

University of Wales Trinity Saint David

Wales Institute of Science & Art



Sustainability Challenges in Industry

Automotive Materials & Sustainability - ACHA6012

Callum Carter-Davies

Student ID: 2008376

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1 Environmental Impact

The environmental impact throughout the life cycle of a tyre can be separated into the stages of manufacturing, transportation, usage, and end-of-life of the tyre (ELT). This report focuses on the sustainability of tyres used in road vehicles.

Nokian Tyres reported that their total emissions in 2021 were at 6.83 million tonnes of CO₂ with 6.04 of these emissions being attributable to the use of sold products, suggesting that 88.4% of the emissions from tyres stem from their usage, this is slightly higher than the findings of the British Tyre Manufacturers' Association (2024) who state it to be 80%, however, this could be due to differences in energy sourcing or efficiencies in the manufacturing processes. Nokian's 3 factories individually source 87.7%, 12.4%, and 2.5% of their energy from renewable sources, overall, 26% of the 2509 TJ used by their factories annually was sourced from renewables (Nokian Tyres PLC, 2022).

1.1 Manufacturing

The manufacturing of a tyre requires a wide range of materials, processes, and has large energy requirements. There are different compositions of tyres, Formela (2021) states a typical composition by weight is 22% natural rubber, 23% synthetic rubber, 28% carbon black, 14% additives, and 13% steel. Carbon black is used to change the properties of rubber to improve its function. Carbon black is created through combustion of petroleum products and has been found to be a carcinogen, as well as causing respiratory issues when people are exposed to it in high concentrations (Dominic *et al.*, 2020).

Natural rubber is generally sourced from Hevea trees which can only be grown in certain climates, particularly in southeast Asia. The demand for raw rubber has led to deforestation to make rubber plantations, with an estimated 7000 km² being deforested between 2005 and 2017 and mainly occurring in Indonesia and Thailand (Wang *et al.*, 2023).

1.2 Transportation

No specific data was able to be found on the emissions caused by the transportation of tyres and the associated materials.

1.3 Usage

A major part of the emissions during the life of a tyre stems from tyre wear from abrasion. As the tread wears down it deposits material in the form of particulate matter. Depending on the size of the particulate matter it can become airborne or be washed into waterways. PM₁₀ and PM_{2.5} are emissions of particulate matter with a diameter < 10 and < 2.5 micrometres respectively.

Exposure to PM10 and PM2.5 have been determined to cause cardiovascular and respiratory health issues and there are guidelines suggesting the presence of these particles should be limited of 5 $\mu\text{g}/\text{m}^3$ and 15 $\mu\text{g}/\text{m}^3$ for PM2.5 and PM10 respectively to mitigate health effects (World Health Organisation, 2021).

The UK government have provided statistics for the annual emissions of PM10 and PM2.5 from major emissions sources (GOV.UK, 2024), the data is separated into industrial processes, domestic combustion, industrial combustion, road transport, and other sources (Figure 1). The UK's 2022 figures for the annual emissions of PM10 show the total emissions being 126.7 thousand tonnes. Road transport was responsible for 16% of the total emissions, however there is no further separation in the data between exhaust and non-exhaust emissions nor does it give separate values for brake, tyre, and road wear (GOV.UK, 2024). Future legislation is likely to cause a reduction in the PM10 emissions from road transport.

