Comprehensive Life Cycle Analysis of Bumpers and Fairings

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Problem Statement

We were approached by PACCAR to determine whether recycling bumpers and fairings into sleeper cabinet components would be environmental beneficial.

Goals and scope

- Conduct a cradle-to-grave LCA to determine whether recycling bumpers and fairings into sleeper cabinet components is worth the environmental offset
- Utilize material property testing to see whether there are strength differences between regrind contents.

What is a Life Cycle Analysis (LCA)?

- An analysis of the environmental impact of a process.
- Conducting LCA from cradle-to-grave provides an understanding of each manufacturing step.

Why is this important?

- The trucking industry is a significant contributor to global GHG emissions, contributing to climate change and environmental injustice.
- Reducing emissions will decrease PACCAR's environmental footprint and improve public image.

Why use LCA?

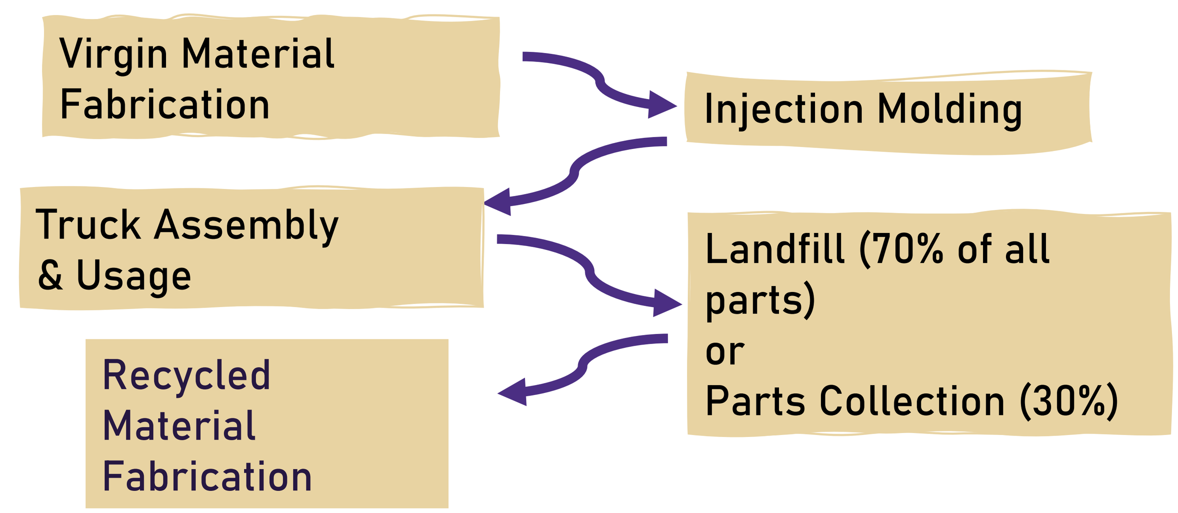
- Can optimize sustainability initiatives
- Allows for continuous improvement through detailed analysis
- Can be used to provide an overview
- Provides holistic views to real industry problems

How can this be quantified?

For the impact assessment, we focused on CO_2 emissions and selected relevant impact categories. We classified and standardized the data to kilograms of CO_2 equivalent per truck manufactured. We then compared the environmental impact of producing virgin bumpers and fairings to recycling them into interior components, and also considered the impact of making the same weight of new interior material. The impact was calculated by summing the emissions from each production stage and the transportation between steps.

