Life Cycle Assessment of Avallen Calvados

Produced from apples in Normandy - France

With Avallen Spirits BV

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Main findings

In this study, an environmental life cycle assessment (LCA) of an alcoholic beverage produced by Avallen Spirits BV, referred to as Avallen Calvados was conducted. The assessment focused on climate impacts represented by the 'Global Warming Potential in the next 100 years (GWP100)'. The study showed a high potential for carbon sequestration in apple orchards that results in negative carbon emissions. This makes Avallen Calvados a carbon negative product (-2,73 kg CO_2-eq / packed bottle of Avallen Calvados). However, current estimates are based on scientific studies from Italy and it is unclear whether the situation is representative for the Normandy orchards. The study showed high potential, but further research is required for determining a more accurate figure. If carbon sequestration in orchards is not taken into account, then the climate impacts are +0,69 kg CO_2-eq / packed bottle of Avallen Calvados. It appears that the packaging glass of the bottle has highest contribution to the climate impacts (around 70%). Next is LPG use for distillation (15%). When compared to benchmark products, Avallen Calvados shows clearly lower impacts compared to the benchmark products (55-60% lower on Climate change impact). Partly this is the result of a lower weight of the bottle and partly a results of lower impacts of the spirit (ethanol) production. All other components (labels, cork, seal, packaging) have minor contribution.
With respect to water use, Avallen Calvados uses much less water compared to the benchmark products (Water consumption of Avallen is 70-95% lower in comparison to benchmark products).

1. Introduction

1.1. Background

Avallen Spirits BV is a company based in Amsterdam, NL that produces a Calvados, a traditional cider brandy made from apples that are grown in Normandy, France. Forty different varieties of apples are used from 300 different orchards, all located in the heart of La Manche, Normandy. The ambition of Avallen is to produce 'the most sustainable spirit that can be made'. Sustainability is at the very core of Avallen's business.
In this study, environmental impacts are calculated of Avallen Calvados using Life Cycle Assessment (LCA). Life Cycle Assessment is the most widely accepted methodology for calculation of environmental impacts and has been standardized in a series of International standards and protocols:
NEN-EN ISO 14040 [1], NEN-EN ISO 14044 [2], NEN-EN 15804 [3] and NEN-EN ISO 14025 [4]. These standards are followed in this study. According to these standards, there are four phases in an LCA study:

a) Goal and scope definition
b) Inventory analysis
c) Impact assessment
d) Life cycle interpretation.

In the goal and scope definition, the purpose of the LCA is defined, as well as the system boundary and the level of detail (which environmental impacts are taken into account). The life cycle inventory analysis is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study. The impact assessment contains the results (environmental impacts) of the analysis. The life cycle interpretation is the final phase of the LCA procedure, in which the results are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

Paragraph 1.2 contains the goal and scope definition. Chapter 2 contains the inventory analysis. Chapter 3 is the impact assessment / life cycle interpretation and chapter 4 describes a comparison to benchmark products.

1.2. Goal and scope definition

The goal of this study is to assess the environmental impacts of a bottle of Avallen Calvados. Results will be used by Avallen Spirits in communication with stakeholders. The scope of the assessment is 'cradle-to-factory gate'. This means that raw materials are taken into account and the assessment is performed up to the production of the product. The product unit is defined as:

- A 0,7 L bottle with Avallen Calvados (40% vol) including cork and labels and the 6 bottle box material.

The assessment will focus on climate change effect represented by the Global warming Potential in the next 100 years (GWP100) as defined by the Intergovernmental Panel on Climate Change (IPCC). For benchmarking, also a comparison on water consumption is made.

2. Inventory analysis

Paragraph 2.1 contains a flow diagram showing the production process of Avallen Calvados. Paragraph 2.2 gives an overview of process data that are used in the calculations. Paragraph 2.3 explains allocation issues and paragraph 2.4 described carbon sequestration by apple trees and cork trees.

