Goal & scope + OpenLCA

LAB 2

LAB 2

3 parts:

- Goal and scope: hand dryers (synchronous)
- Carbonated water cans: alternative scenario (synchronous)
- Carbonated water cans: alternative scenario modeling in OpenLCA asynchronous)

Part 1: Goal and scope

EX 1

Context – Hand dryers

COMPARATIVE ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF HAND DRYING SYSTEMS:

The XLERATOR® Hand Dryer, Conventional Hand Dryers and Paper Towels

Compagy Excel Dryer, hand dryer XLERATOR :

- Produced and sold in the US.
- Designed for public spaces
- Excellent energy-efficiency

http://www.exceldryer.com/PressKit/Green.php

Step 1 : Goal & scope

Goal of the study :

- Show the environmental performances of the product
- Position the product compared to other alternatives:
  - Traditional hand dryer and paper towel
- Know the influence of several key parameters on the environmental performances
  - use intensity, electricity source, use of recycled material etc.

Question 1

1.1 Identify a shared function for the three products.

1.2 Are the three products functionally equivalent?

1.3 Define a functional unit to use to compare the three products.

1.4 Create cradle-to-grave process trees for the XLERATOR and the paper towel systems

1.5 Identify the aggregated (cradle-to-gate) and disaggregated (gate-to-gate) processes

1.6 Identify the reference flows associated with each of the three products.

1.7 Identify the key parameters you need to calculate the reference flows

Question 1

1.1 Identify a shared function for the three products.

Dry hands after washing

1.2 Are the three products functionally equivalent?

Yes, but….

There are non-equivalent secondary functions such as heat production, hands disinfection etc.

1.3 Define a functional unit to use to compare the three products.

Dry a pair of hands in a public bathroom in the US in 2022.

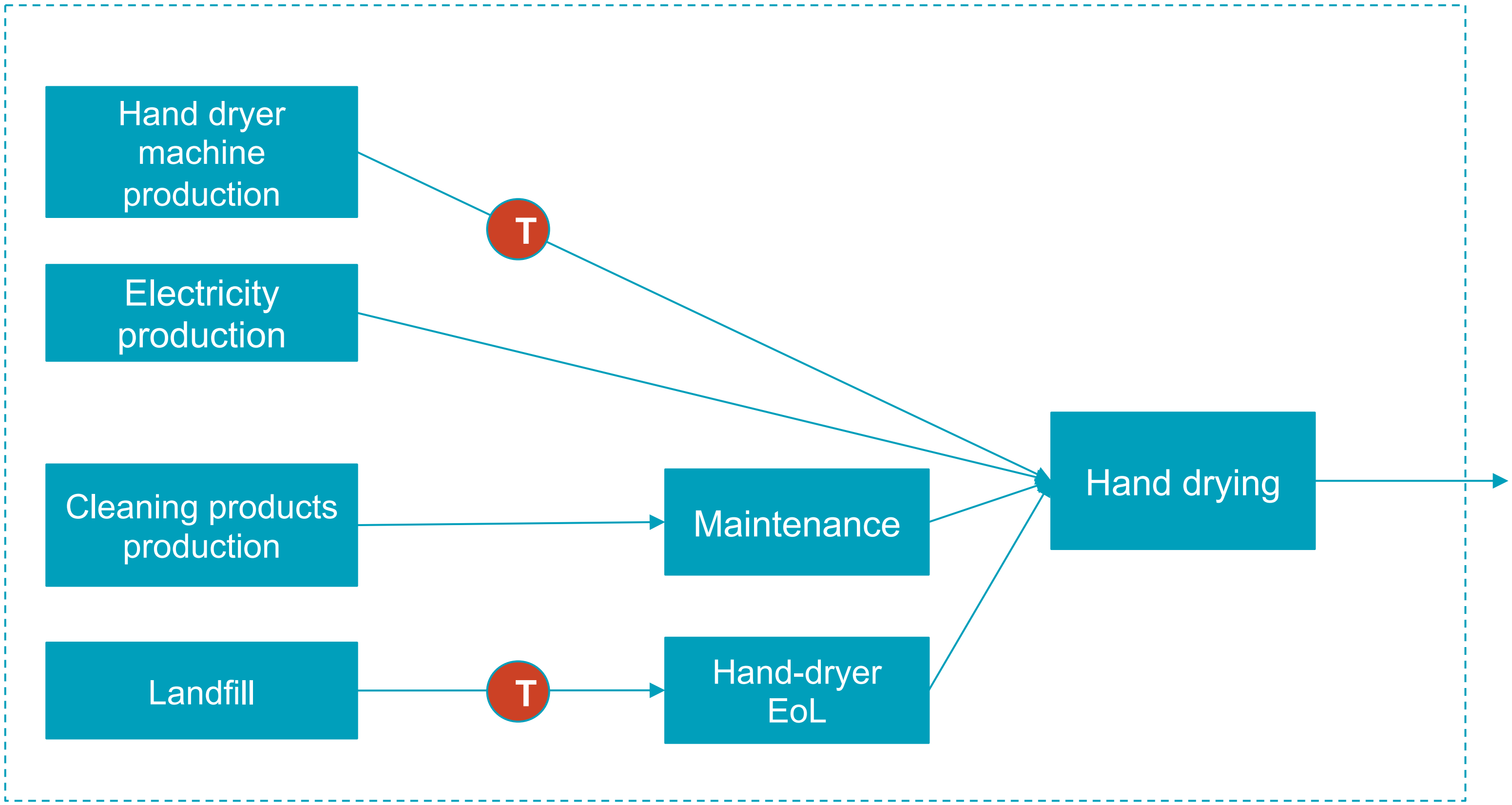
Question 1

1.4 Draw the « cradle-to-grave » process trees for each one of the three product systems

1.5 For each product system, identify the aggregated (cradle-to-gate) and disaggregated (gate-to-gate) processes

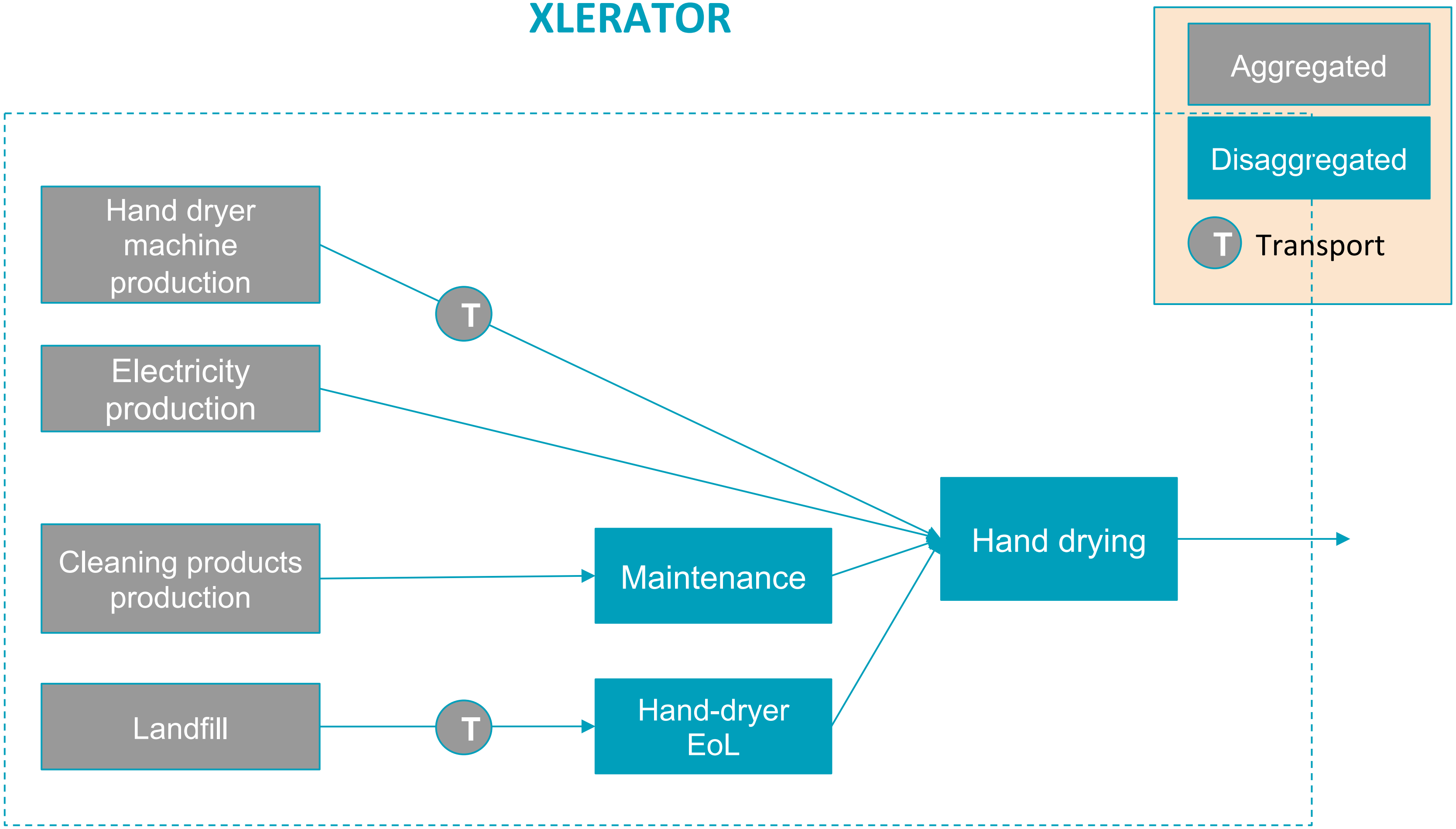
1.4 – 1.5 « cradle-to-grave » process trees

