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Metals

A joint initiative of the ETH domain and Swiss Federal Offices

ETH EPFL PSI EMPA EAWAG FAL

Special LCA forum, December 5, 2003
EPFL Lausanne / session „metals"

Introduction

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contributors

- responsible institute: EMPA, Dübendorf
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- authors: Hans-Jörg Althaus, Mischa Classen, Silvio Blaser
- contributions from: ESU-services, Niels Jungbluth
- financial support: BUWAL, BBL, ASTRA, EMPA

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Main differences to ÖvE3

- Consideration of resource quality
- Consideration of slag, filter dust, overburden and tailings
- ferroalloys
- couple production
- New land use
- Meta information
- Material and processing separately

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metals in ecoinvent

- iron and steel
- aluminium
- copper / molybdenum
- nickel / ferronickel
- chromium/ ferrochromium
- manganese / ferromanganese
- Platinum group metals (PGM)
- other (lead / zinc, tin, bronze, brass)
- processing

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Workshop

- copper / molybdenum (Mischa Classen)
- iron / steel (Hans-Jörg Althaus)
- discussion

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Non ferrous metals

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Content

- Nonferrous metals in ecoinvent
- Chief Differences to ÖvE3
- Data Sources

- Copper / Molybdenite: Production Chain
- Selected Results

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Non Ferrous Metals in ecoinvent

- Nickel, platinum group metals (Pt, Pd, Rh), copper, molybdenum, chromium, lead, zinc, tin
- Processing: welding, rolling, drawing of wire and pipe, casting
- Auxiliary modules: tailings (dump heaps), slag disposal, infrastructure
- use: mostly as ferroalloys (ferrochromium, ferronickel, ferromanganese)

➢ Metainformations „General Comment"

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Chief Differences to ÖvE3

- Tailings are included
- Modelled consistently as multi-output process (allocation by value, except for resources)
- Higher burden as compared to ÖvE3
  - Copper (swiss ecopoints) + 57% to 1.9 10^4 UBP / kg Cu
  - Copper ($EI_{H,A}$) + 97% to 2.1 EP / kg Cu

➢ Increased importance of materials (infrastructure) as compared to operation phase (energy)

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Data Sources (Copper)

- Materials & Energy
  - values for Germany 1994 (Krauss et al. 1999)
  - general process data (Ayres et al. 2002)
- Land use
  - publication in *Erzmetall* (Martens et al. 2002)
- Process specific emissions from IPPC's BAT-report
  - copper (Rentz et al. 1999)
  - exploitation und beneficiation (IPPC 2002)

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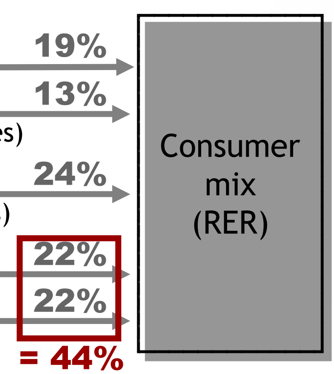
Copper: Consumer Mix

- Regional consumer mix as starting point
- Characteristics:
  - imported **primary copper**
  - regional **primary copper** (imported copper concentrates)
  - regional **primary copper** (regional copper concentrates)
  - regional **secondary copper**
  - recycled **copper scrap**



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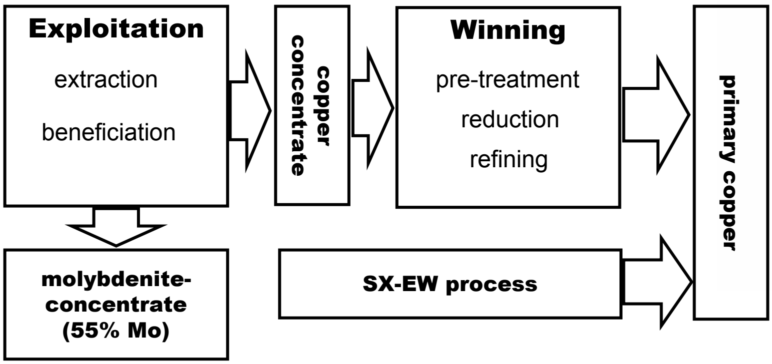
Copper: Production Chain

- Primary copper, at refinery



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Copper: Winning of Primary Metal

- Technology:
  - different **pyrometallurgical** processes
  - varying emission factors
- Regions
  - varying concentration in ore
  - specific production technology mix
  - specific abatement technology

➢ Regional production mixes in ecoinvent

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Copper: SX-EW

- Solvent-Extraction / Electrowinning (SX-EW) is a **hydrometallurgical** process
- oxidic ores only, sulfidic ones have to be roasted previously
- consists of exploitation, beneficiation, extraction and electrolytical winning
- copper is dissolved with acid from ore
- env. 10% production worldwide
- characterised by
  - high demand in electricity
  - high land use due to leaching
  - moderate demand in quality of the raw ore

