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Environmental Assessment of a TCT Product

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Executive Summary

This report includes a simplified comparative LCA study between a generic product produced by TCT–Europe via compression moudling and an Ethylene Propylene Diene Monomer (EPDM) Product via impression moulding. The functional unit that has been selected is one product with a final weight of 1.2 kg (to align with the final weight of the TCT Product). Primary data was collected and input to specific life cycle assessment (LCA) database. The database used for this analysis are Ecoinvent v2.2, v3.3 and v3.8, and the software used is OpenLCA. The main life stages captured through this analysis are the raw material extraction, manufacturing, and transportation to and from the production site, based on assumptions from the bill of materials (BOM) as well as the reported manufacturing and transportation processes. Thus, this simplified life cycle assessment adopts a 'cradle-to-gate' approach. The impact assessment methods used for analysis were based on the European Commission's Environmental Footprint approach which consists of sixteen environmental indicators. The results indicate that the materials of the TCT Product contribute the highest impacts across the key components and manufacturing processes whilst the impact categories of Water Depletion Potential is the greatest area of concern. When compared against the EPDM Product, the TCT Product has lower environmental impacts across thirteen out of the sixteen impact categories used as part of this study. However, suggestions to lower these impacts have also been outlined, including a recommendation to rerun the analysis once more complete data is collected for the product system across the additional life cycle stages of use and end of life.

Contents

Scope and network overview

All environmental impacts stated in this report are relevant to the selected functional unit, which has been selected is one product with a final weight of 1.2 kg. The functional unit of a product system is a quantified description of the performance requirements that the product system fulfils and can be used in life cycle assessment studies to enable objective comparisons across different products that serve the same final function. Figure 1 and 2 provide an illustration of the network of the selected products based on the defined system boundary, which is relevant for the main life stages of raw material extraction, manufacturing, and transportation to and from the production site. The material required to produce the moud itself has been excluded from this analysis due to a lack of data stemming from injection moulding of the EPDM product. The use and end of life phases have also been scoped out of this analysis due to a lack of data. Using a cut-off value of 0%, the main contributors of both product systems are depicted in the figures.