XLERATOR



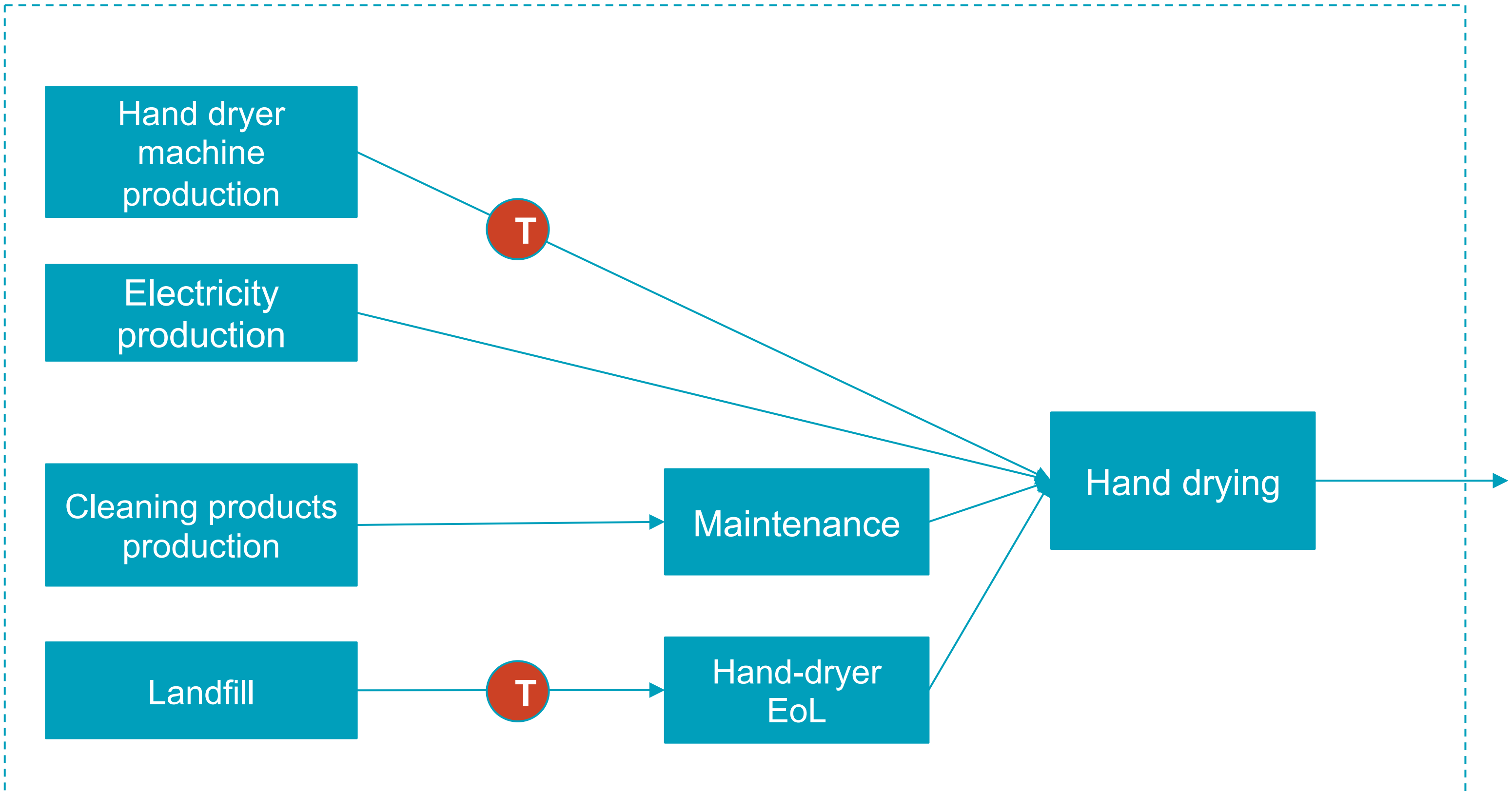
1.4 – 1.5 « cradle-to-grave » process trees

