Exercise session 2

Week 3

https://moodle.epfl.ch/pluginfile.php/2713570/mod_resource/content/2/ExerciseW3_Q.pdf

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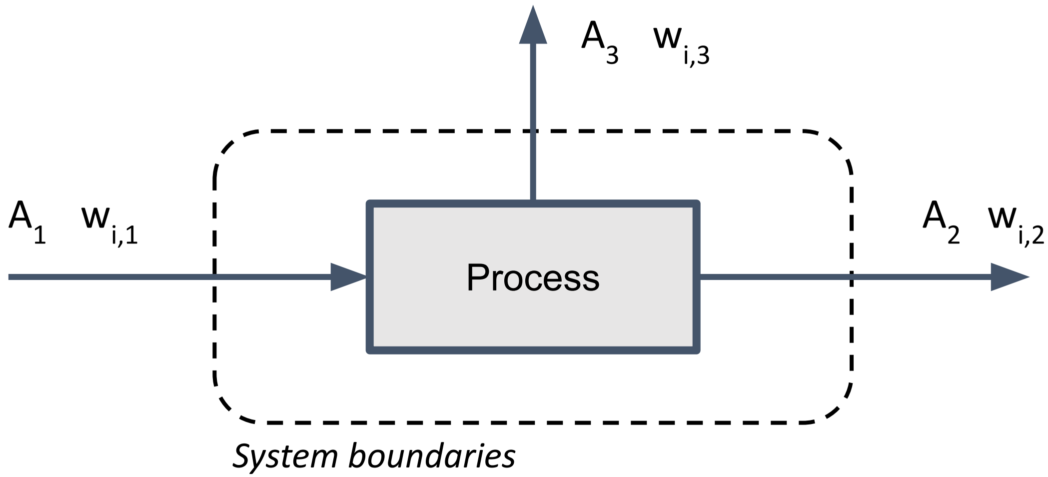
Exercise 1 — MSW separation

Municipal solid waste (MSW) is separated by a mechanical sorting plant into a combustible fraction (30%) and another fraction (70%) that is digested by a subsequent biochemical process. Approximately half of the latter fraction is transformed to biogas during the anaerobic treatment.

1. Draw the system as a quantitative flow chart.
2. The concentrations of Hg are: Municipal solid waste input – 1.5 mg/kg, combustible fraction – 1 mg/kg, biogas – 0.005 mg/kg, digestion product – 3.4 mg/kg. Calculate all mass flows and transfer coefficients for Hg.

Exercise 1 — Theory



$$A_{i,1} = A_1 * w_{i,1}$$

$$TC_{i,2} = \frac{A_2 * w_{i,2}}{A_1 * w_{i,1}} = \frac{A_{i,2}}{A_{i,1}}$$

A_i Mass flow

w Mass fraction

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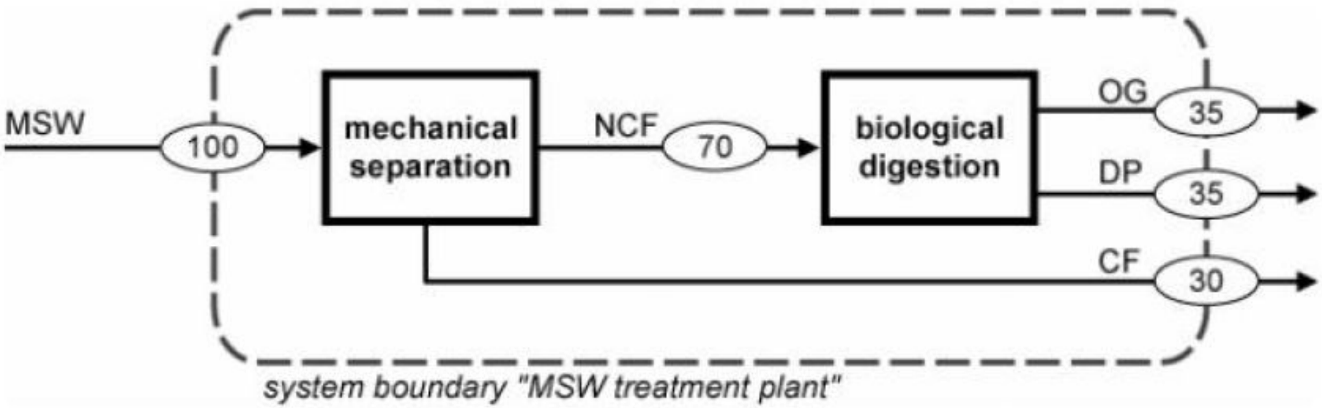
Exercise 1 — MSW separation

