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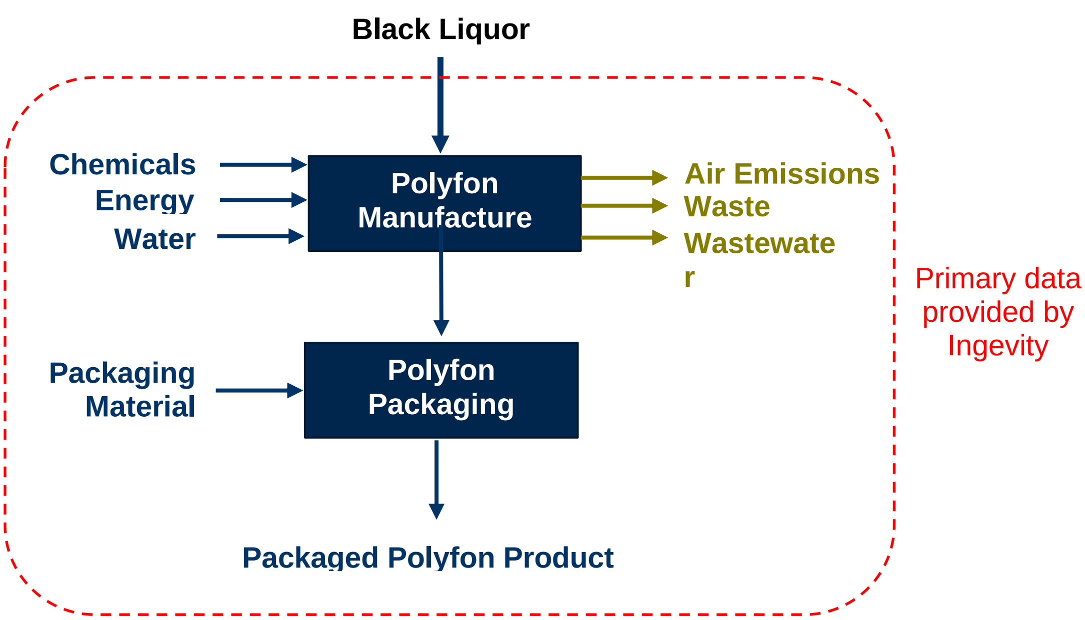
Project Summary – Carbon Footprint for Ingevity of Polyfon® H and its Substitute

Methodology

ERM conducted a carbon footprint study of the product Polyfon® H, manufactured by Ingevity. Polyfon® is a lignin-based chemical made from black liquor, which is a by-product of the kraft pulping process. Polyfon® is mainly used as a dispersant in the agriculture industry for a diverse set of end applications, such as pesticide formulation and seed treatment. The objective of this study was to determine the cradle-to-gate carbon footprint associated with the Polyfon product manufactured by Ingevity.

In a model developed in the SimaPro software, we considered the life cycle carbon footprint of raw material and energy inputs to the manufacture of Polyfon. ERM used production data from Ingevity, and inventory data from the ecoinvent 3.6 database, as inputs to the SimaPro model to calculate life cycle greenhouse gas (GHG) impacts in units of metric tons of carbon dioxide equivalent (CO_2e) per 1 metric ton (MT) of Polyfon. The study also compared the carbon footprint of Polyfon to a typical hydrocarbon-based substitute, naphthalene sulfonate, assumed to be functionally equivalent as a 1:1 substitution. The system boundary is shown below.



Polyfon Carbon Footprint

The feedstock for the Polyfon® product is black liquor. Black liquor is the waste liquor from the kraft pulping process after pulping is completed. In the LCA field, the ISO standards define 'waste' as a substance or object which the holder intends or is required to dispose of, and a waste input is modelled burden-free. As the black liquor is characterized as a waste product it is modelled as an empty flow with no burdens associated with its production.

The carbon footprint for 1 MT of Polyfon H, calculated using the "IPCC 2013 GWP 100a" impact method, is 1.46 MT. The main contributor to the carbon footprint of Polyfon, with 28% of the impact, is the CO_2 process emission resulting from the liquid CO_2 input. This is followed by the liquid CO_2 process input (contributing 23% to the total emissions). The fossil carbon footprint of Polyfon could be significantly reduced by using a biogenic source of liquid CO_2 in the manufacturing process.