XLERATOR



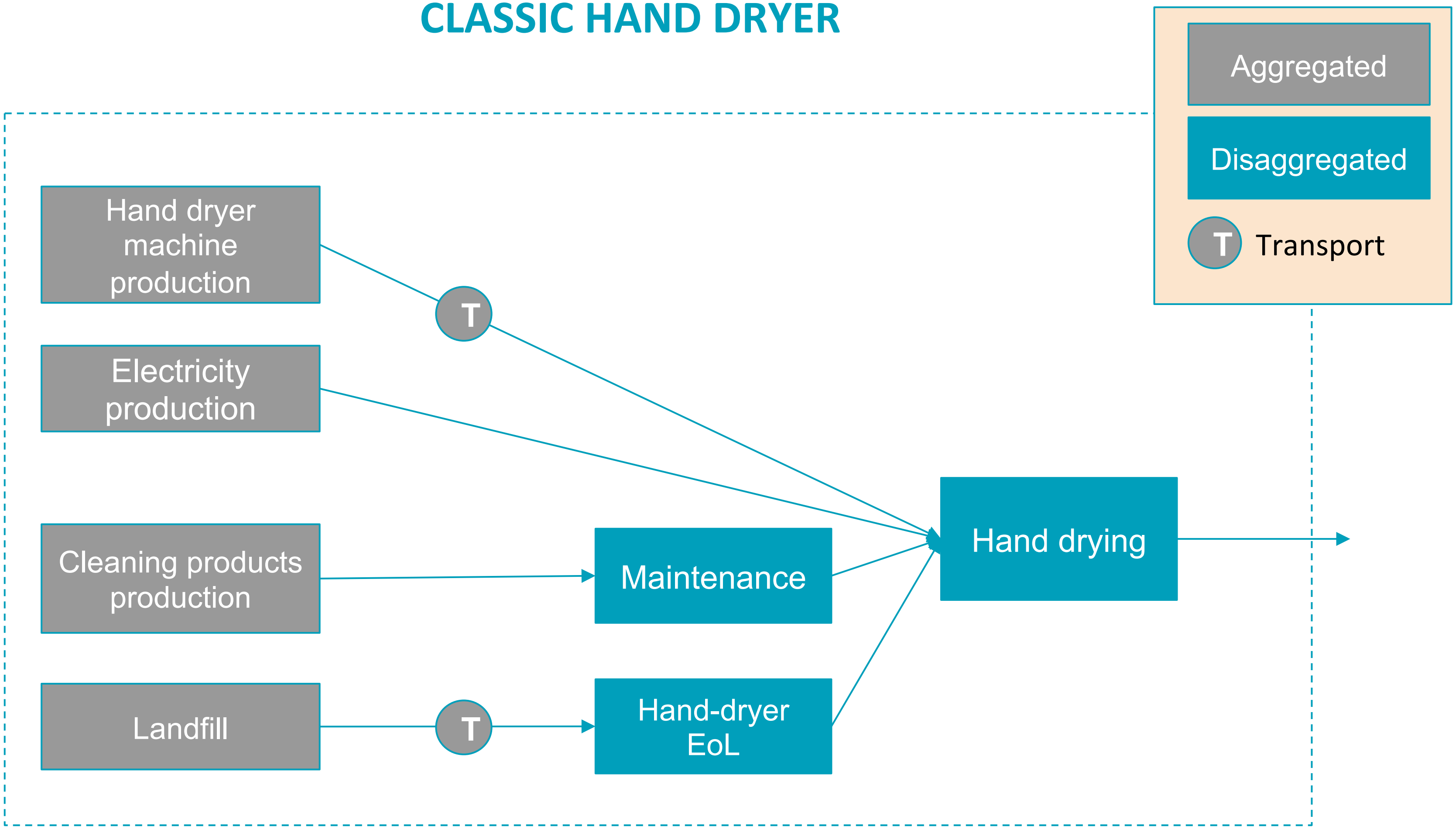
1.4 « cradle-to-grave » process trees

CLASSIC HAND DRYER



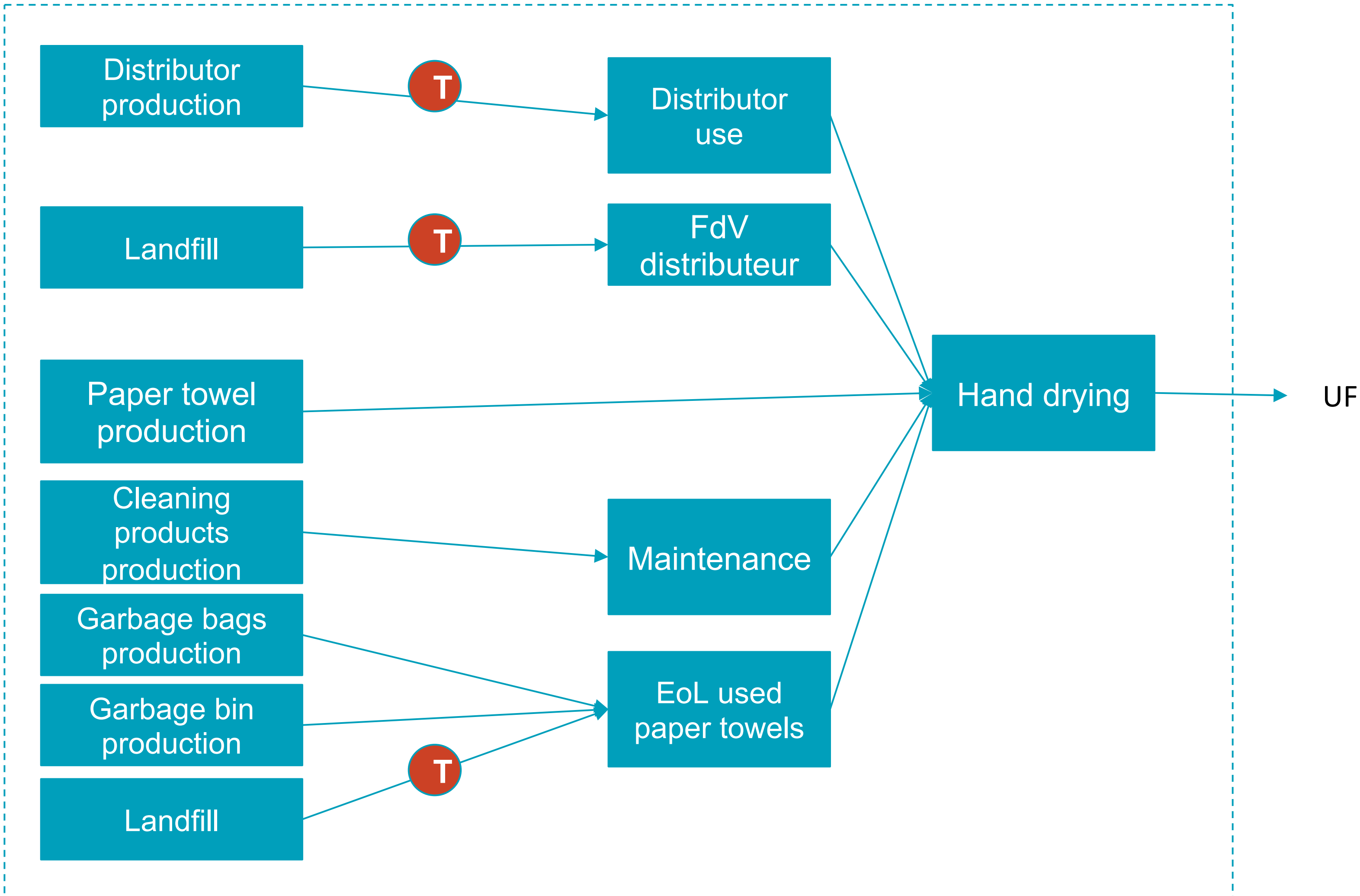
1.4 « cradle-to-grave » process trees

CLASSIC HAND DRYER



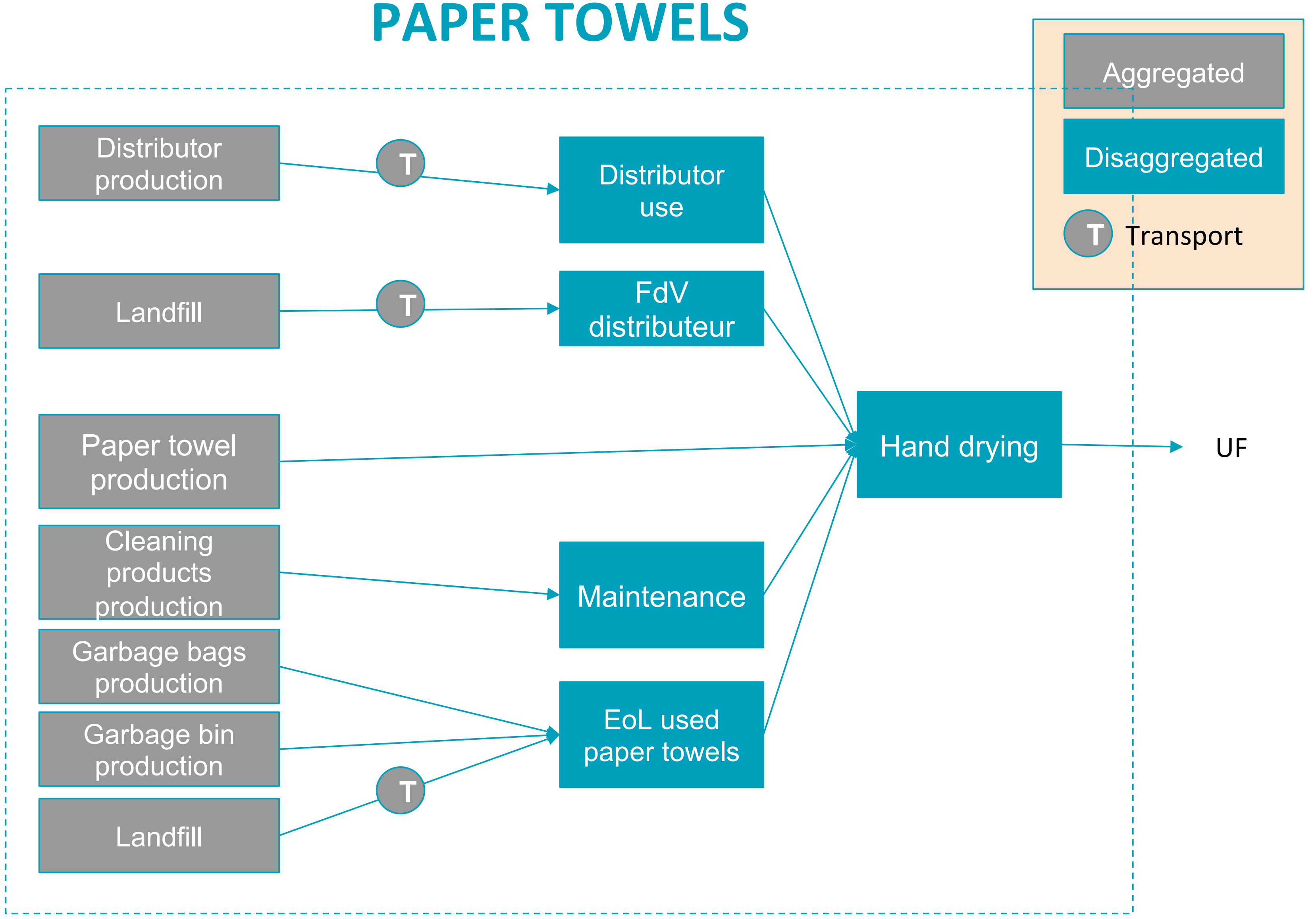
1.4 « cradle-to-grave » process trees

PAPER TOWELS



1.4 « cradle-to-grave » process trees

PAPER TOWELS



Question 1

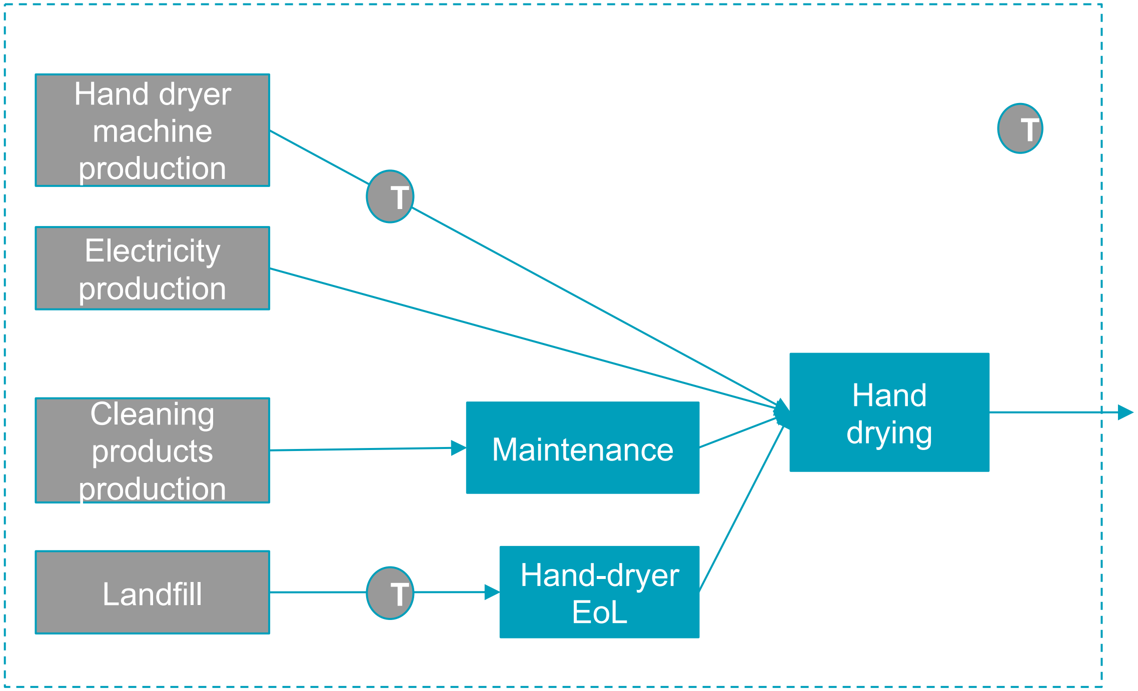
1.6 Recall the definition of a reference flow. Identify reference flows associated with each of the three product systems.