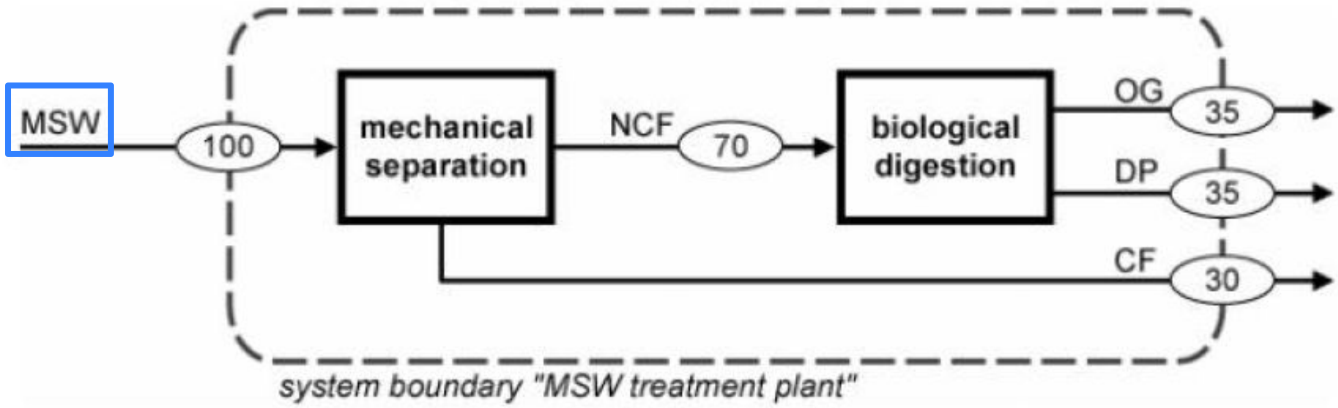
Municipal solid waste is separated by a mechanical sorting plant into a combustible fraction (30%) and another fraction (70%) that is digested by a subsequent biochemical process. Approximately half of the latter fraction is transformed to biogas during the anaerobic treatment.

1. Draw the system as a quantitative flow chart.



MSW – municipal solid waste, **NCF** – non–combustible fraction,
CF – combustible fraction, **DP** – digestion product, **OG** – off–gas (biogas)

Exercise 1 — MSW separation



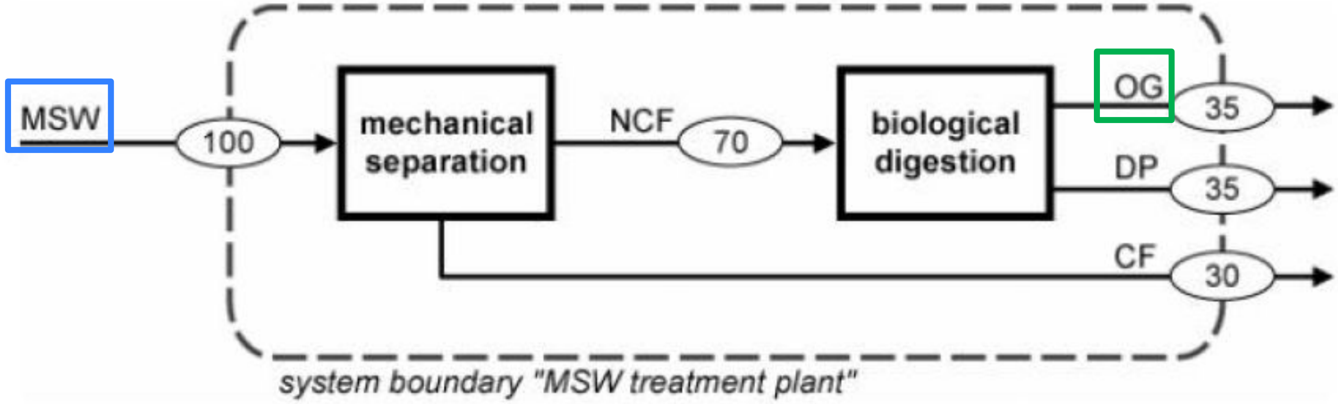
2. Calculate all mass flows and transfer coefficients for Hg.

$$\text{Hg in MSW} = \text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW} = 1.5\ \text{mg/kg} \cdot 100\ \text{kg} = 150\ \text{mg}$$

Calculating mass flows:

