reCIRCLE

LIFE CYCLE ANALYSIS AND CIRCULARITY

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Content & Reading guide

READING GUIDE

Key messages, e.g. description of main impacts .

Assumptions or limitations to bear in mind

Main impact .

Summary of results:
CO_2eq, UBP, plastic impacts & circularity

The following table presents the CO_2eq, UBP and plastic impacts of 10,582,000 meals distributed (equivalent to the number of meals distributed by reCIRCLE in 2019) per type of container:

Product	CO2 impact (t CO_2eq)	UBP impact (Mio UBP)	Plastic leakage (t)	Circularity (%)
Average disposable box 	873	1088	2,3	32%
	-77%	-65%	-100%	+67%
reCIRCLE BOX 2*, mixed-washing 	199	380	0	99%

* For an average of 200 uses

① Objective & Assumptions

Functional unit

UF: Distribution of a meal in a takeaway box.

Food photo created by freepik - www.freepik.com

Comparative assumptions

ReCIRCLE BOX 2

Volume: 1000 mL: total weight = 186 g
Description: box in iQ PBT and lid in PP

Polypropylene (PP) box[1]

Volume: 800 mL; total weight = 31.5 g
Description: box and lid in PP

Aluminium (Alu) box[1]

Volume: 980 mL; total weight = 14.5 g
Description: box in aluminium with lid in cardboard and PE film

Kraft paper box[2]

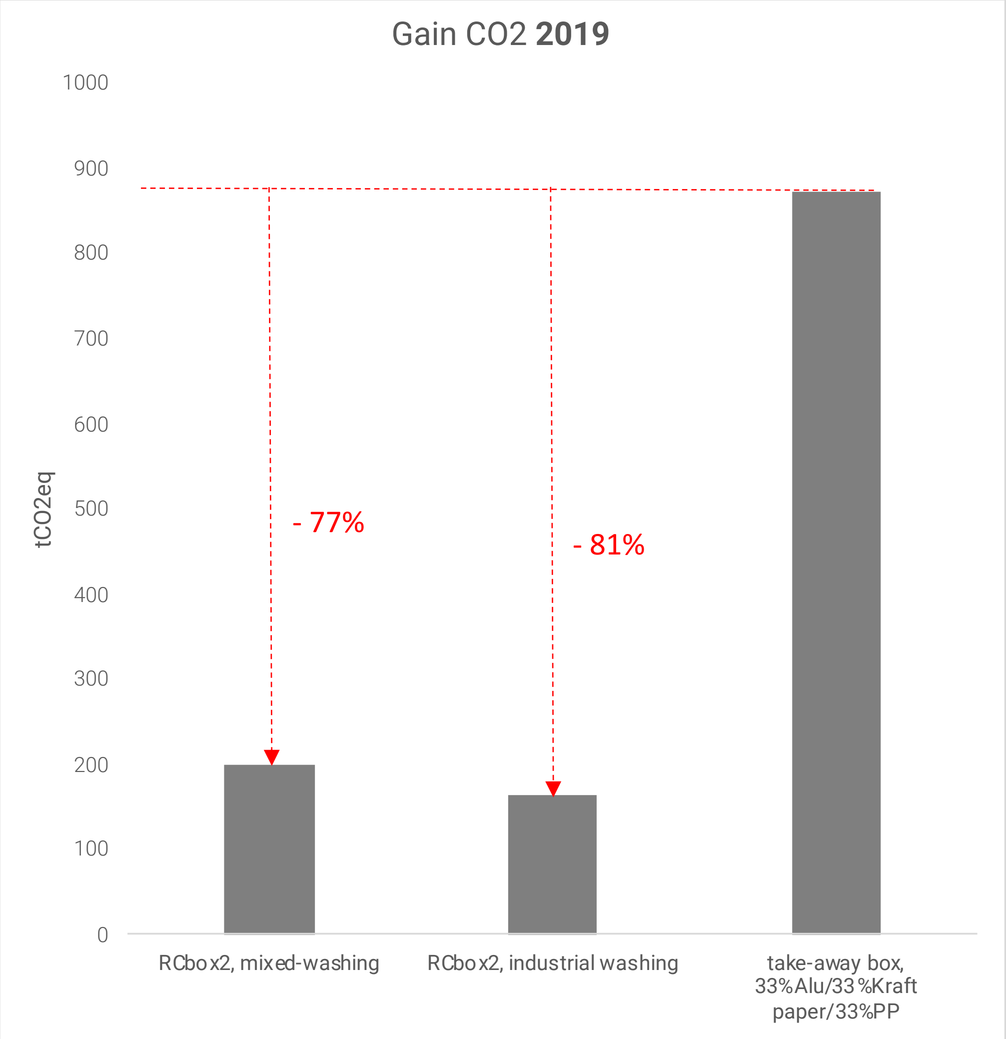
Volume: 940 mL; total weight = 26 g
Description: box in kraft paper and PE film

[1] Gallego-Schmid, A., Mendoza, J. M. F., & Azapagic, A. (2019). Environmental impacts of takeaway food containers. *Journal of Cleaner Production*, *211*, 417-427.
[2] https://www.alibaba.com/product-detail/Custom-printed-disposable-take-away-kraft_1600080237094.html ; https://www.dsymachinery.com/paper-cup-business-tips/

② Environmental impact (CO_2, UBP, Plastic)

2.1 Carbon footprint

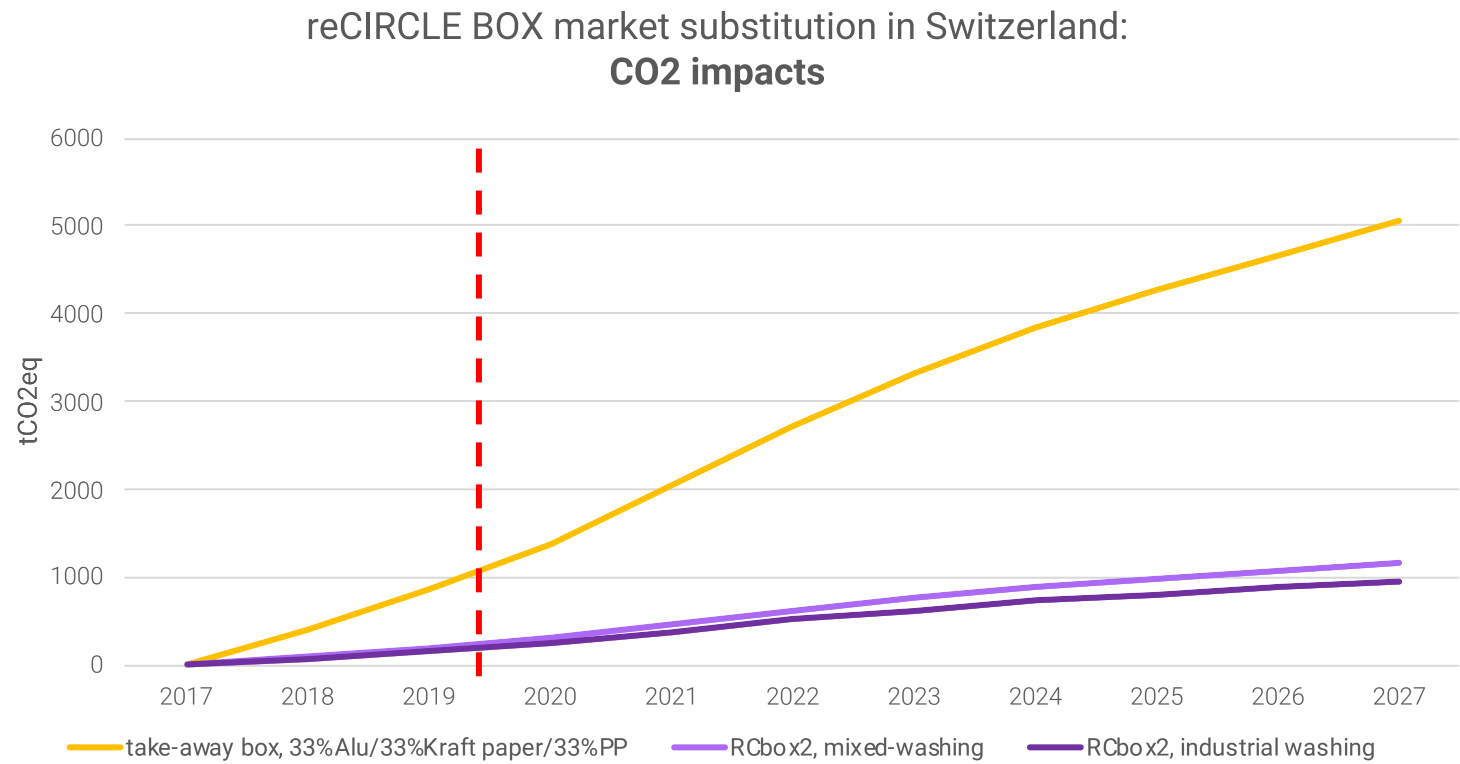
CO_2 gains from reCIRCLE meals in 2019



An average of **200 uses** per reCIRCLE box is assumed.

