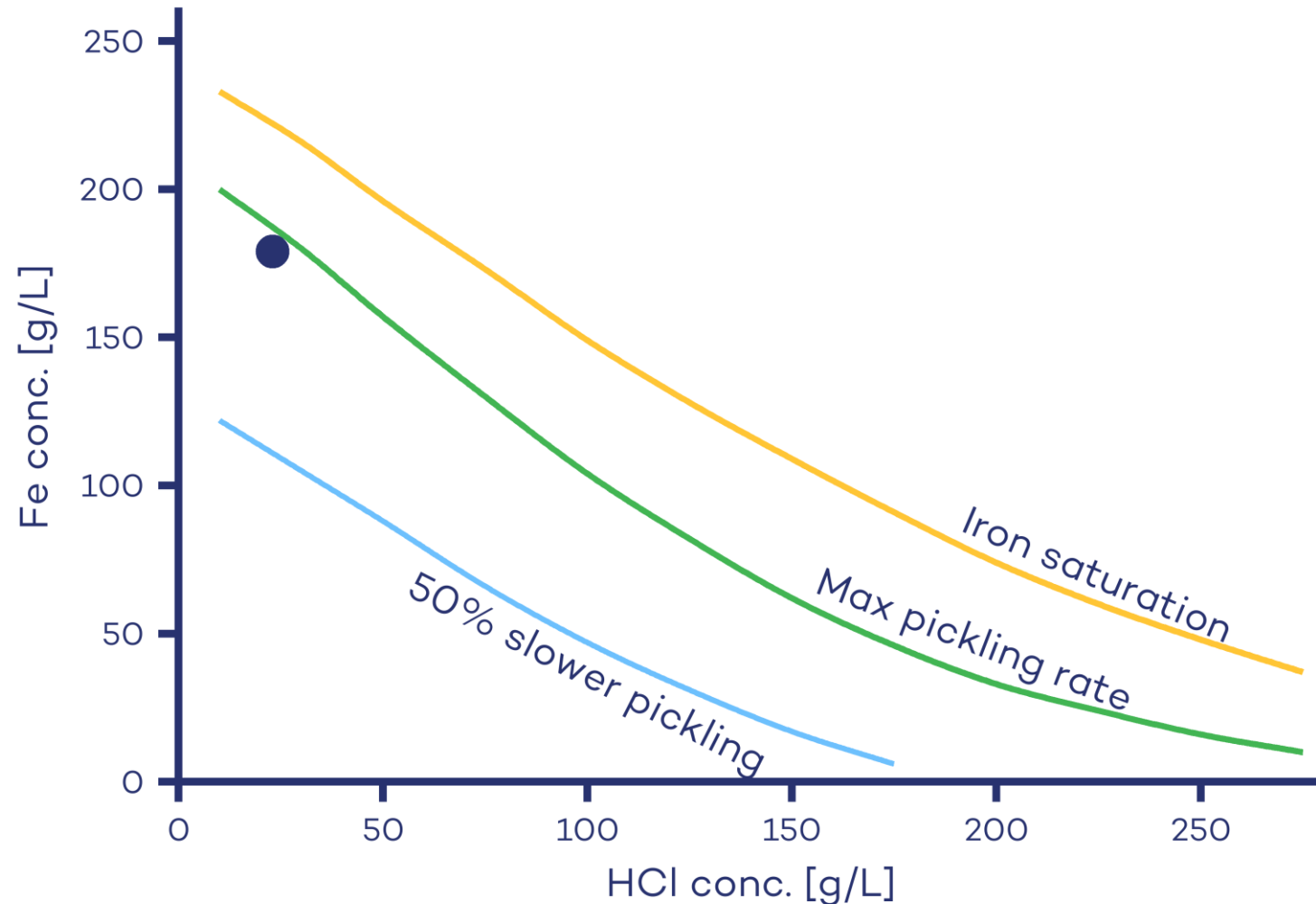




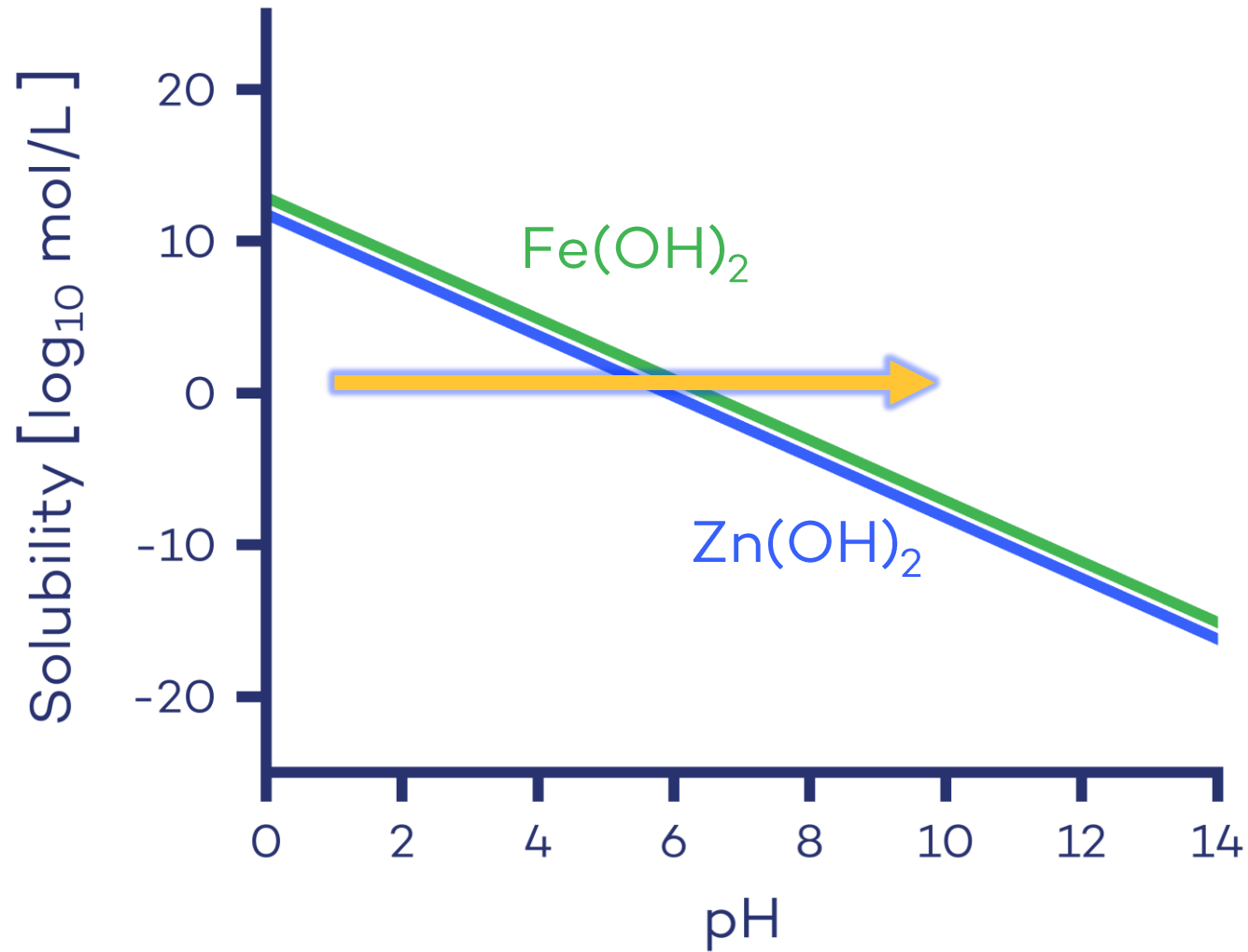
Lab bench data processing Fe-rich acid from galvanizing plant

