Exercise Session 7 – MFA in matrix form

ENV–501 Material and Energy Flow Analysis

October 31, 2019

Exercise 1: Wood management in Switzerland

This exercise investigates the use of wood for construction and energy purposes. Two types of wood are harvested in Switzerland: logs for lumber and wood for energy. The first one is used in buildings whereas the second is for space heating. Roundwood logs are transported to sawmills in order to be transformed into construction materials. The wastes generated by sawmills are recycled, as well as the secondary wood materials collected in buildings during demolition. The recycling process produces additional wood for heating. The system boundaries do not include the stock accumulating in buildings, therefore it will be considered as an output. In 2010, a total of 5'500'000 m^3 of wood were harvested and two scenarios should be considered, (a) 30% of the harvest is used for heating, (b) 70% of the harvest is used for heating. In both scenarios, the remaining fraction of wood harvested is used for construction materials.

Available data:

The transfer coefficients are the following:

	Sawmill	Recycling	Heating	Construction	Outputs
Sawmill		0.4		0.6	
Recycling			1		
Heating					1
Construction		0.5			0.5
Roundwood harvest (input)	1				
Energy wood harvest (input)			1		

Questions:

1. Draw the flow diagram of the system for wood management in Switzerland in 2010 using the above description. Calculate the output quantities for the two scenarios.
2. This question has two parts to evaluate the impact of the energy transition, which essentially has two objectives: decarbonizing energy consumption by promoting the use of renewables and increasing energy efficiency in buildings (as well as in industry and transportation).
    a. If the energy demand for heating from wood combustion increased by 20%, what would be the impact on outputs for both scenarios?
    b. The demolition rate increases to allow the construction of energy efficient buildings. What if the transfer coefficient to recycling increases to 0.7 instead of 0.5? What would be the outputs then?

Exercise 2: Alternative fuels in cement factories

Cement factories play an increasingly important role in waste management. They rely more and more on alternative fuels for their rotating kilns (ovens at temperatures of ~1500 ^{o}C) which replace coal and other primary fuels. Alternative fuels include tires, sludge, meat or hazardous wastes. The goal of this exercise is to investigate the impact of such shift in fuel sources on mercury (Hg) emissions.

Questions:

1. Draw a flow diagram and describe the system in matrix form based on the data given below (Inputs I_i, Flows A_{ij}).
2. Calculate the concentration of mercury in exhaust gases and cement (Outputs O_j).
3. Assume that all the primary fuels are replaced with alternative fuels. What are the new mercury concentrations? The heat capacity of primary fuels is 35 MJ/kg and that of alternative fuels 21 MJ/kg.

A_{ij} O_j	Flows	Mass (t/y)	Hg (g/y)	I_i	Inputs	Mass (t/y)	Hg (g/y)
A_{12}	Grinded raw materials	1,260,000	434,000	I_1	Raw materials	821,000	60,000
A_{23}	Exhaust gas	772,200	116,000	I_3	Air in active coke filter	436,000	0
A_{24}	Homogenized raw materials	790,000	497,000	I_3	Coke for coke filter	2,120	100
A_{25}	Filter ashes	11,800	88,000	I_4	Primary fuels	42,900	10,500
A_{34}	Used active coke	2,120	114,000	I_4	Alternative fuels	23,980	19,500
A_{41}	Combustion gases	439,000	374,000	I_4	Air in rotary kiln	62,000	0
A_{42}	Combustion gases	314,000	267,000	I_5	Air in mill	373,000	0
A_{45}	Clinker	512,000	0	I_5	Additives	54,971	2,500
A_{54}	Ashed air	344,000	0				
O_3	Exhaust gases	1,208,200	?				
O_5	Cement	607,771	?				