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Copper: Ore Exploitation

- Extraction
  - >90% sulfidic ores, >10% oxidic ores
  - decreasing grades in worked deposits (1%w)
  - 30% underground mining, rest open cut with increasing trend
- Beneficiation
  - ore is ground
  - unwanted minerals are removed in water using chemicals
- Environmental critically issues
  - use of cyanide (sulfidic ores)
  - use of organic chemicals (frother, flocculant)
  - tailings (dump heaps)
  - land use by open cut operations / leaching heaps

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Copper: Allocation of Coupled Product

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- 54% of Molybdenum originates from copper-molybdenum porphyry deposits
- Two coupled products from ore exploitation
  - copper-concentrate
  - molybdenite-concentrate (MoS_2)
- Ore exploitation is modelled as multi-output process
- Allocation by value (price x output)
- Small fraction of molybdenite in output: 1.5 kg Mo-conc. / t Cu-conc.
- Split of total environmental burden as follows
  - molybdenite-concentrate = 1% US$ 3'188 / t x 5.3 kg
  - copper-concentrate = 99% US$ 522 / t x 3'480 kg
- Due to higher market price higher burden per unit (kg) is assigned to molybdenite than to copper-concentrate

Molybdenite as Main Product

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- Analogous process as exploitation of copper ore (GLO)
- Differences
  - resource (0.041% Mo in crude ore, identical grade in Cu)
  - output (21 kg Mo-concentrate per t Cu-concentrate)
- Allocation
  - molybdenite-concentrate = 11% US$ 3'188 / t x 74 kg
  - copper-concentrate = 89% US$ 522 / t x 3'480 kg
- Higher burden per unit for molybdenite-concentrate compared to copper-concentrate.
- Molybdenite production mix composes of molybdenite as main product (46%) and molybdenite as coupled product from copper ore exploitation (54%)

Results: Copper-Modules - Energy

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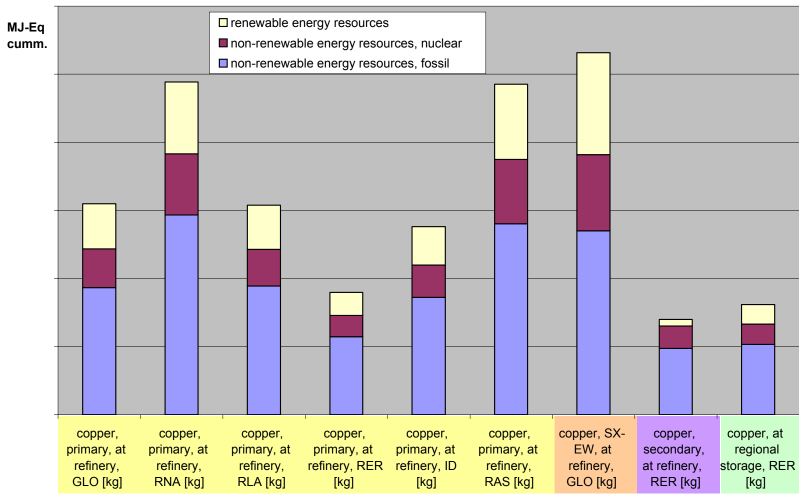

Results: Copper-Modules - IPCC

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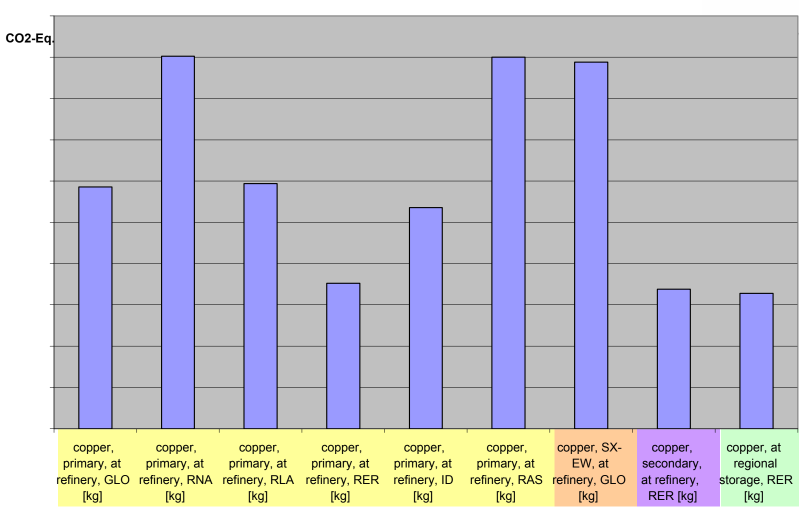
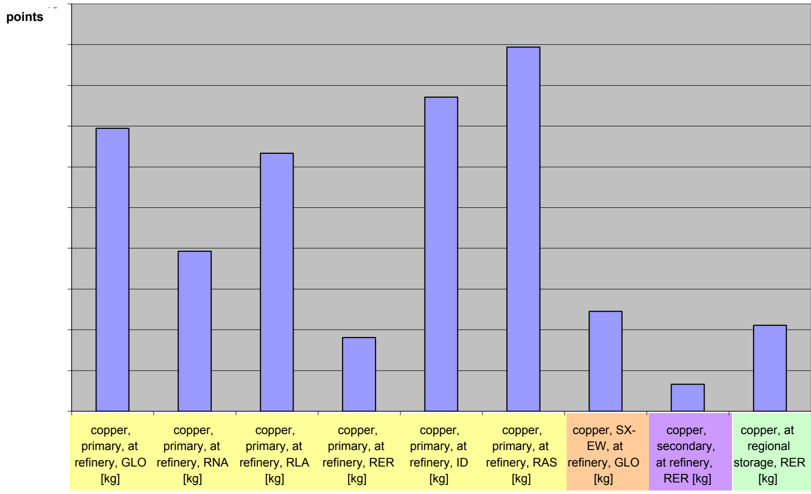


