Tyre waste and resource management: A mass balance approach

A B Hird, P J Griffiths and R A Smith
This project was funded by Biffaward under the Landfill Tax Credit Scheme, with contributions from the Highways Agency, Department of Trade and Industry, National Tyre Distributors Association, British Tyre Industry Federation and REG UK. A second document entitled ‘The status of post-consumer tyres in the European Union’ was also produced through an extension to the contract and is available as a separate publication. Both publications are available for download from the Viridis website (www.viridis.co.uk).

Viridis was the Entrust Approved Environmental Body (AEB) responsible for the project and the work was undertaken by a team comprising Viridis and TRL Limited. The project team was assisted by a ‘Tyre Advisory Group’ made up of relevant Government organisations, tyre associations and leading industrial stakeholders. This group raised issues and gave feedback on progress throughout the project, enabling real issues to be highlighted and practical solutions to be proposed.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.
Biffaward Programme on Sustainable Resource Use

This report forms part of the Biffaward Programme on Sustainable Resource Use. The aim of this programme is to provide accessible, well-researched information about the flows of different resources through the UK economy based either singly or on a combination of regions, material streams or industry sectors.

Information about material resource flows through the UK economy is of fundamental importance to the cost-effective management of the flows, especially at the stage when the resources become ‘waste’

In order to maximise the Programme’s full potential, data is being generated and classified in ways that are consistent both with each other, and with the methodologies of other generators of resource flow/waste management data

In addition to the projects having their own individual means of dissemination, their data and information will be gathered together in a common format to facilitate policy making at corporate, regional and national levels.

Members of the Tyre Advisory Group:

- Mike Head (Chairman) Viridis
- David Bavaird Waste Tyre Solutions
- John Campbell Continental Tyre Group/Used Tyre Working Group
- Jeff Cooper Environment Agency
- John Dorken British Rubber Manufacturers’ Association/Used Tyre Working Group
- Richard Edy National Tyre Distributors Association
- Paul Hallett Department of Trade & Industry/Used Tyre Working Group
- Peter Hallett Biffa Waste Services Ltd
- Gilbert Johnson European Tyre Recycling Association
- Conor Linstead Forum for the Future
- Simon Price Highways Agency
- Valerie Shulman European Tyre Recycling Association
- Peter Taylor Imported Tyre Manufacturers Association/Used Tyre Working Group

Additional assistance in compiling the report was given by a range of industry representatives. Although too many to mention by name, their co-operation was gratefully received

Department of Trade and Industry

Waste Tyre Solutions

Highways Agency

REG

BTif
## CONTENTS

**Executive Summary**  
1  

1 **Introduction**  
1.1 The problem with tyres  
1.2 Objectives  

2 **Life of a tyre in the UK**  
2.1 Tyre manufacture  
2.2 Tyre use  
2.3 Post-consumer tyre arisings  
2.4 Post-consumer tyre processing and disposal  

3 **Mass balance model of the UK Tyre Industry**  
3.1 Mass balance boundaries  
3.2 The manufacture of new and retread tyres in the UK  
3.3 The use of tyres in the UK  
3.4 Post-consumer tyre arisings in the UK  
3.5 The processing, treatment and disposal of post-consumer tyres in the UK  
3.6 Data sources, assumptions and confidence  

4 **Mass balance outputs**  
4.1 Summary mass balance  
4.2 Tyre stocks  
4.3 Tyre manufacturing mass balance  
4.4 Tyre use mass balance  
4.5 Tyre arisings  
4.6 Tyre processing and disposal mass balance  
4.7 Environmental impact of the UK Tyre Industry  

5 **Issues and future scenarios**  
5.1 Introduction  
5.2 Influences on the recovery market  

6 **Conclusions and Recommendations**  
6.1 Conclusions  
6.2 Recommendations  

7 **References**
<table>
<thead>
<tr>
<th>Appendix A: Mass balance study concept and boundaries</th>
<th>49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix B: Details of manufacturing model</td>
<td>50</td>
</tr>
<tr>
<td>Appendix C: Details of tyre use model</td>
<td>51</td>
</tr>
<tr>
<td>Appendix D: Details of post-consumer tyre arisings model</td>
<td>52</td>
</tr>
<tr>
<td>Appendix E: Details of tyre processing and disposal model</td>
<td>53</td>
</tr>
<tr>
<td>Appendix F: Data sources and confidence levels</td>
<td>54</td>
</tr>
<tr>
<td>Abstract</td>
<td>72</td>
</tr>
<tr>
<td>Related publications</td>
<td>72</td>
</tr>
</tbody>
</table>
Executive Summary

Lack of consistent and available information for the whole Tyre Industry has hindered understanding of current and future issues that need to be addressed to improve sustainability. There has also been a lack of awareness of how one sector of the Industry can influence sustainable change in the other sectors. This report sets out the current situation regarding the manufacture, use, reprocessing and disposal of tyres within the UK. It identifies current and future challenges and recommends options to achieve more sustainable changes.

Currently over 400,000 tonnes per annum of post-consumer tyres are generated in the UK. With traffic forecasts predicted to increase this number is only likely to increase. In 1998 it is estimated that 11% of post-consumer tyres were exported, 62% were reused, recycled or sent for energy recovery, and 23% were sent to landfill. With the implementation of the Landfill Directive and the End of Life Vehicle Directive the Tyre Industry faces the challenge of dealing with post-consumer tyres economically and in a sustainable manner. The risk is that with the implementation of the Landfill Directive lack of provision of sufficient reprocessing capacity will cause the rapid increase of illegal dumping and stockpiling of post-consumer tyres.

