Updates on Solveteq's Process Development

Dr A.K. Ola Hekselman
CEO & Co-founder, Solveteq Ltd.
www.solveteq.co.uk

RECYCLE100 - 9th International Secondary Lead & Battery Recycling Conference

01/09/2025 | Kota Kinbalu, Malaysia

The Technology

Proprietary Solvents

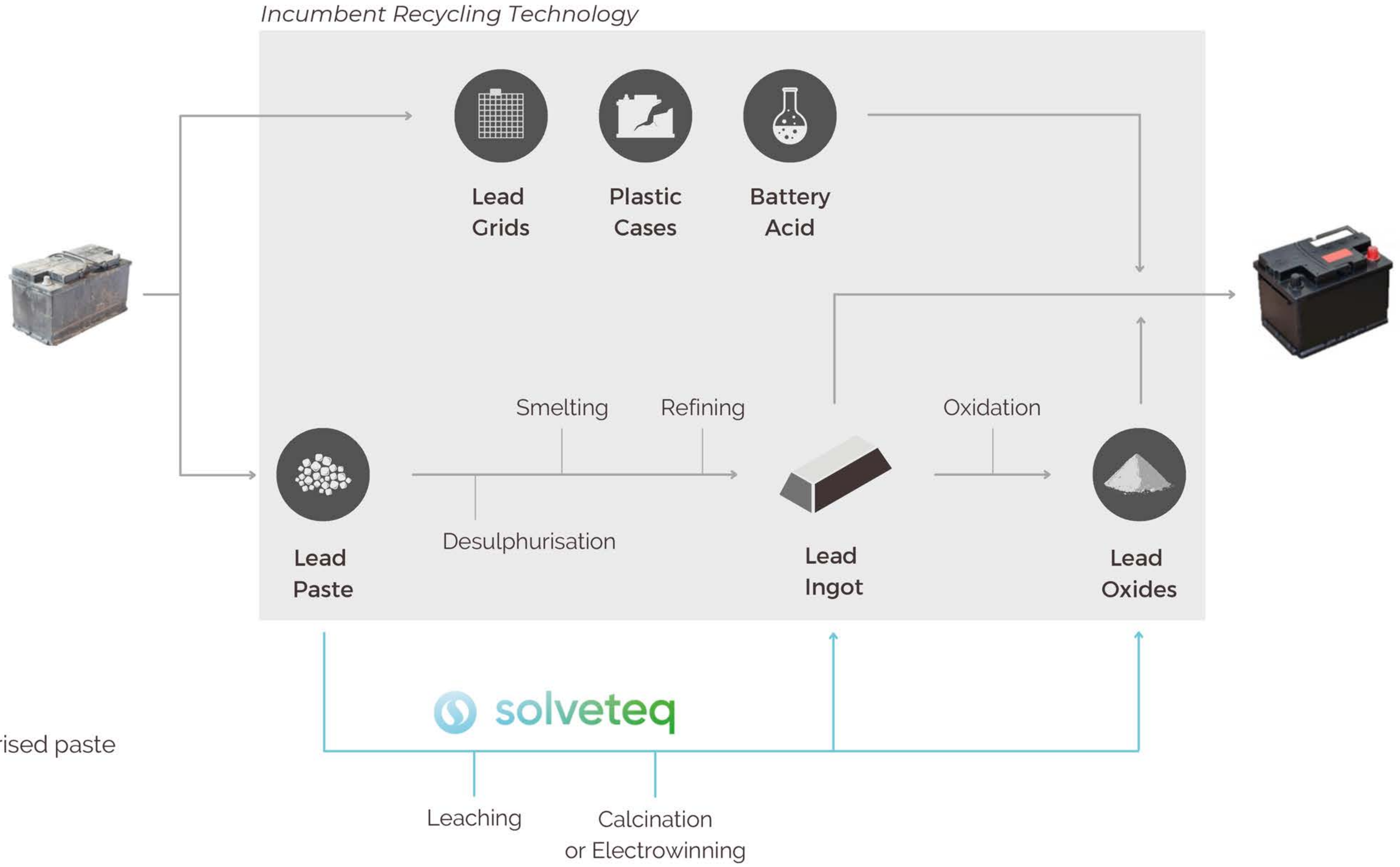
Benign chemicals
Readily available
Reusable
Environmentally friendly