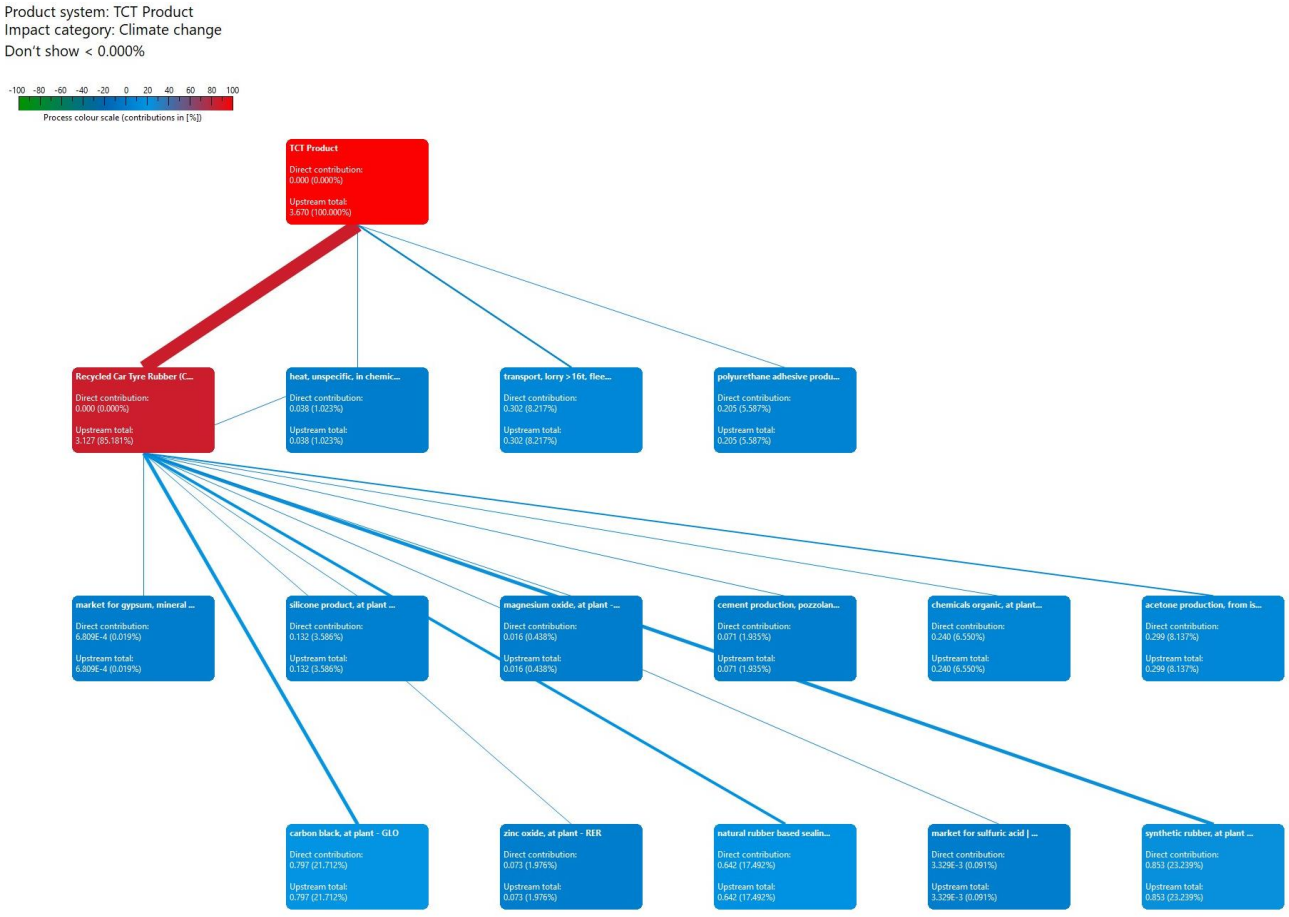

FIGURE 1: NETWORK OF THE TCT PRODUCT – CHARACTERISATION / GLOBAL WARMING POTENTIAL 100A

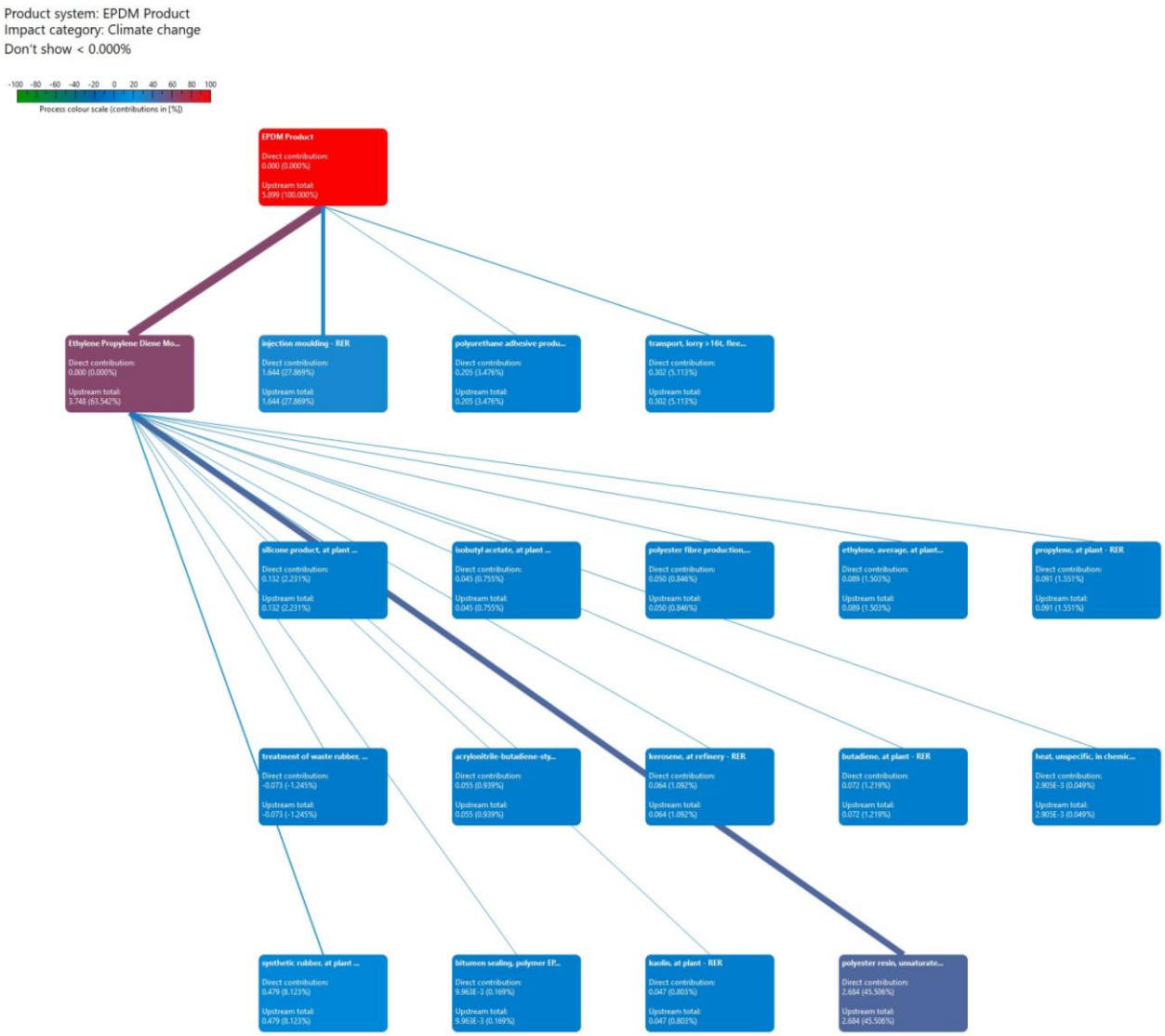

FIGURE 2: NETWORK OF THE EPDM PRODUCT– CHARACTERISATION / GLOBAL WARMING POTENTIAL 100A

Inventory inflows and contribution

Table 1 presents the stated values of each inflow based on the data collection procedures. The assumptions column provides all estimations made in the modelling procedures, particularly in relation to the values which were applied in cases where no values were provided by the data collection sheet. Table 2 then maps these study inflows with Ecoinvent v2.2, v.3.3 and v3.8 datasets. These Ecoinvent datasets were applied to conduct this analysis using OpenLCA software.

TABLE 1: DATA COLLECTION INCLUDING ASSUMPTIONS

Inflow	Unit	Assumptions
Recycled car tyre rubber (crumb) [1.0 kg]		
Acetone extract	0.099 kg	No assumptions. From data sheet.
Calcium oxide	0.005 kg	No assumptions. From data sheet.
Carbon black	0.286 kg	No assumptions. From data sheet.
Ash at 550 °C	0.083 kg	No assumptions. From data sheet.
Non-polymetric auilary organic substances	0.102 kg	No assumptions. From data sheet.
Iron (III) oxide or ferric oxide	0.001 kg	No assumptions. From data sheet.
Mineral substances	0.078 kg	No assumptions. From data sheet.
Heat	No value	Assumption of 0.0068 kWh based on data sheet.
Magnesium oxide	0.013 kg	No assumptions. From data sheet.
Rubber (natural)	0.267 kg	No assumptions. From data sheet.
Silicon dioxide	0.040 kg	No assumptions. From data sheet.
Sulphur	0.017 kg	No assumptions. From data sheet.
Rubber (synthetic)	0.267 kg	No assumptions. From data sheet.