In order to quantify the current situation in the Tyre Industry mass balance models were developed to generate post-consumer tyre arisings by region, and resource use and environmental impacts of tyre manufacture, tyre use and tyre reprocessing. Post-consumer tyre arisings were generated for base year of 1998 and predicted for future years. These were compared with estimated future reprocessing capacities. The other mass balance models gave data on the resource use from tyre manufacture, use and reprocessing. Some of the main findings are highlighted below:

Tyre manufacture

In 1998 only 18% of the tyres manufactured in the UK were used in this country, the rest being exported. To satisfy remaining demand in the UK we imported 432kT of tyres from other countries.

Tyre use

9070kT of fuel were consumed in 1998 just to overcome the rolling resistance between tyres and the road surface. As a direct consequence, 40,000kT of air emissions were released resulting from fuel combustion.

If traffic grows as predicted there will be an increase in post-consumer tyre arisings of approximately 30% over the 14 year period to 2012.

Post-consumer tyre disposal

41% of the post-consumer tyre arisings in 1998 were not reprocessed but disposed of in landfill, stockpiles or illegally dumped.

The high cost of responsible disposal of post-consumer tyres is contributing towards the growth of unregulated tyre disposal.

Post-consumer tyre reprocessing capacity

During the implementation of the Landfill Directive it is likely that post-consumer tyre arisings will exceed national capacity by 127 - 140kt per annum. By 2006 this amounts to over 500kt of post-consumer tyres.

Reprocessing capacity for post-consumer tyres is not spread evenly across the UK. Certain regions (such as the Midlands) already have an over capacity, while others (such as the Southeast) are in serious deficit.

Small reprocessing companies find it difficult to become established due to market instability and high investment costs.

Energy recovery is growing as a reprocessing option due to the ability to deal with large quantities of tyres. Long approval procedures are a risk to this continuing in the long term.

Having detailed information on the resource use and waste outputs within the Industry allows actions to be focused in areas where the greatest sustainable benefit can be achieved. Concentrating on solutions for post-consumer tyres is vital now because of the immediate challenge of the Landfill Directive. However the overall sustainability of the Tyre Industry needs to be improved to reduce the use of natural resources, and to minimise waste by reducing the number of post-consumer tyres arising which then reduces the immediate in hand problem.

Many issues that are influencing the Tyre Industry are highlighted in the report. While some of these are being addressed there is presently no co-ordinated strategic framework of actions. This is needed to give increasing emphasis not just on the minimisation and recycling of waste but also on sustainable resource management throughout the life of a given material. If the Tyre Industry does not effect more sustainable change in its practices, further legislation and greater regulation of the Industry may result.
Five primary recommendations are presented that will achieve improvements in tyre sustainability.

- Improve sustainability in the UK Tyre Industry through Integrated Product Policy development
- Implement comprehensive, consistent and permanent resource flow monitoring and reporting procedures
- Implement waste planning initiatives that maintain balance of centralised reprocessing with regional reprocessing, and target capacity to need
- Promote and encourage investment in prioritised new recycling technologies and markets
- Implement Environment Agency national ‘Duty of Care Awareness/Compliance’ campaign’

Each recommendation has an associated list of actions that can create positive sustainable change. It is acknowledged that within each list some actions are contentious, some are conflicting and others may simply not be practicable at this time. The aim at this stage is to raise awareness of the range of options available to the Tyre Industry.

To decide upon, and implement, an actual package of measures that will effect sustainable change within the Tyre Industry, Stakeholders, Government and the Regulators need to work together to identify a ‘National Strategy’ of sustainability objectives and actions. Those responsible for undertaking each action need to be clearly identified and their commitment to achieving these actions obtained. Targets need to be agreed for the accomplishment of each action, and the degree of success reported on an annual basis. In this manner sustainable change can be achieved through co-operation rather than regulation.

This project has highlighted the importance of taking a holistic view to an entire industry in order to identify ways to improve sustainability. The report has gathered and modelled current and future data, suggested methods for consistent data reporting, identified future challenges, identified components of a national stakeholder strategy and liaised with stakeholders to facilitate the development of a national strategy

Addendum

This report was prepared in 2000/01 and the base year for the study was 1998. When reading the report it should be recognised that while every attempt has been made to keep this report current there will be changes that have occurred in the Tyre Industry that we have not been able to report within the scope of this work.

Since the project has been completed actions have been taken by Government and the Tyre Industry to address the problems and issues highlighted here. These include:

- The launch of the Environment Agency’s Waste Tyre Programme.
- The release of a Discussion Paper on a Possible Producer Responsibility Model for Used Tyres by the DTI.
- Surveys on post-consumer tyres implemented by the Scottish Environmental Protection Agency (SEPA) and Environment and Heritage Service (EHS) Northern Ireland.
1 Introduction

1.1 The problem with tyres

In 1998, approximately 435,000 tonnes of post-consumer tyres arose in the UK. Of these, it is estimated that about 11% were exported, 62% were reused, recycled or sent for energy recovery, and 23% were sent to landfill. The remaining 4% were either stockpiled or disposed of illegally.

Under new European legislation (The Landfill Directive) disposal to landfill, either as whole or shredded tyres, will be banned from July 2003 and July 2006 respectively. If alternatives to landfill disposal are not found, disposal costs will increase and illegal dumping or inadequate storage will continue to worsen. The fire risk associated with illegal dumps has the potential to cause significant environmental harm.

Alternative post-consumer options currently available for post-consumer tyres are under developed as highlighted in Box 1.1.