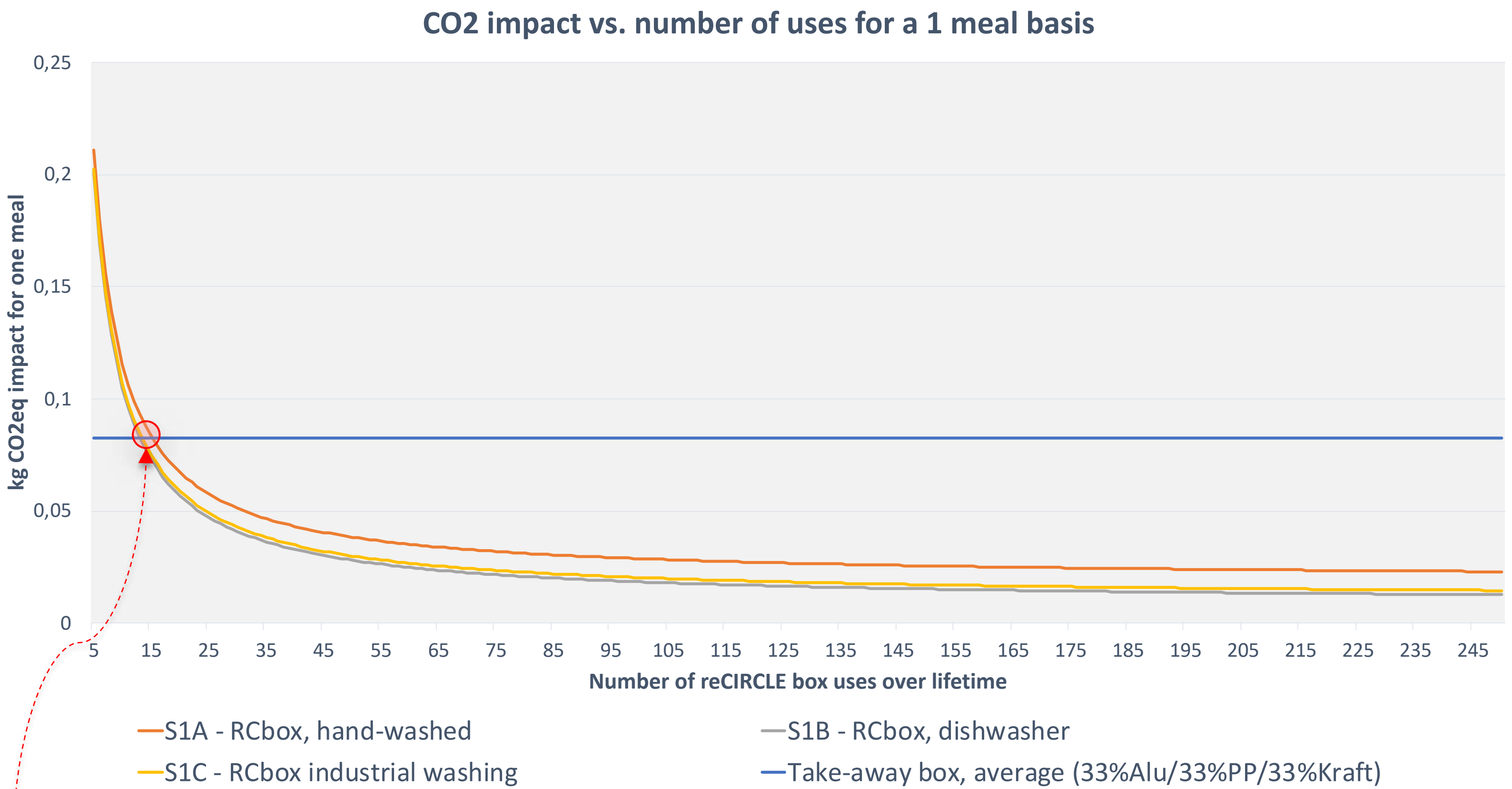
In 2019, substituting the reCIRCLE box2 for some **10 million disposable meal boxes made of** aluminium, kraft paper or polypropylene (assumed in equal shares) **avoided 254 tonnes of disposable meal boxes**. This generated a gain of about **674** tCO_2eq in mixed-washing (50% hand-washing/50% dishwasher) and **709** tCO2eq in industrial washing alone.

Past and future **CO_2 gains** with reCIRCLE boxes



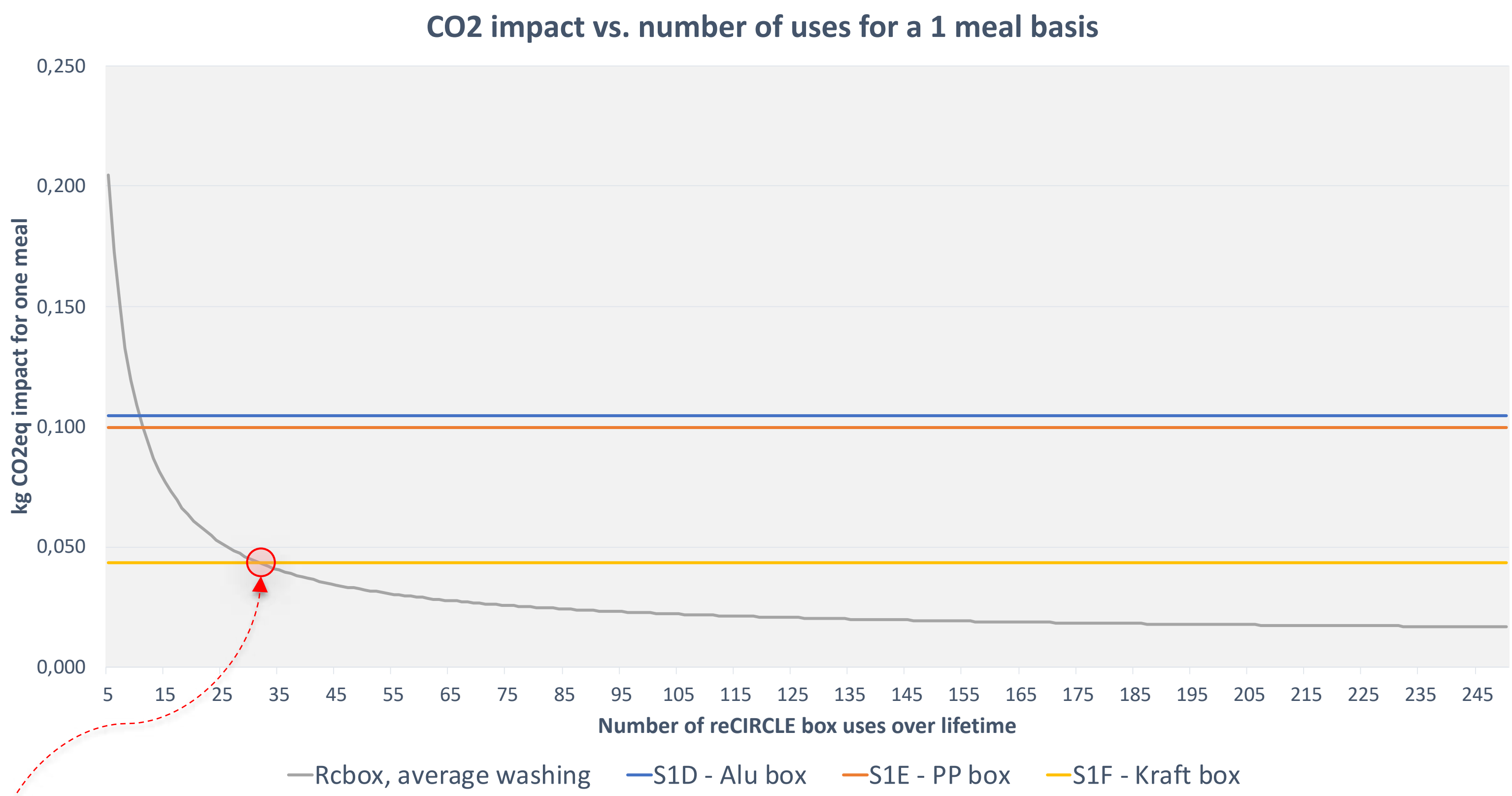
From 2017 to 2019, reCIRCLE boxes (used in mixed-washing) generated gains of about **989** tCO_2eq and could generate future gains of **21,100** tCO_2eq from 2020 to 2027.