Results: Copper-Modules - $EI_{H,A}$



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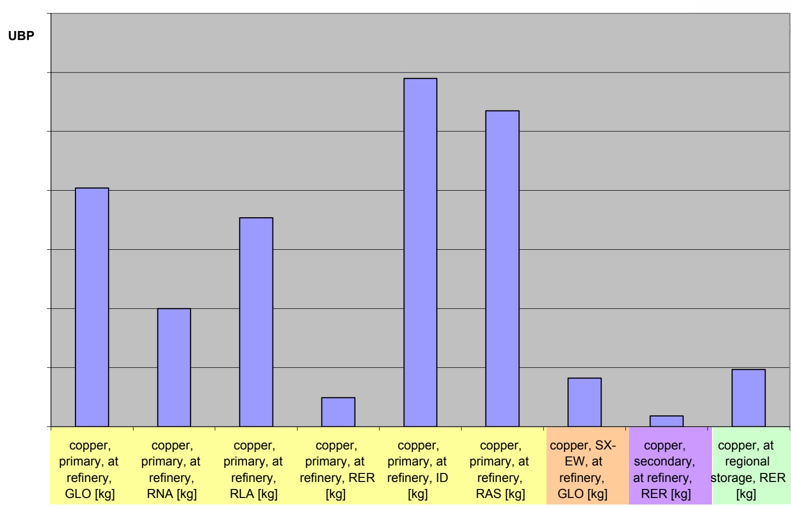
Results: Copper-Modules - BUWAL



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Results: Consumer Mix

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- Regional consumer mix of copper (RER)

	content	$EI_{H,A}$	UBP
imported primary copper	19%	59%	75%
regional primary copper (imported concentrate)	13%	14%	8.8%
regional primary copper (regional concentrate)	24%	21%	12%
regional secondary copper	22%	6.9%	4.0%
recycled copper scrap	22%	0.1%	0.1%

Results: Production Chain- $EI_{H,A}$

Valued impacts of the production of 1 kg primary copper (GLO)

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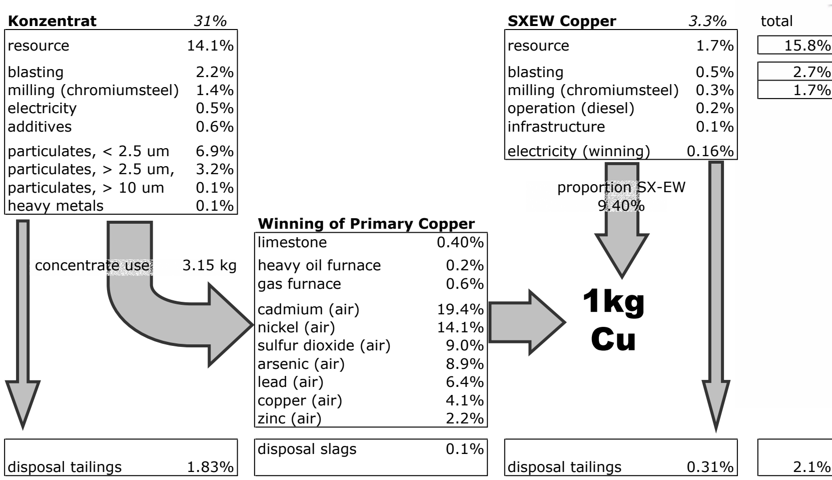

Particular percentages sum up to a total impact of 100%

Conclusions

- Metal emissions to air domintate pyrolytical winning.
- Particulate emissions (dust) dominate open cut mining.
- Ressource depletion. Copper deposits last another 60 years.
- Tailings: marginal importance, but: long-term emissions!
- Emissions from energy production play minor role.
- SXEW: high energy use, but lower specific emissions to air.
- Molybdenite: per mass 3.7 times higher burden than copper concentrate.