The real scale of the problem is uncertain as post-consumer tyres are derived from a number of different sources (both recognised and illicit), and there is no comprehensive system of monitoring either their generation or their movement. Consequently, current figures are only estimates of the real situation. Also, the environmental burden that tyres represent is not adequately quantified. Without a comprehensive understanding of both the current and future problem, sensible decisions regarding the promotion of sustainable alternatives to landfill cannot be made.

1.2 Objectives

This report provides a full appreciation of the current and future situation within the UK Tyre Industry in terms of its resource use, environmental impact, generation of waste and the reuse, recycling and disposal of waste. Current issues and future trends are identified. Those activities that have the greatest environmental impact are highlighted and examined in more detail, and sustainable solutions are developed within the context of the Industry as a whole (not just within the area where impacts are apparent).

A mass balance database and model was developed to establish a tyre’s total demand on natural resources (including energy) and to assess the effects of changes in process practices on resources and the environment. This will be used further to inform the Tyre Industry, Government, Local Authorities and Regulators of ways in which the Industry can become more sustainable; by encouraging investment in post-consumer products and markets, recognising land use planning requirements, and by identifying where economic and/or legislative drivers need to be provided by Government and Regulators.

2 Life of a tyre in the UK

The life of a tyre can be simplified as shown in Figure 2.1.
Figure 2.2 sets out the life-cycle of a tyre in more detail. This diagram illustrates the many different tyre movements within the UK and highlights why it is difficult to monitor the number of post-consumer tyres arising.

A brief summary of the component parts of the life cycle is given in the following sections for information. More detailed information can be found in ‘Tyres in the Environment’ (Environment Agency, 1998).

2.1 Tyre manufacture

Although worldwide over 130 manufacturing companies make a total of over 1,000 million tyres every year, the manufacturing industry is dominated by a small group of multi-national companies, many of which are present in the UK.

Currently the following countries/areas dominate new tyre production; USA, Japan, China, Korea and the EU. Although the UK is acknowledged as one of the largest tyre producing countries, it produces less than 4% (40 million tyres in 1998) of the total world production, and production rates are currently falling. At present there are 10 sites in the UK: the location of which are presented in Figure 2.3.

85% (35 million) of the tyres produced in the UK are manufactured for road vehicles (as opposed to planes and or agricultural/plant vehicles), and of these the majority are manufactured for cars.

The raw materials used in manufacture are listed in Box 2.1. The proportions of each raw material vary slightly depending on the type of tyre (car, truck, aeroplane etc) being produced.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Car tyre</th>
<th>Truck tyre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber</td>
<td>48%</td>
<td>45%</td>
</tr>
<tr>
<td>Carbon</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>Black metal (mainly steel)</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>Textile</td>
<td>5%</td>
<td>–</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Additives</td>
<td>8%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: ETRA (2000)
As there are over 3,000 different types and sizes available, individual components of tyres are made off-site and transported to manufacturing sites for assembling and moulding. Consequently, the main impacts on the environment from tyre manufacture in the UK alone result primarily from the use of natural resources (natural rubber, oil, zinc oxide etc) and the use of solvents (which release volatile organic compounds (VOCs)). This is reflected in the legislation surrounding the manufacture of tyres, as summarised in Box 2.2.

The main issues of concern resulting from tyre manufacture are summarised in Box 2.3.

2.2 Tyre use

In 1998, there were 27.5 million motor vehicles in use in the UK (DETR, 2000). Figure 2.4 shows the increase in both vehicle ownership and average distance travelled over the last 10 years.

Road traffic is predicted to increase another 17% between 2000 and 2010 (DETR 2000). This will be due to increased mileage and vehicle ownership, both of which will result in greater tyre use. Although tyres are becoming more durable, with car tyres lasting an average of 47,000 km in 1998 compared with less than 25,000 km in 1980 (Environment Agency, 1998), the
Box 2.2 Legislation relating to tyre manufacture

**Integrated Pollution Prevention and Control (IPPC)**

The UK *Pollution Prevention and Control Regulations 2000*, which implement the IPPC Directive (96/61/EC), have been in force since 1st August 2000. They supersede the Environmental Protection Regulations, 1990. They mirror the previous regulations in that processes are categorised as Part A (1 and 2) and Part B processes, and are regulated by either the Environment Agency or Local Authorities. Tyre manufacture, which mixes or blends natural rubbers or synthetics with carbon black, remained a Part B process, regulated by Local Authorities. New installations are affected immediately by the new PPC regulations; existing installations are being phased in by sector in over a seven year period from 2000 to 2007. As part of these regulations, tyre manufacturing sites require prior authorisation of sites and the application of BATNEEC (Best Available Technology Not Exceeding Excessive Costs) practices. Site authorisations stipulate site emission limits, controls and monitoring requirements.

**Solvents**

As solvents are also used in the manufacture of tyres, sites are subject to Directive 99/13/EC on ‘the limitation of emissions of volatile organic compounds (VOCs) due to the use of organic solvents in certain activities and installations’. This Directive proposes to reduce industrial emissions in the EU by 70%, with existing sites having to comply with the reduced emission levels by 2007 (EA, 1998).

**Type approval**

Before a new tyre is introduced onto the market, it must be tested by the Type Approval Authority to ensure it complies with relevant EU Directives relating to the load carrying capacity and speed capability of tyres. It is then marked in accordance with Directive 92/23/EEC relating to ‘tyres for motor vehicles and their trailers and to their fitting’, as implemented in the UK through the Motor Vehicles Tyres (Safety) Regulations 1994 or ECE Regulations 30 or 54.

---

Box 2.3 Issues for tyre manufacturing

1. What is the current environmental impact of tyre manufacturing?
2. What percentage of the total environmental impact of the UK tyre Industry is derived from tyre manufacture?
3. What is the effect of increasing the number and use of retreaded tyres?
4. What is the effect of increasing the life of a tyre?