2.1. Process description

Figure 1: Process diagram Avallen Calvados bottle 0,7 L

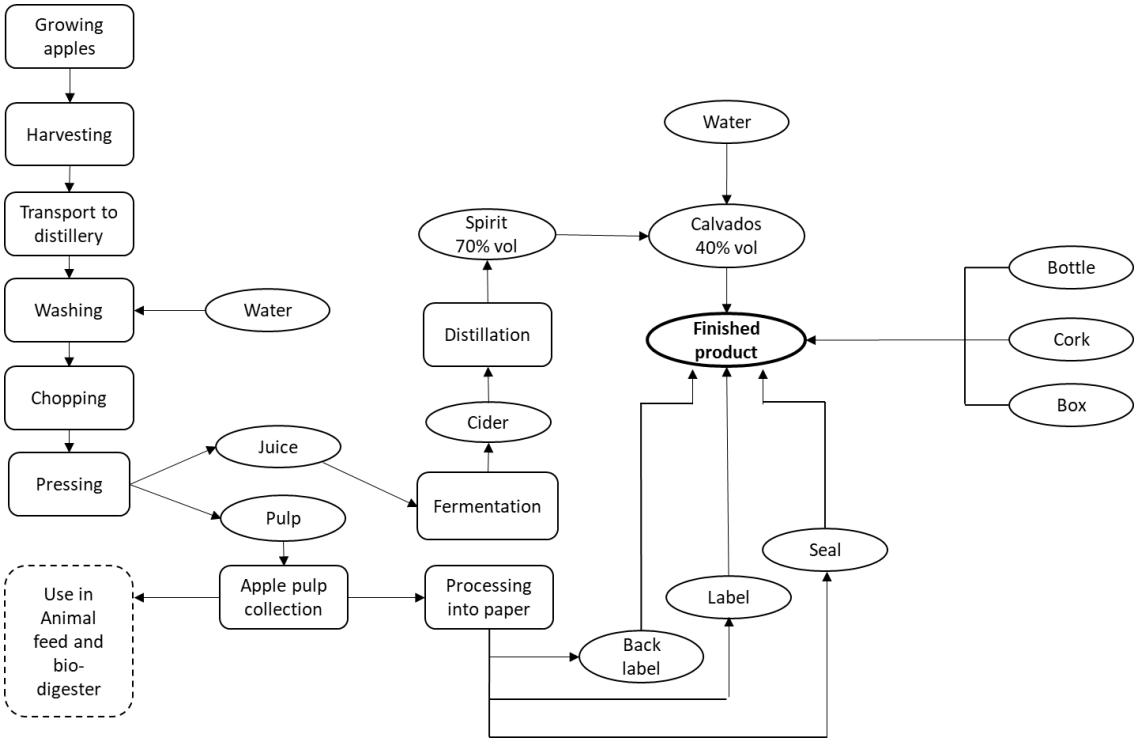


Figure 1 shows the production process of a bottle of Calvados (0,7 L / 40% vol). It starts with growing the apples in orchards in Normandy. The apples are collected/harvested and transported to the distillery where they are washed with water. Then they are chopped and pressed to extract the juice (cider). The remaining pulp is collected and used as a raw material to produce 'Apple touch', a paper-like material. This paper is used for the production of a label, a back-label and a seal that are used on the bottle. The cider is fermented and distilled to obtain a spirit with 70% of alcohol. By adding water, the alcohol concentration is brought down to 40% to obtain the Avallen Calvados. This liquor is bottled, closed with a cork and packed in a box to be sold / shipped. One box contains 6 bottles.

2.2. Process data

Tables 1 – 5 show the various material-, energy- and transport requirements of all processes in the life cycle of a packed bottle of 0,7 L Avallen Calvados 40% vol. Table 1 shows energy and transport requirements for harvesting of apples and transport to the distillery. Table 2 shows water use for washing of apples. Table 3 shows energy requirements of chopping and pressing of apples. Table 4 shows input requirements of distillation of the spirit. Table 5 shows packaging requirements, i.e. bottle, labels and packaging. Table 6 shows water use in the distillery.