LCA Methods

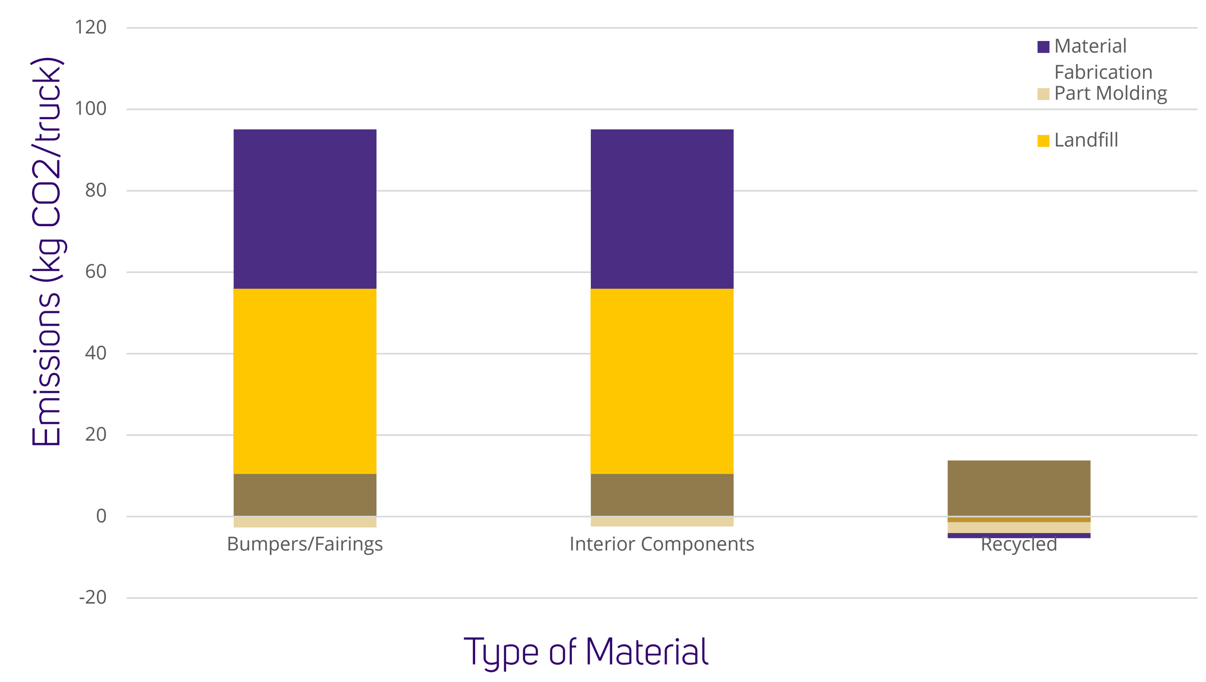
The following cycle was derived from PACCAR'S manufacturing process and was used to calculate final emission values for virgin bumpers and fairings, inner sleeper cabinet components, and recycled combinations. Each step has an additional transportation impact as well.



LCA Results & Discussion

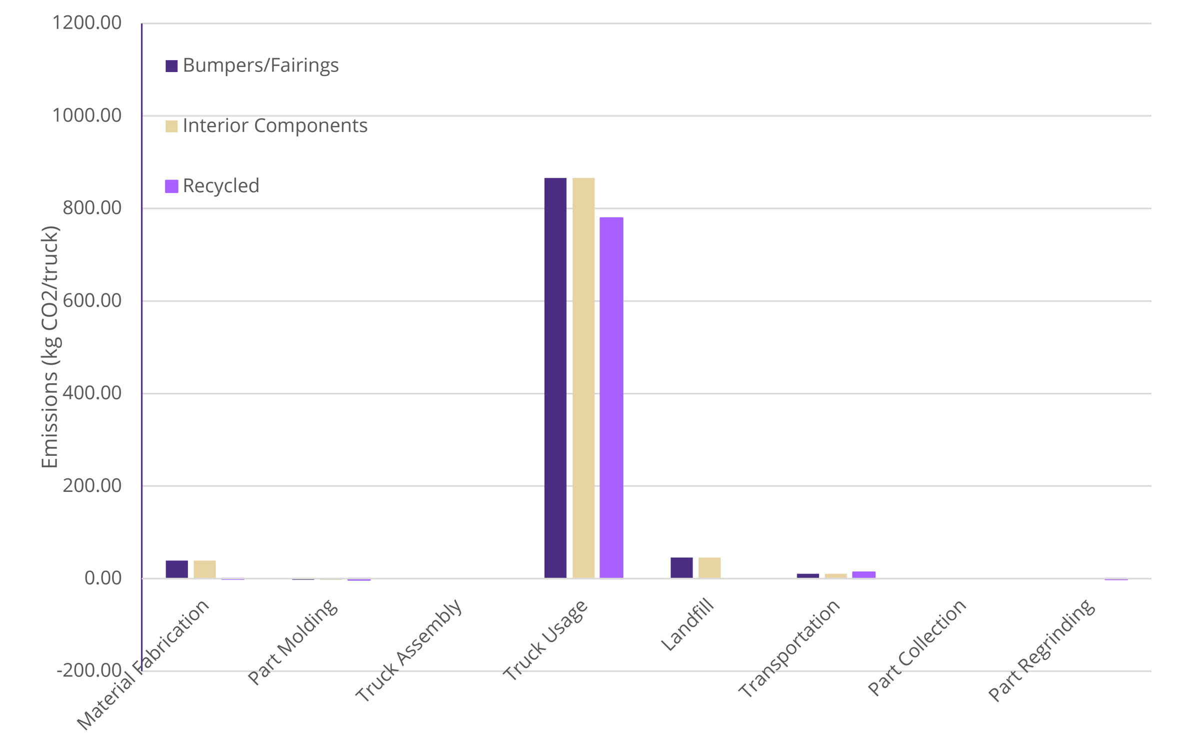
It is environmentally beneficial to recycle the TPO bumpers and fairings into either interior components or bumpers and fairings. Significant savings can be found by increasing the number of trucks recycled, increasing the recycled content of the recycled compound, increasing clean energy use, and reducing part weight.