Draft legislation is currently being developed to address the generation of noise from tyre/road interactions (see Box 2.4).

The amount of energy required to overcome the friction between the tyre and road pavement surface is termed the ‘rolling resistance’. It is estimated that fuel used to overcome rolling resistance can account for 24% (for car) and 27% (for truck) of the total fuel consumed while driving (Cena & Travaglio, 1995; Blackmore, 1996). The exact percentage depends on a number of different factors, including driver behaviour and having the correct tyre pressures (e.g. a 7 psi decrease in tyre pressure can result in a 5% increase in fuel use according the Environment Agency; 1998). ‘Energy efficient’ tyres are being promoted by some manufacturers. These claim to reduce rolling resistance by up to 30%, although actual fuel savings are difficult to determine due to the variable effects of driver behaviour and vehicle maintenance.

A tyre loses between 10 and 20% of its total weight during use (Environment Agency, 1998), primarily from the rubber tread. The rubber itself adds to the sediment loading in road runoff, and constituent parts, such as zinc and cadmium, can add to soluble metal concentrations. All of these can impact on the ecology and quality of receiving watercourses.

---

The main environmental impacts of using tyres on vehicles are threefold:

- Generation of noise.
- Overcoming rolling resistance.
- Rubber loss.

The number of post-consumer tyres arising in the UK is likely to increase.
Box 2.4 Legislation relating to tyre use

**Noise**

Until recently, no legislation was in force that specified or recommended limits of traffic noise resulting from tyre/road interactions. However, a Green Paper on Noise Pollution published by the European Commission in November 1996 (COM(96)540) recognised that current measures for reducing people’s exposure to unacceptable levels of noise – particularly traffic noise - were not enough.

The Green Paper suggested that noise from road, air and rail sources should be reduced, and made a number of proposals to initiate progress. These included:

- Mapping to assess noise climate and noise exposure.
- Development of harmonised measurement methods.

Based on the recommendations of the Green Paper, and responses to it, the EC has proposed a draft framework Directive’ (Assessment and management of environmental noise from transport and industry – COM2000 468 (final), and a more specific amendment to an existing Directive (Tyres for motor vehicles and their trailers and their fitting (EEC/92/23)). The aim of the amendment is to limit the noise arising from contact between pneumatic tyres and road surfaces whilst preserving adequate safety standards; recommended limits are between 72 dB(A) and 76 dB(A) depending on the width of the tyre. This, together with the measures already adopted to limit noise emitted by the mechanical parts of vehicles (92/97/EEC – Permissible sound level and exhaust system of motor vehicles, and all subsequent amendments), aims to help to reduce road traffic noise.

The main issues of concern resulting from tyre use are summarised in Box 2.5.

Box 2.5 Issues for tyre use

1. What is the current environmental impact of tyre use?
2. What percentage of the total environmental impact of the UK Tyre Industry is derived from tyre use?
3. What weight of rubber is lost through tyre wear?
4. What is the effect of increasing the durability (life) of a tyre?
5. Can the rolling resistance of a tyre be reduced further?
6. What other ways are there of reducing fuel use?

2.3 Post-consumer tyre arisings

**Number**

The number of post-consumer tyres arising in the UK each year is difficult to determine. The reasons for this are outlined in Box 2.6.

The Used Tyre Working Group (UTWG) (formerly the Scrap Tyre Working Group) was set up in 1995 to examine and report the number of post-consumer tyres arising annually in the UK. This was to enable the Industry to ‘monitor the UK’s performance against expected EC targets and to facilitate the emergence of recovery targets’
(UTWG, 1995), and was a direct result of the Government’s promotion of producer responsibility. Their annual reports provide an overview of the efforts being made by the Industry to deal with post-consumer tyre arisings, and track the estimated number of post-consumer tyres. It includes representatives from the major Tyre Industry trade organisations, with a representative from the DTI as secretariat.

The historical trends in post-consumer tyre arisings from 1994 can be seen in Figure 2.5. According to the figures, arisings have decreased over the last five years, while road traffic has continued to increase. Possible reasons why arisings appear to have decreased despite the increase in traffic are outlined in Box 2.7.

**Box 2.6 Reporting of post-consumer tyre arisings in the UK**

Numbers of post-consumer tyres arising annually in the UK are currently estimated. A series of factors reduce confidence levels at present. These include:

- The number of post-consumer tyres sent to landfill is not currently tracked.
- Many post-consumer tyres are illegally dumped or stockpiled.
- The number of post-consumer tyres reused whole for applications such as agricultural silage clamps is unknown.
- The number of commercial vehicles scrapped or dismantled is estimated by the SMMT on the basis of change in vehicle registrations year on year.
- Of all vehicles scrapped or dismantled, the proportion of tyres removed before shredding is not recorded.
- Under Duty of Care requirements all tyre collectors should maintain a paper trail of their tyre recovery/disposal activities. However there is no formal system to record the number of tyres disposed which encompasses all tyre collectors.
- The number of imported and exported ‘part worns’ are not monitored.

**Box 2.7 Explanation for apparent decrease in post-consumer tyre arisings**

- Continual refinements to the method of calculation.
- Incomplete data make the margins of error relatively large.
- Imports/exports of post-consumer tyres are difficult to track.
- Trucks are being serviced abroad more frequently and therefore post-consumer tyres arise outside of the UK.

