Lab4 – Assessment of impacts and interpretation in LCA

Context: Carbonated water can

During the previous labs, you calculated:

- the **carbon footprint** of the consumption of a refrigerated can of carbonated water in the US (Lab 1)
- the **carbon footprint** of two alternative scenarios in which the aluminum cans are from Quebec and China (Lab 2)
- the **carbon footprint** of this can when recycled via different approaches (Lab 3).

Now, we want you to calculate a more comprehensive profile of **cradle-to-grave potential environmental impacts** of the carbonated water cans produced in Portland (Maine, US, Lab 1), and to **interpret the results** of this study. To do so, in Table 1 we provide you with a subset of inventory results of this scenario and in Table 2 the corresponding characterization factors of the IMPACT World+ impact method.

Table 1: Inventory results for the reference scenario (FU = Drinking 1 can of refrigerated carbonated water, aluminum UE, 100% landfill, cut-off criteria at 11%)

Substance	Unit/FU	[quantity]	Type of flow
Carbon dioxide, fossil	kg	1.69e-1	Emission to environment
Chromium VI	kg	1.46e-6	Emission to environment
Arsenic, ion	kg	9.82e-7	Emission to environment
Particulates, <2.5um	kg	2.60e-4	Emission to environment
Aluminium	kg	3.04e-5	Emission to environment
Coal, hard, unspecified, in ground	kg	3.83e-2	Resource consumed
Gas, natural, in ground	m^3	1.31e-2	Resource consumed
Oil, crude, in ground	kg	8.08e-3	Resource consumed
Coal, brown, in ground	kg	3.34e-2	Resource consumed
Uranium, in ground	kg	4.79e-7	Resource consumed
Water	m^3	3.51e-3	Resource consumed

Table 2: Characterization factors of potential impacts (taken from IMPACT World+ method, footprint version)

Substance	**Carbon footprint** (kg CO2-eq)	**Fossil and nuclear energy use** ($MJ_{deprived}$)	**Water scarcity footprint** (m3 world-eq)	**Remaining human health damage** (DALY)	**Remaining ecosystem quality damage** (PDF.m2.yr)
Carbon dioxide, fossil (/kg)	1	-	-	-	0.0165
Chromium VI (/kg)	-	-	-	1.14E-1	5.32
Arsenic, ion (/kg)	-	-	-	7.19E-2	-
Particulates, <2.5um (/kg)	-	-	-	2.60E-4	-
Aluminium (/kg)	-	-	-	-	1080
Coal, hard, unspecified, in ground (/kg)	-	19.1	-	-	-
Gas, natural, in ground (/m3)	-	40.3	-	-	-
Oil, crude, in ground (/kg)	-	45.8	-	-	-
Coal, brown, in ground (/kg)	-	9.9	-	-	-
Uranium, in ground (/kg)	-	5.6e5	-	-	-
Water (/m3)	-	-	43.0	-	-

Table 3: External normalization factors for IMPACT World+ areas of protection (expert method)

Human health	33.3	points/DALY
Ecosystem quality	1.1 e-5	points/PDF

The IW+ 2.0.1 explicitly distinguishes three versions of IW+, namely: the *Footprint* version, the *Expert* version, and the *Midpoint* version. The first one is proposed as a default for practitioners with a lower degree of expertise in LCA and impact assessment, the second one as the expert version for experienced users and the third one is destined for practitioners wanting to stay at the midpoint level.

The Footprint version aims at displaying indicators of general interest in decision making, along with indicators ensuring comprehensiveness in respect to all the environmental issues considered in the Expert version. The Footprint version is compliant with the optional ISO LCIA elements *grouping*. Table 3 displays categories, indicators, and the units of the Footprint version. Please note that:

1. The three midpoint impact categories “Carbon footprint”, “Water scarcity footprint”, and “Fossil and nuclear energy use” (which units are expressed in equivalent quantities of substances) do not contribute to the “remaining HH” and “remaining EQ” damages. This is to avoid double counting these impacts and ensure that indicators of the impact profile remain independent from each other.
2. The “remaining HH” and “remaining EQ” indicators regroup all other impact categories contributing to those two areas of protection, as shown in Figure 1.

