KU LEUVEN

# Solvent extraction for Fe-removal and HCl recovery from Ni/Co PLS

## Flowsheet optimization and thermodynamic modelling

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RawMat 2023

29 August 2023

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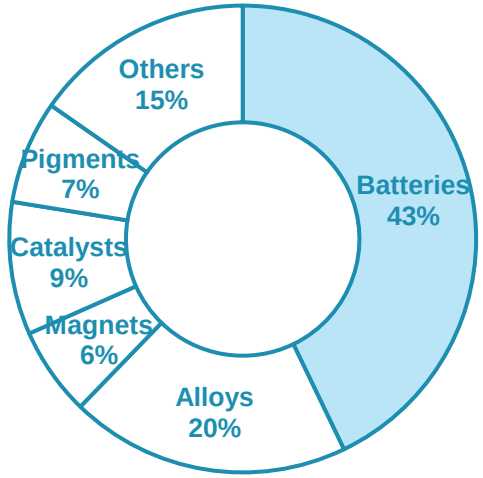
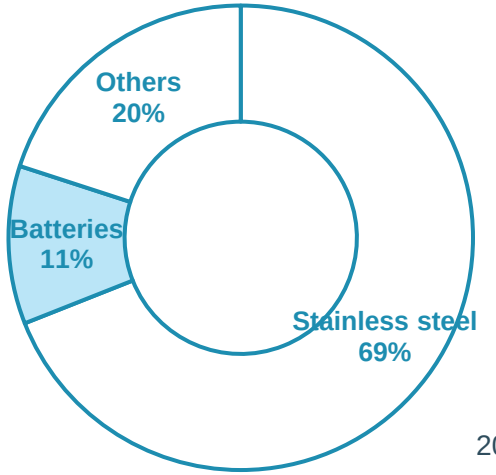


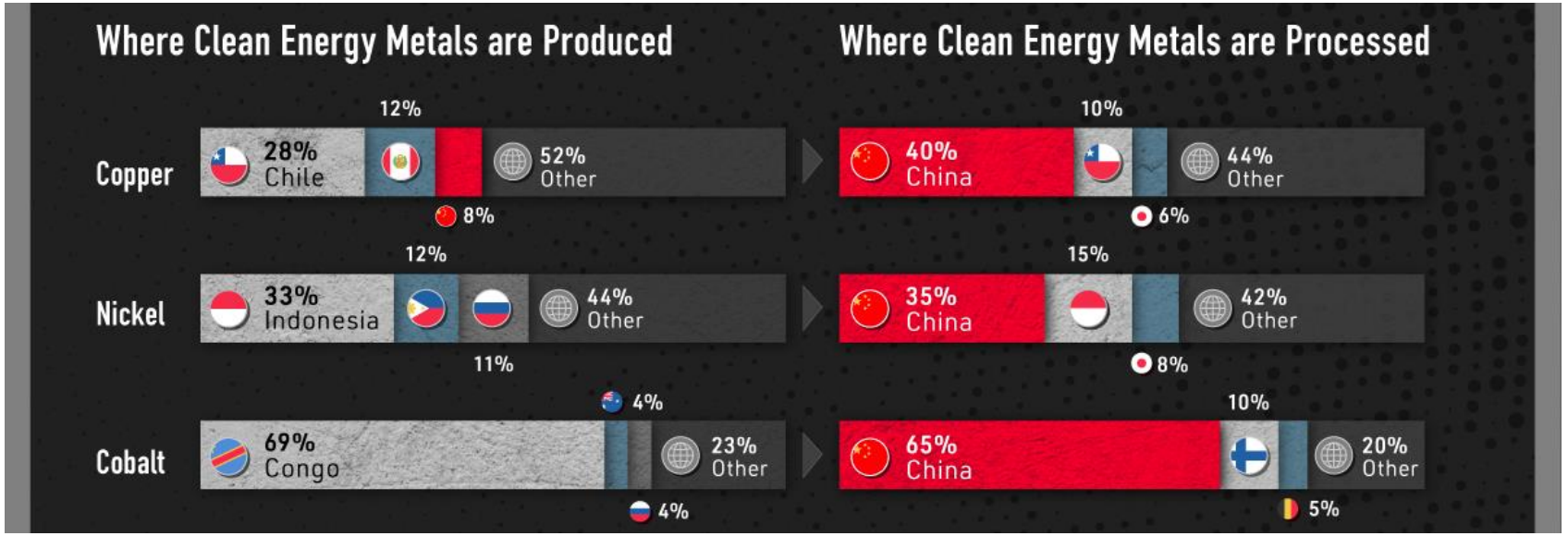

2018




2021


EV demand 2019: 19 kt
→2030: 180 kt (x10)