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Iron and Steel

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content

- iron and steel in ecoinvent
- the iron and steel chain in ecoinvent
- data sources
- main differences to ÖvE3
- selected results
- uncertainties
- conclusion
- future steps

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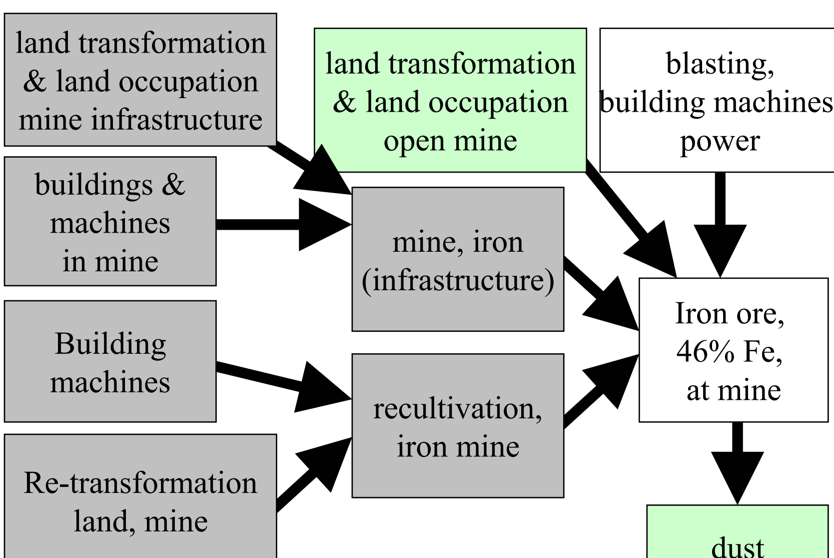
iron and steel in ecoinvent

- pig iron
- cast iron (electric-)
- un-alloyed steel (converter, electric, mix (reinforcing steel))
- low alloyed steel (converter, electric, mix)
- chromium steel (18/8) (converter, electric, mix)
- Processing of steel (hot and cold rolling, section bar rolling, tube and wire drawing, welding, zinc coating)

iron and steel chain



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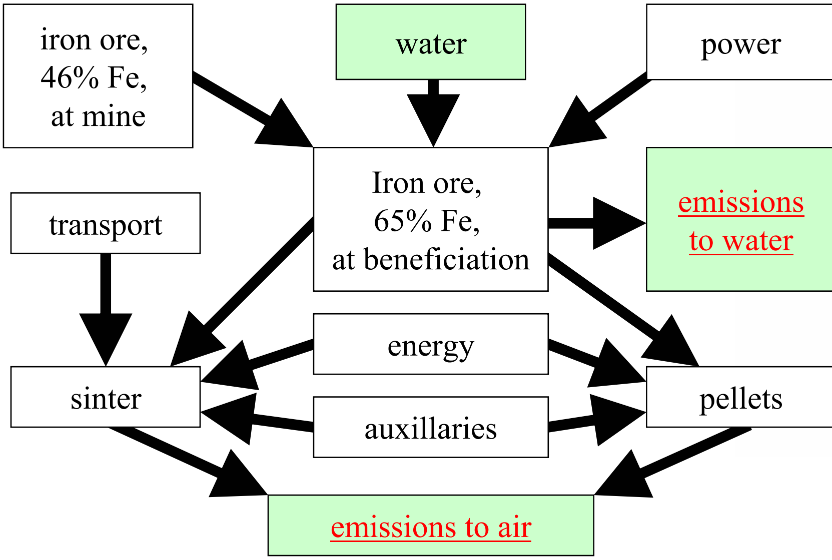
iron and steel chain



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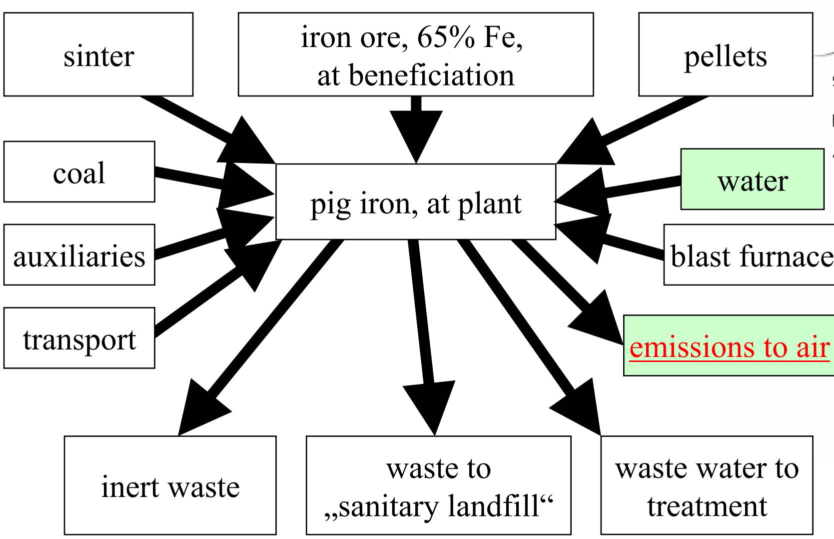
iron and steel chain



