# Recycling hazardous steel grinding sludge into iron chloride and hydrogen

For Swedish Manufacturing conference May 2026

# Who we are

A Chalmers University spin-out translating industrial recycling research into scalable chemical process technology.

**ORIGIN**

**From research to venture**

- Originated from Chalmers University research
- Patent filed in 2023
- Anferra founded in 2024
- Focus: chemical recycling of steel grinding sludge

**CORE TEAM**

**Technical + entrepreneurial mix**

- Thomas Ottink — Inventor; PhD Industrial Materials Recycling
- Ebba Adolfsson — CEO; Industrial Design & Entrepreneurship
- Max Lumetzberger — CTO; Organic Chemistry
- Julie Ponchart — Process Engineer; Chemical Engineering

**TRACTION**

**Supported by Industry and the Public**

- Supported by grants, awards and customer project financing 2024-2025
- Completed fundraise from Investors + Industry in 2026
- Current focus: technical validation and pilot scale-up

CHALMERS




Swedish Metals & Minerals impact innovation

Energimyndigheten

VINNOVA Sveriges innovationsmyndighet

Co-funded by the European Union

# Steel grinding sludge: a high-metal hazardous waste stream

| 500 kt/y | €350/t | 50–80% | EWC 12 01 18* |
| --- | --- | --- | --- |
| Generated in Europe | EU average disposal cost | Iron content | Hazardous waste |

- Fine iron and alloy-rich particles mixed with cutting fluid, water, and abrasive residues
- Conventional routes often destroy the iron value or require pre-processing that is not robust at scale
- Technical opportunity: convert the iron content into a controlled chemical product instead of treating it as waste

# Feedstock morphology drives process design


PARTICLE SIZE

**100–200 µm**

Typical particle length

PARTICLE SIZE

**5–25 µm**

Typical particle width

PARTICLE SIZE

**2–10 µm**

Typical particle thickness

REFERENCE

**50–100 µm**

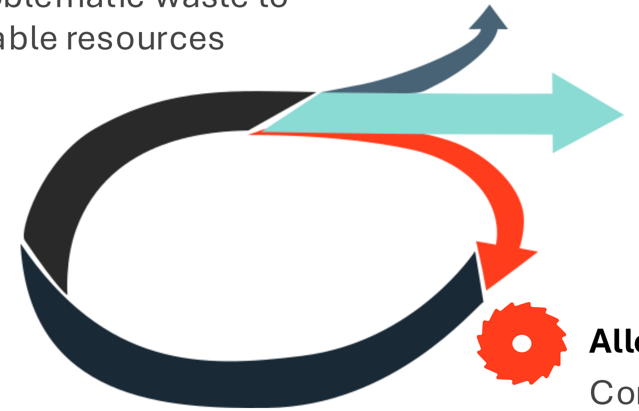
Human hair diameter, for scale

- The large surface area impedes cutting-fluid removal, promotes spontaneous oxidation - constrains steel recycling routes
- Feedstock variability must be accepted by the process, not solved by extensive sorting
- Small particle size facilitates chemical recycling

# Anferras process for Grinding sludge → ferric chloride

**Recycling grinding sludge**
A problematic waste to valuable resources

**Hydrogen gas**
Green energy as by-product



**Iron chloride**
High purity Ferrous Chloride can be oxidized into Ferric Chloride

**Alloys**
Concentrated and recycled into new steel

High recycling rate

Resource efficient

Scalable

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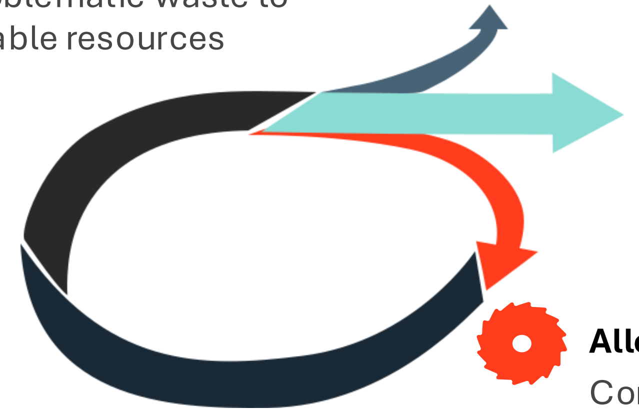

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GO-TO-MARKET CASE

**Water treatment**

- Established ferric-chloride application: coagulation & phosphorus removal
- EU purity norms type 1-2 (EN:888)

FUTURE MARKET OPTION

**Battery value chains**

- Potential use in LFP batteries or other battery chemistries

High recycling rate

Resource efficient

Scalable

# Process route: chemical recovery of iron from sludge

**1 Washing**
To remove majority of cutting fluid (corrosion-inhibitors)

**2 Leaching**
Iron reacts with HCl to form $FeCl_2$ & Hydrogen gas is formed

**3 Precipitation**
Alloy impurities selectively removed

**4 Filtration**
Solids and filter cake separated

**5 Oxidation option**
$FeCl_2$ can be oxidised to $FeCl_3$

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## Core reactions

$$Fe(s) + 2\,HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

Optional oxidation: $2\,FeCl_2 + 2\,HCl + \frac{1}{2}\,O_2 \rightarrow 2\,FeCl_3 + H_2O$