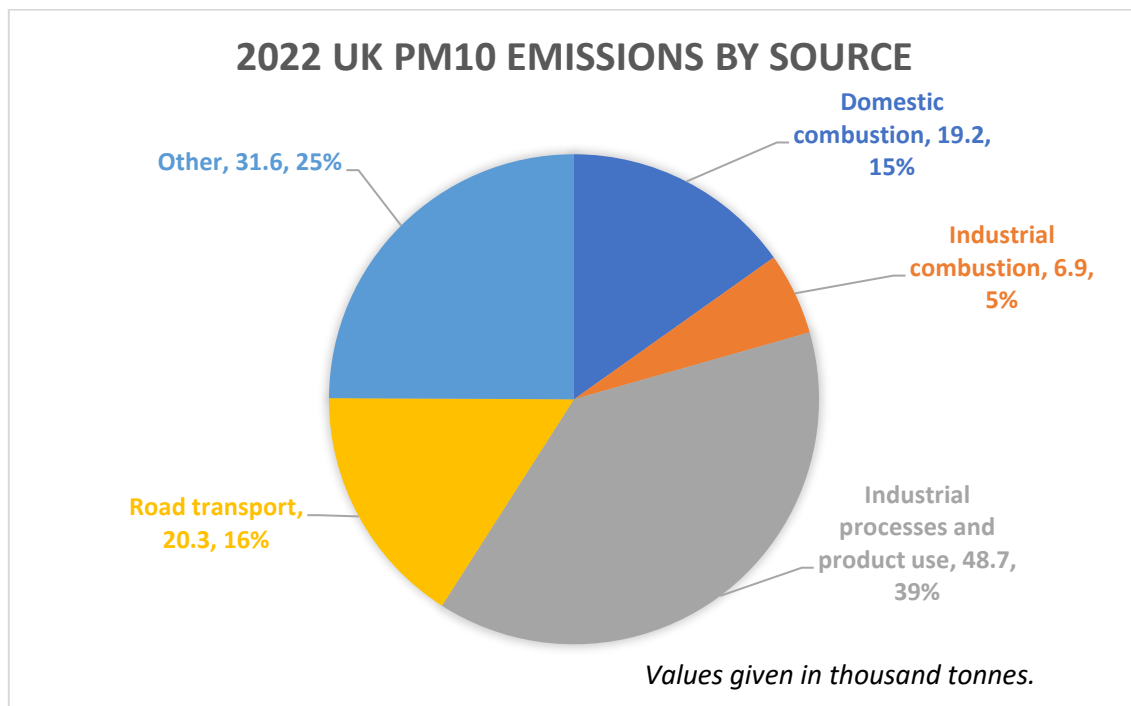


Figure 1 - PM10 emissions figures for the UK in 2022 (GOV.UK, 2024).

The PM10 emissions figures for 2005 (Figure 2) show that annual PM10 emissions from road transport have reduced by 14,000 tonnes between 2005 and 2022, this is likely due to vehicle emissions regulations becoming more restrictive, the use of diesel particulate filters, and more modern efficient vehicles. In this same period, the total estimated distance driven by vehicles in the

UK annually has risen by 5.9%, from 305.8 billion to 323.8 billion miles (*Road traffic statistics - Summary statistics*, no date), while the PM10 emissions have decreased by 41% in the same period.

It has been estimated that between 50 and 85% of PM10 emissions from vehicle travel can be attributed to non-exhaust sources however this depends on the climate and the time of year, as winter tyres tend to produce more emissions (Ketzel *et al.*, 2007). Harrison *et al.* (2012) found in a study at various locations around London, that particles from tyre abrasion were responsible for between 5 and 30% of non-exhaust emissions, with brake dust and resuspended particles making up the remaining amount.