Assuming initial mass of 100kg

Exercise 1 — MSW separation



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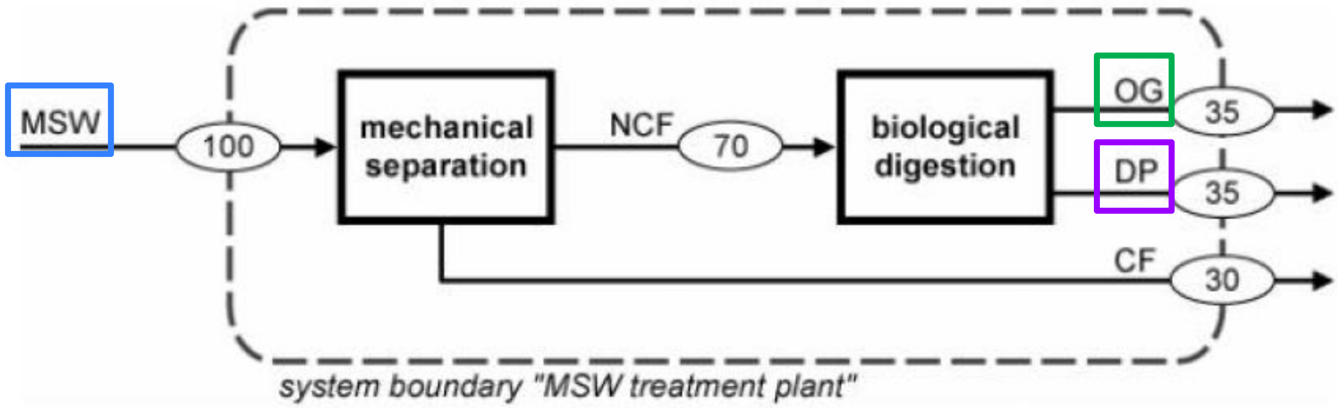
$$= 150 \text{ mg}$$

$$\text{Hg in OG} = \text{Hg concentration}_{\text{OG}} \times \text{Off–gas} = 0.005 \text{ mg/kg} \cdot 35 \text{ kg}$$
$$= 0.175 \text{ mg}$$

Exercise 1 — MSW separation



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$$\text{Hg in DP} = \text{Hg concentration}_{\text{DP}} \times \text{Digestion product} = 3.4\ \text{mg/kg} \cdot 35\ \text{kg} = 119\ \text{mg}$$

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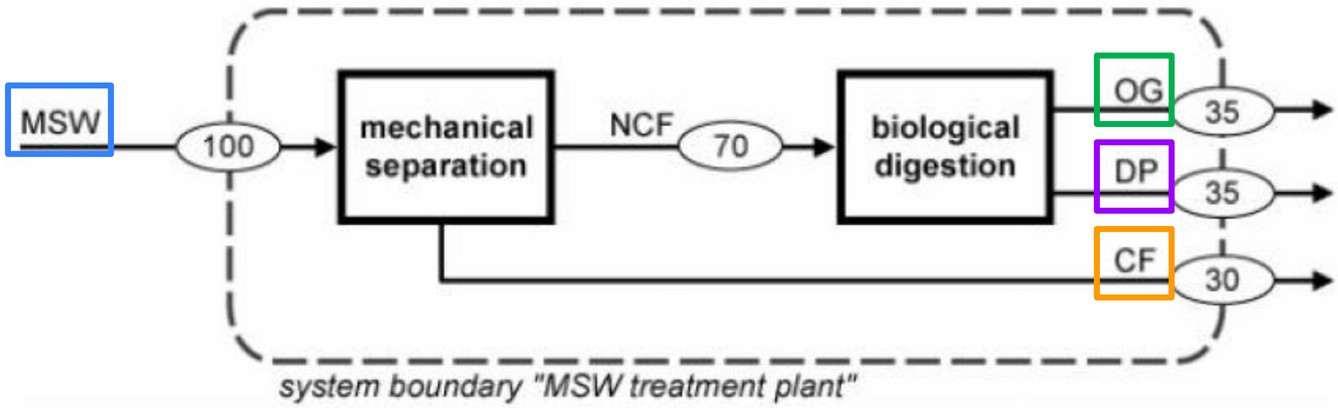
Exercise 1 — MSW separation



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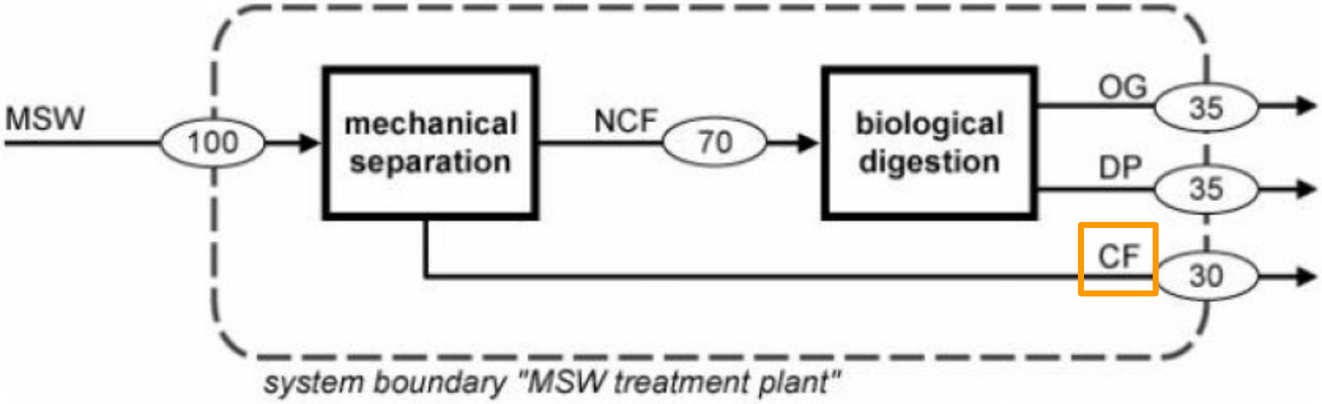
$$\text{Hg in DP} = \text{Hg concentration}_{\text{DP}} \times \text{Digestion product} = 3.4\ \text{mg/kg} \cdot 35\ \text{kg} = 119\ \text{mg}$$

