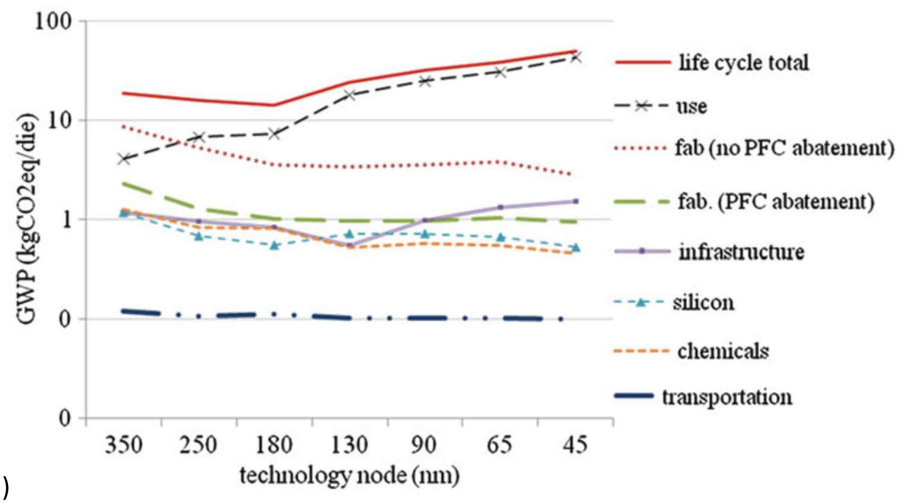
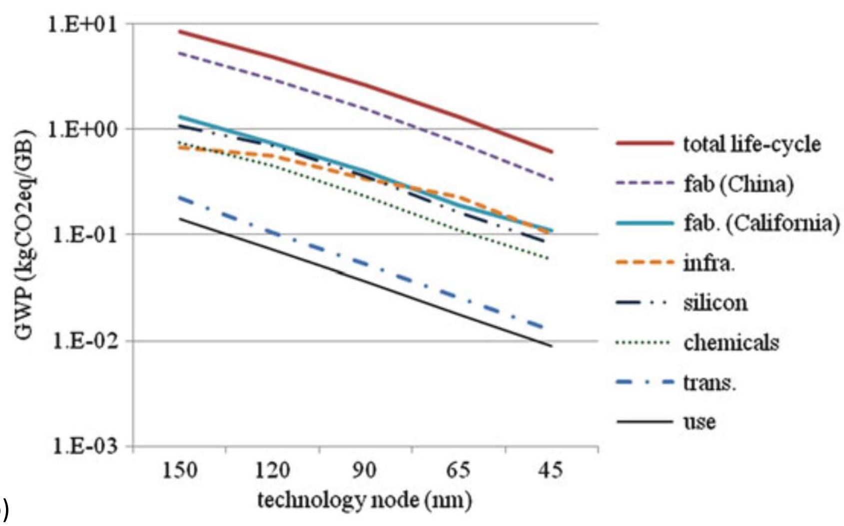
Final exam ELEC-E8714 Sustainable electronics Wednesday 2.12.2020 at 14:00 – 16:30

1. Figure 1 presents Global Warming Potential and its development with the technology node a) for a large (about 140 mm^2) logic die and b) per gigabyte (GB) flash memory capacity. The functional unit is for a) one die over a lifetime of 6,000 h b) one GB memory over a typical lifetime of 100,000 cycles. End-of-life is excluded from the results.
   - What kind of conclusions can you make of the different contributions to the GWP of these components and their development with technology node reductions? Explain the large relative contribution differences in life cycle phases between a) and b) (4 p.)
   - Think back to your inventory data exercise in the 2nd LCA case smartwatch. What kind of issues do you see in the component model selection using an advanced LCA software such as GaBi and what size of an error can be caused in the final GWP results of a small electronic device such as a smartwatch? (2 p.)



a)



b)

Figure 1. GWP by life-cycle stage per a) logic die b) gigabyte (GB) flash memory capacity

2. Table I presents GWP values for three different EEE products. The impacts are presented per one piece of product used for a certain time. Study the data and answer the following – separately for all A, B and C.
    - Give an example of an electrical and electronic equipment which matches the profile – indicating also your estimation for the lifetime of the device. Provide **reasoning** for your selection/estimation. (3 p.)
    - What seems to be the EoL scenario in each case (A, B and C)? (1 p.)
    - Name realistic measures for each of the three example products you proposed to reduce the GHG emissions by 50% from the original value (2 p.)

