Vehicle Tyres

Policy Options for a Circular Economy

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Contents

The data presented and discussed in the report were correct at the time of report completion.

Glossary

The definitions used in this report are in line with those detailed in the Waste Framework Directive[1] and are as follows:

Waste: any substance or object, which the holder discards or intends or is required to discard. For tyres in the UK, all used tyres on arising are considered to be waste.

Collection: the gathering of waste, including the preliminary sorting and preliminary storage of waste;

Treatment: recovery or disposal operations, including preparation prior to recovery or disposal;

Reuse: any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;

Recycling: any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

Recovery: any operation for which the principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function. For tyres, recovery is incineration as an alternative fuel for energy from waste plants or incineration as an alternative fuel for industry such as cement kilns;

Disposal any operation which is not recovery even where the operation has as a secondary consequence as the reclamation of substances or energy.

Tyre classification[2]:

C1 = Tyres that are intended for vehicles of category M1 (vehicles used for the carriage of passengers) plus O1 (trailers with a maximum mass not exceeding 0.75t [tonnes]) and O2 (trailers with a maximum mass exceeding 0.75t, but not exceeding 3.5t);

C2 = Tyres intended for vehicles above 3.5t of category M2 (vehicles comprising of more than eight seats in addition to the driver's seat used for the carriage of passengers, and having a maximum mass not exceeding 5t) plus category M3 (vehicles comprising of more than eight seats in addition to the driver's seat used for the carriage of passengers, and having a maximum mass exceeding 5t) plus category N (power-driven vehicles having at least four wheels and used for the carriage of goods) plus category O3 (trailers with a maximum mass over 3.5t, but not exceeding 10t) and category O4 (trailers with a maximum mass over 10t), and

C3 = Tyres intended for vehicles above 3.5t of category M1 (vehicles used for the carriage of passengers) plus category M2 (vehicles comprising of more than eight seats in addition to the driver's seat used for the carriage of passengers, and having a maximum mass not exceeding 5t) plus category M3 (vehicles comprising of more than eight seats in addition to the driver's seat used for the carriage of passengers, and having a maximum mass exceeding 5t) plus category N2 (vehicles used for the carriage of goods and having a maximum mass in excess of 3.5t but not exceeding 12t) plus category N3 (vehicles used for the carriage of goods & having a maximum mass exceeding 12t) plus category O3 (trailers with a maximum mass over 3.5t, but not exceeding 10t) and category O4 (trailers with a maximum mass over 10t).

Tyre naming convention – there are instances where the terminology used for different types of tyres changes. For example, original equipment manufacturer (OEM) data uses the term “HGV” (heavy

[1] European Commission (2016) *Directive 2008/98/EC on waste (Waste Framework Directive)*, accessed 25 June 2019, http://ec.europa.eu/environment/waste/framework/

[2] PROTYRE (2020) *Tyre label values explained*, accessed 22 June 2020, https://www.protyre.co.uk/tyre-label-information

goods vehicle) whilst for replacement sales, the data from Used Tyre Working Group (UTWG) uses the term “truck & bus” tyres. In both instances, we are referring to C3 tyres but are using terminology used by the source data for accuracy.

Abbreviations

ATF	Authorised treatment facility
BEIS	Department for Business, Energy & Industrial Strategy
BTMA	British Tyre Manufacturing Association
DEFRA	Department for Environment, Food & Rural Affairs
EPR	Extended producer responsibility
ETRMA	European Tyre & Rubber Manufacturers' Association
GPP	Green Public Procurement
HGV	Heavy goods vehicle
LCV	Light commercial vehicle
OEM	Original equipment manufacturer
PRO	Producer Responsibility Organisation
PoM	Placed on the market
RFID	Radio-Frequency Identification
SEPA	Scottish Environment Protection Agency
SMMT	Society of Motor Manufacturers and Traders
TPMS	Tyre Pressure Monitoring Systems
TRA	Tyre Recovery Association
TSS	Trading Standards Scotland
UTWG	Used Tyre Working Group

1 Executive Summary

1.1 Background and Methodology

Eunomia Research & Consulting Limited ('Eunomia') was engaged by Zero Waste Scotland to produce an assessment of the state of the market for vehicle tyres in Scotland. This report is the second deliverable in a wider project exploring the circular economy potential for tyres in Scotland. Stage 1 provided an overview of the Scottish market for vehicle tyres throughout their life cycle[3]. This second stage report presents an assessment of possible policy measures that could be introduced in Scotland in order to make the Scottish tyre market more circular. The study involved:

- A brainstorming exercise to:
    - Identify the objectives that, if achieved, would contribute to a more circular economy; and the opportunities in relation to specific stages of the tyre life cycle; and
    - Develop a longlist of measures covering production, use, remanufacture, reuse and end-of-life;
- An assessment of the longlisted measures against a number of criteria to arrive at a shortlist for assessment, including:
    - Their ability to contribute to objectives which could result in a more circular economy for tyres;
    - Whether there already exists sufficient motivation to implement a measure due to the other benefits it provides such that increasing tyre circular economy would be seen as a co-benefit of said measure; and
    - The degree to which a measure is actionable in Scotland, with the absence of barriers related to either jurisdiction or feasibility based on currently available technologies.
- An analysis of the likely effectiveness of the shortlisted measures, noting in particular the way they might interact with other measures to accelerate the move towards a circular economy for tyres in Scotland.

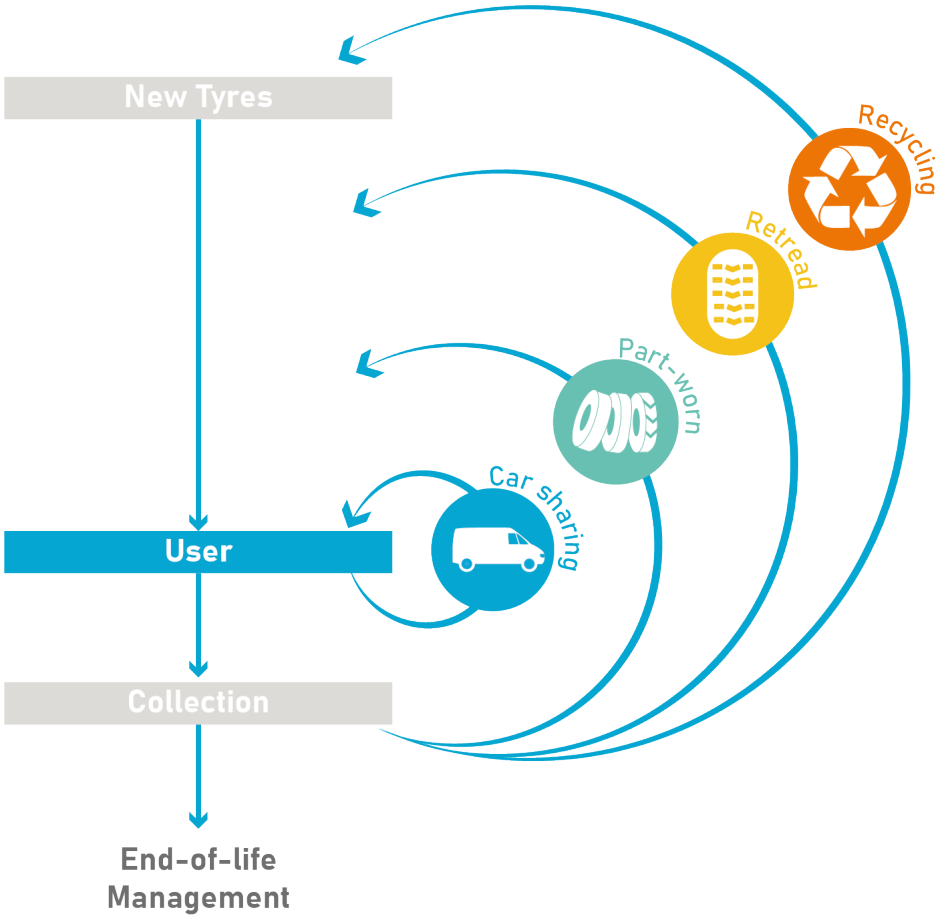
1.2 Objectives, and Possible Opportunities for Greater Circularity

In line with a move towards greater circularity (shown conceptually in Figure 1-1), the determined overarching objectives of policy interventions on tyres would be to:

- Reduce the impacts associated with manufacturing; and
- Bring about waste prevention through:
    - Using fewer tyres; and
    - Extending the lifetime(s) of those tyres that are used.

[3] The first stage report, Vehicle Tyres: Market Overview, is available at: https://zerowastescotland.org.uk/sites/default/files/20200617DraftForPubStage1FINALREPORTPubFV1.0.pdf

Figure 1-1: Conceptual Diagram of a Circular Economy for Tyres



The specific opportunities identified within these objectives are:

- Greater use of recycled content in tyres;
- Using fewer tyres through driving less / achieving modal shift; and
- Extending the lifetime of tyres through:
    - Maximising tyre tread lifetimes through reducing abrasion rates;
    - Improving tyre stewardship and driving behaviour;
    - Maximising use of part-worn tyres; and
    - Maximising use of retreading.

In addition, a cross-cutting objective, which would support many of the opportunities identified above, relates to tyre traceability and data capture. Furthermore, an overarching objective is to ensure that the polluter pays principle is applied in respect of tyre use and end-of-life management in Scotland.

1.3 Identification, Screening and Analysis of Measures

Drawing on an examination of the barriers to, and potential for, circularity in the tyre industry, Table 1-1 summarises a longlist of measures and the objectives which they could impact to improve the circular economy potential for tyres in Scotland.

Table 1-1: Longlist of Measures and the objectives they contribute to meeting

Measures \ Objectives	Minimising environmental impact of production	Using fewer tyres	Extending tyre lifetime	Maximising use of part-worn	Maximising opportunities for retreading	Ensure application of the polluter pays principle
Incentives/requirements for recycled content	✓					
Road User Pricing		✓				✓
Car sharing		✓				
Car clubs		✓				
Taxation		✓		✓	✓	✓
Standard test for tyre tread abrasion rate		✓	✓			✓
Improved Tyre Stewardship and Driving Behaviour including Public Awareness Campaigns		✓	✓	✓	✓	
Trading standards enforcement for part-worn tyres		✓	✓	✓		
Green Public Procurement		✓		✓	✓	
Extended Producer Responsibility			✓	✓	✓	✓
Data and traceability		✓	✓	✓	✓	✓

The following measures were taken forward for further appraisal, based on the assessment criteria outlined in Section 1.1:

1. Trading standards enforcement for part-worn tyres;
2. Maximising opportunities for retreading of tyres;
3. Extended Producer Responsibility (EPR) scheme for tyres; and
4. Data and traceability.

In addition, an analysis was undertaken of a measure involving the taxation of new tyres which would need to be implemented at a UK level, given the limited devolved taxation powers. As such taxation is considered as a complimentary measure to the other policy measures taken forward for review.

No one measure will address all the issues currently impeding greater circularity for tyres in Scotland. However, the measures which have, in combination, the potential to bring about a circular economy for tyres in Scotland where:

- Fewer tyres are used;
- Those that are used have an extended lifetime;
- Key externalities associated from tyre use are better reflected in the price paid by consumers;
- End of life costs are covered by producers/consumers; and
- Better data and traceability provide improved transparency over the management of tyres during their useful life and at end-of-life.

In addition to improved environmental outcomes, co-benefits can arise. Indeed, in the case of **trading standards enforcement for part-worn tyres**, there is a compelling safety argument for undertaking such enforcement, regardless of the beneficial 'side-effect' of increasing consumer confidence in part-worns.

To incentivise retreading, **green public procurement** is a powerful tool available to Scotland. In the short term, Scottish local authorities could specify retreaded tyres for waste collection fleets. Similar requirements can be introduced for other such C3 tyres and subsequently for all other fleet vehicles (C2 and C1). This will serve to demonstrate that retreading is a 'normal' and desirable activity, and help to build up capacity, skills and expertise in the provision of such services in Scotland.

Beyond where Scotland has direct control over tyre choices, price signals can be used to further incentivise use of part-worns and retreading. While new tyres might be seen as financially attractive relative to retreading, it is important to note that the price paid by consumers for tyres at the point of purchase does not (as yet) reflect the full end-of-life costs of managing that tyre. **Implementing an extended producer responsibility (EPR) scheme, where the EPR fee is only paid the first time a tyre is placed on the market**, will provide a financial incentive for retreading (and indeed the use of part-worns) as the purchaser of a retreaded tyre (or a part-worn tyre) will not pay an EPR fee.

However, the scope of EPR fees is currently limited to the necessary costs of managing tyres at end of life, as well as other standard costs such as PRO administration costs, communications, monitoring and data collection. The wider the scope of end-of-life costs included in the EPR fee, for instance, fly-tipped tyres and tackling historic accumulations/illegal storage, the greater the magnitude of the fee and the associated incentive to opt for retreading. However, it may be that a financial incentive greater than that provided by the EPR fee alone would be required to bring about a meaningful shift. Such an incentive could be provided through a complimentary tax on new tyres.

A **tax on new tyres** would be a means of internalising some of the externalities associated with use of tyres, such as impacts on air quality, noise, and wider - but as yet incompletely understood impacts – such as tyre-derived microplastics that end up in soil, rivers and the marine environment. Such a tax, in increasing the upfront cost to consumers of purchasing new tyres, would provide a further incentive to obtain tyres with a lower rate of tread wear abrasion (which consumers will be able to determine once a measurement standard is developed), to use part-worns, and opt for retreading. While the

revenues from such a tax would, in principle, accrue to general UK Government funds, some or all could be hypothecated (or 'ring-fenced) and directed towards related activities. These might include:

- Covering (or contributing to) the costs of enhanced enforcement by trading standards of part-worn tyres;
- Implementing measures to capture tyre wear particles in run-off from roads via the use of sustainable drainage systems (SuDS) or other approaches; or
- Implementing measures to tackle the adverse effects of road traffic noise in communities particularly affected by this issue.

While taxation has the potential to internalise some of the externalities associated with the use of tyres outlined above it should be noted that devolved product taxation powers are limited. As such Scottish Government are not currently in a position to place a tax on tyres, and this would need to be a measure taken forward by UK Government. As such taxation is considered a complimentary measure to the other policy measures taken forward for review.

Underpinning all of these measures is a need for better data on the life cycle of individual tyres. This could be introduced by placing a requirement on an EPR scheme operator. This would involve demonstrating performance in improving the management of tyres, possibly relying on the **use of radio frequency identification (RFID) tagging and data capture** combined with Blockchain to facilitate automated, transparent, tamper-proof record keeping. As well as being a potentially efficient way of demonstrating compliance, and avoiding free-riding, the technology has the potential to further increase public confidence in retreads and part-worn tyres by providing detail about the tyre's usage over its lifetime. Such an approach could also disincentivise fly tipping through better traceability and, therefore, enforcement.

All of the above measures can be implemented alongside each other and, indeed, are mutually reinforcing. While difficult at this point to identify the 'impact' as such of the measures, this is largely because current data on tyre usage (including sale of part-worns and retreading) is poor. All of the measures above will contribute to improving the data, either directly or indirectly. With improved data, the changes that could result from measures such as EPR and taxation will become clearer, and a better understanding will develop as to the likely future shifts that can be expected with, for example, changes in the level of tax applied.

The way in which the above measures contribute to the development of a circular economy for tyres in Scotland is shown in Figure 1-2. It is recommended that each of these measures is explored further with a view to their implementation. While some measures can readily be introduced on a Scotland-only basis, such as improved enforcement of trading standards on part-worns, and the use of green public procurement, for all measures, co-ordination with other national governments leading to a UK-wide implementation would reduce certain complexities, such as cross-border flows.

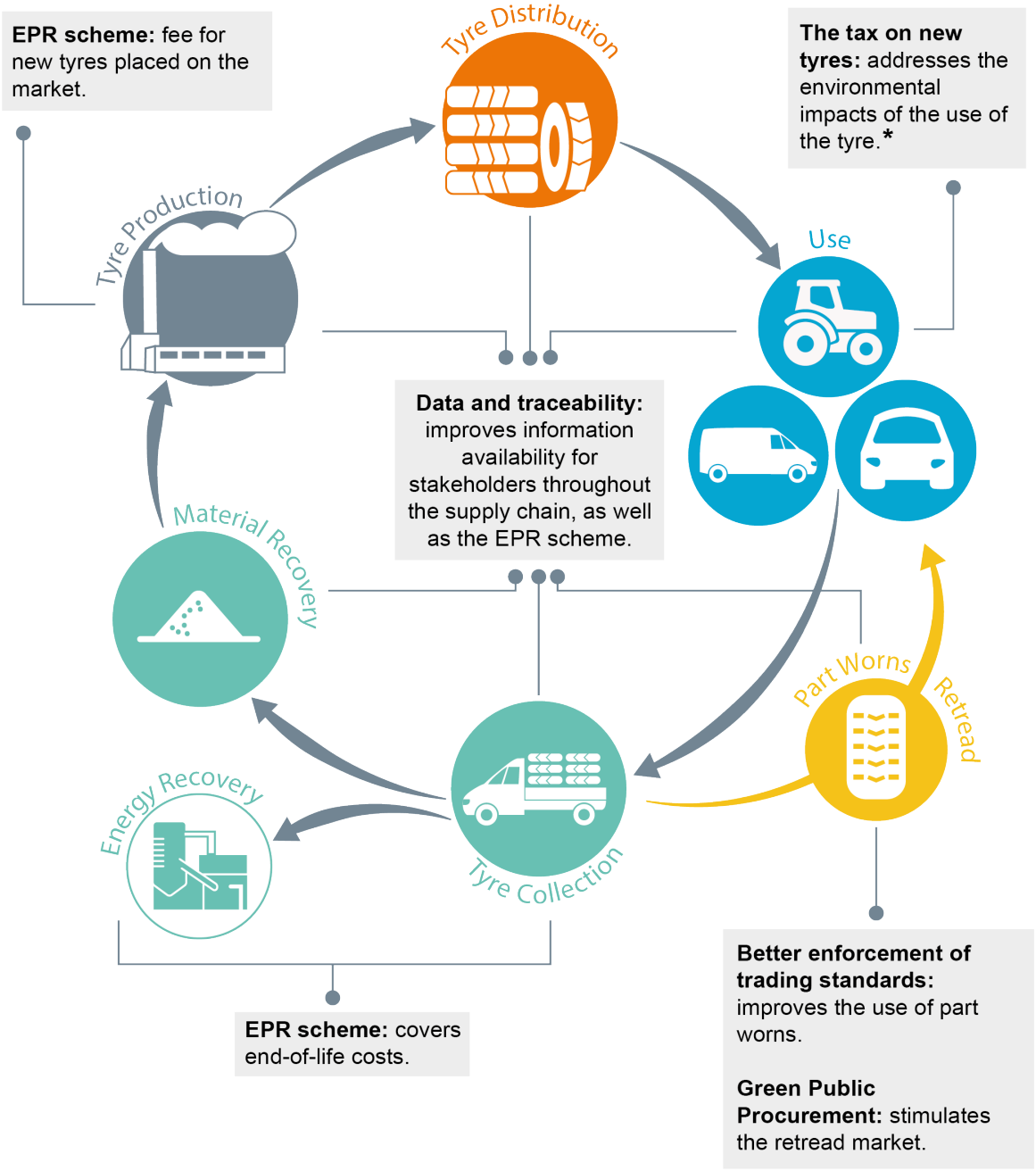
In terms of sequencing, there is no reason why Scotland should delay on improving **trading standards enforcement for part-worn tyres** and **green procurement** to incentivise the use of retreads. These are activities that Scotland can undertake alone. These actions should therefore commence first.