$$\text{Hg in CF} = \text{Hg concentration}_{\text{CF}} \times \text{Combustible fraction} = 1\ \text{mg/kg} \cdot 30\ \text{kg} = 30\ \text{mg}$$

Exercise 1 — MSW separation



2. Calculate all mass flows and transfer coefficients for Hg.

Calculating transfer coefficients (TC):

Assuming initial mass of 100kg

$$
\begin{aligned}
TC_{CF} &= \frac{\text{Hg concentration}_{\text{Combustible fraction}} \times \text{Combustible fraction}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} \\
&= \frac{1\ \text{mg/kg} \cdot 30\ \text{kg}}{1.5\ \text{mg/kg} \cdot 100\ \text{kg}} = 0.2
\end{aligned}
$$

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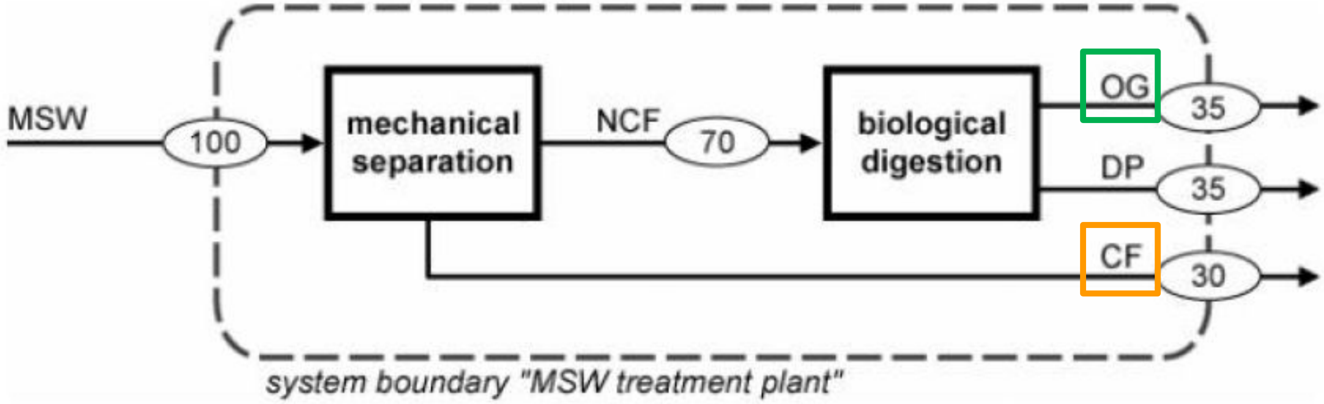
Exercise 1 — MSW separation



2. Calculate all mass flows and transfer coefficients for Hg.

Calculating transfer coefficients (TC):

Assuming initial mass of 100kg

$$TC_{CF} = \frac{\text{Hg concentration}_{\text{Combustible fraction}} \times \text{Combustible fraction}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} = \frac{1\ \text{mg/kg} \cdot 30\ \text{kg}}{1.5\ \text{mg/kg} \cdot 100\ \text{kg}} = 0.2$$

$$TC_{OG} = \frac{\text{Hg concentration}_{\text{Biogas}} \times \text{Off–gas}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} = \frac{0.005\ \text{mg/kg} \cdot 35\ \text{kg}}{1.5\ \text{mg/kg} \cdot 100\ \text{kg}} = 0.0012$$

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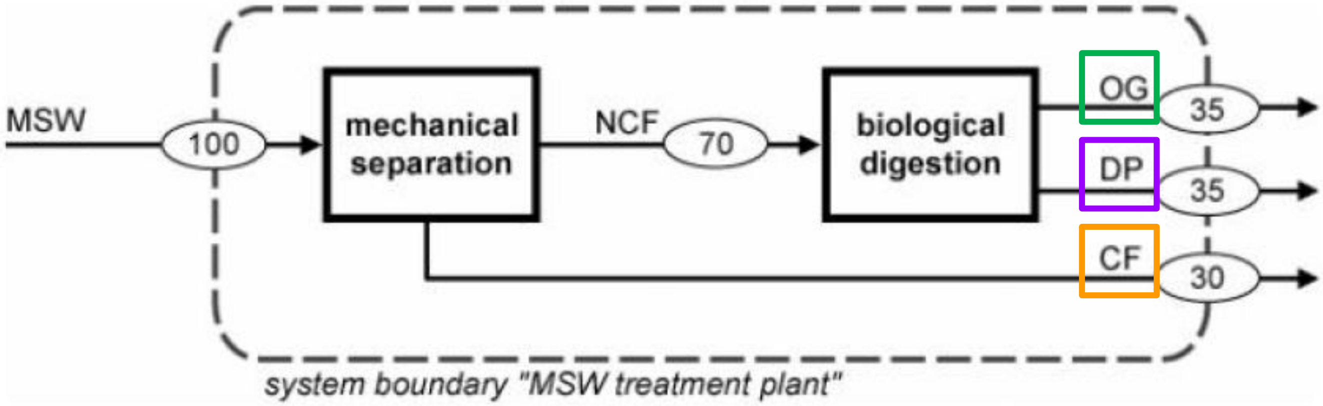
Exercise 1 — MSW separation



