Consequential vs. attributional approach to the LCA of zinc recovery from spent pickling acids

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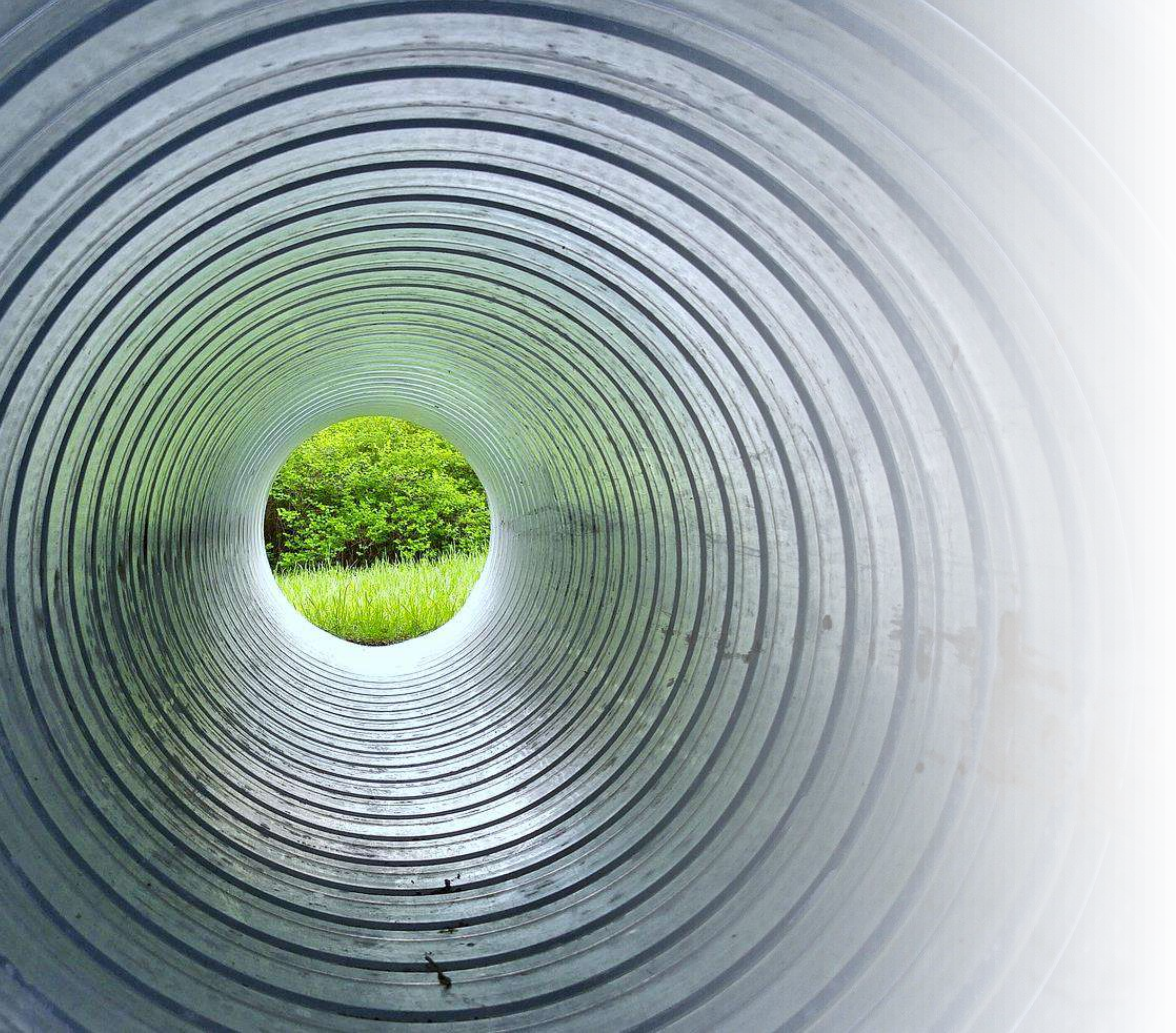

