Electronic Supplementary Information (ESI)

for the article

Exploitation of printed circuit board feeds for high-purity copper recovery using hydrometallurgy: process and life cycle assessment considerations

N. Kelly[1*#], P. Boelens[1,2*#], A.M. Parvez[1,3], S. Kutschke[1], D. Ebert[1], B.M. Guy[1], R. Möckel[1], M.H. Aamir[1], C. Sanchez-Garrido[1], U. Fischer[1], M. Sajjad[1], A.D. Renno[1], L. Ott[4], F. Ellinger[4], A.B. Patil[1,5], J. Gutzmer[1]

Table S1: Energy and resources provider

Energy and Resources	**Provider**
Electricity	Electricity, medium voltage APOS, S – NO
Hydrogen peroxide	market for hydrogen peroxide, without water, in 50% solution state | APOS, S
Nitrogen	market for nitrogen, liquid | nitrogen, liquid | APOS, S
Sulfuric acid	market for sulfuric acid | sulfuric acid | APOS, S
Sodium hydroxide	market for sodium hydroxide | APOS, S
Water, decarbonised	market for water, decarbonised | water, decarbonised | APOS, S

Table S2: Concentration of selected metal ions (in mg·L^{-1}) in leach solutions for size fraction 630µm-1mm. c(H_2SO_4) = 3 mol·L^{-1}, c(H_2O_2) = 3 wt% (addition in 60 min), S/L = 1:10, t = 12 h., r.t.; c(HNO_3) = 3 mol·L^{-1}, S/L = 1:3, t = 61 h, r.t.; BDL: below detection limit.

Leaching system	**Sulfuric acid**	**Nitric acid**
Metal ion	Concentration in mg·L^{-1}	Concentration in mg·L^{-1}
Cu^{2+}	32600	96100
Fe^{3+}	7.51	19.4
Ni^{2+}	841	2550
Au^{3+}	BDL	0.397
Al^{3+}	527	2000

Ca^{2+}	265	2800
Ba^{2+}	<1	59
Si^{4+}	21.5	14.7

Table S3: Impact assessment results, expressed per kg of copper, without economic allocation

Category	Unit	Impact assessment results	
		H_2SO_4	**HNO_3**
agricultural land occupation (ALOP)	m^2a	1.87E+00	1.13E+00
climate change (GWP100)	kg CO_2-Eq	4.03E+01	2.77E+01
fossil depletion (FDP)	kg oil-Eq	1.39E+01	7.01E+00
freshwater ecotoxicity (FETPinf)	kg 1,4-DCB-Eq	9.34E+00	7.94E+00
freshwater eutrophication (FEP)	kg P-Eq	3.19E-02	2.17E-02
human toxicity (HTPinf)	kg 1,4-DCB-Eq	7.82E+01	6.29E+01
ionising radiation (IRPHE)	kg U235-Eq	4.33E+00	1.64E+00
marine ecotoxicity (METPinf)	kg 1,4-DCB-Eq	8.48E+00	7.20E+00
marine eutrophication (MEP)	kg N-Eq	6.08E-02	3.62E-02
metal depletion (MDP)	kg Fe-Eq	1.94E+01	1.67E+01
natural land transformation (NLTP)	m^2	9.22E-03	6.93E-03
ozone depletion (ODPinf)	kg CFC-11-Eq	1.20E-05	2.13E-06
particulate matter formation (PMFP)	kg PM10-Eq	1.97E-01	1.36E-01
photochemical oxidant formation (POFP)	kg NMVOC	2.04E-01	1.26E-01
terrestrial acidification (TAP100)	kg SO_2-Eq	6.11E-01	5.19E-01
terrestrial ecotoxicity (TETPinf)	kg 1,4-DCB-Eq	1.80E-02	1.19E-02
urban land occupation (ULOP)	m^2a	1.22E+00	9.02E-01
water depletion (WDP)	m^3	6.17E-01	4.53E-01

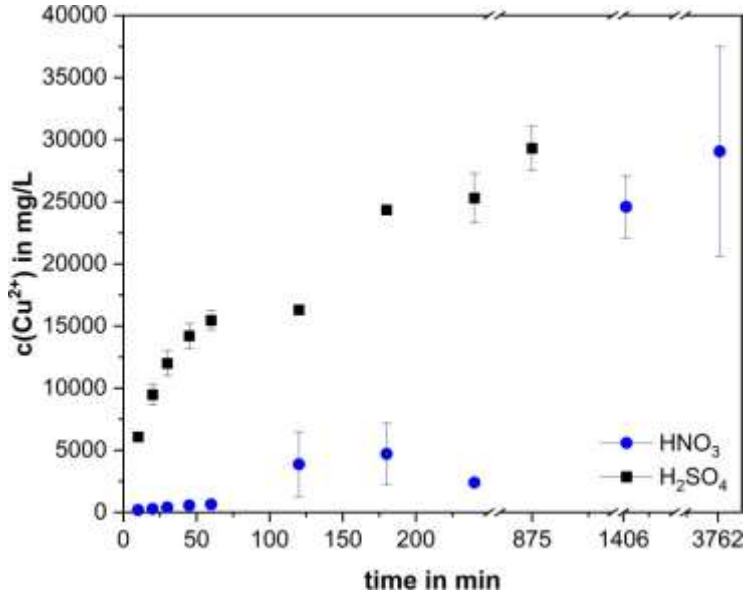

Figure S1: Leaching of copper (concentration in mg·L^{-1}) from PCB material (630 µm – 1 mm) in dependence on reaction time. c(H_2SO_4) = 3 mol·L^{-1}, c(H_2O_2) = 3 wt%; c(HNO_3) = 3 mol·L^{-1}, S/L = 1:10, t = 10 min-3765 min, r.t.