2. Calculate all mass flows and transfer coefficients for Hg.

Calculating transfer coefficients (TC):

Assuming initial mass of 100kg

$$TC_{CF} = \frac{\text{Hg concentration}_{\text{Combustible fraction}} \times \text{Combustible fraction}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} = \frac{1 \text{ mg/kg} \cdot 30 \text{ kg}}{1.5 \text{ mg/kg} \cdot 100 \text{ kg}} = 0.2$$

$$TC_{OG} = \frac{\text{Hg concentration}_{\text{Biogas}} \times \text{Off–gas}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} = \frac{0.005 \text{ mg/kg} \cdot 35 \text{ kg}}{1.5 \text{ mg/kg} \cdot 100 \text{ kg}} = 0.0012$$

$$TC_{DP} = \frac{\text{Hg concentration}_{\text{Digestion product}} \times \text{Digestion product}}{\text{Hg concentration}_{\text{MSW input}} \times \text{Total MSW}} = \frac{3.4 \text{ mg/kg} \cdot 35 \text{ kg}}{1.5 \text{ mg/kg} \cdot 100 \text{ kg}} = 0.79$$

Exercise 4 — Photovoltaic cell production

The production of photovoltaic cells can be represented in a simplified manner depicting only the two main processes; silicon wafer production and photocell production. The flow data for each of the processes are as follows:

Wafer production (for 1kg silicon wafers)	
Input	
Silicon [kg]	1
Energy [MJ/kg]	420
Output	
Silicon wafers [kg]	1

Photocell production (for 1m^2 photovoltaic cells)	
Input	
Energy [MJ/m^2]	13.6
Glass [kg]	10
Silicon wafers [kg]	1.6
Output	
Photovoltaic cells [m^2]	1

1. Perform a system analysis: establish the system diagram and derive the balance equations.
2. Develop the output equations considering each of the inputs, and calculate the amount of energy, silicon and glass needed to produce 1 m^2 of PV cells.