**Figure 2.5** Trends in post-consumer tyre arisings and vehicle use
Composition

Different types of tyres in terms of size, shape and strength are used on the wide range of vehicles currently in use. As a result, considerable variability exists within post-consumer tyres. Car, van, truck, bus, motorbike, bicycle, aircraft and off-road vehicles represent the vast majority of the tyre stock. There are approximately twice as many car tyres (including vans) as truck tyres (including buses and coaches) in terms of tonnage. However, no consistent or reliable data are available on the number of post-consumer tyre arisings from other sources. For this reason only car and truck tyres are considered in this study.

Sources/Location

When tyres come to the end of their life, they can be replaced at retailers/garages or removed from an ‘end of life’ vehicle by dismantlers/scrap yards. Vehicles entering scrap yards may not have the tyres removed before the vehicle is either shredded for metal recovery and/or disposed of in landfill. In this case the tyre is lost before any attempt at recovery can take place. Post-consumer tyres can also be imported for reuse as part-worns/retreads.

The main legitimate sources of post-consumer tyres are given in Figure 2.6.

![Diagram of sources of post-consumer tyres](image)

**Figure 2.6** Diagram of sources of post-consumer tyres

As can be seen in Figure 2.6 by far the largest source of post-consumer tyres are the retailers. The National Tyre Distributors Association (NTDA) represents 400 individual companies that in turn represent a larger number of outlets located throughout the UK. There are approximately 250 members of the Motor Vehicle Dismantling Association and the British Vehicle Salvage Federation. As with retailers these are distributed throughout the UK. In addition there are a huge number of small garages and vehicle breakers/dismantlers, which are not under the banner of these organisations. Consequently, most post-consumer tyres arise in small numbers at a large number of locations throughout the UK.

In addition to the legitimate sources of post-consumer tyres identified above, in 1995 it was reported that there were at least 44 sites where they were stored in large quantities and it was estimated that between 30 and 50 million tonnes were present in these locations (ETSU 1995). These estimates take no account of smaller individual illegal dumping incidents that occur frequently throughout the UK. Figure 2.7 indicates the location of known stockpiles or dumps.

Tyre collection/Auditing schemes

Auditing schemes can help encourage the disposal of post-consumer tyres in a sustainable and responsible manner by tracking and recording their disposal. The drivers for such schemes are largely legislative pressures and the Government’s continual threat of the introduction of Producer Responsibility.

The Tyre Industry response to this has been the introduction of the Responsible Recyclers Scheme (RRC) in 1999. This is a voluntary scheme set up by the Tyre Industry Council (TIC) to ensure that post-consumer tyres collected from any designated premises are reused and recycled in ways which comply with UK and European statutory requirements. The structure of the RRC is set out in Figure 2.8, which shows the current membership, and companies that may join in the future. The TIC considers that the scheme already encompasses a large proportion of the UK’s annual arisings of casings.

The scheme is carefully structured and audited as set out in Box 2.8 and an example of how the RRS operates within a tyre collection company is set out in Box 2.9.

The RRS is providing a way for the Industry to demonstrate to Government that they are dealing responsibly with post-consumer tyre disposal. Unfortunately, the auditing requirements of the scheme make it expensive for companies to comply, and this appears to be preventing smaller tyre collection business from joining. Scheme members are considering the appointment of a single audit company to reduce costs. Compliance means that operating costs are slightly higher allowing non-compliant companies to charge less to their customers. Ways in which the Tyre Industry is attempting to overcome these current problems are outlined in Box 2.10.

The main issues of concern resulting from tyre arisings are summarised in Box 2.11.
Figure 2.7 Location of known tyre stockpiles/dumps in the UK (ETSU, 1995)

Figure 2.8 The responsible recyclers scheme (2001)
Box 2.8 Responsible recyclers scheme outline

- Independent auditors acceptable to the Council must regularly appraise the performance of every member.
- The cost of accreditation and monitoring is recovered through a charge of 0.1p per tyre.
- The council may terminate the membership of any Scheme member at any time.
- The site should have and maintain appropriate licences and authorisations or exemptions for the qualifying process and related operations.
- The operator of the process should provide a process profile and description to demonstrate how the process complies with the scheme requirements and how the recycling/reclamation can be sustained.
- The operator should keep records which demonstrate compliance.
- The operator should operate an audit system to demonstrate traceability of waste received so that processing can recycling/reclamation can be shown to have applied to that waste.
- For each metric tonne of waste processed, the site should be required to issue one Tyre Recovery Note (TRN) back to the scheme operator.

Records of the amount of tyres processed are kept in the form of Tyre Recovery Notes. This information is passed onto Government and the Used Tyre Working Group for industry statistical and compliance purposes.

Box 2.9 Case study of a member of the RRC

Waste Tyre Solutions – V-Prompt

Waste Tyre Solutions (WTS) is the UK’s largest tyre collector and manages and administers the scheme V.Prompt (voluntary partnership for responsible management of post-consumer tyres). This accreditation scheme was a forerunner to the RRS. V-Prompt is now operated under the umbrella of the RRS. WTS say that the scheme is a voluntary partnership for responsible management of post-consumer tyres to demonstrate that tyres are being managed in a responsible and sustainable way towards compliance with future targets. Ernst & Young are the auditors of the scheme. WTS include the costs of organising and running the initiative in the existing cost of their waste casings collection service and therefore the scheme costs the retailer nothing. WTS customers can benefit by being able to demonstrate to their own customers their responsible attitude to the problem.

WTS have a hierarchy of disposal options; their preferred method of recovery is to send the tyres to retreading plants, followed by material recovery (mainly crumbing), energy recovery, engineering and finally where no other option exists to send the post-consumer casings to landfill. Currently WTS accredited reprocessors include: Colway Tyres (retreaders), Motorway Retreads and Duralay Ltd (crumbers).

