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Life Cycle Inventories of Different Types of Gold Extraction from Small-Scale Mining in the Amazonian Rainforest in Brazil

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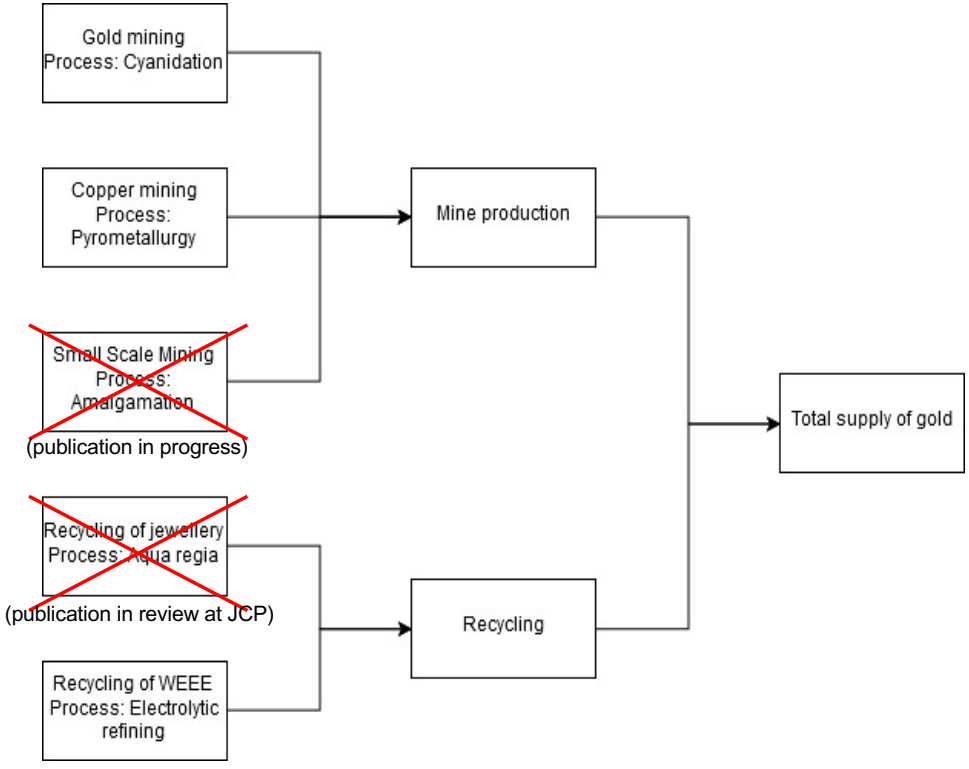
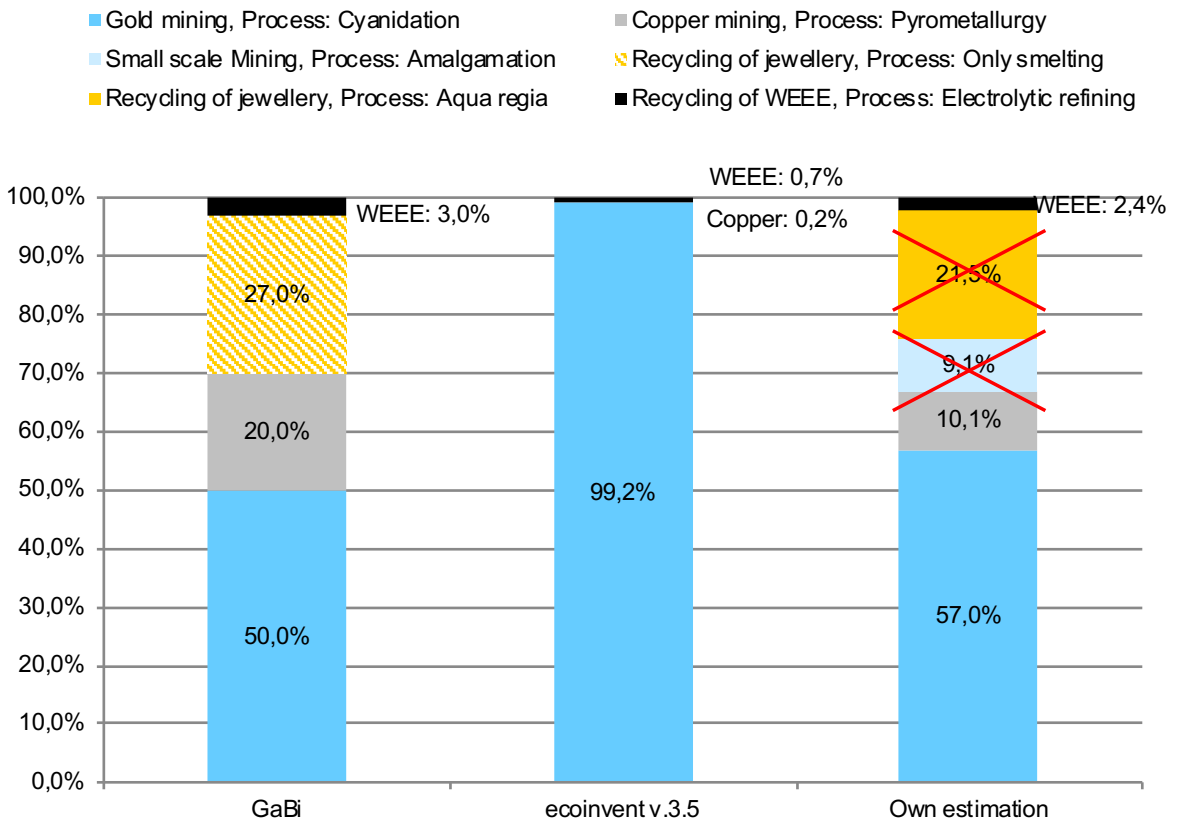
Overview and Introduction

