



Carbon footprints of tyre production – new versus remanufactured

A report comparing the carbon footprint of a new and a retread tyre for use by light commercial vehicles

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July 2008





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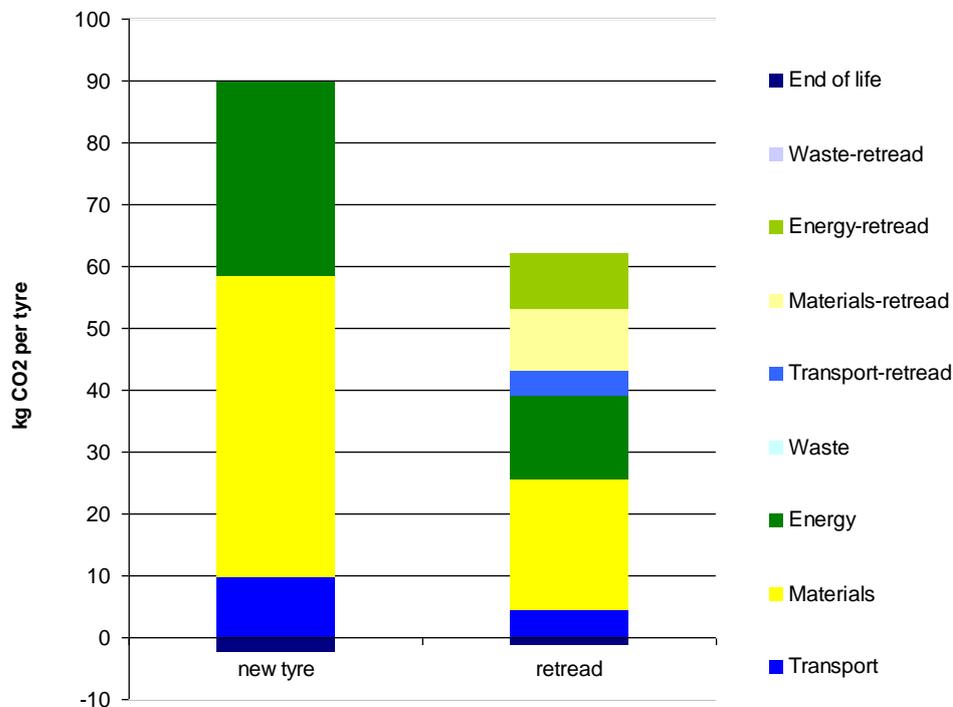


Executive summary

This report compares the carbon footprint of a new and a retread 17.5” tyre for use by light commercial vehicles. Retread tyres are tyres where a new tread is applied to a used tyre casing. This process effectively increases the number of cycles for a tyre casing, and this project was commissioned to assess the carbon balance of new tyre production compared to retreading.

This study shows that a 17.5” new tyre produces 86.9 kg CO₂ emissions compared to 60.5 kg CO₂ for an equivalent retread tyre. These figures are based on each retread tyre being resurfaced an average of 1.3 times (which is a figure supplied by a remanufacturer). This equates to a reduction of emissions by 30%. Figure 1 below shows a comparison of the impacts arising from each stage of the product lifecycle

Figure 1: Comparison of carbon footprint of a new and a retread tyre



Note: The impact of a retread tyre is based on the assumption of 1.3 retreads per tyre.

The embodied carbon of materials required to produce a tyre accounts for the biggest portion of the carbon footprint of both tyre types - more than half of the total carbon footprint for each. The material used in new tyre manufacture is responsible for 48 kg CO₂, while for retreading it is 31 kg of CO₂.

The second largest impact is attributed to the energy needed in the manufacturing and retreading process, which accounts for 31 kg CO₂ for a new tyre and for 22 kg CO₂ for a retread. A relatively significant impact is associated with transport, which accounts for almost 10 kg CO₂ of a new tyre and 8.3 kg CO₂ for a retread. Although transport impacts for retreading include the collection of casings, the absolute impact is slightly lower than for new tyres which require long distance import of raw

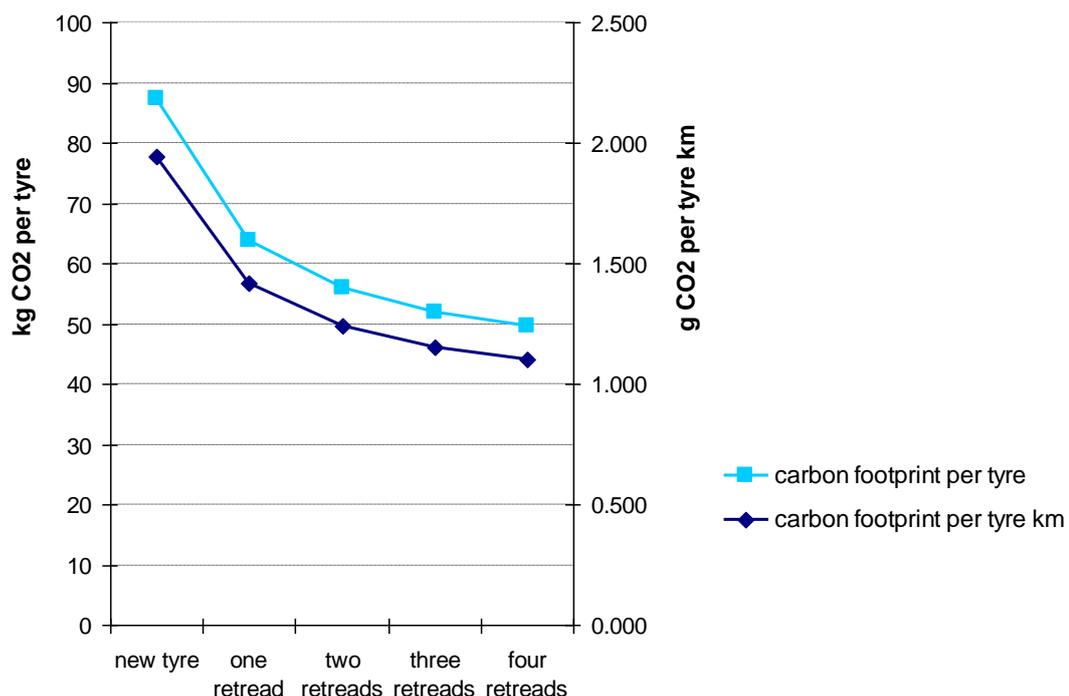


materials. Impacts from waste and end of life are relatively low but have been accounted to reduce the overall carbon footprint of the tyre because the waste materials displace other fuels and materials in the economy. This approach is explained in detail in the body of the report.

Figure 1 shows that the impacts of a new tyre account for almost 70% of total retread impacts (including end of life). This is because the initial manufacturing process and material used in a tyre casing form the most significant impact of the production of the retread tyres and therefore these must be accounted for. This accounting means that the carbon savings from retreading are a result of reusing a tyre casing several times over. With each re-use cycle the impacts of the casing (manufacture and end of life) are amortised over the multiple use cycles which therefore account for a significant net carbon saving.

Figure 0.2 below demonstrates the effect of multiple retread cycles compared to production of a new tyre. The figure shows the impact per tyre produced and per km driven, and demonstrates that with each progressive retread cycle the carbon footprint decreases.

Figure 2: Relation between the carbon footprint per tyre, per tyre km and the number of tyre retreads



This analysis has found that retreading 17.5” tyres improves the carbon efficiency of tyre production. Retreading requires less inputs than new tyre manufacture at each stage of a product life cycle. The impacts of the new casing production and end of life are amortised over retread cycles and the results show that the more times each casing is retreaded, the bigger the carbon savings achievable by retreading.