Box 2.10 Tyre industry strategies to encourage auditing schemes

- Introduce consistency by ensuring one company does all audits. This can help reduce the costs if everyone is following the same procedures.
- The Retread Manufacturers Association (RMA) is considering setting up a similar scheme for smaller companies who cannot afford the administration costs of joining RRS.
- Encourage Government to introduce greater enforcement of regulations to force the whole Industry to be responsible and share costs.
- Move from individual audits to shared audits.
2.4 Post-consumer tyre processing and disposal

Options for post-consumer tyres

Tyres that have come to the end of their life are currently classified as a waste, and need to be processed in a manner that causes the least impact in environmental, economic and social terms. Although essentially inert in the natural environment, post-consumer tyres that have been illegally dumped or stockpiled present a considerable fire risk, with the potential to produce pollutants that can contaminate both the atmosphere and groundwater. In addition, the manufacture of tyres consumes considerable inputs of valuable resources that need to be recovered at their end-of-life if the Tyre Industry is to become more sustainable. How to process the growing number of post-consumer tyre casings in a sustainable manner is now an important international issue. The UK Tyre Industry has now been put under increasing pressure from European and national legislation to deal more effectively with post-consumer tyre arisings (see boxes 2.12 and 2.13).

Under the waste management legislation outlined in Box 2.13, dumping of any waste or treating it without a licence may result in a maximum fine of £20,000 and/or six months in prison on summary conviction or an unlimited fine and/or two years in prison on conviction. There are a number of licensing ‘exemptions’ (typically requiring registration with the Environment Agency or its counterparts in Scotland and Northern Ireland). These include materials within the ‘commercial cycle or chain of utility’, ‘material which can be put to immediate use without the need for waste recovery operations’ and ‘waste which has been processed to such a state that it can be used as a raw material’. The main purpose of these exemptions is primarily to avoid the unnecessary use of legislation and regulation, indirectly encouraging the recovery of waste.

In addition, the Government plans to use a combination of regulations, economic instruments, and research, information and education initiatives. A current key economic instrument is the Landfill Tax, which was first
Box 2.13 UK legislation relating to waste

The first detailed policy framework for waste management in the UK was set out in the 1995 White Paper Making Waste Work. Since then, the Government has published a waste strategy for England (Waste Strategy 2000 for England and Wales; DETR, 2000). Within this document a number of targets have been set which reflect both targets identified in EC Directives. The key principles underlying the Government’s waste strategy are listed below:

- the Best Practicable Environmental Option (BPEO) - the option that ‘provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term’;

- the waste hierarchy - a conceptual framework or guide that places the options in order of priority, starting with waste reduction and followed by re-use, recovery (recycling, composting or energy recovery) and finally disposal;

- the proximity principle - the principle that waste should generally be disposed of as near to its place of production as possible (recognising that the transportation of wastes can have a significant environmental impact); and

- the polluter pays principle – the principle that if waste is created, it cannot be passed on or out, but must be treated and paid for by those who create it, adding that existing damage to the environment must be paid for. The main waste management legislation which applies to ‘Directive’ wastes and, therefore, applies to post-consumer tyres, includes the following:

  Environmental Protection Act 1990, Section 33 - This states that it is an offence to deposit, knowingly cause or permit the disposal of controlled waste on land without a waste management licence.

  Environmental Protection Act 1990, Section 34 - This imposes a ‘duty of care’ on all those who produce, handle or dispose of controlled waste. The duty is to keep waste safely, to transfer it only to an authorised person, and to provide an appropriate transfer note.

  Environmental Protection (Duty of Care) Regulations 1991 - These introduced a mandatory system of signed ‘transfer notes’ and require all those subject to the duty of care to keep records of waste transferred and/or received.

  Waste Management Licensing Regulations 1994 - These set out the procedures for obtaining a waste management licence. A typical charge for a licence application is £1,500 to dispose of less than 5,000 tonnes of inert waste in or on land. There is also an annual subsistence charge covering the cost of supervision and, in order to get a licence, the licence holder must undergo training. (Source: Agricultural Waste Strategy for England, 1999).

introduced in 1996. The of tax as of April 2002 for active waste is £13 per tonne (£2 per tonne for specified low risk wastes), and will increase by £1 per tonne per year until 2004, when it will be reviewed. This increase will have a significant affect on the cost of waste disposal by landfill, and is designed to motivate waste producers to reduce waste and to consider options other than landfill (i.e. re-use, recycle or recovery).

Planning Authorities play a key role by facilitating the provision of waste management facilities in line with the new waste strategy. In 1999 revised guidance on waste management and disposal was issued in Planning Policy Guidance Note 10 Planning and Waste Management (PPG10).

PPG10 sets out good practices for delivering the land use planning aspects of overall waste policy, and defines the roles of the various parties. These include the Regional Planning Bodies (responsible for developing Regional Planning Guidance), Regional Technical Advisory Bodies (responsible for advising Regional Planning Bodies), and the Environment Agency (responsible for providing up to date information on waste arisings and the extent of, and need for, management and disposal facilities).

In the following boxes, the options for post-consumer tyre processing and disposal in the UK are examined. No attempt has been made to list every possible option for post-consumer tyres, rather to present a summary of the situation in the UK in 2000.

Note: some confusion currently exists over the categorisation of reprocessing options as reuse, recycle or recovery options. The definitions used in this report are those suggested by the United Nations Basel Convention report ‘Technical Guideline for the Identification and Management of Used Tyres’ (1999).
Their definition of re-use in the context of tyres is ‘a used tyre that is legally re-used for its originally intended purpose’. Using this definition, the following classification was adopted:

**Reuse includes:** Part-worns and retreading.

**Recycling includes:** Engineering applications, crumbing and shredding.

**Material recovery includes:** Pyrolysis, gasification and microwave technology applications.

**Energy recovery includes:** Dedicated incineration, use in cement kilns (and energy recovery associated with material recovery technologies).