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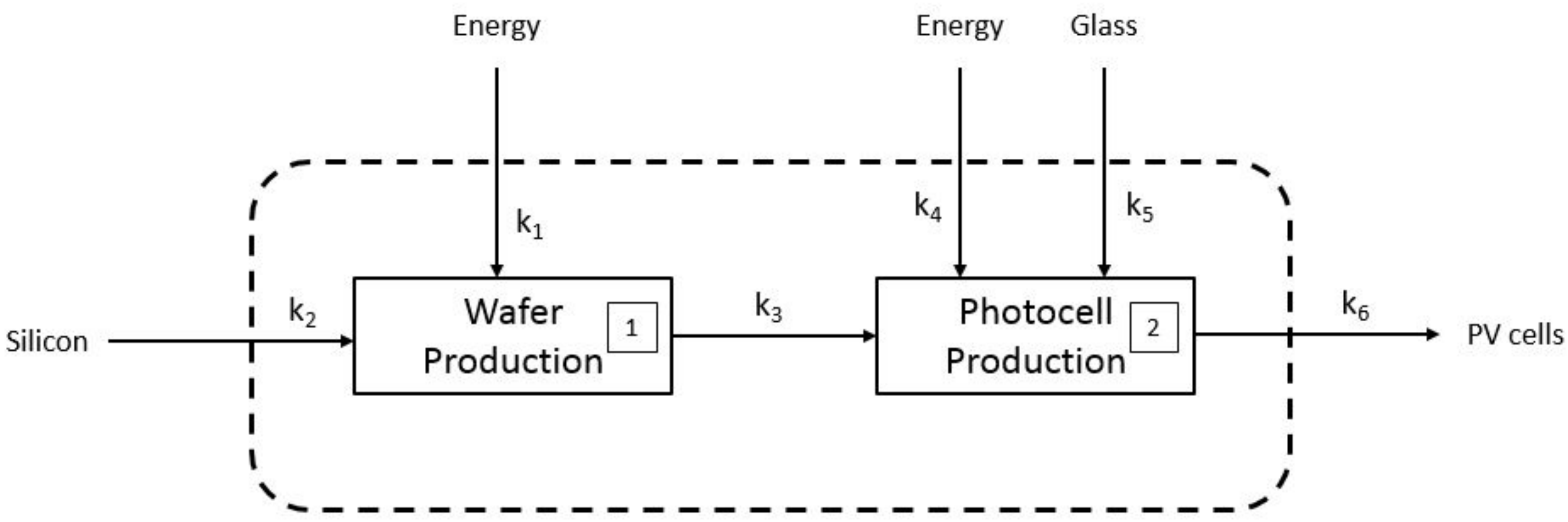
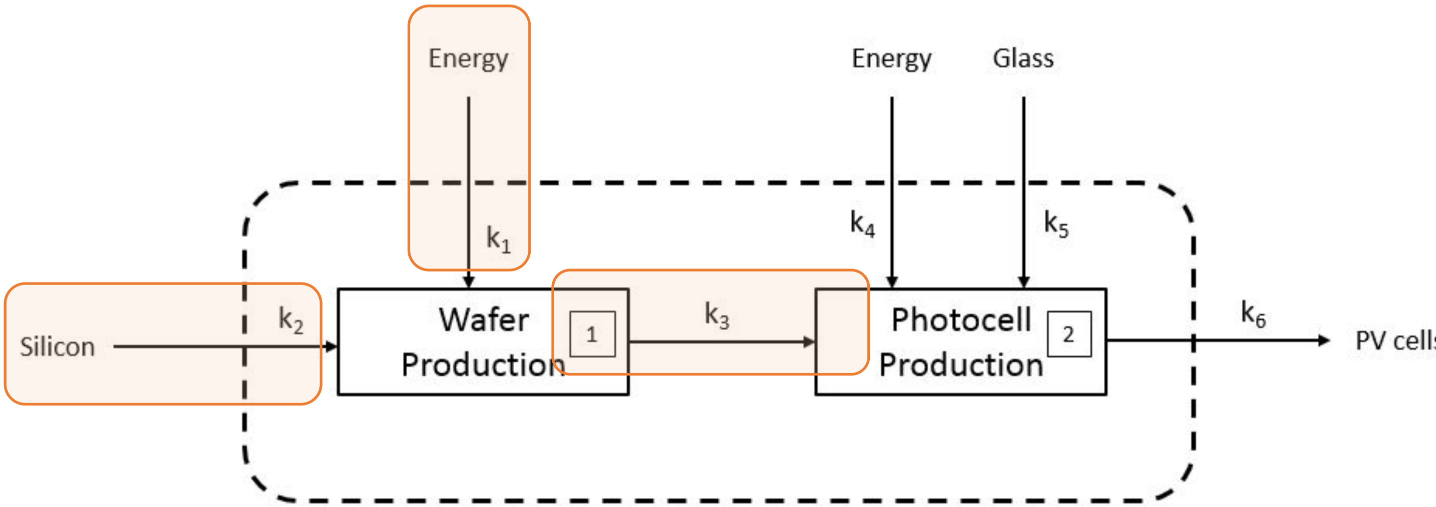
Exercise 4 — Photovoltaic cell production