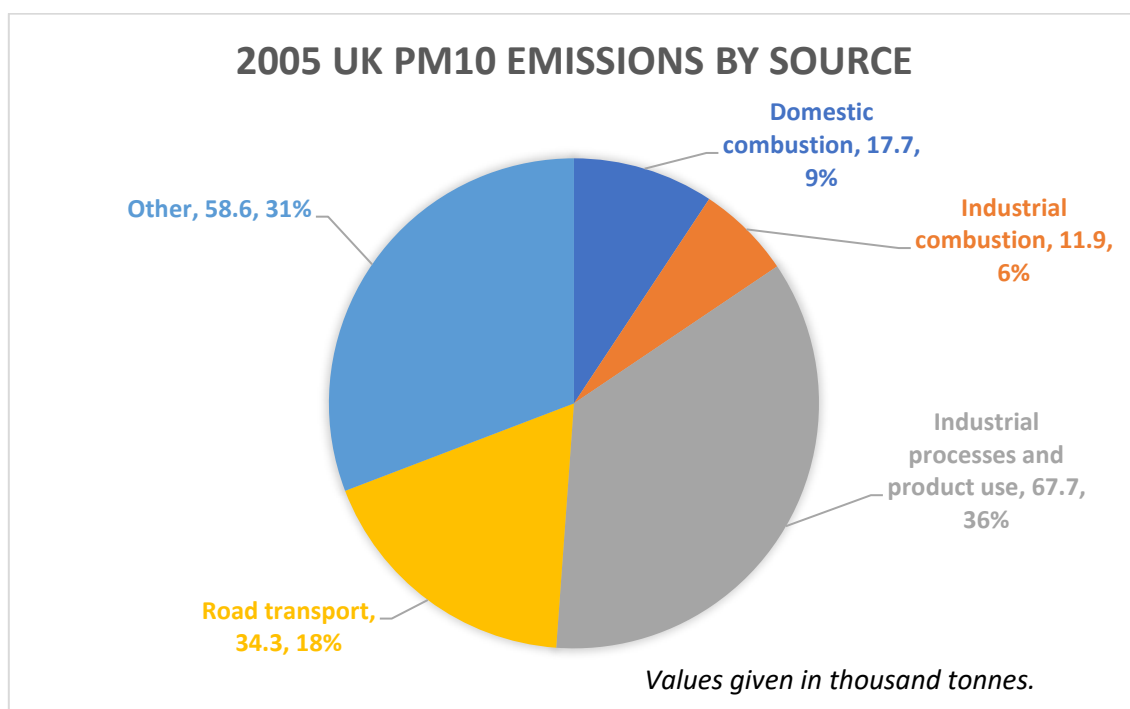


Figure 2 - PM10 emissions figures for the UK in 2005 (GOV.UK, 2024).

A similar trend is seen in the PM2.5 emissions with a 55% decrease in annual emissions linked to the UK road transport sector from 2005 to 2022, and a reduction in the portion of the emissions attributable to the road transport sector from 23.6% of the national total of 109.5 thousand tonnes in 2005, down to 17.8% of the national total of 64.9 thousand tonnes.

An analysis by Timmers & Achten (2016) found ICE vehicles produce 6.1 mg/km of PM10 particles from tyre abrasion, whereas EVs emitted 18% more than this, producing 7.2 mg/km. It also found that PM2.5 emissions were at 3.7 mg/km and 2.9 mg/km for ICE and EVs respectively.

It has been estimated that Germany produces 133 thousand tonnes of particles due to tyre abrasion every year, with 8.2% of the total ending up in waterways however this is likely to vary substantially

based on the infrastructure around capturing the runoff from the road. The overall mass of tyre particles generated per year is estimated at 1.3 million and 1.1 million tonnes per year in the EU and US respectively (Wagner *et al.*, 2018).

Tyres contain many toxic compounds that are released throughout the life of the tyre. A compound called 6PPD is presently used in many tyres to prevent tyre degradation has been found to be released into the environment in the form of road dust, be washed into rivers where it reduces the fish populations due to its toxicity. The tyre industry has been advised to avoid selling products using 6PPD and seek out a replacement for it (DTSC, 2023).

Another issue is road dust resuspension where a vehicle's aerodynamic wake and tyre abrasion cause road dust to become airborne increasing the concentrations of harmful particulate matter in the air (Harrison *et al.*, 2012).

The rolling resistance of a tyre affects the fuel consumption of the vehicle, reducing the rolling resistance coefficient of the tyre by 20% was found through simulations to decrease the fuel consumption of a vehicle by up to 3.5%, reducing CO₂ emissions by 5.5% on the NEDC (Barrand and Bokar, 2008).

1.4 ELTs

Once a tyre is worn down to the point where it requires replacement, it is disposed of and enters the ELT stage. There are numerous methods used for tyre disposal or recycling, such as combustion for energy production, recycling to reclaim tyre products, and retreading.