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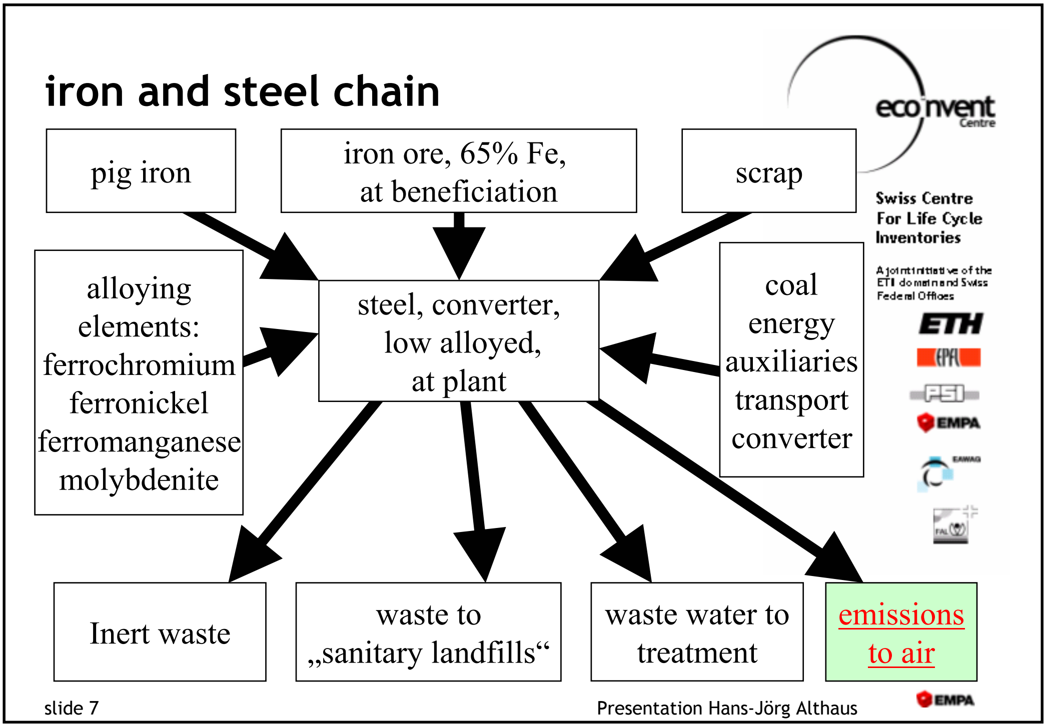
iron and steel chain
pig iron
iron ore, 65% Fe, at beneficiation
scrap
alloying elements: ferrochromium ferronickel ferromanganese molybdenite
steel, converter, low alloyed, at plant
coal energy auxiliaries transport converter
Inert waste
waste to „sanitary landfills“
waste water to treatment
emissions to air
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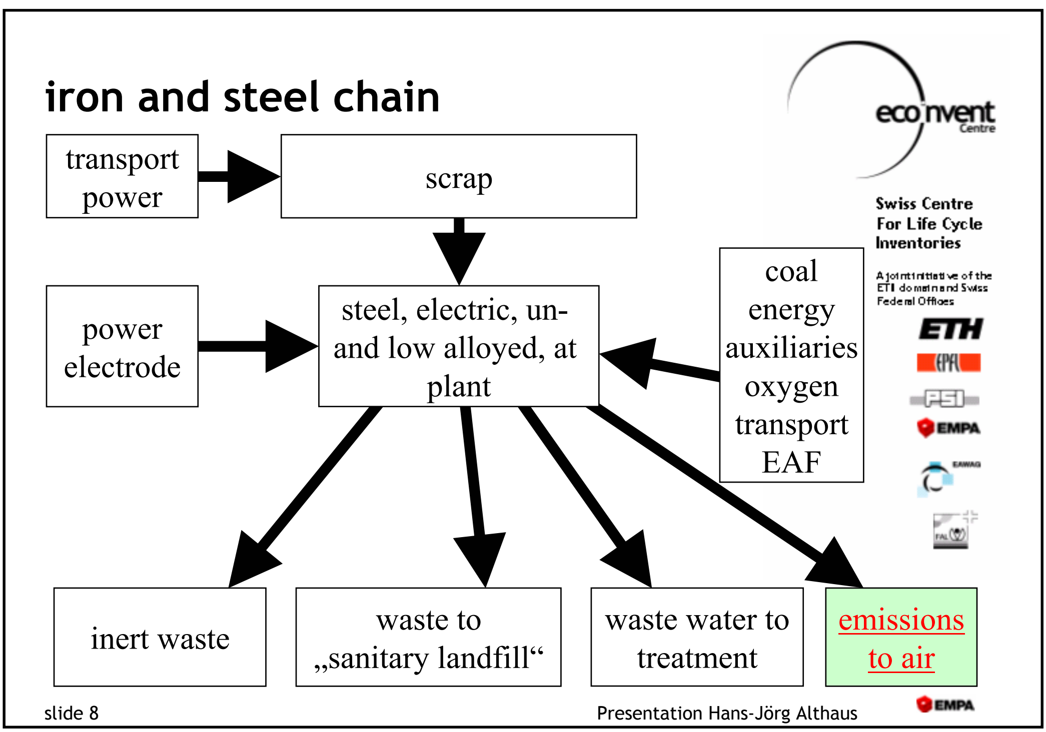
iron and steel chain
transport power
scrap
power electrode
steel, electric, un- and low alloyed, at plant
coal energy auxiliaries oxygen transport EAF
inert waste
waste to „sanitary landfill“
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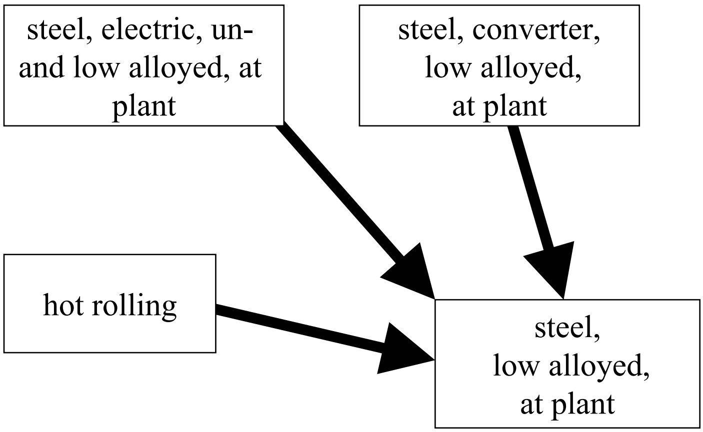
iron and steel chain