Chemical composition of feed

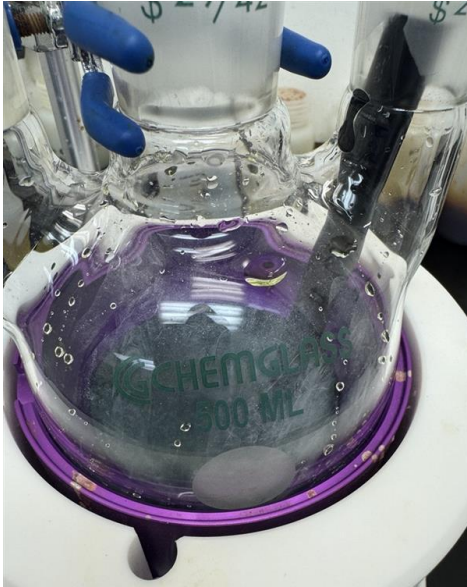
- 179 g/L Fe
- 145 g/L Zn
- 22.7 g/L HCl



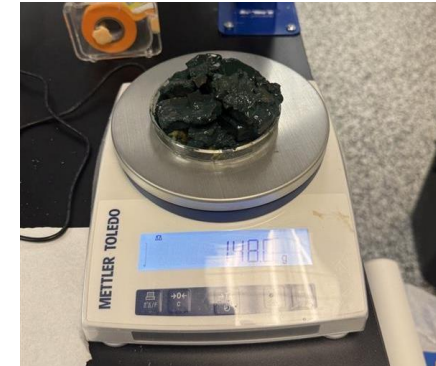
Fe & Zn removal by pH swing



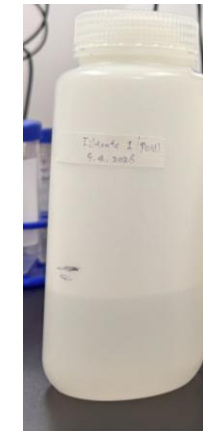
Precipitation method



Vacuum filtration

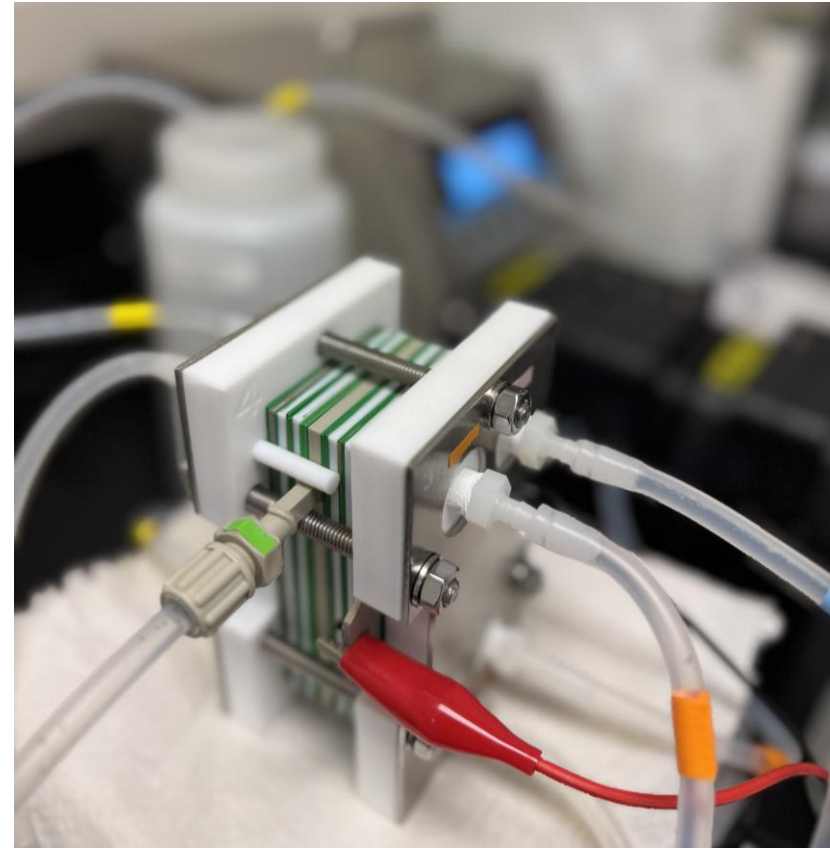


- 100 mL starting volume
- 3.0 N (18 wt%) NaOH added
- 1 hr hold after target pH reached
- Room temperature