^a Assumes comparable performance of new and retread tyres. The authors are unaware of definitive data comparing performance of the two products.



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1 Introduction

1.1 Purpose and objectives of the study

This document presents the carbon footprint of a remanufactured 17.5” tyre and compares it with the carbon footprint from production of a new tyre. In this study, the terms ‘remanufactured’ and ‘retread’ tyres will be used interchangeably as definitions of tyres produced by resurfacing used casings to produce functional products which can be used equivalently to new tyres.

Retreading tyres is a proven technique and there are many companies performing the process. One element of retreading which has not been categorically determined is the relative eco-efficiencies of the entire lifecycle of retreading compared to new tyre equivalents. This study was commissioned by the Centre for Remanufacturing and Reuse to objectively assess the carbon footprint of new and retread 17.5” tyres. The study was commissioned to cover the entire product lifecycles, and to include CO₂ emissions but not other greenhouse gases.



2 Methodology

2.1 Carbon footprint

Carbon footprint analysis is the measurement of carbon dioxide (CO₂) emissions from fossil fuel combustion. Carbon dioxide is an important contributor to climate change and one of the key greenhouse gases covered by the Kyoto Protocol.

Carbon dioxide emissions occur during the everyday operations of an organisation, business or enterprise; and include energy use, material flows, and transportation to and from the workplace. The emissions from products, also called embodied energy, refer to the amount of energy required to manufacture and supply the product to the point of use. Individual or household emissions refer to the CO₂ generated by the daily lives of people.

2.2 Scope of the study - definition of boundaries

It is critical that project boundaries used in footprint analyses are appropriately defined to capture all of the impacts associated with the activity under investigation. Although standards for carbon footprinting exist (including WBSCD's GHG Protocol, ISO14064 and the draft PAS 2050) there is no absolute guidance for deriving boundaries for a study of this type. The boundaries of this project therefore encompass all the stages in the life cycle of a tyre except for the impacts arising from its usage. In order to directly and fairly compare impacts of retreading and manufacturing, boundaries of both life cycles have to be consistent. However, because the retreaded product depends on new manufacture for the casing at its core, the new tyre impacts are nested within the boundaries of the retread lifecycle.

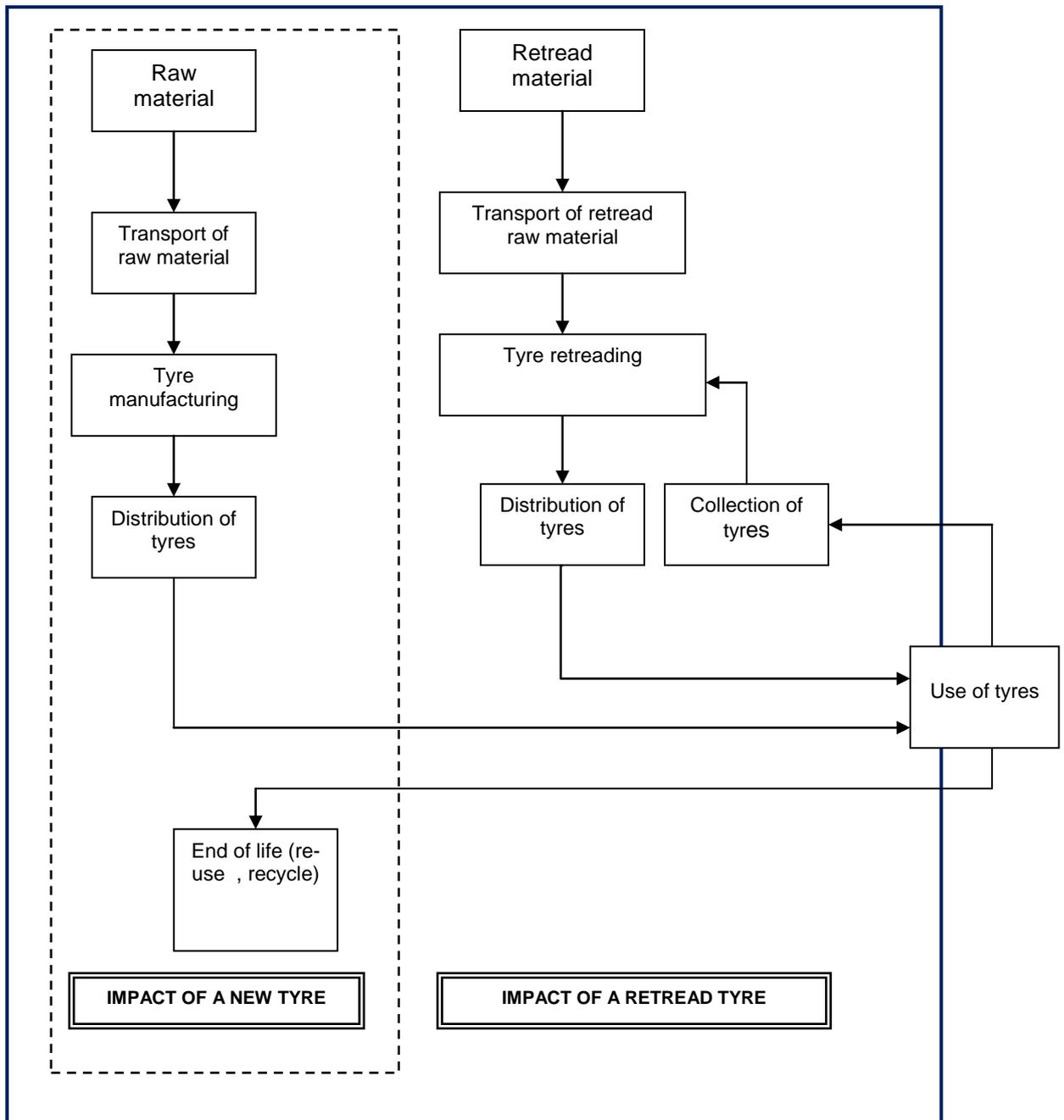
These boundaries are schematically presented in Figure 3 below, which shows the relationship between the new and remanufactured lifecycles. The diagram shows that the retreading lifecycle encompasses new tyre manufacture but additionally includes dedicated activities for the retreading process. The lifecycle stages for each tyre type are listed below in **Table 1**.

Table 1: Comparison of impacts arising from a new and a retread tyre

New tyre	Retread tyre
Raw material	Raw material
Transport of raw material from the country of origin to the manufacturing site	Transport of raw material from the country of origin to the manufacturing site
Tyre manufacturing	Tyre manufacturing
Distribution of new tyres	Distribution of new tyres
	Collection of used tyres
	Raw materials for retread
	Transport of retread material
	Tyre retreading
	Distribution of retreaded tyres
End of life	End of life



Figure 3: New and retread tyre lifecycles and project boundaries



2.3 Calculations

The calculation of the carbon footprint was performed by firstly identifying and mapping out the inputs of each life cycle stage. In the next step conversion factors for each input were applied to convert material use and energy/fuel consumption into carbon dioxide emissions.

The objective of the study was to compare remanufacturing to new tyre production. As explained above, impacts of a new tyre encompass all emissions associated with the lifecycle while the impacts of tyre retreading consist of dedicated retread inputs and the

discounted impacts of the casing from the new tyre. Emissions from tyre end of life are included in the final result and because of the Landfill Directive the different waste treatment routes must be considered. A full account of the impact of alternative end of life destinations is included in Appendix 1.

