Examen – Winter 2017 Answers
of quantitative questions

2.4) 537.1828
2.5)

PET	88%
Elect	10%
Transport	0%
GN	0%
Combustion GN	2%

4.2) 1.32 kg log wood/kg wood board
4.3) 1 kg log wood /kg wood board

1. Functiuonnual unit, reference flow calculation (1,5 point)

Suppose you have to do some work for a Quebec environmental organization whose mission is to educate the local population about the environmental impacts of current products and to propose "green" alternatives. Your current task is to perform a Life Cycle Assessment (LCA) comparing:

- A disposable polyethylene plastic bag
- A reusable polypropylene plastic bag

Disposable polyethylene plastic bag

Reusable polypropylene plastic bag

Figure 1: Bags

1.1 Name three aspects that distinguish the two product systems compared from an environmental performance point of view (0.5 points)

1.2 Suggest an appropriate functional unit for this LCA. (0.5 point)

1.3 For a reference flow, considering the functional unit you chose (question 1.2), write the full equation used to scale the reference flow (you do not have to put any numbers, simply indicate the nature and units of the different key parameters used).
(0.5 point)

2. Simple calculation of carbon footprint - case of PET bottle (5 points)

You need to make a "cradle-to-door" carbon footprint on a 1L PET bottle used to sell drinking water to consumers (Figure 2). The filling, the transport of the full bottle, the use and the end of life of this bottle are excluded from your study. As a reminder, a carbon footprint is a LCA that considers only the "climate change" impact category.

Figure 2 : PET water bottle

You have the following information:

- The bottle is made of 100% virgin PET (not recycled)
- The empty water bottle has a mass of 35 grams.
- It is formed by injection molding of PET granules. This process uses 1.5 kWh of electricity and 4 MJ of heat per kg of PET pellets. The losses of this process are negligible.
- The heat comes from burning natural gas. It takes 0.03 m^3 of natural gas per MJ of heat.
- The combustion of one m3 of natural gas emits 2 kg of CO2.
- PET pellets are purchased at a factory 200 km from the bottle production site
- Cradle-to-the-door emissions (aggregate data) for PET, transportation, natural gas and electricity are given in Table 2.1.
- The characterization factor for methane is 34 kg CO2e / kg CH4.

Tableau 2.1 : GHG emission of cradle to door process (aggregated data)

	CO_2	**CH_4**
	[kg]	[kg]
Electricity, per kWh	1	-
Transport, per tkm	0,25	-
Production and transport of natural gas, per m^3	0,28	0,006
Production of PET granules, per kg	1,6	0,35

2.1 What does the unit "kg CO2e" represent? (0.25 point)

2.2 When referring to an inventory, what do the following terms mean: "cradle to door", "door to door" and "cradle to grave"? (0.25 point)
2.3 Represent the complete life cycle of a PET bottle by a process tree. Clearly indicate the boundaries of this study. Identify aggregated elementary processes with an asterisk* (0.5 point)
2.4 Calculate the "cradle to door" carbon footprint for the following functional unit: Produce 1000 1 liter PET bottles. (3 points)
2.5 Calculate the relative contribution of each of the stages of the life cycle considered in your study. (1 point)

3. Recycling (1,5 point)

You must now extend the LCA performed in question 2 to the complete life cycle of the bottle. You also want to consider the fact that 50% of PET is recycled at the end of life, but of that 50%, only 10% is used to produce new PET bottles.

3.1 Draw two process trees: one that discusses recycling through the "end-of-life recycling" approach and one that processes recycling through the "recycled content" approach (1 point)

3.2 You know that the recycling of PET is constrained by the collection: all PET collected is recycled, but there is a lot of PET (50%) that is simply discarded. Which of the two approaches (end-of-life recycling or recycled content) would be better to stimulate additional PET collection? (0.5 point)

4. Multifunctional process (2 points)

Consider the elementary process in Figure 3.

4.1 Give a reason why the elementary process in Figure 3 can not be integrated into an LCA as such without imputation or extension of boundaries. (0.5 point)

4.2 Using an economic allocation, what is the amount of roundwood attributed to boards, in kg of roundwood per kg board? (0.5 point)

4.3 Using a mass allocation, what is the amount of roundwood attributed to boards, in kg of roundwood per kg board? (0.5 point)

4.4 What additional information would you need to extend the boundaries?

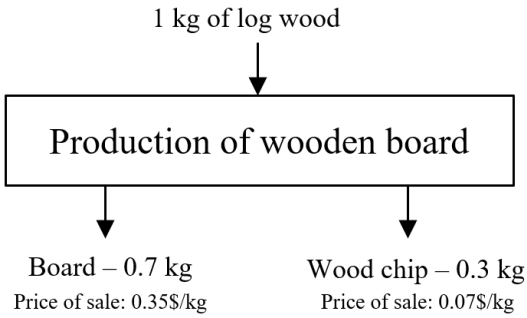


Figure 3: Multifunctional process of wooden board production

5. Interpretation (5 points)

Hydro-Québec commissioned the CIRAIG to conduct a LCA study of the electric vehicle (EV) and analyze if it is a significant environmental advantage compared to the conventional gasoline vehicle (CV). The results are shown in Figure 4.