The reference flows (RF) of the product system are the flows necessary to realize the functional unit. They correspond to the flows entering the last process delivering the functional unit.

The reference flows (RF) of the product system represent the quantity of products needed and purchased to fulfill a given functional unit (Jolliet et al. 2015)

1.6 Reference flows

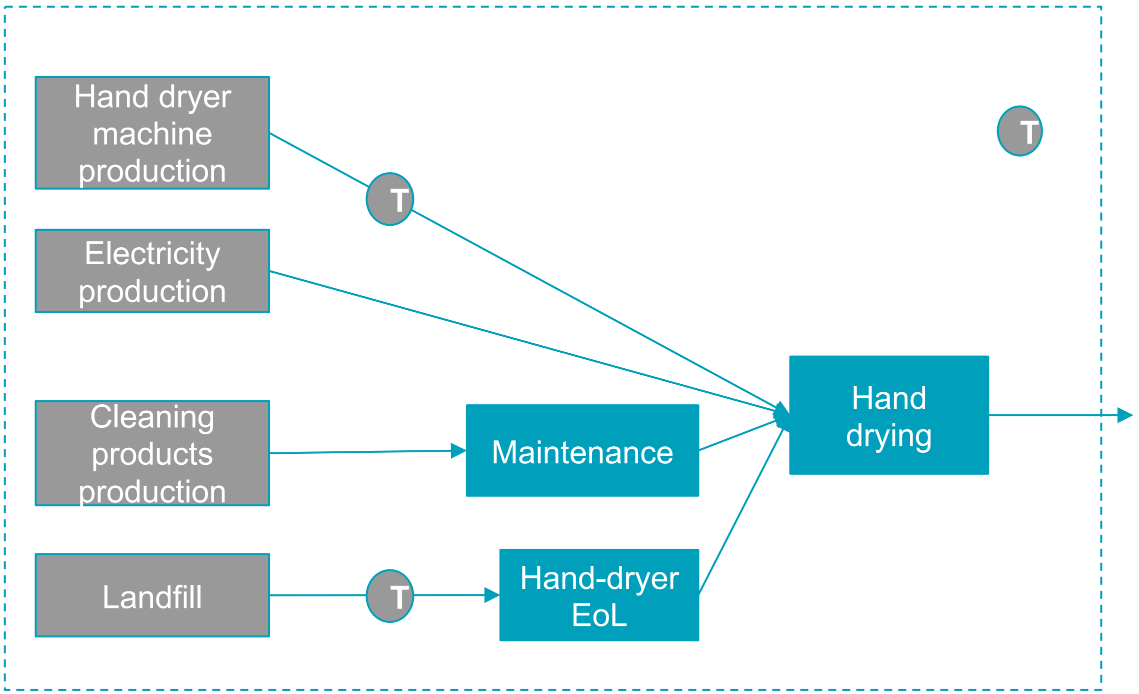
XLERATOR



- Producted hand dryer machine
- Transported hand dryer machine
- Electricity
- Hand dryer machine in maintenance
- Hand dryer machine at end of life

1.6 Reference flows

CLASSIC



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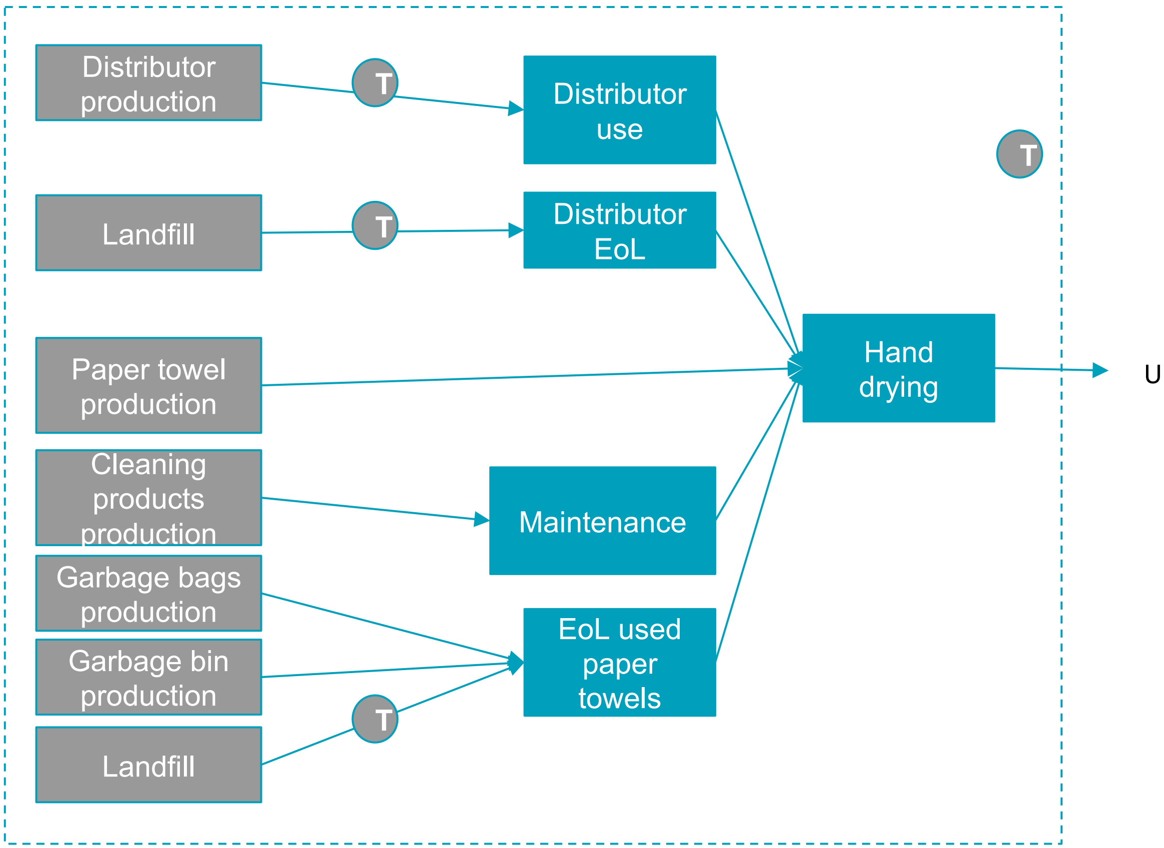
1.6 Reference flows