The accounting methodology is critical to the result of the study, and the calculation methodology is presented in Box 1.

Box 1: Calculation steps for the calculation of the carbon footprint of both tyre types

New tyre

The carbon footprint of a new tyre comes from the emissions from making a new tyre (N) and those arising from disposing of the tyre at the end of life (EOL). This can be written as:

$$\text{New tyre} = N + EOL$$

The emissions from making a new tyre (N) can be subdivided into transport (T), materials (M), manufacturing energy (E) and waste (W). Superscript n denotes impacts associated with a new tyre. Thus the above equation can be rewritten as:

$$\text{New tyre} = (T^n + M^n + E^n + W^n) + EOL$$

Retread tyre

The carbon footprint of a retread tyre over its life span can be calculated by adding the emissions from retreading (R), a portion of those from making a new tyre (N), and a portion of the emissions from the product end of life (EOL). Unlike a new tyre which is produced and used once, the retread product can be a function of multiple retread production cycles. The impact of an average retread tyre can therefore be obtained by dividing the total lifecycle emissions by the number of production cycles (PC) through which a retread tyre typically passes^b. The carbon footprint of retread tyre can thus be written as:

$$\text{Retread tyre} = \frac{N + (PC - 1) * R + EOL}{PC}$$

In this equation (PC-1) denotes the number of *retread* cycles and is used to multiply the retread inputs (R) required each time. Written out fully the above equation can be expressed as:

$$\text{Retread tyre} = \frac{(T^n + M^n + E^n + W^n) + [(PC - 1) * (T^r + M^r + E^r + W^r)] + EOL}{PC}$$

Superscript r denotes impacts associated with a retread.

Two complex elements of the equations in Box 1 are the production cycles and end of life are complex elements so it is useful to consider these further.

^b The value of PC for a new tyre is equal to 1 and is therefore not shown for the first equation representing emissions for a new tyre.



The production cycle (PC) value enables calculation of the average impacts of a typical retread across its entire lifespan. Tyre casings are made during new tyre manufacture, and then used as the core unit for resurfacing during retreading. There is a direct relationship between the number of times a casing is resurfaced, and the resource inputs related to retread tyre production. If casings are used multiple times, fewer casings are required and the impact of the initial casing manufacture is amortised across the average number of production cycles for a retread tyre.

Tyres have been identified as a problem waste stream and it is important to consider end of life in more detail. Tyres have been excluded from landfill since 2003 when the EU Landfill Directive was passed. Alternative disposal methods include: incineration of tyres to produce electricity; incineration of tyres in cement kilns; recycling of materials; and reusing tyres for physical structures (e.g. landfill engineering, boat fenders, etc). The waste treatment method has significant implications for the carbon footprint and is discussed in Section 3.6 and Appendix 1, but the overall calculation methodology amortises EOL impacts over product cycles. This accounting rule has been used because retreading casings effectively reduces disposal as the 'old' tyres enter the retread production cycle. Therefore, EOL impacts are amortised in a similar way to 'new production' impacts.

2.4 Data quality

The project was planned with the expectation of receiving primary data on manufacturing inputs for new and remanufactured tyre production processes. During data collection the authors were informed that the expected source of primary data for new tyre manufacture was unable to provide the necessary information. Consequently all data used for new tyre manufacture has been derived from secondary sources (which largely report results for car tyres only). In contrast, data for retread inputs have been supplied as primary data collected in collaboration with Vaculug, one of Europe's largest independent retreaders of commercial and industrial vehicle tyres.

Table 2.2 presents the data sources and data quality assessment. The unavailability of primary data for new tyres is a weakness of the study because the secondary data available is variable in quality, especially in relation to energy required for manufacture. Furthermore, these data are not specifically for 17.5" tyres so the authors have extrapolated available data for other tyre sizes. Although this data shortage reduces confidence in the final outputs, the report has been structured to readily enable input of primary data for new tyres should this become available.

The data related to retreading has been directly provided by a remanufacturing company. There is therefore high confidence in the data received, although ideally multiple remanufacturers' data would be used to produce average figures.



Table 2: Assessment of data quality

	Life cycle stage	Data quality (red = low, orange = medium, green = high)
1. New tyre	Raw material for new tyres	Primary data unavailable during study. Wide range of data sources used to generate average values. Extrapolation of figures from studies of tyres of different dimensions reduces data confidence.
	Transport of raw material for new tyres	
	New tyre manufacturing	
	Distribution of new tyres	
2. Retread tyre	Collection of used tyres	Primary data obtained directly from retreader. High confidence in data quality, although single manufacturer may not be representative of wider industry
	Raw materials for retread	
	Transport of retread material	
	Tyre retreading	
	Number of production cycles	
	Distribution of retread tyres	Manipulation of primary data obtained from retreader. Low confidence but consistent for both tyre types.
3. End of life	End of life	Treatment methods from secondary reports, EOL destinations from official UK source. Medium confidence overall.



3 Carbon footprint analysis

3.1 Total footprint overview

Carbon footprints of a new and a retread 17.5" tyre are obtained by applying the formulae developed in the previous chapter. The analysis shows that a new tyre produces 86.9 kg CO₂ emissions, while a retread is responsible for 30% less emissions with a total of 60.5 kg CO₂ per tyre. Retread impacts calculated in this study are specific to a tyre that has been retreaded 1.3 times (from primary data) and this figure will vary for different retreaders and tyre types.

The breakdown of the carbon footprint of a new and a retread tyre are presented in Table 3.1. This allows comparison of impacts arising from different product stages. It shows that the embodied carbon of materials is the largest component for both tyres accounting for more than 50% of the total impact. It is responsible for 49 kg of CO₂ in new tyres compared to 31 kg CO₂ in retreads.

The second largest impact is attributed to the energy needed in the manufacturing and retreading process. The energy used to manufacture a new tyre produces 31 kg CO₂, while retread energy is 22 kg CO₂.

The footprint of transport is roughly the same for both tyre types. In total transport emissions add almost 10 kg CO₂ for a new tyre and over 8 kg CO₂ for a retread. The higher emissions for transport of new tyres come from the long distance import of raw materials from overseas.

In total the impact of production waste from both tyres is low. The production process generates very little waste and the waste rubber material is useful in other applications with little additional processing.

End of life emissions are accounted with consideration of the final destination and of old casings. In some instances, waste tyres may act as a more carbon efficient substitute and can therefore be shown to contribute to a reduction of the overall footprint. End of life destinations are discussed in detail in Appendix 1, but the largest net saving^c is derived from displacing coal with tyres as a fuel in cement kilns.

Results show that remanufactured tyres are overall more carbon efficient to produce than new tyre equivalents. The distribution of the carbon footprint for discrete components of each tyre type is presented in Table 3 and demonstrated graphically in Figure 4

^c Disposing of tyres is not a 'carbon positive' activity as such. The study accounts for the impacts of producing tyres at earlier life cycle stages and these are significant. However, when examining end of life only, net savings can be attributed to tyres through displacement of other fuels/materials.