5.1 Interpret the results in response to the question of whether the latter represents a significant environmental benefit compared to conventional vehicles. (1 point)

5.2 Why are VE impacts based on distance traveled consistent across all impact categories, or almost? (0.5 point)

5.3 The reviewers insisted on including in the environmental profile the Mineral Resource Extraction indicator in addition to the 4 IMPACT 2002+ indicators of damage. How do you explain this query? (0.5 point)

5.4 The study was reviewed by a panel of experts. Was it really necessary? Justify your answer (0,5 point)

5.5 Can the results of the study, conducted in a Quebec context, inform the choice of a consumer in the United States on the environmental preference between the two vehicles? Justify your answer and indicate how it would be possible to use these results. (0.5 point)

5.6 Finally, can the study be used to justify the promotion of the electric vehicle in Quebec on a large scale or would it be necessary to complete the analysis with other results? Which ones, if any? (1 point)

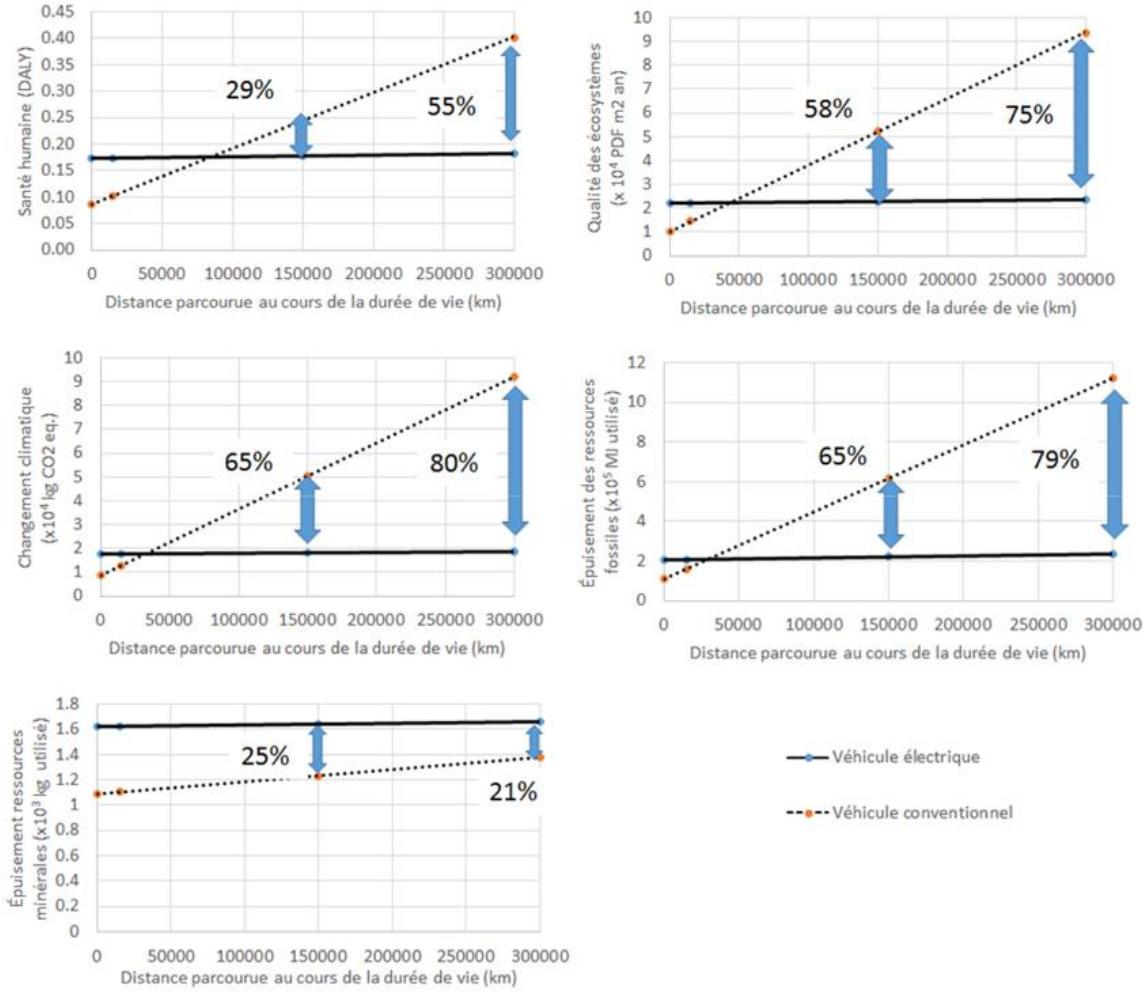


Figure 4: Potential impacts in function of total distance traveled by the car

6. Impact Assessment (4 points)

6.1 On the basis of the information given in Table 6.1 and Figure 4, determine for the four IMPACT 2002+ damage indicators, which of the two vehicles (electric or conventional) offers the best environmental performance in a context of United States. Based on your answer on the functional unit "to travel 150 000 km", considering the same consumption as for the study in the Quebec context, ie for the VE of 19kWh / 100km and the VC of 7.6 l / 100km. (2 points)

6.2 What is the significance of a normalization factor and its units expressed in points? Is this element mandatory in life cycle assessment? For what purpose is standardization useful? (0.5 points)

6.3 Describe a chain of cause and effect of your choice. For this one, please identify the inventory data (1-2 elementary flows), the problem-oriented indicator, the damage-oriented indicator and the corresponding characterization factors. (1.5 points)

Tableau 6.1: Processus d'électricité

	Climate Change	Ecosystem quality	Human health	Ressources