EV demand 2019: 65 kt
→2030: 925 kt (x14)

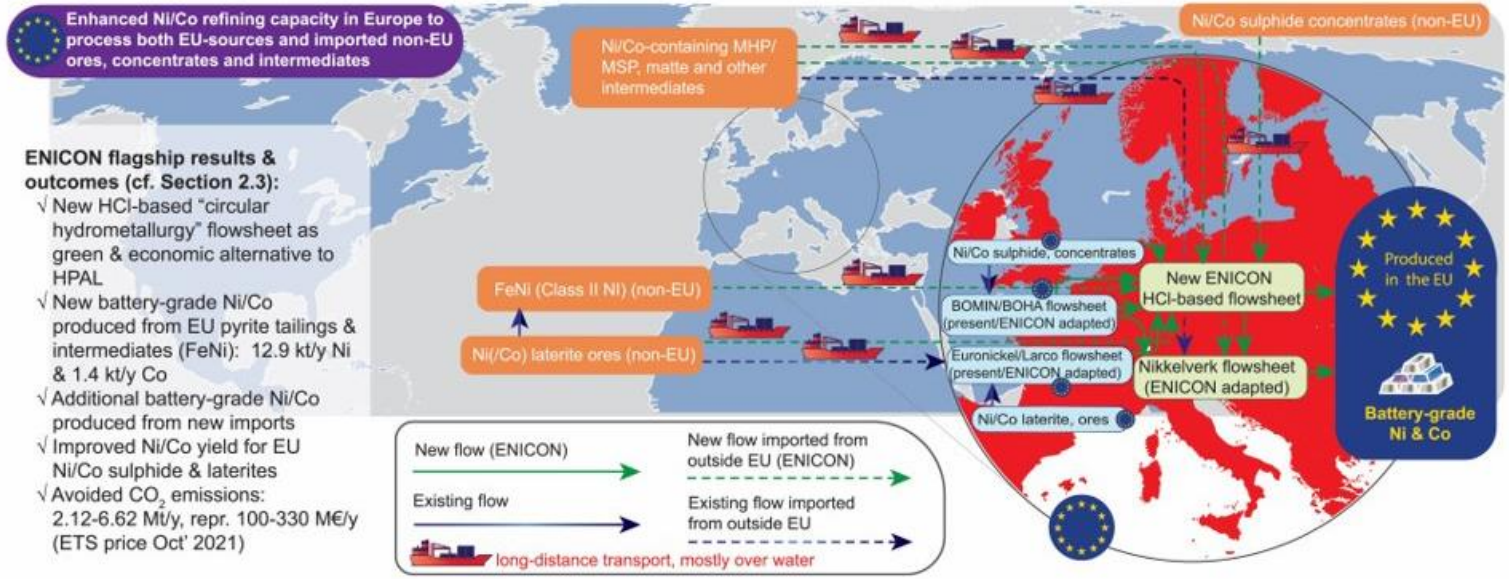





IEA Global EV Outlook 2020, url: https://www.iea.org/reports/global-ev-outlook-2020
www.statista.com
https://elements.visualcapitalist.com/visualizing-chinas-dominance-in-clean-energy-metals/

https://enicon-horizon.eu/

SCAN ME




## Unlock the potential of Europe's (low-grade) Ni/Co resources

### 5 Case studies:

- Ni-laterite
- Ni-sulphide
- Ferronickel (class-II Ni)
- MHP/MSP
- Ni silicate tailings

### Domestic European Ni/Co processing:

- Improve existing flowsheets
- Development of new HCl-based route for laterites, sulphides and secondary sources
- Focus on near-zero waste processing – Circular Hydrometallurgy



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Solvomet Group

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# Why developing HCl flowsheet?

