ENV-501 Material and Energy Flow Analysis
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Name: _____
Sciper: _____

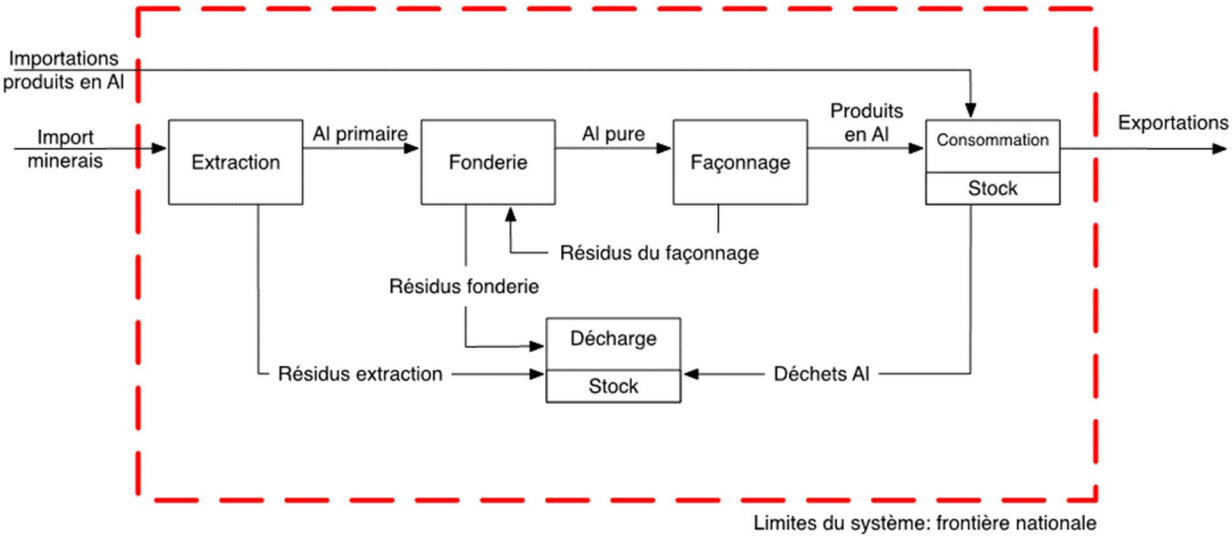
Intermediate Exam
Thursday, 23 November 2023

Duration 8:15 to 10:15

Part 1: Material Flow Analysis (30 points)

Following new regulations, Switzerland is seeking to assess the benefits of having aluminum recycling facilities on its territory, to meet its internal demand. To assess the benefits of recycling, you start from an initial scenario with no recycling of used aluminum within the limits of your system. Used aluminum from consumption is exported, representing 67% of the Export flow. A flow model of the aluminum production/consumption chain is proposed below (Figure 1).

Figure 1: Aluminum (Al) flow model



		Turnover	Stock growth	Stock
		kg/hab/an	kg/hab/an	kg/hab
Import minerais	Import minerals	16.5		
Al primaire	Al primary	16		
Al pure	Al pur	23		
Produits en Al	Al products	15		
Exportations	Exports	12		
Résidus extraction	Extraction residues	0.5		
Résidus fonderie	Foundry residues	1		
Résidus du façonnage	Shaping residues	8		
Déchets Al	Al waste	2		
Consommation	Consumption		+ 16	800
Décharge	Landfill		80	+ 3.5

Questions

1. Describe mathematically the system illustrated in Figure 1, i.e. the system equations for the stocks and the equations for the flows (do not solve). List the chosen parameters and describe them briefly **(8 points).**

2. Implement an internal recycling loop by introducing a recycled used aluminum flow from the consumption process into the foundry process.

   a) Describe mathematically the equation for the new consumption stock **(2 points).**

   b) Describe mathematically the transfer coefficient of the recycled used aluminum flow. In addition, describe mathematically the relationship between this transfer coefficient and the export **(5 points).**

   c) Describe the relationship between the transfer coefficient of the recycled used aluminum flow and the mineral import input flow in the case where consumption remains constant. What is the percentage reduction in imports with a recycling rate of 87% **(6 points)?**