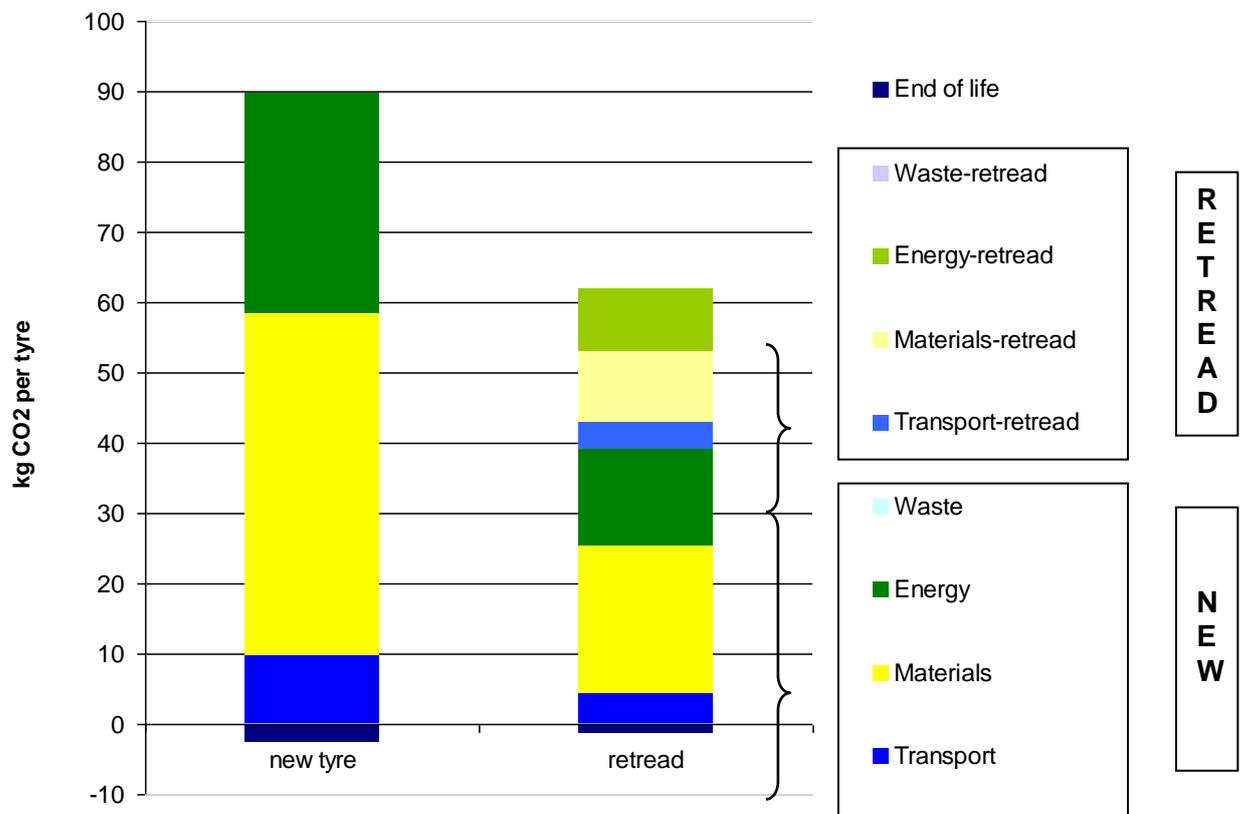


Table 3: Carbon footprint of a new and a retread tyre

	New tyre		Retread tyre					
	kg CO2	%	Retread total		Casing		Retreading process	
Total impact	kg CO2	%	kg CO2	%	kg CO2	%	kg CO2	%
Materials	48.6	55.7	31.1	51.2	21.1	55.6	10.0	43.9
Transport	9.9	11.3	8.3	13.7	4.3	11.3	4.0	17.7
Energy	31.4	36.0	22.5	37.1	13.6	35.9	8.9	39.0
Waste	-0.1	-0.1	-0.1	-0.2	0.0	0.1	-0.2	-0.7
End of life	-2.5	-2.8	-1.1	-1.8	-1.1	-2.8	-	-
Total carbon footprint	87.2	100	60.7	100	38.0	100	22.7	100

Note: numbers may not add up due to rounding.

Figure 4: Carbon footprint of a new and a retread tyre



3.2 Materials

Tyre manufacturers produce different tyre types for different weather conditions, loads and road conditions. To make a tyre suitable for most conditions manufacturers use composite/blended materials so it is very difficult to typify an “average” tyre. The composition of the new tyre used for this study is based on publicly available sources and the authors recognise that the robustness of the study would be improved with direct data from manufacturers. Conversely, data on material needed for a tyre retread is based on information provided directly by Vaculug. The type and quantities of material inputs are presented in Table 4 below.



The total weight required for the new tyre is almost three times that of the retread. The main material savings attributed to retreading are a result of not needing to manufacture the casing (effectively reusing the steel and textile components) which account for a substantial part of a tyre's structure and weight.

Table 4: Structure and weight of material components need for manufacturing a new and a retread 17.5" tyre

Material	New tyre		Retread tyre	
	Weight (kg)	Structure (%)	Weight (kg)	Structure (%)
Synthetic rubber	3.8	14.5	3.3	37.4
Natural rubber	8.1	30.5	0.3	3.7
Carbon black	5.8	22.0	3.0	33.5
Steel	6.6	25.0		
Rayon/polyester	0.5	2.0		
Plasticizers (oils and resins)			1.8	20.2
Zinc oxide	0.3	1.0		
Sulphur	1.3	5.0		
Other			0.5	5.2
Total	26.5	100	8.9	100

When the materials figures are translated into carbon dioxide emissions the result for a new tyre is 48.6 kg CO₂ and for a retread is 31.1 kg CO₂ of which old casing is responsible for 21.1 kg while the remaining 10 kg CO₂ are attributed to the remanufacturing process. The carbon footprint of retread materials is about 35% smaller than for new tyres. Lower material consumption represents the first carbon saving that can be attributed to retreading.

Table 5: Carbon Footprint per tyre

	New tyre		Retread tyre					
	kg CO ₂	%	Retread total		Casing		Retreading process	
	kg CO ₂	%						
Synthetic rubber	16.3	33.6	15.1	48.7	7.1	33.6	8.0	80.6
Natural rubber	12.4	25.6	5.7	18.3	5.4	25.6	0.3	2.9
Carbon black	4.7	9.7	3.4	11.0	2.1	9.8	1.4	13.8
Steel	12.1	24.8	5.2	16.9	5.2	24.8	0	
Rayon/polyester	2.9	6.0	1.3	4.1	1.3	6.0		
Plasticizers (oils and resins)	0.0	0.0	0.2	0.7	0.0	0.0	0.2	2.2
Zinc oxide	0.1	0.2	0.0	0.1	0.0	0.2	0	
Other	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.6
Total	48.6	100	31.1	100	21.1	100	10.0	100

Note: figures may not add up due to rounding.

The highest materials impact can be attributed to synthetic rubber in both tyre types. It accounts for almost half of the carbon impact of a retread tyre and almost a third for a new tyre. The second and the third largest materials impacts come from natural rubber and steel. These are each responsible for around 25% of new tyre material emissions and just under 20% for a retread tyre. Carbon black accounts for about 10% of the



material impacts for both tyres, and the impact of other materials is relatively small. All of these results are presented graphically in **Figure 5** and Figure 6 below.