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data sources

- Mining / beneficiation:
  Roth et al. 1999
  Anonymous 1998 (world bank) (water emissions beneficiation)
- sinter and pellet production and metallurgy:
  Roth et al. 1999 (input materials up to pig iron)
  IPPC 2000 (emissions, input materials (after pig iron), waste (amount, share to recycling, composition)
- mixes: „steel at plant“
  IISI 2002

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Main differences to ÖvE3

- New sources
- Specific chromium steel instead of "high alloyed steel" (high alloyed steel in ÖvE3 was the same steel as today but not obviously declared)
- Consideration of waste

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Selected results; interpretation

- ecological scarcity points in chain
- ecoindicator 99 H,A in chain
- CED in chain

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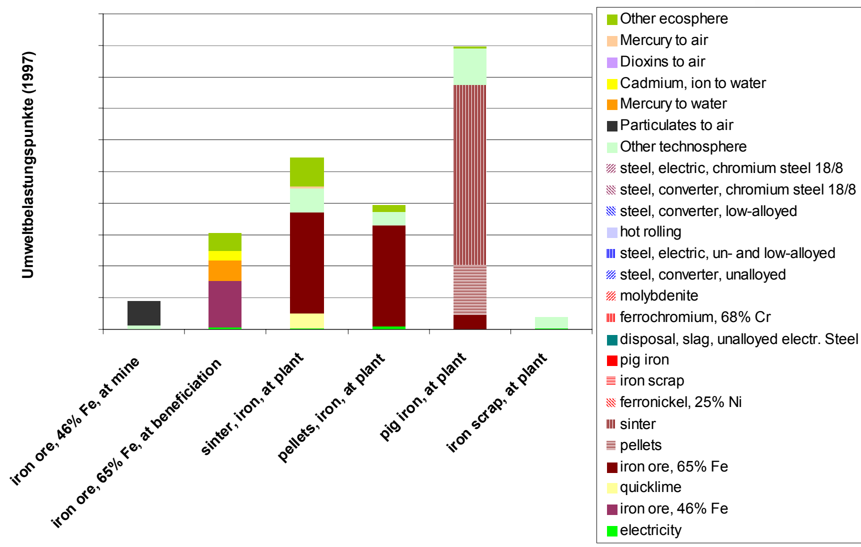
ecological scarcity points