Discussions on potential scheme design could begin rapidly on an EPR scheme for tyres Scotland between Scottish Government, industry and other related parties. This should include mechanisms for high quality data, with a view to this being the next policy measure to be introduced. It would also be beneficial to advance conversations with the other Devolved Nations to ensure a joined up approach, where appropriate and feasible.

While a tax could, in theory, be introduced in advance of an EPR scheme, it would seem better to provide advanced notice that such a tax is under consideration. As noted earlier however, this would rely on implementation by UK Government. None-the-less, the benefit of implementing a tax in advance is that it would give a clear sense of the direction of travel, allowing an EPR scheme to

become established and allow time for review of the extent to which a tax, and the level at which it is set, could lead to further moves towards circularity.

Figure 1-2: Towards a Circular Economy for Tyres in Scotland



* It should be noted that limited devolved taxation powers suggest a new tax on tyres would need to be implemented by the UK Government and so is presented here as a complimentary measure.

2 Introduction

Eunomia Research & Consulting Limited ('Eunomia') was engaged by Zero Waste Scotland to produce an assessment of the state of the market for vehicle tyres in Scotland. This report is the second deliverable in a wider project exploring the circular economy potential for tyres in Scotland. Stage 1 provided an overview of the Scottish market for vehicle tyres throughout their life cycle[4] and involved an appraisal of the Scottish market for vehicle tyres throughout their life cycle, taking into account the number and type of tyres placed on the market (PoM) and as waste arisings, the disposal or treatment routes, end-markets and destinations.

This second stage report presents an assessment of possible policy measures that could be introduced in Scotland in order to make the Scottish tyre market more circular. This assessment covers all stages of the tyre life cycle:

- Production;
- Use;
- Reuse and remanufacture; and
- End-of-life.

The report structure is broken down as follows:

- Section 3 outlines the methodology used;
- Section 4 identifies the objectives and possible opportunities to improve the circularity of the tyre market;
- Section 5 identifies the longlist of measures and describes those measures not taken forward; and
- Section 6 contains the appraisal of shortlisted measures with concluding recommendations.

3 Methodology

A three step methodology was used to identify and appraise possible measures to improve the circularity of the tyre market in Scotland. The first step involved Eunomia holding an internal 'brainstorm'. The brainstorm served to:

- Capture and share the wide-ranging knowledge of Eunomia's internal experts;
- Ensure a shared understanding of the key findings from stage 1 and relevant knowledge from previous research undertaken by Eunomia;
- Identify any knowledge gaps; and
- Guide subsequent research as required.

The brainstorm focused on identifying challenges and measures in relation to specific stages of the tyre life cycle: production, use, reuse and remanufacture and end-of-life. As a result of this brainstorm, a 'longlist' of focus areas and measures was created.

Following this, the longlist created in the brainstorm was investigated in greater depth. The aim of this was to screen the list and develop a set of detailed policy measures and outline their impact on the circular economy potential for tyres. The first step taken involved identifying the key objectives and opportunities to improve the circularity of the tyre industry, as identified in stage 1 (as detailed in Section 4). These were subsequently fleshed out through desk-based research, investigating schemes already in place in other countries around the world. This work was also supplemented with industry

[4] The first stage report, Vehicle Tyres: Market Overview, is available at: https://zerowastescotland.org.uk/sites/default/files/20200617DraftForPubStage1FINALREPORTPubFV1.0.pdf

engagement in-line with the stage 1 report, with Eunomia reaching out to key contacts to help resolve any information gaps.

The longlist of measures was reduced to a shortlist by assessing themagainst several criteria, including:

- Their ability to contribute to objectives which could result in a more circular economy for tyres, including through;
    - Minimising environmental impact of production;
    - Stimulating the use of fewer tyres;
    - Extending tyre lifetime;
    - Maximising the use of part-worn tyres;
    - Maximising opportunities for retreading; and
    - Ensuring the application of the polluter pays principle;
- Whether there already exists sufficient motivation to implement a measure due to the other benefits it provides, for example in terms of improved driver safety or carbon emissions reduction, such that increasing tyre circular economy would be seen as a co-benefit of said measure; and
- The degree to which a measure is actionable in Scotland, with the absence of barriers related to either jurisdiction or feasibility based on currently available technologies.

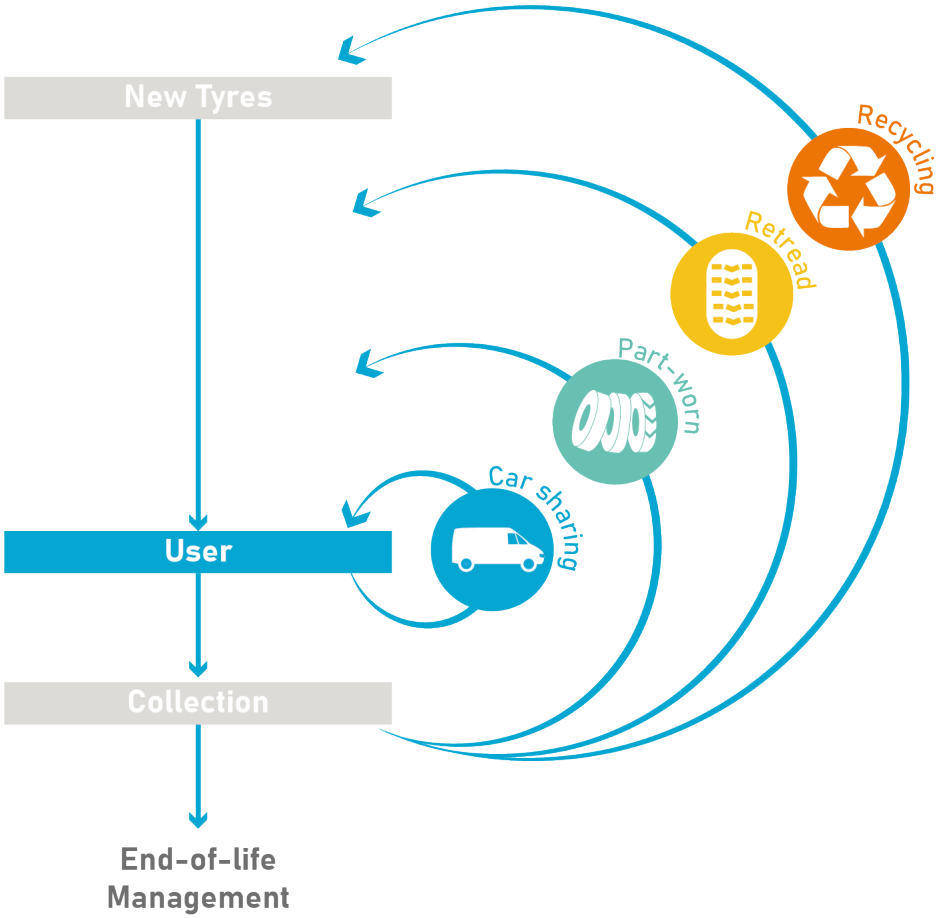
The final step of the methodology involved considering the likely effectiveness of the shortlisted measures, noting in particular the way they might interact with other measures to accelerate the move towards a circular economy for tyres in Scotland. The details of this appraisal can be found in Section 6.

4 Objectives, and Possible Opportunities for Greater Circularity

In line with a move towards greater circularity (shown conceptually in Figure 4-1), the elected overarching objectives of policy interventions on tyres would be to:

- Reduce the impacts associated with manufacturing; and
- Bring about waste prevention through:
    - Using fewer tyres; and
    - Extending the lifetime(s) of those tyres that are used.

Figure 4-1 Conceptual Diagram of a Circular Economy for Tyres



The specific opportunities identified within these objectives are:

- Greater use of recycled content in tyres (Section 4.1.1);
- Using fewer tyres through driving less / achieving modal shift (Section 4.2.1); and
- Extending the lifetime of tyres through:
  - Maximising tyre tread lifetimes through reducing abrasion rates (Section 4.2.2.1);
  - Improving tyre stewardship and driving behaviour (Section 4.2.2.1.1);
  - Maximising use of part-worn tyres (Section 4.2.2.2); and
  - Maximising use of retreading (Section 4.2.2.3).

In addition, a cross-cutting objective, which would support many of the opportunities identified above, relates to tyre traceability and data capture (Section 4.2.3). Furthermore, an overarching objective is to ensure that the polluter pays principle is applied in respect of tyre use and end-of-life management in Scotland.

In the sections below we describe the opportunities and highlight the current barriers to uptake.

4.1 Reducing the Impacts of Manufacturing

4.1.1 Greater use of recycled content

Tyre recycling involves the processing of rubber from end-of-life tyres into rubber shred and crumb of different sizes. The primary uses for shredded and crumbed rubber are playground and sport

surfaces, equestrian and road surfaces. However, recycled rubber can also be incorporated into new tyres. This reduces the amount of virgin materials and resources required to produce new tyres, such as synthetic and natural rubber, water and energy. Closed loop recycling also diverts end-of-life tyres from landfill and incineration. Michelin and Continental tyres for instance, contained around 2-3% recycled content (as a percentage of the rubber weight of the tyre) in 2018[5]. Michelin has also proposed to include 30% recycled materials in its tyres by 2048, although it is unknown what proportion of this would be tyre crumb,[6] as well as actively exploring options for incorporating recycled wood, plastic and textiles into tyre manufacturing[7]. However, increasing the recycled content of tyres faces a number of technical, economic and social challenges.

Current recycling practices produce low quality granulate which cannot be used in large quantities in new tyres for performance reasons. Tyres are complex products containing a variety of different materials which complicates the recycling process. For example, a typical passenger tyre contains 30 kinds of synthetic rubber, eight kinds of natural rubber and polyester and nylon fibre amongst other materials[8]. Moreover, the vulcanisation process used to make finished rubber tyres forms sulphur bonds between the polymer chains in the rubber. This increases rigidity and durability but renders the rubber unable to be remelted and reused at high concentrations.

While vulcanisation is generally irreversible, the process of devulcanisation has been subject to much research over the past 50 years. In devulcanisation, the sulphur bonds are broken in order to recover higher quality rubber which could then constitute up to 30% of a new tyre[9].

However, devulcanisation is not yet commercially viable, nor has it reached large scale operation. The production process is not economically competitive with virgin rubber. Not only does recycling technology require significant capital costs, but maintenance costs are also high. This is due to the steel and fibre content in tyres which blunt the shredding knives or wear down the grounding hammers[10]. This is compounded by a lack of collaboration throughout the supply chain which can inhibit innovation and investment[11]. It should be noted that new techniques are under development, such as chemical and biological devulcanisation, as well as pyrolysis, which can recover recycled carbon black and cryogenic grinding which recovers micronised rubber powder[12]. Pyrolysis however also faces economic barriers due to high energy costs.

Second, current recycled tyre rubber is not only of low, but also varying, quality and there is a large variety in crumb rubber size. Indeed, there is no standard for recycled crumb[13]. Tyres are high-tech products requiring well-defined and raw materials of a consistent quality. The lack of certainty and variability of recycled rubber thus presents a challenge for tyre manufacturers. Moreover, there is mixed opinion amongst the scientific and engineering community regarding the ability for rubber, once vulcanised, to return to its original virgin state. Indeed, many recycling techniques produce an end-product which is reportedly inferior to virgin rubber, although research and development is ongoing.

Third, and very much related to point two, is the lack of information. There is a failure relating to the quality of information regarding secondary materials in tyres. Barriers include information that is

[5] Crisan-Heavilin, H. (2018) *Michelin announces sustainability plan*, accessed 9 July 2020, https://www.recyclingtoday.com/article/michelin-tire-recycling-plan/
[6] Crisan-Heavilin, H. (2018) *Michelin announces sustainability plan*, accessed 9 July 2020, https://www.recyclingtoday.com/article/michelin-tire-recycling-plan/
[7] Michelin (2022) https://www.michelin.com/en/innovation/vision-concept/sustainable/, accessed 9 May 2022
[8] WRAP (2006) *Composition of a Tyre: Typical Components*, accessed 22 July 2020, https://www.wrap.org.uk/sites/files/wrap/2%20-%20Composition%20of%20a%20Tyre%20-%20May%202006.pdf
[9] Markl, E., and Lackner, M. (2020) Devulcanization Technologies for Recycling of Tire-Derived Rubber: A Review, *Materials*, Vol.13, No.5, p.1246
[10] OECD (2006) *Working Group on Waste Prevention and Recycling: Improving Recycling Markets*, accessed 9 July 2020, https://www.oecd-ilibrary.org/environment/improving-recycling-markets_9789264029583-en
[11] Campbell-Johnston, K., Calisto Friant, M., Thapa, K., Lakerveld, D., and Vermeulen, W.J.V. (2020) How circular is your tyre: Experiences with extended producer responsibility from a circular economy perspective, *Journal of Cleaner Production*, Vol.270, p.122042
[12] Tzoganakis, C., and Visaisouk, J. (2019) Understanding Devulcanization: the path to a circular economy, *Rubber World*, Vol.259, No.5
[13] Phillips, M. (2001) *The Trouble with Tires*, accessed 22 June 2020, https://www.recyclingtoday.com/article/the-trouble-with-tires/

inadequate, inaccessible or missing, which can impact the perceived value of the material / product to the buyer[14]. Public perception of remanufactured tyres more broadly tends to be negative, due to concerns over safety and inferior quality[15].

Ultimately, measures to increase the use of recycled content in tyres need to address both technological barriers, including quality standards of recycled tyre rubber, as well as consumer perception.

4.2 Waste Prevention

In 2018, approximately 4.3 million tyres were bought in Scotland[16]. The majority of these tyres (over 75%) were bought by car and 4x4 drivers[17]. LCVs were the next largest group with around 340,000 sales. Only 469,000 tyres bought were part-worn and, again, the majority (95%) of these were for cars. This is due to the high reclamation rate from end of life cars at dismantlers and retailers. Around 60,000 retreaded tyres were bought in 2018. However, these were only for trucks and buses. Data suggests that a small number of retreaded passenger car tyres were sold in the UK as a whole and this number is assumed to be negligible for Scotland. This is thought to be due to the availability of cheap imported tyres from Asia for passenger cars and vans[18]. Waste prevention in this context would involve using fewer tyres in the first place and extending the lifetime(s) of those tyres that are used.

4.2.1 Using fewer tyres / modal shift

Paths for All report that 41% of *all* journeys made are less than 3 km long[19]. This indicates that there should be significant potential for modal shift to walking, cycling or public transport for many of these journeys. Modal shift could reduce the use of tyres through reduced purchases of cars in the first place, and/or delaying the point at which tyres on private cars need to be replaced through reduced mileage driven each year.

Furthermore, the RAC Foundation report that on average cars are unused for 96% of the time[20]. This indicates great potential for a more resource efficient approach to vehicle use/ownership, by moving towards a sharing economy[21]. However, for a number of reasons, travel by private car remains the predominant modal share for journeys. Reasons for this include:

- Lack of awareness of alternatives for specific journeys;
- Lack of full internalisation of costs of private vehicle ownership and use; and
- Linked to the above point, the low apparent private marginal cost of undertaking a journey in a private car.

[14] OECD (2006) *Working Group on Waste Prevention and Recycling: Improving Recycling Markets*, accessed 9 July 2020, https://www.oecd-ilibrary.org/environment/improving-recycling-markets_9789264029583-en

[15] WRAP (2006) *Remoulds and Retreads: the re-use of tyres for cars and light trucks*, accessed 9 July 2020, https://www.wrap.org.uk/sites/files/wrap/Car%20and%20light%20truck%20tyres%20v2.pdf

[16] The first stage report, Vehicle Tyres: Market Overview, is available at: https://zerowastescotland.org.uk/sites/default/files/20200617DraftForPubStage1FINALREPORTPubFV1.0.pdf

[17] Scottish Transport Statistics No. 38 2019 Edition: A National Statistics Publication for Scotland. Accessed 07/04/20 https://www.transport.gov.scot/publication/scottish-transport-statistics-no-38-2019-edition/

[18] Centre for Remanufacturing and Reuse (2015) Circular Economy Evidence Building Programme - Remanufacturing Study, Report for Zero Waste Scotland, 2015, http://www.zerowastescotland.org.uk/sites/default/files/Remanufacturing%20Study%20-%20Full%20Report%20-%20March%202015_0.pdf

[19] https://www.pathsforall.org.uk/tip-and-story/making-everyday-journeys-more-active, accessed 8 June 2022

[20] https://www.racfoundation.org/media-centre/cars-parked-23-hours-a-day, accessed 8 June 2022

[21] McGee, P. (2019) *Share your car to make it go further*, accessed 18 June 2020, https://www.ft.com/content/ea45ca12-eea5-11e9-a55a-30afa498db1b

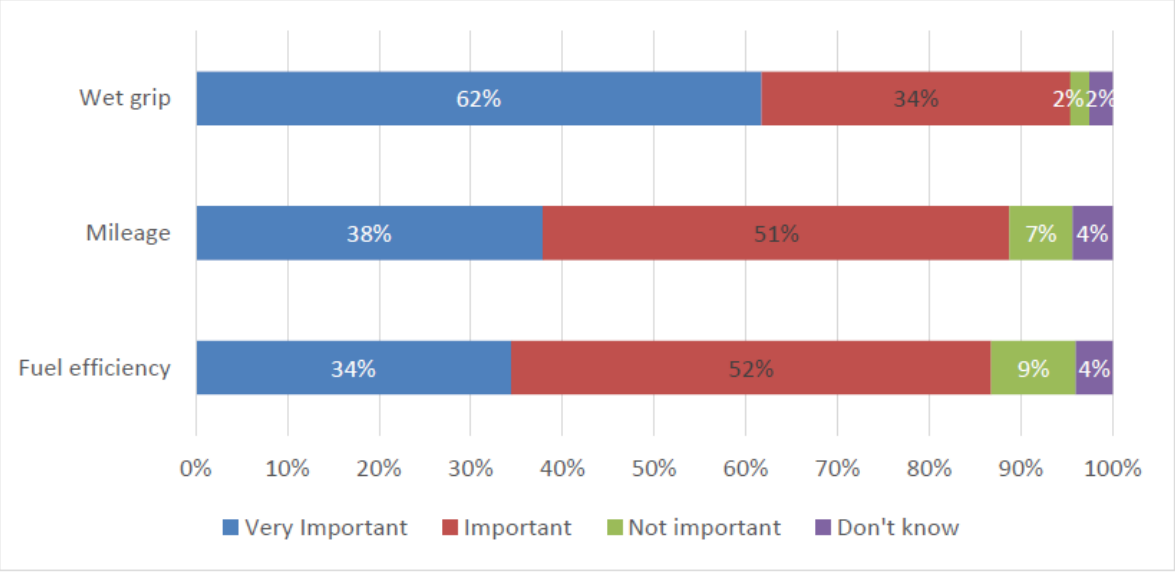
4.2.2 *Making Tyres Last Longer*

4.2.2.1 Reducing tread abrasion rates to maximise tread lifetime

In-use tyres wear due to forces acting on the tyre tread when it interacts with road surfaces. The rate of tyre tread abrasion is influenced by a number of factors, including: tyre design (materials and tread), vehicle characteristics, road surface, driving behaviour and weather[22]. Tyre wear particles comprise of both coarse and fine particles, and there is increasing concern regarding the finer particulate matter that is generated. Such particulates become airborne and contribute to air pollution[23]. The quicker the tyre wears, the sooner it requires replacement. Thus, reducing tyre abrasion and extending the lifetime of the tyre, will help reduce tyre waste with the possible co-benefit of reducing air pollution from tyre-derived particulate matter.