Inputs	Amount	Unit
Diesel use	15	L / ha
Apple harvest	31,5	ton / ha
Transport to distillery		
Average distance to distillery	10	km

Table 1: Harvesting and transport to distillery

Input	Amount	Unit
Water	0,056	m3 / ton of apples

Table 2: Washing of apples

Input	Amount	Unit
Electricity	10,21	kWh / ton of apples
Output	**Amount**	**Unit**
Output juice	650	L / ton of apples
Output pulp	300	kg / ton of apples

Table 3: Chopping and pressing of apples

Inputs	Amount	Unit
Cider	13	L
LPG	0,16	kg per L alcohol
Output	**Amount**	**Unit**
Spirit	1	L spirit at 70% vol.

Table 4: distillation of cider

Inputs	Amount	Unit
Spirit (70% vol)	0,42	L
Water	0,3	L
Bottle	0,54	kg

Label	0,824	g
Back Label	0,829	g
- Pulp	0,29	g
- Recycled paper	0,539	g
Cork	7,2	g
- Wooden stopper	4,6	g
- Cork	2,6	g
Seal	0,489	g
Box per 6 bottles	229	g

Output		
Finished product	1	Packed bottle 0,7 L Avallen Calvados 40% vol.

Table 5: Bottling and packaging of Avallen Calvados

Inputs	Amount	Unit
Water use in distillery	590.000	L
Total produced bottles in distillery	480.000	Bottles
Net water use	1,23	L/Bottle

Table 6: Water use in distillery

2.3. Dataset references

Table 7 gives an overview of database references that have been used to calculate environmental impacts from the process data listed in the previous section. All references are taken from Ecoinvent version 3.5.

Name	Dataset reference	Database
Box material	market for containerboard, fluting medium | containerboard, fluting medium | Europe	Ecoinvent 3.5, Cut-off
Cork, material	market for cork, raw | cork, raw | Global	Ecoinvent 3.5, Cut-off
Diesel	diesel, burned in agricultural machinery | diesel, burned in agricultural machinery | Global	Ecoinvent 3.5, Cut-off
Electricity	market for electricity, medium voltage | electricity, medium voltage | France	Ecoinvent 3.5, Cut-off
LPG	market for propane, burned in building machine | propane, burned in building machine | Global	Ecoinvent 3.5, Cut-off
Recycled paper	graphic paper production, 100% recycled | graphic paper, 100% recycled | Europe	Ecoinvent 3.5, Cut-off
Saverglass	packaging glass production, white | packaging glass, white | Europe without Germany and Switzerland	Ecoinvent 3.5, Cut-off
Transport	market group for transport, freight, lorry, unspecified | transport, freight, lorry, unspecified | Global	Ecoinvent 3.5, Cut-off
Water	market for tap water | tap water | Europe without Switzerland	Ecoinvent 3.5, Cut-off
Wooden stopper	market for sawnwood, softwood, raw, dried (u=10%) | sawnwood, softwood, raw, dried (u=10%) | Europe	Ecoinvent 3.5, Cut-off

Table 7: Dataset references used in the model

2.4. Allocation

Allocation means distributing process inputs / environmental inputs over multiple output products, if applicable. In the production process of Avallen Calvados there is an allocation issue in the multi-output process 'pressing apples' as it produces juice and pulp. The pulp is collected at 0,002 € / kg. As this value is much lower compared to the economic value of the juice[1], it is assumed that impacts are negligible. Therefore all impacts of growing, washing and chopping the apples are allocated to the juice. A ton of apples produces 650 L of juice. As a result, for 1 L of juice 1,54 kg of apples are needed.

[1] The value of the Avallen Spirit is €2,38 / bottle. As 5,51 L of Cider are needed per bottle, the value of the cider is estimated at €0,43 / L. The same value is assumed for the juice. This makes the value of the pulp around 200 times lower compared to the juice. Hence, impacts are 200 times lower (i.e. ~0,4% of juice impacts)

2.5. Carbon sequestration

When trees grow, they use carbon from the atmosphere as the main building block. Carbon in the atmosphere occurs in the form of carbon dioxide (CO_2). Carbon is sequestered in the biomass, root system and soil, removing CO_2 from the air. Several studies investigated carbon sequestration by fruit trees in orchards but the values differ. Scandellari et al. [5] studied carbon sequestration in Italian vineyards and Wu et al. [6] studied carbon sequestration by fruit trees in Chinese apple orchards. An overview is given in Table 8 and 9.The Gala apple grown in Italy is considered to be most comparable to the Normandy situation. Therefore these figures are used in the calculations. The figures from China result in very optimistic figures but uncertainty is also very high. They estimated carbon sequestration to be 14 t C ha^{-1} $year^{-1}$, compared to 0,5 t C ha^{-1} $year^{-1}$ for the Fuji apples and 4,4 t C ha^{-1} $year^{-1}$ for the Gala apples.