Context

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LIFE UE Programme

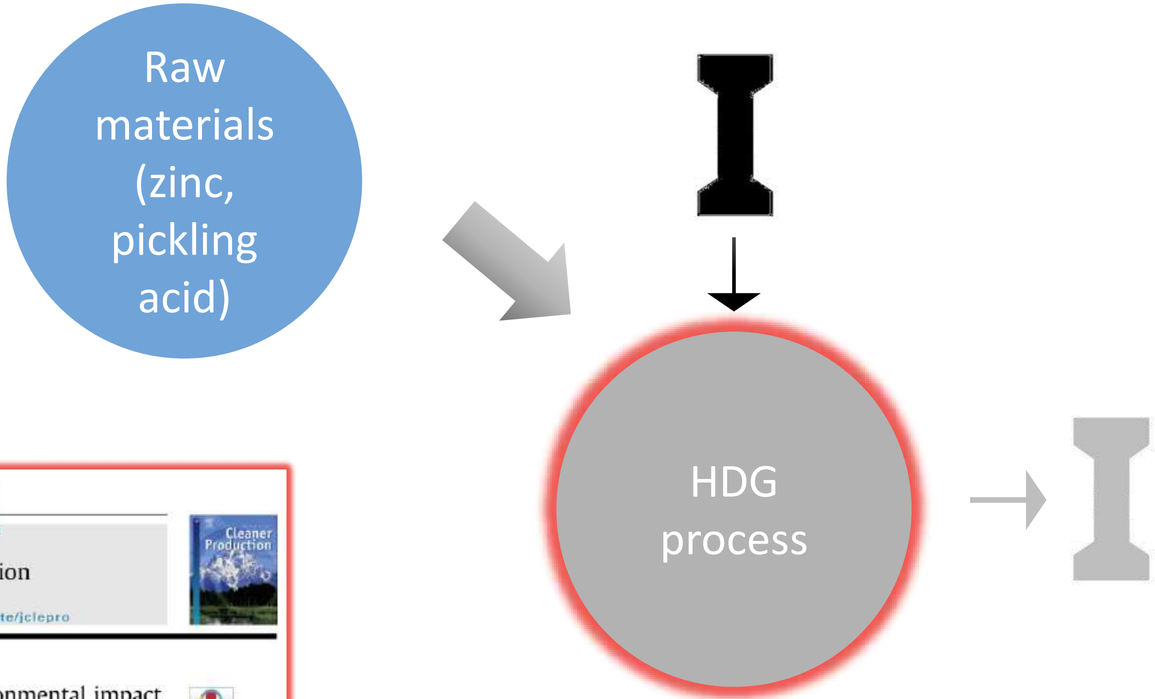
LIFE2 acid

http://www.life2acid.eu/

Towards a sustainable use of metallic resources in the galvanic industry

- Demonstration actions
- Replicability
- Environmental assessment

AIAS Asociación de Industrias de Acabados de Superficies · AIDIMME Instituto Tecnológico · APRIA systems · GALESA Galvanizadora Valenciana, S.L.U. · mare · Universitat Politècnica de València · UC Universidad de Cantabria



LCA of the HDG process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ELSEVIER

Life-cycle assessment as a tool to evaluate the environmental impact of hot-dip galvanisation

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ELSEVIER

Carbon footprint of the hot-dip galvanisation process using a life cycle assessment approach

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Environmental impact of the **primary zinc production**

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Raw materials (zinc, pickling acid)

HDG process

Spent pickling acids

92 ± 6 g·L^{-1} Zn^{2+}
91 ± 2 g·L^{-1} Fe^{2+}
pH ≈ 0
200 g·L^{-1} Cl^{-}
↓ Concentration of Mn, Pb, Al, Cr, Cd, Ni, Cu, Co

Neutralisation-precipitation

LANDFILL

membranes MDPI

Article

Scale-Up of Membrane-Based Zinc Recovery from Spent Pickling Acids of Hot-Dip Galvanizing

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check for updates

Raw materials (zinc, pickling acid)

HDG process

Spent pickling acids

Neutralisation-precipitation

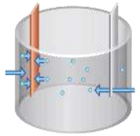
LANDFILL

Valorisation of spent pickling acids

1) Non-dispersive solvent extraction (NDSX)

Zn^{2+} (aq)

2) Electrowinning (EW)



Zn^{0} (s)