Mileage, the distance that can be covered before the tyre has to be replaced, is an important factor for consumers, and is directly related to tyre wear. For instance, Figure 4-2 illustrates the relative importance of performance parameters included on labels, namely wet grip, fuel efficiency and mileage, to purchasers of C1 tyres in Europe. The survey included consumers as private persons buying tyres for their own cars, as well as leasing companies buying tyres for their lease cars[24]. However, over half of car owners in the survey sample were not aware of labels before the survey. Price and brand also significantly influence tyre choice[25].

Figure 4-2 C1 end-user rating of fuel efficiency, mileage and wet grip importance (source: Viegand Maagøe A/S, 2016)



However, reducing tread abrasion rates faces several key barriers:

- There is insufficient incentive, either financial, regulatory or reputational, for manufacturers to prioritise reducing tyre abrasion amongst other key performance characteristics valued by consumers such as grip in wet conditions and fuel efficiency. Making tyres that abrade at

[22] Klueppel, M. (2014) Wear and abrasion of tires, accessed 8 June 2022, https://www.researchgate.net/publication/278707187_Wear_and_Abrasion_of_Tires

[23] Charron, A., Polo-Rehn, L., Besombes, J.-L., et al. (2019) Identification and quantification of particulate tracers of exhaust and non-exhaust vehicle emissions, *Atmospheric Chemistry and Physics*, Vol.19, No.7, pp.5187–5207

[24] Viegand Maagoe (2016) *Review study on the Regulation (EC) No 1222/2009 on the labelling of tyres*

[25] Bartlett, J.S. (2019) *The Driving Forces Behind Tire Purchases Revealed*, accessed 27 July 2020, https://www.consumerreports.org/tire-buying-maintenance/driving-forces-behind-tire-purchases-revealed-survey/

lower rates would mean that manufacturers would sell fewer tyres over a given period[26]. This could act as a disincentive to further reduce abrasion rates;

- There is no standard test method for tyre tread abrasion. This means that there is a lack of a standard way of communicating the tread abrasion rate to consumers and tyres cannot be compared objectively, preventing informed customer choice and targeted action by regulators. While there are efforts to develop a reliable and reproducible method to measure tyre abrasion[27], this currently represents a significant knowledge/evidence gap. There is also no standard measure regarding the air quality impacts of fine particles from tyre use;
- EU tyre labels currently focus on fuel efficiency, wet grip and noise. Thus, these factors are likely to influence consumer choice to a greater extent than wear rates; and
- There is no regulation on the minimum rate at which tyres can abrade.

Opportunities to extend the lifetime of tyres by reducing tyre abrasion would need to address the way in which tyre abrasion rate is first measured by industry and communicated to consumers.

4.2.2.1.1 Improved Tyre Stewardship and Driving Behaviour

Historic surveys have suggested that around 60% of car tyres in the UK have typically been at least 4psi below recommended pressure. As driving on tyres which are only 10% underinflated can reduce the life of a tyre by 10%[28], this tendency towards poor stewardship results in tyres needing to be replaced more frequently, and thus greater waste arisings. In addition, driving behaviour including the frequency and extent of acceleration, braking and cornering, are known to influence the rate of wear of tyres with most material lost during these activities[29]. It is believed that eco-driving techniques which encourage “smooth” driving with limited braking and acceleration and reducing the weight of vehicles where possible for the sake of fuel efficiency, will also contribute to reductions in tyre wear and, all else being equal, extend the tyre lifetime and reduce arisings[30].

Barriers to improving tyre stewardship and driver behaviour include insufficient information to encourage behavioural change. Despite the requirement for new cars to come fitted with Tyre Pressure Monitoring Systems (TPMS) since 2014, these will not have yet penetrated the market fully such that many drivers are likely to remain unaware that they are running tyres that are underinflated.[31] Behaviour change is unlikely to occur without clear and accurate information.

Additionally, WheelRight, a company which produces drive-over tyre pressure monitoring systems, suggests that TPMS can result in driver complacency regarding general maintenance and checking tyre pressure[32]. TyreSafe highlight TPMS is not a replacement for ongoing tyre checks[33].

Interventions might be made to both encourage and facilitate better upkeep of tyres, and to make drivers aware of the driving style they could adopt to save fuel and extend their tyre lifetime.

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[26] Viegand Maagoe (2016) *Review study on the Regulation (EC) No 1222/2009 on the labelling of tyres*

[27] Euractiv (2021) https://www.euractiv.com/section/circular-materials/news/eu-seeks-reliable-method-to-measure-microplastic-pollution-from-tyres/, last accessed 10 May 2022

[28] TyreSafe (2018) Promoting UK Tyre Safety and Driver Awareness, accessed 2 July 2020, https://www.tyresafe.org/other-information/statistics/

[29] Boulter, P. (2005) *A review of emission factors and models for road vehicle non-exhaust particulate matter*, Final Report for TRL Limited, 1 September 2005, https://uk-air.defra.gov.uk/assets/documents/reports/cat15/0706061624_Report1__Review_of_Emission_Factors.PDF

[30] European Tyre and Rubber Manufacturers Association (2020) *Addressing tyre and road wear particles*, accessed 9 July 2019, https://www.tyreandroadwear.com/

[31] TyreSafe (2018) *TPMS*, accessed 9 July 2020, https://www.tyresafe.org/tyre-safety/tpms/

[32] WheelRight (2020) *Tyre Pressure*, accessed 2 July 2020, http://www.wheelright.co.uk/tyre-pressure/

[33] TyreSafe (2018) *TPMS*, accessed 9 July 2020, https://www.tyresafe.org/tyre-safety/tpms/

4.2.2.2 Maximising use of part-worn tyres

The use of part-worn tyres prolongs the useful life of the tyre, whilst reducing the need for new tyres. Part-worns can come from a variety of sources: salvaged by garages from cars which are scrapped, from customers who have new tyres fitted, or they may be imported form European markets such as Germany where the minimum legal tread depth is 3mm, compared to the UK's minimum tread depth of 1.6mm. Purchasing a second-hand vehicle without fitting new tyres also means that part-worns are used. According to the industry body TyreSafe, around 5.5 million used tyres are sold in the UK every year[34]. As identified in the Vehicle Tyres: Market Overview report[35], in Scotland just under two thirds of part-worns are placed on the market by vehicle dismantlers (although the data is considered quite uncertain), approximately 14% are imported and approximately 21% are retained for resale by retailers replacing used tyres.

Part-worns can be a popular choice for price conscious consumers as their cost is lower than that of a new tyre. However, their value for money in the long term has been questioned. Although the purchase price of part-worns can be half the cost of new tyres, the price per mm of tread can be more. This is because the part-worn tyre will need replacing sooner than a new tyre[36]. TyreSafe calculates that the average cost per mm of useable tread on a part-worn is £6.33 per mm, compared to £5.32 per mm on a comparable new tyre[37].

In the UK, the sale of part-worn tyres is subject to the Motor Vehicle Tyres (Safety) Regulations 1994 part of the Consumer Protection Act, and the General Product Safety Regulations (2005). The regulations apply to all operators in the supply chain, not just the retailers. Part-worn tyres must fulfil the following criteria:

- Have an EC approval mark and a speed and load capacity index;
- Be marked with 'PART-WORN' in upper case letters at least 4mm high;
- Not have a cut over 25mm or 10% of the section width of the tyre;
- Not have any internal or external lump, bulge or tear;
- Not have any ply or cord exposed;
- Not have any penetration damage that has not been repaired; and
- The original tread pattern of the tyre must be at least 2mm deep[38].

The greatest challenge is the enforcement of these criteria. Indeed, a campaign by TyreSafe found that 98% of the part-worn tyres sampled were sold illegally, and 34% were sold with dangerous damage[39]. The illegal sale of part-worn tyres presents a serious safety risk to motorists. Issues which were identified included incorrect markings, bulges, cuts and age-related deterioration and repair not carried out in accordance with British Standard BS AU 159[40]. Without the use of x-ray technology, it is not possible to determine whether a part-worn tyre is damaged internally. Moreover, there is a lack of information available to the consumer regarding the history and age of the tyre.

Increasing the use of part-worn tyres depends to a significant degree on quality assurance, standards and inspections, as well as information availability, in order to ensure safety and to provide confidence to the buyer.

[34] Prosser, D. (2019) *Are part-worn tyres safe?*, accessed 22 June 2020, https://www.autocar.co.uk/car-news/advice/part-worn-tyres
[35] https://zerowastescotland.org.uk/sites/default/files/20200617DraftForPubStage1FINALREPORTPubFV1.0.pdf
[36] Black Circles (2020) *Part worn tyres vs new tyres*, accessed 29 July 2020, https://www.blackcircles.com/helpcentre/tyres/part-worn-tyres
[37] TyreSafe (2015) *Part worn tyres= part safe tyres*, accessed 22 June 2020, https://www.tyresafe.org/wp-content/uploads/2015/12/pwt_infographic.pdf
[38] Black Circles (2020) *Part worn tyres*, accessed 22 June 2020, https://www.blackcircles.com/helpcentre/tyres/part-worn-tyres
[39] TyreSafe (2015) *Part worn tyres= part safe tyres*, accessed 22 June 2020, https://www.tyresafe.org/wp-content/uploads/2015/12/pwt_infographic.pdf
[40] Tyre Pros (2019) *Are Part-Worn Tyres Safe To Use*, accessed 2 July 2020, https://www.tyrepros.co.uk/blog/are-part-worn-tyres-safe-to-use

4.2.2.3 Maximising use of retreading

Retreading is the process in which a used tyre is reconditioned by replacing the worn tread with new material. As only the tread is replaced, this means on average that 70-80% of the original tyre is reused[41]. Unlike other forms of tyre recycling or disposal, retreading is not downcycling. With the ability to retread a commercial tyre up to three times, it extends the life of the main body of the tyre – the casing. This actively contributes towards reducing the number of tyres being used and reduces the environmental impact of manufacture. According to truck tyre retreader Bandvulc, extending the life of one worn truck tyre saves 44kg of rubber, 68l of oil and 182kg CO_2e[42].

Only sound, carefully inspected tyre casings are used for retreading. The worn tread is buffed away, and a new tread is bonded to the tyre body in a process very similar to the manufacture of a new tyre. There are different processing techniques: mould cure and pre-cure. Both produce a similar quality of retreaded tyre.

The mould cure technique applies an unvulcanised layer of tread rubber to the buffed tyre casing which is then placed into a rigid mould with the chosen tyre tread for the curing process. In the pre-cure technique, a tread is precured with the chosen tread design and then applied using a cushion gum for bonding. The tyre is then placed into a curing chamber to complete the adhering process[43]. The ultimate objective is always the same – affixing a new tread through the application of heat and pressure.

In recent years however, the European retread market has shown a general decline. Overall, between 2007 and 2016, sales volumes of retreads decreased by a quarter (although there was a notable peak in 2010/11)[44]. For instance, compared to 2010, the truck tyre retreading market in France, Italy, Spain, Germany and the UK was down 20% in 2016[45]. Figure 4-3 illustrates the decline in the European truck tyre retread market between 2007 and 2018. The retreading market showed a slight increase in 2018 for the first time since 2011[46].

[41] Oponeo (2013) *Are retreaded tyres worth buying?*, accessed 10 July 2020, https://www.oponeo.co.uk/blog/are-retreaded-tyres-worth-buying

[42] Bandvulc (2019) *How retreading reduces environmental impact*, accessed 8 July 2020, https://www.bandvulc.co.uk/uncategorised/how-retreading-reduces-environmental-impact/

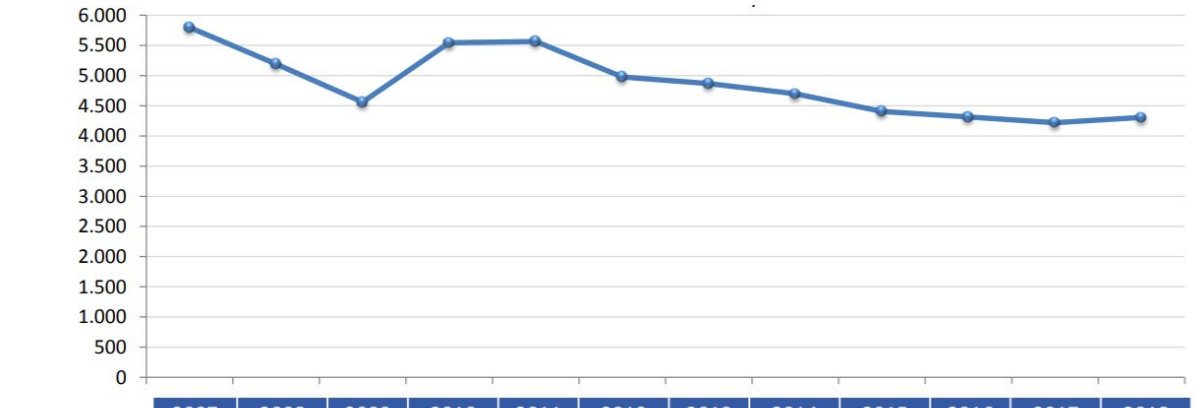
[43] Roberts, F. (2016) *Two sides of the same coin: mold cure vs. pre cure*, accessed 8 July 2020, https://www.tirerecappers.com/tire-recappers-news/two-sides-of-the-same-coin-mold-cure-vs-pre-cure/

[44] Tyrepress (2016) *Europe's retreading market - is a structural change in full swing?*, accessed 8 July 2020, https://www.tyrepress.com/2016/11/europes-retreading-market-is-a-structural-change-in-full-swing/

[45] EY (2016) *The socio-economic impact of truck tyre retreading in Europe: The circular economy of tyres in danger*, accessed 8 July 2020, https://rechile.mma.gob.cl/wp-content/uploads/2019/06/3.-ARNEC3-201611-ey_retreading.pdf

[46] ETRMA (2019) *European Tyre and Rubber Industry: Statistics Edition 2019*, accessed 16 July 2020, https://www.etrma.org/wp-content/uploads/2019/10/20191114-Statistics-booklet-2019-Final-for-web.pdf

Figure 4-3 Truck Tyre Retreading Market in Europe (including Turkey), 2007-2018 (thousand units) (Source: Europool, in ETRMA 2019)



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Retreaded Truck Tyres	5.800	5.193	4.561	5.546	5.567	4.978	4.867	4.699	4.406	4.316	4.218	4.307

It is estimated that around 44,000 retreaded passenger car tyres were manufactured in the UK in 2018[47]. Based on our assessment of the tyre market in Scotland, we have found no evidence of retreaded C1 tyres being sold in Scotland between 2016 and 2018[48]. According to the Retread Manufacturers Association (part of the BTMA), this service is currently offered for passenger and taxi cars by two small firms as and when demand arises[49]. In comparison, nearly half the truck and bus tyres on the road in the UK have been retreaded. The number of retreaded tyres PoM in Scotland has remained largely static for the years 2016 to 2018, at just under 65,000 units per year[50].

As previously noted, truck tyres are designed for durability, meaning they are also suitable for retreading. The majority of truck and bus retreaded tyres are carried out by independent retreaders and tyre manufacturers using the mould cure process. Around 55% are sold on service contracts – whereby a management company will be used to service vehicles, including replacing tyres. For large fleet operators, it is better value to have a tyre lease arrangement whereby they are charged per mile rather than per tyre. The remaining 45% are sold on a one-off purchase basis with fleet owners often running a tendering exercise in order to gain the best market rate[51].

The primary challenge to retreading in the UK and Europe, which is typically conducted by SMEs, is competition from what some stakeholders describe as 'low-end non-retreadable' tyres imported principally from Asia[52]. As shown in Figure 4-4, whilst the number of commercial tyre replacement sales in the EU has declined, the sale of commercial tyre imports has increased[53,54].

[47] Office for National Statistics (2019) UK Manufacturers' Sales by Product Survey (Prodcom), 1 July 2020, https://www.ons.gov.uk/businessindustryandtrade/manufacturingandproductionindustry/bulletins/ukmanufacturerssalesbyproductprodcom/2019results

[48] Eunomia Research & Consulting, and Zero Waste Scotland (2020) *Vehicle Tyres - Market Overview*, June 2020

[49] Personal correspondence with BTMA (April 2020)

[50] Eunomia Research & Consulting, and Zero Waste Scotland (2020) *Vehicle Tyres: Market Overview*, June 2020

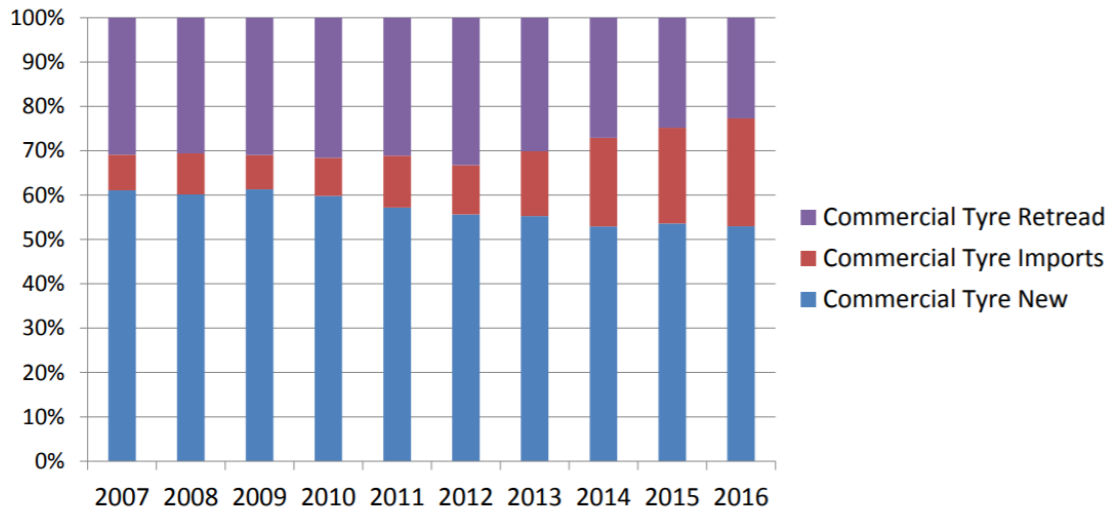
[51] Personal correspondence with BTMA (March 2020)

[52] EY (2016) *The socio-economic impact of truck tyre retreading in Europe: The circular economy of tyres in danger*, accessed 8 July 2020, https://rechile.mma.gob.cl/wp-content/uploads/2019/06/3.-ARNEC3-201611-ey_retreading.pdf

[53] Jean-Pierre Taverne (2018) *Retreading – a virtuous Circular Economy model*, paper given at Global Retreading Conference 2018, Cologne, 29 May 2018, https://bipaver.org/wp-content/uploads/2017/10/2018-05-11_Global-Retreading-Conference_ETRMA-presentation_vF_16-9.pdf

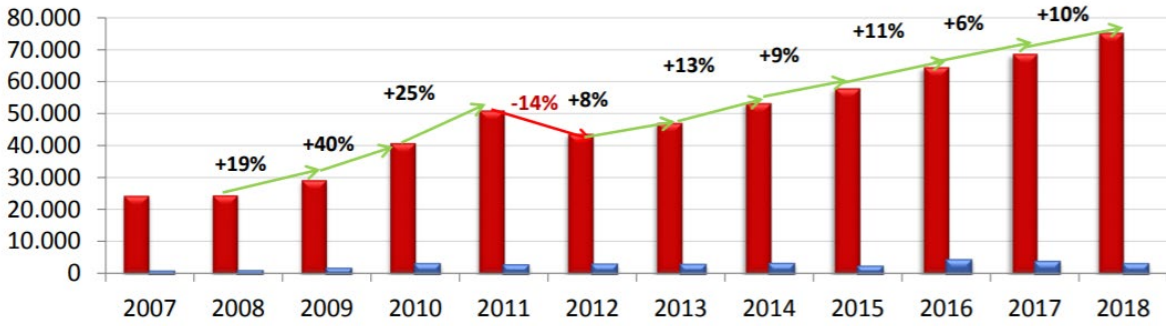
[54] Tim van der Rijken (2017) *Retreading in Europe*, paper given at Global Retreading Conference, Cologne, 2017, https://bipaver.org/wp-content/uploads/2017/10/The-role-of-retreading-in-Europe-GRC2018.pdf

Figure 4-4 EU Commercial Tyre Market (Source: BIPAVER 2017)



Moreover, with regards to imports of passenger car tyres, China alone represents 48% of all EU imports and in 2018 Chinese exports to the EU increased by nearly 10%, as shown in Figure 4-5 (EU imports are in red, exports in blue)[55]. Imports of truck and bus tyres from China fell by 52% in 2018 due to the introduction of anti-dumping duties by the EU. Imports from Thailand, South Korea and Turkey increased to fill the gap in the market[56].