Zinc oxide	0.021 kg	No assumptions. From data sheet.
EPDM [1.0 kg]		
Material	0.300 kg	Value taken from literature review. Assumed synthetic rubber [0.15 kg], butadiene [0.05 kg], ethelene [0.05 kg] and propylene [0.05 kg].
Base resin (EPDM)	0.300 kg	Value taken from literature review.
Filler	0.190 kg	Value taken from literature review.
Paraffinic oil	0.110 kg	Value taken from literature review.
Pigment	0.030 kg	Value taken from literature review.
EPDM scrap (internal)	0.020 kg	Value taken from literature review.
Fire retardant	0.010 kg	Value taken from literature review.
Actuator	0.010 kg	Value taken from literature review.
Curative	0.010 kg	Value taken from literature review.
Polyester scrim	0.010 kg	Value taken from literature review.
Processing aid	0.010 kg	Value taken from literature review.
Heat	No value	Assumption of 0.0068 kWh based on above.
TCT Product [1.2 kg]		
Recycled car tyre rubber (crumb)	1.164 kg	No assumptions. From data sheet.
Binder (Polyeurethene)	0.036 kg	No assumptions. From data sheet.
Heat	No value	Assumption of 0.1015 kWh based on data sheet.
Transportation from suppliers	50 km	No assumptions. From data sheet.

Transportation to end customer	900 km	No assumptions. From data sheet.
Transportation from end customer	900 km	No assumptions. From data sheet.
EPDM Product [1.2 kg]		
EPDM	1.164 kg	Assumed to match TCT Product.
Binder (Polyeurethene)	0.036 kg	Assumed to match TCT Product.
Injection moulding	1.2000 kg	No assumptions.
Transportation from suppliers	50 km	Assumed to match TCT Product.
Transportation to end customer	900 km	Assumed to match TCT Product.
Transportation from end customer	900 km	Assumed to match TCT Product.