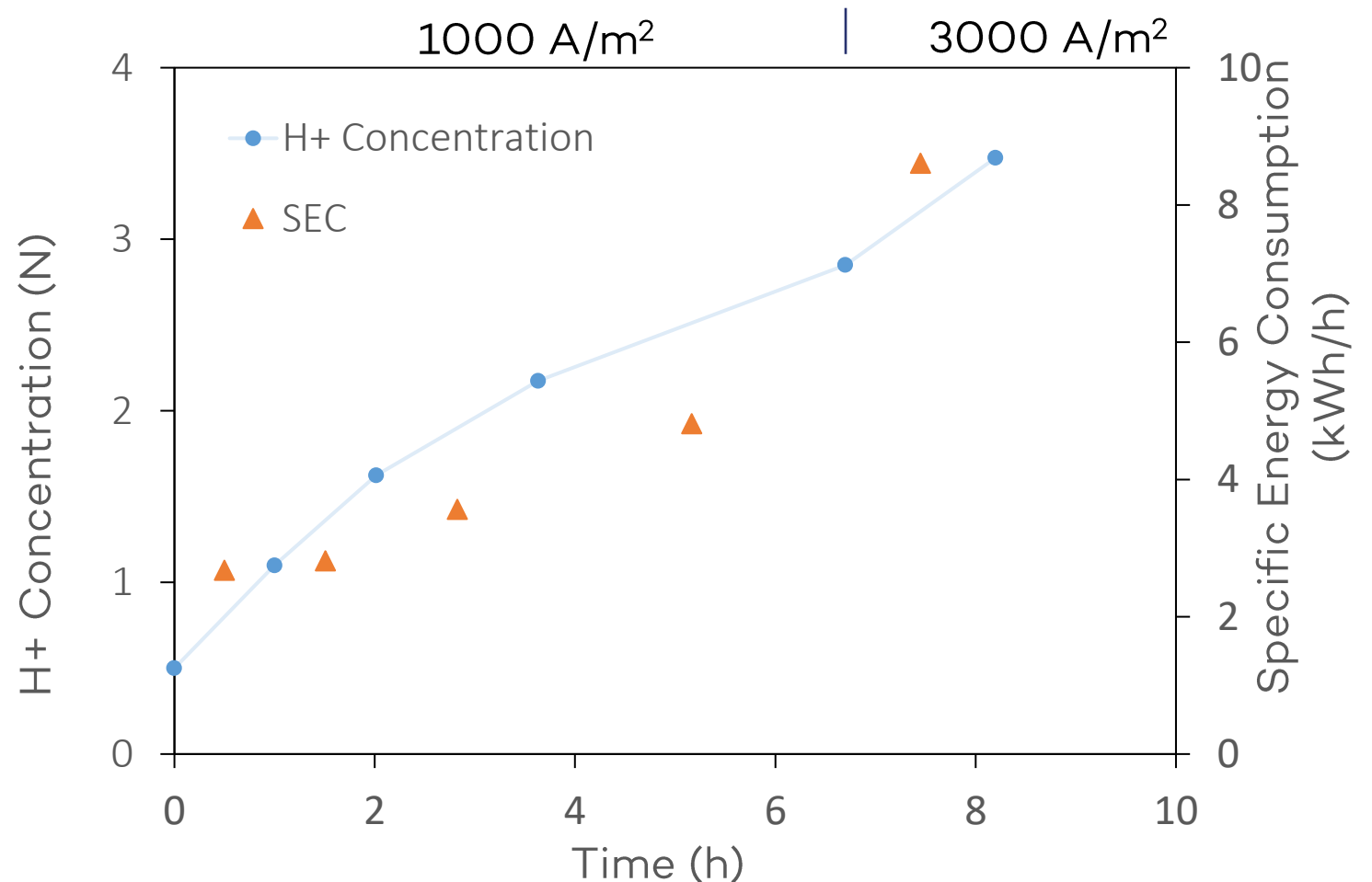
BPED method

- 10 cm² effective electrode area
- 4 membranes
 - 1CEM
 - 1 AEM
 - 2 BPM
- 5 compartment
 - 1 saline feed
 - 1 base
 - 1 acid
 - 2 electrode rinse solutions
- Galvanostat technique
(constant current)



Specific Energy Consumption (SEC)

- 3.48 N (12 wt%) HCl produced
- Commercial BPMs showed average SEC of 3.67 kWh/kg HCl for 1000 A/m² period and 5.18 kWh/kg HCl overall
- No membrane fouling observed



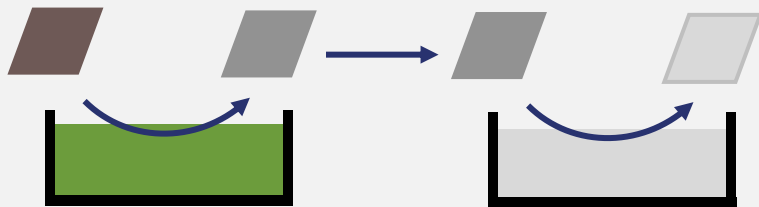


Technoeconomic analysis

Business model assumption

Galvanizer

- Pays treatment charge per quantity of Fe-rich acid
- Sublets space within their work site to Uplift