Apple type	Process	Amount	Unit
Fuji apple	Carbon sequestration	0,5	t C ha^{-1} $year^{-1}$
		1,83	ton CO2 ha^{-1} $year^{-1}$
	Harvest	61	t ha^{-1} $year^{-1}$
	Net carbon sequestration	0,030	ton CO2/ton apples
Gala apple	Carbon Sequestration	4,4	t C ha^{-1} $year^{-1}$
		16,13	ton CO2 ha^{-1} $year^{-1}$
	Harvest	40	t ha^{-1} $year^{-1}$
	Net sequestration	0,40	ton CO2/ton apples

Table 8: Estimate of CO_2 sequestration in apple orchards, based on Scandellari et al. [5]

Apples					
Low row orchards	35	ton apples/ha	65%	22,75	ton apples ha^{-1} $year^{-1}$
High row orchards	25	ton apples/ha	35%	8,75	ton apples ha^{-1} $year^{-1}$
(Avallen situation)			Total	31,5	ton appels ha^{-1} $year^{-1}$
Carbon sequestration in orchard				14	ton C ha^{-1} $year^{-1}$
(Chinese situation)				51,3	ton CO_2 ha^{-1} $year^{-1}$
				1,63	ton CO_2 / ton apples
Carbon sequestration in apples[2]				0,257	ton CO_2 / ton apples
Net carbon sequestration				**1,37**	ton CO_2 / ton apples

Table 9: Estimate of CO_2 sequestration in apple orchards, based on Wu et al. [6]

Also the cork that is used as bottle stopper sequesters carbon dioxide. Carbon sequestration of cork trees has been estimated by Croezen et al. [7] They estimated sequestration to be 0,9 – 1,25 ton C / ton cork. An overview is listed in Table 10.

Cork

[2] based on personal communication with Dr Alan Lakso - Cornell University – NY / USA

Sequestration	0,9-1,25	ton C / ton cork
Average	1,1	ton C / ton cork
	4,0	ton CO2 / ton cork

Table 10: Estimate of CO_2 sequestration in cork trees. [7]

3. Impact assessment / Interpretation

Results of the life cycle impact assessment are shown in Figures 2 and 3. It shows the various elements in the life cycle of the Avallen Calvados bottle. In Figure 2, carbon sequestration in the orchard is taken into account. In Figure 3 carbon sequestration has not been taken into account (only for 'cork' it has been taken into account). As a result of the current assumptions for carbon sequestration, Figure 2 shows a negative result for the climate impact of the Avallen Calvados bottle, caused by the carbon sequestration of the apple orchards. That is '- 2,73 kg CO_2-eq' per packed bottle of Avallen Calvados. This means a net CO_2-uptake. If this were not taken into account, impacts increase and are '+0,69 kg CO_2-eq' / bottle of Avallen Calvados.

Figure 2: Climate impacts of a packed bottle of 0,7 L Avallen Calvados, including carbon sequestration in the orchard.