Once it is unsuitable for road use, tyre material can be shredded and used in a variety of applications, one of which being as a filler material for asphalt pavements. This potentially contributes additional pollution as the asphalt can deteriorate and spread the recycled material into the nearby environment, causing further pollution (Bank, 2022, p.50). The shredded material can be separated by decomposition in an oxygen-free atmosphere through a process called pyrolysis. Pyrolysis allows the carbon black, steel, and petroleum products to be recovered and used for other purposes (Daniel Martínez *et al.*, 2013). This method can allow for extraction of liquid fuel which can be used as a fuel in diesel engines with 94% of the calorific value of diesel per kg. This is likely to be an unsuitable use case as combustion of this fuel was found to emit nearly 4 times more SO₂ and 3 times more CO than diesel (İlkılıç and Aydın, 2011).

Another method of tyre disposal is the use of landfills to store the waste, however this poses environmental and health risks with the potential for fires to occur causing the release of hazardous compounds into the air (Singh *et al.*, 2015).

It is estimated that the UK recycles almost 100% of its 55 million ELTs annually with the average recycling rate in Europe being between 92 and 95%, the USA recycled 81% of 290 million ELTs with 16% going to landfill. It is also estimated that there are 1 billion ELTs generated annually worldwide, of which 75% are disposed of in landfills and 10% are recycled (Ferdous *et al.*, 2021). This high rate of landfill disposal is likely due to less developed countries not having sufficient facilities for recycling ELTs combined with a lack of legislation or enforcement of disposal requirements. There are also discrepancies in the data where not all tyres are accounted for which could be a result of a lack of traceability of ELTs.

Tyre retreading requires that the tyre carcass is undamaged but allows for a 70% reduction in energy usage and 75% less raw materials than manufacturing a new tyre as well as being a valuable option for using the ELT. This method is typically only used for the tyres of larger vehicles as the cost of retreading a passenger car tyre is similar to the price of a new tyre (Sienkiewicz *et al.*, 2012).

2 Sustainable Practices and Legislation

The European Parliament plan to introduce Euro 7 regulations in 2030 to limit the emissions of PM10 from brakes and tyres. In this legislation, fully electric vehicles are limited to 3 mg/km of PM10 emissions, whereas ICE, hybrid electrics, and fuel cell vehicles will have a higher limit of 7 mg/km (European Parliament, 2023).

It was not possible to find legislation specifically addressing PM2.5 emissions for road transport however there are environmental targets (Department for Environment, no date) to reduce the air pollution from fine particulate matter.

Nokian tyres have claimed to be manufacturing tyres with the lowest CO2 emissions in the industry with an average of 420 kg of CO2 produced per tonne of tyres manufactured in 2022 (Nokian Tyres PLC, 2022), approximately a 50% reduction from the industry average range of 700 to 1100 kg of CO2 per tonne. This value appears to be based on the energy usage of their 3 factories with the factories emitting 0.09, 0.63, and 0.52 tonnes of CO2 per tonne of produced manufactured in 2022. It is not clear if these values for the greenhouse gases released are solely for manufacturing energy or if they include the emissions from the sourcing and processing of raw materials. The reduction in CO2 emissions has been attributed to heat recovery systems and purchasing energy from renewable sources.

The European Parliament implemented Directive 2000/53/EC which requires 85% of the material of a vehicle to be recycled at the end-of-life stage. The material is not considered to be recycled if it is combusted for energy recovery by heat ((European Union, 2000). Directive 1999/31/EC was implemented to ban the disposal of tyres of certain sizes in landfills in Europe due to the potential for leakage of hazardous compounds (European Union, 1999).

Tyre labelling schemes are performed to provide consumers with insight on tyre performance, typically in terms of fuel efficiency, grip in various conditions, and noise levels. This allows the consumer to make a more informed decision when seeking to replace tyres and improves the visibility of tyres with low rolling resistances (ETRMA, 2019).

The European Commission has introduced regulations to improve the tracking of rubber in an attempt to reduce deforestation in an attempt to maintain biodiversity (*European Commission*, no date).