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| Element | Sludge input | After purification | Quality implication |
|---|---|---|---|
| **Cr** | ~20,000 ppm | <10 ppm | Below Type 1 limit |
| **Ni** | ~1,300 ppm | ~62 ppm | Close to Type 1, within Type 2 |
| **Mn** | Feedstock dependent | Pass-through | May define final grade |
| **As, Cd, Hg, Pb, Sb, Se** | — | <1 ppm | Below listed limits |

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# Proof-of-concept (2024): full waste-to-product chain demonstrated

**PoC Q2 2024**

**5× scale-up**

Robustness preserved when moving from initial lab scale.

**IRON RECOVERY**

**90–95%**

Recycled iron achieved with washing in PoC work.

**QUALITY**

**High purity**

Type 1-2 EN 888 purity confirmed through analytical testing.

**DOWNSTREAM**

**Oxidation**

$FeCl_2$ oxidation tested with Kemira.

**BOTTLENECK**

**Filtration**

Main bottleneck observed and prioritized for scale-up.

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# Feasibility study (2025): feedstock tolerance across industrial samples

**14 / 16**
Samples viable

**Business Case**
Initial CAPEX & OPEX estimation show technoeconomic feasibility

**LCA**
Show potential climate benefit

**TRL 4–5**
Current maturity

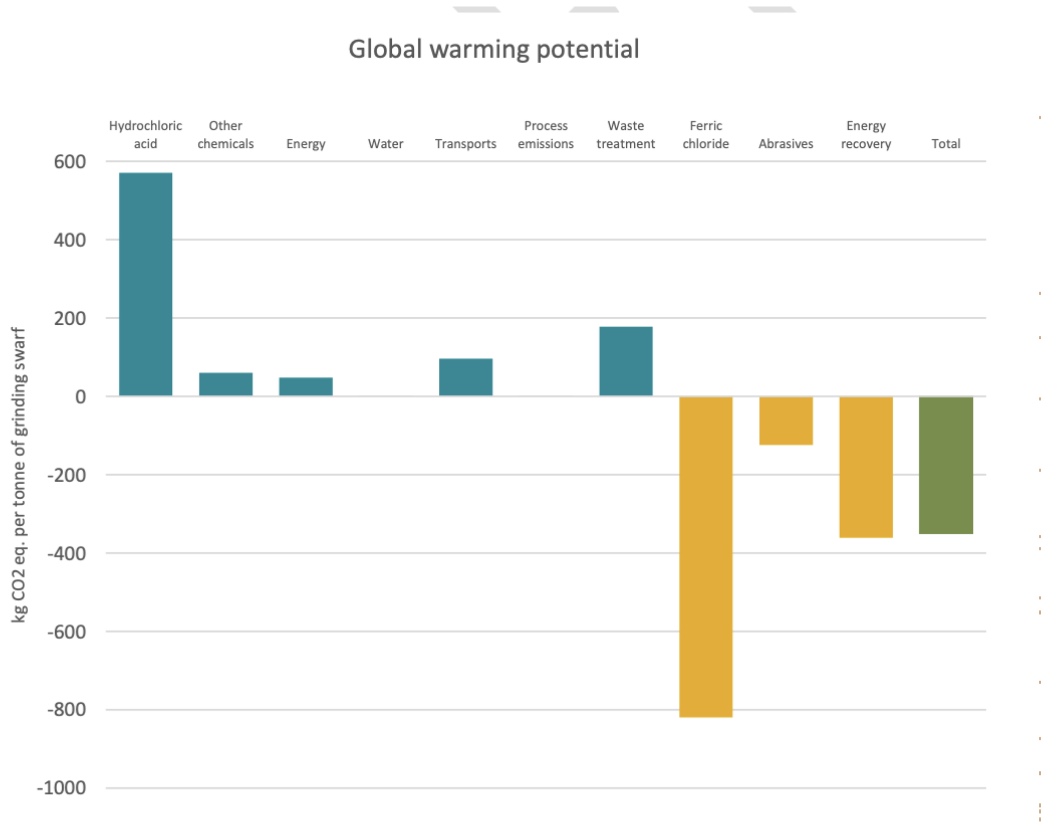
| Sample | Cr (ppm) | | Ni (ppm) | | Mn (ppm) | |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After |
| 1 | 1,277 | 39 | 329 | 66 | 8,183 | 6,358 |
| 2 | 1,020 | 5 | 297 | 123 | 7,370 | 6,520 |
| 3 | 2,247 | 28 | 139 | 76 | 3,571 | 3,479 |
| 4 | 9,587 | 35 | 740 | 221 | 2,109 | 2,590 |

ICP-OES across sludge samples 1–4

Swedish Metals & Minerals
impact innovation

Arbetet har utförts inom Impact Innovation-programmet Swedish Metals & Minerals, en gemensam satsning av Energimyndigheten, Formas och Vinnova.

