# 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 m3 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).
   1. If the energy demand for heating from wood combustion increased by 20%, what would be the impact on outputs for both scenarios?
   2. 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 ⁰C) 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 Ii, Flows Aij).
2. Calculate the concentration of mercury in exhaust gases and cement (Outputs Oj).
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.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Aij Oj | Flows | Mass (t/y) | Hg (g/y) | Ii | Inputs | Mass (t/y) | Hg (g/y) |
| A12 | Grinded raw materials | 1,260,000 | 434,000 | I1 | Raw materials | 821,000 | 60,000 |
| A23 | Exhaust gas | 772,200 | 116,000 | I3 | Air in active coke filter | 436,000 | 0 |
| A24 | Homogenized raw materials | 790,000 | 497,000 | I3 | Coke for coke filter | 2,120 | 100 |
| A25 | Filter ashes | 11,800 | 88,000 | I4 | Primary fuels | 42,900 | 10,500 |
| A34 | Used active coke | 2,120 | 114,000 | I4 | Alternative fuels | 23,980 | 19,500 |
| A41 | Combustion gases | 439,000 | 374,000 | I4 | Air in rotary kiln | 62,000 | 0 |
| A42 | Combustion gases | 314,000 | 267,000 | I5 | Air in mill | 373,000 | 0 |
| A45 | Clinker | 512,000 | 0 | I5 | Additives | 54,971 | 2,500 |
| A54 | Ashed air | 344,000 | 0 |  |  |  |  |
| O3 | Exhaust gases | 1,208,200 | ? |  |  |  |  |
| O5 | Cement | 607,771 | ? |  |  |  |  |