Fe-rich acid



Fe-free acid



Treatment Charge



Uplift Geosystems

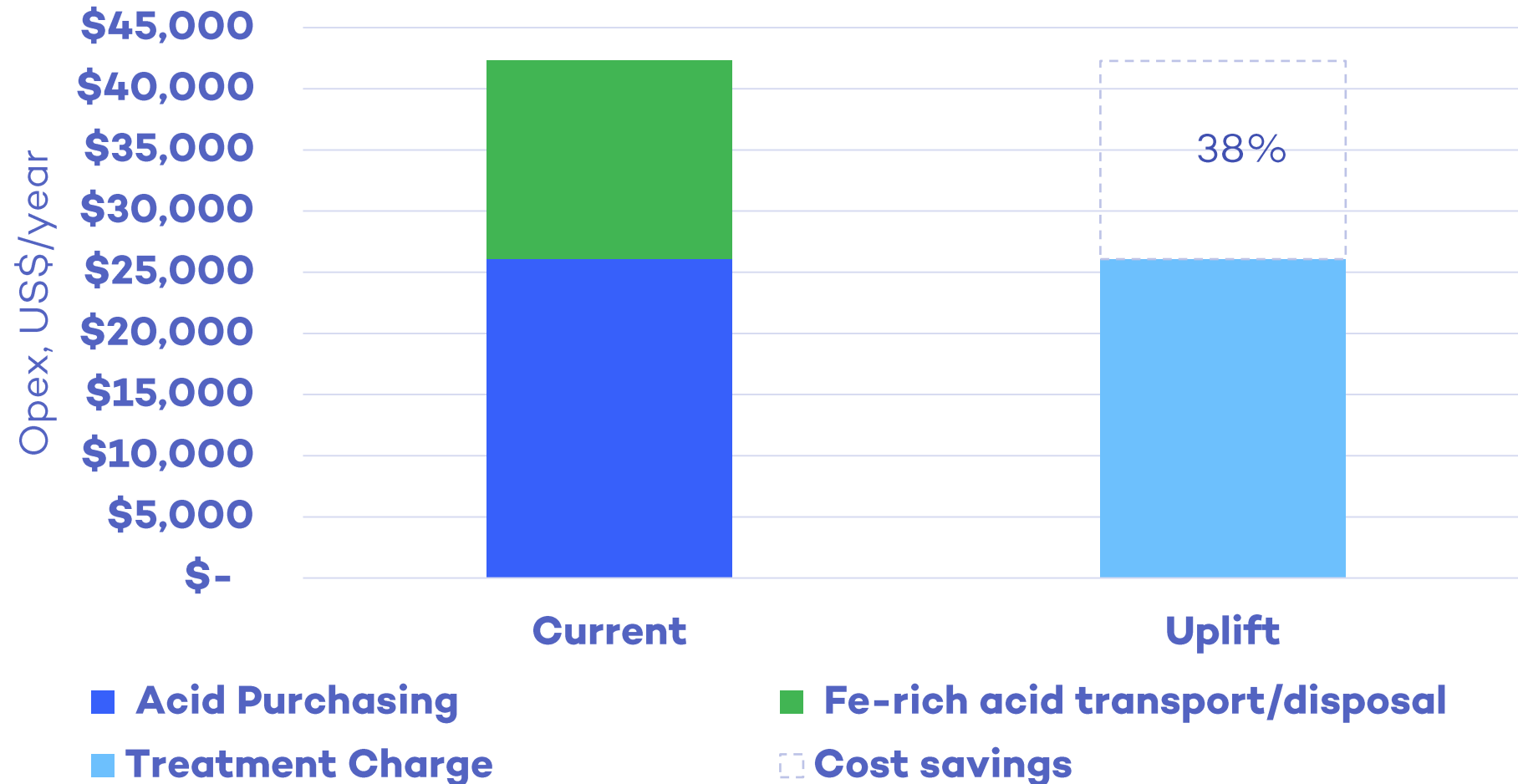
- Owns BPED and peripheral equipment
- Pays utilities and maintenance for that equipment
- Sends Fe-Zn hydroxides solids offsite for refining



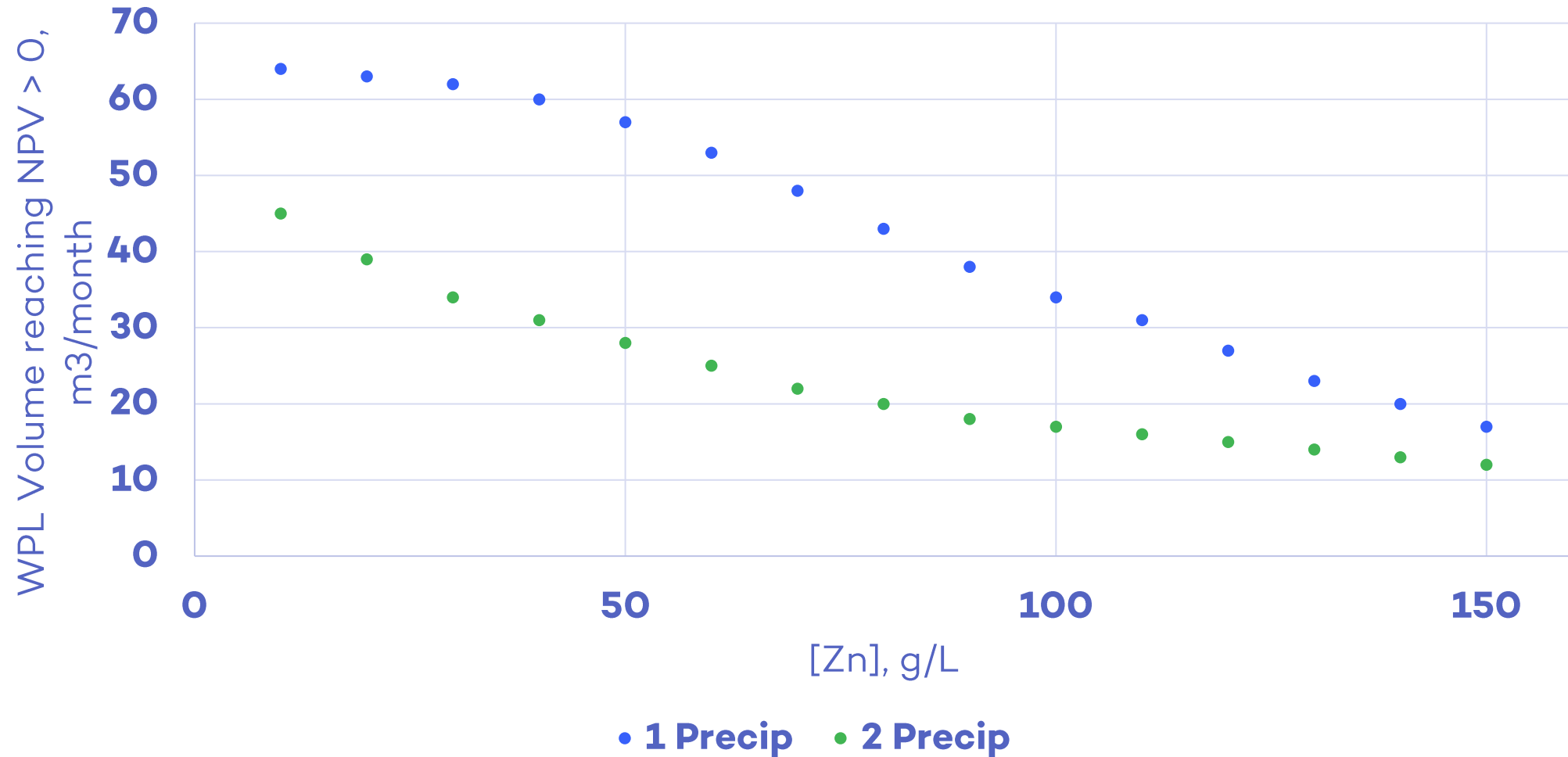
Technoeconomic model assumptions

Parameter	Value	Unit
Electricity Price	0.07	US\$ / kWh
Plant Uptime	8000 (91)	hours / year (%)
HCl Spot Price (32 wt%)	280	US\$ / tonne
Fe-Rich Acid Throughput	9	m ³ / month
Net Present Value (NPV) Discount Rate	10	%
CAPEX Scaling Exponent	0.6	-
BPED Membrane Replacement Rate	3	Years
BPED Current Density	1000	A / m ² electrode