PAPER TOWELS



- Fonctioning distributor
- Distributor in EoL
- Paper towels
- Distributor in maintenance
- Paper at end of life

Question 1

1.1.7 Recall the definition of a set of key parameters. Identify the key parameters you need to calculate the following flows: 1) Hand dryer and electricity for the ELECTRIC hand dryer, and 2) paper, distributor, bin bags and bin for the PAPER system

The information needed to calculate the value of the flows scaled to the outgoing intermediate flow.

Question 1

1.1.7 Recall the definition of a set of key parameters. Identify the key parameters you need to calculate the following flows: 1) Hand dryer and electricity for the ELECTRIC hand dryer, and 2) paper, distributor, bin bags and bin for the PAPER system

Electric hand dryer	
Hand dryer machine (piece)	• Number of pairs of hands dried during the hand dryer machine lifetime (p) ○ Hand dryer machine life time (years) ○ Number of pairs of hands dried per year (p/year)
Electricity (kWh)	• Hand dryer power (W) • Use time per drying (s)

Question 1

1.1.7 Recall the definition of a set of key parameters. Identify the key parameters you need to calculate the following flows: 1) Hand dryer and electricity for the ELECTRIC hand dryer, and 2) paper, distributor, bin bags and bin for the PAPER system

Paper towels	
Paper (kg)	○ Number of sheets used per drying(p) ○ Dimension of each sheet (m2/p) ○ Paper mass (kg/m2)
Distributor (p)	○ Distributor lifetime (years) ○ Number of pair of hands dried per year (p/yr)
Bin bags (p)	○ Frequency of bag change (p/day) ○ Number of pairs of hands dried per day (p/day)
Bin (p)	○ Bin lifetime (year) ○ Number of hands pairs dried per year (p/year)

Question 2

2.1 From the following information, calculate the "electricity" and "hand dryer" flows of the XLERATOR and CLASSIC product systems (be sure to scale the flows to the functional unit!)

- Both hand-dryers are used 500 times per week on average (500 hands pairs) and have a 10 years lifetime.
- The use phase of both hand-dryers is described in the following table:

	XLERATOR	CLASSIC
Power (W)	1 500	2 300
Use time (s)	12	30
Shutdown time (s)	1,5	1,5
Average power during shutdown (W)	750	1150

Question 2

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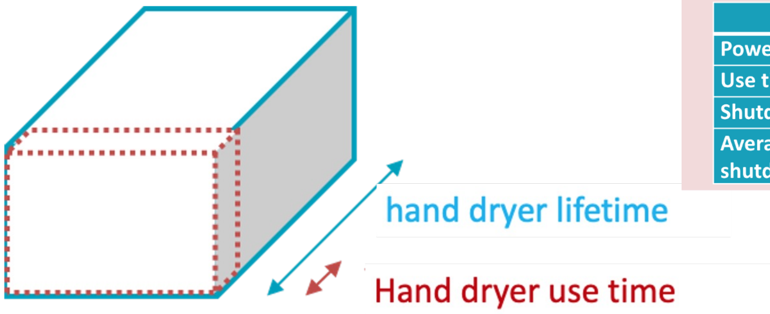
2.1 Flows Calculation - XLERATOR

Hand dryer:



$$\frac{hand\ dryer}{dried\ pair\ of\ hands} = \frac{1\ week}{500\ hands\ pairs} \times \frac{year}{52\ weeks} \times \frac{hand\ dryer}{10\ years}$$

$$= \frac{3.85 \times 10^{-6} hand\ dryer}{dried\ pair\ of\ hands}$$

Electricity:

$$\frac{electricity}{dried\ pair\ of\ hands} = \frac{(1500w \times 12s) + (750W \times 1{,}5s)}{dried\ pair\ of\ hands} = \frac{19125Ws}{dried\ pair\ of\ hands}$$

$$\frac{19125Ws}{dried\ pair\ of\ hands} \times \frac{h}{3600s} \times \frac{kW}{1000W} = \frac{5.31x10^{-3} kWh}{dried\ pair\ of\ hands}$$

Question 2

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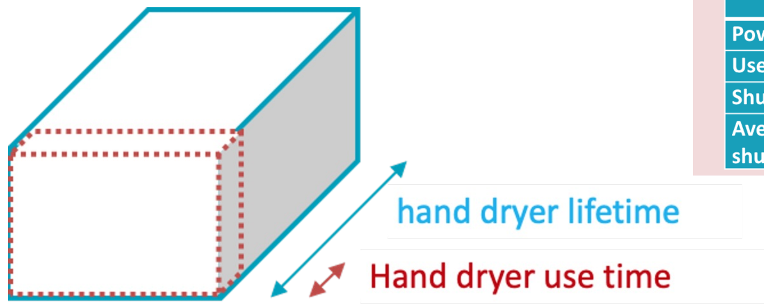
2.1 Flows Calculation - Classic

Hand dryer:



$$\frac{hand\ dryer}{dried\ pair\ of\ hands} = \frac{1\ week}{500\ hands\ pairs} \times \frac{year}{52\ weeks} \times \frac{hand\ dryer}{10\ years}$$

$$= \frac{3.85\times10^{-6} hand\ dryer}{dried\ pair\ of\ hands}$$

Electricity:

$$\frac{electricity}{dried\ pair\ of\ hands} = \frac{(2300w\times30s)+(1150W\times1,5s)}{dried\ pair\ of\ hands} = \frac{70725Ws}{dried\ pair\ of\ hands}$$

$$\frac{70725Ws}{dried\ pair\ of\ hands} \times \frac{h}{3600s} \times \frac{kW}{1000W} = \frac{1.96x10^{-2}kWh}{dried\ pair\ of\ hands}$$

Question 2

2.2 What happens to these flows when the average use time is cut by half? Calculate for XLERATOR only.

- Both hand-dryers are used 500 times per week on average (500 hand pairs) and have a 10 years lifetime.
- The use phase of both hand-dryers is described in the following table

	XLERATOR	CLASSIC
Power (W)	1 500	2 300
Use time (s)	12	30
Shutdown time (s)	1,5	1,5
Average power during shutdown (W)	750	1150

Question 2

2.2 Decrease of half the use time of XLERATOR

Electricity:

12s/use -> 6s/use

$$\frac{electricity}{dried\ pair\ of\ hands} = \frac{(1500w \times 6s)+(750W \times 1{,}5s)}{dried\ pair\ of\ hands} = \frac{10125Ws}{dried\ pair\ of\ hands}$$

$$\frac{10125Ws}{dried\ pair\ of\ hands} \times \frac{h}{3600s} \times \frac{kW}{1000W} = \frac{2.81x10^{-3}kWh}{dried\ pair\ of\ hands}$$

$$\frac{2.81x10^{-3}}{5.31x10^{-3}} = 0.53$$

The flow "electricity" decreases by almost a half (not exactly half because of the shutdown time remains the same).