Figure 5: Carbon footprint of materials of a new tyre

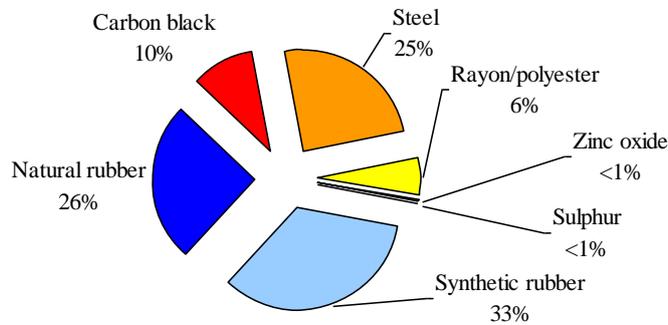


Figure 6: Carbon footprint of materials of a retread tyre

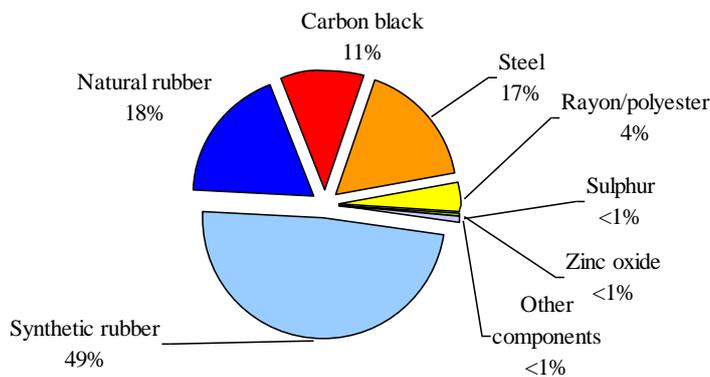


Figure 7: Carbon footprint of materials of a retread tyre (casing only)

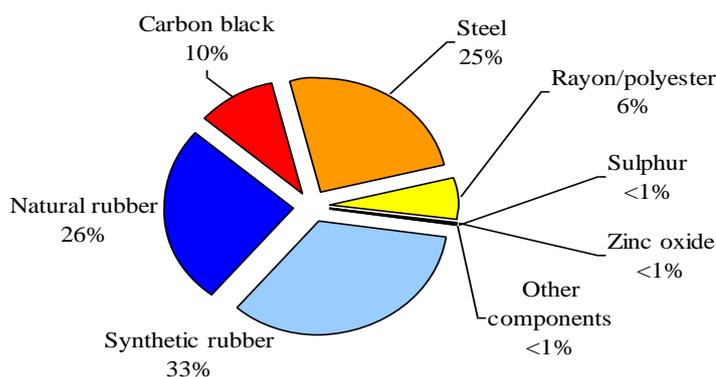
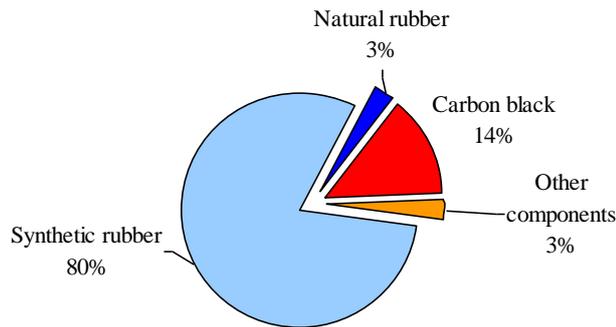
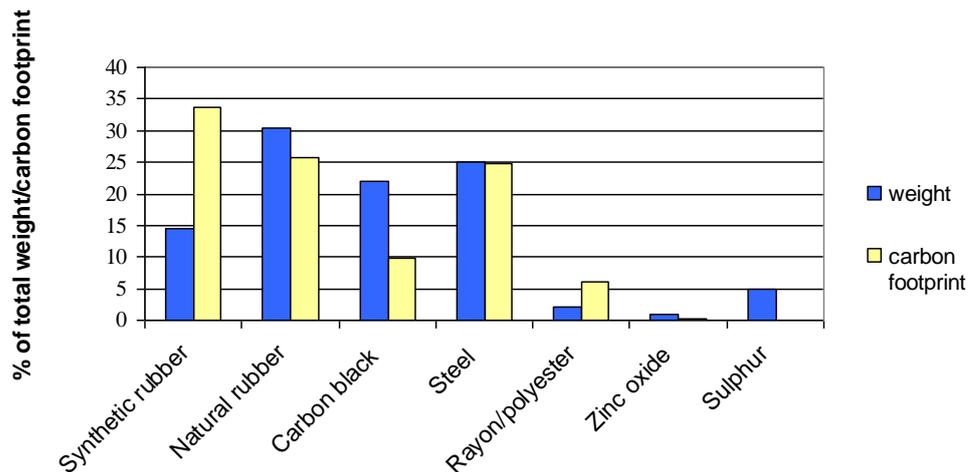


Figure 8: Carbon footprint of materials of a retread tyre (retreading process)



A direct comparison of each material by weight and carbon footprint is shown in Figure 3.6 below. The figure compares the weight of materials (required to produce a new tyre) and their corresponding carbon footprint. The purpose of this graph is to show that weight and carbon intensity are not necessarily correlated. The highest impact materials per kg include synthetic rubber, steel and rayon/polyester.

Figure 9: Comparison of material weight with carbon footprint (data for new tyre)



3.3 Transport

The carbon footprint of transport comes from bringing raw materials from the manufacturing site, distribution of final tyre products, collection of casings (for retread only), and collection of tyres for disposal. These separate activities are presented in Table 6 below.

Primary data was not available for either tyre types, for the distribution of the final products to market or the collection of tyres for disposal. The shortage of primary data for new tyres has been discussed, and for distribution and disposal the impacts were assumed to be the same for both tyre types. In reality, distribution emissions may vary considerably if new tyres are manufactured abroad but for this study a conservative position (i.e. consistent figures for both types) was adopted when data was unavailable.



Table 6: Impacts of transport related to a new and a retread tyre

Transport	New tyre	Retread tyre
Transport of raw materials	Transport of raw materials required for construction of a new tyre.	Transport of raw materials required for construction of a new tyre and transport of raw materials required for a retread.
Distribution of tyres	Distribution of finished tyres to authorised sellers.	
Collection of retread tyres	N/a	Collecting tyres for retreading.
Collection of old tyres	Collecting tyres for disposal.	

Table 7 below shows that the largest portion of the transport footprint is related to the transportation of raw materials. These figures were derived using primary data where available, and assumptions based on common production centres for materials of unspecified origin. The methodology used to derive these figures is shown in Appendix 1. Retreading requires smaller quantities of material than making a new tyre and consequently produces a smaller transport footprint.

Collecting old tyres for disposal contributes about 20% of transport impacts for both tyre types. Collection of old casings for retreading has a relatively small impact, shown by the low fuel use per casing collected (about 0.6 litres diesel). In other words, the logistics of casing collection is very fuel efficient and therefore does not significantly add to the remanufacturing footprint.

Overall, transport associated with retreads contributes further savings compared to new tyres even accounting for the collection of casings.

Table 7: Transport carbon footprint

	New tyre		Retread tyre					
	kg CO ₂	%	Retread total		Casing		Retreading process	
	kg CO ₂	%						
Transport of raw material	6.1	62.1	3.6	43.5	2.7	62.1	1.0	23.7
Collecting casings for retreading	/	/	1.0	11.5	/	/	1.0	23.8
Distribution of new/retread tyres	2.0	20.7	2.0	24.6	0.9	20.7	1.2	28.7
Collecting old tyres for disposal	1.7	17.2	1.7	20.4	0.7	17.2	1.0	23.8
Transport	9.9	100	8.3	100	4.3	100	4.0	100

Note: figures may not add up due to rounding.