Projected acid cost savings for galvanizers



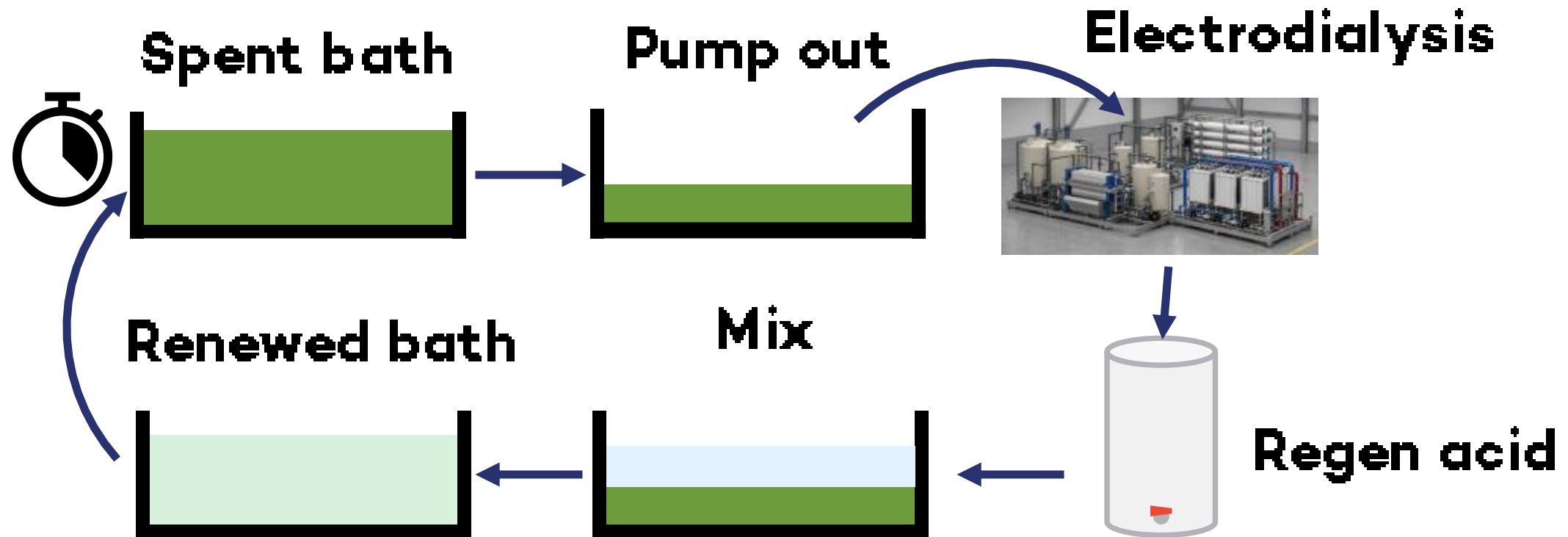
Economies of scale and Zn content matter