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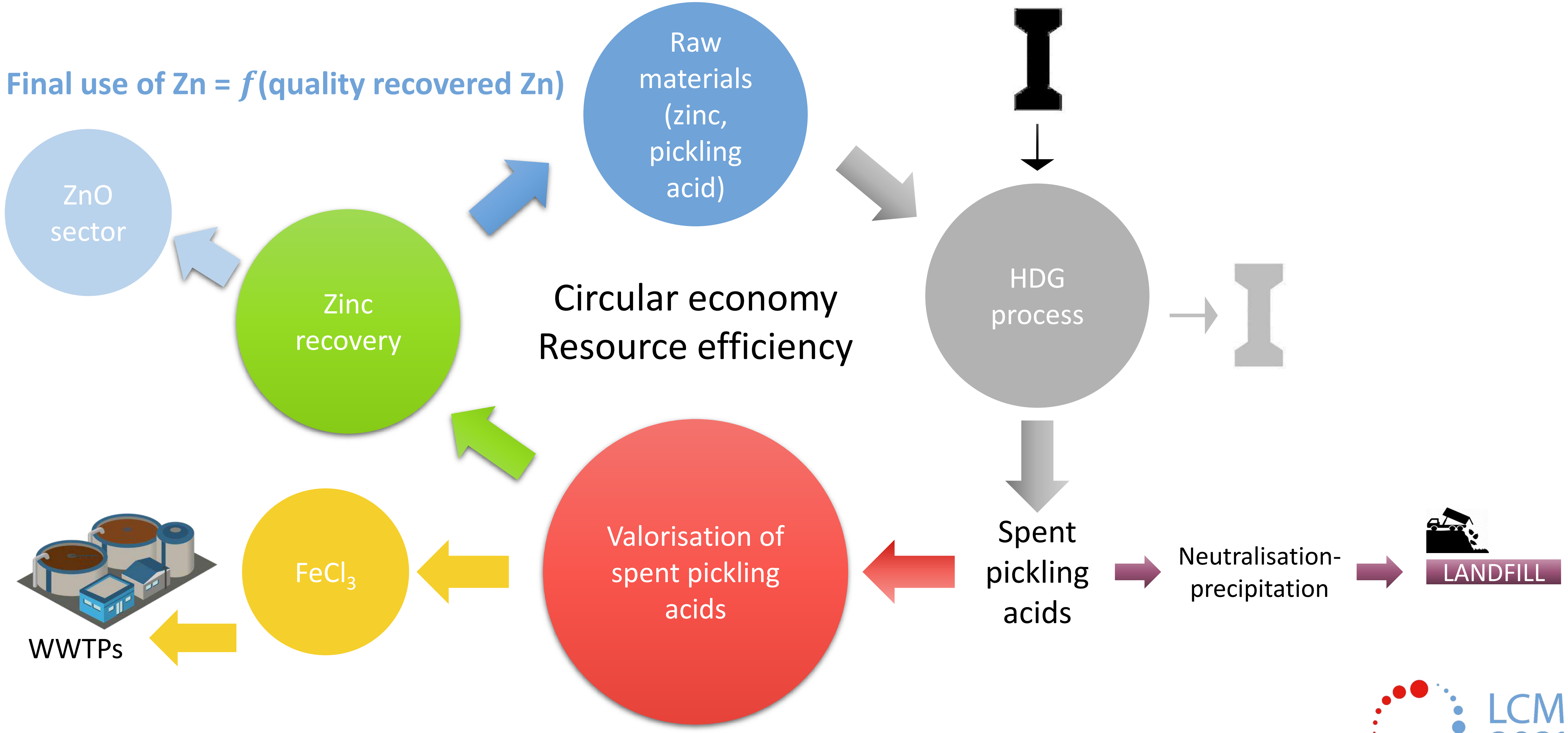
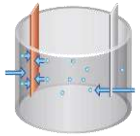
Final use of Zn = f(quality recovered Zn)



Objectives

Environmental assessment of the **LIFE2ACID technology**

Non-dispersive solvent extraction  Electrowinning 

Consequential and **attributional** approaches to recycling credits

30 65.38
Zn
Zinc

Methodology

Life cycle assessment methodology

Interpretation

Goal & scope definition

- To analyse the use of resources and environmental impacts **of LIFE2ACID technology**
- **Cradle to grave** approach
- **One m³ of spent pickling acids (SPAS)** as functional unit