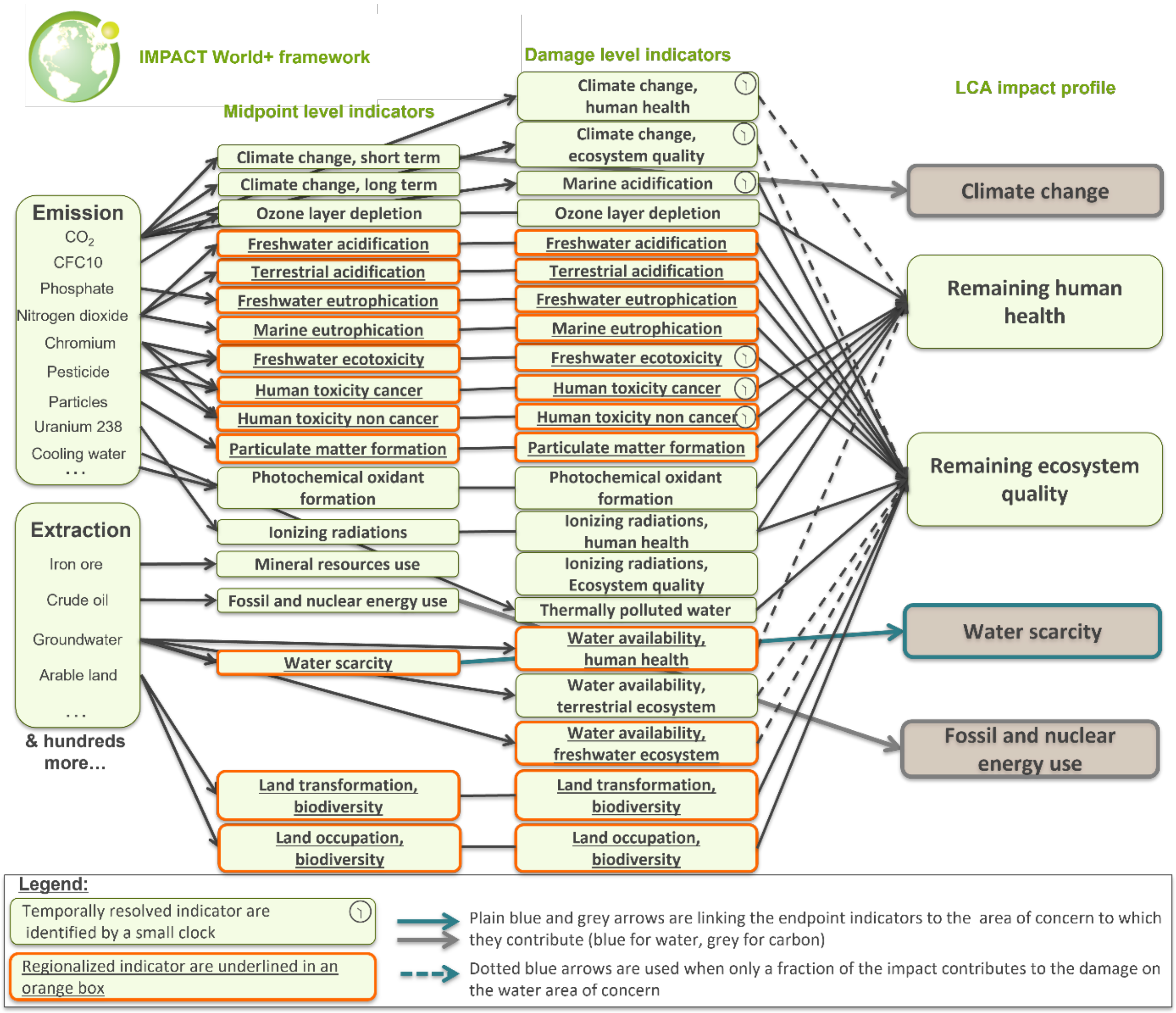

Figure 1: Methodological framework of potential impacts assessment: visual representation adapted from IMPACT World+ method.

Table 4: Impact categories, indicators, and indicators' unit of the Footprint version

Impact categories	Indicators displayed and units
Carbon footprint	- Climate change, short term (in kg CO_2 eq)
Water scarcity footprint	- Water scarcity (in m^3 world-eq)
Resource depletion	- Fossil and nuclear energy use (in MJ deprived)
Rest of human health AoP (minus the contribution of climate change and water related issues)	- Rest of human health (in DALY)

Rest of ecosystem quality AoP (minus the contribution of climate change and water related issues)	- Rest of ecosystem quality (in PDF.m².yr)

The three IW+ versions, for all software and database can be found here: https://zenodo.org/records/8200703

If a decision-maker wants to know the contribution of the climate change and water availability impact categories into HH and EQ areas of protection, we just need to apply IMPACT World+ expert version and analyze the contribution of each of those categories contributing to damage-oriented scores including climate change and water scarcity.