3.4 Energy

Energy is required for new manufacturing and retreading tyres. Retreading is taking place in the UK and, without primary data for new tyres, it was assumed that manufacturing of a new tyre also took place in the UK (for consistent analysis). Production is an extensive process during which different materials and components are combined to produce the final product.

Secondary data sources were used for the manufacturing energy for new tyres. A number of reports were consulted but the authors only felt sufficiently confident in one



result which was a report commissioned for Environment Australia^d. This report measured the energy inputs for several different tyre sizes which were scaled up or down to account for the 17.5” tyre focussed on in this study. The carbon intensity of Australia differs from the UK so adjustments were also made here, all of which are explained in Appendix 1. These figures were proportionally scaled down to derive results for the 17.5” tyre weighing 26.5 kg. As a result of applying this assumption, emissions arising from energy for production of a 17.5” new tyre were calculated as 31 kg CO₂.

Data on the energy required to retread a tyre was obtained directly from Vaculug and shows that retreading a tyre consumes 13.69 kWh of electricity and 41.57 kWh of gas producing 15.56 kg CO₂ in total. As explained in section 2.3, after including the energy inputs for making a new tyre (amortised over the use cycles) the energy emissions for a retread tyre are more than 22 kg CO₂. Table 3.6 has the results for both tyres, and shows retreading of a 17.5” tyre saves approximately 8 kg CO₂ per tyre from reduced energy demand.

Table 8: Carbon footprint from energy (kg CO₂)

	New tyre	Retread tyre		
		Total retread	Casing	Retreading process
Energy	31.4	22.5	13.6	8.9

3.5 Waste

Waste is accounted as a residual material that is generated in the production process but is not part of the product and is subsequently landfilled or recycled. This section does not include end of life impacts, which are described in Section 3.6.

To estimate the quantity of waste arising from the new tyre manufacturing, secondary data^e was extrapolated to apply to a 17.5” tyre. This estimation calculated that producing a new tyre was responsible for over 0.4 kg of waste, which was either landfilled, recycled or re-use d.

Data from Vaculug shows that the retreading process generates 71,455 kg of buffing dust (5 kg per tyre). This dust is all recycled as an input material for matting. Other waste generated from the site includes 643 kg of plastic packaging and 972 kg of pallets which are recycled.

Tyre waste has valuable properties which make it useful for other applications. If this material is used as an input to other products it reduces/eliminates the need for other material inputs which can be accounted for as a ‘saving’ through displacement. The degree of saving is calculated as the difference between the emissions needed to produce the material that is being displaced, and the emissions needed to make the waste material a suitable input. This methodology means that tyre waste has scope for reducing the footprint, particularly for retreads because the rubber removed by buffing can be used for surfacing.

Primary data on waste from new tyre manufacture was not available, but secondary sources show it is of mixed materials and relatively low volume. This waste is assumed

^d<http://www.environment.gov.au/settlements/publications/waste/tyres/national-approach/pubs/national-approach.pdf>

^e AEA Technology Environment, Overcoming Market Barriers for Key Stakeholders in Retread Tyre Markets, 2003



to go to mixed disposal routes, and is responsible for some additional emissions. Owing to the absence of new tyre data, the known impact of production waste for retread tyres was applied consistently to both tyre types. This extrapolation appears justifiable for such a low (arguably *de minimis*) impact

Table 8: Carbon footprint of waste

	Carbon footprint (kg CO ₂)	
	New tyre	Tyre retread
Waste	-0.1	-0.1

3.6 End of life

The EU Landfill Directive states that tyres cannot be landfilled and therefore other methods of disposal must be used. Using data from the Used Tyre Working Group (UTWG)^f the main end of life options for tyres were identified:

- Re-use for purposes such as motorway embankments, crash barriers, various marine applications (erosion control, artificial reefs), tree guards, fences.
- Retreads (remoulds).
- Reprocessing and recycling by shredding granulating or crumbling old tyres in order to use them in other applications (sports and play surfaces, shoe soles, carpet backing/underlay, adhesives, road surfacing).
- Burning (energy recovery) to produce energy
- Landfill engineering.

In order to make the lifecycles of new and retread tyres comparable in this study, the 'retread' destination was excluded and is included in the accounting methodology used.

The end of life emissions of a tyre were determined by calculating the weighted average of the alternative destinations. As waste tyres can be used in different applications their disposal is likely to reduce the need for the use of other materials. A consistent approach was used as for waste above, whereby the waste value was calculated as the difference between the emissions needed to produce the material that is being displaced, and the emissions needed to make the waste material a suitable input. Examples include: incineration of tyres replacing coal in cement kilns; or re-use of tyres (landfill engineering, guards, embankments) in place of other materials. It is not easy to readily determine what materials old tyres replace in all instances, so for some routes (e.g. landfill engineering) the displacement value used was zero. Detailed explanations of the calculations completed are presented in Appendix 1.

The net savings from end of life are primarily achieved by using tyres in place of coal in cement kilns. This net saving is derived because the carbon intensity of whole tyres is 77kgCO₂/GJ compared to 90kgCO₂/GJ for thermal coal^g. However, as stated in Section

^f www.tyredisposal.co.uk

^g <http://www.environment.gov.au/settlements/publications/waste/tyres/national-approach/pubs/national-approach.pdf>



3.1, the 'savings' attributed to end of life are net values which apply only to this final stage of the lifecycle and the entire lifecycle must be considered when drawing comparisons.

The accounting methodology amortises end of life for retreads over average casing cycles (as explained in Section 2.3). Effectively, this means there is less displacement of coal 'per retread tyre' so the net saving is lower, as shown in Table 3.8.

Table 9: Carbon footprint of the end of life

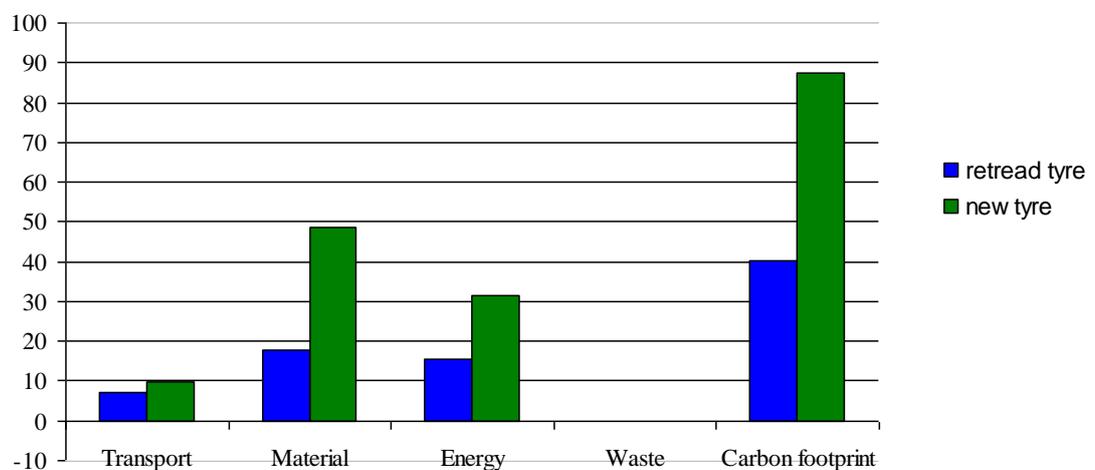
	Carbon footprint (kg CO ₂)	
	Retread tyre	New tyre
End of life	-1.1	-2.5



4 Interpretation of results and scenarios

The analysis has found that producing tyres by retreading emits less carbon dioxide than manufacturing new tyres. The savings arising from different lifecycle stage stages are presented in Figure 10 below (excluding end of life). It shows that the greatest savings are associated with materials and then energy for retreading compared to manufacturing.

