IEooc_Methods2_Exercise 2: Material Cycle, Recycling, Sensitivity Analysis, Error Propagation, Elasticities

Goal: *System insight into material cycles and recycling systems using the example of beverage cans in Germany. Conduct a sensitivity analysis, error propagation and calculation of result elasticities.*

In 2014, about 1.9 billion beverage cans were sold in Germany (source: Verband der Getränkedosenhersteller (BCME)). Beverage cans are made from either aluminum or tin; for this exercise we assume that all beverage cans are made from aluminum, have a capacity of 0.5 l, and weigh 16 g. It is estimated that after the introduction of can deposits (compulsory deposits for beverage containers), 96 % of all cans are returned and follow proper recycling channels. Before the introduction of can deposits, the share of cans returned was probably only around 25 %. About 95 % of the aluminum contained in the cans is reclaimed as scrap during the material recovery process and re-melted to produce new beverage cans. However, since the true quantity recovered is uncertain, an error analysis with a value of 95 ± 3 % must be conducted. During the remelting process of the drinking can scrap to produce cast bars as well as the rolling of the bars into thin metal sheets, about 3 ± 2 % of the aluminum is lost due to oxidation processes. During the stamping process of the metal sheets to produce cans, 10 % of the aluminum inputs remains as trimming waste, which is then collected and returned to the remelting process. Figure 1 below shows a typical system definition of the material cycle. The flows that are actually part of the material cycle are shown in bold. It is assumed that the all secondary aluminum is returned to the can production process. (The beverage can recycling system actually is one of only few closed loop recycling systems.)

Exercises:

1) How big are the four model parameters α-δ? What error intervals or alternative values are assigned to the four parameters?
2) Can the system be completely quantified using only the given parameters? Give an explanation why or why not!
3) Derive an analytical solution for the system from fig. 1 for Germany in 2014!
4) What is the total loss of aluminum V in the Germany 2014 system ($V = \Delta S_U + \Delta S_L$)?
5) How big is the ratio between total loss and total quantity of aluminum in beverage cans (total rate of loss r)? ($r := \frac{V}{c} = \frac{\Delta S_U + \Delta S_L}{c}$)
6) What is the share of secondary aluminum in sold beverage cans (recycled content)? Is this a realistic result and why or why not?
7) What is the difference between sensitivity analysis, error propagation, and the calculation of elasticities?

8) Conduct a sensitivity analysis: first for the total loss of Al and then for the share of secondary aluminum in the sold beverage cans! Consider two parameter changes: first the historical parameter value β and second a potential increase of sold beverage cans by 50 %.

9) Conduct an error propagation (maximal error) for the total loss V regarding parameters γ and δ! Interpret the results! Is the calculation method actually applicable for γ and δ?

10) Calculate the point elasticity for the total loss ($\Delta S_U + \Delta S_L$) in Germany 2014 regarding the four parameters α-δ and the quantity of sold cans! Interpret the results!

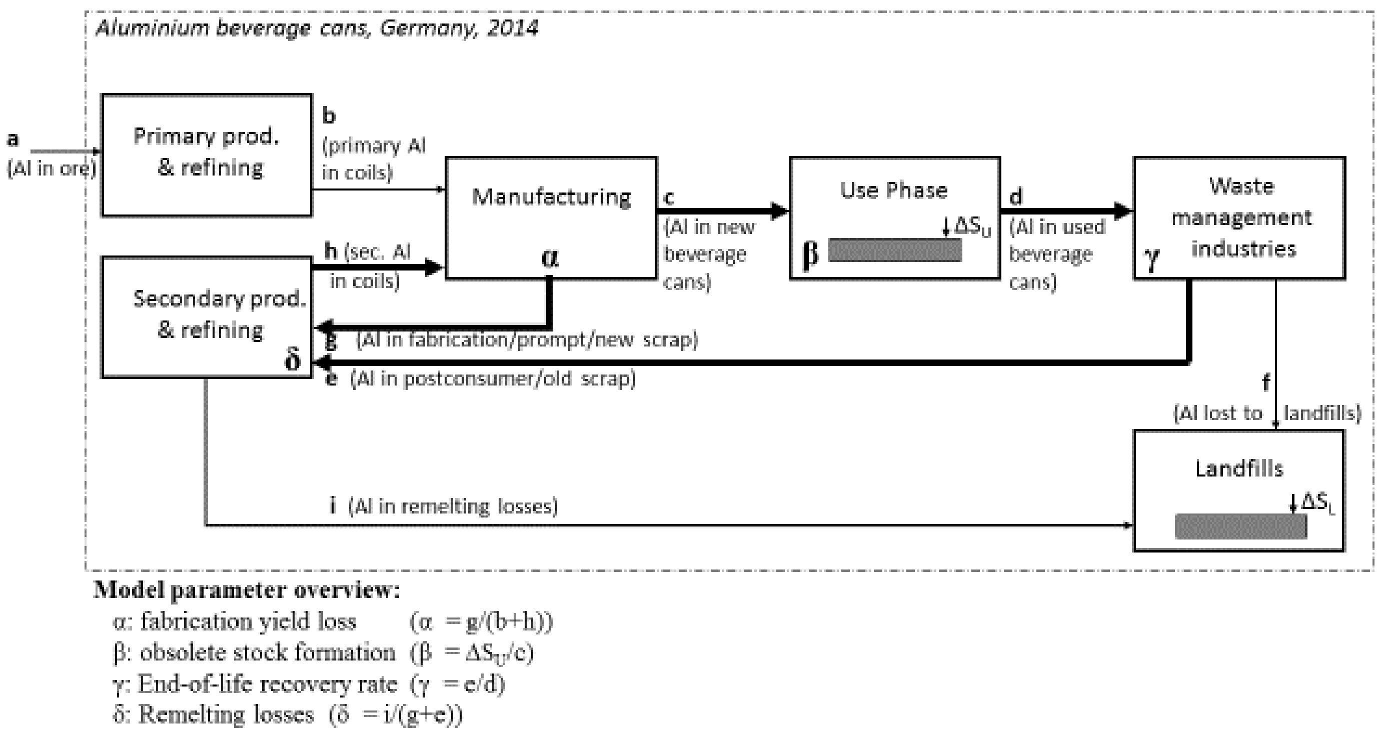

Figure 1: General system definition of the material cycle. Loss during use (ΔS_U) and in landfills (ΔS_L) are balanced through adjustments to the quantity of inflow of ore and other resources (a).