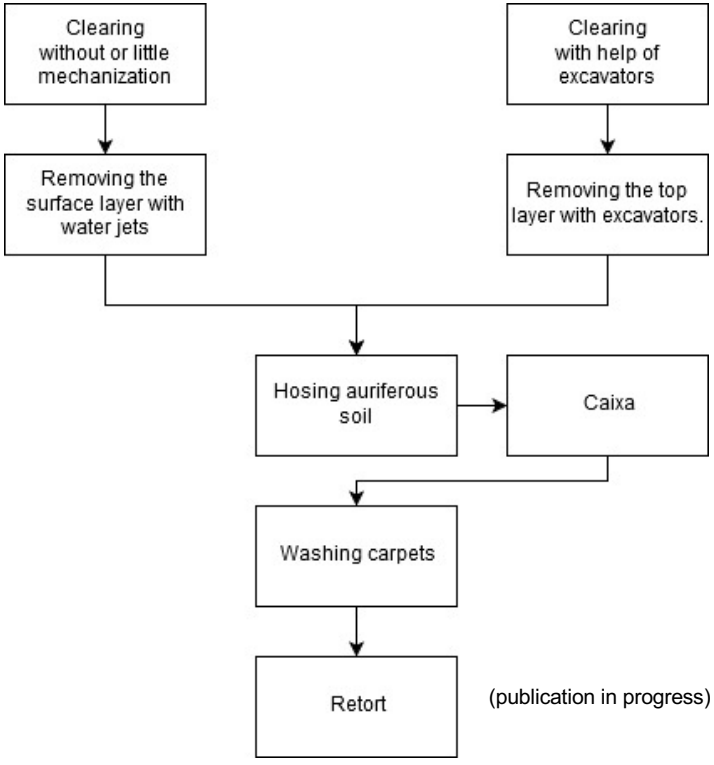
Research of the different types of gold production	Production routes are: Gold mining, refining of copper ores, Artisanal and Small Scale Mining (ASM), Waste Electrical and Electronic Equipment Directive (WEEE), recycling of high-value gold scraps
Analysis of the LCA-Datasets for the material gold	No data for ASM (publication in progress) and recycling of high-value scraps (publication in review at JCP), very uncertain data for gold mining, refining of copper ores and WEEE (publication submitted)
Collection of primary data for productions routes missing in LCA-Databases	Field trip to 11 ASM sites (Garimpos) in Brazilian Amazon Rainforest in September 2018, several factory tours of companies that recycle high-value gold scraps in Pforzheim, Germany
Preparation of environmental analyses with Umberto for the missing production routes	For ASM two inventories for Garimpos with and without the use of excavators were developed (publication in progress), for high-value gold scrap recycling a inventory and analysis for energy demand and CO_2-emissions was created (publication in review at JCP)
Comparison with existing studies on the material gold	First preliminary results for ASM show that its energy demand and CO_2-emissions are in the same ballpark as industrial mining while recycling of high-value gold scraps is significant better than all outer gold production routes.
Analysis of technological changes in ASM in Brazil	Mechanization of ASM processes lead to more deforestation through enhanced productivity. Rudimental cyanidation plants carries risks for Garimpeiros.