TABLE 2: MAPPING OF INFLOWS TO ECOINVENT DATASETS

Inflow	Mapped Ecoinvent dataset
Recycled car tyre rubber (crumb)	
Acetone extract	acetone production, from isopropanol | acetone liquid | APOS, S - RER
Calcium oxide	Emissions to air/unspecified
Carbon black	carbon black, at plant – GLO
Ash at 550 °C	cement production, pozzolana and fly ash 6-14% | APOS, S - RER
Non-polymetric auilary organic substances	chemicals organic, at plant - GLO
Iron (III) oxide or ferric oxide	Emissions to air/unspecified
Mineral substances	market for gypsum, mineral | gypsum, mineral | APOS, S - RER
Heat	heat, unspecific, in chemical plant - RER
Magnesium oxide	magnesium oxide, at plant - RER
Rubber (natural)	natural rubber based sealing, at plant - DE
Silicon dioxide	silicone product, at plant - RER
Sulphur	market for sulfuric acid | sulfuric acid | APOS, S - RER
Rubber (synthetic)	synthetic rubber, at plant - RER
Zinc oxide	zinc oxide, at plant - RER
EPDM	
Material	synthetic rubber, at plant – RER butadiene, at plant – RER ethylene, at plant – RER propylene, at plant - RER
Base resin (EPDM)	polyester resin, unsaturated, at plant - RER
Filler	kaolin, at plant - RER
Paraffinic oil	kerosene, at refinery - RER
Pigment	silicone product, at plant - RER
EPDM scrap (internal)	treatment of waste rubber, unspecific | APOS, S – Europe without Sw…
Fire retardant	bitumen sealing, polymer EP4 flame retardant, at plant - RER
Actuator	silicone product, at plant - RER
Curative	isobutyl acetate, at plant - RER
Polyester scrim	polyester fibre production, finished | fibre, polyester | APOS, S - RoW
Processing aid	acrylonitrile-butadiene-styrene copolymer, ABS, at plant - RER
Heat	heat, unspecific, in chemical plant - RER
TCT Product	
Recycled car tyre rubber (crumb)	Recycled car tyre rubber (crumb) [new dataset]
Binder (Polyeurethene)	polyurethane adhesive production | APOS, S - GLO

Heat	heat, unspecific, in chemical plant - RER
Transportation from suppliers	transport, lorry >16t, fleet average - RER
Transportation to end customer	transport, lorry >16t, fleet average - RER
Transportation from end customer	transport, lorry >16t, fleet average - RER
EPDM Product	
EPDM	EPDM [new dataset]
Binder (Polyeurethene)	polyurethane adhesive production | APOS, S - GLO
Injection moulding	injection moudling - RER
Transportation from suppliers	transport, lorry >16t, fleet average - RER
Transportation to end customer	transport, lorry >16t, fleet average - RER
Transportation from end customer	transport, lorry >16t, fleet average - RER

Impact assessment

This section presents the impact assessment for sixteen different environmental impact categories at midpoint level. The selected environmental impact categories are based on the European Commission's published 'Recommendations for Life Cycle Impact Assessment in the European Context'. The environmental impact assessment methods recommended by this document forms form the baseline for the product environmental footprint approach of the European Commission. For this reason, it was considered reasonable to apply these environmental impact categories as part of this study. These environmental impact categories are outlined in Table 3 below.

TABLE 3: ENVIRONMENTAL IMPACT CATEGORIES

Impact Category	Indicator	Model
Global Warming Potential 100a (GWP_{100})	Radiative forcing as GWP_{100} [kg CO_2 eq.]	IPCC (2013)
Ozone Depletion Potential (ODP)	Steady-State ODPs as in WMO (1999) [kg CFC-11 eq.]	WMO (1999)
Human Toxicity Potential, Cancer (HTPc)	Comparative toxic unit for humans [CTUh,c]	USEtox (2008)
Human Toxicity Potential, Non-Cancer (HTPnc)	Comparative toxic unit for humans [CTUh,nc]	USEtox (2008)
Particulate Matter Potential (PMP)	Impact on human health [disease incidence]	UNEP (2016)
Ionising Radiation Potential (IRP)	Human exposure efficiency relative to U^{235} [kBq U^{235} eq.]	Frischknecht et al (2000)
Photochemical Ozone Formation Potential (POFP)	Tropospheric ozone concentration increase [kg NMVOC eq.]	ReCiPe (2008)
Acidification Potential (AP)	Accumulated exceedance (AE) [mol H^+ eq.]	Seppälä et al (2006), Posch et al (2008)
Terrestrial Eutrophication Potential (TEP)	Accumulated exceedance (AE) [mol N eq.]	Seppälä et al (2006), Posch et al (2008)
Freshwater Eutrophication Potential (FEP)	Nutrients reaching freshwater compartment (P) [kg P eq.]	ReCiPe (2008)
Marine Eutrophication Potential (MEP)	Nutrients reaching marine compartment (N) [kg P eq.]	ReCiPe (2008)
Freshwater Aquatic Ecotoxicity Potential (FAEP)	Comparative toxic unit for ecosystems [CTUe]	USEtox (2008)
Land Use (LU)	Soil quality index [Dimensionless (pt)]	LANCA (2016)
Water Depletion Potential (WDP)	User deprivation potential [m3 world eq.]	AWARE (2016)
Mineral & Metal Resource Depletion Potential (MMRDP)	Abiotic resource depletion (ultimate reserves) [kg Sb eq.]	CML (2002)
Fossil Resource Depletion Potential (FRDP)	Abiotic resource depletion (fossil) [MJ]	CML (2002)

A. Characterisation

Figure 3 and 4 outlines the relative charactierised results for each product system across the sixteen environmental impact categories. Figure 5 then compares the final values of each product system whilst Table 4 provides the absolute charactierised results. It is clear that the materials contribute the most to the environmental footprint of the TCT Product whilst the materials and moulding process are more significant across most impact categories for the EPDM Product.

