TP1 –Define the scope and model the carbon footprint of Aluminum cans of carbonated water

Lab objectives:

- Get familiar with basic concepts used when defining the scope of a Life Cycle Assessment (LCA).
- Quantify reference flows, intermediate flows and elementary flows of a simplified product system
- Calculate by hand (or using Excel) the inventory of a simplified product system as well as the associated environmental impacts
- Briefly interpret the case study results
- Model a "cradle-to-grave" system for cans of carbonated water in OpenLCA
- Introduce the process to obtain lifecycle impact assessment results in OpenLCA

Context: aluminum cans of carbonated water

You want to **calculate the "cradle-to-grave" carbon footprint of aluminum cans of carbonated water** produced in the United States (Portland, Maine). You have access to information (primary data) on the production processes of aluminium cans and on the filling process. You also have access to aggregated data for a series of products (electricity, aluminium, water, etc.)

Context and LCA assumptions

- Your objectives are to:
  - Calculate the "cradle-to-grave" carbon footprint of cans of carbonated water produced in the United States
  - Identify areas of improvement
- The scope of the study is as follows:
  - Function: to drink a can of carbonated water
  - Functional unit: Drinking 1 can of refrigerated carbonated water of 355ml in Portland in 2021
  - Here, only CO_2 and CH_4 emissions will be considered in the calculation of the carbon footprint
  - We consider the following global warming potential (GWP) characterization factors (IPCC, 2013):
    - GWP CO_2: 1 kg CO_2e/kg CO_2
    - GWP CH_4: 29,7 kg CO_2e/kg CH_4

Available data

The following tables provide data on the production, filling, use and end-of-life of cans as well as data on the production of the various inputs for these processes. Here are a few additional pieces of information:

- The emission factor related to the combustion of natural gas is 1.9 kg CO_2/Nm^3 natural gas.
- We assume that the cans are 100% virgin aluminium.
- We assume that there are no aluminium losses during the production of the empty cans.
- We assume that all the filled and refrigerated cans will be consumed (no loss of finished product).
- We assume that all the consumed cans (= end-of-life) are disposed in a landfill.
- The cans are refrigerated for one week during the use phase before being consumed.
- The volume of the refrigerator used for cooling is 290L and its lifespan is 15 years. It consumes 288 kWh/year.
- The transport between the production of the can and the use of the can is assumed to be 30 km.
- Other inputs (lubricants, solvents, etc.) are assumed to be environmentally negligible.

Unit processes	Flow type	Flow	Quantity	Unit
Filling of cans of carbonated water	Intermediary flows - Outputs	Can of carbonated water	1	Can
	Intermediary flows– Inputs	Electricity	9	Wh
		Tap water	0.355	L
		Pressurized CO_2	2	g
		Empty aluminium can	1	Can
Production of an aluminium can	Intermediary flows - Outputs	Empty aluminium can	1	Can
	Intermediary flows – Inputs	Electricity	30	Wh
		Natural gas	0.003	Nm3
		Aluminium	13	g
	Elementary flows	CO_2	**Tbd**	gCO2
Use of a can of carbonated water	Intermediary flows - Outputs	Can of carbonated water used	1	Can
	Intermediary flows – Inputs	Filled can of carbonated water	**Tbd**	Can
		Can at end-of-life	**Tbd**	Can
		Refrigerated can	**Tbd**	Can

		Transport	**Tbd**	tkm
Refrigeration	Intermediary flows - Outputs	Refrigerated can	**Tbd**	Can
	Intermediary flows – Inputs	Electricity	**Tbd**	Kwh
		Fridge	**Tbd**	fridge
End-of-life of can	Intermediary flows - Outputs	Can at end-of-life	1	Can
	Intermediary flows – Inputs	Transport	3.9 E-03	tkm
		Aluminium landfilled	13	g

Table 1: Description of the disaggregated processes of the product system modelled by the LCA practitioner (yourself): Inputs and Outputs flows. Tbd = To be determined

Aggregated processes	**Elementary flows**		**Unit**	**Ecoinvent 3.6 process**
	CO2	CH4		
Tap water production	9.80E-04	2.30E-06	kg/m^3 potable water	market for tap water | tap water | Cutoff, S - RoW
Pressurized CO_2 production	5.18E-01	1.15E-02	kg/kg CO_2 (pressurized)	market for carbon dioxide, liquid | carbon dioxide, liquid | cut-off, S
Primary aluminium production	1.06E+01	1.72E-02	kg/kg primary aluminium	aluminium production, primary, ingot | aluminium, primary, ingot | Cutoff, S - RNA
Natural gas production	1.57E-01	9.79E-03	kg/Nm^3 natural gas	market for natural gas, high pressure | natural gas, high pressure | Cutoff, S - US
Electricity production, medium voltage	2.22E-01	7.10E-04	kg/kWh electricity	electricity, high voltage, production mix | electricity, high voltage | Cutoff, S – NPCC, US only
Transport service	1.32E-01	1.83E-02	Kg/tkm	market for transport, freight, lorry, unspecified | transport, freight, lorry, unspecified | Cutoff, S - RoW
Refrigerator Production	1.92E+02	9.43E-01	kg/unit	market for refrigerator | refrigerator | Cutoff, S - GLO
Landfilling	9.37E-02	2.91E-02	Kg/kg waste	treatment of municipal solid waste, sanitary landfill | municipal solid waste | Cutoff, S - RoW

Table 2: Description of the aggregated processes of the product system and correspondence in the Ecoinvent database

1. Goal and scope

1.1. Draw a process tree that represents the “cradle-to-grave” of the can of carbonated water product system.

1.2. Identify the aggregated (“cradle-to-gate”) and disaggregated (“gate-to-gate”) processes of the process tree.

1.3. Recall the definition of a reference flow, then identify which of the intermediate flows in the product system are reference flows.

1.4. Certain flows in table 1 are Tbd (to be determined). For each of them, identify the information you need to put their value at the scale of the output intermediary flow. What is the name of this type of information when it allows to quantify the reference flows allowing to achieve the functional unit?

2. Inventory calculation “by hand”

2.1. Quantify the reference flows (scaled to the functional unit) identified in question 1.3.

2.2. Calculate the value of the flows associated with each unit process (scaled to the output intermediary flow first and to the functional unit of the product system afterwards).

2.3. Carry out the life cycle inventory, i.e., calculate all the quantities of elementary flows involved in the system and scaled to the functional unit. *(Note: for simplification, only CO_2 and CH_4 flows are considered here. In a “classic” LCA, an inventory can be made up of several hundred different elementary flows).*

3. Impact assessment

3.1. Calculate the carbon footprint for the entire life cycle of the product system (scaled to the functional unit).

3.2. How would the results evolve if the functional unit was changed to the following: “Consume 1000 refrigerated can of carbonated water in Portland in 2021”?

4. Interpretation

4.1. Calculate the relative contribution of each unit process to the total carbon footprint. Which process if the largest contributor? Which stage of the life cycle does it correspond to?

4.2. Identify areas for improvement in the carbon footprint of aluminum cans of carbonated water. *(Note: the improvement can concern both the environmental performance and the study itself).*

5. Inventory modelling in OpenLCA

To answer these questions, you should have installed the openLCA software on your computer and imported the new condensed database provided by your supervisors.

5.1. Use the openLCA software to model the “gate-to-gate” process of the product system (can filling, can production, can consumption, can cooling, can end-of-life).

5.2. On OpenLCA, generate the “cans of carbonated water” product system and calculate its carbon footprint.

6. Matrix formulation of the model

6.1. Build the technology and environmental matrices, and a final demand vector for this product system.