An alternative definition used in the UK, e.g. by the TiC, follows the rule that reuse involves use (of a post-consumer tyre) without any form of additional processing, while recycling involves use (of a post-consumer tyre) with additional processing. In this context retreading would be classified as recycling and some engineering applications could be classified as reuse.

The main issues of concern resulting from reprocessing and disposal are summarised in Box 2.22.

---

**Box 2.14 Reuse: Part-worn**

A number of post-consumer tyre casings can be reused as ‘part-worns’ without the need for retreading. These have to be checked and marked to show they meet quality standards. The proportion of arisings that can be re-used in this way is not expected to change markedly with time. Currently, there is no legislation relating to the reuse of part-worn tyres other than those relating to safety covered in the Motor Vehicle Tyres (Safety) Regulations 1994 Part II. This stipulates that tyres should be tested and marked in accordance with EU Directives and the tread depth should be at least 2 mm.

**Advantages**

- No reprocessing required.
- No additional material resources required.
- Ensures tyres are not disposed of before full use has been made.

**Disadvantages**

- No potential for growth in sector.
- Only delays tyre arisings, does not prolong life above that already expected.

**Quantity of tyres reused as part-worns in 1998:** 29,000 tonnes

**Number of outlets:** numerous

**Location:** Nationwide
Box 2.15 Reuse: Retreading

Retreading involves removing or ‘buffing off’ the remainder of worn tread, overlaying a new strip of rubber, and remoulding. Car tyres are generally only retreaded once. A greater depth of rubber on truck tyres allows these tyres to be regrooved twice before the tyres are retreaded (usually only once).

Passenger car retreading rates are falling dramatically in the UK due to competition from low budget new tyres and the strength of the UK pound. Retreads also have an unfavourable image with consumers of passenger car tyres, who view that performance is below that of new tyres. While some in the Industry feel that this market will not grow any further in the UK, others including the UTWG consider retreading to be the preferable and most effective method of re-using worn tyres, and are currently seeking ways to improve the market.

Historically, retreaded tyres have suffered from a poor public image regarding safety, even though retreads are tested to the same standards as new tyres. New tyres are marked in accordance with ECE regulations 30 or 54. Although there is no systematic type approval marking in the EU for retreads, the UK Motor Vehicle Tyres (Safety) Regulations 1994 specify that retreads must be marked in accordance with British Standard BS AU 144e. Retreading regulations (EN/ECE 108/109) are currently being developed to raise the standard of retreads throughout the rest of Europe. By the end of 2001, all retreads will have to be type approved to ECE Regulation 109, demonstrating the same safety standards as new tyres.

Advantages

- Efficient reuse of resources.
- Saving of natural resources.
- High quality buffed rubber can be resold as a high value resource.
- Reduces overall tyre arisings as fewer new tyres are needed.
- High up waste hierarchy.

Disadvantages

- Does not deal with ultimate problem of post-consumer tyre casing.
- Public perception of poor quality.
- Lack of market demand across all of the wide range of tyre types and sizes.

Quantity of tyres retreaded in 1998: 85,000 tonnes

Number of facilities: 36 members of the Retread Manufacturers Association (RMA) + three truck tyre retreaders

Location: Nationwide
Box 2.16 Recycling: Engineering uses

At present in the UK, the most common engineering use is for landfill engineering (drainage layers and daily cover). Other uses include creation of artificial reefs, currently being developed and monitored by Southampton University, and use in embankments on golf courses and motorway verges. Tyres used in landfill engineering are still subject to landfill tax. It has been suggested by the Tyre Industry that tyres used for this purpose should be exempt from landfill tax, because of the large volume of natural aggregates and soil that would otherwise be needed.

At present engineering applications for tyres are small scale and often ‘single projects’. This makes engineering applications an unstable market with the quantity of tyres used in this manner varying from year to year. However, it is recognised that this form of application is under-utilised and represents a potential significant growth area for post-consumer tyres. Other applications either under development, or used outside the UK, include breakwaters, construction anchors, drainage culvert beds, road embankments, sea embankments, slope stabilisation, sound barriers, roof tiles, road surfacings, lightweight fill, insulation, backfill for retaining walls and bridge abutments, playground surfaces.

Advantages

- Tyres need little/no processing.
- Potential to use large volumes.
- Variety of uses therefore not dependant on one ‘market sector’.

Disadvantages

- Uncertain/variable market at present.
- Lack of specifications limits use in larger scale applications e.g. highway construction.

Quantity of tyres used in engineering projects in 1998: 25,000 tonnes (landfill engineering only)

Number of facilities: Numerous

Location: Nationwide
Box 2.17 Recycle: Shredding and crumbing

Shredding involves the mechanical shearing of whole tyres into pieces ranging in size from 25 – 300 mm. Shredded tyres are used directly in roadside filter drains or other road construction projects. More often, they are shredded as a pre-treatment either to facilitate their transport, or for use in energy recovery processes.

Crumbing usually involves removal of the steel and fabric component and reduction of remaining rubber to granular rubber. Three main types of crumb rubber can be identified (Dufton, 1995):

- Buffings: produced when post-consumer tyres have tread worn off to prepare them for retreading (not technically crumb).
- Whole tyre crumb: tyres are shredded and then passed through a grinding mill.
- Cryogenic crumb: tyres are cooled to temperatures of between -80 and -120°C and then fragmented.