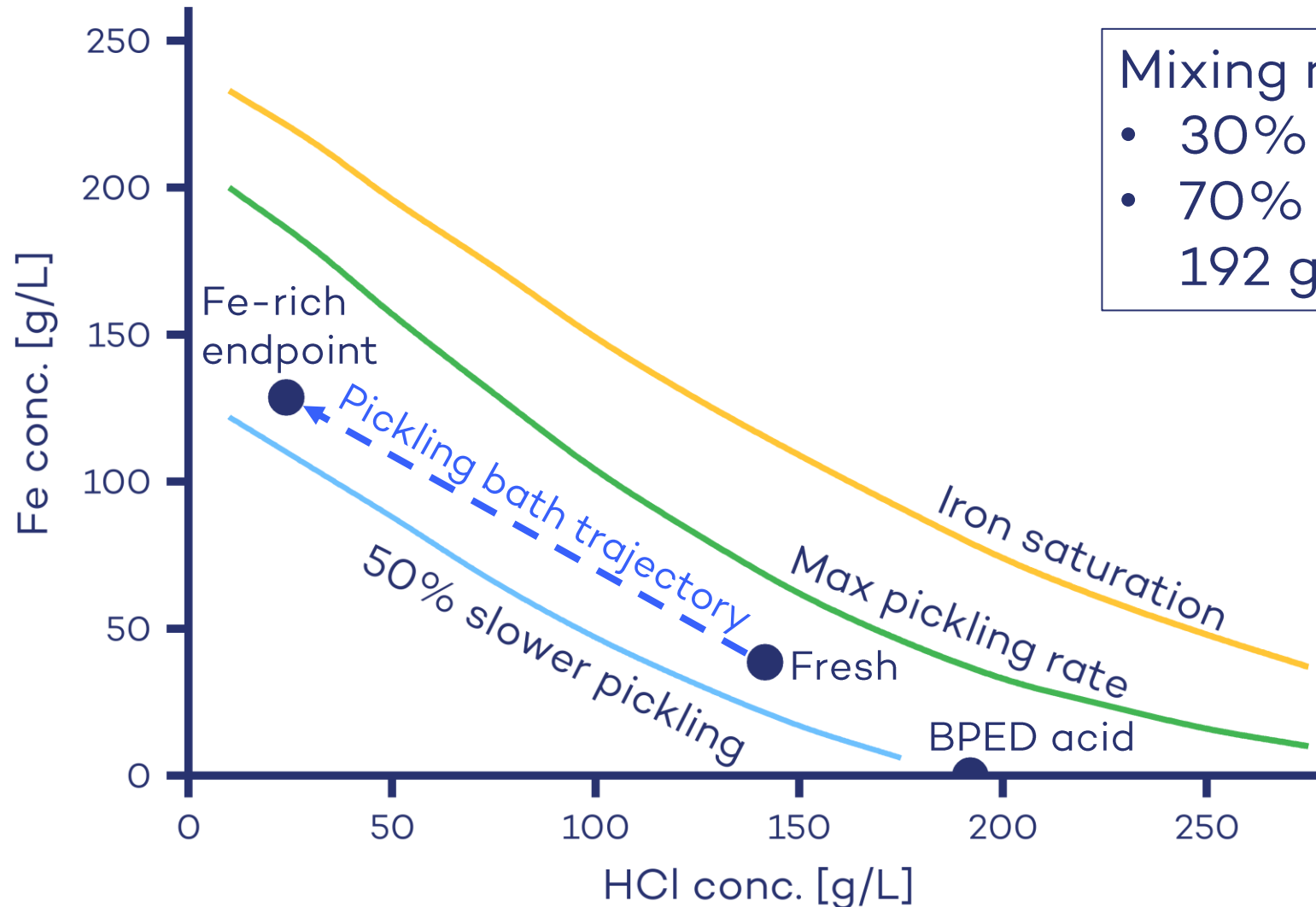


Plant workflow

Batch Refill



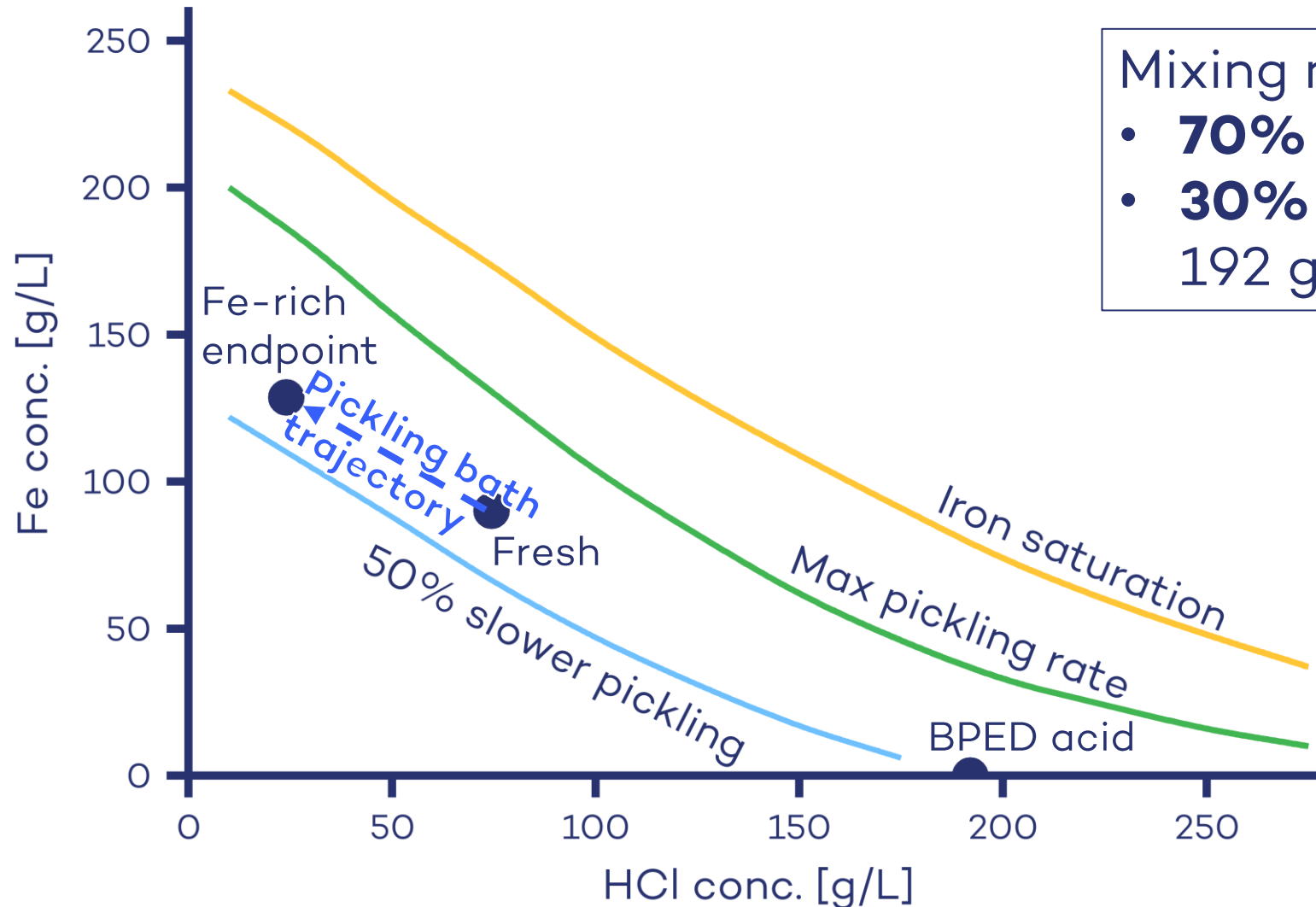
Batch Refill



Mixing model:

- 30% Fe-rich acid
- 70% BPED acid at 192 g/L (16 wt%)

Batch Refill

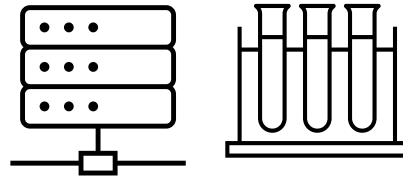


Mixing model:

- **70% Fe-rich acid**
- **30% BPED acid** at 192 g/L (16 wt%)