Total emissions excluding steps with a value of 0 and truck usage.



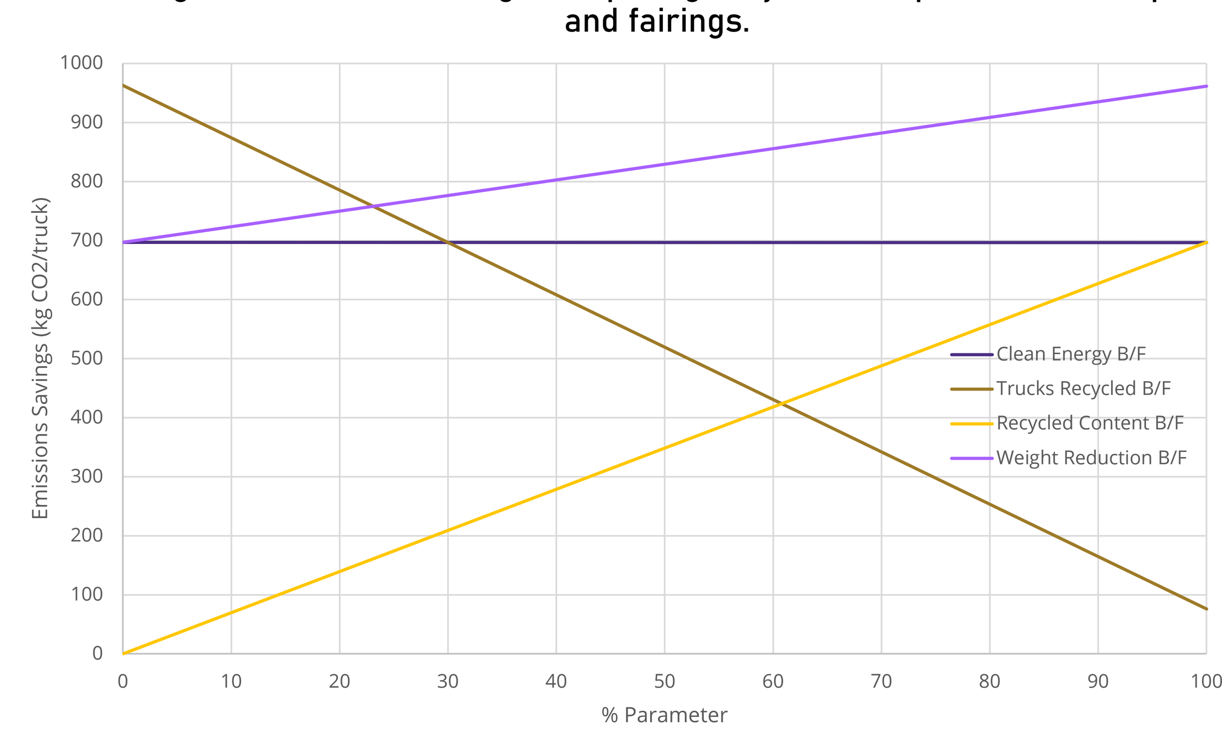
The transportation cost of using recycled interior components is higher than the virgin because of the recycling process. However, this emissions cost can easily be reduced by using electric or hydrogen powered vehicles.

Comparison of emissions at each non-zero step, excluding truck usage.