Results

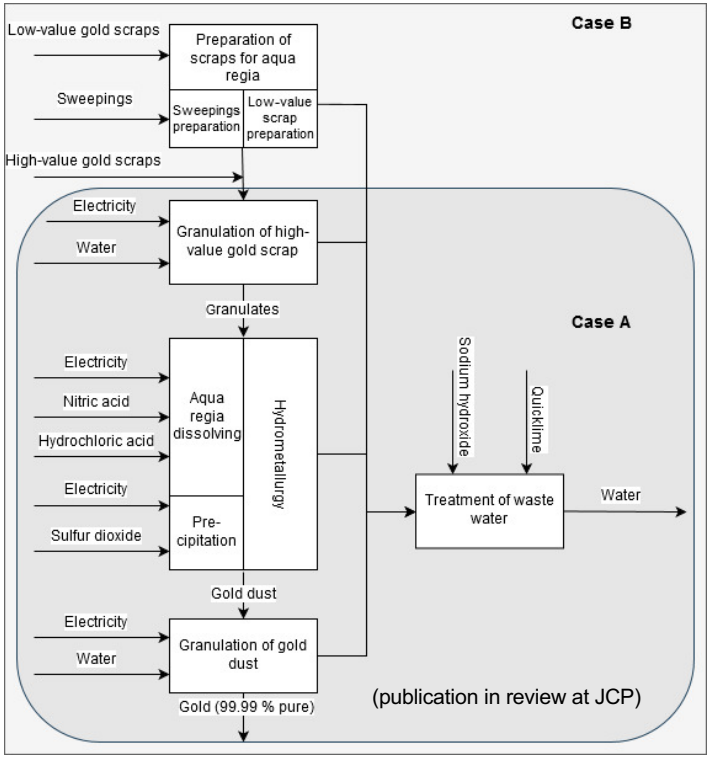

Gold mining Process: Cyanidation
Copper mining Process: Pyrometallurgy
Small Scale Mining Process: Amalgamation
(publication in progress)
Recycling of jewellery Process: Aqua regia
(publication in review at JCP)
Recycling of WEEE Process: Electrolytic refining
Mine production
Recycling
Total supply of gold


Gold mining, Process: Cyanidation
Copper mining, Process: Pyrometallurgy
Small scale Mining, Process: Amalgamation
Recycling of jewellery, Process: Only smelting
Recycling of jewellery, Process: Aqua regia
Recycling of WEEE, Process: Electrolytic refining
100,0%
90,0%
80,0%
70,0%
60,0%
50,0%
40,0%
30,0%
20,0%
10,0%
0,0%
WEEE: 3,0%
27,0%
20,0%
50,0%
WEEE: 0,7%
Copper: 0,2%
99,2%
WEEE: 2,4%
21,5%
9,1%
10,1%
57,0%
GaBi
ecoinvent v.3.5
Own estimation