Continuous Feed-and-Bleed

**Autotitrator
control**



Active bath



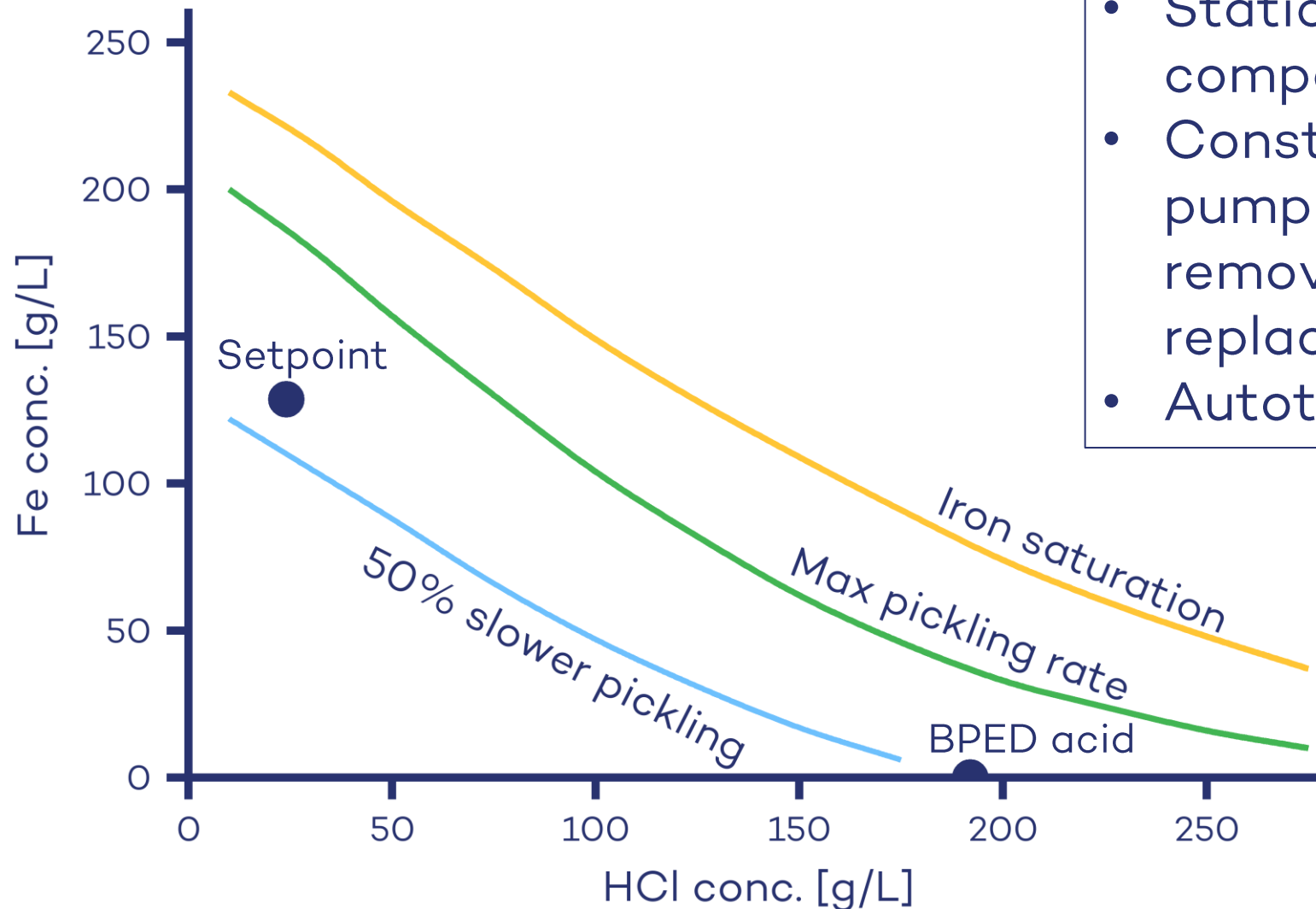
Electrodialysis



**Regen
acid**



Continuous Feed-and-Bleed



- Static pickle bath composition
- Constant low-flow pumping out bath, removing Fe/Zn, and replacing with acid
- Autotitrator control

Conclusions

- pH swing can remove Fe and Zn to levels suitable for BPED
- BPED is a cost-effective approach to recovering value from Fe-rich acid
- BPED improves environmental health and safety profile of plant

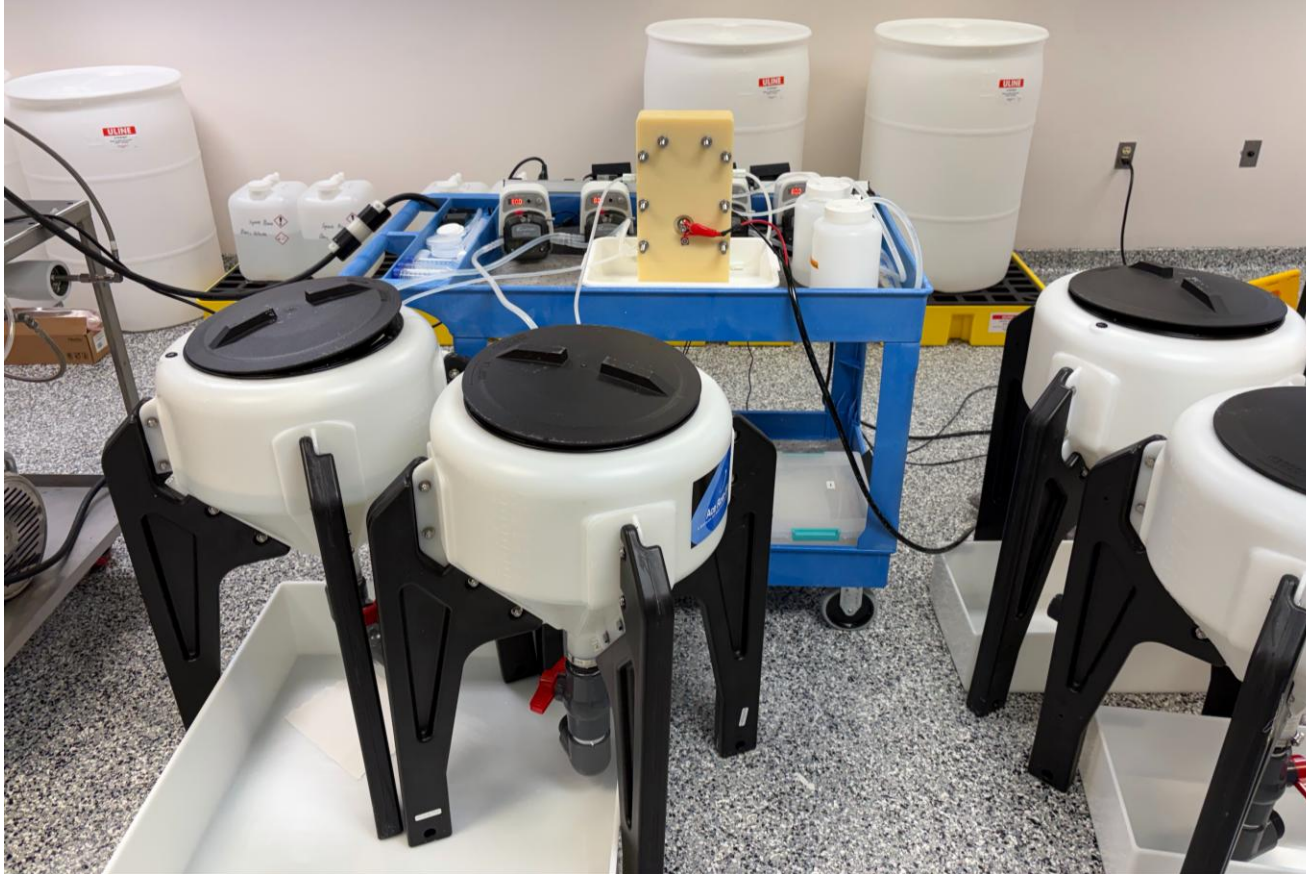
Let's connect!