Inventory analysis

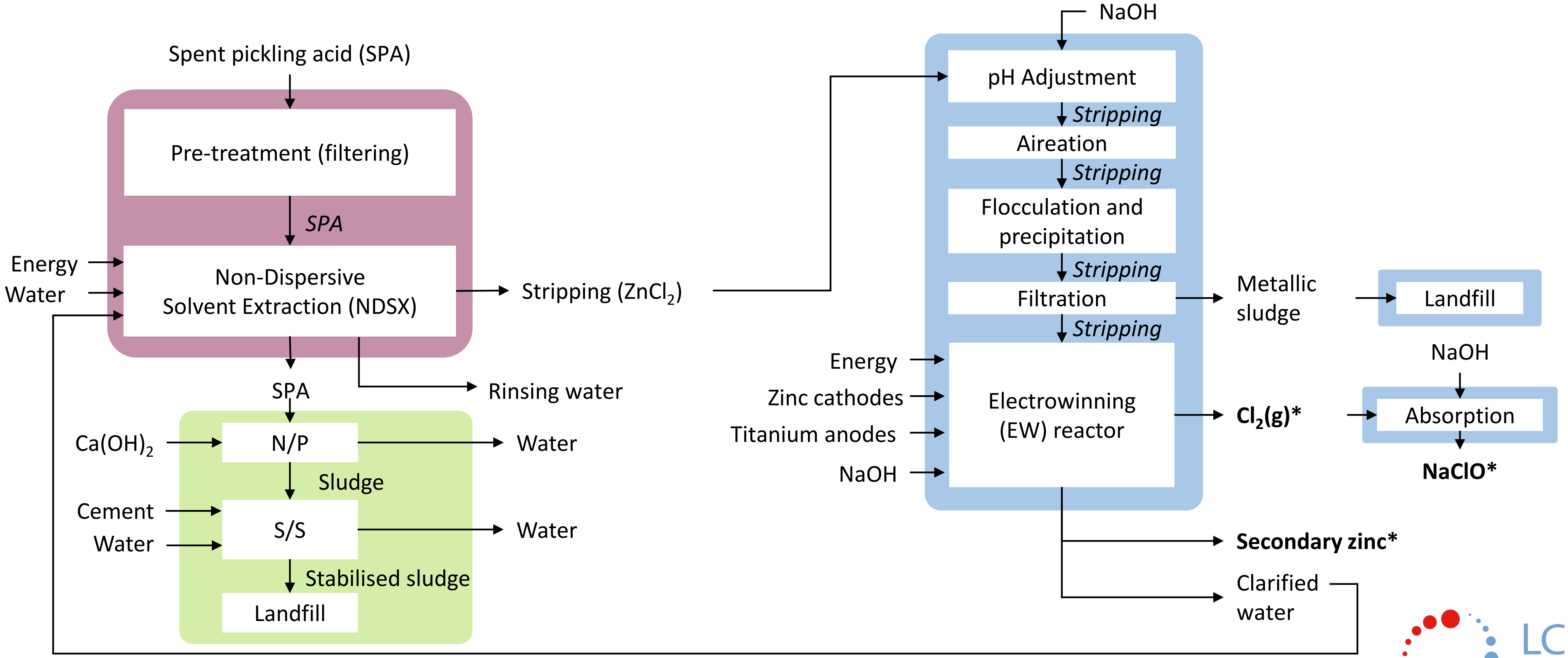
- Pilot plant results and mass balances
- **Sphera** professional database for secondary data