Figure 4-5 Car and Light Truck Tyres, Import/Export with China (thousand units) (Source: Eurostat in ETRMA 2019)



Underpinned by the decline in global raw material prices, some new tyres are cheaper than retreaded tyres at the point of purchase, an option favoured by cost-conscious consumers[57]. Furthermore, it is reported that consumers, mainly in the car market, perceive retreaded tyres to be of a lower quality or less safe than new ones[58].

Retreaded tyres are, however, produced to a quality equal to that of new tyres. They are manufactured to the requirements of the British Standard AU 144 series and two EC Regulations

[55] ETRMA (2019) *European Tyre and Rubber Industry: Statistics Edition 2019*, accessed 16 July 2020, https://www.etrma.org/wp-content/uploads/2019/10/20191114-Statistics-booklet-2019-Final-for-web.pdf
[56] ETRMA (2019) *European Tyre and Rubber Industry: Statistics Edition 2019*, accessed 16 July 2020, https://www.etrma.org/wp-content/uploads/2019/10/20191114-Statistics-booklet-2019-Final-for-web.pdf
[57] EY (2016) *The socio-economic impact of truck tyre retreading in Europe: The circular economy of tyres in danger*, accessed 8 July 2020, https://rechile.mma.gob.cl/wp-content/uploads/2019/06/3.-ARNEC3-201611-ey_retreading.pdf
[58] Centre for Remanufacturing and Reuse (2015) *Circular Economy Evidence Building Programme - Remanufacturing Study*, Report for Zero Waste Scotland, 2015, http://www.zerowastescotland.org.uk/sites/default/files/Remanufacturing%20Study%20-%20Full%20Report%20-%20March%202015_0.pdf

relating to the 'type approval' of retreaded tyres[59]. These regulations identify uniform conditions for the approval of individual retreading facilities. Consequently, retread producers are effectively 'licensed' operations. Despite this, there is an information failure regarding the quality and standards of retreaded tyres. The lack of consumer confidence as a result, means that demand is low.

In addition to economic barriers, retreading also faces technical challenges. In preparing for retread, potential tyres undergo various inspections and must meet certain quality requirements. If the tyre is damaged or internally 'fatigued', it is not retreadable. Van / commercial tyres are designed to carry greater loads and are thus made with more material to make them stronger.

Tyre treads must be matched to the casing. The tread should have the same depth as the base casing used in the process. Given that the UK minimum tread depth is 1.6 mm, any casing less than 2mm deep cannot be used as it cannot handle a deep enough tread[60]. Not only must the tread and casing match, but tyres also need to fit the cure moulds. One retreader consulted reported that they have created a mould which only fits a certain type of tyre. All standard size tyres are in reality slightly different which makes the matching process very complex[61].

Two further barriers preventing the expansion of retreading to passenger car and light commercial vehicles include:

I) OEM lock-in: The tendency of tyre distributers is to favour certain OEM makes or not offer retreaded tyres as an option to the customer on new cars. This is largely due to perceived rolling resistance savings from these particular tyres that can drive fuel efficiency saving; and

II) Poor availability: For car tyres, low usage rates mean that in some regions, there is a poor availability of retread distributors and thus a lack of access and information for consumers[62].

Overall, retreading is a key component of a circular economy for tyres. As a remanufacturing process, retreading reuses and extends the lifetime of tyres. Enhancing circularity for tyres will need to address the economic, technological and public perception barriers to retreading.

4.2.3 Improving Tyre Traceability and Data Capture

At present the unique identification and tracking of individual tyres through their use phase, and of waste tyres through collection, reuse, remanufacture, recycling and disposal operations is not routinely undertaken. Additionally, where the tracking of large quantities of end of life tyres does occur for the purposes of reporting to voluntary or mandatory accreditation schemes, the systems used are frequently paper-based, laborious and error-prone[63].

This creates a number of problems including:

- The collation of collection and treatment data for reporting to government is challenging[64];
- Retreaders cannot be sure of the number of retreads a tyre has undergone when they receive it, and have no oversight of its use or service history which might influence decisions as to whether or not it should be retread;

[59] *The Motor Vehicle Tyres (Safety) Regulations 1994* (SI 1994/3117), accessed 13 July 2020, http://www.legislation.gov.uk/uksi/1994/3117/regulation/2/made

[60] Oponeo (2013) *Are retreaded tyres worth buying?*, accessed 10 July 2020, https://www.oponeo.co.uk/blog/are-retreaded-tyres-worth-buying

[61] Private communication with confidential company (July 2020).

[62] Centre for Remanufacturing and Reuse (2015) *Circular Economy Evidence Building Programme - Remanufacturing Study*, Report for Zero Waste Scotland, 2015, http://www.zerowastescotland.org.uk/sites/default/files/Remanufacturing%20Study%20-%20Full%20Report%20-%20March%202015_0.pdf

[63] Hanlon, A. (2019) *Use case. Item-level digital monitoring for waste management*, accessed 8 July 2020, https://www.pragmatic.tech/newsroom/blog/use-case-item-level-digital-monitoring-for-waste-management

[64] Hanlon, A. (2019) *Use case. Item-level digital monitoring for waste management*, accessed 8 July 2020, https://www.pragmatic.tech/newsroom/blog/use-case-item-level-digital-monitoring-for-waste-management

- Those assessing used tyres against the requirements of the relevant regulation for potential part-worn use have no oversight of the use and service history of a tyre which might influence their judgement; and
- Law-enforcement bodies are unable to trace waste tyres in the environment to whoever might have fly tipped them.

Drawing an analogy with personal passports used in controlling, permitting and monitoring the movement of people, '*Product Passports'* are unique and trustworthy logs of key information about products[65]. Typically this includes components and materials that a product contains, and how they can be disassembled and recycled at the end of the product's useful life[66]. If individual tyres were consistently tracked through their use and end-of-life life cycle phases, with a database of key information available to all relevant organisations, then a number of these challenges could be overcome. Such an approach could result in reduced cost of retreading if the process can be made more efficient, greater consumer confidence in part-worn tyres; greater safety-assurance for part-worn tyres and greater disincentives for fly tipping through improved enforcement.

Some tyre brands already offer C3 tyres equipped with Radio-Frequency Identification (RFID) tags, coupled with cloud data storage to allow for high-detail recording of key aspects of individual tyres' life cycles[67]. Additionally, a number of private companies and Defra are collaboratively exploring the use of RFID tags and readers for tracking end of life management of waste tyres[68,69].

5 Identification and Screening of Measures

This section identifies and assesses the various mechanisms that could contribute to a circular economy for tyres. Drawing on the previous examination of the barriers to, and potential for, circularity in the tyre industry, Section 5 first presents a longlist of measures which could impact the circular economy potential for tyres. This longlist is then assessed and screened in order to develop a set of key mechanisms which will be further detailed in Section 6.

5.1 Longlist of Measures

Table 5-1 presents measures which could contribute to a circular economy for tyres and the objectives that they could contribute towards. The measures relate to the different stages of the tyre life cycle: production, use, reuse, recycling and end-of-life.

[65] The Product Passport: A Practical and Scalable Standard - Consumption of Products & Services 2014, accessed 18 August 2020, https://www.climatecolab.org/contests/2014/consumption-of-products--services/c/proposal/1306601
[66] *European Resource Efficiency Platform pushes for'product passports' - Eco-innovation Action Plan - European Commission*, accessed 24 August 2017, https://ec.europa.eu/environment/ecoap/about-eco-innovation/policies-matters/eu/20130708_european-resource-efficiency-platform-pushes-for-product-passports_en
[67] Michelin (2020) *The technologies used*, accessed 13 July 2020, https://trucks.michelin.co.uk/Expertise/Technology
[68] Paul, A. (2019) *Smart waste tracking challenge: are we any closer to solutions?*, Defra digital, accessed 8 July 2020, https://defradigital.blog.gov.uk/2019/05/13/smart-waste-tracking-challenge-are-we-any-closer-to-solutions/
[69] Insights, L. (2019) *SAP, GS1 explore blockchain for tire retreads*, accessed 8 July 2020, https://www.ledgerinsights.com/sap-gs1-blockchain-tire-retreads/

Table 5-1: Longlist of Measures and the objectives they contribute towards

Measures \ Objectives	Minimising environmental impact of production	Using fewer tyres	Extending tyre lifetime	Maximising use of part-worn	Maximising opportunities for retreading	Ensure application of the polluter pays principle
Incentives/requirements for recycled content	✓					
Road User Pricing		✓				✓
Car sharing		✓				
Car clubs		✓				
Taxation		✓		✓	✓	✓
Standard test for tyre tread abrasion rate		✓	✓			✓
Improved Tyre Stewardship and Driving Behaviour including Public Awareness Campaigns		✓	✓	✓	✓	
Trading standards enforcement for part-worn tyres		✓	✓	✓		
Green Public Procurement		✓		✓	✓	
EPR			✓	✓	✓	✓
Data and traceability		✓	✓	✓	✓	✓

5.2 Assessment of Measures

In the sections below we describe a number of measures that have not been taken through for further appraisal and provide a justification for not taking them forward.

The longlist of measures outlined in Table 5-1 was assessed against a number of criteria to arrive at a shortlist for assessment, including:

- Their ability to contribute to objectives which could result in a more circular economy for tyres, including through;
    - Minimising environmental impact of production;
    - Stimulating the use of fewer tyres;
    - Extending tyre lifetime;
    - Maximising the use of part-worn tyres;
    - Maximising opportunities for retreading; and
    - Ensuring the application of the polluter pays principle;
- Whether there already exists sufficient motivation to implement a measure due to the other benefits it provides, for example in terms of improved driver safety or carbon emissions reduction, such that increasing tyre circular economy would be seen as a co-benefit of said measure; and
- The degree to which a measure is actionable in Scotland, with the absence of barriers related to either jurisdiction or feasibility based on currently available technologies.

Additionally, it should be noted that the focus of this study is the potential to increase tyre circular economy through waste and resources policy. Therefore, while some measures which might traditionally fall under other policy areas could influence tyre circular economy, where they do not fall under waste and resource policy, they have not been taken forward.

In Section 6 we provide a full description of the measures that have been taken forward, along with an appraisal of these selected measures.

5.2.1 Increasing the Recycled Content of Tyres

There are several measures which could be taken to overcome the barriers to increasing recycled content in tyres. Partnerships and collaboration needs to be fostered between producers, importers, collectors and processors and will be crucial in order to share information to improve tyre recycling and to foster R&D. The investment and R&D necessary to ensure high quality recyclate could be financed by a Producer Responsibility Organisation (PRO) for tyres, as has been the case in the Netherlands[70].

Furthermore, eco-design requirements could encourage both the production of tyres which are easier to recycle, and which contain greater recycled content. The European Commission's Circular Economy Package and revised Waste Framework Directive provide the regulatory framework for both recycled content in products and Extended Producer Responsibility (EPR), through which design criteria could be set using fee modulation.

Overall, the development of devulcanisation technology is a significant barrier. Given the extent of technological investment required in this process, it is not considered feasible for Scotland at present. Whilst such domestic R&D would be a sizeable challenge, the technology is being researched across Europe and beyond; Scotland could support such research at an EU level in the future. This option will not be taken forward because, while theoretically interesting, there remain too many technical barriers at present and Scotland is not considered to be well placed to incentivise this beyond simply supporting research.

[70] Campbell-Johnston, K., Calisto Friant, M., Thapa, K., Lakerveld, D., and Vermeulen, W.J.V. (2020) How circular is your tyre: Experiences with extended producer responsibility from a circular economy perspective, *Journal of Cleaner Production*, Vol.270, p.122042

5.2.2 Standard Test for Tyre Tread Abrasion Rate

One possible measure to help extend the lifetime of tyres is the development of a standard measure of tyre tread abrasion. Such a test could determine the rate at which different tyres abrade (measured as mg/km) under standard conditions, thus providing consistent information to tyre manufacturers. While testing for tyre tread abrasion already takes place, this is not based on a standardised test procedure.

Crucially, a standard measure of tyre tread abrasion is a pre-requisite for other measures which can enhance circularity, such as inclusion of tyre tread abrasion rates in the EU Tyre Label Regulation (EC/1222/2009) and using the Type-Approval Regulation (EC/661/2009) to restrict the worst performing tyres (in respect of tyre tread abrasion) from the market. Including tyre tread abrasion rates on the tyre label aims to have the following effects: a move by consumers towards existing tyre models that exhibit a lower abrasion rate; and a shift by producers towards the manufacture of tyres that have a lower abrasion rate than current models. The test and subsequent labelling could also be used to inform green public procurement of tyres.

However, there are a number of issues related to the development of a standard tyre abrasion measure. The current lack of a standard test is underpinned to a large extent by the complexity of tyre wear and the range of factors which influence it.

Moreover, major tyre brands may not agree on a standard test procedure, especially if they have already invested in their own approach. Producers might also have concerns regarding sensitive data and sharing information which gives a competitive advantage. A further question is how the standard measure would be enforced and monitored.

Ultimately, a standard measure for tyre abrasion is being considered at the EU level both by the European Commission and UNECE. Indeed, the Commission has proposed to prepare a standardisation request to initiate development and revision of test methods relating to mileage and tyre abrasion. This is considered necessary in order to provide consumers with information which is currently missing from labelling parameters[71]. With regards to Scotland, it is an area which the government may consider contributing research support, such as fostering collaboration between government authorities with responsibility for the environment and transport across Europe. However, with the emphasis at the EU level, this measure is not taken forwards at this stage.

5.2.3 Sharing Economy

Far too many cars and therefore tyres are produced in relation to society's transport needs[72]. This can be avoided using a sharing economy business model for which the central idea is to optimise the use of underutilised assets (e.g. cars and apartments) by pooling or sharing them through digital platforms.

Two measures falling within this category are car clubs and shareable transport.

Car clubs are short-term car rental services that allow members access to locally parked cars. The payment mechanism is usually managed through a monthly or annual subscription fee with additional rental cost per minute, hour or day. The fee usually includes all costs such as insurance, wear and tear and fuel. Car clubs offer an alternative model to private car ownership for individuals and businesses. One could argue that the higher usage of a single car will result in a higher tyre wear and therefore the overall number of tyres would not be reduced by a sharing model. This is not the case as is shown in the Annual Car Club Survey for Scotland 2019/20, which shows an overall increase in walking and cycling (16% and 10% respectively) and a reduction in private car use by 26% since

[71] European Commission (2018) *COMMISSION STAFF WORKING DOCUMENT: IMPACT ASSESSMENT. Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on the labelling of tyres with respect to fuel efficiency and other essential parameters and repealing Regulation (EC) No 1222/2009*, accessed 6 July 2020, https://eur-lex.europa.eu/resource.html?uri=cellar:bdd88462-59bb-11e8-ab41-01aa75ed71a1.0001.02/DOC_1&format=PDF

[72] McGee, P. (2019) *Share your car to make it go further*, accessed 18 June 2020, https://www.ft.com/content/ea45ca12-eea5-11e9-a55a-30afa498db1b

joining a car club[73]. In addition, as tyres age, UV light oxidises the rubber, causing it to dry out. While tyres contain anti-oxidising chemicals to slow this process, these only work when the tyres are in use, i.e. moving. Tyres on cars that are not moving therefore will deteriorate faster than tyres on cars that are used more frequently. The production week of the tyre is printed on the rubber sidewall.[74]

In 2016, OECD's International Transport Forum concluded that if cars and buses in Lisbon were replaced with a fleet of shareable taxis and mini-buses, the same level of mobility could be achieved with just 3% of the current number of vehicles[75]. Unlike car clubs, this sharing model offers driven or autonomous fleets that ferry passengers to their destinations, collecting additional passengers on the way (e.g. UberPool or MOIA, a VW offering of a fleet of electric shared minibus taxis). This business model lends itself to large urban areas in which a large number of commuters need to be transported flexibly.

There is already a strong focus on such transport-related sharing economy business models as car clubs and shareable transport as they address a multitude of urban environmental issues e.g. air pollution, space, safety concerns and a reduction in use of tyres is a logical result following on from a rise of these sharing economy business models. Additionally, it should be noted that the focus of this study is the potential to improve the tyre circular economy through the use of waste and resources policy, and so while some measures which might traditionally fall under other policy areas could influence a circular economy for tyres, where they do not fall under waste and resource policy they have not been taken forward. As a result, measures related to encouraging a sharing economy have not been taken forward for further consideration in this study.

5.2.4 Road user pricing

Road user pricing involves charges being levied for the use of roads such as road tolls, distance or time-based fees and congestion charges. More recently road user pricing has been used for charges designed to discourage use of certain classes of vehicle, fuel sources or more polluting vehicles (e.g. low emission zones and additional parking charges for diesel vehicles). These measures are designed to promote a modal shift to public transport or even walking or cycling. Road user pricing is traditionally designed to reduce congestion but has been linked to environmental benefits such as reductions in air pollution.

As per the approach of the sharing economy, this measure has not been taken forward, as reduction in tyre use is indirectly linked to the already known benefits of this measure.