Importance of the **number of reuses** for the reCIRCLE (1/2) box



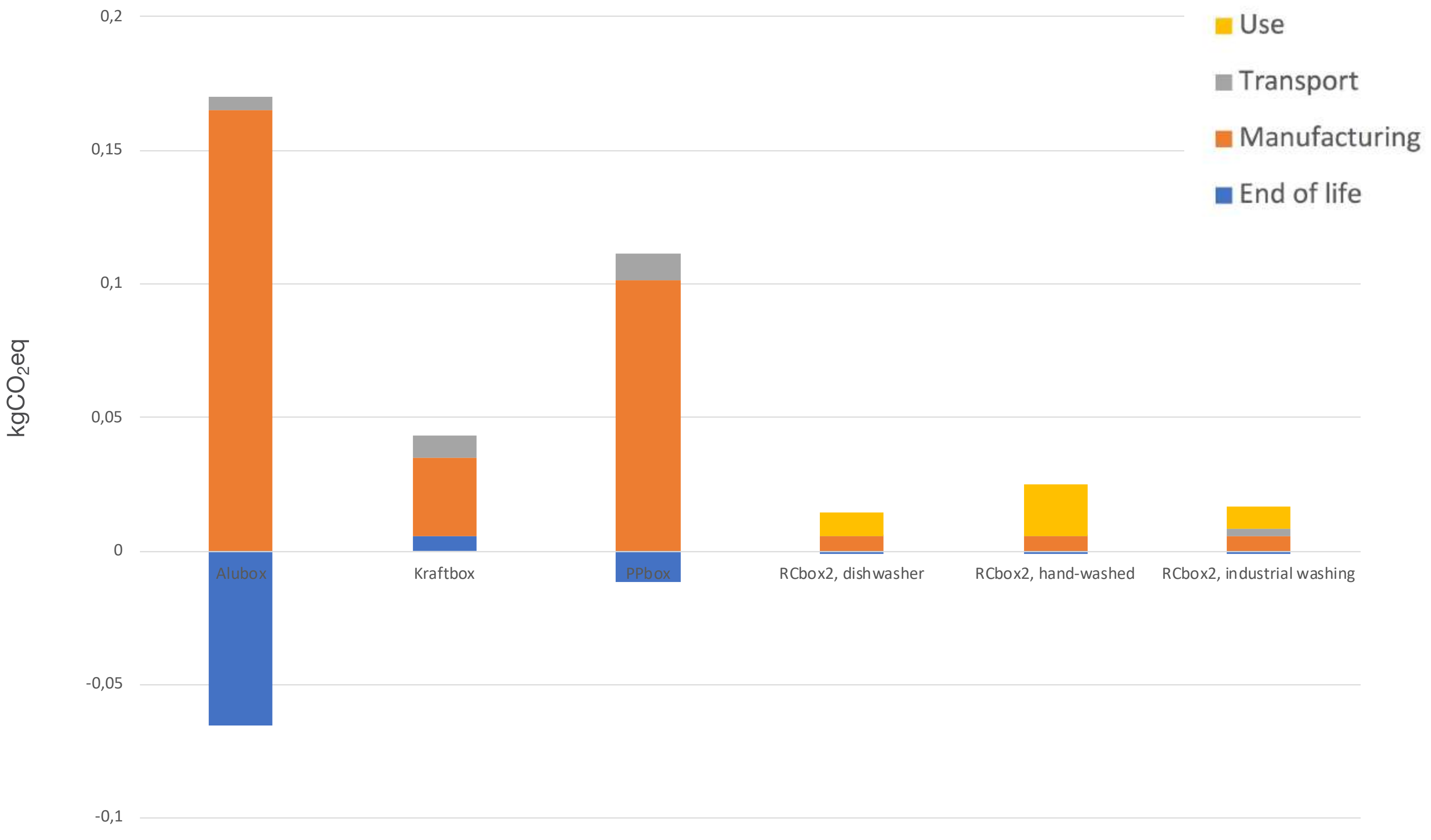
We note that a reCIRCLE box **must be reused** at least **13 to 15 times depending on the type of washing** to have less CO_2eq impact than an average disposable box.

Importance of the **number of reuses** for the reCIRCLE (2/2) box

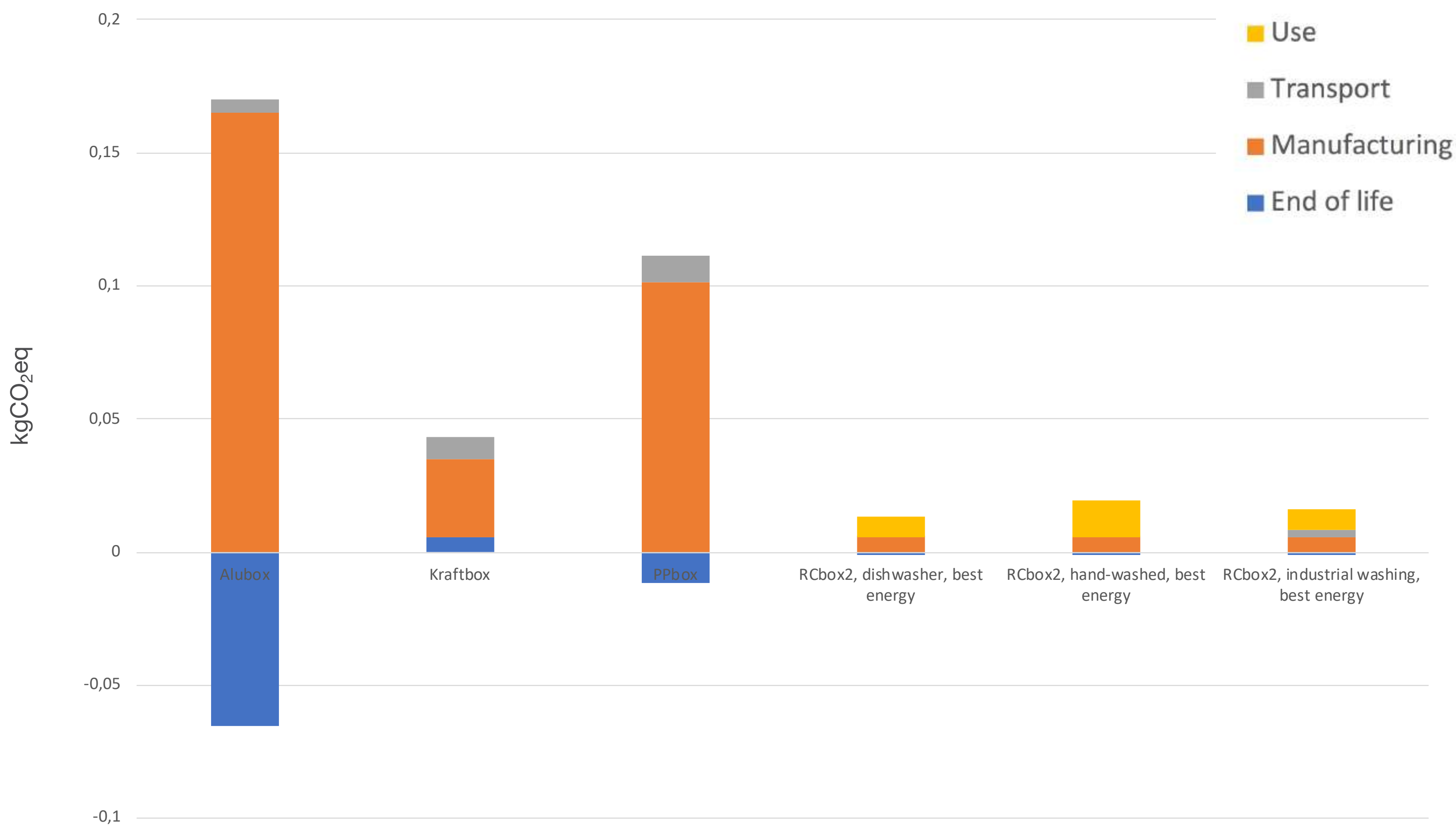


However, if we look at the best disposable alternative considered (at present «Kraft box»), between **30 to 35 reuses** with mixed-washing of the reCircle box are required to have a lower impact

reCIRCLE 2 boxes: $kgCO_2eq$ impacts per meal compared to disposable alternatives, with a **standard energy mix**



reCIRCLE 2 boxes: kgCO_2eq impacts per meal compared to disposable alternatives, with a **50% solar energy mix**