3 Sustainability & Technological Challenges

The main issue with the sustainability aspect of tyre usage is that tyres are consumable items, and the uncontrolled shedding of the material into the environment means that the use of a tyre will create pollution. The issue is further complicated as the tyre experiences substantial forces from vehicle operation and is constantly exposed to environmental factors, such as UV exposure, and wide temperature and humidity ranges. These factors create limitations on suitable alternative materials that can be used in the construction of the tyre. From a consumer perspective, a tyre created from alternative materials would need to have similar performance to that of the current market tyres in terms of tyre life, wear rate, grip level, rolling noise, and rolling resistance. It is likely that these factors would also be required through legislation as a higher rate of tyre wear could achieve negligible effects in emissions per km, and could increase emissions in the manufacturing, transport, and ELT stages.

The market is trending towards heavier vehicles due to a mixture of safety requirements, consumer demand, and a transition towards electric drivetrains. The extra mass and instantaneous torque of electric vehicles increase the rate of tyre wear, producing greater amounts of tyre emissions.

One of the main challenges in recycling tyres is the difficulty in separating the materials, this is due to the rubber being cured through vulcanisation to improve the durability and stability of the tyre. The processes used for separating tyre materials are typically energy intensive and the solvents used have the potential to cause environmental damage, as well as adding cost (Landi *et al.*, 2018). The recycling of ELTs could be made more efficient through the use of ultrasonic fields to assist the grinding process, as this would allow for more of the rubber waste material to be separated from the tyre carcass. Making this change could reduce energy consumption by more than 50%, decrease the time required to recycle each tyre, and increase the amount of material recovered per tyre by up to 50% (Dobrotă and Dobrotă, 2017).

Many studies have been conducted in an effort to replace portions of the carbon black in tyres with less harmful, renewable additives which are typically fibrous plant waste however more development is needed (Dominic *et al.*, 2020).

There are also efforts to replace the natural rubber from Hevea trees with rubber from alternate sources. Bridgestone have developed tyres with similar performance to tyres containing Hevea rubber using rubber sourced from a Guayule plant and Continental are experimenting with rubber sourced from dandelion roots called taraxagum however the details are considered trade secrets (Köllner, 2016). Alternate rubber sources allow rubber to be produced closer to factories, reducing

transportation costs and emissions, as well as increasing the biodiversity of rubber sources resulting in a market less susceptible to failure in the event of a disease impacting yields.

4 Future Outlook

There is likely to be more motivation stemming from public opinion as the general public becomes more aware of the environmental and health risks involved with the release of microplastics. An analysis of the environmental and health costs associated with the pollution from tyres could also lead to governments providing financial aid to manufacturers in the form of financial support to perform research into alternate materials and processes, implementing energy recovery systems, and supporting projects to supply the factories producing tyres and recycling ELTs with alternate energy sources to reduce the greenhouse gas emissions from processing tyres.

Regulations on non-exhaust emissions such as the Euro 7 standards will push tyre manufacturers towards seeking alternative, non-petroleum-based materials. It is expected for more research to be carried out regarding the use of biodegradable waste materials such as corn husks as a replacement for additives in tyres, as well as vegetable oils to replace the petroleum oils currently used in tyres. Regulations around non-exhaust emissions may also impact vehicle manufacturers as there is a greater incentive to reduce the mass of the vehicle in order to meet limits on particulate matter.

There is also an expectation for a reduction in the percentage of tyres going to landfill as the technology used in tyre recycling becomes more effective and processing costs reduce. This change could also be stimulated through countries that currently have a large percentage of ELTs going to landfill implementing legislation to prevent disposal through this method, increase traceability of ELTs, and funding the creation and expansion of recycling plants. As these countries are poorer, they may require funding for these solutions however this could make the financing liable to being lost through corruption. Instead, an international effort could be made to supply these countries with equipment for recycling facilities.

Consumers and manufacturers could be impacted if the cost of tyres increases due to the research and development necessary to improve sustainability. This could result in consumers being more likely to purchase a cheaper tyre with worse rolling resistance, reducing the emissions improvements.

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