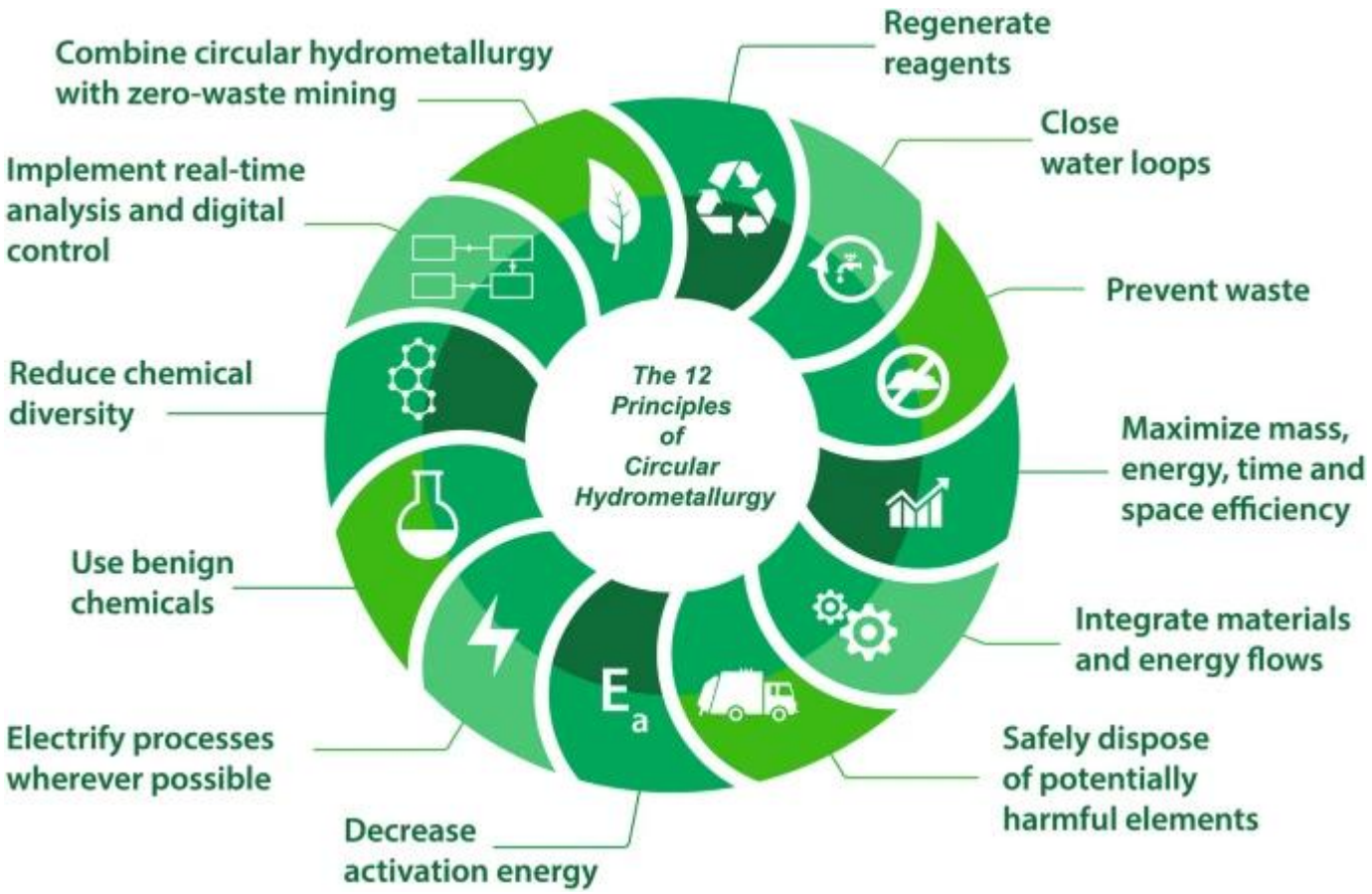
Provide a best-in-class alternative for HPAL

- Possibility of working at ambient temperatures and pressure
- HCl as ‘catalyst’ → near-complete regeneration
- Avoid use of limestone for increasing pH by usage of SX = avoid $CO_2$ emissions
- Avoided generation of gypsum and $Na_2SO_4$ by-products
- Lower input of chemicals
- Reduced water use

Resistance to HCl in metallurgical industry → corrosion

- Industry can handle HCl on large scale – proven by chloride-based processes Nikkelverk and Eramet
- Chloride salts are roughly 2x more soluble than sulphate salts → double throughput possible!