5.2.5 Improved Tyre Stewardship and Driving Behaviour

Interventions to encourage and facilitate better upkeep of tyres and to make drivers aware of the driving style they could adopt to save fuel and extend their tyre lifetime could result in lower waste tyre arisings.

We are aware that Scotland's third report on the proposals and policies of its 2018-2032 Climate Change Plan already contains a policy to support fuel efficient driving, referencing government support to the Energy Saving Trust in training drivers in eco-driving techniques and states that behaviour change will be a major driver of success in achieving emissions reductions targets[76]. Scotland might consider, in light of the additional benefit of increasing tyre lifetime and reduced waste tyre arisings,

[73] CoMoUK, CAR CLUB ANNUAL SURVEY FOR SCOTLAND 2019/20 Summary, 2020, https://como.org.uk/wp-content/uploads/2020/03/80264-Comouk-Car-Club-Survey_final-WEB-R-Edit.pdf

[74] Uniroyal Tyres (2020) *The importance of tyre age as well as tread depth*, accessed 18 June 2020, https://www.uniroyal-tyres.com/car/tyre-guide/tyre-knowledge/the-importance-of-tyre-age-as-well-as-tread-depth

[75] McGee, P. (2019) *Share your car to make it go further*, accessed 18 June 2020, https://www.ft.com/content/ea45ca12-eea5-11e9-a55a-30afa498db1b

[76] *Climate Change Plan: The Third Report on Proposals and Policies 2018-2032* (SG/2018/18), February 2020, p.222, https://www.gov.scot/binaries/content/documents/govscot/publications/corporate-report/2018/02/scottish-governments-climate-change-plan-third-report-proposals-policies-2018/documents/00532096-pdf/00532096-pdf/govscot%3Adocument/00532096.pdf

increasing support given for eco-driving schemes, or simply noting these additional benefits within communication materials encouraging the uptake of eco-driving techniques.

To improve tyre stewardship, including maintaining correct pressures, all new cars have been required to come fitted with Tyre Pressure Monitoring Systems (TPMS) since 2014. Despite this, as was noted in Section 4.2.2.1.1 these will not yet have penetrated the market fully such that many drivers are likely to remain unaware that they are running tyres that are underinflated[77]. There are ongoing efforts being made to reduce the number of tyre-related traffic incidents which result from poorly-maintained tyres such as campaigns coordinated by the industry-funded tyre safety charity, Tyre Safe[78].

Additionally, a range of companies have developed innovative technology targeting HGVs with underinflated tyres. WheelRight produces drive-over tyre pressure monitoring systems which uses ground-level sensors that transmit data directly to drivers via SMS or on-site touch-screen kiosk, or the maintenance staff of transport-operators at depots. Highways England and Welcome Break collaborated on a year-long trial of this system in Keele Services on the southbound M6 motorway in 2016 and are now conducting further trials with a number of commercial HGV fleet operators.

The use of telematics solutions by fleet operators whereby sensors equipped to tyres gather real-time information on tyre condition and driver behaviour and transmit it to displays for drivers, or to fleet operator facilities is also growing[79]. This has the benefit of alerting drivers and fleet managers as soon as tyre inflation, repair or replacement is needed, or the data gathered can inform predictive maintenance models. Systems have also been designed whereby a pump can be retrofitted to HGVs which tops up the tyre pressure while the vehicle is moving in the case of loss of pressure[80].

We have decided not to take forward for further analysis any measures directly related to improved tyre stewardship and driving behaviour. There is sufficient motivation to act on these issues provided by the fuel efficiency, and thus climate change mitigation and cost-reduction imperatives and the safety benefits that come with correctly maintained tyres and careful driving.

6 Appraisal of Selected Measures

The following measures are taken forward for further appraisal:

1. Trading standards enforcement for part-worn tyres;
2. Maximising opportunities for retreading of tyres;
3. Extended Producer Responsibility (EPR) scheme for tyres; and
4. Data and traceability.

These measures were shortlisted based on assessment against the following criteria;

- Their ability to contribute to objectives which could result in a more circular economy for tyres, including through;
    - Minimising environmental impact of production;
    - Stimulating the use of fewer tyres;
    - Extending tyre lifetime;
    - Maximising the use of part-worn tyres;
    - Maximising opportunities for retreading; and
    - Ensuring the application of the polluter pays principle;

[77] TyreSafe (2018) *The Law*, accessed 18 June 2020, https://www.partworn-tyres.co.uk/?qards_page=the-law

[78] TyreSafe (2018) *Tyre Safety Month 2019,* accessed 22 June 2020, https://www.tyresafe.org/campaigns/tyre-safety-month-2019/

[79] Fleet Europe (2019) *Connected transformation: from tyres to telematics to car sharing*, accessed 2 July 2020, https://www.fleeteurope.com/en/connected/europe/analysis/connected-transformation-tyres-telematics-car-sharing

[80] BPW Newsroom (2019) *AirSave: BPW automatically controls tyre and cost pressure*, accessed 14 July 2020, https://newsroom-en.bpw.de/pressreleases/airsave-bpw-automatically-controls-tyre-and-cost-pressure-2871284

- Whether there already exists sufficient motivation to implement a measure due to the other benefits it provides, for example in terms of improved driver safety or carbon emissions reduction, such that increasing tyre circular economy would be seen as a co-benefit of said measure; and
- The degree to which a measure is actionable in Scotland, with the absence of barriers related to either jurisdiction or feasibility based on currently available technologies.

In addition, an analysis was undertaken of an additional measure involving the taxation of new tyres which would need to be implemented at a UK level. Given the limited devolved powers on taxation, it is considered complimentary to the other policy measures taken forward for review. This analysis is presented in Section 6.2.

6.1 Description of Measures

6.1.1 Trading Standards Enforcement for Part-worn Tyres

In order to prevent waste in the tyre sector, actions which result in the use of fewer tyres and which extend the lifetime of tyres are necessary. Reuse of part-worn tyres is the first step in managing post-consumer tyres. As previously discussed, the primary barriers to tyre reuse are safety concerns and illegal part-worns. Trading standards offer a potential mechanism for addressing these challenges and to improve the use of part-worn tyres.

Trading standards enforce consumer protection legislation and safeguard legitimate businesses. The implementation of trading standards can take place through a number of organisations which provide support and representation to businesses or consumers, or which investigate criminal activities. Trading standard bodies also play a role in gathering data and intelligence on illegal trade. In the UK, local authorities have trading standards departments, whilst organisations such as the National Trading Standards and Chartered Trading Standards Institute (CTSI) operate at the national level. Local authorities have trading standards officers who respond to and investigate consumer complaints as well as conducting regular inspections of businesses.

In Scotland, the national body for trading standards is Trading Standards Scotland (TSS) which is jointly funded by BEIS and HM Treasury, and is managed by the Convention of Scottish Local Authorities (COSLA). TSS supports local authorities and works with a variety of stakeholders, including Police Scotland and Advice Direct Scotland. At present however, tyres are not a focus of TSS activities.

With regards to part-worn tyres, trading standards play a role because they seek to enforce fair trading, combat illegal trade and monitor product safety. Indeed, trading standards are a key tool through which the regulations on part-worn tyres could be better enforced. For instance, trading standard teams/organisations could run awareness raising campaigns regarding consumer rights relating to illegal part-worns and the legal safety standards which part-worns need to meet.

Moreover, trading standards activities could focus on dismantlers in particular. As highlighted in the Vehicle Tyres: Market Overiew[81] report, dismantlers as Authorised Treatment Facilities (ATF) play a significant role in sourcing part-worn tyres. The sector is regulated by SEPA, and thus could present an avenue through which trading standard officers would test compliance with tyre regulations before part-worns enter the market. This would help with the identification and reporting of illegal practices. Furthermore, the part-worn inspection process could take a lead from retread enforcement actions. Retreads undergo an inspection process during preparation in which potential tyres must meet certain quality requirements. The retread inspection process is subject to an annual audit by a third party, at a cost of about £1,000/yr[82]. As reported in the Vehicle Tyres: Market Overview[77] report, it is estimated that around 300,000 tyres are recovered for part-worn sale by ATFs. According to SEPA there are 133

[81] https://zerowastescotland.org.uk/sites/default/files/20200617DraftForPubStage1FINALREPORTPubFV1.0.pdf

[82] Personal correspondence with BTMA (July 2020).

licensed ATFs in Scotland[83]. The distribution of recovery of tyres across these dismantlers is not known, but if an even distribution is assumed, then an approximate additional cost per part-worn tyre due to auditing of inspection can be estimated at £0.44 based on a similar cost of auditing each site per year. For context, although a representative cost of a part-worn tyre is hard to gauge due to variation based on brand and type, costs between £10 and £25 are reported by some tyre retailers[84,85,86].

Partnerships between relevant stakeholders, such as between trading standards and product safety groups are an important component. Collaboration not only heightens capacity, but the information, data and intelligence sharing which it enables is key. Indeed, efforts could be government- or industry-led. For instance, between January and June 2018, London Trading Standards (LTS), a partnership between 33 local authority trading standards services in London, and the charity TyreSafe undertook a tyre safety project called Operation GRIP. The project involved officer visits to over 150 businesses offering guidance on how to legally store, mark and assess used tyres. Officers also covertly purchased part-worn tyres which were assessed by TyreSafe[87].

In Scotland, SEPA, Police Scotland, North Lanarkshire Council, South Lanarkshire Council, Renfrewshire Council and TyreSafe launched a campaign in 2019 to tackle the illegal sale of unsafe waste tyres as part-worns. The campaign involved site visits to tyre dealers across Renfrewshire and North and South Lanarkshire, checking for trading standards and licence breaches[88].

Ultimately, there is a role for Scotland to play, not only in providing or facilitating funding and additional resources for trading standards, but also fostering collaboration. With regards to funding, it is possible that part of a tax on tyres (see Section 6.2) could be hypothecated (ring-fenced) to fund such enforcement activity which is enhancing the safety of roads for all users.

Supporting harmonisation between local authorities both within Scotland and England will also be key to ensuring that enforcement does not create uneven cross-border flows of illegal tyres. Overall, the intended outcome of this measure is improved safety and consumer confidence in part-worns. If such actions were taken, it is likely that the part-worn market would contract due to the eradication of illegal tyres. Moreover, if tyres are close to their end-of-life, tighter enforcement of part-warn regulations could push more tyres towards retreading.

It is not possible, given the current lack of data, to estimate the likely effect of this measure on the circularity of tyres in Scotland. Indeed, as alluded to above, it may be that there is *too much* use of part-worns tyres at present, which may extend their lifetime but at the expense of safety. Therefore for a range of reasons, it is important that adequate enforcement is in place.

6.1.2 Maximising Opportunities for Retreading of Tyres

Retreading is another key means by which to extend the lifetime of tyres. In doing so, the environmental impacts of tyre production are also reduced. Overcoming the current challenges to retreading requires measures which stimulate the retread market. Components of this include economic incentives as well as improving the public perception of retreads. Green Public Procurement is a key policy option and is examined further in Section 6.1.2.1.

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[83] *End-of-life vehicles | Scottish Environment Protection Agency (SEPA)*, accessed 29 July 2020, https://www.sepa.org.uk/regulations/waste/end-of-life-vehicles/

[84] *Are Part-Worn Tyres False Economy? | Tyre Savings*, accessed 22 June 2020, https://www.tyresavings.com/part-worn-tyres-economy

[85] *The true cost of part worn tyres*, accessed 29 July 2020, https://www.kwik-fit.com/blog/the-true-cost-of-part-worn-tyres

[86] *What are part-worn tyres?*, accessed 29 July 2020, https://www.carbuyer.co.uk/go/156275

[87] Chartered Trading Standards Institute (CTSI) (2018) *74% of used tyres checked by Trading Standards failed to meet safety standards*, accessed 3 July 2020, https://www.tradingstandards.uk/news-policy/news-room/2018/74-of-used-tyres-checked-by-trading-standards-failed-to-meet-safety-standards

[88] Scottish Environment Protection Agency (SEPA) (2019) *Tyre safety campaign aims to drive out Scotland's illegal dealers*, accessed 3 July 2020, https://media.sepa.org.uk/media-releases/2019/tyre-safety-campaign-aims-to-drive-out-scotland-s-illegal-dealers.aspx

Other countries are exploring economic instruments. In Italy for instance, a tax credit of 20% on the purchase of retreaded tyres (businesses only) has been proposed[89]. In Finland, there is an economic incentive at the recycling stage; for retreaded passenger car tyres there is no recycling charge[90]. Similarly, an EPR scheme where, as described in Section 6.1.3, fees are only applied to new tyres would, at the margin, incentivise greater use of retreads. Taxation of new tyres, as discussed in Section 6.2 would also provide a further incentive for the use of retreads.

Lastly, greater provision of data and information is a key component of boosting uptake of retreads. Better access to information regarding the quality and standards of retreaded tyres for instance could help to improve consumer confidence. Data and traceability are addressed in Section 6.1.4.

6.1.2.1 Green Public Procurement

Public procurement is the process by which public authorities, including government departments, regional and local authorities, purchase works, goods or services from companies. Green public procurement (GPP) involves public authorities seeking to procure such works, goods and services with a reduced environmental impact throughout their life cycle. GPP encompasses circular public procurement, an approach which seeks to support the transition to a circular economy by contributing to closed energy and material loops within supply chains and minimising and avoiding negative environmental impacts and waste creation across supply chains[91].

GPP is highlighted as a key mechanism to promote circular economy principles both in EU and Scottish policy. In Europe, government expenditure on works, goods and services represent around 14% of EU GDP[92]. In Scotland, for the 2018/19 period, public expenditure was £75.3 billion, with transport making up around £3.8 billion, or 5% of total Scottish public expenditure[93]. Government authorities thus exert significant purchasing power and can represent a large share of the market for certain goods and services.

Moreover, GPP can drive innovation, provide industry incentives for developing green services / products and help develop markets. For government authorities, a GPP policy can demonstrate commitment to sustainability goals as well as present cost-savings.

Given these objectives, public procurement is an appropriate measure through which to foster circularity in the tyre sector. Public authorities purchase vehicles on a large scale, covering a variety of purposes, including: passenger cars used as official vehicles, delivery vans, emergency vehicles, waste collection vehicles and buses. A GPP policy for vehicles with firm emphasis on environmental procurement criteria for tyres could therefore have a relatively broad impact.

It is recommended that retreaded tyres are required under Scottish GPP. Given the current prevalence of retreads in the C3 market, it would be logical to set an initial target for retreaded tyres on waste collection vehicles for instance. When new tenders are initiated or current contracts are renewed, a requirement for government-owned or suppliers' vehicles to use retreaded tyres could be included in the procurement rules. In Italy for instance, the Financial Act of 2002 requires authorities to reserve a quota for the purchase of retreaded tyres equal to at least 20% of the total[94].

Two further points for subsequent consideration include:

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[89] Pneurama (2020) *The retreading sector looks ahead*, accessed 9 July 2020, https://www.pneurama.com/en/rivista_articolo.php/The-retreading-sector-looks-ahead-?ID=39500

[90] Finnish Tire Recycling (2020) *Recycling fees*, accessed 9 July 2020, https://www.rengaskierratys.com/ammattilaisille/kierratysmaksut

[91] European Commission (2017) *Public procurement circular economy brochure: Good practice and guidance*, accessed 8 July 2020, https://ec.europa.eu/environment/gpp/pdf/Public_procurement_circular_economy_brochure.pdf

[92] European Commission (2016) *Buying green! A handbook on green public procurement 3rd Edition*, accessed 8 July 2020, https://ec.europa.eu/environment/gpp/pdf/Buying-Green-Handbook-3rd-Edition.pdf

[93] Scottish Government (2019) *Government Expenditure and Revenue in Scotland (GERS): 2018 to 2019*, accessed 8 July 2020, https://www.gov.scot/publications/government-expenditure-revenue-scotland-gers/pages/5/

[94] Regione Autonoma Valle d'Aosta *Acquisti Pubblici Verdi*, accessed 9 July 2020, https://www.regione.vda.it/territorio/ambiente/rifiuti/Acquisti_Pubblici_Verdi/default_i.aspx

- Different vehicle types: requiring retreaded tyres would benefit from an understanding of the current scope of an authority's fleet, including across different departments and authority activities; and
- The procurement procedure: the process of procurement can be conducted in a number of different ways, including open or restricted procedures, where any or a limited number of operators can tender respectively, a competitive procedure with negotiation and dialogue, or an innovation partnership. Innovation partnerships were introduced by the suite of EU public procurement directives in 2014 and could be particularly relevant in relation to retreads[95]. Where a contracting authority seeks to purchase goods and services which are not currently available on the market, or are not sufficiently advanced to meet the needs of the authority, an innovation partnership can be established with multiple partners. This provides a framework for R&D and piloting of new products[96].

The aim of such a policy would be to directly boost the market for tyres which are retread or which contain recycled content. This also sends a positive signal to consumers and the private sector.

GPP could also be used to specify tyres that score well on existing environmental criteria within the Tyre Label such as rolling resistance and external noise. GPP could also be used to specify tyres that score well on tread wear abrasion rate, once a standard measurement technique is established.

The overall impact of maximising opportunities for retreading of tyres in the wider context of tyre circular economy is uncertain. The number of retreaded tyres PoM in Scotland has remained largely static for the years 2016 to 2018, at just under 65,000 units per year. However, the total demand for C3 tyres in Scotland in 2018 was around 225,000 units according to analysis carried out for the Vehicle Tyres: Market Overview report. This suggests that around only a third of C3 tyres are being retreaded. Industry sources however have reported that between 50% and 60% of C3 tyres are *suitable* for retreading at end of life[97]. As was outlined in detailed in section 4.2.2.3, retreadable tyres may not undergo retreading for a range of reasons, including:

- That tyres may not meet the specific mold of the retreader it happens to arrive at, which will relate to its size, quality, structure and load/speed rating[98];
- That end-of-life tyre collectors may not have the resource available to sort retreadable tyres out of the tyres they collect[99]; and
- Being outcompeted on price by what some stakeholders describe as 'low-end non-retreadable' tyres imported principally from Asia[100].

Theoretically, if demand could be stimulated and logistics optimised such that all of the 50% - 60% of end of life C3 tyres that are technically retreadable actually went to retread, then this would result in an additional roughly 2,400 – 3,500 tonnes of end of life C3 tyres being diverted towards remanufacturing. This would be equal to between 4% and 7% of total end of life tyre arisings.

6.1.3 Extended Producer Responsibility for Tyres

EPR is a policy approach which applies the polluter pays principle to a product. In an EPR scheme, producers have financial (and in some cases organisational) responsibility for the end-of-life management of post-consumer products.

EPR is an important tool for facilitating the circular economy. Indeed, it is a key element of the EU Circular Economy Package. Companies can be incentivised, through EPR, to implement circular

[95] European Commission (2016) *Innovation partnerships keep public services up to date*, accessed 16 July 2020, https://ec.europa.eu/growth/content/8699-innovation-partnerships-keep-public-services-date_en

[96] European Commission (2017) *Public procurement circular economy brochure: Good practice and guidance*, accessed 8 July 2020, https://ec.europa.eu/environment/gpp/pdf/Public_procurement_circular_economy_brochure.pdf

[97] Personal correspondence with BTMA (April 2020)

[98] Personal correspondence with confidential tyre retreader

[99] Personal correspondence with confidential tyre collector

[100] EY (2016) *The socio-economic impact of truck tyre retreading in Europe: The circular economy of tyres in danger*, accessed 8 July 2020, https://rechile.mma.gob.cl/wp-content/uploads/2019/06/3.-ARNEC3-201611-ey_retreading.pdf

business models which design out waste, increase reuse and recycling, and which also enhance waste collection and the capture of materials at a product's end-of-life.