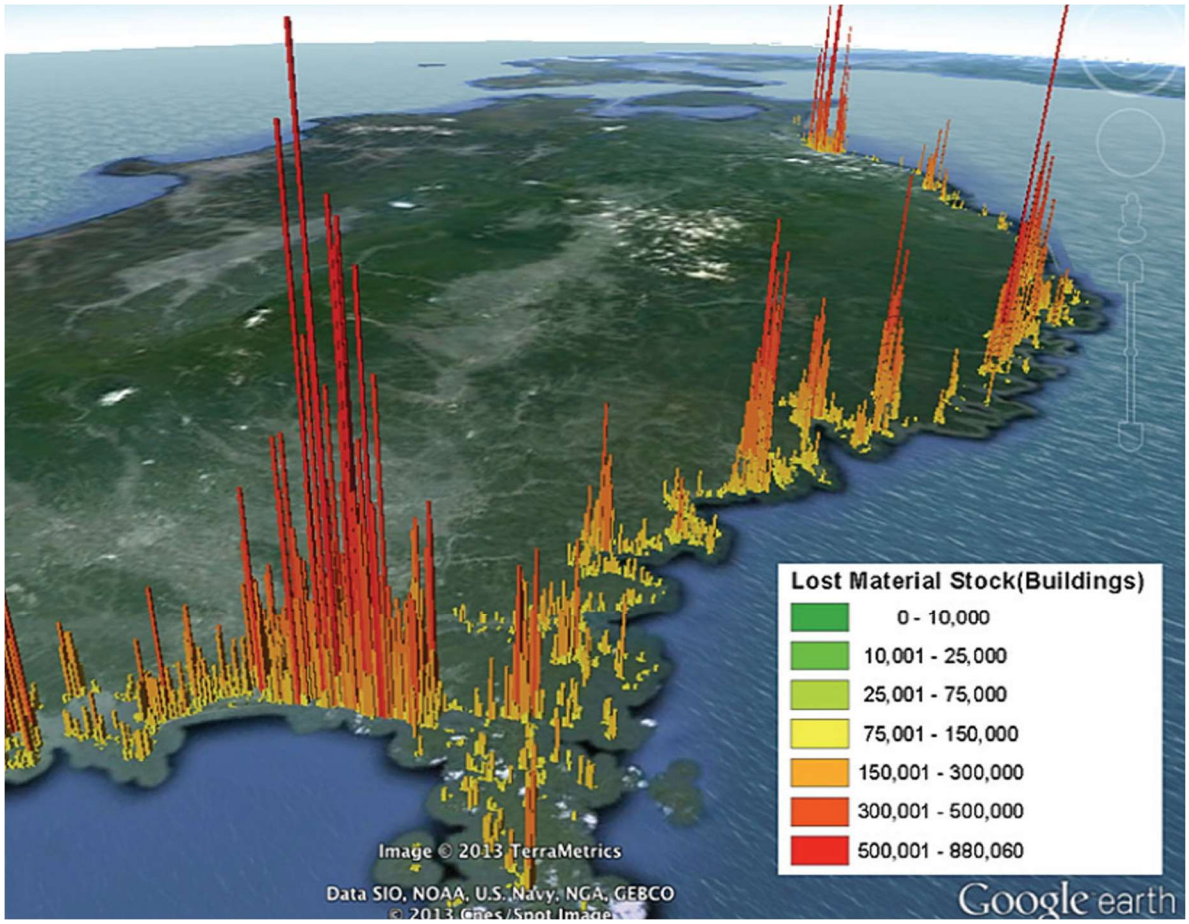
3. The recycling rate will gradually increase to 95%. How would you account for its evolution over time? Propose a simplified equation to do so **(9 points).**

Part 2: Spatial Material Flow Analysis (10 points)

Spatial analysis of material flows and stocks can greatly improve resource management, in particular reuse and recycling. This part is inspired by the work of Tanikawa et al. 2014. Figure 2 below represents the lost material stock of buildings in Sanriku and Ishinomaki due to the Great East Japan Earthquake in 2011, in tons (TerraMetrics 2013; map Data SIO, NOAA, U.S. Navy, NGA, GEBCO, and Cnes/Spot Image 2013). Buildings on the east coast of Japan included wooden houses, up to three story building structures made of steel and reinforced concrete buildings.

Based on the results shown in Figure 2, briefly explain how you would split the lost material stock between wood, steel and aggregates **(7 points)**. State one advantage and one disadvantage of your approach **(3 points)**.

Figure 2: Lost material stock of buildings in Sanriku and Ishinomaki (tons)



Part 3: Input Output Analysis (20 points)

Financial services represent an important part of economic activities in Switzerland. In monetary terms, approximately 5% of gross domestic product is the result of financial activities, excluding but equivalent to insurances. The environmental impact of such activities in Switzerland remains small, but much of the funding remains dedicated to extractive industries, fossil fuels, metallic and non-metallic minerals. This is much talked about, thanks to citizens and associations holding private banks as well as the national bank accountable. The value added of financial services means jobs in the sector are well paid, and much of these high wages are spent on luxury cars and air travel. In fact, recent research has shown that if the impact generated by employees and their lifestyles were factored in the impact of each economic activity, banking would be just as damaging as extractive industries.

Your task is to estimate the impact of fossil fuel consumption and emissions from transportation associated with financial activities. The direct consumption of fuels corresponds to approximately 250'000 and 6 million tons of CO_2 emissions per year as a result of financial and transport activities, respectively. Households, which represent the largest share of final consumption, spend approximately 8 billion swiss francs (CHF) on financial services and 9.4 billion in transportation.

A quick look at economic input output data allows you to establish the links between both activities, financial services and transportation, summarized in the table below, in million CHF.

	Financial services	Transport	Output
Financial services	16'300	600	70'000
Transport	110	420	30'000

When Matrix A = $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$

$$A^{-1} = \frac{1}{ad - bc}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

Questions

1. Considering the interactions between both financial services and transport, estimate the CO_2 emissions from the transport sector induced by the final consumption of financial services from Swiss households **(12 points)**

2. Are your results over- or underestimating the actual emissions? Briefly explain why and how you would improve your estimate **(8 points)**

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Answer sheet

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Answer sheet

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Answer sheet