# LCA result: climate benefit versus incineration + landfill




## IVL Svenska miljöinstitutet LCA RESULT

**−470 kg $CO_2$e / t**

Reported climate benefit compared with incineration plus landfill.

## DRIVERS

### Why it improves

Iron content is recovered as a chemical product; avoided primary $FeCl_3$ input and avoided incineration/landfilling drive the benefit.

IVL Swedish Environmental Research Institute LCA carried out in collaboration with SKF; comparison to EAF recycling and incineration + landfill.

# Mass balance: what 1 tonne of grinding sludge becomes

**INPUT**

**1 t**

Steel grinding sludge

Typical composition:
70–80% iron/steel fines
5–20% cutting fluid
0–5% abrasive grit
Balance: Ni, Cr, Mo, Mn alloys

**+ ~3.1 t HCl solution (32%)**

| | | |
|---|---|---|
| **~3.8 t** | **$FeCl_2$ solution** | ≥15 wt% Fe; oxidisable to $FeCl_3$; EN 888 Type 1–2 quality band. |
| **~25 kg** | **Hydrogen gas** | Not captured at pilot scale; meaningful energy stream at commercial scale. |
| **150–200 kg** | **Alloy-rich filter cake** | Ni, Cr, Mo hydroxide sludge; valorisation or disposal route |
| **30–50 kg** | **Recovered cutting-fluid fraction** | Likely to be energy recovered |

# Process scale-up

Moving from proven lab chemistry to industrially relevant operation

## Scale-up path

**Lab**
**1 L reactor**
>100 batches across 20+ production lines

**PoC**
**5 L reactor**
5 batches; bottlenecks identified

**2026 - 2027**
**250 L reactor**
6-8 batches: 1 ton grinding sludge

**2028-**
**Demo/full-scale engineering**
2 × 18 $m^3$ reactors; 5,000 t/y design basis

## Proof points

**Industrial relevance and consistent purity**
**TRL 4 → TRL 6**

- **Cycle times**
  Leaching, precipitation and filtration at pilot scale
- **Process efficiency**
  Iron recovery, reagent use, water balance and throughput
- **Product quality**
  $FeCl_2$ / $FeCl_3$ suitability and by-product characterization
- **Scale-up data**
  Energy demand, OPEX/COGS drivers and operating envelope

**Output: data package for demo design and partner decisions.**

## Key Scale up risks

- **Hydrogen gas evolution**
  Mitigated with ATEX-set up
- **By-product quality and classification**
  Aim to reach by-product characteristics facilitating valorization to avoid environmental and economic burden
- **Filtration & solids handling**
  Throughput risk driven by filterability, clogging and solids discharge at pilot scale.

# Going forward

1.

## Process scale up

Observed bottleneck in PoC. Pilot must quantify filterability, filter cake moisture, cycle time, and solids handling.

2.

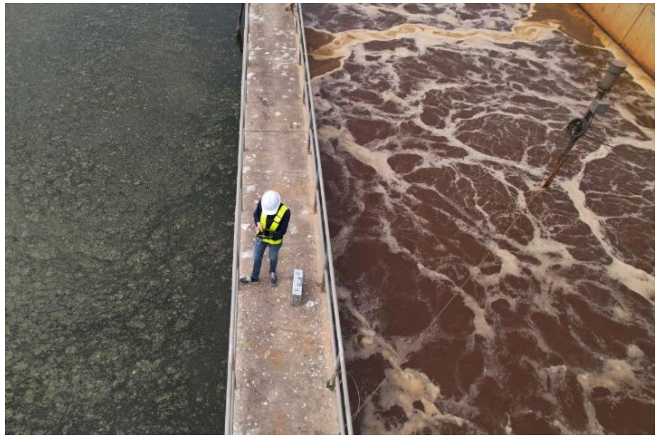
## Water treatment market

Near-term validation: $FeCl_2$/$FeCl_3$ EN 888 Type 1–2 consistency and off-taker data package (CAPEX, OPEX).

3.

## Battery applications R&D

Future option: assess iron-chloride suitability for battery value chains with partner specs and purity targets.



# Conclusion: proven chemistry, pilot-defined scale-up path

RESULT

## 1. Waste-to-product route proven

Hazardous grinding sludge has been converted into $FeCl_2$ solution, $H_2$ co-product and separated alloy-rich solids.

RESULT

## 2. Product quality supports GTM

Selective purification gives $FeCl_2$/$FeCl_3$ quality in the EN 888 Type 1–2 range; water treatment is the first market case.

RESULT

## 3. Climate benefit quantified

IVL LCA indicates −470 kg $CO_2$e/t versus incineration plus landfill under the assessed system boundaries.

NEXT

## 4. Scale up risks are explicit

Main risks: filtration and solids handling, hydrogen/HCl safety, and by-product classification.

NEXT

## 5. Pilot next

200–250 L pilot, 6–8 batches and ~1 t total feedstock to reach TRL 6 data quality in Q4 2026–Q1 2027.

NEXT

## 6. Future option: batteries

Battery value chains remain an R&D market option after further validation of purity, concentration and partner specifications.

# Thank You

## Questions?

Ebba Adolfsson | ebba@anferra.com | www.anferra.com