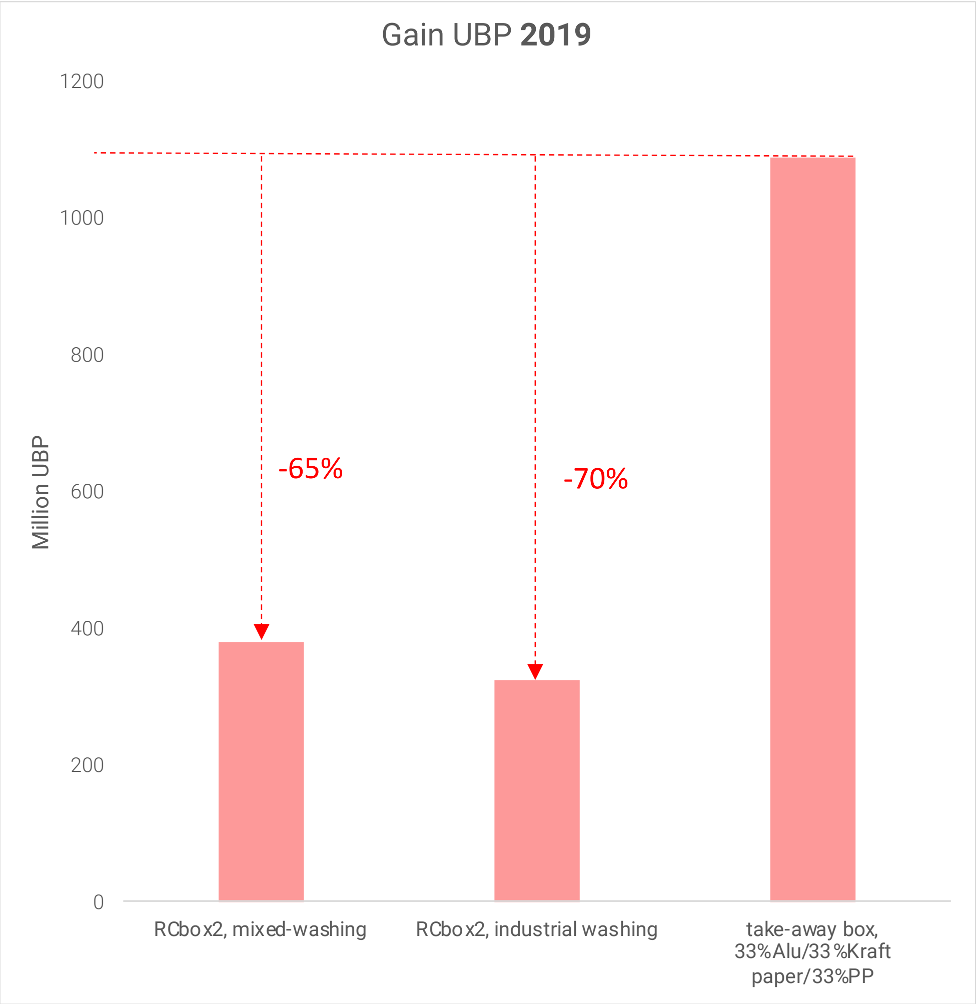


2.2

Ecological load units

UBP

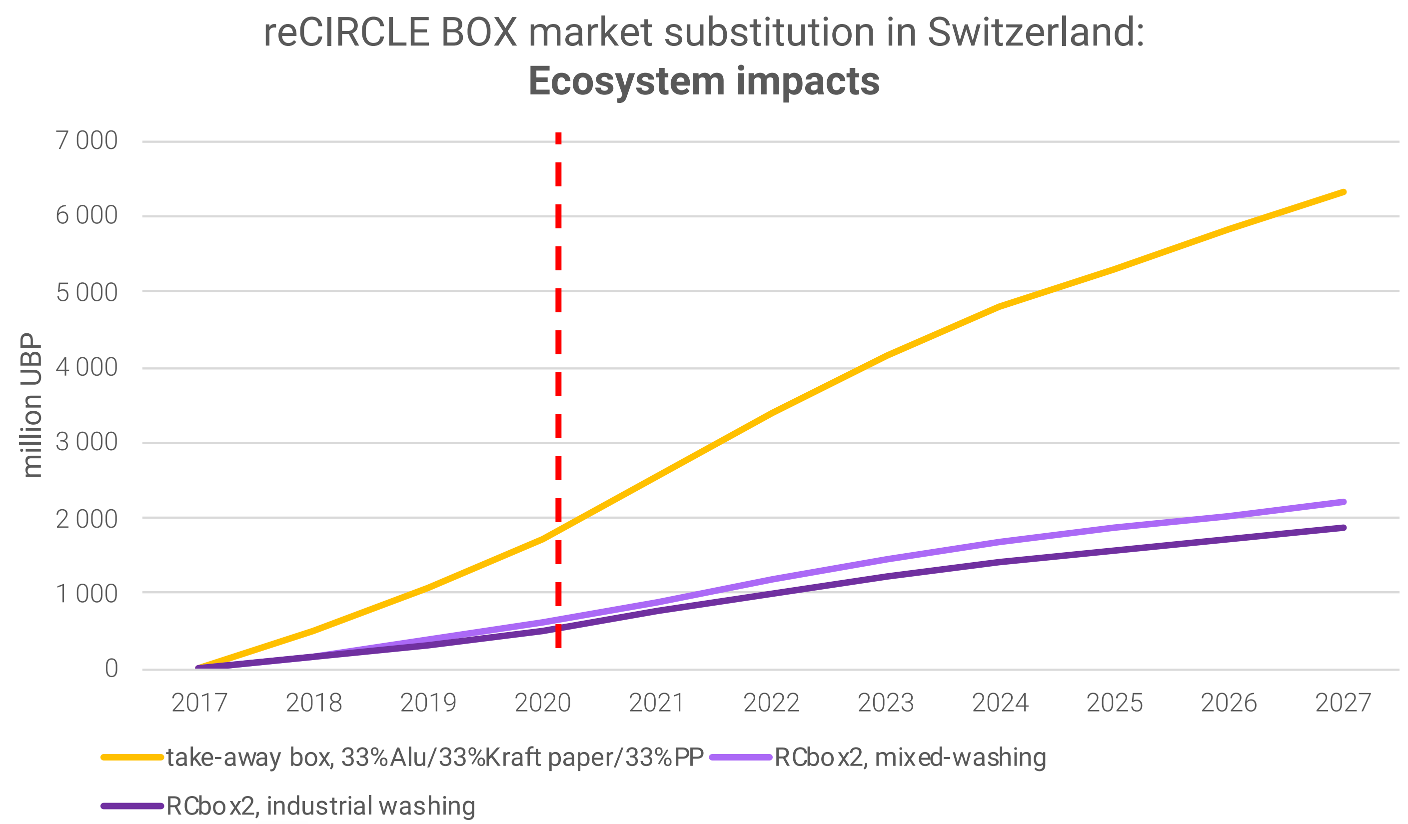
UBP gains with reCIRCLE meals in 2019



An average of **200 uses** per reCIRCLE box is assumed.