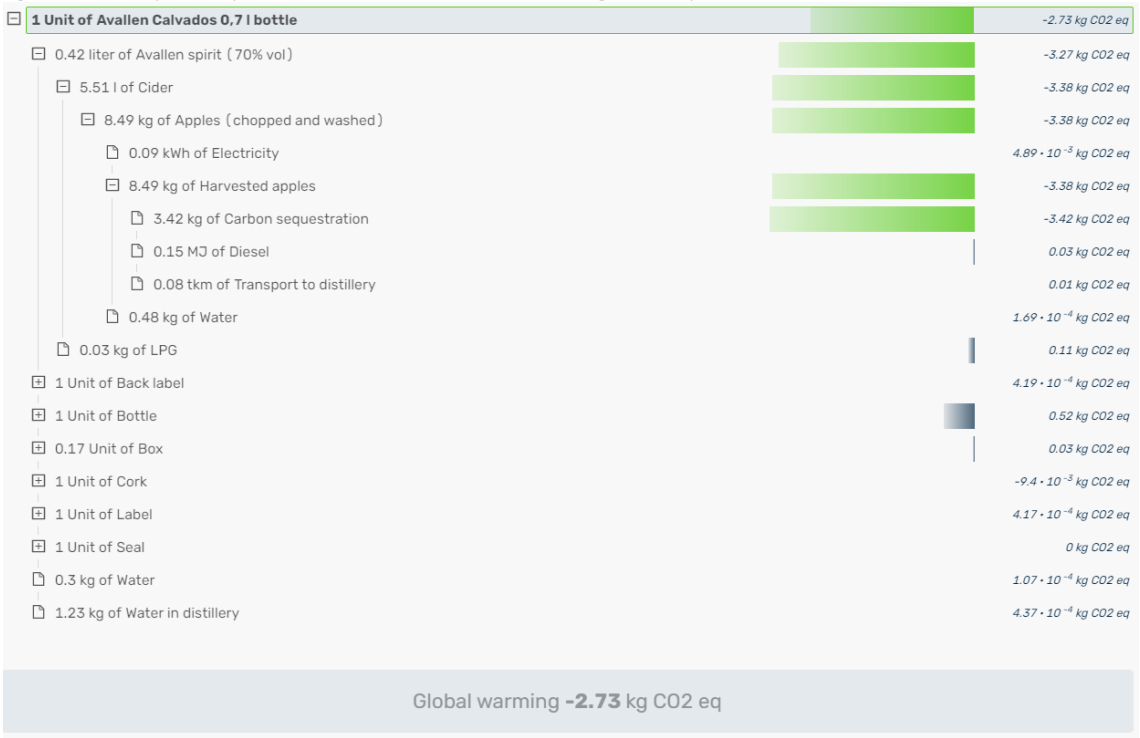
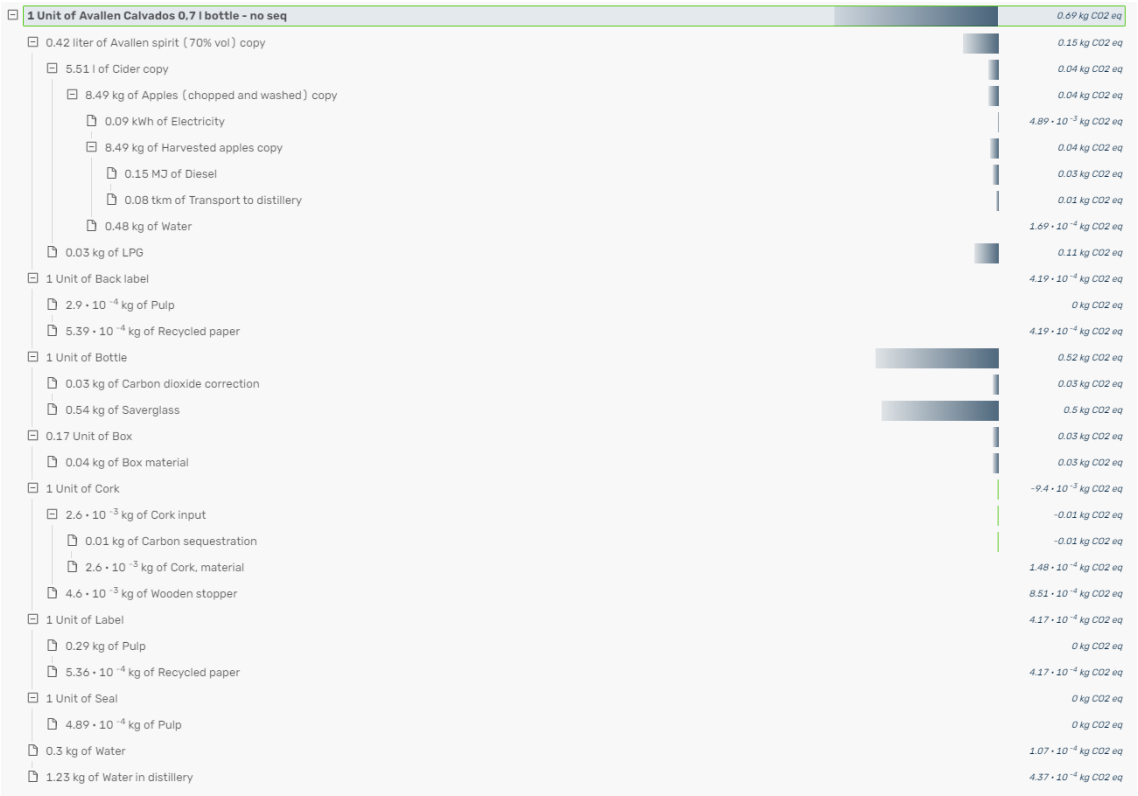
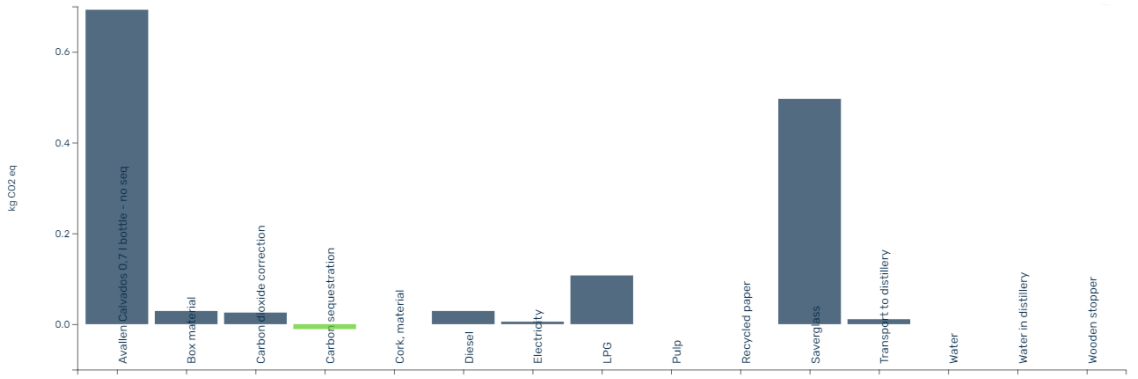