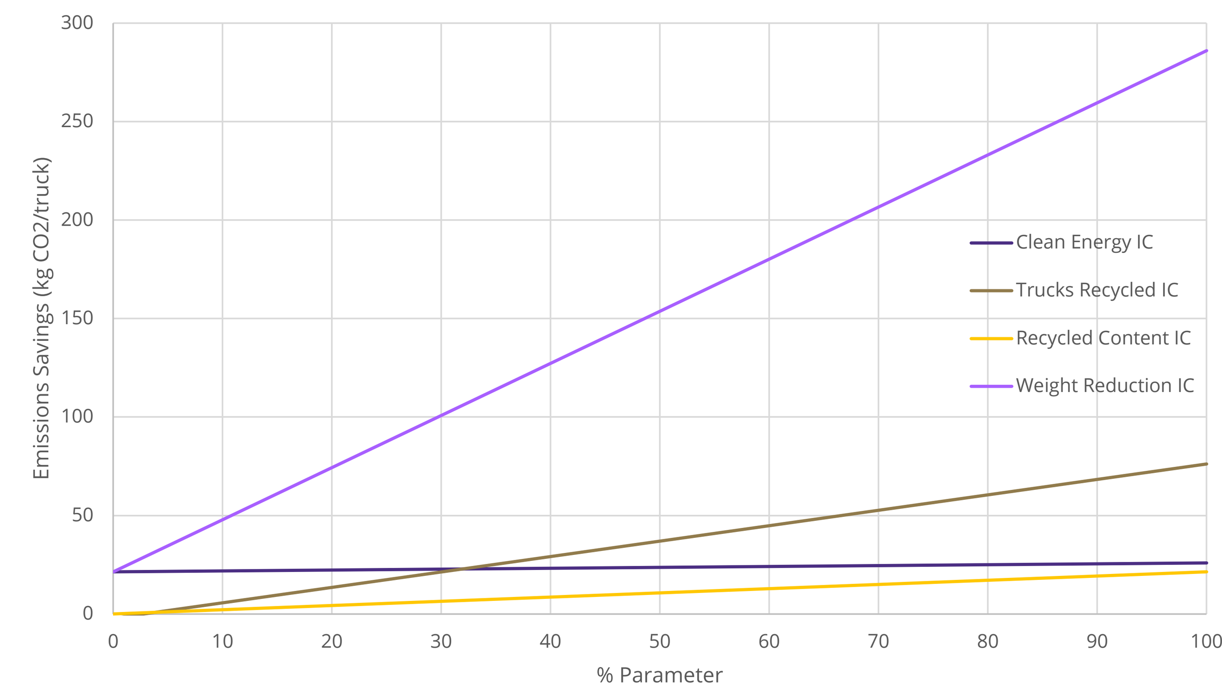


The largest emissions by far are from the truck's lifetime mileage since using diesel to drive one million miles will dwarf any other contribution. Ignoring this step, the next most impactful processes are landfill degradation and material fabrication.

Change in emissions savings comparing recycled components to bumpers and fairings.



Change in emissions savings comparing recycled components to virgin interior components



Testing Methods

To encompass a comprehensive assessment, the mechanical testing strategy will include a variety of material samples: 100% virgin material, 100% regrind, and blends of 50/50, 25/75, and 75/25. This structured approach allows for direct comparison between pure and recycled materials, highlighting the effects of regrinding on the physical properties.

Test	Test Standard
Tensile Testing	ASTM D638
DMA	ASTM 4065
3-point Bend Test	ASTM D790
Rockwell Hardness B	ASTM D785
Multiaxial Impact Resistance	ASTM D3763
Density	ASTM D792
Melt Flow	ASTM D1238

Testing Results

Test Value	Virgin Bumper	Virgin Fairing	Virgin Interior	0% Recycled	25% Recycled	50% Recycled	75% Recycled	100% Recycled
Tensile Strength (MPa)	16	24	21	21.0	20.8	20.7	19.8	19.2
Tensile Modulus (MPa)	-	-	2900	1852	1770	1496	1567	1188
Flexural Modulus (MPa)	1400	1500	2000	1585	1390	1531	1422	1361
Tg (°C)	-	-	-	159.7	159.0	159.1	159.1	159.4
Density (g/cm^3)	1.08	0.96	1.05	1.06	0.99	1.02	1.03	0.99
Rockwell Hardness B	-	-	-	99	93	89	82	83
Multiaxial Impact -30°C (J)	-	-	-	10	8	9	14	8.5
Multiaxial Impact 23°C (J)	-	-	21	29	30	29	31	27
Melt Flow (g/10 min)	25	40	24	28	28	27	27	29