Question 2

2.3 What happens to these flows when the number of uses is cut by half? Calculate for XLERATOR only.

Question 2

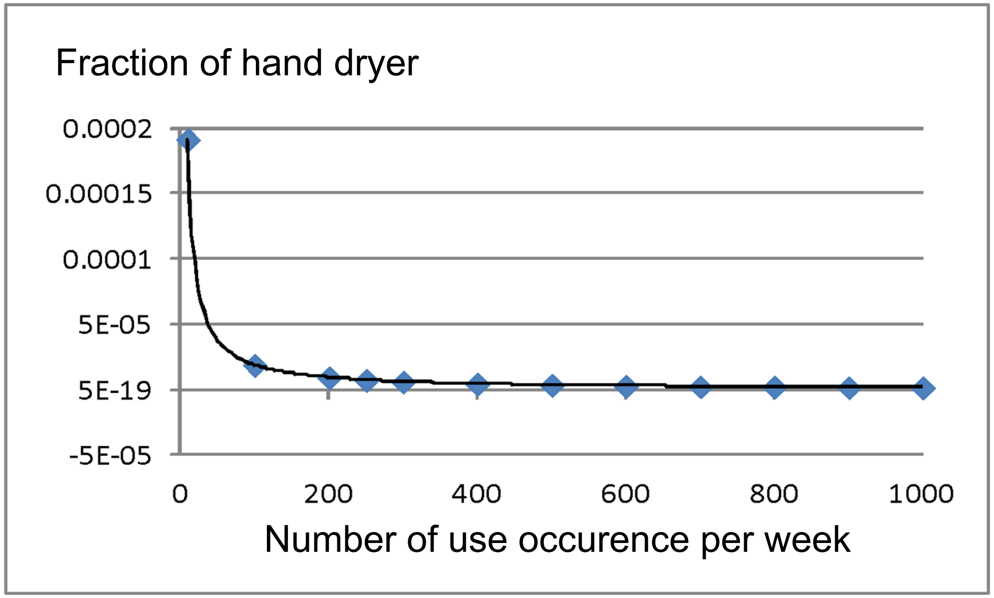
2.3 Decrease of half the use occurences of XLERATOR

500 pairs/week -> 250 pairs/week

$$\frac{hand\ dryer}{dried\ pair\ of\ hands} = \frac{1\ week}{250\ hands\ pairs} \times \frac{year}{52\ weeks} \times \frac{hand\ dryer}{10\ years} = \frac{7.67x10^{-6} hand\ dryer}{dried\ pair\ of\ hands}$$

$$\frac{7.67x10^{-6}}{3.83x10^{-6}} = 2$$

The flow "hand dryer" doubles.

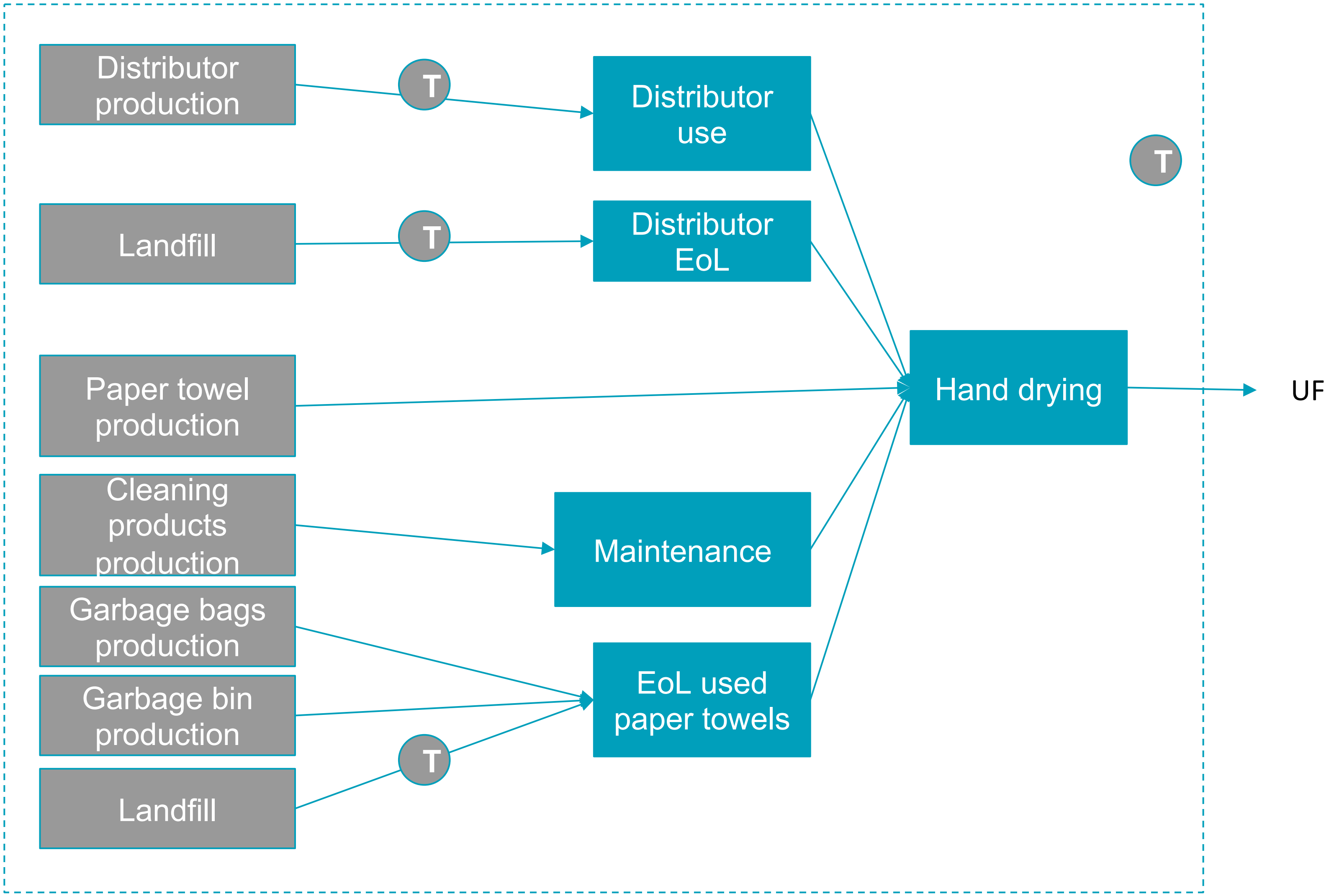


Question 3

3.1 Use the following data to calculate the reference flows for the paper towels (PAPER) product system : Paper, Distributor, Distributor in EoL, Distributor in maintenance, EoL paper towel

- On average, 2 sheets are used to dry a pair of hands.
- The surface of a sheet is 0,073 m2.
- The paper density is 28,17 g/m2.
- The paper distributor has a 10 years lifetime.
- On average, 500 pairs of hands are washed and dried per week (same bathroom than the electric hand dryer)
- Garbage bags are changed daily
- The garbage bin has a 10y lifetime
- Maintenance occurs every 24 weeks
- Paper landfill is located 20km from the place of use

Product system



Question 3

3.1 RF calculation – Paper towels

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- The paper distributor has a 10 years lifetime.
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- Garbage bags are changed daily
- The garbage bin has a 10y lifetime
- Maintenance occurs every 24 weeks
- Paper landfill is located 20km from the place of use

Paper:

$$\frac{paper}{dried\ pair\ of\ hands} = \left(\frac{2\ sheets}{dried\ pair\ of\ hands}\right) \times \left(\frac{0.073m^2}{sheet}\right) \times \left(\frac{28.17g}{m^2}\right) = \frac{4.11\times10^{-3}kg}{dried\ pair\ of\ hands}$$

Distributor:

$$\frac{distributor}{dried\ pair\ of\ hands} = \frac{1\ week}{500\ pairs\ of\ hands} \times \frac{year}{52\ weeks} \times \frac{distributor}{10\ years} = \frac{3.85\times10^{-6}}{dried\ pair\ of\ hands}$$