Figure 3: Climate impacts of a packed bottle of 0,7 L Avallen Calvados, **excluding** carbon sequestration in the orchard.



In addition to Figure 3, Figure 4 shows a contribution analysis of climate impacts of materials and processes involved in the production of the Avallen Calvados product excluding carbon sequestration in the orchard. It shows that impacts of the saverglass, used for production of the bottle have the highest contribution to the environmental impact of the product (70%). Contribution of all other elements is relatively low. There are some impacts of LPG burning during distillation (15%).

Figure 4: Contribution of different processes and materials to the climate impacts of a packed 0,7 L bottle of Calvados excluding carbon sequestration in the orchard (sequestration in 'cork' is included!)



4. Comparison to benchmark products

The Avallen Calvados bottle is compared to other spirits to benchmark the results. Similar packaging has been assumed but without the use of renewable materials such as apple pulp. Generic datasets for ethanol production have been used to reflect various alternative spirits. Table 10 shows the input requirements that have been assumed in the benchmark alternatives. Figure 5 shows the comparison of the benchmark products in comparison with Avallen Calvados for the Climate change impact. It shows that the impacts of the Calvados spirit is clearly lower, even if carbon sequestration is not taken into account. However, it should be noted that 0,95 kg CO_2-eq in each of the benchmark products are caused by the bottle. The remainder is due to a difference in spirit impacts.
Figure 6 shows the impacts on water use. It shows that Avallen Calvados uses much less water compared to the benchmark products. Water consumption in the benchmark products occurs primarily during growing the feedstocks and the production of the liquor.