# Circular Hydrometallurgy




Binnemans, K.; Jones, P. T. The Twelve Principles of Circular Hydrometallurgy. *J. Sustain. Metall.* **2022**, *9* (1), 1–25. https://doi.org/10.1007/s40831-022-00636-3.

# Methodology

HCl leaching

Presentation by Dr. Seyedehmaryam Sadeghi
Wednesday 11:00 – 12:45
Session C1

Fe 20-40 g/L
Ni 5-10 g/L
Co 0.5-1 g/L
[HCl] 2 – 4 M

TBP

Iron removal

Regeneration TBP
$FeCl_3$ → HCl and Fe oxide

TEHA

HCl removal

Regeneration TEHA by hot water stripping

Versatic Acid 10

Co/Ni separation and purification

Regeneration VA10
+water
$CoCl_2$
$NiCl_2$

HCl

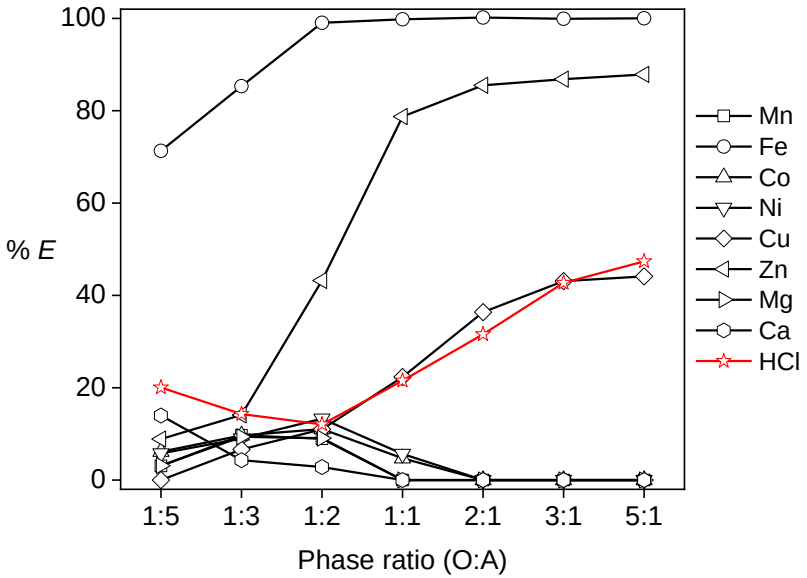
HCl back to leaching

CIRCULAR HYDROMETALLURGY

# Bench-scale optimization on synthetic Ni/Co PLS

| | Fe(III) | Ni(II) | Co(II) | Mg(II) | Ca(II) | Cu(II) | Mn(II) | Zn(II) |
|---|---|---|---|---|---|---|---|---|
| g/L in feed | 16.9 | 3.4 | 0.96 | 1.5 | 1.3 | 0.37 | 0.33 | 0.28 |