Most countries in Europe have implemented EPR for tyres. Under EU requirements, several EPR schemes exist in the UK including for packaging, waste electrical and electronic equipment (WEEE), batteries and accumulators, and end-of-Life vehicles. This section sets out the core principles, benefits and challenges of an EPR scheme for tyres in Scotland and the UK more widely. The principles of EPR design outlined apply to a Scotland-only scheme, although the issue of cross-border flows in the Scottish context should be considered. With reference to other relevant European case studies, the main components which affect programme performance and cost are discussed, as well as potential issues and limitations.

6.1.3.1 Elements of EPR for Tyres

Governance Structure

There are a range of governance models for EPR schemes. EPR responsibilities can be discharged individually, or collectively via one or multiple Producer Responsibility Organisations (PROs). The majority of Member States in Europe have a single PRO for tyres, though there are examples of numerous operators such as in Italy where there are 37 PROs. Croatia and Hungary have a scheme for end-of-life management of tyres implemented and run by the national government.

An efficient approach for EPR is for a single industry-owned not-for-profit scheme to be set up, as this will have the inherent incentive to discharge its responsibilities as efficiently as possible, and thus seek to minimise the fees paid by producers. The role of the government is thus to set the rules, to determine who is a 'producer', what costs are to be covered, what collection rate is to be achieved, and the nature of the evidence that the PRO has to provide to demonstrate fulfilment of the objectives.

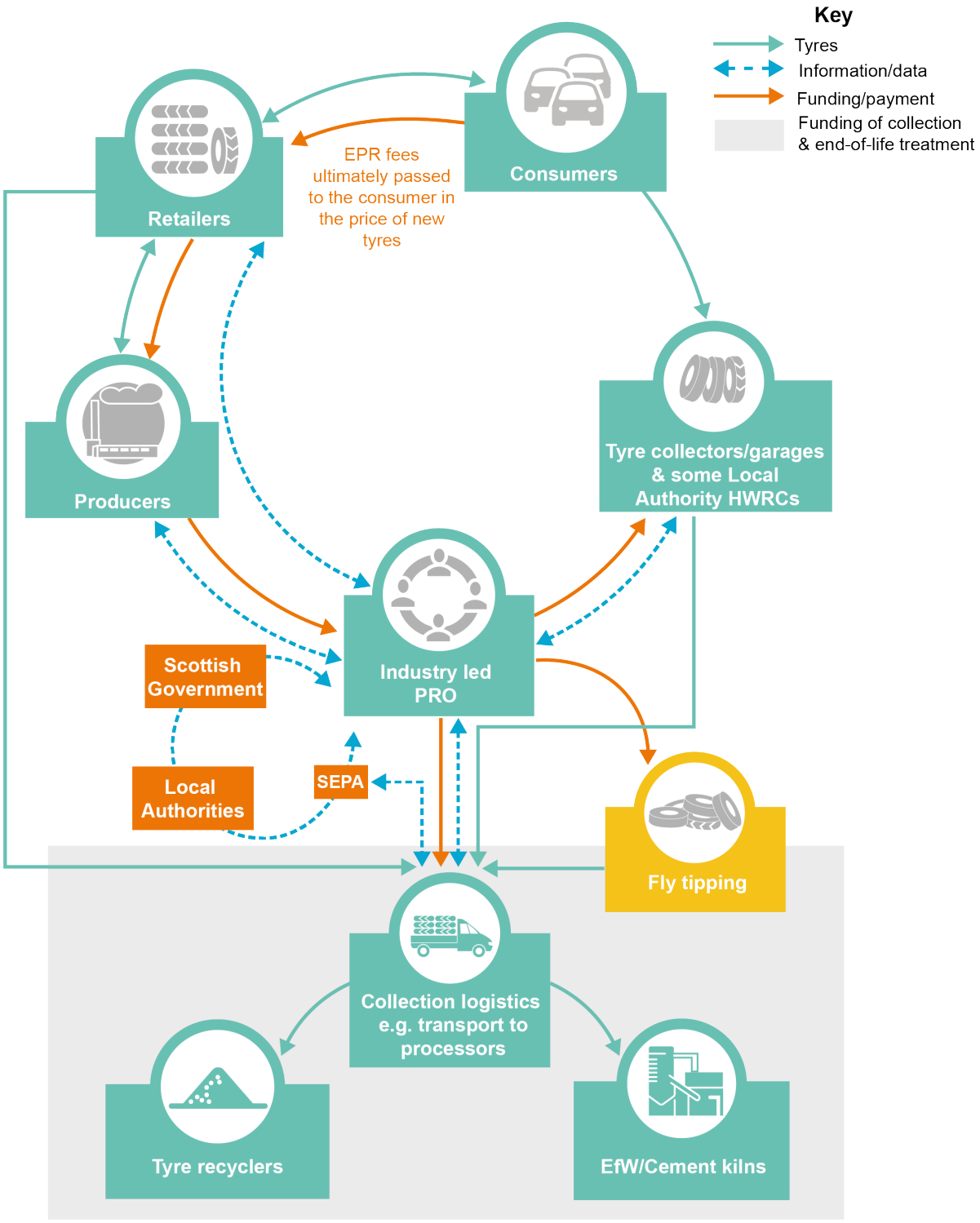
For Scotland specifically, a system with a single PRO is likely to be more appropriate than multiple competing PROs, especially given the number of relatively remote locations. A single PRO system is often more straightforward than multiple PRO schemes and is better placed to ensure efficient delivery of services and to reduce investment risk. It is also more straightforward in terms of the requirements for government oversight/audit.

With regards to organising the collection and treatment of end-of-life tyres, the degree of involvement by the PRO can vary. In Belgium and the Netherlands for instance, the PROs contract with private collectors who deliver tyres to predominantly private treatment facilities which are approved by the PROs. This ensures the quality of the recyclers, and other facility operators.

Lastly, the relationship between the EPR scheme and local authorities may vary. In some European countries, municipalities collect tyres on a voluntary basis, such as from civic amenity sites, as well as dealing with fly tipping. In the UK, not all household waste recycling centres (HWRCs) accept tyres; if they do, a charge may apply.

Figure 6-1 illustrates the key components and structure of a single industry led EPR scheme for tyres in Scotland.

Figure 6-1 Schematic Diagram of an EPR Scheme for Tyres in Scotland



Scope of the Scheme

The type of tyres covered by the EPR scheme needs consideration. For instance, the scheme could include only tyres from passenger vehicles (C1 tyres) or a greater range of tyre types (C1, 2 and 3). Additionally, tyre takeback could be on a one-to-one basis or unlimited. The Italian system for instance operates a one-for-one principle; collection points are required to accept a waste tyre in return for a

sold one. This means that historical stocks are included in the scheme. Alternatively, in Belgium under the Recytyre scheme, waste tyres must be accepted at collection even if no new tyres are purchased[101].

Fees, Financing and Cost Coverage

The fee structure and funding model determine how the scheme will raise funds for the end-of-life management of tyres and the administrative costs of the system. Obligated producers would pay fees to the PRO according to the type and quantity of tyres placed on the UK market, as well as a base membership / administrative fee.

The overall fees should provide for full coverage of end-of-life management costs. This could include the cost of cleaning up illegally dumped tyres. Under Italian legislation for example, at least 30% of a PRO's financial surplus must be dedicated to the removal of illegal or historical stocks[102].

There is potential for fees to be modulated (i.e. varied) according to certain environmental criteria, such as tread wear abrasion rate, although this particular example would depend on the successful development of the measurement approach. The intention of this would be to incentivise improved design of tyres, and to bring about a market shift towards those that perform better in respect of the criteria of relevance. It is not necessary to modulate fees at the outset of the scheme, but it is important to bear in mind the potential for modulation and how this might be used, in combination with other instruments, to bring about further moves towards circularity.

Across many European schemes producers choose to recover the waste management costs obliged under EPR schemes by incorporating them into the purchase price of the new product. Typically, this either takes the form of a fee which is visible to the consumer, such as on a receipt, or as an 'invisible charge', where the final price reflects the cost of the system but the exact amount is not specified. Crucially, the fee is only paid on new tyres, not reused or retreaded tyres. Clear guidance on the legal definition of when a tyre becomes waste is therefore important.

In Ireland for example, the establishment of the current EPR scheme for tyres operated by Repak ELT (RELT) was accompanied by an additional visible Environmental Management Cost (vEMC) for tyres. The vEMC is separately displayed on websites, invoices and receipts. RELT members pay collectors directly for other non vEMC category commercial tyres including truck / bus and agricultural / construction tyres[103].

The membership fee to producers is currently €70 including VAT per year, with a €2.80 fee (plus VAT) for each new passenger car tyre placed on the market. This tyre fee funds the whole scheme. RELT contracts with a number of collectors who are paid per tonne of waste tyres which they collect. The payment level is dependent upon the method of disposal. Payments are higher for tyres which are recycled in Ireland, compared to ones sent to Europe and other countries across the world. The aim of the payment structure is to encourage domestic industry investment and enables RELT oversight of the money trail between retailers and collectors.

The vEMC is collected by RELT from the tyre producer/importer, and appears as a line item on all invoicing from that point on. As RELT pays for waste tyre collection, the commercial link between the collector and the tyre retailer is broken. This further serves to discourage fly tipping[104].

Additionally, in Belgium the management of waste tyres is also paid through a visible fee which is calculated by Recytyre, the country's single PRO, and approved by the regional public authority. The

[101] Winternitz, K., Heggie, M., and Baird, J. (2019) Extended producer responsibility for waste tyres in the EU: Lessons learnt from three case studies – Belgium, Italy and the Netherlands, *Waste Management*, Vol.89, pp.386–396

[102] Winternitz, K., Heggie, M., and Baird, J. (2019) Extended producer responsibility for waste tyres in the EU: Lessons learnt from three case studies – Belgium, Italy and the Netherlands, *Waste Management*, Vol.89, pp.386–396

[103] Repak ELT (2020) *Annual Report 2019*, accessed 27 July 2020, https://repakelt.ie/wp-content/uploads/2020/06/RepakELT_AnnualReport2020-Final.pdf

[104] Personal correspondence with Repak ELT, July 2020.

fee covers the collection and treatment of tyres, waste tyre prevention programmes, public communications and administrative costs of the PRO.

In the Netherlands however, the waste management contribution fee is internalised. Between 2004 and 2017, the cost of this fee to importers and producers reduced from €2.00 per new tyre sold, to €1.30. The collectors are paid from the fee, at €1.05 in 2017. The difference between the recovery and collecting fee covers the administrative costs of the scheme and unexpected expenses. The fee is revised annually based on market analysis[105].

Scheme Performance

In order to ensure an efficient and effective EPR scheme, Scotland should set mandatory targets for producers. This should include at least a collection target of 100%, as is the case in Belgium and the Netherlands, but material recovery and energy recovery (treatment) targets could also be set. None of the examples referred to below have separate reuse and retread targets. If targets are not met, or reporting is inadequate, penalties can be issued, typically in the format of fines. According to scheme performance, targets should be reviewed over time.

In Ireland for instance, RELT report quarterly to the Irish Government and work closely with the Irish EPA, the central permit office and local authorities. At present, there are no national targets set by the government for quantities or recycling rate. RELT set their own targets and aim to collect and recover 100% of their members' waste tyres. The scheme does not incentivise the use of part-worns but RELT does favour the use of truck retreads as a vEMC is not collected twice on these tyres[106]. The management and accounting of tyre casings under the compliance scheme is currently under further discussion.

RELT also supports collectors to improve their environmental management and reporting, such as through guidance on controls, ISO standards and electronic reporting systems. RELT is also currently looking into the development of an app to connect retailers to contracted collectors[107].

With regards to performance, the Irish scheme reported 95% collection and 97% recycling rates in 2019. 67.8% of end-of-life tyres by tonnage were recycled outside the EU, with 26% recycled in Ireland. India was the predominant country outside the EU to which end-of-life tyres were sent. Less than 1% of such tyres went to kilns or were reused[108].

RecyBEM in the Netherlands is subject to a legal target for material recovery of 20% including reuse and retread, as well as a voluntary material and product reuse target of 90% by 2015[109]. In 2017, RecyBEM achieved a 100% collection rate, with only 5% of end-of-life tyres going to energy recovery and zero landfilling. Although, it should be noted that a large proportion of end-of-life tyres are exported for reuse and retreading, at around a third in 2017. The lack of monitoring on the final destination and treatment of these tyres means that environmentally safe treatment is not necessarily guaranteed[110].

Belgium's Recytyre reported a 97.45% material recovery rate in 2019, with just over 2% energy recovery[111]. The scheme has exceeded the previous treatment targets (which expired in 2015) of a

[105] Campbell-Johnston, K., Calisto Friant, M., Thapa, K., Lakerveld, D., and Vermeulen, W.J.V. (2020) How circular is your tyre: Experiences with extended producer responsibility from a circular economy perspective, *Journal of Cleaner Production*, Vol.270, p.122042

[106] Personal correspondence with Repak ELT, July 2020.

[107] Personal correspondence with Repak ELT, July 2020.

[108] Repak ELT (2020) *Annual Report 2019*, accessed 27 July 2020, https://repakelt.ie/wp-content/uploads/2020/06/RepakELT_AnnualReport2020-Final.pdf

[109] Campbell-Johnston, K., Calisto Friant, M., Thapa, K., Lakerveld, D., and Vermeulen, W.J.V. (2020) How circular is your tyre: Experiences with extended producer responsibility from a circular economy perspective, *Journal of Cleaner Production*, Vol.270, p.122042

[110] Campbell-Johnston, K., Calisto Friant, M., Thapa, K., Lakerveld, D., and Vermeulen, W.J.V. (2020) How circular is your tyre: Experiences with extended producer responsibility from a circular economy perspective, *Journal of Cleaner Production*, Vol.270, p.122042

[111] Recytyre (2019) *Annual report Recytyre 2019*, accessed 10 May 2022, https://indd.adobe.com/view/5ccbab35-0719-421b-8e76-e4c27005ea5e

minimum of 55% material recovery including reuse and retread, and maximum 45% energy recovery[112]. Finally, the success of the Italian EPR system, which achieves a high level of local reuse and retread, has in part been attributed to legislation which clearly defines when a tyre becomes waste. Tyres become waste after they have been deemed non-reusable by garages. This helps create an economic incentive for garages to sort and sell reusable tyres[113]. Although, of the EU Member States with tyre EPR schemes, Italy sent the second highest number of tyres in tonnes to energy recovery in 2017[114].

Limitations and Challenges

It is important to acknowledge that EPR schemes are currently primarily designed to ensure that the polluter pays principle is put into practice regarding end-of-life management. While there are increasing efforts to utilise EPR schemes to influence product design, a core principle relates to covering end-of-life costs. This means that the fees to cover 'necessary costs', as per the European Union Waste Framework Directive, are limited overall to those that are required to cover the costs of the scheme (which should be efficiently run). Thus, while EPR fees should be charged on new tyres, but not on retreaded tyres, this alone may not be enough of a financial incentive to bring about a significant shift towards retreads. A tax however, as described in Section 6.2, could provide a further, and potentially more significant, financial incentive for the use of retreads.

The quality and capacity of the existing waste management infrastructure for tyres is also important to note. At present, the tyre recycling and retread capacity in the UK is limited, as is the market for retread tyres (albeit we envisage this could be stimulated through Green Public Procurement). Collection operations could also pose a challenge. In the current system, collectors form individual contracts with collection points, mainly garages, giving collectors control over the price. In a competitive market however, this can result in collectors charging low prices and collecting tyres at prices which hamper their ability to finance the correct waste management[115].

In an EPR scheme, collectors have less influence during negotiations over collection as the PRO manages collection contracts. Whilst this brings benefits in terms of material ownership and waste management, EPR schemes can face backlash from collectors. Indeed, in Belgium, the development of the EPR system was contested by waste collection companies who felt that their profit margins were undermined by Recytyre's pricing policy. Recytyre had previously tendered collection, yet decisions were frequently challenged by collectors in court. Even with an independent consultancy calculating the cost for collection, the collectors are dissatisfied.

There is also the challenge of historic stocks of tyres. Tyres which have been placed on the market prior to the establishment of an EPR scheme, or which have been stockpiled prior to the scheme, will not have been subject to producer responsibility fees but will still enter the waste management system. In Italy, this is addressed through the requirement that PROs dedicate resources to the removal of illegal or historical stocks. However, in the Italian system, collection takes place on a 1-for-1 basis, meaning collection points only have to accept a waste tyre in return for a sold tyre and the collection of tyres from historical stocks contributes to the collection target. This means the effective collection rate for all other tyres is lowered.

Finally, as in all EPR schemes regardless of product, free riders pose an issue. Free riding typically takes the form of companies selling goods into a country where they are not contributing to either take-back for separate collection, or funding the subsequent collection and treatment. The free rider experiences the benefits without accruing the costs. In this context, free riders are those who place

[112] Winternitz, K., Heggie, M., and Baird, J. (2019) Extended producer responsibility for waste tyres in the EU: Lessons learnt from three case studies – Belgium, Italy and the Netherlands, *Waste Management*, Vol.89, pp.386–396

[113] Winternitz, K., Heggie, M., and Baird, J. (2019) Extended producer responsibility for waste tyres in the EU: Lessons learnt from three case studies – Belgium, Italy and the Netherlands, *Waste Management*, Vol.89, pp.386–396

[114] ETRMA (2019) *End of Life Tyres Management - Europe -2017 Status*, accessed 27 July 2020, https://www.etrma.org/wp-content/uploads/2019/11/ELT-Management-Figures-2017-vf.xlsx.pdf

[115] Personal correspondence with Repak ELT, July 2020.

tyres onto the UK market but do not report data or take responsibility for the costs of collecting or treating end-of-life tyres. This is a problem because it often means that the amounts of tyres placed on the market are underestimated and there is a risk of reporting substantially inaccurate values.

The issue of free riding can occur in a number of ways:

- Online Sales: In a 2018 study by the OECD, multi-seller online platforms are a major contributor to free riding[116]. Indeed, the study estimated that online free-riding accounts for 5% to 10% of all EEE sales for instance;
- Wrong or mis-reported data: Intentional and unintentional under-reporting of tyres PoM by producers reduces the accuracy of data. Producers may under-report in order to minimise the fees they are required to pay under EPR schemes; and
- Cross border sales: Cross border sales and purchases can also facilitate free riders. What is placed on the market in one country does not necessarily become waste there. Where the flow of a product between countries is significantly imbalanced, this may lead to inaccurate PoM and increase in the risk of free riders.

The issue of free riding can be addressed chiefly through effective enforcement and penalties for mis-reporting. Market surveillance is important in order to identify all obligated producers, as is data and information sharing between the relevant authorities.