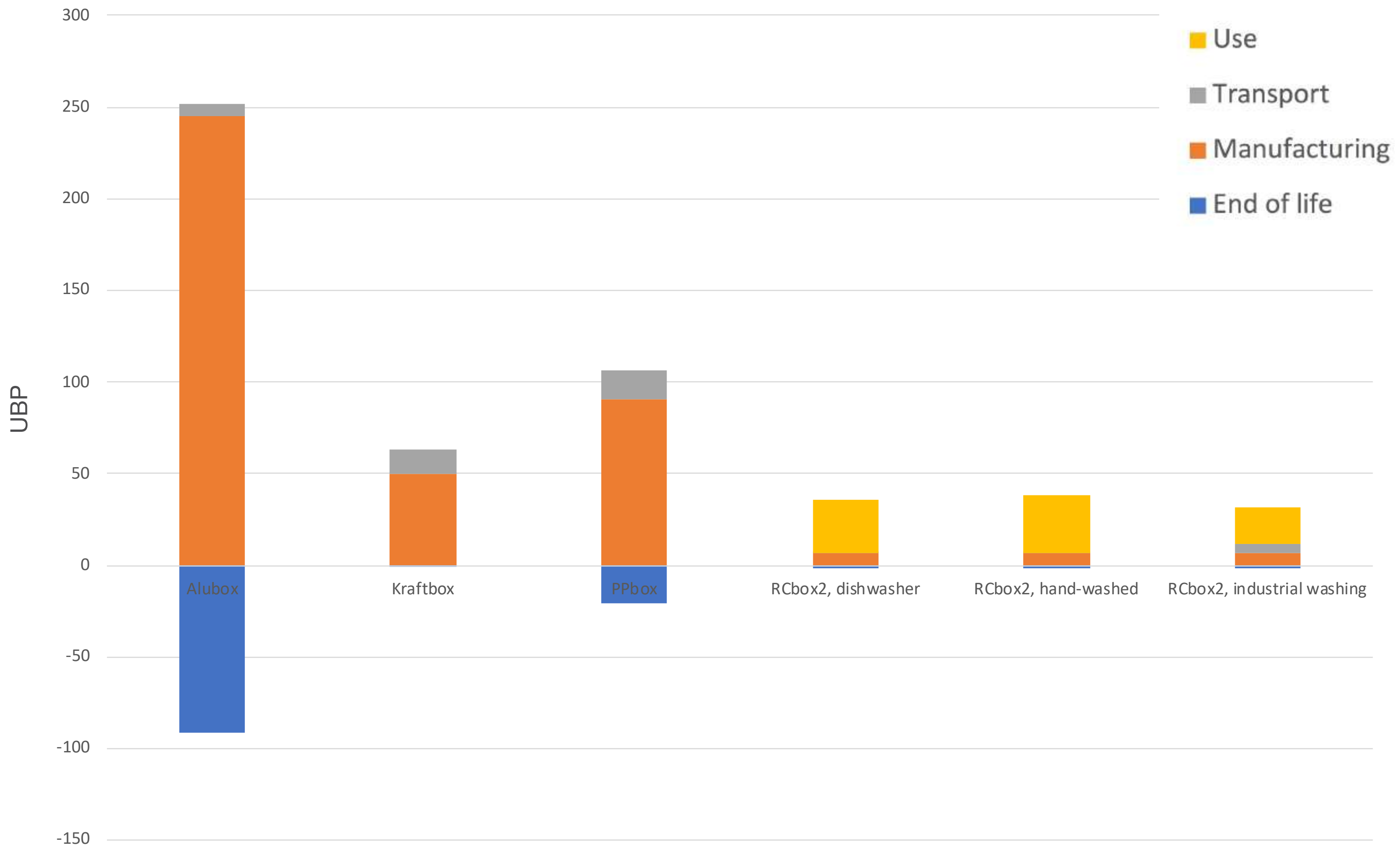
In 2019, substituting the reCIRCLE box2 for some **10 million disposable meal boxes** made of aluminium, Kraft paper or polypropylene (assumed in equal shares) generated a gain of **708** million UBP in mixed-washing (50% hand-washing/50% dishwasher) and **764** million UBP in industrial washing alone. This corresponds to about **1%** of the objective set by the Swiss Government (70 billion UBP)

Past and future **UBP gains** with reCIRCLE boxes

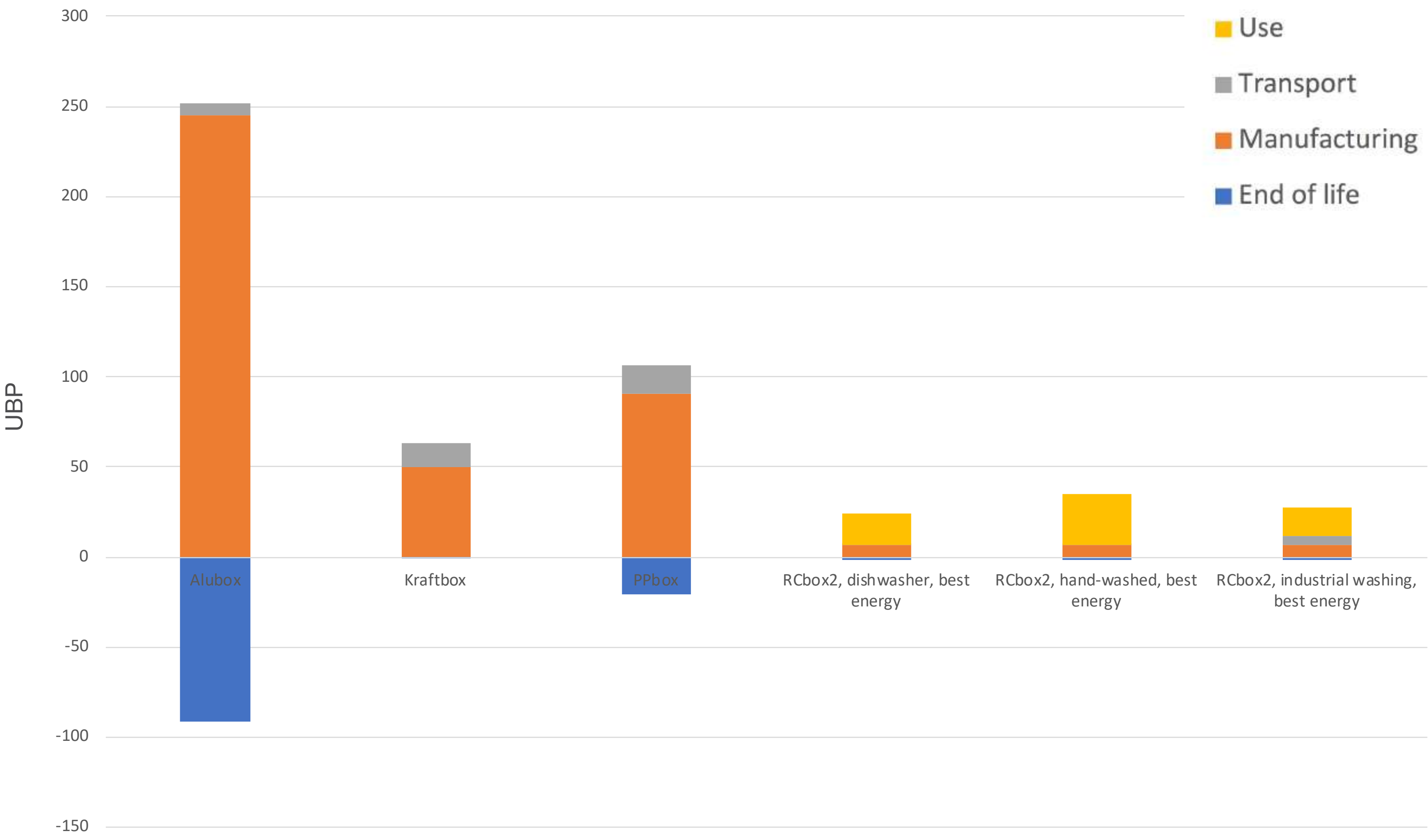


From 2017 to 2019, reCIRCLE boxes (in mixed-washing) generated gains of about **1,038** million UBP and could generate future gains of **22,1477** million UBP from 2020 to 2027.

reCIRCLE 2 boxes: UBP impacts per meal compared to disposable alternatives, with a **standard energy mix**



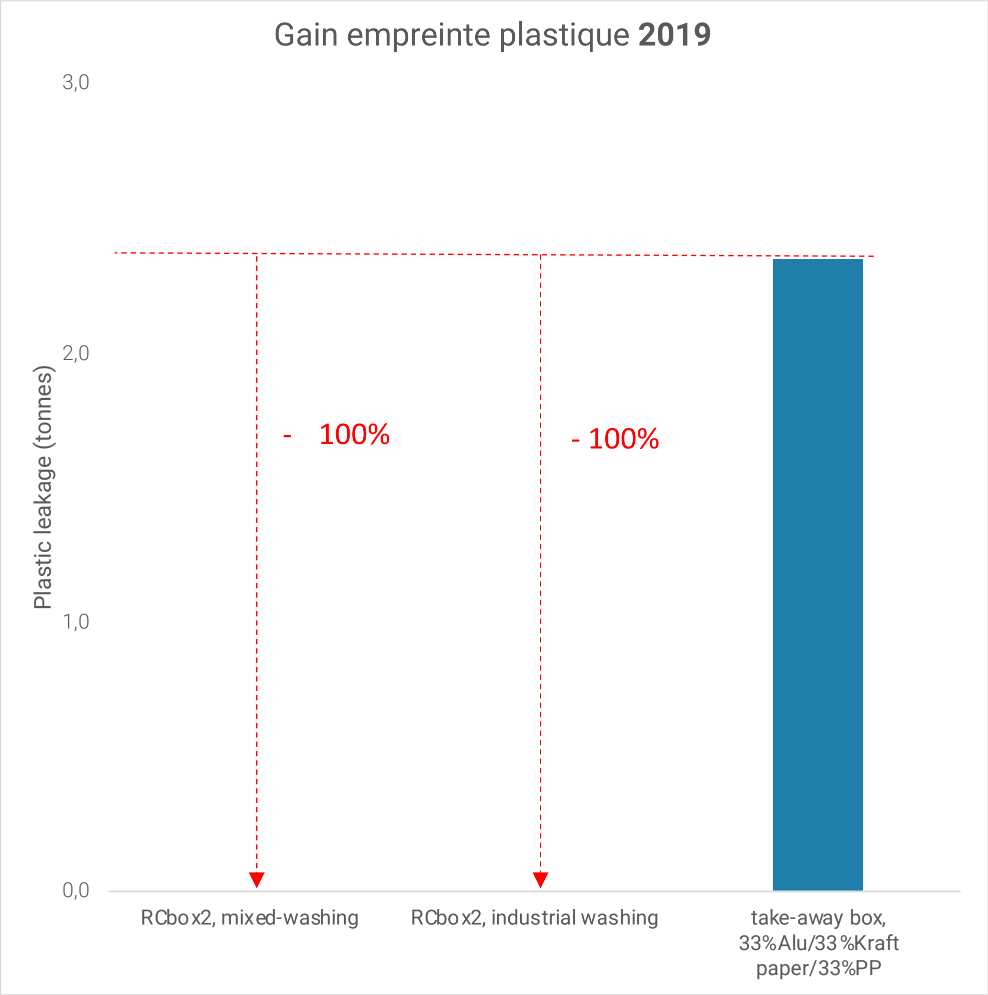
reCIRCLE 2 boxes: UBP impacts per meal compared to disposable alternatives, with a **50% solar energy mix**