Figure 10: Comparison of retreading and manufacturing impacts (end of life impacts are excluded)

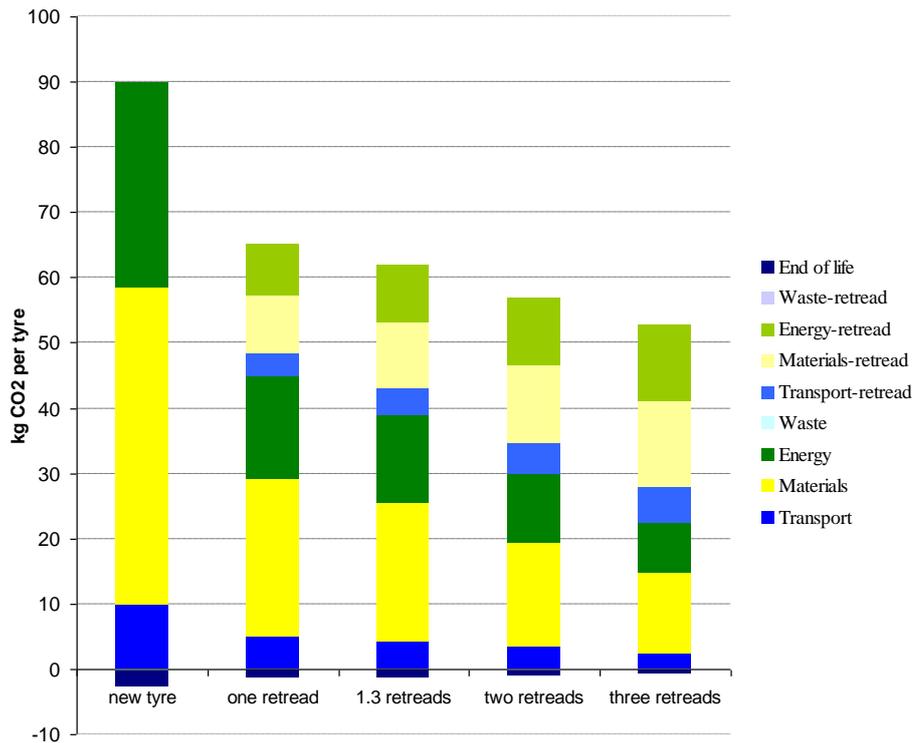


The material savings for retreading are derived from reusing the casing which has been previously manufactured. This means that the more often a casing is re-used the more carbon savings accrue. It is useful to therefore investigate the effects of increasing the number of retread cycles per casing, and Figure 11 presents the comparison by lifecycle stage for tyres that were retread one, two, and three times. It shows that with an average of three retreads, emissions from tyre production can be reduced to 51.8kg CO₂ (compared to 86.9 kg CO₂ for a new tyre). There will be a limit to the number of cycles for which the casing's integrity remains intact, but the data shows the clear benefit of extending the casings' lifespans.

Figure 12 presents the carbon footprint per km driven by a tyre. Data from Vaculug estimated that a new tyre can last for 45,000 km and the same distance can be covered with every retread products irrespective of age. This shows the impact of a new tyre is ~ 2 g CO₂ per km while the impact of at tyre that has been retread 1.3 is approximately 1.3 grams of CO₂ per km.

Figure 13 plots the footprints of the casing, new tyre and retread tyre alongside the footprint for the retreading process. The figure clearly shows that with successive retread cycles, the emissions from the casing become lower and thus achieve greater reductions in emissions for the retread tyre.

Figure 11: Comparison of impacts associated with the different number of retreads



Note: In order to present all footprint components simultaneously, the net savings from end of life are presented below the x-axis. Although listed elsewhere, the total footprint of a tyre can be obtained by adding the negative end of life impacts from the footprint shown above the x-axis.

Figure 12: Carbon footprint reduction related to number of retreads

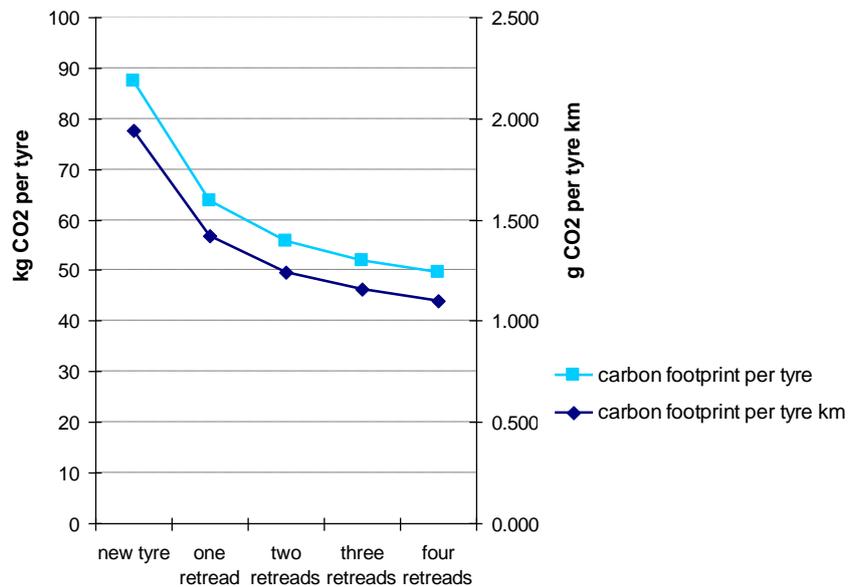
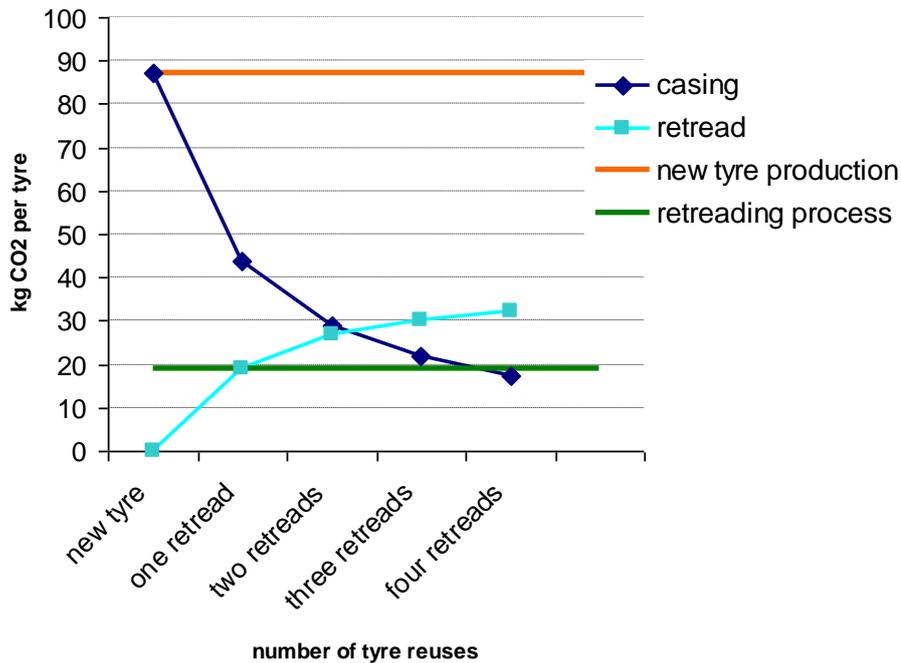


Figure 13: Carbon footprint of different stages of a tyre re-use



This study has found that retreading offers significant carbon savings over a tyre lifecycle in comparison to new tyre manufacture. There are a number of critical elements to this study which determine this outcome and where further research should be focussed to increase confidence in the result. These include:

- the data used for new tyre production was from secondary sources and had to be manipulated to apply to 17.5” tyres
- retread data came from a single manufacturer and would be expected to vary across organisations
- the number of retread cycles is a highly sensitive factor in determining the carbon efficiency of retreading
- this analysis does not consider tyre performance, and further work should link production impacts to lifespan and durability in use.