RELT in Ireland for instance, uses a unique ID system in order to enhance market visibility. Every producer and retailer is assigned a unique ID when joining the scheme. Members report monthly on who they bought tyres from, who they sold them to and how many waste tyres were generated. Collectors are also subject to yearly financial audits and compliance, and Repak authorise treatment sites, including in India, where a significant proportion of end-of-life tyres are shipped. Collectors can also report 'non-scheme' tyres - those which they have been paid to collect by the retailer.

RELT validates the data, such as through cross-check processes and requiring documentation like gate fees and shipping documents. They also maintain a list of organisations active in the Irish tyre market who are not members of the EPR scheme. The unique ID and data system have been key to the success of the scheme, enabling RELT to investigate anomalies and identify reporting issues[117]. Other steps to combat malpractice include random site visits with local authorities.

In terms of an overall effect, the EPR scheme can be the means by which the enhanced data and traceability requirements, as described in Section 6.1.4 can be met, as well as ensuring that the polluter pays principle is applied. Enhanced data should mean a considerable improvement in understanding of flows of tyres, and thus the ability to better manage these tyres at end of life, including preventing / detecting flytipping. The EPR fees themselves, and the fact that they should be incurred only on the first occasion that the tyre is PoM, should provide an incentive for use of part-worns and retreading.

6.1.4 Data and Traceability through Product Passports

As explained earlier, *'Product Passports'* are unique and trustworthy logs of key information about products, which typically include a record of components and materials that a product contains, and how they can be disassembled and recycled at the end of the product's useful life[118,119]. The ability to track individual tyres through their use and end-of-life life cycle phases, with a database of key information available to all relevant organisations, would contribute to addressing a number of issues:

116 OECD (2018) Extended Producer Responsibility and the Impact of Online Sales, accessed 1 July 2020, https://www.oecd.org/environment/waste/policy-highlights-extended-producer-responsibility-and-the-impact-of-online-sales.pdf

117 Personal correspondence with Repak ELT, July 2020.

118 *The Product Passport: A Practical and Scalable Standard - Consumption of Products & Services 2014*, accessed 18 August 2020, https://www.climatecolab.org/contests/2014/consumption-of-products--services/c/proposal/1306601

119 *European Resource Efficiency Platform pushes for'product passports' - Eco-innovation Action Plan - European Commission*, accessed 24 August 2017, https://ec.europa.eu/environment/ecoap/about-eco-innovation/policies-matters/eu/20130708_european-resource-efficiency-platform-pushes-for-product-passports_en

- The collation of collection and treatment data by the TRA for reporting to government is challenging[120];
- Retreaders can't be sure of the number of retreads a tyre has undergone when they receive it, and have no oversight of its prior use or service history which might influence decisions both as to whether it should be retreaded;
- Those assessing used tyres against the requirements of the relevant regulation for potential part-worn use have no oversight of the use and service history of a tyre which might influence their judgement; and
- Law-enforcement authorities are unable to trace waste tyres in the environment to whoever might have fly tipped them.

Full tracking of individual tyres could result in:

- Reduced cost of retreading if the process can be made more efficient;
- Greater consumer confidence in part-worn tyres;
- Greater safety-assurance for part-worn tyres; and
- Greater disincentives for fly-tipping through improved enforcement.

At present, it appears that the most promising technology for facilitating such data capture is the use of RFID tags and readers. Tags are fitted to tyres giving them an item-level unique digital identity, and digital readers connected to sensors or other data capture devices can then be used to transfer information attributed to the specific tyre to a central Cloud database. Through the GovTech Catalyst Project[121], UK Research and Innovation awarded funding to a consortium of organisations who collaborated with the Tyre Recovery Association to trial this technology in the UK. At present, the design of the system is such that tyres are fitted with RFID tags in the form of stickers applied to the outside of the tyre at the point of collection from tyre retailers (See Figure 6-2)[122].

[120] Hanlon, A. (2019) *Use case. Item-level digital monitoring for waste management*, accessed 8 July 2020, https://www.pragmatic.tech/newsroom/blog/use-case-item-level-digital-monitoring-for-waste-management

[121] Government Digital Services (2018) *GovTech Catalyst*, accessed 8 July 2020, https://www.gov.uk/government/collections/govtech-catalyst-information

[122] Tyre Recovery Association (2019) *TRA announces successful trial to introduce digital traceability into the tyre waste stream*, accessed 8 July 2020, https://tyrerecovery.org.uk/2019/06/18/tra-announces-successful-trial-to-introduce-digital-traceability-into-the-tyre-waste-stream/

Figure 6-2 RFID tags fitted to tyres as part of a UKRI-funded waste tyre tracking project[123]

The TRA has reported that initial trials of the technology show promise in improving the visibility of the entire collection chain including the number of tyres collected by each operator, and their intended and actual fate[124].

Although use of RFIDs has only recently been explored for improving end of life management of tyres, tyre manufacturers have been embedding RFID tags at the point of manufacture for the sake of stock management for some time[125,126] and there is now a growing interest in the data that could subsequently be collected throughout the tyres' life cycle including during use[127]. The basic idea is that an RFID reader is used to log the unique ID while other sensors capture important information that is attributed to the unique tyre and forwarded to a cloud-based server. Tyre manufacturers, cloud computing companies and business communications standards companies are exploring the potential to record a variety of data including:

- The current condition of the tyre including pressure, tread depth and temperature[128]; and
- Service and performance history, including the mileage the tyre has covered and how many times it has been repaired, retreaded or regrooved[129].

[123] Hanlon, A. (2019) *Use case. Item-level digital monitoring for waste management*, accessed 8 July 2020, https://www.pragmatic.tech/newsroom/blog/use-case-item-level-digital-monitoring-for-waste-management
[124] Tyre Recovery Association (2019) *TRA announces successful trial to introduce digital traceability into the tyre waste stream*, accessed 8 July 2020, https://tyrerecovery.org.uk/2019/06/18/tra-announces-successful-trial-to-introduce-digital-traceability-into-the-tyre-waste-stream/
[125] SMMT (2018) *How RFID technology is smartening up CV tyres*, accessed 13 July 2020, https://www.smmt.co.uk/2018/05/feature-how-rfid-technology-is-smartening-up-cv-tyres/
[126] Swedberg, C. (2011) *Continental Tire Uses RFID to Keep Production Rolling*, RFID Journal, accessed 13 July 2020, https://www.rfidjournal.com/continental-tire-uses-rfid-to-keep-production-rolling
[127] Tangemann, C. (2019) *Radio Frequency Identification (RFID) is coming to a tire near you*, accessed 13 July 2020, https://www.automotive-iq.com/chassis-systems/articles/radio-frequency-identification-rfid-is-coming-to-a-tire-near-you
[128] SMMT (2018) *How RFID technology is smartening up CV tyres*, accessed 13 July 2020, https://www.smmt.co.uk/2018/05/feature-how-rfid-technology-is-smartening-up-cv-tyres/
[129] Ledger Insights (2019) *SAP, GS1 explore blockchain for tire retreads*, accessed 8 July 2020, https://www.ledgerinsights.com/sap-gs1-blockchain-tire-retreads/

The publication of ISO standards for the attachment, coding and use of RFID tags on tyres, between August 2019 and April 2020[130,131,132] should facilitate unique identifiers being readable by all stakeholders and increase the scope for use of this technology across the industry[133].

A further innovation being explored is the use of Blockchain alongside RFID tagging and data capture. Blockchain is a distributed ledger whereby records (also known as "Blocks") are stored in multiple locations, time-stamped and linked to other records in such a way that they cannot be altered[134]. This removes any potential for information stored about a tyre to be manipulated by anyone in the chain[135]. The business communications standards organisation, GS1, has partnered with SAP, a software company to develop a Blockchain prototype for tracking the mileage and service history of C3 tyres to help resolve disputes over warranties for tyre servicing and retreading[136]. It is possible to envisage similar technology being used in future to help with quality assurance of part-worn tyres, whereby those assessing used tyres could access a database detailing the use and service history of a tyre to inform a judgement as to its suitability for reuse. Additionally, the enhanced potential for tracing transaction of tyres which this technology would provide might also help law-enforcement in addressing the fly tipping of tyres if information such as the site of the last service, or the registration of the vehicle the tyre was removed from, could be captured.

Another obvious use of RFID tagging and data capture would be in demonstrating compliance with a potential future EPR Scheme. Participants in an EPR scheme have an incentive to keep the costs of the system as low as possible, and so there is an incentive to find the most efficient way of self-monitoring. Given that the use of RFIDs tagging and data capture is already growing in the tyre industry, a system based on this technology might be adopted. This form of unique identification and record keeping could also help in terms of preventing free-riding under EPR. As was mentioned in Section 6.1.3.1, free riding typically takes the form of companies selling goods into a country where they are not contributing to either take-back for separate collection, or funding the subsequent collection and treatment. The free rider experiences the benefits without accruing the costs. In this context, free riders are those who place tyres onto the UK market but do not report data or take responsibility for the costs of collecting or treating end-of-life tyres. An RFID tagging requirement, and tamper-proof storage of records of fee payment via Blockchain, would ensure that those that have not paid their fees would be identified.

Overall, it appears that the industry is proactively developing product passports in the form of universally-readable systems of RFID tagging and data capture due to the potential benefits it provides across stock management in manufacturing, resolving disputes over warranties, retread optimisation and real-time monitoring of tyre and vehicle performance for fleet management. Scotland could require the use of RFIDs tagging and Blockchain within an EPR scheme, to facilitate automated, transparent, tamper-proof record keeping.

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130 ISO (2019) *ISO 20909:2019 - Radio frequency identification (RFID) tyre tags*, accessed 13 July 2020, https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/94/69435.html

131 ISO (2020) *ISO 20911:2020 - Radio frequency identification (RFID) tyre tags — Tyre attachment classification*, accessed 13 July 2020, https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/94/69437.html

132 ISO (2019) *ISO 20910:2019(en) Coding for radio frequency identification (RFID) tyre tags*, accessed 8 July 2020, https://www.iso.org/obp/ui/#iso:std:iso:20910:ed-1:v1:en

133 Tangemann, C. (2019) *Radio Frequency Identification (RFID) is coming to a tire near you*, accessed 13 July 2020, https://www.automotive-iq.com/chassis-systems/articles/radio-frequency-identification-rfid-is-coming-to-a-tire-near-you

134 Raleigh P. (2019) *Technology Q&A: Understanding blockchain in the tire industry*, European Rubber Journal, accessed 8 July 2020, https://www.european-rubber-journal.com/news/technology-qa-understanding-blockchain-tire-industry

135 Ledger Insights (2019) *SAP, GS1 explore blockchain for tire retreads*, accessed 8 July 2020, https://www.ledgerinsights.com/sap-gs1-blockchain-tire-retreads/

136 Rohr, J. (2019) *Keeping Highways Safe with RFID and Blockchain*, SAP News Center, accessed 8 July 2020, https://news.sap.com/2019/10/sap-gs1-blockchain-rfid-safe-highways/

6.2 Complimentary Taxation Measure at UK Level

As mentioned in Section 6, a complimentary measure to the policy measures appraised above, would be taxation of new tyres, implemented at UK level given the limited devolved powers. The benefits and structure of a potential tax are discussed below.

Taxation can be used to internalise some of the externalities (the uncompensated costs imposed on others) associated with the use of tyres, and at the same time seek to change behaviour. Two relevant issues that could justify the imposition of a tax are the noise generated by tyres, and generation of particles from tyre wear, including the fine fraction which contribute to air pollution. The tax would therefore seek to internalise some of these external costs, while concurrently providing an incentive (through making new tyres more expensive) to opt for part-worns and/or retreads.

The effect would depend on the magnitude of the tax relative to the price of new tyres. It is not possible, at this point, to estimate the scale of the shift that would occur for a tax of a given size – in large part because the supporting infrastructure for wide-scale uptake of retreads, and consumer confidence in retreads are currently lacking. However, an initial indication may be obtained from observing the effects of EPR fees on the level of retreading.

6.2.1 External Rolling Noise

Environmental noise is defined as “unwanted or harmful outdoor sound created by human activities, including noise from road, rail, airports and from industrial sites”[137]. Environmental noise caused by road traffic increases the risks of cardiovascular disease, sleep disturbance, hearing impairment, poor mental health and overall quality of life[138]. According to a World Health Organization (WHO) report, environmental noise is the second largest environmental health risk in Western Europe[139]. To avoid these adverse impacts the WHO recommends reducing the average noise produced by road traffic to below 53dB and to below 45dB during night time[140]. Tyre-road interaction is the main cause of noise from road traffic above 20-50 km/h (12-25 mph) for cars and 30-60 km/h (19-37 mph) for lorries. In both urban areas and on roads with high speed limits reducing noise pollution depends on reducing rolling noise[141].

Tools have been developed for the UK Government, for use in project and policy appraisal, which convert changes in noise exposure to estimated monetary impacts relating to the effects of environmental noise. The central estimated values for road noise range from around £11 per household for a one-decibel increase in day-time noise from 45 to 46 decibels, to £118 for an increase of one decibel from 80 to 81 decibels. The cost of one-decibel increase from 45 to 46 decibels is valued at around £29 and an increase from 80 to 81 decibels is create disamenity valued at around £87[142,143].

A graphical presentation of the total road noise marginal values (excluding sleep disturbance) from Table 7-1 is shown in Figure 6-3. Decibels are a logarithmic unit of measurement. On the decibel scale the smallest audible sound (near silence) is 0 dB. A sound ten times more powerful is 10 dB. A sound 100 times more powerful than near total silence is 20 dB.[144] It can therefore be readily understood why a marginal reduction from 70 dB (the equivalent of a passenger car travelling at 60

[137] Environmental Noise Directive (2002/49/EC)

[138] World Health Organisation (2018) Environmental Noise Guidelines for the European Region, available here: https://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf

[139] World Health Organisation Regional Office for Europe (2011) Burden of Disease from Environmental Noise: Quantification of Healthy Life Years Lost in Europe, available at http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf

[140] World Health Organisation (2018) Environmental Noise Guidelines for the European Region, available here: https://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf

[141] European Conference of Ministers of Transport, and OECD/ECMT Transport Research Centre (2006) Speed Management, available at: https://www.itf-oecd.org/sites/default/files/docs/06speed.pdf

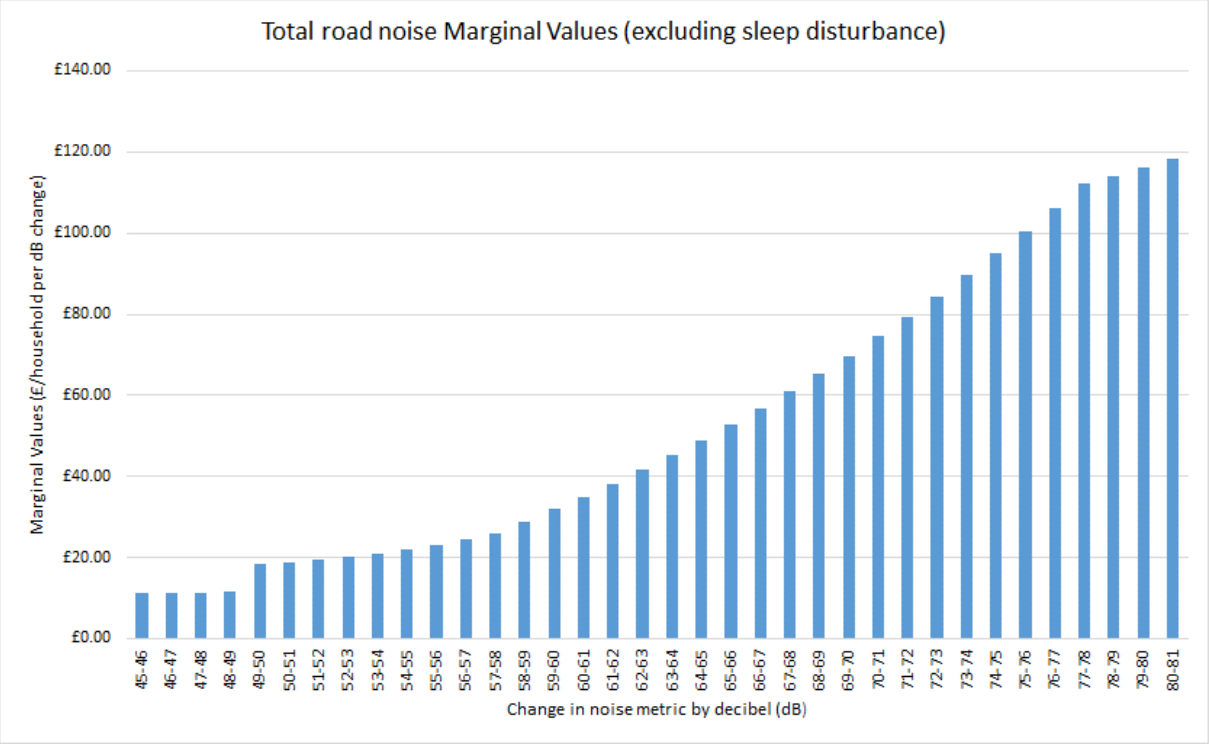
[142] *Noise pollution: economic analysis*, accessed 29 July 2020, https://www.gov.uk/guidance/noise-pollution-economic-analysis

[143] A detailed breakdown of marginal costs of noise pollution is presented in Appendix 1.

[144] Defra Glossary of Noise Terms, available at http://services.defra.gov.uk/wps/portal/noise/help

km/h at 7m distance) to 69 dB is valued more highly than a reduction from 60 dB (akin to an office environment) to 59 dB.

Figure 6-3: Total road noise marginal values (excluding sleep disturbance), £ per household per dB change, Central Values in 2014 prices



Rolling noise levels for tyres are determined in accordance with Regulation (EC) No 661/2009[145]. Part C of Annex II of Regulation 661/2009 outlines the limit values in dB(A) for Class C1 tyres (with limit values varying by width of the tyre), and Class C2 and C3 tyres (with limit values varying by whether the tyres are normal tyres or traction tyres).

The performance of an individual tyre will be noted on the Tyre Label as required under Regulation (EU) 2020/740[146]. Accordingly, it would be possible to introduce differential taxation based on the external rolling noise performance of the tyre. Further analysis would need to be undertaken to determine an appropriate level for such a tax if it were to seek to internalise costs. However, a tax need not simply be set on the basis of measured externalities, but also to bring about changes in behaviour – in this case a switch towards tyres that generate less external noise.

6.2.2 Particulate Emissions to Air

Another externality associated with the use of tyres is the generation of tyre wear particles. Research into such emissions have until recently focused on their contribution to microplastics pollution of water bodies, but there is increasing concern about the fraction that is airborne. In a recent study for SEPA, Eunomia noted that the most recent and thorough literature review suggests that around 6.1 mg of

[145] REGULATION (EC) No 661/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0661&from=EN

[146] REGULATION (EU) 2020/740 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on the labelling of tyres with respect to fuel efficiency and other parameters, amending Regulation (EU) 2017/1369 and repealing Regulation (EC) No 1222/2009

PM_{10} is emitted from tyre wear per kilometre driven in a car (with four wheels)[147]. This would mean that an individual tyre emits 1.5mg/km (on average). Assuming a tyre lifetime of 32,000 km (20,000 miles) that would mean a total of 48g of PM_{10} emitted over the tyre's lifetime. Of that PM_{10}, a fraction will be emitted as $PM_{2.5}$. Based on a 2019 review for Scottish Government (and others) we assume this to be 70%[148]. This would mean emissions of 34 grams of $PM_{2.5}$ and 14 grams of PM_{10} over the tyre's lifetime.