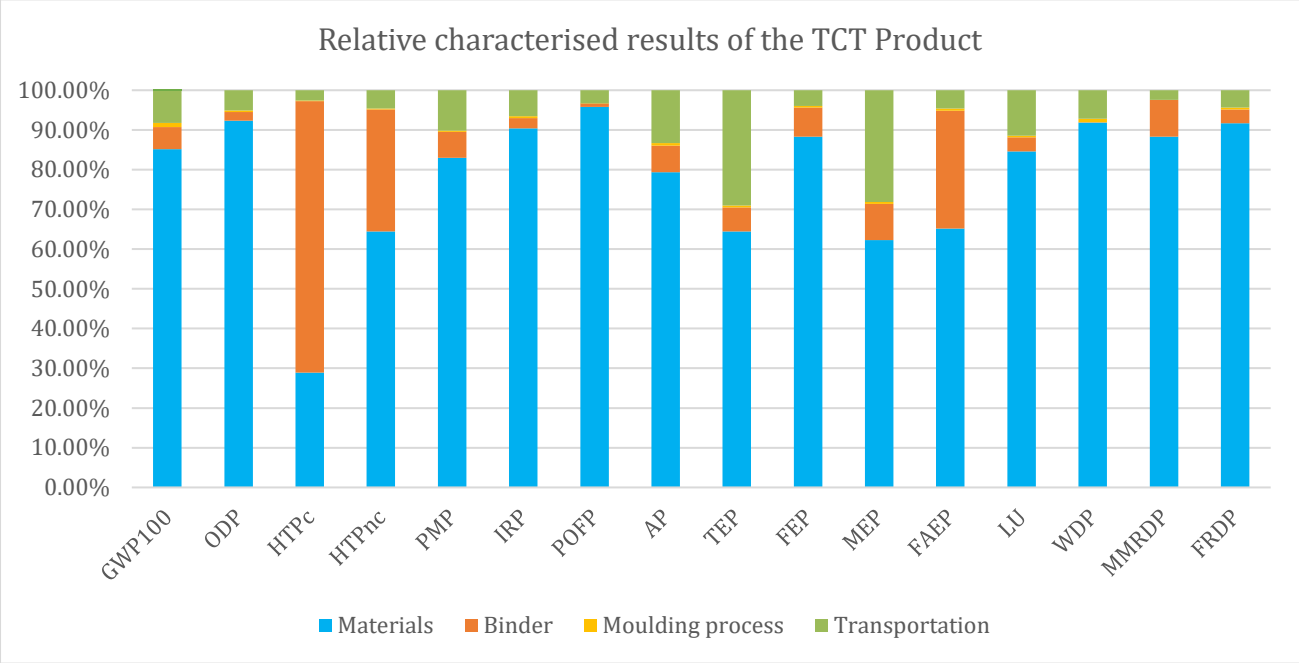

FIGURE 3: RELATIVE CHARACTERISAED IMPACT ASSESSMENT RESULTS OF THE TCT PRODUCT

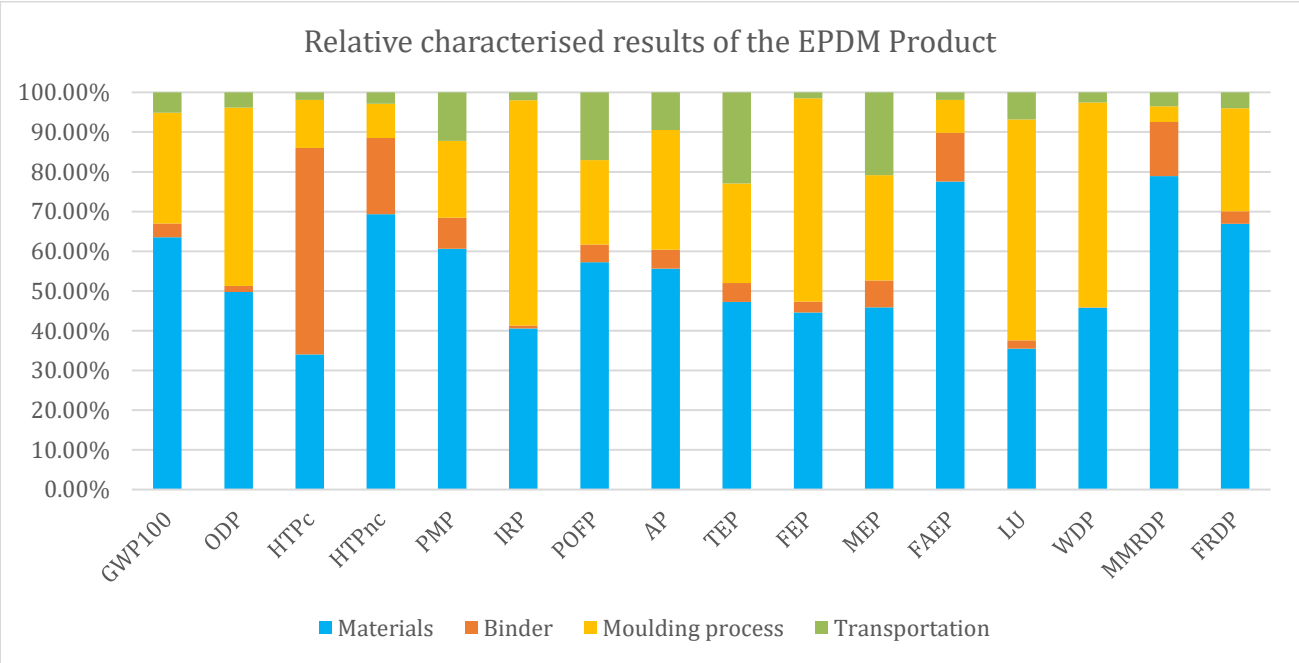

FIGURE 4: RELATIVE CHARACTERISAED IMPACT ASSESSMENT RESULTS OF THE EPDM PRODUCT

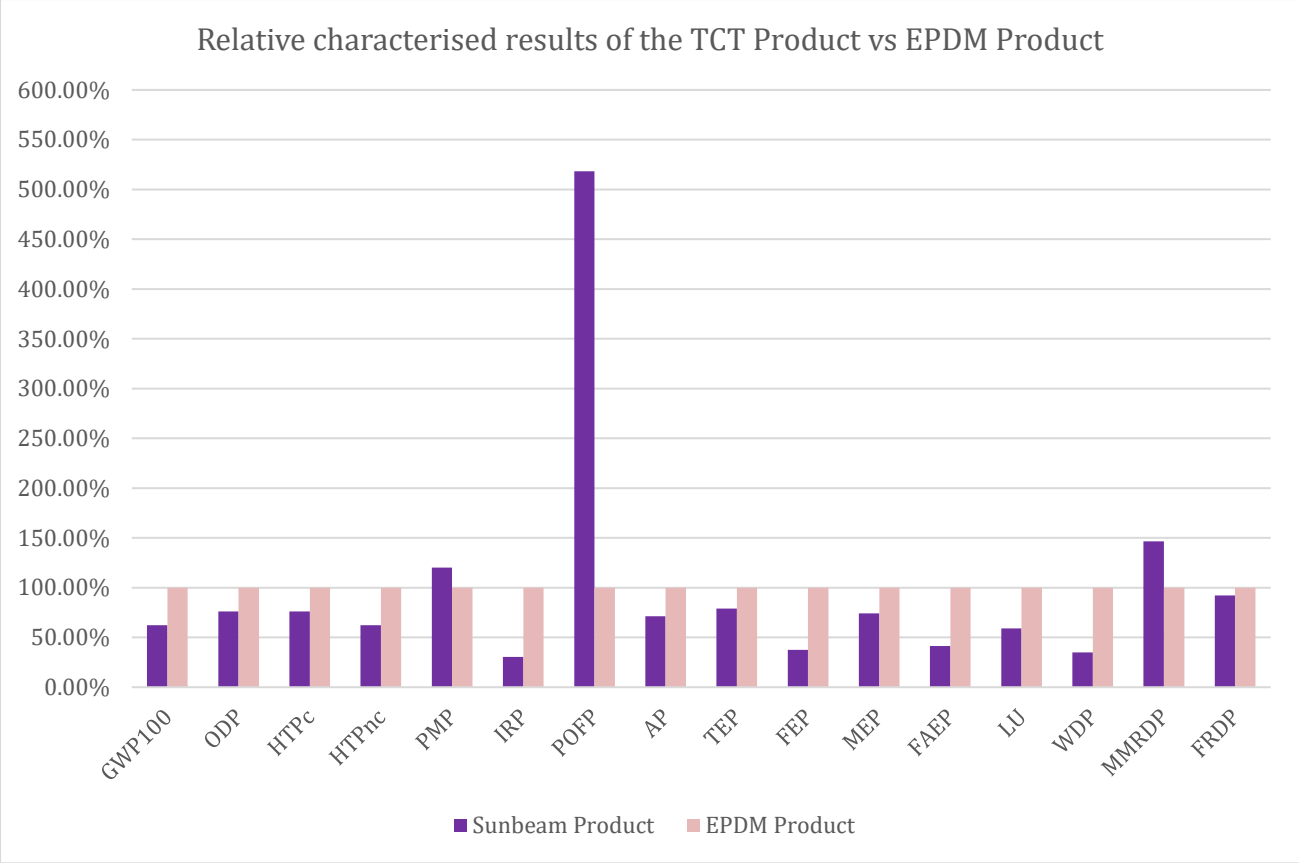

FIGURE 5: RELATIVE CHARACTERISAED IMPACT ASSESSMENT RESULTS

TABLE 4: ABSOLUTE CHARACTERISED IMPACT ASSESSMENT RESULTS

Impact Category	Indicator	TCT Product Result	EPDM Product Result
GWP_{100}	kg CO_2 eq.	3.67049341276138	5.89909400708203
ODP	kg CFC-11 eq.	1.18592954112798E-06	1.55988214896096E-06
HTPc	CTUh,c	2.92829821189843E-09	3.85304100673237E-09
HTPnc	CTUh,nc	7.17379794613584E-08	1.14669867833197E-07
PMP	disease incidence	2.40088996894454E-07	1.99968226984132E-07
IRP	kBq U^{235} eq.	0.414236821830469	1.36323531157539
POFP	kg NMVOC eq.	0.0875955821988811	0.016905008448623
AP	mol H^+ eq.	0.0168082255449135	0.0235612403112594
TEP	mol N eq.	0.0359799272870316	0.0456082988459217
FEP	kg P eq.	0.000715597876713757	0.00190758911563384
MEP	kg P eq.	0.00339865539129376	0.00457937949652536
FAEP	CTUe	49.9513194909389	120.866344539881
LU	Dimensionless (pt)	7.18939217889149	12.1420788553946
WDP	m3 world eq.	214.721715146929	615.133243519458
MMRDP	kg Sb eq.	0.0000356803636279796	0.0000243479793018814
FRDP	MJ	107.259465590066	116.549527122592

B. Normalisation

To determine the importance of the results stemming from each impact category, the European Commission JRC Technical Report 'Global normalisation factors for the Environmental Footprint and Life Cycle Assessment' was consulted. Normalisation factors are typically used to adjust values measured on different scales to a notionally common and easily understandable scale. The JRC report provided global normalisation factors for emissions and resource extraction in 2010, based on EF method. These factors have been applied within this analysis to express the results of the TCT Product and EPDM Product in terms of an average global citizen in one year (i.e. per captia). The results of this process can be seen in Figure 6.