Questions 1 to 4 of this lab will be answered applying the IMPACT World+ Footprint version. Question 5 (optional) will require the application of the Expert version.

Question 1 – Computing impact scores in LCA – Hand computations

Here we want to calculate the impact score of the reference scenario for the five indicators of IMPACT World+ and identify the most contributing elementary flow

1.1) Compute **by hand** the impact score of at least two categories (remaining human health and fossil and nuclear energy use) of the reference product system based on the functional unit "Drink one can of refrigerated carbonated water produced in Portland" (Lab 1). To do so, use the life-cycle inventory (Table 1) and the characterization factors of the Footprint version of IMPACT World+ for each of the 5 impact categories.

1.2) Identify the most contributing elementary flows for each category.

Question 2 – Computation of the LCA impact profile - OpenLCA

2.1) **With OpenLCA**, compute the complete scores of the impact profile (i.e., the 5 categories of the Footprint version of IMPACT World+) for the same reference product system based on the functional unit "Drink one can of refrigerated carbonated water produced in Portland" (Lab 1).

2.2) Compare the results to the ones you obtained by hand. How do you explain the gap between those results?

Question 3 – Contribution analysis

Question 1 and 2 allowed us to calculate an impact score for the reference scenario and identify the most contributing elementary flows. However, we still don't know which activities (unit processes) such emissions/resource consumption are related to.

3.1) **Contribution analysis per process** – Which unit processes of the reference scenario are the most contributing to the 5 impact categories:

- At the first modelling level (unit process feeding the reference flows)?
- At successive levels (upstream intermediate flows)?

Need a little help? In the tab "Contribution tree" you will find the contribution of processes to the product system potential impacts for different impact categories. Select "Carbon footprint" and "Water scarcity footprint". The first modelling level refers to the processes directly connected with the process "drinking of carbonated water". When you open these folders, you can access the successive levels.

3.2) **Contribution analysis per elementary flow** for the 5 impact categories for the reference scenario. Which are the most contributing elementary flows to the RHH and REQ areas of protection? Which are the most contributing elementary flows to climate change?

Are the results on the environmental performance of the scenarios compared consistent between the impact profile indicators?

Question 4 – Comparative analysis

Now that we know how to compute an impact profile of a product system and perform a contribution analysis, we could compute the same for the alternative product systems and compare them

4.1) We want to compare the impact profiles of three aluminum can scenarios (produced in the US, in China and in Québec) by applying the footprint profile of the IMPACT World+ method. To be done via Excel graphs:

a) Represent the results of the comparison with a figure presenting the impact profile via an internal normalization (100% being the scenario with the highest impact score per category).

Are the environmental performance results of the compared scenarios coherent among the impact profile indicators, or are there some inverse trends (trade-offs between indicators)? Is it important to give a comprehensive set of indicators to the decision-maker, going further than impact categories asked for by the latter?

b) Propose a contribution analysis per process at the first level (i.e., feeding reference flows) and second level (i.e., feeding upstream intermediary flows) on the same graph.

c) For elementary processes being important contributors, identify the main elementary flows.

Question 5 (Optional) – Interpretation with the Expert version

With the help of the Expert version of the IMPACT World+ method:

5.1) **Analyze the contribution per environmental problem to the areas of protection HH and EQ.**

Compute the damage-level scores of the Expert version of IMPACT World+ for the same reference product system with OpenLCA.

Which environmental problem is contributing the most to the total HH and EQ, respectively? What is the link that we can establish with the elementary flows' contribution analysis?

5.2) Compute the **normalized impact scores** for the HH and EQ categories. How do we interpret the units of the normalized scores? Can we add up the normalized scores (environmental impact points) obtained for HH and EQ? If yes, in which conditions?

5.3) Compute a unique score with:

1. an explicit egalitarian weighting of normalized impact scores to the areas of protection (i.e., HH, EQ)
2. the monetary weighting factors proposed by IMPACT World+: HH = 74000 € / DALY, EQ = 0.14 € / PDF.m2.yr

How do we interpret the results from these two weighting approaches?