Results

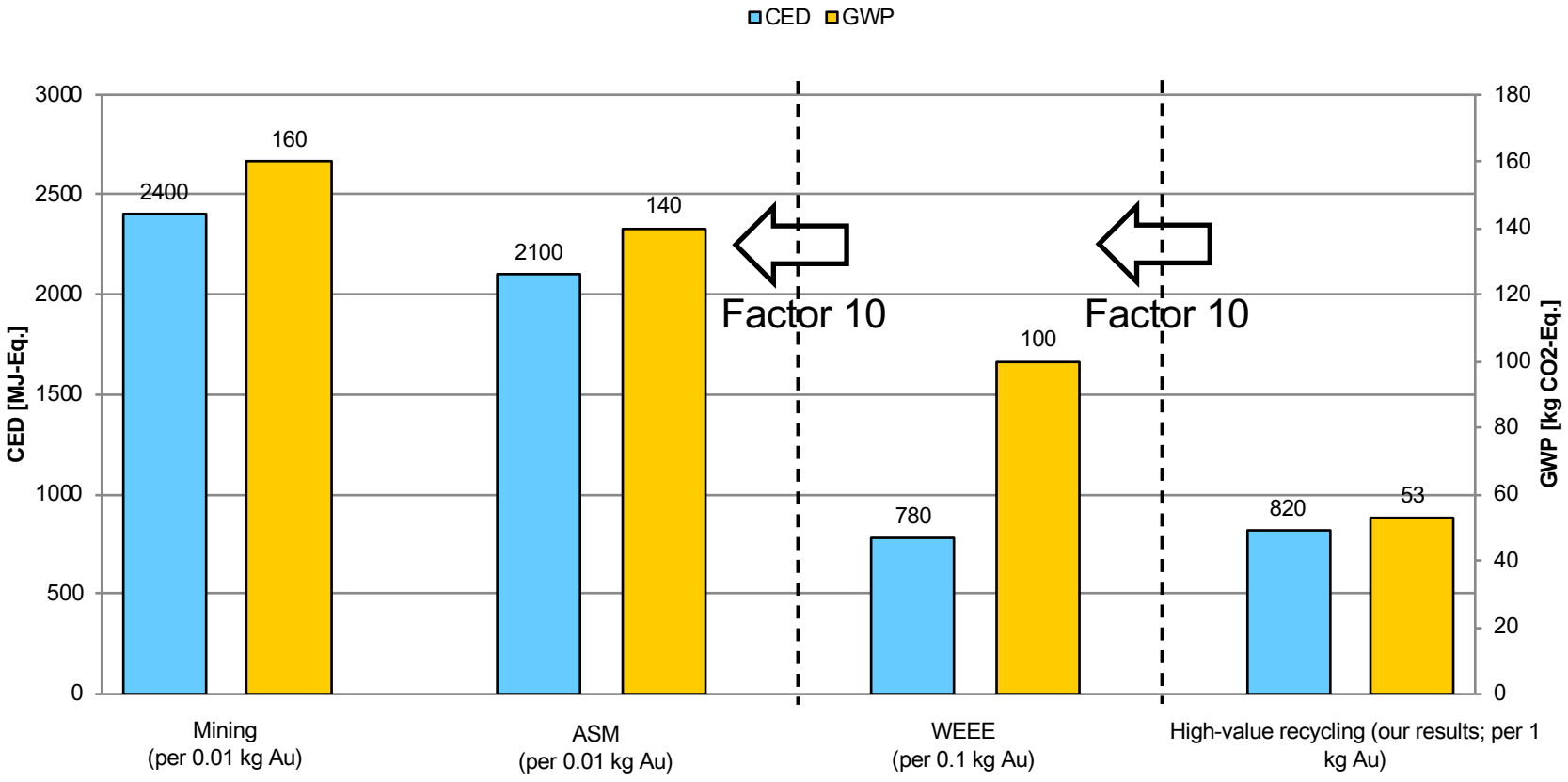


(publication in progress)



(publication in review at JCP)

Results



Source: ecoinvent v.3.5

Results

Technological improvements

- Rebound-effect.

Excavators enable more efficient production -> faster gold extraction -> cutting larger areas of rainforest

Better pumps -> higher sedimentation of the rivers -> faster production -> cutting larger areas of rainforest

- Symbiosis

Excavators for gold are used for building roads which are attractive for activities like soy or cattle farming.

Own picture

Cyanidation in ASM context

- Provisional pits, uncovered from rain and lined with plastic foils serve as tanks for cyanide leaching.
- Mobilization and emissions of heavy metals and cyanide complexes in various process steps.
- Garimpeiros without professional background working with highly lethal chemicals.


Own picture

Conclusion

- No LCA data for recycling of high-value gold scraps (more than 20% of worlds gold production) and ASM (around 10% of world gold production) in LCA databases
- Recycling of high-value gold scraps is significant better than all other gold production routes
- First preliminary results for ASM show that the environmental impact this activity is in the same ballpark as industrial mining
- Technological improvements in the context of ASM vs industrial mines require different consideration

Outlook

- We started to collect primary data in site visits and by distributing questionnaires about how much mercury is lost and recovered through distillation per amount of gold .
- First and very preliminary results

Mercury recovered [g]	230	200	240	110	170	110	110	Ø 94 %
Mercury lost [g]	16	4	14	8	7	13	7	Ø 6%

- Publications: High-value gold scrap recycling in review at JCP, analysis of gold in LCA datasets submitted, ASM topic in progress

Sources

Adams, Mike D. (Hg.) (2016): Gold ore processing. Project development and operations. Second edition. Amsterdam, Boston, Heidelberg, London: Elsevier.

Classen, Mischa; Althaus, Hans-Joerg et al. (2009): Life Cycle Inventories of Metals Data v2.1 (2009), S. 495–608

World Gold Council (2019): Gold Mining Production Volumes. https://www.gold.org/goldhub/data/historical-mine-production, last visit: 10.2019.