Impact assessment

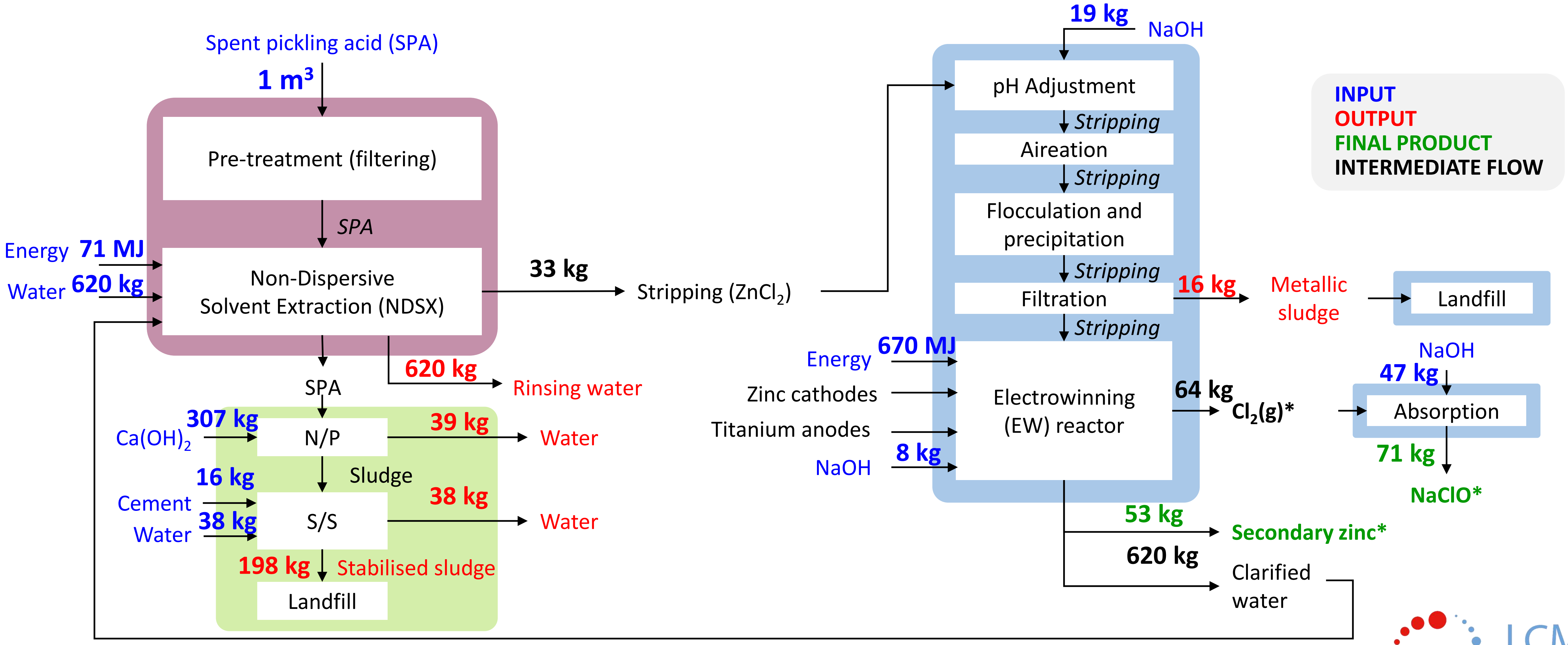
CML 2001 as impact assessment method

ISO 14040 and 14044

System boundaries



Life cycle inventory



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Life cycle inventory

Functional unit

One m³ of SPA

Inputs	Units	NDSX	EW
SPA	-	1	-
$Ca(OH)_2$ (N/P)	kg/m³ SPA	306.6	-
Portland cement (S/S)		16.4	-
Tap water (S/S)		38.2	-
Electricity	MJ/m³ SPA	71.2	670.0
Tap water	kg/m³ SPA	620.4	-
NaOH 100% wt. (pre-treatment EW)		-	18.9
NaOH 100% wt. (EW reactor)		-	7.6
NaOH 100% wt. (absorption Cl_2)		-	46.5
Outputs	**Units**	**NDSX**	**EW**
Rinsing water (after NDSX)	kg/m³ SPA	620.4	-
Water (after N/P)		39.0	-
Water (after S/S)		38.2	-
Stabilised sludge (after S/S)		197.9	-
Metallic sludge (pre-treatment EW)		-	16.1
Chlorine		-	64.2
FeCl3 without water (from FeCl3 40% wt. in solution)		-	-
Secondary zinc		-	53.3
NaClO (175 g Cl_2/L)		-	70.6

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Results

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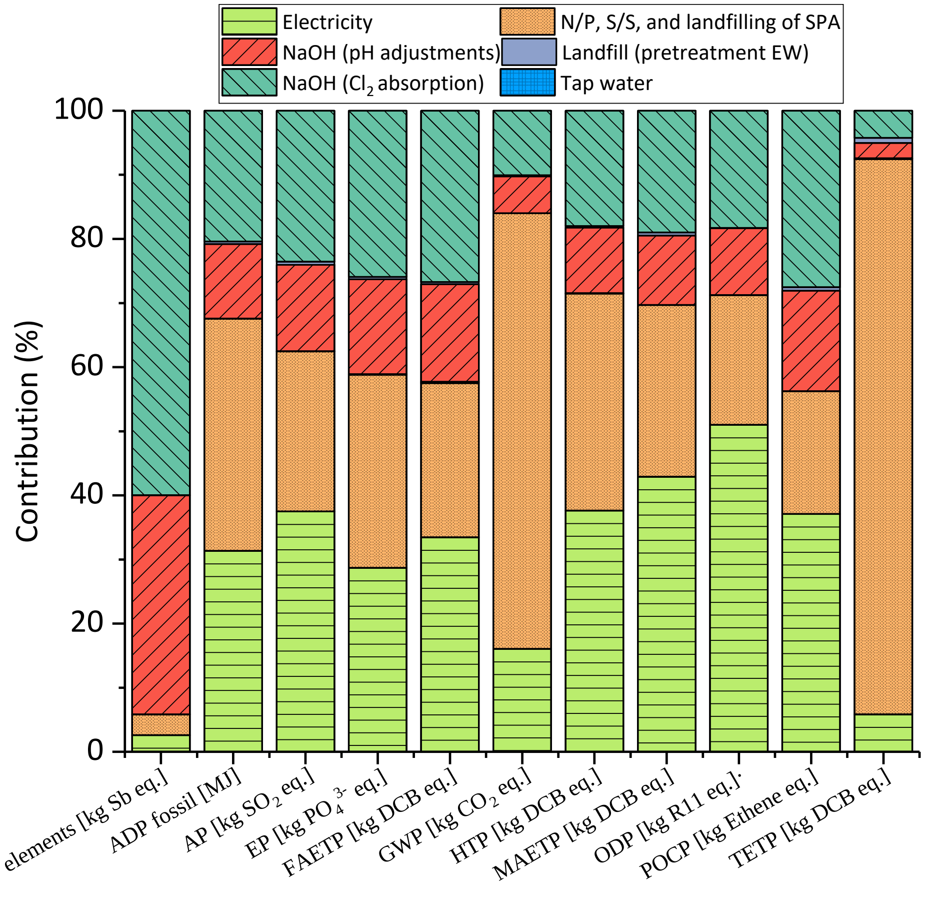
Environmental assessment of the **LIFE2ACID technology**