Input	Amount	Unit
Back label – paper	1	g
Bottle – glass	900	g
Box – box material	38,2	g
Cork – cork	2,6	g
Cork – Wooden stopper	4,6	g
Label – paper	1	g
Seal – LDPE film	0,3	g
Ethanol (from maize, potato, rye, sugar cane)	0,28	l
	0,22	kg
Water	0,42	l

Table 11: Input requirements for benchmark products

Figure 5: Climate change impacts of benchmark products

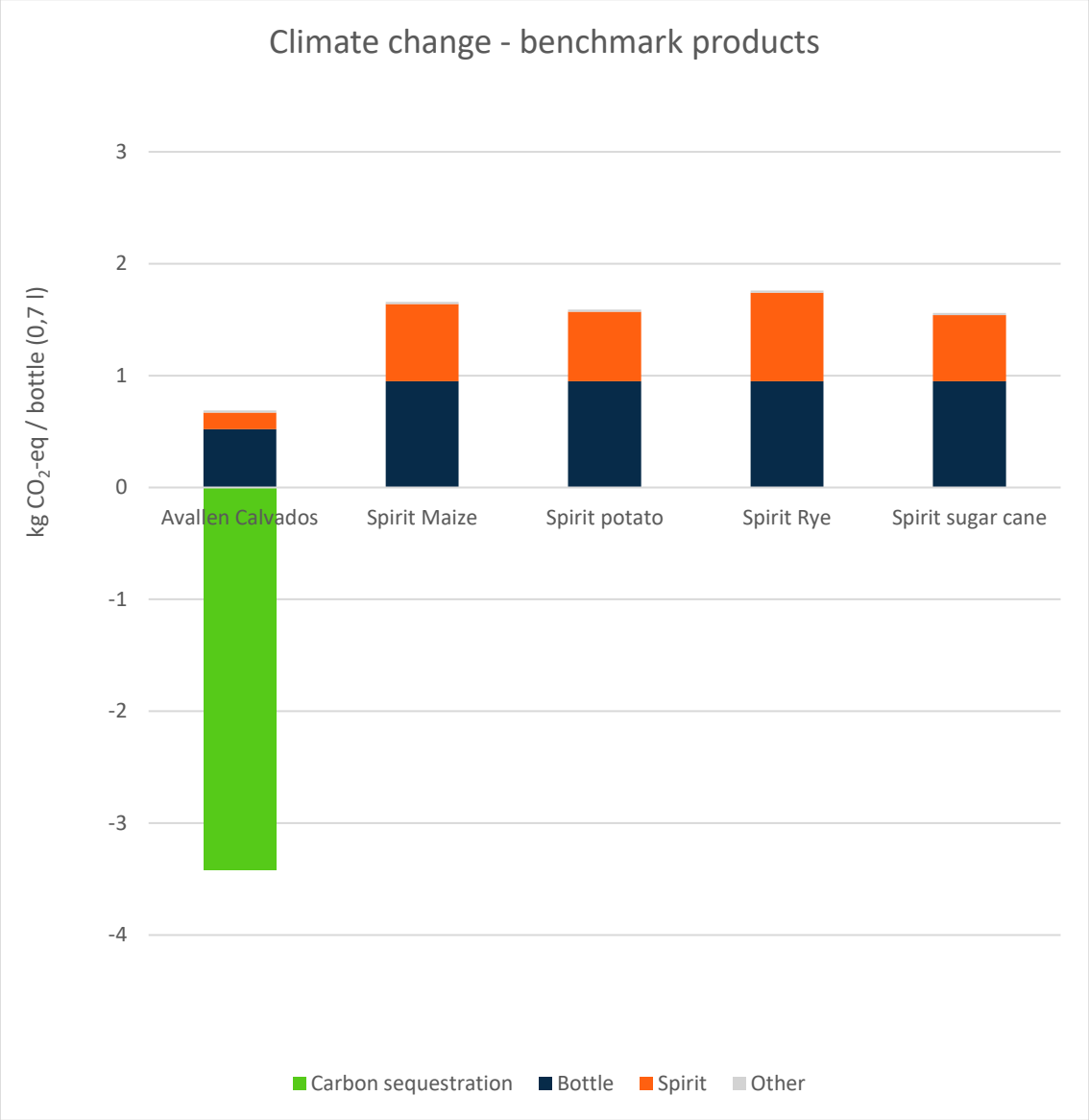
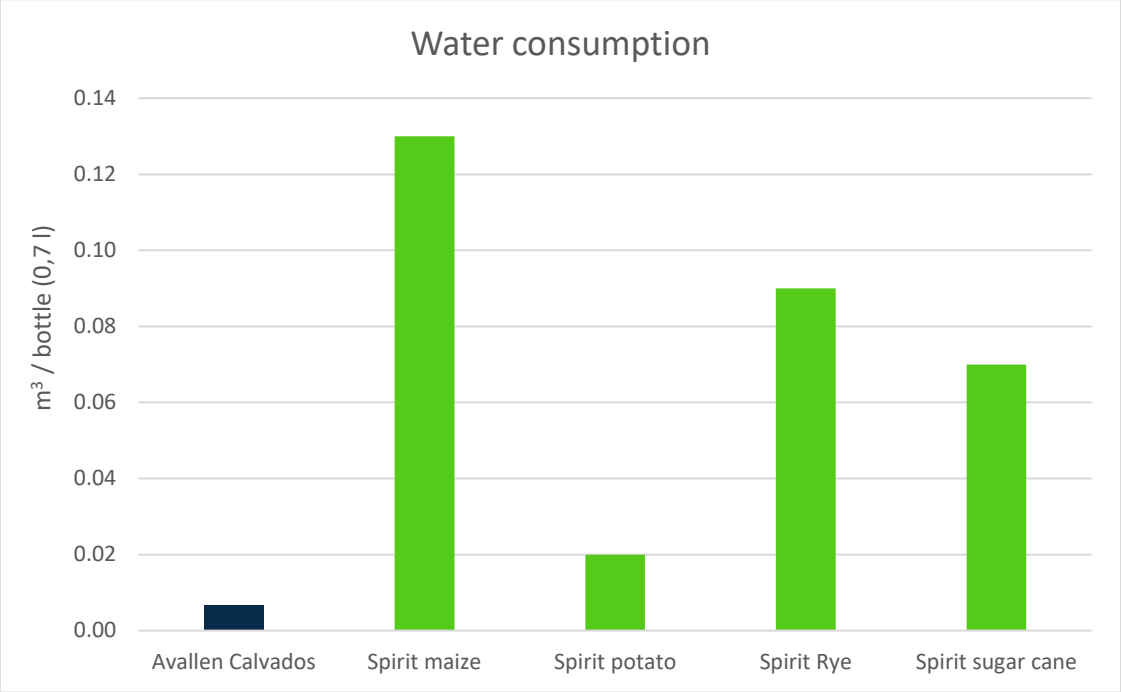