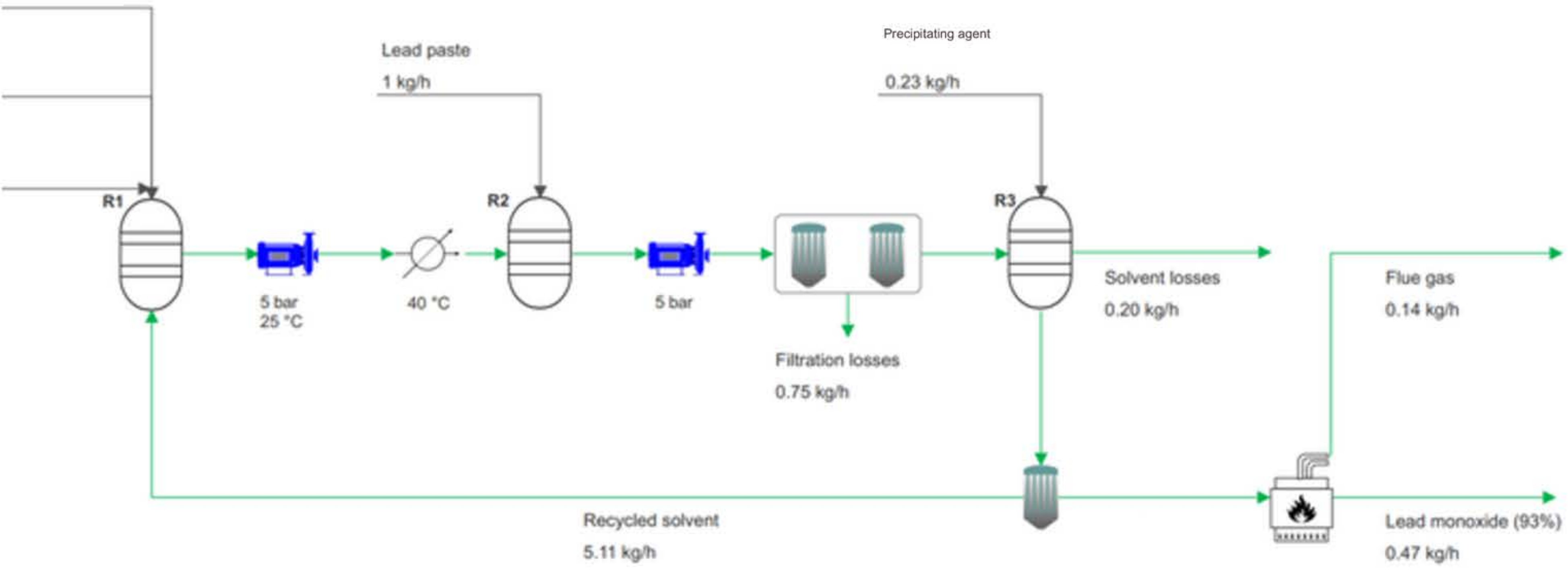
Solvent-based

Low temperatures
Lower energy consumption
Minimised lead dust & no slag
Safer processing

Modular & Scalable

Easy integration
Add-on, retrofit or stand-alone
Lower CapEx
Agnostic to feed - sulphurised/desulphurised paste





The process involves leaching and calcination to produce materials for new batteries.

Prototype (TRL 4)

Rapid prototype to test chemistry at scale (flows, mixing, chemical stability, yields, etc.):