Distributor in EoL: *Same as Distributor (no loss)*

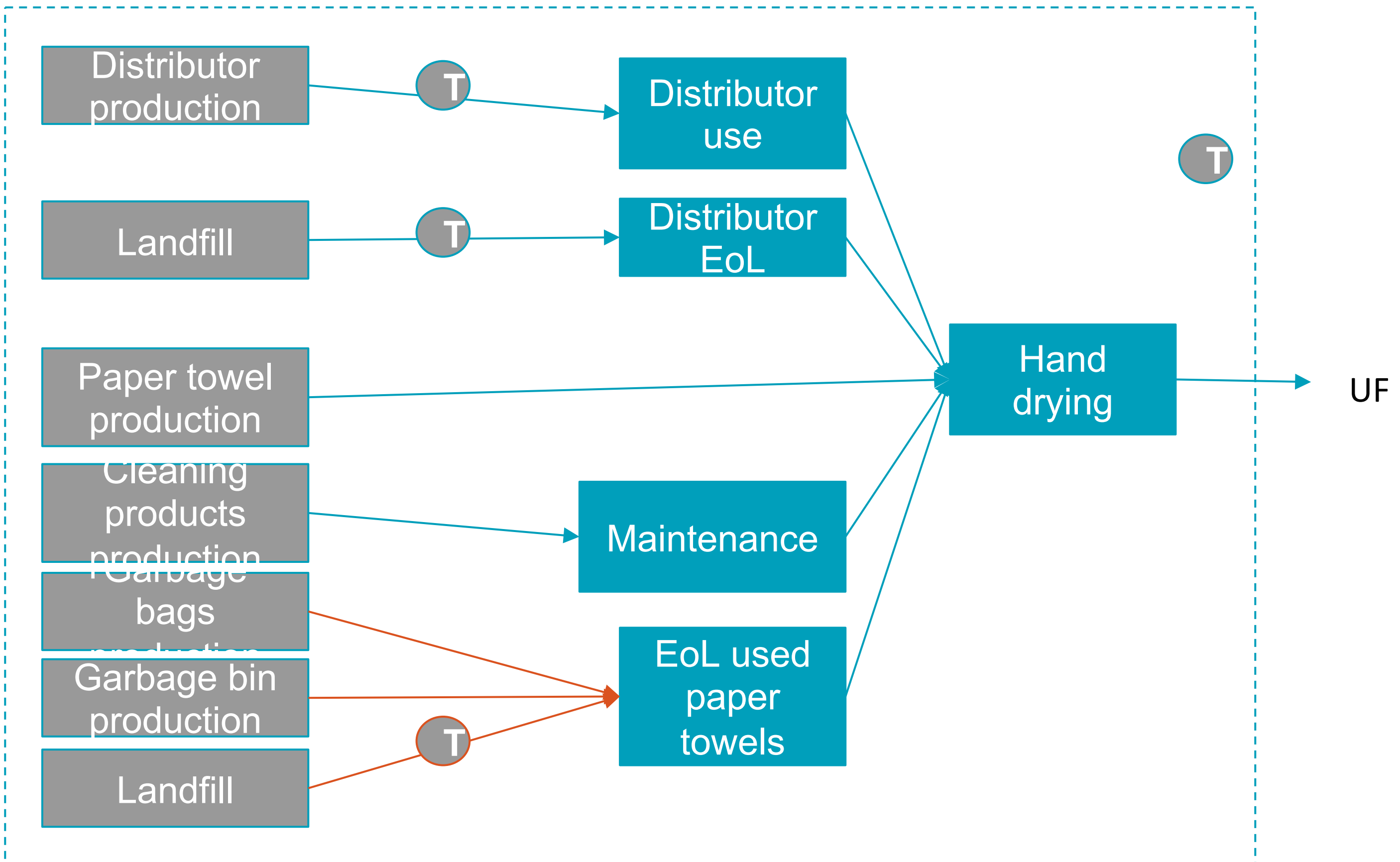
Distributor in Maintenance:

*(number of pair of hands for FU)/(number of pair of hands dryied during one maintenance cycle)= 1/ (24*500)=8.3^{E}-4 distributor in maintenance/FU*

EoL paper towel: *Same as paper (no loss)*

Question 3

3.2 Calculate the value of the intermediate flows involved in the end-of-life process for used towels



Question 3

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- Paper landfill is located 20km from the place of use

3.2 Calculate the value of the intermediate flows involved in the end-of-life process for used towels

Garbage bin

*Number of pairs of hands dried per FU/(number of pairs of hands dryed during lifetime)= 1 pair/(10y*500 pairs*52weeks/y)*

Garbage bags

$$\frac{bin\ bag}{dried\ pair\ of\ hands} = \frac{7\ bags}{week} \times \frac{1\ week}{500\ dried\ pairs\ of\ hands} = \frac{0.014 bags}{dried\ pair\ of\ hands}$$

Landfill

Mass of paper landfilled (same as paper used, no loss)= 4.11E-3g/FU

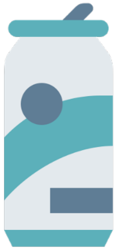
Transportation to landfill

*Mass of paper landfilled in ton * distance = 4.11E-3 / 1E6 * 20=8.2E-5*

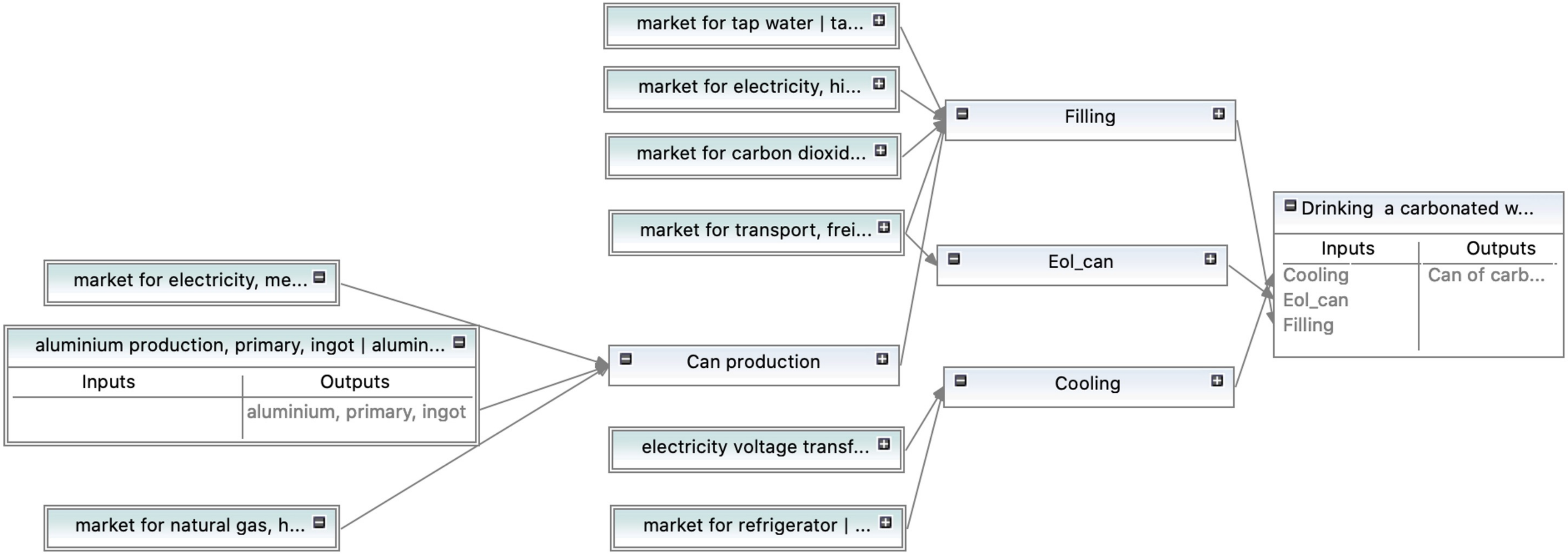
Modelling a can of carbonated water: alternative scenario

EX 2

Context

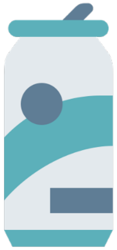


During last pratical work…



FU: Drinking 1 can of carbonated water refrigerated of 355ml in 2022 in the United States