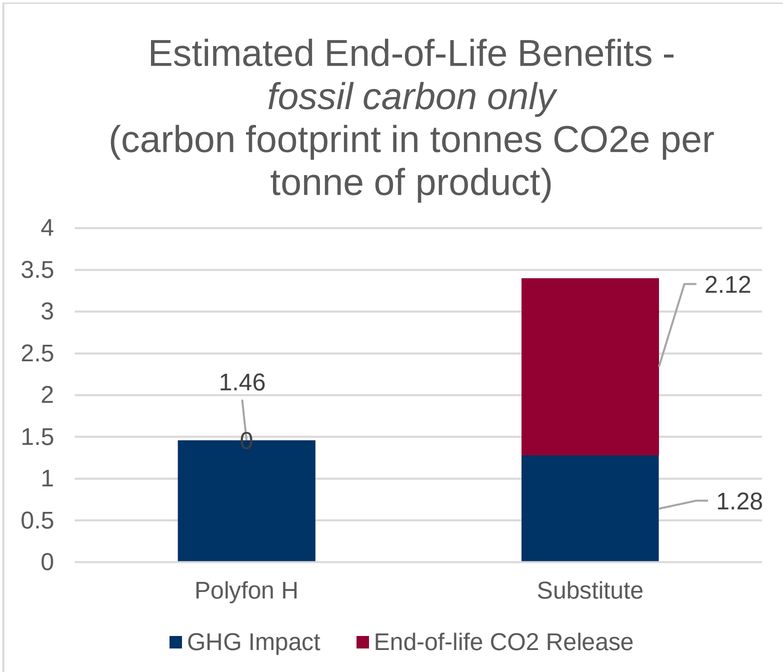
Biogenic Carbon and End-of-Life Comparative Benefits

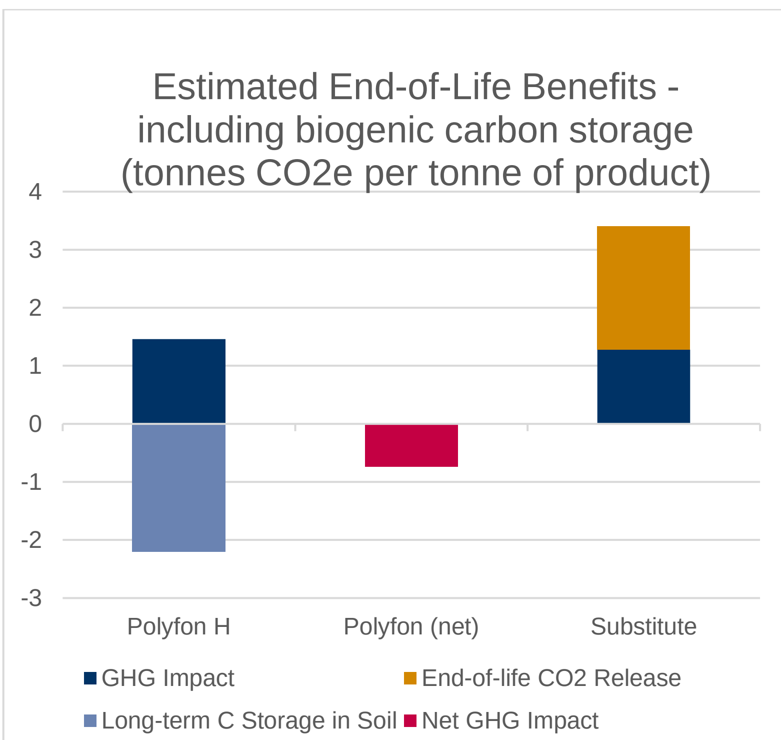
The base case results consider fossil carbon only and do not incorporate storage of biogenic carbon in the black liquor raw material derived from a by-product of paper mills. The biogenic carbon contained within the black liquor, and ultimately within the Polyfon product, represents carbon that has been taken up from the atmosphere and is stored during the lifetime of the product.

