

## IEooc\_Methods4\_Exercise5: Life cycle impact assessment

### - Sample solution -

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1. One option for a functional unit is to just compare the bags with each other. That might not be the best functional unit though. Define an appropriate functional unit for comparing the four shopping bag alternatives. It is assumed that an average customer goes 45 times a year to the supermarket and buys on average 200 l of goods each time (i.e. he fills the shopping trolley to 80 %).

➔ Functional Unit : Packaging for carrying home 1 year customer shopping

2. In the following table some more information on the four bags is given. How many bags are used to pack the shopping volume of one year? What is the mass of the used bags per option, assuming that the re-usable bags are used three times? Round the number of bags. Which option uses most and least material?

	PE bag, one-time	PE bag, multi-use	Paper bag	Biodegradable bag
Material	high density PE	high density PE	paper (recycled)	50% maize starch 50% Polycaprolacton
Mass per bag	6.04 g	44 g	52 g	17 g
Volume	14 l	29.6 l	20.5 l	25 l
Re-usable?	No	Yes	No	No

	PE Bag	PE bag multi use	Paper Bag	Bio Bag
Mass	6,04	44	52	17
Volume	14	29,6	20,5	25
Number of Bags	642,8571	101,3513514	439,0244	360
	643	102	440	360
Material	<b>3883,72</b>	4488	<b>22880</b>	6120
L to packed for 1 Functional Unit	9000			

3. Life Cycle Inventory. Look at the Life Cycle Inventories for the four options (in provided spreadsheet 'LCI'). The values are collapsed over all life cycle stages. What are the largest and what are the smallest emissions per bag?

Part II Methods

Methods part 4 (Life cycle assessment)

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Compartment	Substance	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
		emission [g/bag]	emission [g/bag]	emission [g/bag]	emission [g/bag]
air	Ammonia (NH3)	3,34E-03	1,23E-02	4,17E-01	1,56E+00
air	Carbon dioxide	1,11E+04	3,64E+04	1,84E+04	1,49E+04
air	Methane, fossil	3,71E+01	1,20E+02	1,74E+02	6,05E+01
air (high pop.)	CFC-113	3,61E-02	2,64E-05	1,10E-05	1,10E-03
air	Nitrous oxide	7,29E-02	9,77E-02	6,01E-01	1,34E+00
air	Nitrogen oxide	2,98E+01	1,06E+02	7,99E+01	5,50E+01
air	Phosphorus	3,00E-01	3,00E+00	4,00E+00	1,00E+01
air	Particulates, < 2.5 um	2,11E+01	7,34E+01	5,19E+00	2,30E+00
air	Sulfur oxides	2,57E+01	9,60E+01	2,87E+01	3,49E+01
land	Land occupation (unit is [m2/bag] !)	2,93E-06	1,16E-05	1,42E-04	2,96E-04
water	Strontium-90	1,00E-07	1,30E-07	1,00E-08	1,00E-08
water	water consumption [1kg=1l]	6,04E-02	8,44E-02	8,56E-01	3,07E-02

4. Calculate the LCIA for the four different options. To do this, you will use the provided values from LC-Impact together with the provided LCIs. Remember that one substance can lead to damages in multiple impact categories.
  - a. Calculate the LCIA on endpoint level in DALY and PDF for all four options, using the site-generic values from LC-Impact. Assume “forestry” as land occupation type for the plastic and paper bags. Assume “annual crops” for the biodegradable bag. Which option performs best regarding human health and which performs best regarding ecosystem quality? Compare the options *per bag* and *per year*.

		PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
		emission [kg/bag]	emission [kg/bag]	emission [kg/bag]	emission [kg/bag]
air	Ammonia (NH3)	3,34E-06	1,23E-05	4,17E-04	1,56E-03
air	Carbon dioxide	1,11E+01	3,64E+01	1,84E+01	1,49E+01
air	Methane, fossil	3,71E-02	1,20E-01	1,74E-01	6,05E-02
air (high pop.)	CFC-113	3,61E-05	2,64E-08	1,10E-08	1,10E-06
air	Nitrous oxide	7,29E-05	9,77E-05	6,01E-04	1,34E-03
air	Nitrogen oxide	2,98E-02	1,06E-01	7,99E-02	5,50E-02
air	Phosphorus	3,00E-04	3,00E-03	4,00E-03	1,00E-02
air	Particulates, < 2.5 u	2,11E-02	7,34E-02	5,19E-03	2,30E-03
air	Sulfur oxides	2,57E-02	9,60E-02	2,87E-02	3,49E-02
land	Land occupation (ur	2,93E-06	1,16E-05	1,42E-04	2,96E-04
water	Strontium-90	1,00E-10	1,30E-10	1,00E-11	1,00E-11
water	water consumption	6,04E-05	8,44E-05	8,56E-04	3,07E-05

Unit: m<sup>2</sup>/bag  
Unit: MBq/bag

Human health per Bag				
	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
Daly	1,57E-04	5,17E-04	2,50E-04	1,97E-04
Daly*yr	2,98E-17	1,06E-16	7,99E-17	5,50E-17

Human health per Year				
	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
Daly	1,01E-01	5,27E-02	1,10E-01	7,08E-02
Daly*yr	1,92E-14	1,08E-14	3,51E-14	1,98E-14

**Human health impact per bag : PE-bag performs best**

**Human health impact per year: PE-bag (multiple use) performs best**

	Ecosystem quality per Bag			
	PE-bag (one-time)	PE bag (multiple us	Paper bag	Biodegradable bag
PDF	2,36E-13	7,69E-13	4,00E-13	3,17E-13
PDF*yr	5,54E-16	5,47E-15	7,27E-15	1,81E-14

	Ecosystem quality per Year			
	PE-bag (one-time)	PE bag (multiple us	Paper bag	Biodegradable bag
PDF	1,51E-10	7,84E-11	1,76E-10	1,14E-10
PDF*yr	3,56E-13	5,58E-13	3,20E-12	6,52E-12

**Ecosystem quality per bag: PE-bag performs best**

**Ecosystem quality per year: PE-bag(multiple use) performs best**

- b. Calculate the LCIA again, this time using values for specific regions from the provided GoogleEarth files, as specified in the table below. What difference does it make for the impacts on human health and ecosystem quality?

	PE bag, one-time	PE bag, multi-use	Paper bag	Biodegradable bag
Land occupation	India	Japan	Norway	South Africa
Particulate matter	India	Japan	Norway	South Africa
Water consumption (HH)	India	Japan	Norway	South Africa

Note: try to pick the highest value within each country

	Pe BAG	Pe Bag multi use	Paper Bag	Bio
Land	0,00000377	0,000000138	7,82E-09	0,00000449
PM	0,00336	0,00147	0,00147	0,000315
WATER	XXX	XXX	XXX	XXX

Note: Unit for land in table above is PDF/km<sup>2</sup>, not PDF/m<sup>2</sup>

Part II Methods

Methods part 4 (Life cycle assessment)

<http://www.teaching.industrialecology.uni-freiburg.de/>

**Human health per Year**

	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
Daly	1,38E-01	5,90E-02	1,12E-01	7,05E-02
Daly*yr	1,92E-14	1,08E-14	3,51E-14	1,98E-14

**Human health per Year --> Local-Global**

	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
Daly	3,71E-02	6,29E-03	1,92E-03	-2,60E-04
Daly*yr	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Bio smaller DALY, all other higher values

	PE-bag (one-time)	PE bag (multiple uses)	Paper bag	Biodegradable bag
<b>Aquatic Ecosystems [PDF]</b>				
<b>SUM [PDF]</b>	3.6E-11	1.8E-11	4.1E-11	2.7E-11
<b>P [PDF*yr]</b>	3.49E-13	5.54E-13	3.19E-12	6.52E-12

	<b>Ecosystems (aquatic and terrestrial) [PDF]</b>			
<b>SUM [PDF]</b>	1.59E-10	7.86E-11	1.76E-10	5.92E-10
<b>Nox [PDF*yr]</b>	3.56E-13	5.58E-13	3.20E-12	6.52E-12