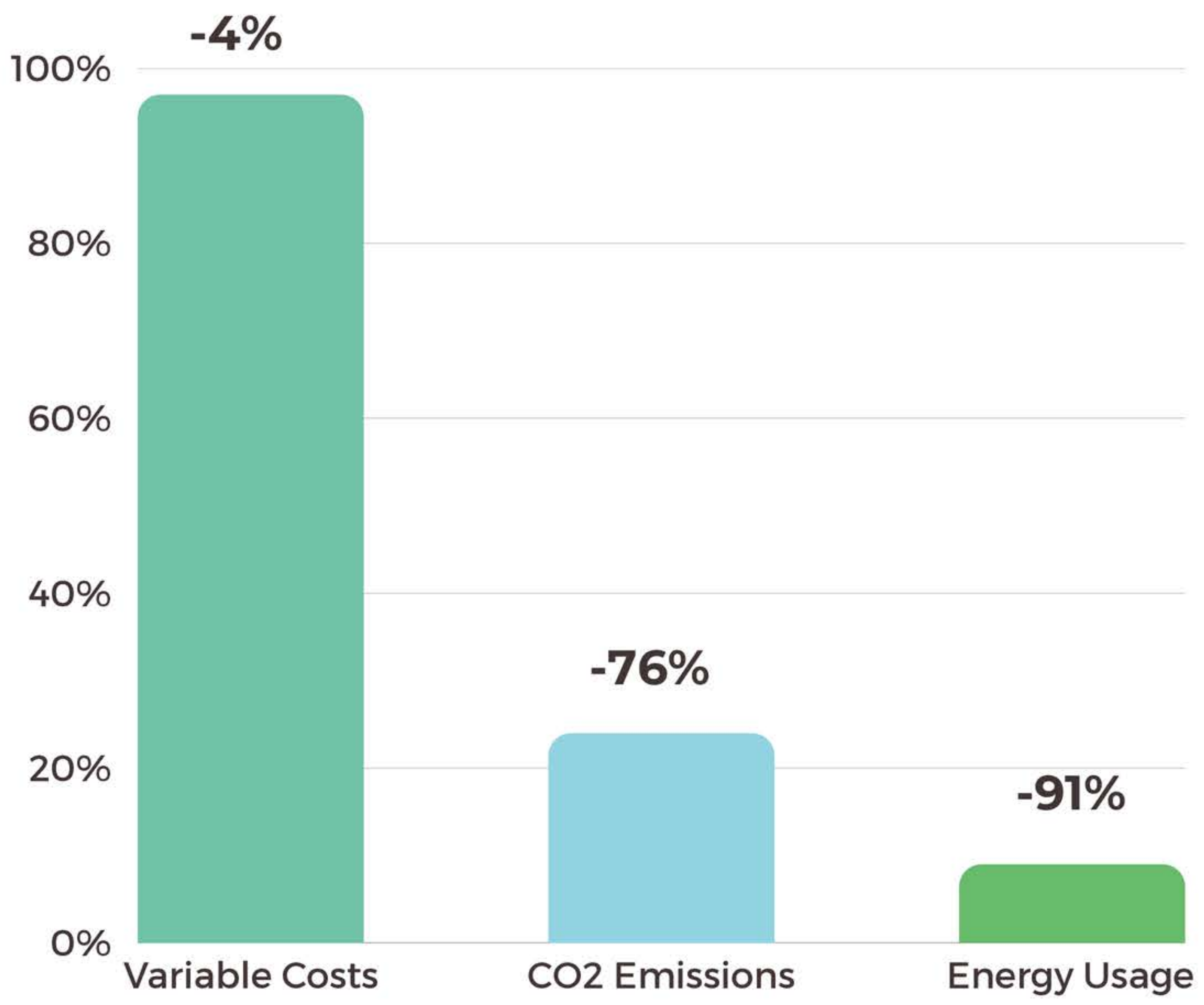
- 3x 5L vessels for solvent synthesis, leaching & precipitation, 2 filtration units, temperature & pressure controls, 2 pumps
- **Closed-loop system** enabling the multiple reuse of solvents
- Ventilated enclosure ensures **safe operations, validated by an accredited lab**
- **Modular design** for easy modification, simplification and transport
- Processing capacity: **1kg of lead paste per hour**

Trials

Lead pastes from **3 different commercial suppliers** were tested:

- Testing conducted **between room temperature and 40°C.**
- Leaching time: **15-60 minutes**
- Precipitation: **83% from sulphated paste**
- Reuse of solvents: **2% losses per cycle**
- Cost of chemicals: **$0.37 per kg Pb(II) at 1kg/h** Prototype (TRL 4)
- Chemicals drive OpEx
- Prototype cost does not reflect industrial-scale CapEx
- KPIs optimised: OpEx, energy consumption, CO2 emissions, Gen 1 Product
- New IP eliminates the need for the calcination step
- **Data used for CapEx, OpEx & LCA projections at industrial scale**

Impact: Prototype data indicates strong potential for commercial competitiveness



100% corresponds to the conventional technology

Energy usage - reduced by 91%

Energy remains the main cost driver in smelting. Many operators have felt the impact of volatility and price spikes over the years - this approach offers a way to insulate operations against that risk.

CO_2 emissions - reduced by 76%

Emissions from recycling processes are under growing scrutiny. This method provides a practical route to lower the carbon footprint of operations and to align with evolving industry and regulatory expectations.

Process costs - reduced by 4%*

Operating costs are already comparable to conventional processes. Further savings are achievable, but competitiveness is not dependent on them.

All KPIs can be further improved.

For comparison: a novel dry coating method in Li-ion battery production reduces process costs by only ~4% at the gigafactory scale

Learnings from the Prototype Stage

Chemistry validated at scale

- Solvent systems performed consistently from grams to kilograms, with reformulations restoring expected kinetics and recovery.

Process operations flagged for optimisation

- Filtration at prototype scale was slower than desired — highlighting areas for engineering improvement in the continuous design.

Solvent reuse economics demonstrated

- Reuse across 10–20 cycles confirmed, with benefits for both costs and environmental impact.

Efficient test–scale–refine loop established

- Lab → Prototype → Economics/LCA approach de-risks scale-up and provides actionable insights for partners.