Exercise 4 — Photovoltaic cell production

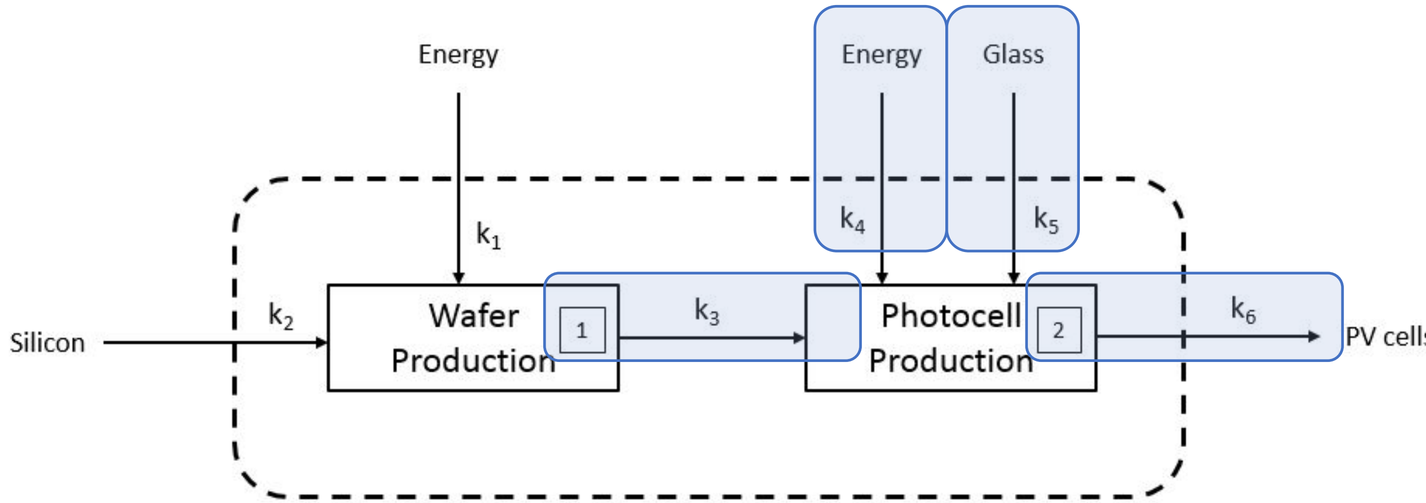


$$Input_{E1} \cdot k_1 + Input_{Si} \cdot k_2 = Output_1 \cdot k_3$$

Input
Output
} Material or energy unit

k material and/or energy ratio

Exercise 4 — Photovoltaic cell production



$$\mathrm{Input}_{E1}\cdot k_1 + \mathrm{Input}_{Si}\cdot k_2 = \mathrm{Output}_1\cdot k_3$$

$$\mathrm{Output}_1\cdot k_3 + \mathrm{Input}_{E2}\cdot k_4 + \mathrm{Input}_G\cdot k_5 = \mathrm{Output}_2\cdot k_6$$

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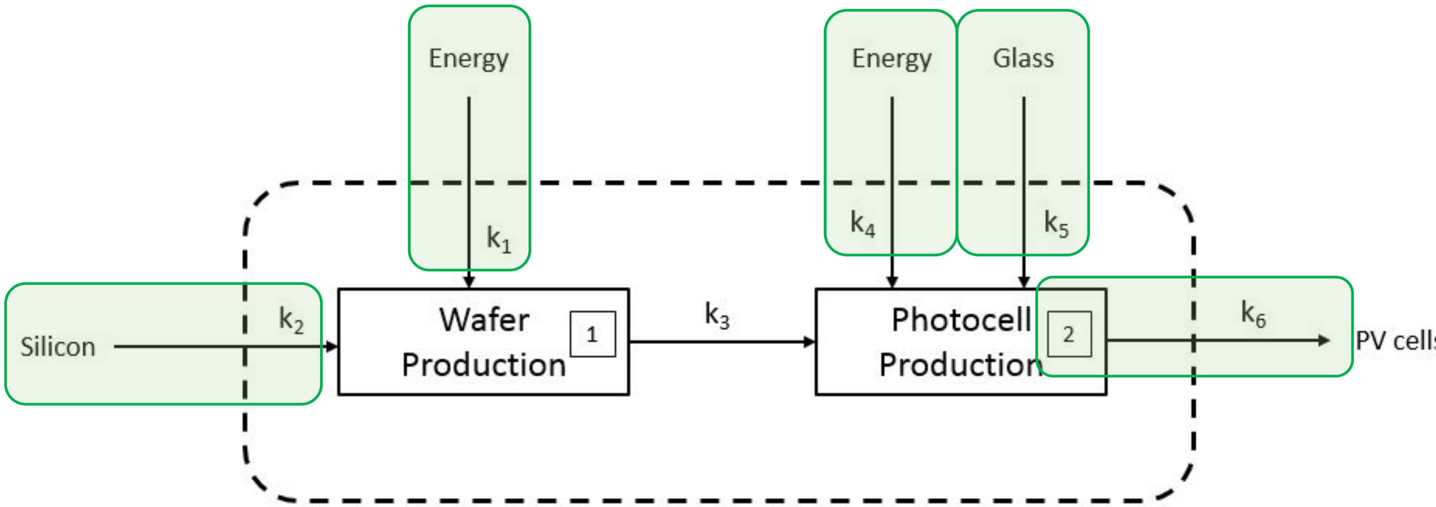
Input
Output } Material or energy unit