2.3

Plastic footprint

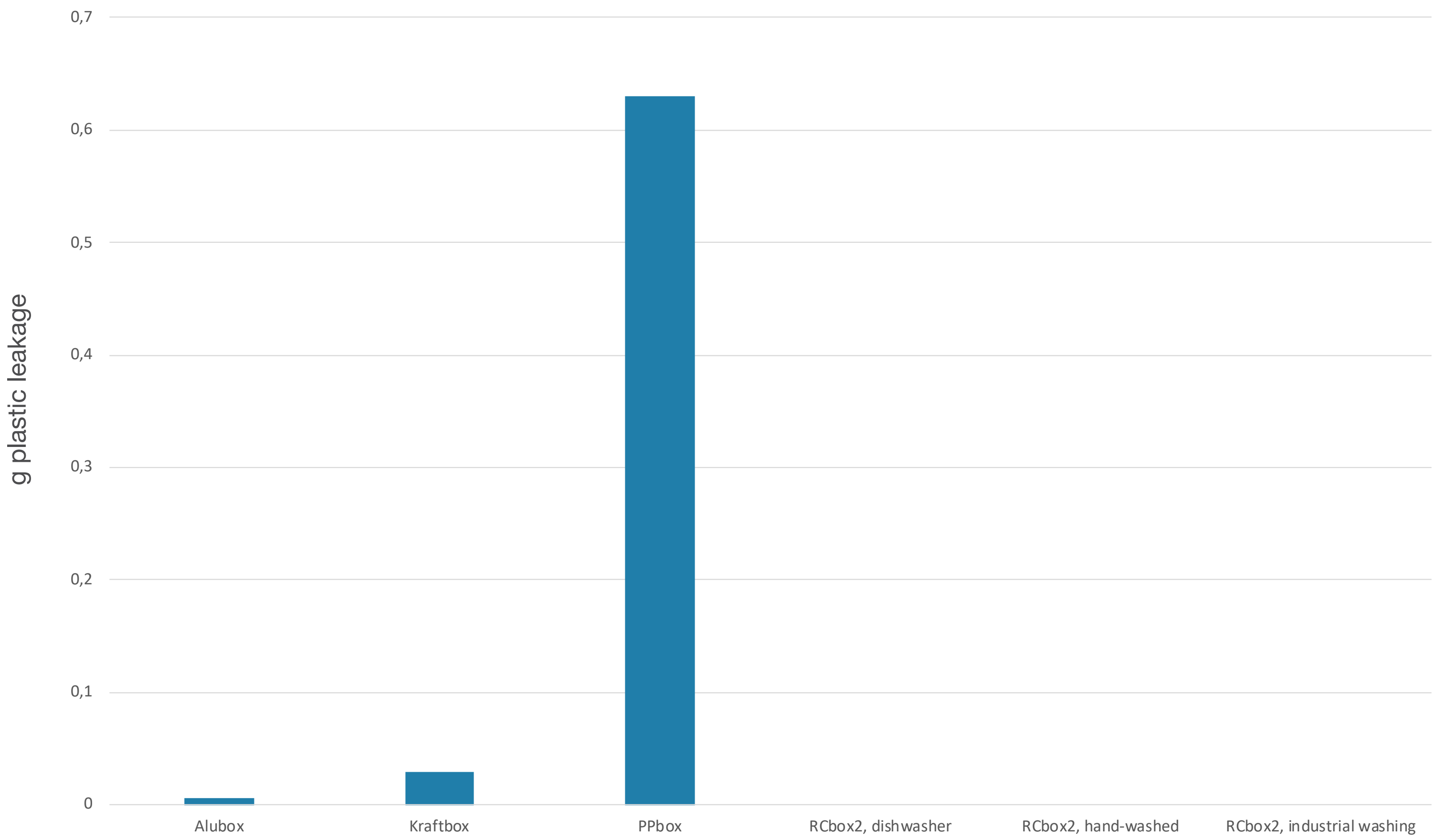
Plastic gains with reCIRCLE meals in 2019



An average of **200 uses** per reCIRCLE box is assumed.

In 2019, substituting the reCIRCLE box2 for some **10 million** disposable meal boxes made of aluminium, Kraft paper or polypropylene (assumed in equal shares) avoided **2.3** tonnes of plastic leakage into the environment.

reCIRCLE 2 boxes: plastic footprint compared to disposable alternatives, in **g of plastic leakage per meal**



2.4 Summary of environmental impacts

Summary:
CO_2, UBP, plastic impacts

The following table presents the CO_2, UBP and plastic impacts of 10,582,000 meals distributed (equivalent to the number of meals distributed by reCIRCLE in 2019) per type of container:

Product		CO_2 impact (t CO_2eq)	UBP impact (mn UBP)	Plastic leakage (t)
Aluminium box		1106 (-82%)	1697 (-78%)	0.1 (-100%)
Kraft paper box		457 (-57%)	663 (-43%)	0.3 (-100%)
Polypropylene box (PP)		1056 (-81%)	905 (-58%)	6.7 (-100%)
reCIRCLE BOX 2*, mixed-washing * For an average of 200 uses		**199**	**380**	**0**

③ Circularity index

Circularity index:
EMF method

By using the approach developed by the Ellen McArthur Foundation in its publication “EMF (2015). Circularity Indicators. An Approach to Measuring Circularity”, we calculated the Material Cirularity Indicator (MCI) for the different boxes, taking a disposable meal box as a reference product. The detailed calculation for the reCIRCLE box is given in the section *“Annexes”.*

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Product		Circularity
Aluminium box		43%
Kraft paper box		44%
Polypropylene box (PP)		10%
reCIRCLE BOX 2		**99%**

④ Conclusions and leads for improved ecodesign

Key findings

- The substitution of disposable boxes by reCIRCLE BOX 2 boxes in mixed-washing (50% hand-washing, 50% dishwasher) made it possible to reduce the CO_2eq impact by 77% and the UBP impact by 65%.
- The reCIRCLE box must be used between 13 to 15 times depending on the type of washing to have less impact than an average disposable box.
- The biggest impact of the reCIRCLE boxes (for 200 uses) is that of hand-washing or dishwashing, with the bulk of the energy required to heat the tap water or run the dishwasher.
- Increasing the solar share of the energy mix to 50% when hand-washing the reCIRCLE box makes it possible to further reduce the CO_2eq impact by about 12% for a Kraft paper box. On the other hand, the same operation via dishwashing or industrial washing yields a slight additional reduction in the CO_2eq impact (2 to 3%).
- Using reCIRCLE boxes instead of disposable boxes makes it possible to avoid the plastic pollution generated by littering with disposable boxes.

Key remarks

- The iQ PBT currently in use provides a 29% reduction in CO2eq impact compared to a standard PBT, but the UBP impact reduction is not known. A thorough analysis of the full environmental impact of the iQ PBT would be desirable.
- The average volume of the disposable meal boxes studied seems to be close to 900 mL, while the volume of the most used reCIRCLE box is 1000 mL.
- The findings presented in this study are conservative because we consider that the reCIRCLE box only replaces one disposable box, whereas in practice a meal may consist of two disposable boxes (one for the main course, one for the side dish) and be served with a napkin and disposable cutlery in a plastic bag. These latter items have not been included in our calculations.

[1] Gallego-Schmid, A., Mendoza, J. M. F., & Azapagic, A. (2019). Environmental impacts of takeaway food containers. *Journal of Cleaner Production*, *211*, 417-427.