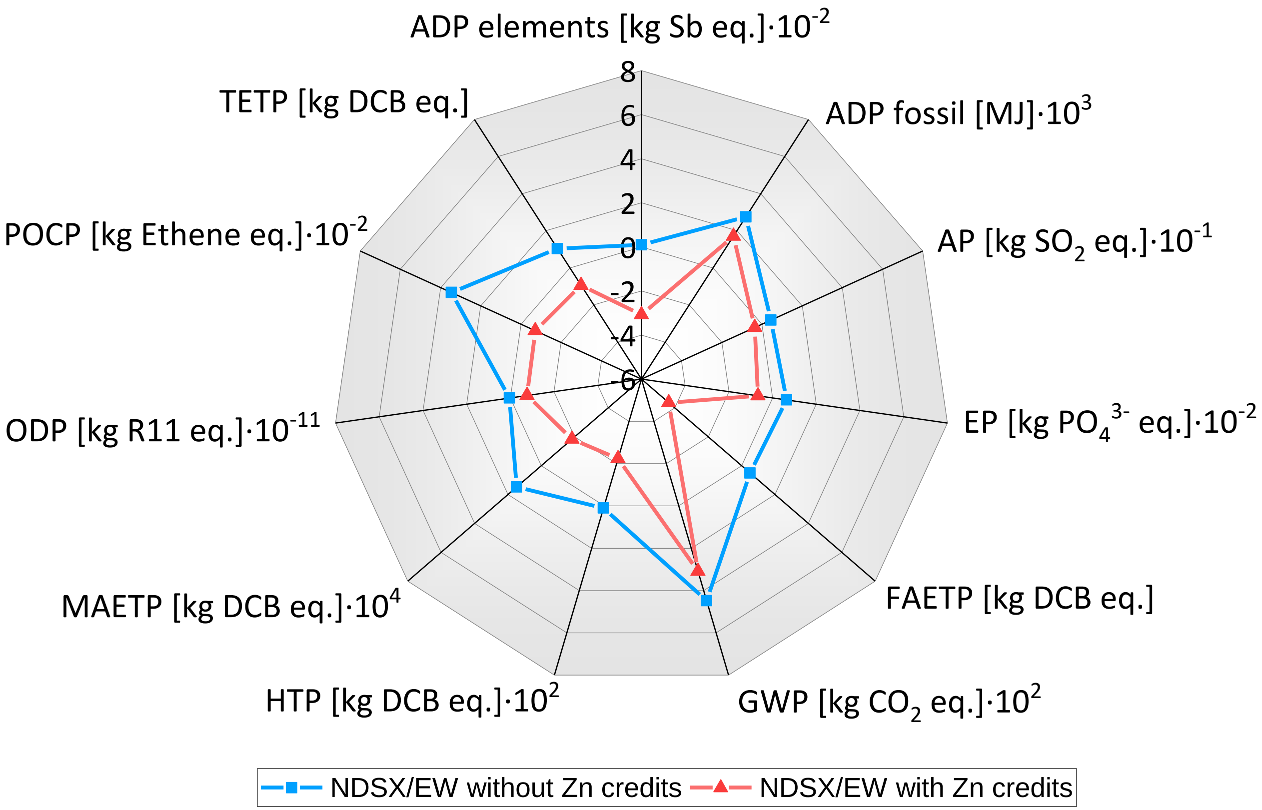
Environmental impacts of NDSX/EW (FU: one m^3 of SPA)

Energy demand for zinc electrodeposition

NaOH production
- pH adjustments
- Cl_2 absorption

Management of SPAs after NDSX by N/P, S/S, and landfilling

Environmental assessment of the **LIFE2ACID technology**



Environmental impacts of NDSX/EW without and with Zn credits
with 1:1 replacement of virgin material (FU: one m³ of SPA)