Context



During last pratical work…

PROCESSES	Intermediary flows			Elementary flows CO2 (kg)	CH4 (kg)	Total CO2 CO2e (kg)	Contribution	Total per process CO2e (kg)	Contrib per process
Drinking of carbonated water	Carbonated water can	1	item					7.43E-03	3.65%
	Refrigerated water can	1	item						
	End of life can	1	item						
	Transport	1.10E-02	tkm	1.45E-03	2.01E-04	7.43E-03	3.65%		
Can production	Electricity production	3.00E-02	kWh	6.66E-03	2.13E-05	7.29E-03	3.58%	1.59E-01	78.28%
	Natural gas production	0.003	Nm3	4.71E-04	2.94E-05	1.34E-03	0.66%		
	Aluminium production	1.30E-02	kg	1.38E-01	2.24E-04	1.45E-01	71.24%		
	Elementary flow link to NG combustion			5.70E-03		5.70E-03	2.80%		
Filling	Electricity production	9.00E-03	kWh	2.00E-03	6.39E-06	2.19E-03	1.08%	1.98E-02	9.71%
	Tap water production	3.55E-04	m3	3.48E-04	8.13E-07	3.72E-04	0.18%		
	Pressurized CO2 production	2.00E-02	kg	1.04E-02	2.30E-04	1.72E-02	8.45%		
	Can production	1	item			0.00E+00	0.00%		
Cooling	Electricity production	0.00652	kWh	1.45E-03	4.63E-06	1.58E-03	0.78%	1.93E-03	0.95%
	Fridge production	1.57E-06	frigo	3.01E-04	1.48E-06	3.45E-04	0.17%		
End of life can	Transport	3.90E-03	tkm	5.15E-04	7.14E-05	2.63E-03	1.29%	1.51E-02	7.41%
	Landfill Aluminium	1.30E-02	kg	1.21E-03	3.78E-04	1.24E-02	6.12%		
				1.69E-01	**1.17E-03**	**2.03E-01**	100.00%	**2.035E-01**	**1.00E+00**

Context

Objective:

Assess the influence of the choice of aluminium production location and see if it is possible to decrease the carbon footprint by changing the provider of aluminium

Model the scenario in which the aluminium cans comes from China or from Quebec

Context

Supplementary informations :

- **1,02kg** liquid aluminium and 0,**067kWh** are needed to produce 1 kg aluminium ingot.
- **14,4kWh** is needed to produce 1kg liquid aluminium.
- The carbon footprints for the electricity used in the aluminium industry are **0,33kg CO2e/kWh** in Northern America (RNA), **0,015kg CO2e/kWh** in Quebec, and **1,19 kg CO2e/kWh** in China.
- The transportation between Portland and the chinese aluminium cans production factory of Guangdong is **11000km** (transportation by freighter). The transportation distance between Portland (Maine) and the Quebec aluminium cans production factory is **1200km** (transportation by truck).
- The emissions of transportation per truck are **1.3E-01 kg CO2/tkm** and **9.3E-05 kg CH4/tkm.** Emissions of transportation freighter by are **6,3E-3 kg CO2/tkm** and **3,22E-6 kg CH4/tkm.**
- The Global Warming Potential (GWP) of methane is **29,7 kgCO2e/kgCH4.**
- An empty can is made of **0.013kg aluminium.**
- The carbon footprint of aluminium ingot production is **12.07kg CO2e/kg aluminium ingot RNA.**

EX2: Question 1

Q1: By-hand inventory calculation of the alternative scenario

1.1 Calculate the amount of electricity needed to produce 1 kg of aluminium ingot

1.2 On the basis of the carbon footprint of the production of aluminium ingots in northern America (RNA), calculate the carbon footprint of the production of 1kg aluminium ingots in China and in Quebec (by changing the RNA energy mix for the Chinese/QC energy mix).

1.3 Calculate the carbon footprint of aluminium cans transportation between the aluminium can production factory and the cans filling factory (tkm: transportation of 1 ton on 1 km) for Chinese and Quebec scenario.

1.4 Calculate the carbon footprint of carbonated cans with the alternative scenario and compare the results to the original scenario.

Ex2: Question 1.1

1.1 Calculate the amount of electricity needed to produce 1 kg of aluminium ingot

- **1,02kg** liquid aluminium and 0,**067kWh** are needed to produce 1 kg aluminium ingot.
- **14,4kWh** is needed to produce 1kg liquid aluminium.

***Elec*_alum, ingot,total = *m*_alum,liq *x Elec*_alum,liq *+ Elec*_alum,ingot**

***Elec*_alum, ingot,total = 1,02 x 14,4 + 0,067**

***Elec*_alum, ingot,total = 14,755 kWh**

Ex2: Question 1.2

1.2 On the basis of the carbon footprint of the production of aluminium ingots in northern America (RNA), calculate the **carbon footprint of the production of 1kg aluminium ingots** in China and in Quebec (by changing the RNA energy mix for the Chinese/QC energy mix).

- The carbon footprint of aluminium ingot production is **12.07kg CO_2e/kg aluminium ingot RNA.**
- The carbon footprints for the electricity used in the aluminium industry are **0,33kg CO_2e/kWh** in Northern America (RNA), **0,015kg CO_2e/kWh** in Quebec, and **1,19 kg CO_2e/kWh** in China.
- **Elec**alum, ingot,total = 14,755 kWh

CFalum, ingots= CFelec + CF process

CFalum, ingots,RNA = CFelec,RNA + CF process

CFprocess = CFalum, ingots,RNA - CFelec,RNA

CFprocess= 12,07 - 14,755 * 0,33

CFprocess= 7,20 kgCO_2e

CFalum,ingots,China = CFelec,China + CF process

CFalum,ingots,China = 14,755*1,19 + 7,20

CFalum,ingots,China = 24,759 kgCO_2e

CFalum,ingots,Quebec = 14,755*0,015 + 7,20

CFalum,ingots,Quebec = 7,42 kgCO_2e

Ex2: Question 1.3

1.3 Calculate the carbon footprint of aluminium transportation between the aluminium can production factory and the cans filling factory (tkm: transportation of 1 ton on 1 km) for Chinese and Quebec scenario (scaled to the FU).

The transportation between Portland and the chinese aluminium cans production factory of Guangdong is **11000km** (transportation by freighter). The transportation distance between Portland (Maine) and the Quebec aluminium cans production factory is **1200km** (transportation by truck).

The emissions of transportation per truck are **1.3E-01 kg CO2/tkm** and **9.3E-05 kg CH4/tkm.** Emissions of transportation freighter by are **6,3E-3 kg CO2/tkm** and **3,22E-6 kg CH4/tkm.**

Transportation Carbon Footprint =

*Mass in tons * Transportation distance * (xCO2 + GWPCH4*xCH4)*

CHINA: mass_can (kg)/1000 x distance x *(xCO2 + GWPCH4*xCH4)*

CHINA: 0,013 (kg)/1000 x 11000 x *(6,3E-3 CO2 + 29,7 x 3,22 E-6 CH4)*

CHINA: 9,15E-4 kgCO2e

QC: 0,013(kg)/1000 x 1200 x *(1,3E-1 CO2 + 29,7 x 9,3 E-5 CH4)*

QC: 2,07E-3 kgCO2e

Ex2: Question 1.4

1.4 Calculate the carbon footprint of carbonated cans with the alternative scenario and compare the results to the original scenario.

1- Carbon footprint of aluminium production and transportation with the alternative scenario

CHINA: CF alum_can + CF_transport
: mass can*CFalum + CF_transport
: 24,759*13/1000 + 9,15E-4
: 2,98E-1 kgCO2

QC: CF alum_can + CF_transport
: mass can*CFalum + CF_transport
: 7,422*13/1000 + 2,07E-3
: 9,86E-2 kgCO2

2- Total carbon footprint of carbonated cans (all life stages)

CF = carbonfootprint_Lab1 - CF alum prod Lab1 + CF cans prod Lab2

CF_CHINA: 0,204 - 0,145 + 2,98E-1 = 3,57E-1kgCO2e/UF

CF_QC: 0,204 - 0,145 + 9,86E-2 = 1,58E-1 kgCO2e/UF

OPENLCA OVERVIEW

Modelling a can of carbonated water with openLCA: alternative scenario

LAB 2