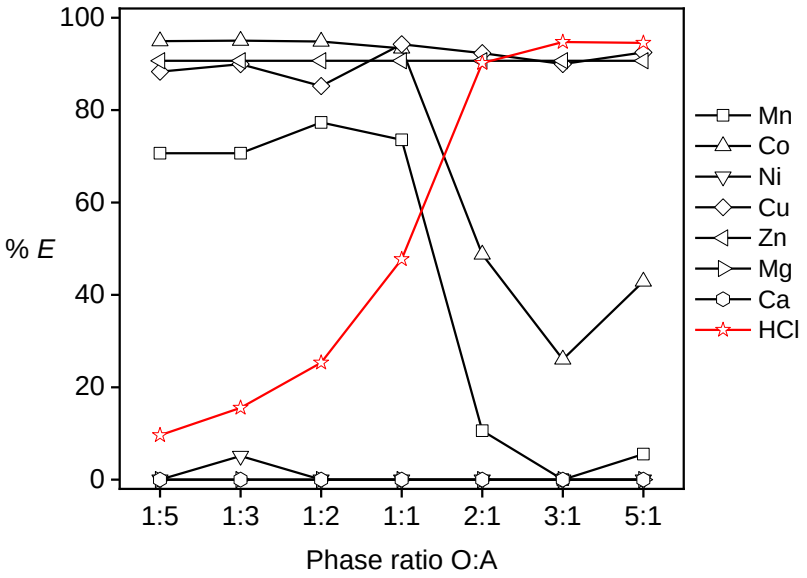
## Removal of Fe(III) and Zn(II) by TBP





**Conditions:** [HCl] = 5.8 M, pure TBP, RT, 30 min, 300 rpm)

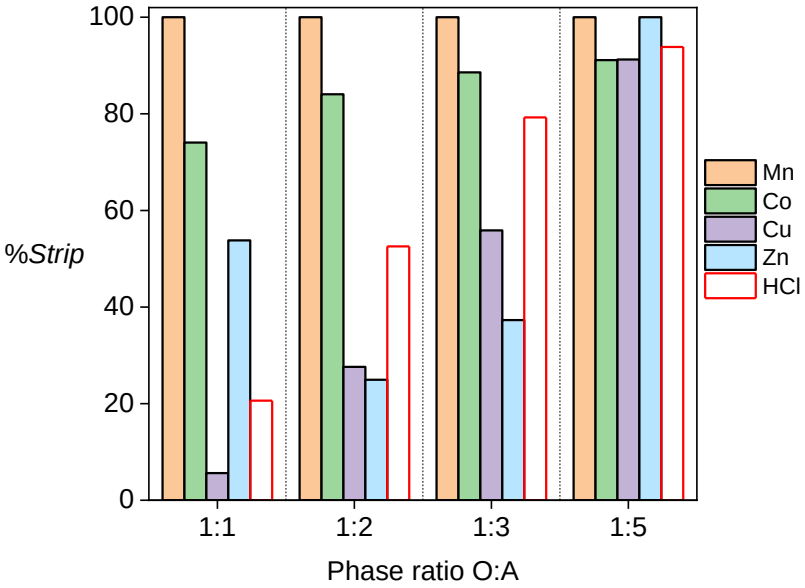
## Recovery of HCl by TEHA





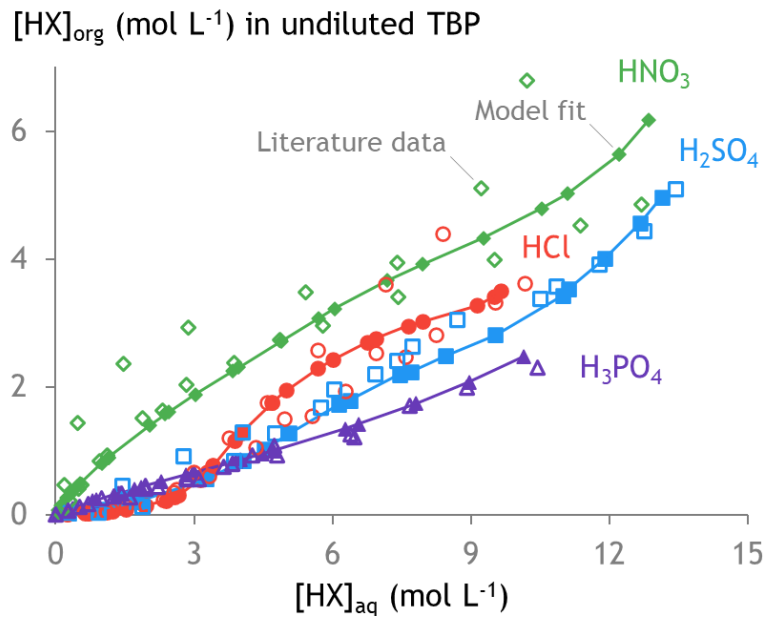
**Conditions:** [HCl] = 4.9 M, pure TEHA, RT, 30 min, 300 rpm)