Table I. GWP for three EEE products A, B and C

	Product A			Product B			Product C		
	Manufacturing	Use	EoL	Manufacturing	Use	EoL	Manufacturing	Use	EoL
Global Warming Potential (GWP 100 years) [kg CO2 eq.]	9,18	1,76	0,04	179,5	524,14	-1,2	61,55	50,78	-4,52

3. A populated printed circuit board (PCB) of an EEE consists of a non-conducting laminate substrate (typically glass fiber reinforced epoxy resin), conducting Cu traces and vias, components attached to the substrate and connectors. Metals in PCBs can include Cu, Fe, Al, Sn, Ta, Ga, In, Au, Ag, Pd, Cr, Pb, Be, Hg, Cd, Zn and Ni. Explain the recycling process flow for a PCB (in developed countries) starting from a WEEE collection and ending to metal refining, and state which materials in the PCB can be recovered as of today. Mention also a few impactful changes in EEE design or recycling processes needed to achieve more effective WEEE recycling. (6 p.)

4. In silver electrorefining impure anodes containing mainly copper and gold as impurities are treated in a silver nitrate – nitric acid electrolyte. The electrolytic cell is a bit different from traditional copper refining as the anodes are held in so-called anode bags to collect the solid impurities (sludge) and the deposited silver does not form a coherent cathode but easily detachable silver crystals. An example of the cell construction is the so-called Moebius cell.

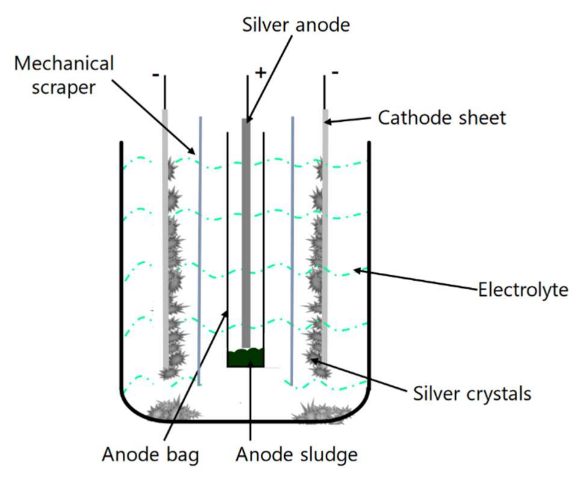


Figure 2. Moebius cell

Operating parameters such as silver nitrate ($AgNO_3$) concentration, current density or electrolyte temperature are set in a way that the less noble metals (e.g. Cu, Pb) will stay dissolved in the electrolyte. The more noble metals (e.g. Au, Pd, Pt) will not dissolve and pass into the anode sludge.

The anode sludge is collected in anode bags around the dissolving anode. Under optimal conditions, only fine silver (purity >99.9%) will deposit on the cathode.

A small electrolysis cell is used to refine impure silver anodes. An anode weighs 15 kg and its composition is 98% Ag, 1% Cu, 0.5% Au and 0.5% Pd. The amount of anode sludge is 1.2 kg and it contains all the Au and Pd from the anode and remaining material in the sludge is detached solid silver particles. Rest of the anode material dissolves in the electrolyte. The mass of deposited and collected silver crystals is 13.8 kg.

Assuming that the cell is operated for four days using total current of 37 A, what is the anodic and cathodic current efficiency for silver? (6 p.)

M (Ag) = 107.87 g/mol, z (Ag) = 1, ρ (Ag) = 10.49 g/cm^3, F = 96485 As/mol