Prototype CAPEX not representative

- Unit was custom-built; industrial deployment will rely on standard equipment with partner-validated costs.

Process Optimisation and Key Learnings

Next Step: Process Optimisation

Structured approach
- A suitable solvent system has been identified, allowing us to move into optimisation.

Lab–prototype loop
- KPIs are refined at lab scale and then re-validated on the prototype to confirm performance.

KPI framework focused on five categories
- Material recovery (rates, selectivity, mass balance closure)
- Product quality (purity, product form, contaminants)
- OPEX drivers (solvent, reagents, energy, time)
- Process engineering (reaction times, throughput, residues)
- Commercial readiness (samples, repeatability, cost inputs)

Optimisation Insights

Objectives
- Achieve product purity that meets industry specifications and ensure seamless integration with smelting.

Key findings
  - Lead paste requires two solvent systems (oxides vs sulfates leach differently).
  - Oxides can be returned directly to smelters directly, while sulphates require solvent-based recovery.
  - Lead purity is influenced by the composition of all smelting charges.

By listening to the industry, we tackled impurities and by-products early - improving smelting efficiency and reducing dead volume, and shifting our focus from lead purity to selective metal separation.

Improving Lead Recycling by Tackling Impurities Early

Starting from the end goal of product purity, we focused on by-products such as slags and drosses - recognising both their impact on smelting efficiency and their potential as valuable sources of metals.

Current practice and gaps

- Some operators already **valorise drosses,** e.g. by selling them to off-takers.
- Wider scope exists to optimise recovery and reduce dead volume.
- Our work examines the **chemical composition** of slags and drosses - not just elemental content - to enable more effective separation and higher purity outcomes.
- Elemental analysis aligned with **industry standards:** our analyses are carried out externally by the same labs that the lead industry routinely uses for quality control, ensuring results are directly comparable.

Why Chemical Composition Matters

- **Elemental content isn't enough:** Industry QC focuses on elemental composition, but this does not reveal how metals are bound.
- **Example: Antimony:** occuring not only as oxide (Sb_2O_3), but also as lead antimonate ($Pb_2Sb_2O_7$), each requiring different solvents and processing conditions.
- **Engineering the approach:** Knowing the phases allows us to design solvent systems that are selective, efficient, and optimised for each metal, e.g. quantitative copper extraction at favourable costs and purity
- **Broader impact:** different sources of critical metals - including e-waste, renewable energy materials, and mining residues - can also benefit from this approach.
- **Timely relevance:** in today's geopolitical climate, the lead industry's global reach and local presence can provide secure supply of critical metals.

Partnering with Solveteq: Commercial Projects

We work with industry partners on commercial projects, co-developing metal extraction processes tailored to their feedstocks and operational needs.

Deep-Dive Analysis: of Feedstocks and Products

We combine complementary techniques to understand not just what elements are present, but how they are bound - enabling us to design selective solvent systems, optimise recovery, and align with industry-grade quality control.

X-ray diffraction (XRD, with Rietveld refinement)
- Reveals crystallographic phases and quantifies crystalline vs. amorphous content.

SEM & grain size analysis
- Examines particle morphology and structure.

EDX elemental mapping
- Visualises the spatial distribution of metals in complex samples.

Surface analysis (XPS, FIB-SEM)
- Determines surface composition and oxidation states.

Bulk elemental analysis (ICP-OES, ICP-MS)
- Provides precise elemental content and validates against industry QC protocols.

This detailed understanding of feedstocks underpins our ability to develop robust, selective, and commercially viable recovery processes

Partnering with Solveteq: Commercial Projects

We work with industry partners on commercial projects, co-developing metal extraction processes tailored to their feedstocks and operational needs.

Scope and Approach

We partner with industry through commercial projects, co-developing extraction processes tailored to specific feedstocks and operational needs. Engagement is always on commercial terms.

Stage-gated pathway

Our structured, capital-efficient process runs from:

- Proof of concept (lab-scale validation)
- Process optimisation (refining KPIs and operating parameters)
- Pilot validation (early performance at meaningful scale)
- Demonstrator (pre-commercial trials under real-world conditions)
- First commercial unit (full deployment with EPC partners)

Current focus and Collaboration

We are currently focused on the **Lab and Pilot stages**, delivering early chemistry validation, process optimisation, subsystem integration, and generation of pilot-scale performance data for partners.
Each project integrates **IP and commercial analysis** to ensure value capture, with collaboration from EPC partners built in throughout the scale-up journey.

Areas of interest

Our active work includes **copper, tin, and antimony**, and we invite interested partners to engage with us.

Contact: info@solveteq.co.uk