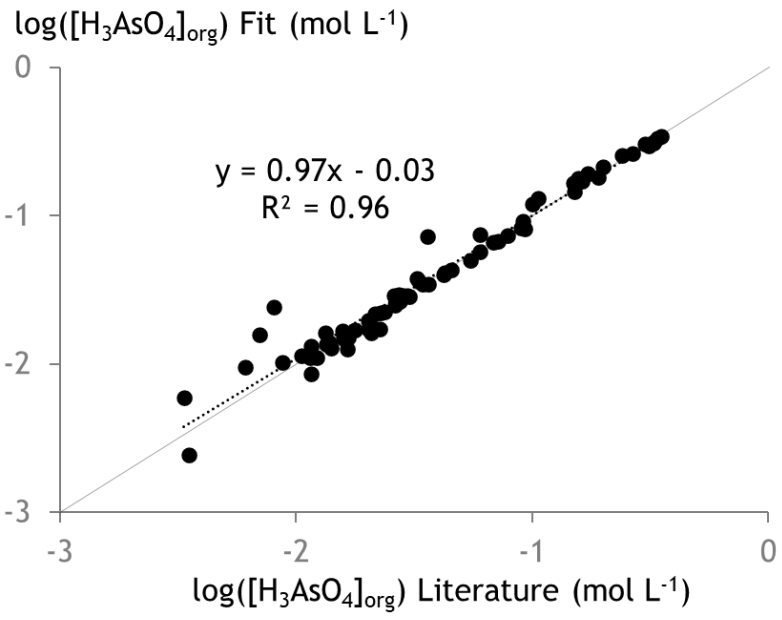
## Recovery of HCl by TEHA

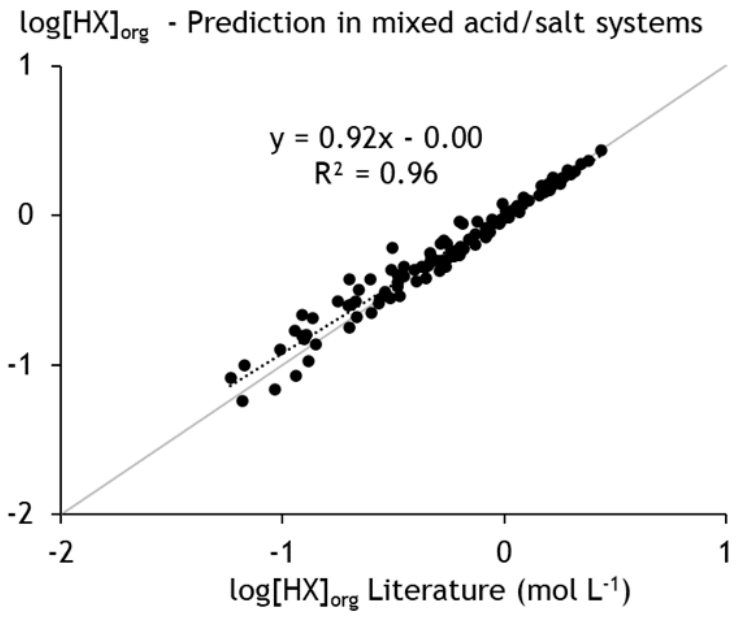



**Conditions :** O: loaded undiluted TEHA, $[HCl]_{ORG}$ = 2 mol $L^{-1}$, respectively, A: pure water, O:A = 1:1 – 1:5, 800 rpm, 30 min, T = 100 °C

# Thermodynamic modeling




- OLI mixed-solvent electrolyte (MSE) framework
- $\overline{\mathrm{TBP}} + \mathrm{H_3O^+} + \mathrm{X^-} \rightleftharpoons \overline{\mathrm{TBPH^+}} + \overline{\mathrm{X^-}} + \mathrm{H_2O}$ or $\mathrm{HX} \rightleftharpoons \overline{\mathrm{HX}}$
- The model is robust: it can be easily extended with other acids and makes predictions in systems not used to construct model (multi-acid)
- Prediction error < 10% (cfr. KPI ENICON)
- More information: rayco.lommelen@kuleuven.be

Thermodynamic calculations performed in OLI Studio V11.5 (OLI Systems Inc., Parsippany NJ)



Lommelen, R.; Binnemans, K. Molecular Thermodynamic Model for Solvent Extraction of Mineral Acids by Tri-n-Butyl Phosphate (TBP). *Sep. Purif. Technol.* **2023**, *313* (February). https://doi.org/10.1016/j.seppur.2023.123475.

# Conclusions

- ENICON envisions development sustainable processing of Europe’s primary and secondary Ni/Co resources
- HCl-route: leaching at ambient T, p + recovery of excess/spent HCl by solvent extraction
- First solvent extraction results indicate possibility of recovery excess HCl
- Modelling of solvent extraction processes promising for enhancing lab-scale optimisation work, knowledge of SX mechanism

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