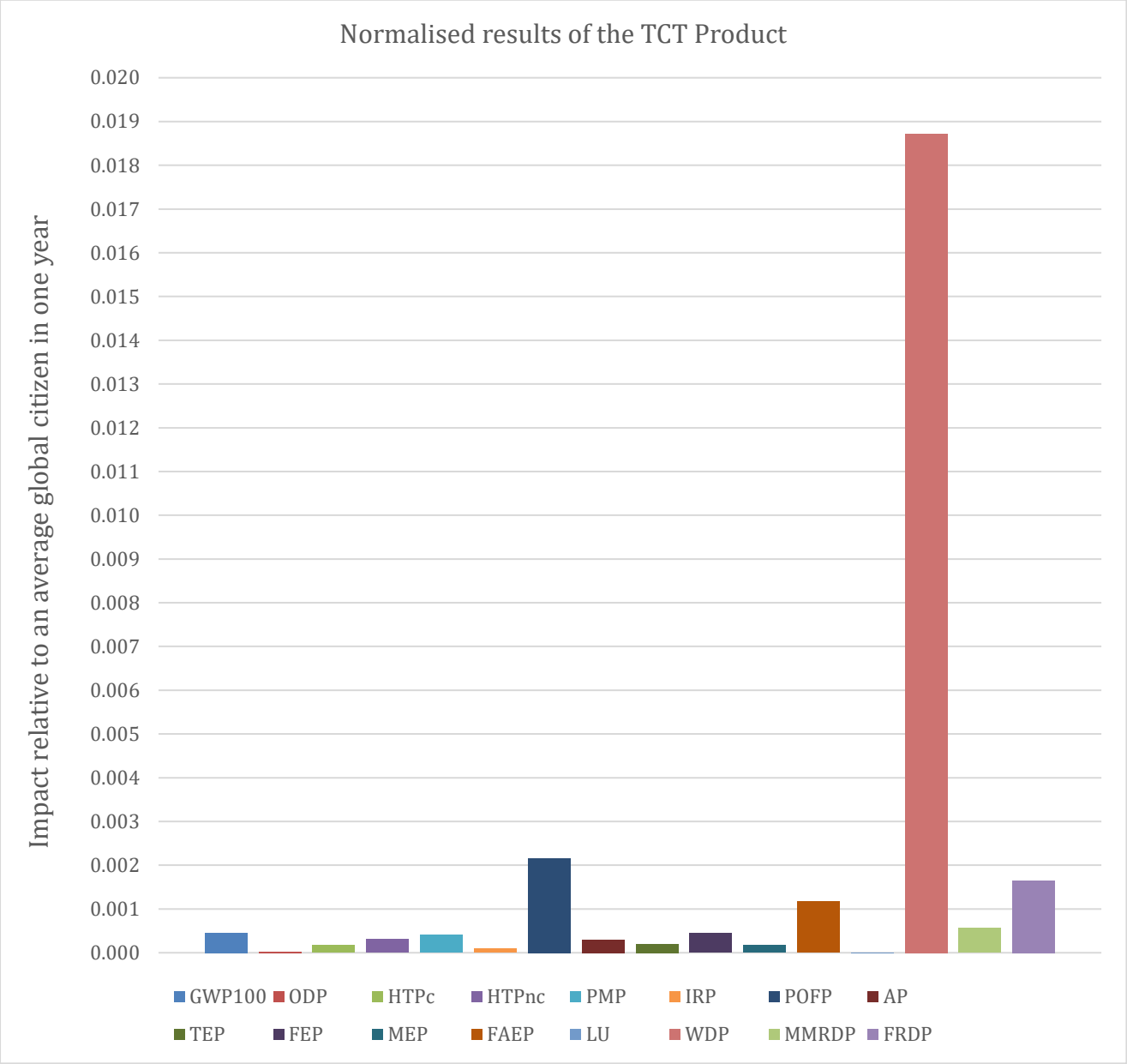

FIGURE 6: NORMALISED IMPACT ASSESSMENT RESULTS

Interpretation of results

In this section, the results from the impact assessment will be described in more detail in terms of the process contribution of the TCT Product. The focus will be on GWP_{100} due to the interests of TCT–Europe, as well as WDP due to its meaningful impacts found during normalisation procedures.

A. Global Warming Potential 100a

Overall, 85.17% of the GWP_{100} results came from the Recycled Car Tyre Rubber (Crumb) process. This impact mainly came from the CO_2 released during the manufacturing processes, specifically in relation to the materials of synthetic rubber (23.24%), carbon black (21.71%) and natural rubber based sealing (17.49%). Whilst the embodied carbon associated with these materials may be classed as unavoidable emissions, methods to reduce these impacts should be investigated, including the possibility of sustainable procurement options.

B. Water Depletion Potential

For WDP, 91.88% of the result comes from the Recycled Car Tyre Rubber (Crumb) process, mainly derived from the synthetic rubber (41.22%), natural rubber based sealing (22.71%) and silicone product (15.93%). The vast majority of this water consumption is required in these processes for energy, particularly relating to turbine use to produce electricity and the amount of water used in cooling loops for the steam exiting the turbine. Again, the embodied carbon associated with these materials may be classed as unavoidable emission, encouraging suppliers to implement a water management strategy and staff education training course could lead to significant reductions in water consumption. This might focus on water capturing, treating and/or recycling water during the manufacturing process.

C. Other

The TCT Product produces a better result across thirteen out of sixteen impact categories. The only exceptions are PMP, POFP and MMRDP. For PMP, the majority of this impact comes from the particulates, ammonia, nitrogren oxides and sulfur dioxide released from the carbon black (39.88%), syntheric rubber (22.36%) and natural rubber (9.46%) materials processes. In terms of POFP, 85.93% of the impact is due to the release of non-methane volatile organic compounds from the natural rubber based sealing process. Lastly, the materials are responsible for 88.29% of the impact for MMRDP of which the use of synthetic rubber is responsible for 65.41% of the total impact. This mainly comes from the depletion of cadmium and zinc as part of the raw material extraction and manufacturing processes. To lower these impacts, again, sustainable procurement options should be investigated.