Figure 6: Water consumption impacts of Avallen Calvados compared to benchmark products.


Water consumption
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
m³ / bottle (0,7 l)
Avallen Calvados
Spirit maize
Spirit potato
Spirit Rye
Spirit sugar cane

References

[1] 'ISO 14040: Environmental management – Life cycle assessment – Principles and Framework', International Organization for Standardization, ISO14040:2006.
[2] 'ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines', International Organization for Standardization, ISO14044:2006.
[3] 'NEN-EN 15804: Duurzaamheid van bouwwerken – Milieuverklaringen van producten – Basisregels voor de productgroep bouwproducten', NEN-EN 15804:2012+A1:2013.
[4] 'ISO 14025: Environmental labels and declarations – Type III environmental declarations – Principles and procedures', International Organization for Standardization, ISO14025:2006.
[5] Scandellari, F., Garuso, G., Liguori, G., Meggio, F., Palese, A.M., Zanotelly, D., Celano, G., Gucci, R., Inglese, P., Pitacco, A. and Tagliavini, M., (2016), 'A survey of carbon sequestration potential of orchards and vineyards in Itly. Eur. J. Hortic. Sci. 81(2), 106-114.
[6] Wu T, Wang Y, Yu C, Chiarawipa R, Zhang X, et al. (2012) Carbon Sequestration by Fruit Trees - Chinese Apple Orchards as an Example. PLoS ONE 7(6): e38883. doi:10.1371/journal.pone.0038883
[7] Harry Croezen, Marijn Bijleveld, Maartje Sevenster Natural cork bottle stoppers: a stopper on CO2 emissions? Delft, CE Delft, May 2013

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