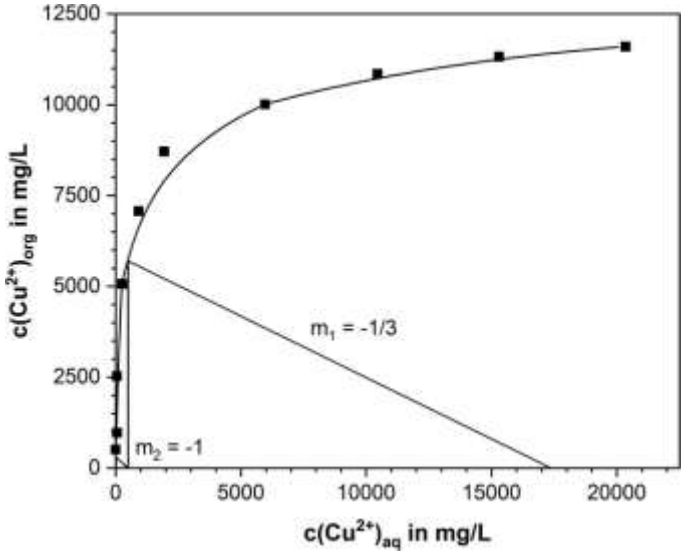

Figure S2: The McCabe-Thiele diagram for $CuSO_4$-$NiSO_4$-Na_2SO_4-H_2SO_4/LIX 84-I-kerosene. Cu(II)$_{ini}$ = 0.5-31.9 g/L, Ni(II)$_{ini}$ = 214 mg/L, c(Na_2SO_4) = 0.5 mol·L^{-1}, pH$_{eq}$ 1.35±0.15, 20 vol% LIX 84-I, t = 15 min, r.t.. Error bars represent mean ± half range (n=2).

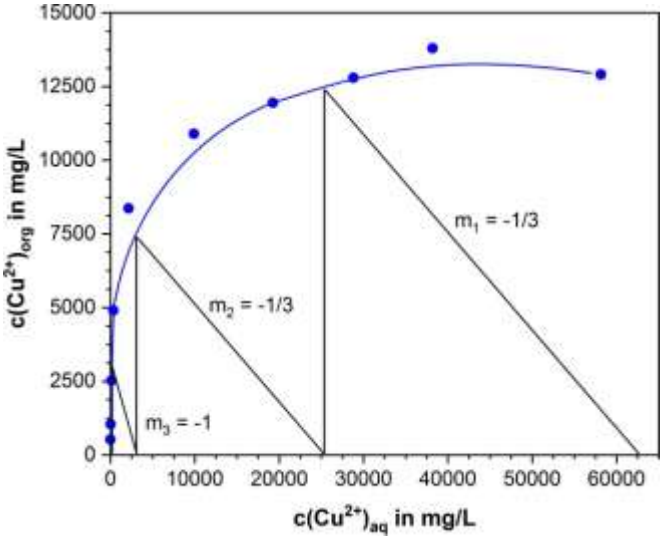

Figure S3: The McCabe-Thiele diagram for $Cu(NO_3)_2$-$Ni(NO_3)_2$-$NaNO_3$-HNO_3/LIX 84-I-kerosene. $Cu(II)_{ini}$ = 0.5-71.1 g/L, $Ni(II)_{ini}$ = 743 mg/L, $c(NaNO_3)$ = 1 mol·L^{-1}, pH_{eq} 1.35±0.15, 20 vol% LIX 84-I, t = 15 min, r.t.. Error bars represent mean ± half range (n=2).

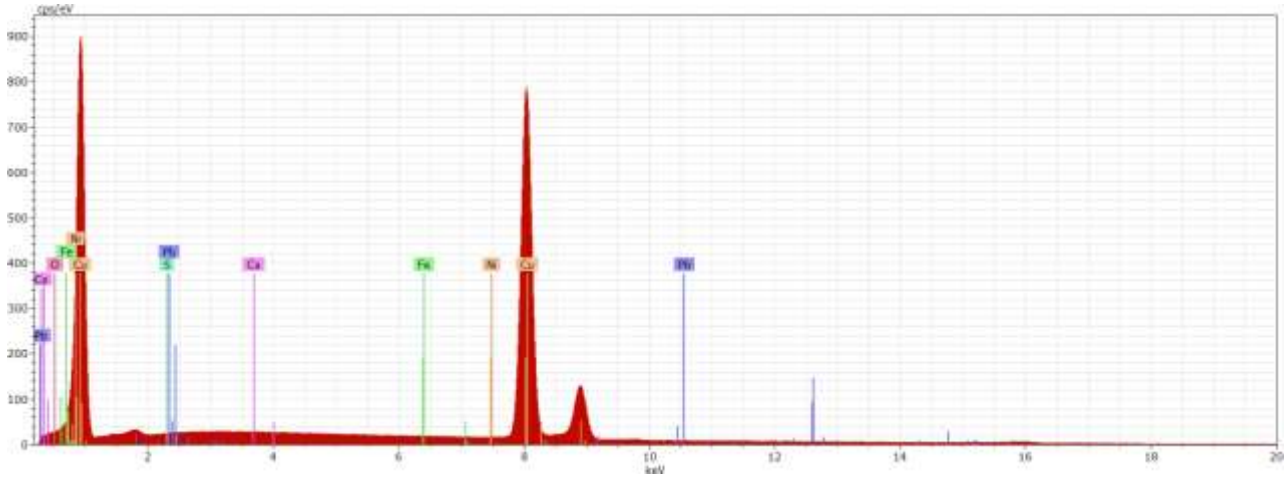

Figure S4: EDX data for the deposited Cu samples showing high purity of Cu