Conclusion

One of the key conclusions of this analysis is that the TCT Product offers significant environmental savings over a common EPDM Product. These savings are relevant both in terms of the material procurement and moulding process. Using a normalisation method which represents an average person's environmental impact, WDP seem to have the stronger impact among the sixteen different categories of environmental impact. Some suggestions to lower these impacts (as well as GWP_{100}, PMP, POFP and MMRDP impacts) were outlined. If these alternative procurement methods for mitigating environmental impacts are implemented, the product can then be reassessed and compared to the original quantifications. However, the initial data collected as part of this analysis provided no values for the use or end of life steps due to a lack of information. This is a significant omission given that the each product system required a dedicated mould to make the product and these products can also be resued/recycled up to four times. As a result, this could significantly alter results, given that some research indicates that the use and end of life phases could dominate results. Therefore, before reduction efforts are pursued, it is recommended that data is collected for these additional life cycle steps/processes and this analysis is re-run to more accurately determine the environmental impacts of the product.

End of report

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A consortium project led by the University of Strathclyde, in collaboration with the Scottish Institute for Remanufacturing, National Manufacturing Institute Scotland, South Ayrshire Council, East Ayrshire Council and South Lanarkshire Council.

The EXTEND project supports SMEs across Scotland support on their journey to becoming more sustainable by providing free expert guidance and knowledge of all the pathways available.

EXTEND addresses the challenges around life extension and repurposing of assets. It focusses primarily on engaging SMEs who traditionally have had some or little involvement and supporting their journey from opportunity identification to technical capability demonstration.

This guide has been developed to support SMEs seeking to unlock opportunities around the global climate emergency and contribute to Scotland’s target of reaching net- zero emissions.

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