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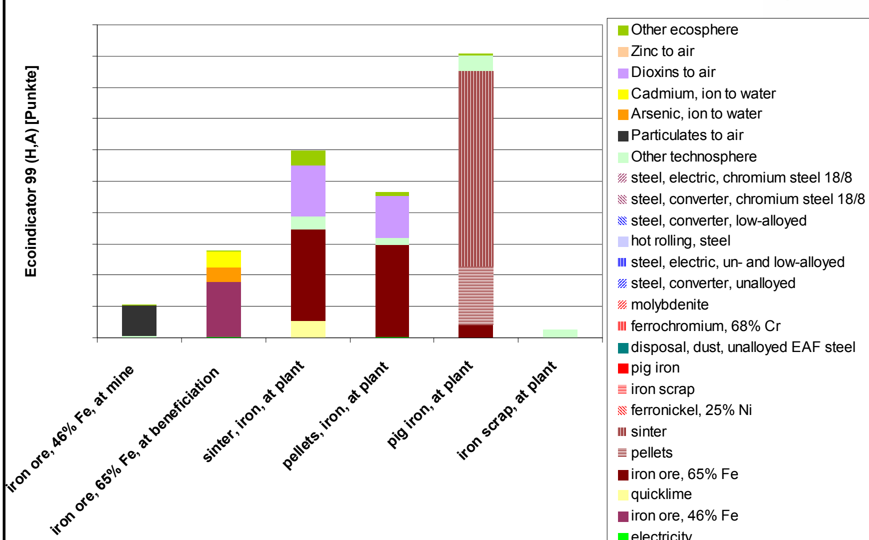
ecoindicator 99 H,A



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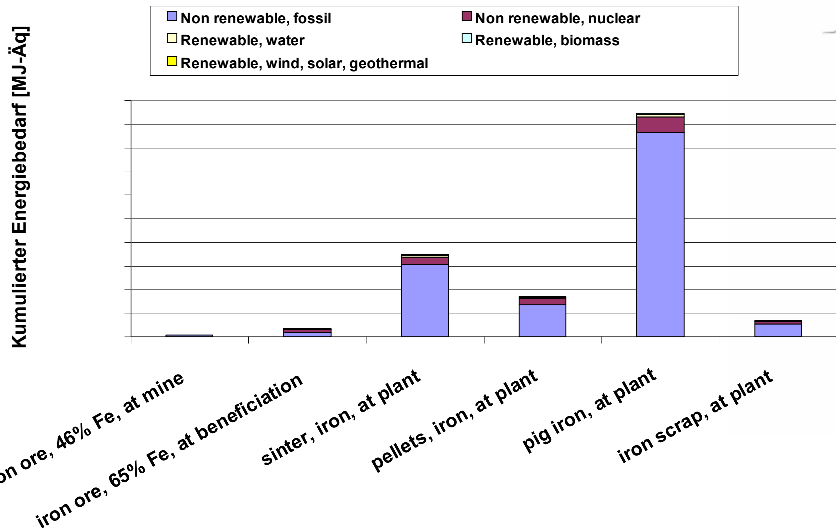
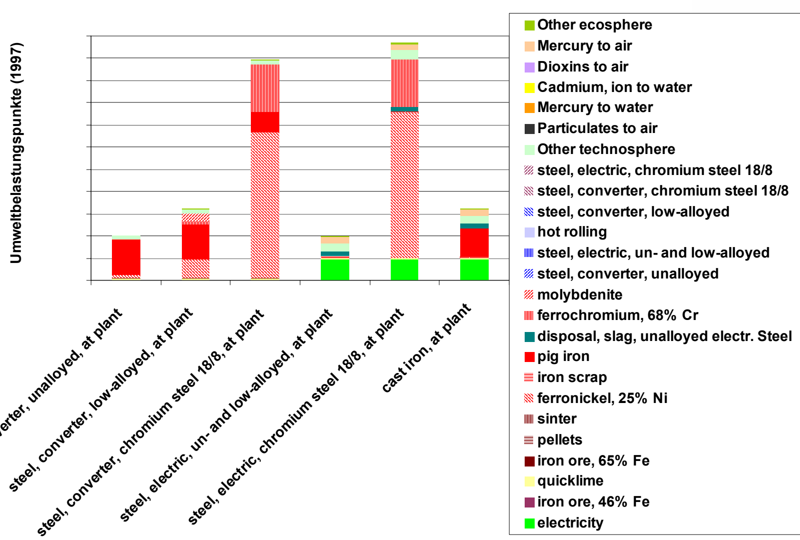
CED