Recycling zinc under a **marginal** approach vs. an **attributional** approach

Marginal/consequential approach

$$REC - VIR$$

REC: environmental load of the LIFE2ACID technology

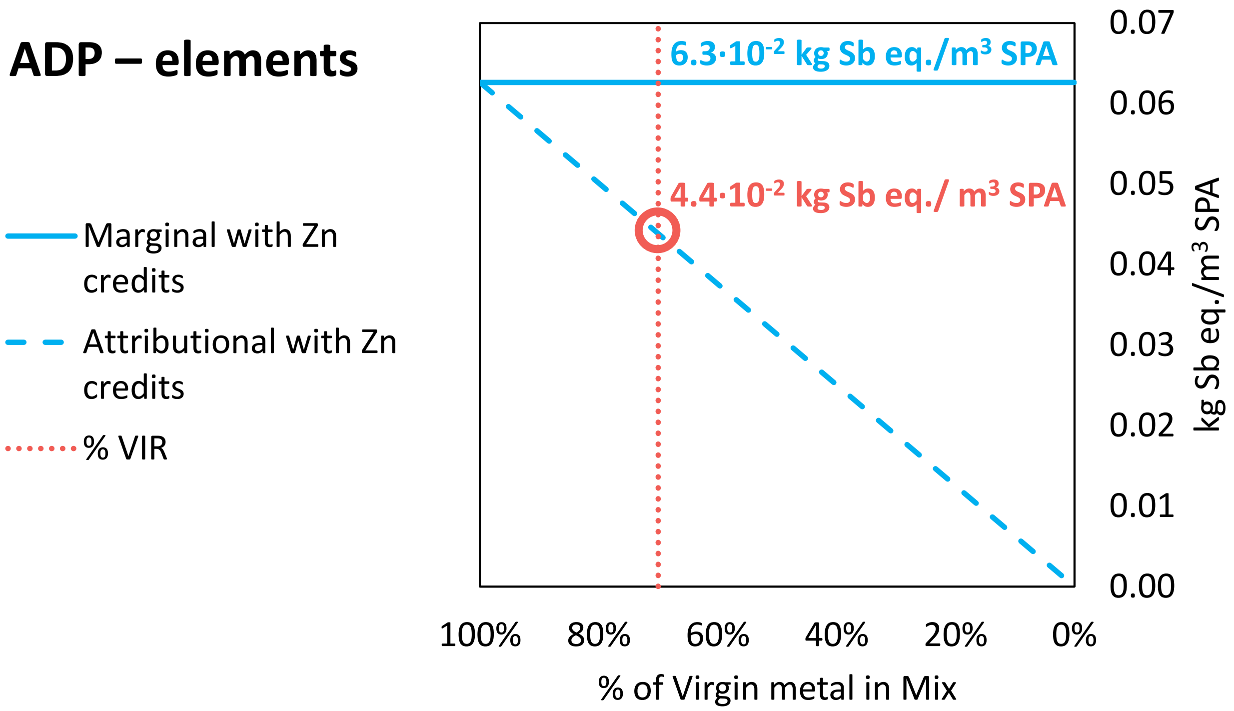
VIR: environmental load of the primary zinc production

	REC	VIR	REC - VIR	Units
ADP elements	-3.1E-02	3.2E-02	-6.3E-02	kg Sb eq./m^3 SPA
ADP fossil	1706	1044	662	MJ/m^3 SPA
AP	-0.36	0.80	-1.16	kg SO_2 eq./m^3 SPA
EP	-0.07	0.13	-0.20	kg PO_4^{3-} eq./m^3 SPA
FAETP	-4.36	4.87	-9.23	kg DCB eq./m^3 SPA
GWP	309	139	170	kg CO_2 eq./m^3 SPA
HTP	-224	234	-458	kg DCB eq./m^3 SPA
MAETP	-1.8E+04	3.3E+04	-5.2E+04	kg DCB eq./m^3 SPA
ODP	-7.7E-11	8.0E-11	-1.6E-10	kg R11 eq./m^3 SPA
POCP	-7.1E-03	4.2E-02	-4.9E-02	kg Ethene eq./m^3 SPA
TETP	-0.94	1.98	-2.91	kg DCB eq./m^3 SPA

A. B. Gala, M. Raugei, and P. Fullana-i-Palmer, "Introducing a new method for calculating the environmental credits of end-of-life material recovery in attributional LCA," *Int. J. Life Cycle Assess.*, vol. 20, no. 5, pp. 645–654, May 2015, doi: 10.1007/s11367-015-0861-3.