	point	Point	point	point
electricity, low voltage//[US] market group for electricity, low voltage	6,74E-05	1,30E-05	2,67E-04	7,54E-05
	kgCO2-eq/ point	PDF-m2-yr/ point	DALY/ point	MJ/ point
Normalization factors IMPACT 2002+	9901	13699	0,0071	151976

7. Interpretation of your project (2 points)

Next questions are related to the interpretation phase of your team project (comparative LCA).

7.1 Qualification of sensitivity and uncertainty. (1.5 points)

You used several types and sources of data during your comparative LCA. Please:

• Briefly identify one (1) piece of data that you would place in quadrants 1, 2 and 3, respectively, and two (2) pieces of data that you would place in quadrant 4.

• Briefly give the source you used in your LCA to obtain those data

Sensitivity→	Quadrant 2	Quadrant 4
	Quadrant 1	Quadrant 3
	Uncertaintieas→	

7.2 Amélioration de l'ACV (0,5 point)

Suppose you have a few extra weeks and a $ 25,000 budget to improve your study. What would you do first?

8. Interpretation **(2 points)**

Two independent LCA studies of a wooden table have very different results for the climate change impact category. You realize it's because one of the studies included biogenic carbon, and the other one excluded it.

8.1 Describe what biogenic carbon is in the context of a stroke. (0.5 point)

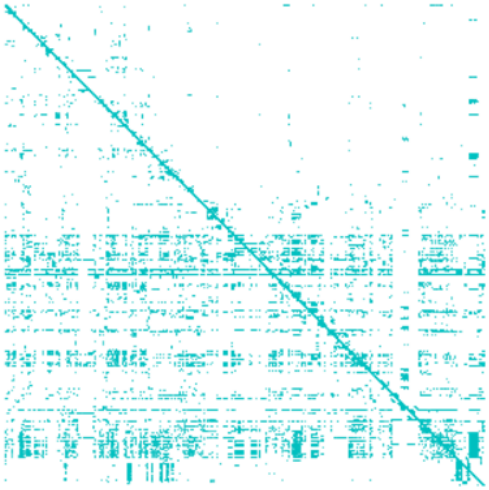
8.2 What is the assumption made when a LCA excludes biogenic carbon? (0.5 point)

8.3 In the case of LCA of a wooden table, how will the consideration of biogenic carbon change the results of the following life cycle stages: wood growth, sawmill production and the end of life of the table (assuming the table is buried). (1 point)

Bonus Questions

The following questions are short bonus questions. You do not have to answer them. Each correct answer is worth +0.25 points (bonus).

Bonus.1 Nome the following matrix. Explain what represent the diagonal. Explain the representation of sign (+ or -) in the matrix.



Bonus.2 Name two things you can do with disaggregated inventory data that you can not do with aggregate inventory data.

Bonus.3 Name two elementary streams classified in the acidification impact category.

Bonus.4 Name 3 differences between risk analysis and life cycle assessment