ecological scarcity points



ecoindicator 99 H,A

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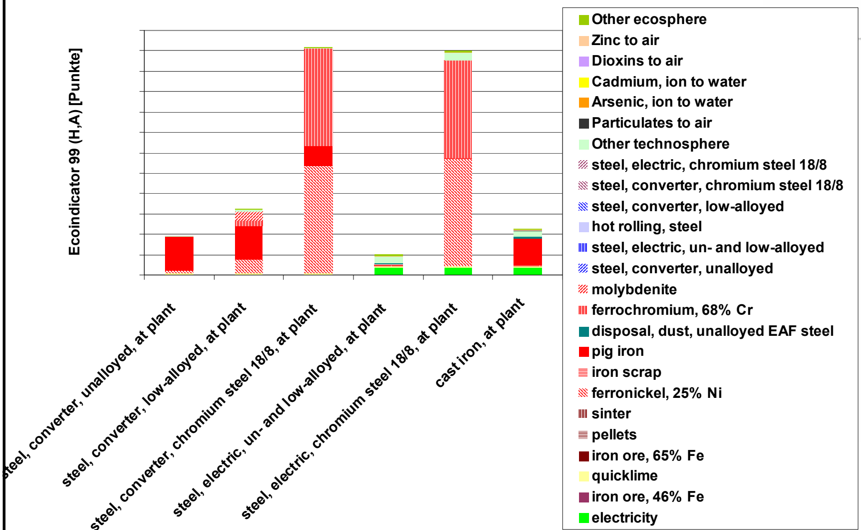

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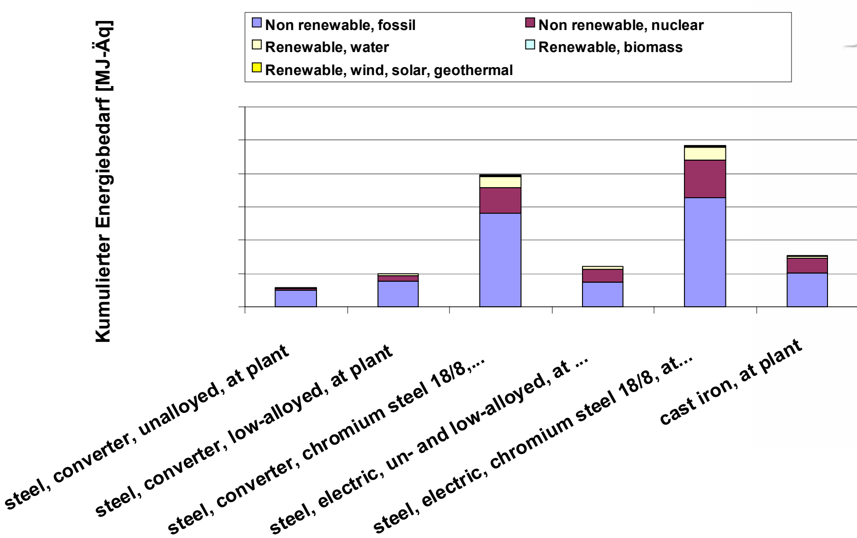

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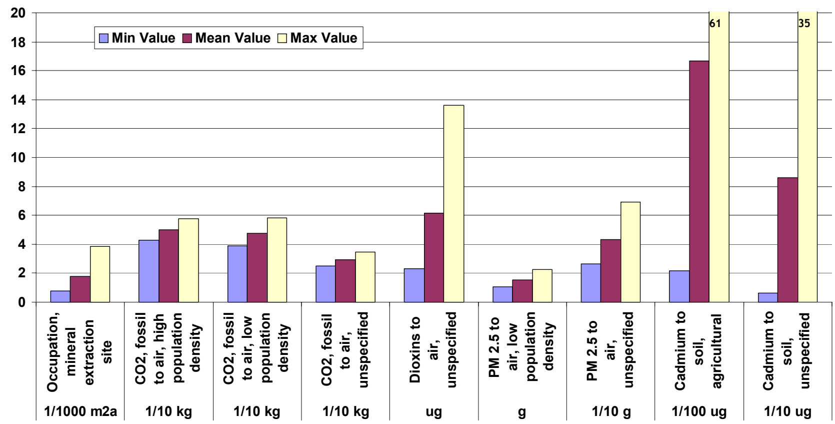
uncertainties



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conclusion

- direct emissions (other then CO_2) are rather relevant
- Contributions of alloying elements are relevant → specific alloys should be inventoried
- Uncertainties (not errors) are large

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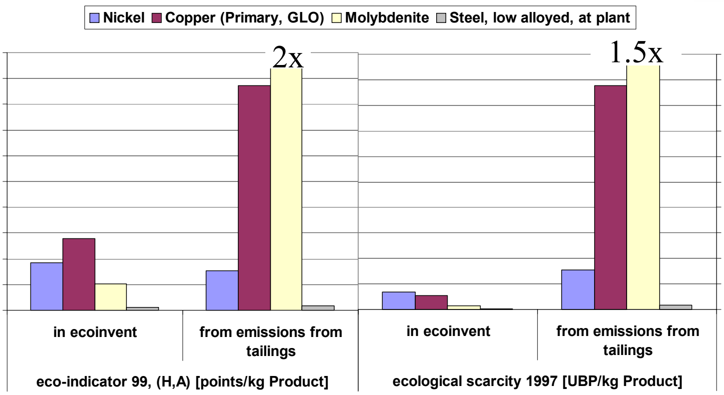
future steps: tailings

1% Mo in steel → UBP of steel raise to 890%
→ ei 99 (H,A) of steel raise to 370%



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