Ecodesign leads

Washing instructions

- Use cold water when hand-washing
- Operation with more renewable energy is recommended

Promote reuse

- Introduce a "gamification" system to encourage the reuse of boxes
- Introduce a kit with reusable cutlery, bag and napkin to avoid collateral waste from takeaway

Rethink design

- Explore alternatives to iQ PBT
- Slightly reduce box size
- Lighten boxes if technically feasible

Possible actions and potential gains in 2019

Number of reCIRCLE meals in 2019: 10,582,000

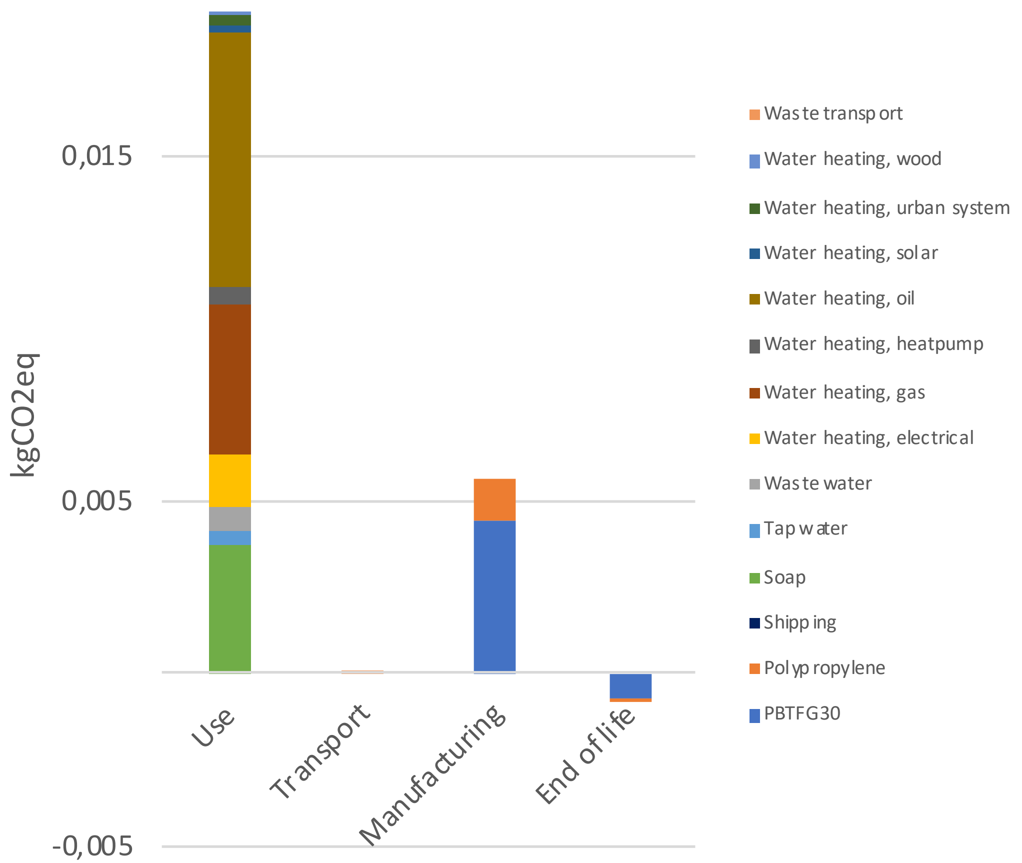
	CO2			UBP		
Actions	Impact tCO2-eq	gain tCO2-eq	gain tCO2-eq (%)	Impact millions UBP	gain millions UBP	gain millions UBP (%)
Scenario mixed washing (50% hand-wash, 50% dishwasher)	*199*			*380*		
Reduce the temperature of the tap water from 35° to 20° when hand-washing	155	**44**	22%	331	**49**	13%
Increase the proportion of solar-thermal energy to 50% for hand-washing	172	**27**	14%	362	**19**	5%
Increase the proportion of photovoltaic solar energy to 50% for using the dishwasher	194	**5**	2%	318	**62**	16%
Reduce by half the quantity of soap used when hand-washing	190	**8**	4%	362	**18**	5%
Reduce by half the quantity of detergent used when using the dishwasher	193	**6**	3%	366	**15**	4%
Lighten reCIRCLE BOX 2 by 10%	195	**4**	2%	375	**5**	1%
Reduce the volume of the reCIRCLE BOX by 20%	190	**9**	5%	369	**11**	3%

⑤ Annexes

5.1

Detailed CO_2eq impacts for the reCIRCLE box

reCIRCLE 2 box: detailed CO_2eq impacts for meal use with hand-washing



An average of **200 uses** per reCIRCLE box is assumed.

Assumptions per use:

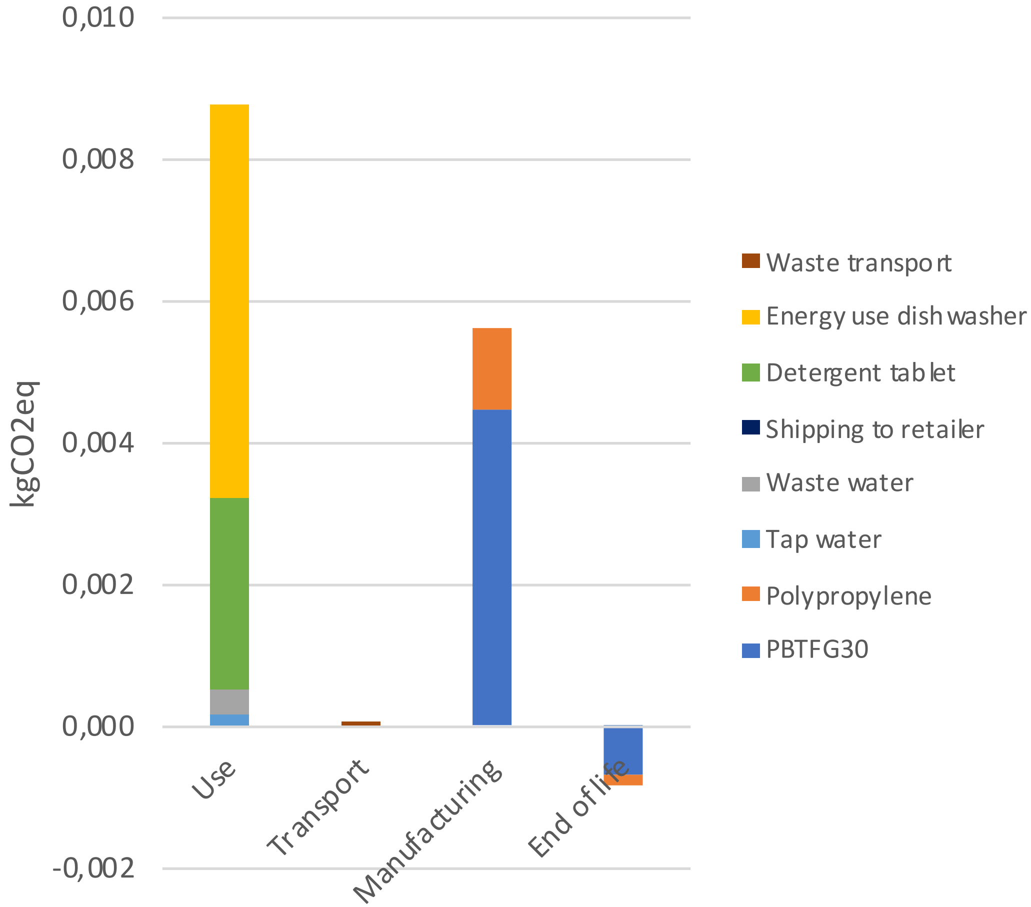
Water temperature = 35°C

Water consumption = 2 litres

Consumption of washing-up liquid = 0.8 g

There is a dominant impact during use, particularly due to the type of energy used to heat the tap water.

reCIRCLE 2 box: detailed CO_2eq impacts for meal use with dishwashing



An average of **200 uses** per reCIRCLE box is assumed.