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Appendix 1: Input data and assumptions

Data and uncertainty

Footprint analyses are data driven processes, and the reliability of results is ultimately determined by the input data used.

The quality of data supplied on retreading was very good and collected directly from onsite operations at Vaculug. However, caution should be used when interpreting results which are based on data from a single remanufacturer.

The authors were unable to gather primary data from a new tyre manufacturer for this project. Consequently, the study progressed using publicly available secondary data and BFF recognise this as a weakness of the study. Follow up work in this area should prioritise ensuring supply of accurate and reliable primary data to supplement the results for new tyre manufacture.

Caution with result interpretation

The conversion factors used for calculating footprints are constantly changing as new studies are completed and data released from official sources. BFF commits to having the most up to date information available. As a reader of this report, you should realise that the conversion factors used were appropriate at the time of writing but may be subject to change in the future.

This study considered carbon dioxide emissions only in line with the agreement made during commissioning. Recent developments in environmental accounting (including the draft PAS 2050) guide practitioners to account for all greenhouse gases, not just carbon dioxide. BFF would encourage further studies to extend the scope of work to include all greenhouse gases, although this data may not be readily available for all materials.

Assumptions

Material assumptions

Information on new tyre materials came from public sources as listed in the References section. The central source used for the study was the material specification of a Bridgestone truck tyre^h. Information about the quantities of materials used in the retreading process was provided directly by the tyre remanufacturing company 'Vaculug'. The average weight of a 17.5" retread tyre used in this study was 26.5 kilograms.

^h<http://www.bridgestone.eu/English/Global/FILES/LEGACY/PR/Corporate/2007/Environmentbrochure.pdf>



Energy assumptions

Data on energy required to manufacture a new tyre has been based on the Australian report: "A National Approach to Waste Tyres". This estimated an energy requirement of 553 MJ (153.6 kWh) to produce a 45 kg tyre. It was assumed that energy used in tyre manufacture comes from oil and electricity (in the ratio stated on energy consumption in the AEA report). By applying conversion factors the whole process produced more than 53.2 kg of CO₂. In order to derive emissions for the 17.5" tyre, emissions were appropriately scaled down proportional to tyre dimensions to produce 31.3 kg CO₂. The necessity to manipulate and derive energy data in this way is a weakness in the study caused by the lack of primary data from the manufacturer.

Energy required to produce a retread tyre was provided by Vaculug. Overall energy figures (electricity and gas) for the remanufacturing site were collected and allocated to the 17.5" production line.

Waste assumptions

Figures for waste produced for a new tyre were derived from the AEA report for an average car tyre. Since a 17.5" tyre is more than three times as heavy as a car tyre, these figures were scaled up accordingly. Then the weights were multiplied by appropriate conversion factors to reflect the impact of the various waste management options.

Waste from new tyre production is composed of a mix of the material needed for the construction of a tyre. The impact of landfilling is accounted for by the transport of these materials to landfill only. For recycling, it was assumed that steel and textiles were recycled in equal proportions. Rubber compounds were assumed to go for incineration and these impacts were calculated as the difference between burning rubber in place of coal.

Data obtained from Vaculug was used to calculate footprints associated with waste arising from the retread process. The main waste arising from tyre retreading is buffing dust which displaces other materials used in manufacturing matting.

Transport assumptions

In order to derive emissions from the transport of raw materials for different assumptions have been made. The majority of the input materials used in both tyre types have been transported by road and sea from overseas. Tables A1.1 and A1.2 show the assumptions made about transport for new and retread tyres respectively.



Table A1.1: Transport assumptions – New tyre

Material	Country of origin	City	Mode of transport	Distance by road (km)	Distance by sea (km)
Synthetic rubber	Russia	Kazan	Ship & Road transport	5,063	41
Natural rubber	Brasil	Manaus	Ship & Road transport	230	8,966
Carbon black	Egypt	Alexandria	Ship & Road transport	230	5,446
Coated wires (steel)	China	Jiangsu	Ship & Road transport	230	19,086
Other	Netherlands	Eijsden	Ship & Road transport	641	41
Zinc oxide	Netherlands	Eijsden	Ship & Road transport	641	41
Rayon	India	Mumbai	Ship & Road transport	230	11,301

Table A1.2: Transport assumptions – retread tyre

Material	Country of origin	City	Mode of transport	Distance by road (km)	Distance by sea (km)
Natural Rubber	West Africa (Nigeria)		Ship & Road transport	295	7.322
Synthetic Elastomer SBR	United Kingdom	West Bromwich	Road transport	117	0
Synthetic Elastomer BR	Netherlands	Antwerp	Road transport	351	254
Carbon Black	Mexico	Mexico City	Ship & Road transport	511	9.038
Process Oil	Germany	Hamburg	Road transport	351	713
Others	Germany	Hamburg	Road transport	351	713

End of life

Data on tyre end of life is taken from the Used Tyre Working Group (UTWG)ⁱ and for the analysis the latest available data (2005) were used.

The main options for used tyres were landfill engineering, re-use, recycling, retreading and energy recovery. The data available showed retreading as one of the end of life options so for this study (to make impacts of retreading and manufacturing comparable) tyres destined for retreading were proportionally divided among the remaining four alternatives. The end uses of tyres are presented in table A1.3 below.

ⁱ <http://www.tyredisposal.co.uk/cms/index.php>



Table A1.3: End of life uses of used tyres

	Weight (tonnes)	%
Re-use	101,488	22
Recycling	186,073	41
Landfill engineering	67,559	15
Energy recovery	98,189	22
Total	453,308	100

Source: UTWG (2005), own calculations.

The carbon footprint of the tyre end of life impacts was obtained by the weighted average of impacts associated with the different the end of life options. The impact of re-use is difficult to determine because of the range of materials the tyres can displace. Therefore the impact of re-use was assumed to be zero on the basis that the emissions from transportation of tyres to site cancel out the benefits of displacing other (low grade) material that would be used otherwise.

Similarly to re-use, recycling waste tyres enables displacement of a new material. Savings arising from recycling waste tyres were obtained by deducting the impact of shredding the old tyres from the displacement of new rubber.

Conventional conversion factors for landfill impact were used for landfill engineering. Impacts from energy recovery were obtained by deducting emissions from burning coal in cement kilns from the emissions that arise from burning tyres. As tyres have high calorific content than and lower carbon intensity than coal they are a valuable fuel source in cement kilns. Thus the impact of burning tyres is lower than the current alternative of burning coal, but would not compare favourably if cement kilns obtained their energy from alternative, low carbon (or renewable) sources. If gas or renewable fuels were used commonly then incinerating tyres would further add to their impact.