Appendix

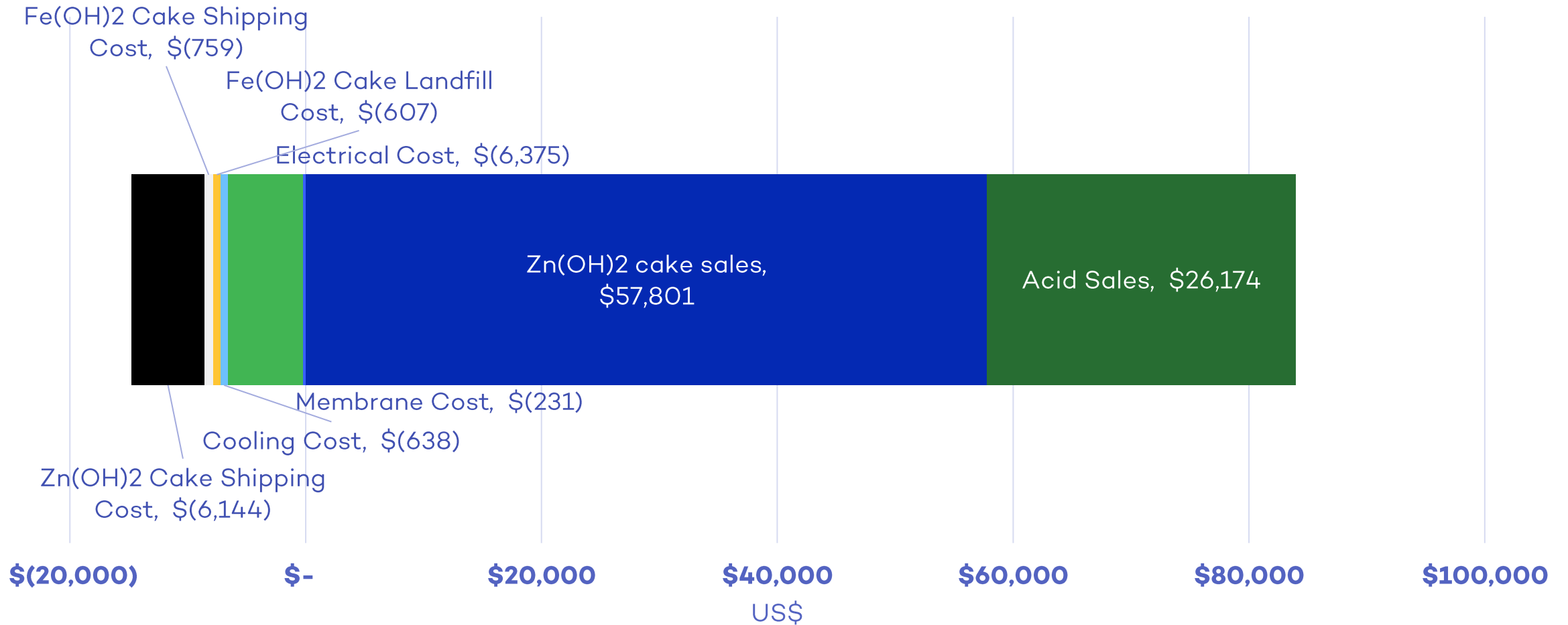
A light blue triangle is located in the bottom right corner of the slide.

Uplift's mini plant



- Effective Membrane Area: 200 cm²
- Number of Repeating Units: 1-10
- Current Density: 10 A/m² to 3000 A/m²
- Estimated Full-stack Throughput: ~2.8 L/hr (~67 L/day) each of 7.4 wt% (2 M) NaOH and 7.1 wt% (2 M) HCl at 1000 A/m² with 10 repeating units.

Operating profit from Uplift's perspective



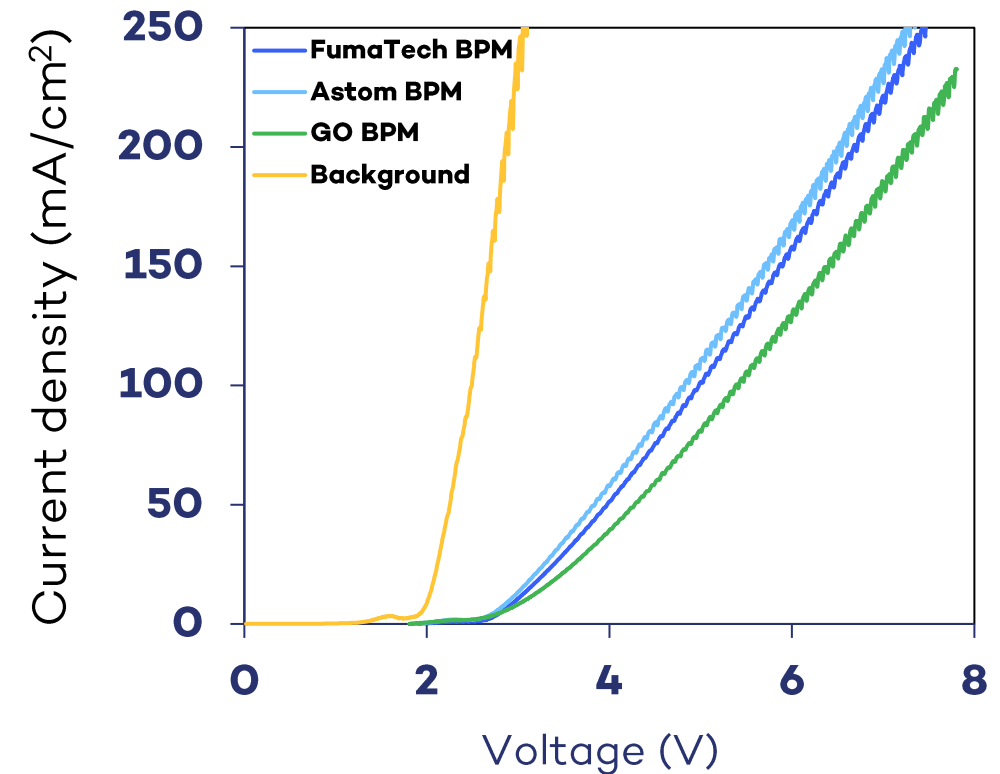
- Uplift's main revenue is Zn(OH)₂ byproduct sales to refiner

Background subtraction methods



- Conduct linear sweep voltammetry scans using electrolyte rinse solution in a cell containing the anode, one BPM and the cathode.
- Measure the background voltage across the relevant current-density range.
- At the target BPED operating current density, use the measured voltage as the background voltage, $V_{background}$.
- Subtract the background from the total BPED stack voltage.

$$V_{corrected} = V_{total} - V_{background}$$



LSV Curves