k material and/or energy ratio

Exercise 4 — Photovoltaic cell production



$$Input_{E1} \cdot k_1 + Input_{Si} \cdot k_2 = Output_1 \cdot k_3$$

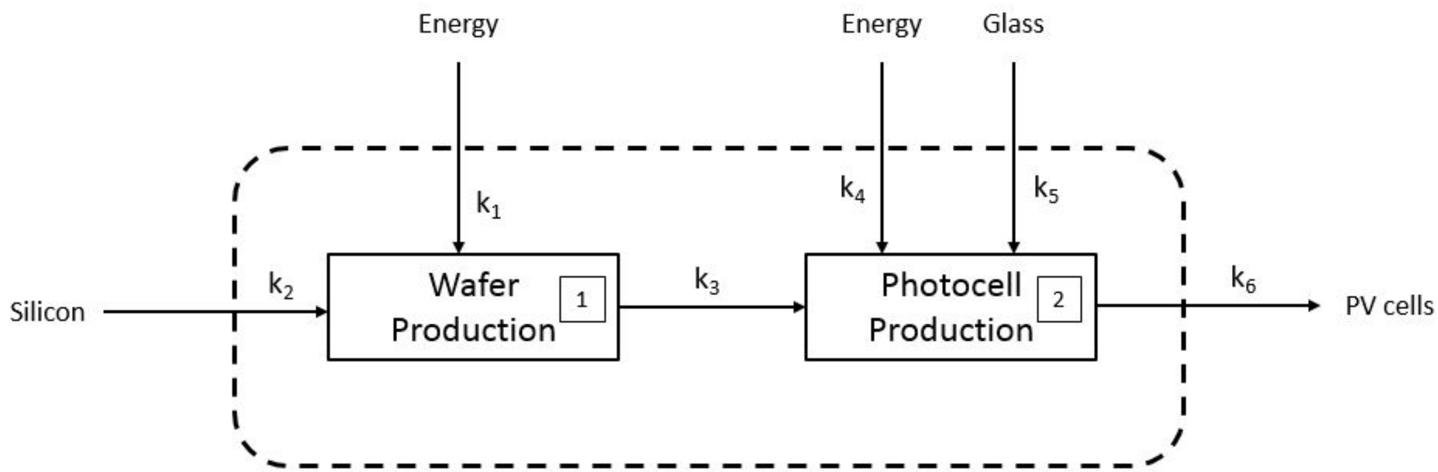
$$Output_1 \cdot k_3 + Input_{E2} \cdot k_4 + Input_G \cdot k_5 = Output_2 \cdot k_6$$

$$Input_{E1} \cdot k_1 + Input_{Si} \cdot k_2 + Input_{E2} \cdot k_4 + Input_G \cdot k_5 = Output_2 \cdot k_6$$

$\left.\begin{array}{l}\text{Input}\\\text{Output}\end{array}\right\}$ Material or energy unit

k material and/or energy ratio

Exercise 4 — Photovoltaic cell production



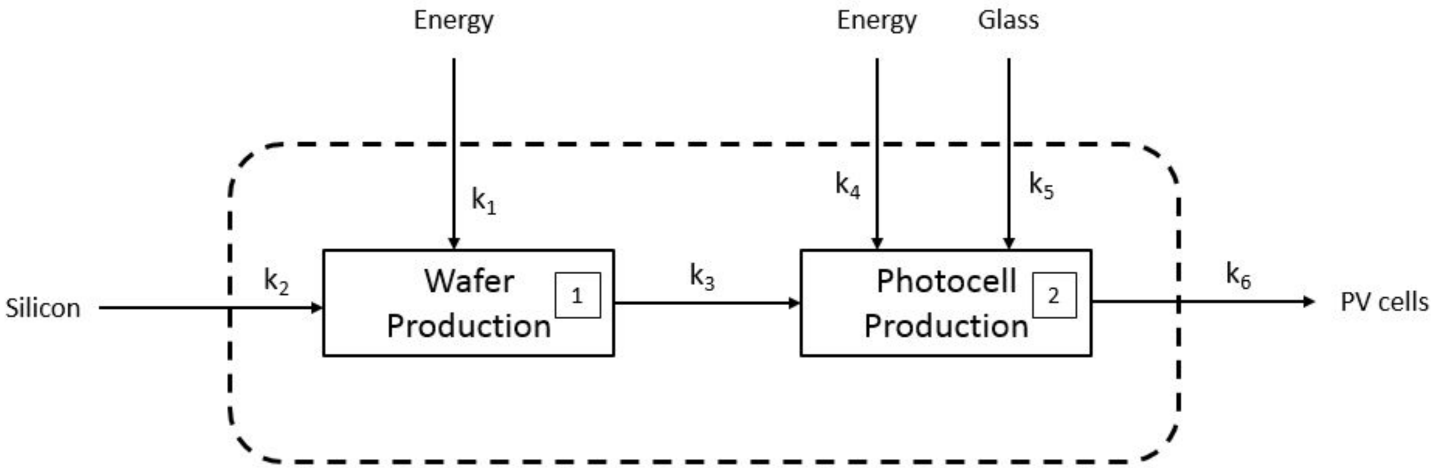
x kg Si-wafers = $k_2 \cdot x$ kg Si + $k_1 \cdot x$ MJ energy

x kg Si-wafers = $1 \cdot x$ kg Si + $420 \cdot x$ MJ energy

y m^2 PV cells = $k_3 \cdot y$ Si-wafers + $k_5 \cdot y$ kg glass + $k_4 \cdot y$ MJ energy

y m^2 PV cells = $1.6 \cdot y$ Si-wafers + $10 \cdot y$ kg glass + $13.6 \cdot y$ MJ energy

Exercise 4 — Photovoltaic cell production



Therefore, to produce 1 m^2 of PV cells, we need 1.6·1 kg Si, 10·1 kg glass, and (420·1.6 + 13.6·1) MJ energy.

→ **1.6 kg Si**, **10 kg glass**, and **685.6 MJ** energy is required.

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