Assumptions per use:

Max. number of boxes per machine cycle = 15

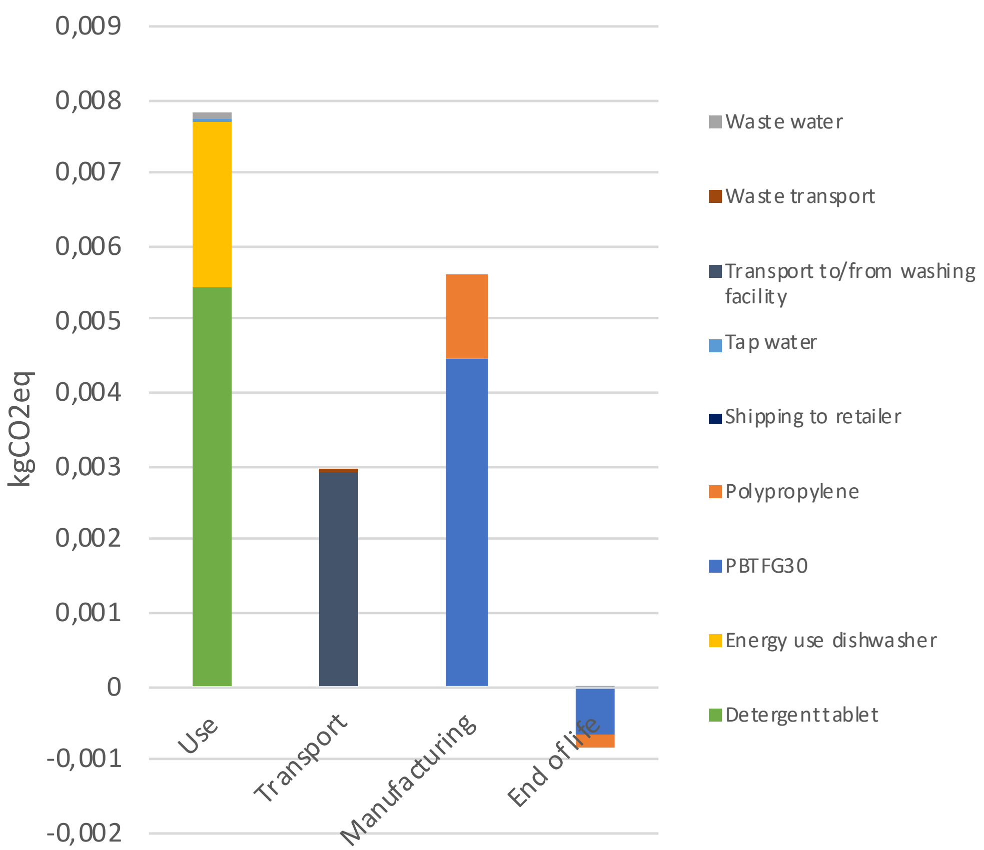
Electricity consumption (box) = 0.055 kWh

Water consumption (box) = 0.9 litres

Detergent consumption (box) = 1 g

One notes a dominant impact during use, particularly due to the origin of the electricity used to run the machine.

reCIRCLE 2 box: detailed CO_2eq impacts for meal use with industrial washing



An average of **200 uses** per reCIRCLE box is assumed.

Variable use:

<u>Assumptions per use:</u>

Max. number of boxes per machine cycle = 100

Electricity consumption (box) = 0.022 kWh

Water consumption (box) = 0.23 litres

Detergent consumption (box) = 2 g

Distance to the factory (one way) = 15 km

There is a significant impact during use, particularly due to the amount of detergent, but also during transport to the industrial washing plant.

5.2

Detailed calculation of circularity for the recircle box

Circularity index:
Details of calculations using the EMF method

The detailed calculation of materials of the **reCIRCLE BOX 2** is described in the table below:

Material	Mass (kg)	% recycled feedstock	% reused feedstock	% recycled after disposal	% reused after disposal	Recycling yield (E_C)	Uses (U)
PBT	0.15	0%	0%	30%	0%	95%[1]	200
PP	0.036	0%	0%	30%	0%	95%[2]	100

[1] Chen, Y. J., Huang, X., Chen, Y., Wang, Y. R., Zhang, H., Li, C. X., ... & Lan, Y. Q. (2019). Polyoxometalate-Induced Efficient Recycling of Waste Polyester Plastics into Metal–Organic Frameworks. CCS Chemistry, 1(5), 561-570.
[2] van Velzen et al. (2017, December). Efficiency of recycling post-consumer plastic packages. In AIP Conference Proceedings (Vol. 1914, No. 1, p. 170002). AIP Publishing LLC

The Material Circularity Indicator is calculated in **5 steps**:

1. Virgin feedstock

We know that $F_{R,PBT} = F_{R,PP} = 0$ and $F_{U,PBT} = F_{U,PP} = 0$

And as $V = M.(1 - F_R - F_U)$,

$V = V_{PBT} + V_{PP} = M_{PBT} + M_{PP} = 0.186$

Circularity index:
Details of calculations using the EMF method

2. Unrecoverable waste

We know that $C_{R,PBT} = C_{R,PP} = 0.3$, $C_{U,PBT} = C_{U,PP} = 0$ and $E_{C,PBT} = E_{C,PP} = 0.95$, then

- The amount going to landfill or energy recovery is $W_0 = M(1 - C_{R-} C_U)$,

  So: $W_0 = W_{0,PBT} + W_{0,PP} = (0.186) . (1 - 0.3) = 0.1302$

- The mass unrecovered during the recycling process is $W_C = M (1 - E_C) C_R$,

  So: $W_{C =} W_{C,PBT} + W_{C,PP} = (0.186) . (1 - 0.95) . (0.3) = 0.00279$

- The mass unrecovered when producing recycled feedstock is $W_F = M ((1 - E_F) F_R) / E_F$,

  So: $W_{F =} W_{F,PBT} + W_{F,PP} = 0$, *since* $F_{R,PBT} = F_{R,PP} = 0$

- Eventually, the total waste unrecoverable is equal to:

  $W = W_0 + (W_C + W_F)/2$

  $W = 0.1302 + 0.00279/2 = 0.1316$

Circularity index:
Details of calculations using the EMF method

3. Linear Flow Index

   According to the methodology,

   $LFI = (V+W) / (2M + (W_F - W_C)/2)$

   $LFI = (0.186 + 0.1316) / (2 . 0.186 + (0 – 0.00279)/2)) = 0.86$

4. Utility Factor

   A single-use food container is assumed to be used U_{av} = 1 time on average, while the reCIRCLE container is used on average U_{PBT} = 200 and the lid U_{PP} = 100.

   Eventually in this case, $X = U/U_{av} = (U_{PBT} + U_{PP})/2 . (1/U_{av}) = 150/1 = 150$

   and $F(X) = 0.9/X = 0.9/150 = 0.006$

5. Material Circularity Index

   The MCI of the reCIRCLE BOX 2 compared to single use containers is:

   MCI = $max(0 ; 1 – LFI . F(X)) = max(0 ; 1 – (0.86) . (0.006)) =$ ***0.99****

* If we assume that we compare our product to reusable containers, the average number of uses would be U_{av} = 43 (*source: Harnoto, M. F. (2013). A Comparative Life Cycle Assessment of Compostable and Reusable Takeout Clamshells at the University of California, Berkeley. LCA Compostable and Reusable Clamshells, 1-24.*) and eventually the Material Circularity Indicator would drop to MCI = 0.78.

Circularity index:
Details of calculations using the EMF method

Then we calculate the MCI for the single-use containers compared in the reCIRCLE study based on the detailed calculations of materials of the **single-use containers** with assumptions used in the study:

Product	Material	Mass (g)	% recycled feedstock	% reused feedstock	% recycled after disposal[3]	% reused after disposal	Recycling yield (E_C)	Uses (U)
Alu box	Aluminium	7.6	60%[1]	0%	40%[1]	0%	100%	1
	Paper	6.6	47%[2]	0%	0%	0%	77%[3]	1
	PE	0.3	0%	0%	0%	0%	-	1
PP box	PP	31.5	0%	0%	0%	0%	-	1
Kraft box	Kraft paper	24.6	47%[2]	0%	0%	0%	77%[3]	1
	PE	1.4	0%	0%	0%	0%	-	1

[1] Expert assessment by IGORA (*https://igora.ch/fr/home/*)
[2] Appendix C in *Nessi S., Sinkko T., Bulgheroni C., Garcia-Gutierrez P., Giuntoli J., Konti A., Sanye-Mengual E., Tonini D., Pant R., Marelli L., Comparative Life Cycle Assessment (LCA) of Alternative Feedstock for Plastics Production – Part 1, European Commission, Ispra, 2020*
[3] Corresponds to the product between recycled pulping and paper making yield ratios from Table 1 in *Van Ewijk, S. et al. (2018). Global life cycle paper flows, recycling metrics, and material efficiency. Journal of Industrial Ecology, 22(4), 686-693.*

Circularity index:
Details of calculations using the EMF method

Following the same approach as for the reCIRCLE BOX 2 and assuming that utility is in the industry average for the single use containers (*X= U/Uav = 1*), we obtain the following MCIs for single-use containers that we compare with the reCIRCLE BOX 2:

Product	Material Circularity Indicator
Aluminium box 	19%
Kraft paper box 	29%
Polypropylene box (PP) 	10%
reCIRCLE BOX 2 	**99%**

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