Using these estimates of emissions, it's possible to give an indication of the magnitude of a tax that could be justified based on air quality damage costs.

Defra's guidance on air quality damage costs uses a central value for $PM_{2.5}$ generated by road transport of £203,331 per tonne (in 2018 values), which is £0.203 per gram[149]. With each tyre generating 34 grams over its lifetime that would equate to £6.83 per tyre.

Defra's guidance uses a conversion factor of 0.673 to convert damage costs for $PM_{2.5}$ generated by road transport to damage costs for PM_{10} generated by road transport. This equates to £136,842 per tonne of PM_{10} generated by road transport, which is £0.14 per gram. With each tyre generating 14 grams of PM_{10} particulates greater than $PM_{2.5}$ in size over its lifetime that would equate to £1.97 per tyre.

This would give a total damage cost of £8.80 per tyre. While the actual damage cost would vary based on where the tyre was used – the central values for $PM_{2.5}$ from road transport range from £69,745 per tonne for rural locations up to £1,132,776 for Inner London – any such tax would have to be set at a uniform level. The exception to this would be if a reliable method of measuring the PM_{10} and $PM_{2.5}$ fraction generated by different tyres could be established. The tax could therefore vary to reflect the relative impact on air quality per km driven.

6.2.3 Other Microplastic Emissions

Eunomia's study for SEPA estimated that total emissions of microplastics from the wear of automotive tyres in Scotland are approximately 6,700 tonnes per year (of which circa 400 tonnes are emitted as PM_{10} or $PM_{2.5}$). In addition, the study estimated that emissions between around 450 and 1,800 tonnes of microplastics are generated from artificial football turf infill material typically made from rubber crumb from recycled tyres. It should be noted that in June 2020, the Committee for Risk Assessment of the European Chemical Agency (ECHA) recommended a restriction on the use of intentionally added microplastics, including a complete ban after a six-year transition period of the use of microplastics as infill material on artificial turf pitches including those produced from recycled tyres, due to incomplete information on the effectiveness of risk management measures[150]. The Tyre Recovery Association has expressed alarm at the decision, claiming that it would set back recycling efforts and result in a default to incineration as one of few available disposal options for post-consumer tyres[151].

Whilst research in the field of microplastics has been developing rapidly over the past few years, there are still significant gaps to fill before it is possible to have a robust understanding of the risks posed by microplastics to the Scottish environment[152]. It is thus not possible to estimate a 'damage cost' for microplastics from tyres beyond those that emitted as PM_{10} or $PM_{2.5}$.

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[147] Eunomia (2019) Understanding Microplastics in the Scottish Environment: The sources, fate and environmental impact of microplastics in the Scottish terrestrial, freshwater and marine environment, Report to the Scottish Environment Protection Agency (SEPA), November 2019

[148] Air Quality Expert Group (2019) Non-Exhaust Emissions from Road Traffic, prepared for Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of the Environment in Northern Ireland

[149] Defra (2019) Air Quality Damage Cost Guidance, January 2019

[150] *RAC backs restricting intentional uses of microplastics - All news - ECHA*, accessed 29 July 2020, https://echa.europa.eu/-/rac-backs-restricting-intentional-uses-of-microplastics

[151] *TRA alarmed at proposed Europe-wide ban on rubber infill – Tyre Recovery*

[152] Eunomia (2019) Understanding Microplastics in the Scottish Environment: The sources, fate and environmental impact of microplastics in the Scottish terrestrial, freshwater and marine environment, Report to the Scottish Environment Protection Agency (SEPA), November 2019

However, as explained in our 2018 study for DG Environment, as an emerging issue, the more we learn, the greater the apparent cause for concern about the damage that is being done to the terrestrial, freshwater and marine environments from microplastics. Accordingly, a strong argument can be made that the precautionary principle should be applied. We may not fully understand the impacts of microplastics in the terrestrial, freshwater or marine environment, but we know the impacts are negative, and expect that furthering our understanding will highlight new and potentially more severe impacts. This strongly suggests that we should do all that can reasonably be done, within bounds of acceptable cost, to address the problem[153].

As well as measures to reduce tyre wear at source, there are opportunities to capture tyre wear, for example through intercepting road run-off. Eunomia's report to SEPA suggested that the agency consider implementing a programme of trial and efficacy monitoring for a range of conventional drainage and SuDS techniques to help close the knowledge gap regarding what best practice for road drainage management would look like, with regards to microplastics emissions from tyres. The costs of covering such a programme could potentially, and with some justification, be funded through revenue raised by a tax on vehicle tyres.

6.3 Concluding Recommendations on Prioritisation, Sequencing and Interactions between Measures

No-one measure on its own will address all the issues currently impeding greater circularity for tyres in Scotland. However, the measures considered in Section 6.1 have, in combination, the potential to bring about a circular economy for tyres in Scotland where:

- Fewer tyres are used;
- Those that are used have an extended lifetime;
- Key externalities associated from tyre use are better reflected in the price paid by consumers;
- End of life costs are covered by producers/consumers; and
- Better data and traceability provide improved transparency over the management of tyres during their useful life and at end-of-life.

The objectives that each measure contributes to meeting are summarised in Table 6-1.

Table 6-1: Shortlisted and complementary measures and the objectives they contribute to meeting

Measures \ Objectives	Using fewer tyres	Extending tyre lifetime	Maximising use of part-worn	Maximising opportunities for retreading	Ensure application of the polluter pays principle
Trading standards enforcement for part-worn tyres	✓	✓	✓		
Green Public Procurement	✓		✓	✓	
EPR		✓	✓	✓	✓
Data and traceability	✓	✓	✓	✓	✓
Taxation	✓		✓	✓	✓

[153] Eunomia (2018) Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products, Report to DG Environment of the European Commission, February 2018.

In addition to improved environmental outcomes, co-benefits can arise. Indeed, in the case of **trading standards enforcement for part-worn tyres**, there is a compelling safety argument for undertaking such enforcement, regardless of the beneficial 'side-effect' of increasing consumer confidence in part-worns.

To incentivise retreading, **green public procurement** is a powerful tool available to Scotland. In the short term, Scotland can require that local authorities specify retreaded tyres in waste collection contracts. Similar requirements can be introduced for other such C3 tyres and subsequently for all other fleet vehicles (C2 and C1). This will serve to demonstrate that retreading is a 'normal' and desirable activity, and help to build up capacity, skills and expertise in the provision of such services in Scotland.

Beyond where Scotland has direct control over tyre choices, price signals can be used to further incentivise use of part-worns and retreading. While new tyres might be seen as financially attractive relative to retreading, it is important to note that the price paid by consumers for tyres at the point of purchase does not (as yet) reflect the full end-of-life costs of managing that tyre. **Implementing an EPR scheme, where the EPR fee is only paid the first time a tyre is placed on the market**, will provide a financial incentive for retreading (and indeed the use of part-worns) as the purchaser of a retreaded tyre (or a part-worn tyre) will not pay an EPR fee.

However, the magnitude of the EPR fee is limited in that it should only cover the necessary costs of managing tyres at end of life, as well as other standard costs such as PRO function, communications, monitoring and data collection. The wider the scope of end-of-life costs included in the EPR fee, for instance, fly-tipped tyres and tackling historic accumulations/illegal storage, the greater the magnitude of the fee and the associated incentive to opt for retreading. However, it may be that a financial incentive greater than that provided by the EPR fee alone would be required to bring about a meaningful shift. Such an incentive could be provided through a complimentary tax on new tyres.

A **tax on new tyres** would be a means of internalising some of the externalities associated with use of tyres, such as impacts on air quality, noise, and wider - but as yet incompletely understood impacts – such as tyre derived microplastics that end up in soil, rivers and the marine environment. Such a tax, in increasing the upfront cost to consumers of purchasing new tyres, would provide a further incentive to obtain tyres with a lower rate of tread wear abrasion (which consumers will be able to determine once a measurement standard is developed), to use part warns, and opt for retreading. While the revenues from such a tax would, in principle, accrue to general UK Government funds, some or all could be hypothecated (or 'ring-fenced) and directed towards related activities. These might include:

- Covering (or contributing to) the costs of enhanced enforcement by trading standards of part-worn tyres;
- Implementing measures to capture tyre wear particles in run-off from roads via the use of SUDS or other approaches; or
- Implementing measures to tackle the adverse effects of road traffic noise in communities particularly affected by this issue.

While taxation has the potential to internalise some of the externalities associated with the use of tyres outlined above it should be noted that devolved taxation powers are limited, and this would need to be a measure taken forward by UK Government. As such taxation is considered a complimentary measure to the other policy measures outlined.

Underpinning all of these measures is a need for better data on the life cycle of individual tyres. Such an approach could be introduced through placing a requirement on an EPR scheme operator. This would involve demonstrating its performance in improving the management of tyres, possibly relying on the **use RFID tagging and data capture** combined with Blockchain to facilitate automated, transparent, tamper-proof record keeping. As well as being a potentially efficient way of demonstrating compliance, and avoiding free-riding, the technology has the potential to further increase public

confidence in retreads and part-worn tyres by providing detail about the tyre's usage over its lifetime. Such an approach could also improve the possibility for anti-fly tipping enforcement through better traceability.

All of the above measures can be implemented together, and indeed are mutually reinforcing. It is difficult at this point to identify the impact of the measures, primarily because current data on tyre usage (including sale of part-worns and retreading) is lacking. All of the measures above will contribute to improving the data, either directly or indirectly. With improved data, the changes that result from measures such as EPR and taxation will be become clearer, and a better understanding will develop as to the likely future shifts that can be expected with, for example, changes in the level of tax applied.

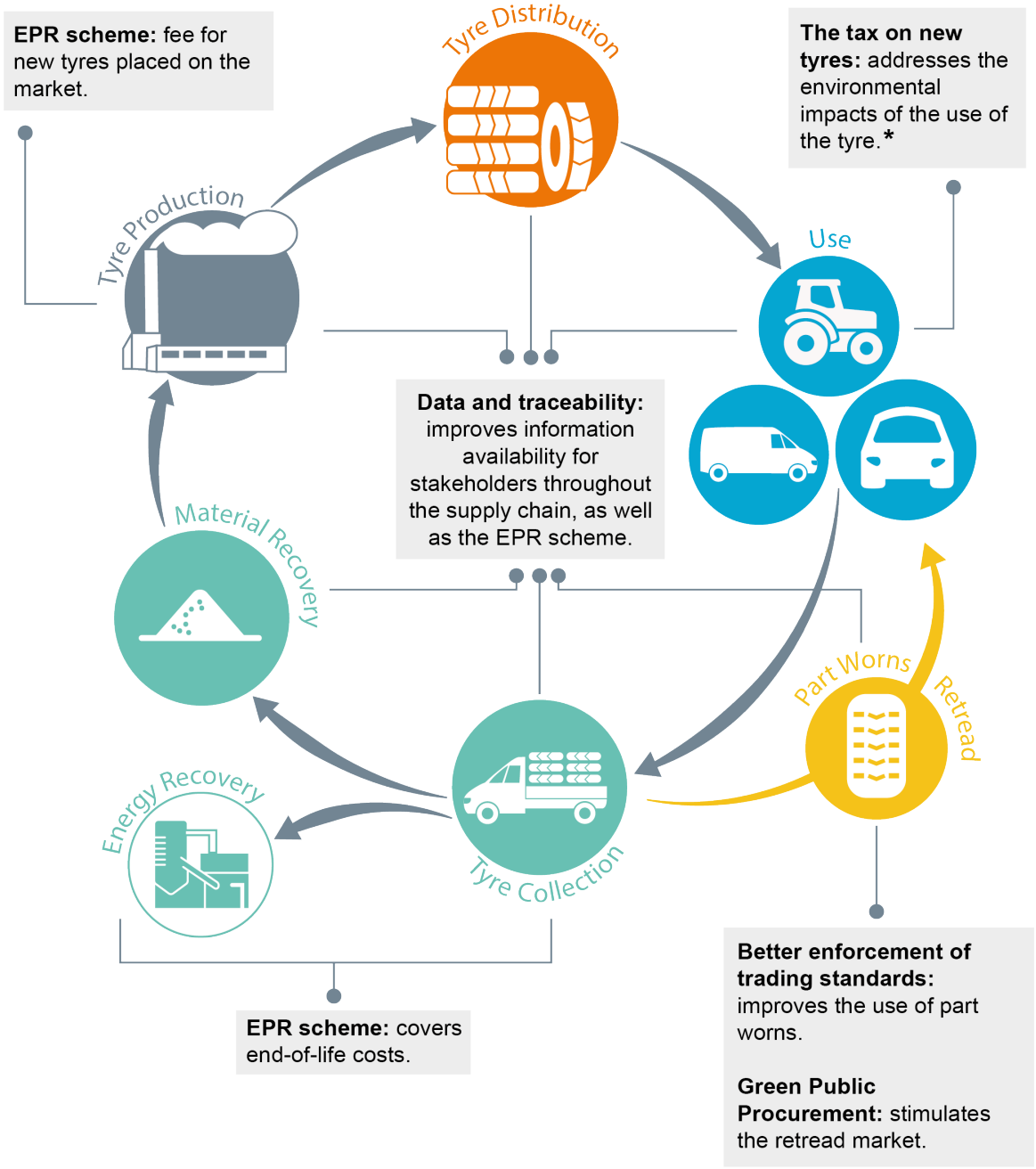
The way in which the above measures contribute to the development of a circular economy for tyres in Scotland is shown in Figure 6-4. It is recommended that Scotland explore each of these measures further with a view to their implementation. While some measures can readily be introduced on a Scotland-only basis, such as improved enforcement of trading standards on part-worns, and the use of green public procurement, for all measures, co-ordination with other national governments leading to a UK-wide implementation would reduce certain complexities, such as cross-border flows.

In terms of sequencing, there is no reason why Scotland should delay on improving **trading standards enforcement for part-worn tyres** and **green procurement** to incentivise the use of retreads. These are activities that Scotland can undertake alone. These actions should therefore commence first.

Discussions on an EPR scheme design for tyres could start quickly in Scotland between Scottish Government, industry and other related parties. It would also be beneficial to advance conversations with the other Devolved Nations to ensure a joined up approach, where appropriate and feasible.

While a tax could, in theory, be introduced in advance of an EPR scheme, it would seem better to provide advanced notice that such a tax is under consideration. The benefit of implementing a UK-wide tax in advance is that it would give a clear sense of the direction of travel, allow the EPR scheme to become established and allow time for review of the extent to which a tax, and the level at which it is set, could lead to further moves towards circularity, before EPR implementation proceeds.

Figure 6-4: Towards a Circular Economy for Tyres in Scotland



* It should be noted that limited devolved taxation powers suggest a new tax on tyres would need to be implemented by the UK Government and so is presented here as a complimentary measure.

7 Appendix 1 – Detailed Breakdown of Marginal Cost of Noise Pollution

Table 7-1: Total road traffic, rail and air noise marginal values (excluding sleep disturbance), £ per household per dB change, Central Values in 2014 prices

Change in noise metric by decibel (dB) Noise Metric (daytime)		Total road (excluding sleep disturbance)	Total rail (excluding sleep disturbance)	Total air (excluding sleep disturbance)
45.0	46.0	£11.28	£3.90	£15.61
46.0	47.0	£11.23	£3.95	£17.72
47.0	48.0	£11.31	£4.11	£19.82
48.0	49.0	£11.52	£4.40	£21.90
49.0	50.0	£18.41	£4.80	£23.96
50.0	51.0	£18.89	£12.46	£38.71
51.0	52.0	£19.49	£13.13	£40.80
52.0	53.0	£20.23	£13.91	£42.88
53.0	54.0	£21.09	£14.81	£44.94
54.0	55.0	£22.07	£15.84	£46.98
55.0	56.0	£23.19	£16.98	£49.01
56.0	57.0	£24.43	£18.24	£51.02
57.0	58.0	£25.80	£19.62	£53.02
58.0	59.0	£28.85	£22.68	£56.56
59.0	60.0	£31.99	£25.82	£60.05
60.0	61.0	£35.02	£28.85	£63.29
61.0	62.0	£38.22	£32.03	£66.54
62.0	63.0	£41.58	£35.37	£69.83
63.0	64.0	£45.11	£38.87	£73.14
64.0	65.0	£48.81	£42.53	£76.47
65.0	66.0	£52.67	£46.34	£79.82
66.0	67.0	£56.71	£50.32	£83.21
67.0	68.0	£60.90	£54.46	£86.61
68.0	69.0	£65.27	£58.76	£90.04
69.0	70.0	£69.80	£63.22	£93.50
70.0	71.0	£74.50	£67.83	£96.98
71.0	72.0	£79.36	£72.61	£100.48
72.0	73.0	£84.40	£77.54	£104.01
73.0	74.0	£89.60	£82.64	£107.57
74.0	75.0	£94.96	£87.89	£111.15
75.0	76.0	£100.50	£93.31	£114.75
76.0	77.0	£106.20	£95.22	£116.66
77.0	78.0	£112.06	£97.17	£118.62
78.0	79.0	£114.06	£99.16	£120.61
79.0	80.0	£116.09	£101.20	£122.64
80.0	81.0	£118.16	£103.27	£124.71

Source: https://www.gov.uk/noise-pollution-economic-analysis

Table 7-2: Sleep disturbance night time noise marginal values per household per dB change, £ per household per dB change, Central Values in 2014 prices

Change in night noise metric by decibel (dB)		Road	Rail	Aviation
45	46	£29.20	£13.59	£37.93
46	47	£32.07	£15.06	£40.79
47	48	£34.94	£16.52	£43.65
48	49	£37.81	£17.99	£46.52
49	50	£40.68	£19.46	£49.38
50	51	£43.55	£20.92	£52.24
51	52	£46.42	£22.39	£55.11
52	53	£49.29	£23.86	£57.97
53	54	£52.17	£25.32	£60.83
54	55	£55.04	£26.79	£63.70
55	56	£57.91	£28.25	£66.56
56	57	£60.78	£29.72	£69.42
57	58	£63.65	£31.19	£72.29
58	59	£66.52	£32.65	£75.15
59	60	£69.39	£34.12	£78.01
60	61	£72.26	£35.59	£80.88
61	62	£75.13	£37.05	£83.74
62	63	£78.00	£38.52	£86.60
63	64	£80.88	£39.99	£89.47
64	65	£83.75	£41.45	£92.33
65	66	£86.62	£42.92	£95.19
66	67	£86.62	£42.92	£95.19
67	68	£86.62	£42.92	£95.19
68	69	£86.62	£42.92	£95.19
69	70	£86.62	£42.92	£95.19
70	71	£86.62	£42.92	£95.19
71	72	£86.62	£42.92	£95.19
72	73	£86.62	£42.92	£95.19
73	74	£86.62	£42.92	£95.19
74	75	£86.62	£42.92	£95.19
75	76	£86.62	£42.92	£95.19
76	77	£86.62	£42.92	£95.19
77	78	£86.62	£42.92	£95.19
78	79	£86.62	£42.92	£95.19
79	80	£86.62	£42.92	£95.19
80	81	£86.62	£42.92	£95.19

Source: *https://www.gov.uk/noise-pollution-economic-analysis*

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