Recycling zinc under a **marginal** approach vs. an **attributional** approach

ADP – elements



Market mix	% Virgin	% Recycled
Zinc	70	**30**

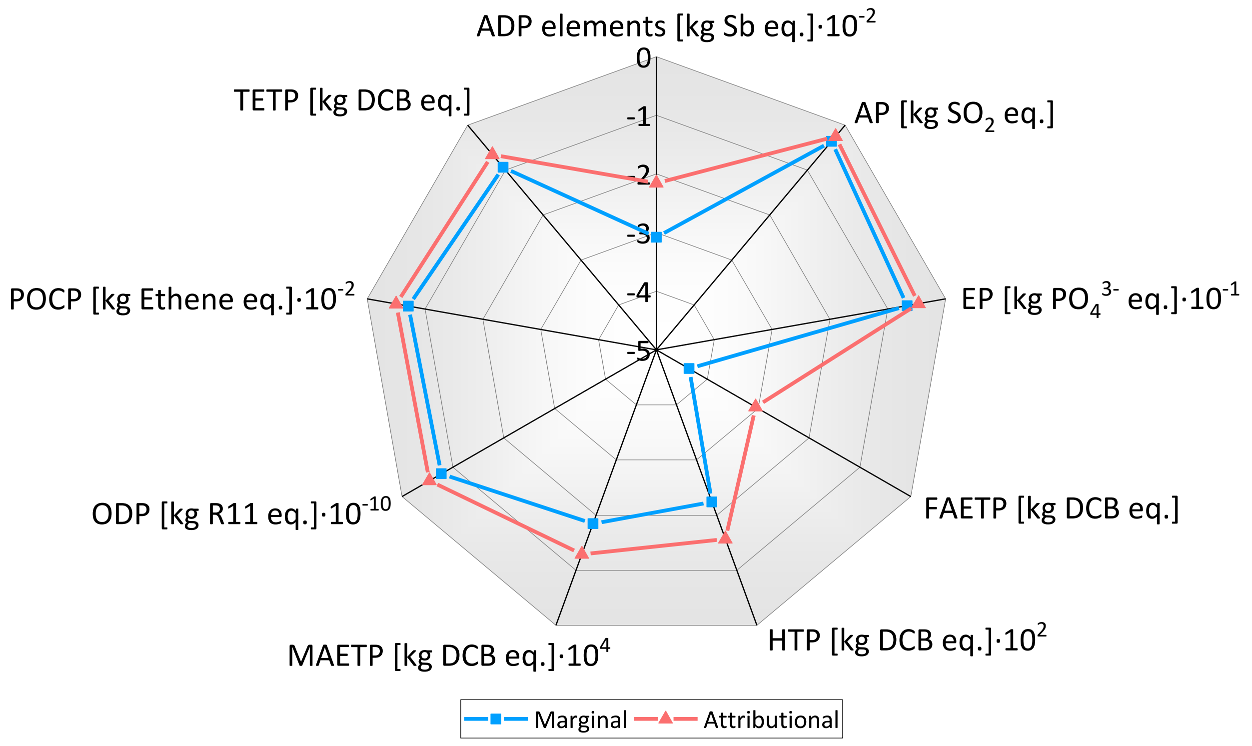
Marginal approach

kg Sb eq./m^3 SPA

	REC	VIR	REC - VIR
ADP elements	-3.1E-02	3.2E-02	**-6.3E-02**

Net benefits of recycling zinc under a marginal approach (1:1 replacement of virgin material) vs. an attributional approach (replacement of virgin and recycled market mix)

Recycling zinc under a **marginal** approach vs. an **attributional** approach



Environmental impacts of NDSX/EW under a marginal approach (1:1 replacement of virgin material) vs. an attributional approach (replacement of virgin and recycled market mix) using as FU one m^3 of SPA

Conclusions

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- In the LIFE2ACID technology, EW has a greater environmental impact than NDSX due to the **energy demand** of zinc electrodeposition and NaOH consumption

- **Recycling credits** are obtained in all the impact categories except for ADP-fossil and GWP due to the energy demand of the LIFE2ACID technology

- Based on the market mixes of primary and secondary zinc, and therefore, using an **attributional approach**, the environmental loads are reduced by 30% compared with the **marginal approach**

- For better technology assessment, the attributional approach provides a less optimistic but **more realistic** view than the marginal approach

Future work

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To include uncertainty analysis and economic evaluation of the LIFE2ACID technology

To apply the Circular Footprint Formula (CFF)

Material $$(1 - R_1) \cdot E_V + R_1 \cdot \left(A \cdot E_{recycled} + (1 - A) \cdot E_V \cdot \frac{Q_{S,in}}{Q_P}\right) + (1 - A) \cdot R_2 \cdot \left(E_{recycling,EoL} - E_V^* \cdot \frac{Q_{S,out}}{Q_P}\right)$$

Energy $$(1 - B) \cdot R_3 \cdot (E_{ER} - LHV \cdot X_{ER,heat} \cdot E_{SE,heat} - LHV \cdot X_{ER,elec} \cdot E_{SE,slec})$$

Disposal $$(1 - R_2 - R_3) \cdot E_D$$

Thank you ;)

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