The product use considered for Polyfon and the substitute is as a dispersant in pesticide formulation; the products are therefore expected to be applied to land. As Polyfon® is produced from a biological feedstock, the emissions released at the end-of-life associated with the biomass input will be biogenic in origin. Any oxidation of the biogenic carbon to carbon dioxide at the end-of-life is considered to be net zero, as it is part of the short-term carbon cycle.

For fossil carbon-based products, such as the substitute, if it degrades at end-of-life any fossil carbon dioxide emissions will contribute to the product's carbon footprint. Assuming a chemical formula for naphthalene-1-sulfonate, $C_{10}H_7O_3S$, the carbon content is around 58% (580 kg of carbon for 1 MT of naphthalene-1-sulfonate). If it was assumed that there would be full oxidation of the product over 100 years, this would result in 2,124 kg of CO_2 emissions, increasing the substitute's carbon footprint to 3.4 t CO_2-eq per MT of product. Literature research confirms that naturally occurring microorganisms are expected to efficiently degrade naphthalene sulfonate after agricultural application.

The lignin in Polyfon is a stable compound that breaks down slowly. To the extent that the biogenic carbon in Polyfon remains sequestered within soils beyond 100 years, that would reduce the overall footprint of Polyfon. We explored the potential benefits from long-term storage of the biogenic carbon in Polyfon, estimated at 60% or 0.6 metric ton of carbon per metric ton of product. If all of this carbon is retained in the soil, this would *avoid* the release of 0.6 X (44/12) or 2.2 MT CO_2e per MT of Polyfon. Agricultural research has shown that increasing lignins in soil improves the capacity for storing additional carbon; thus the use of Polyfon contributes to additional carbon sequestration benefits compared to the fossil-based alternative compound. We were not able to quantify this additive benefit, however, since the extent of increase depends on a wide variety of factors including agricultural practices and soil conditions.


Estimated End-of-Life Benefits - *fossil carbon only* (carbon footprint in tonnes CO2e per tonne of product)
4
3.5
3
2.5
2
1.5
1
0.5
0
1.46
0
2.12
1.28
Polyfon H
Substitute
GHG Impact
End-of-life CO2 Release


Estimated End-of-Life Benefits - including biogenic carbon storage (tonnes CO2e per tonne of product)
4
3
2
1
0
-1
-2
-3
Polyfon H
Polyfon (net)
Substitute
GHG Impact
End-of-life CO2 Release
Long-term C Storage in Soil
Net GHG Impact

Conclusions

- The base case study is a cradle to gate assessment that accounts for fossil carbon emissions only. In this conservative base case, Polyfon H shows a carbon footprint of **1.46 MT CO_2e per MT of product**. This is based on the energy use, materials, packaging and wastes associated with the Polyfon manufacturing process, without taking into account any potential carbon benefits from the bio-based feedstock. The primary raw material for Polyfon is black liquor, a waste generated from the pulp and paper industry. As a waste, black liquor carries no carbon burden.

- The biogenic carbon contained in Polyfon would be considered net-zero if it is oxidized and released to the atmosphere as CO_2 at end of life, because it was originally drawn from the atmosphere during tree growth. The amount of biogenic carbon is estimated to be 0.60 MT as carbon, which corresponds to **2.2 MT of CO_2**.

- Because the lignin in Polyfon breaks down very slowly in the soil, after agricultural use **much of the biogenic carbon is expected to remain sequestered in the soil** for at least a 100-year timeframe – the standard impact horizon for carbon footprint studies. Taking into account the credit of -2.2 MT CO_2e resulting from long-term storage of Polyfon carbon in the soils, the estimated product footprint becomes negative: **-0.74 MT CO_2e**, assuming that all of the carbon content remains in the soil for longer than 100 years. This result reflects the combination of biogenic carbon in Polyfon and the fossil carbon associated with materials and energy required to manufacture the product. Assuming at least two-thirds of the biogenic carbon remains stored in the soil for longer than 100 years, Polyfon will have a negative carbon footprint, i.e., a net global warming benefit.