Current applications of crumb rubber include solid wheels, casters, moulded products, equestrian mats, carpet underlay, road surfacings, playground surfacing, sports ground surfacing, bowling greens, golf courses and grass car parks. The present UK market for shredded and crumb rubber is growing but not at the rate of nominal capacity. A number of trials for large scale applications are currently in progress (e.g. the use of rubberised asphalt in road surfacings, the use of rubber roof tiles and as an aggregate replacement in concrete). If successful, such applications could significantly increase the demand for shredded and crumbed rubber.

Advantages

- Limited use of natural resources.
- High up the waste hierarchy.

Disadvantages

- Expensive processing may be required (cryogenic crumb).
- Market currently limited.

Shredding

As shredding is primarily a pre-treatment for other uses, no data is available on the location and capacity of shredding facilities.

Crumb rubber

Quantity of tyres crumbed in 1998: 48,000 tonnes

Number of facilities: 10

Location: Nationwide
Box 2.18 Recover: Energy recovery

The rubber component of tyres yields large amounts of energy on combustion. As a comparison coal provides about 29MJ/kg while tyre rubber provides about 32.5MJ/kg of heat energy (Dufton, 1995).

At present energy recovery from tyres can take three forms:

- Burnt in cement kilns.
- Burnt in dedicated incinerators.
- Broken down by pyrolysis for energy (and material) recovery.

Within cement kilns, the steel content of the tyres provides an essential source of iron, avoiding the need for shales and clays, and reduces the amount of oxides of nitrogen formed in the process. The high temperatures within the kilns enable the tyres to be combusted ‘cleanly’, reducing solid waste. Due to the extremely high temperatures in the kilns any size or type of tyre can be used as long as it is fed in uniform size, although car tyres/shredded tyres tend to be preferred for ease of handling.

If tyres are allowed to burn in an uncontrolled manner large amounts of air pollution can be generated in the form of black smoke and sulphur dioxide. Costs of controlling these emissions are large and, consequently, investment costs for cement kilns/incinerators which can burn tyres are ten times more than those burning liquid fuel (Dufton, 1995).

Currently the application and trial process remains long and expensive for cement kiln operators and the growth in use has not been as rapid as expected. It is possible, therefore, that post-consumer tyres will face competition from other waste streams. The Environment Agency published in November 2001 guidance on the procedures to be followed and the considerations to be given to the use of tyres as a substitute fuel in cement manufacturing processes (EA, 2001).

Post-consumer tyres can be burnt in special incinerators to produce electricity for use by industry and local communities. The only dedicated tyre incineration plant in the UK (SITA Tyre Recycling Ltd in Wolverhampton) was closed early in 2000. The future of this application is now uncertain as installation and operating costs are high, and public concern regarding emissions makes planning consents difficult to obtain.

Advantages

- Reduction in nitrous oxide emissions and no solid ash residue.
- Stability of market/guaranteed market for large volume of tyres.
- Saving of natural resources.

Disadvantages

- Unfavourable public image.
- Emission controls are expensive.
- Low in waste hierarchy.

Cement kilns

Quantity of tyres used in cement kilns in 1998: 20,000 tonnes of a possible 35,000 tonnes total capacity

Number of facilities: 2 (of a total of 20 cement kilns in UK).

Location: Variable incinerators.

Quantity of tyres used in incinerators in 1998: 64,300 tonnes

Number of facilities: 1

Location: Wolverhampton (NB this site was closed in 2000)
**Box 2.19 Recover: Material recovery**

**Pyrolysis**

Pyrolysis involves the breakdown of tyres into its component parts: oil, gas, carbon black (char) and steel, in the absence of oxygen. In this way pyrolysis is both an energy and material recovery process, with most plants concentrating on one aspect. The char produced can normally only be used for industrial processes; however, if microwave technology is used then the carbon black produced is of higher quality and has a wider variety of applications including reuse in new tyre manufacturing.

In the UK only Beven Recycling Ltd are operating a tyre pyrolysis plant, although this operation is currently being moved to an alternative site and is not yet operating commercially. Other plants planned in the near future include a tyre pyrolysis plant at Four Ashes in Wolverhampton, run by Energy Power Resources Limited. This plant, costing £32 million to develop would be able to utilise 63,000 tonnes per year of tyres to generate 15.5 MW of power.

Coalite is converting part of their existing coke producing plant in Bolsover, Derbyshire for tyre pyrolysis. The steel and carbon black will be recycled and the gas produced will be cleaned and used in the next pyrolysis cycle. The company has applied to the Environment Agency for permission to process between 60,000-80,000 tonnes of tyres per annum (Materials Recycling Week 25/8/00, www.tyretradenews.co.uk/Econote News Review October 2000).

Although those in the Industry view pyrolysis as promising technology there are some doubts as to how commercially viable these plants can be. The plants are very expensive to set up, for instance the Beven Recycling Plant cost £410k and can only process 200 tyres per day, and the technologies are not yet proven sufficiently for finance to be secured easily (UTWG).

**Microwave technology**

A pilot plant constructed by Advanced Molecular Agitation Technology Ltd (AMAT Ltd) is capable of degrading organic-based materials such as vehicle tyres to their component parts using microwaves. Trials are currently taking place to economically justify the process. The products of the breakdown by this process are steel, oil and carbon black.

**Advantages**

- Stability of market/guaranteed market for large volume of tyres.
- Recovery of raw materials.

**Disadvantages**

- Batch and continuous facilities have been commercialised but technology not seen as proven.
- Difficult to obtain investment.

*Quantity of tyres sent to pyrolysis plants in 1998: Nominal amount (trials only)*

*Number of facilities: 1*

*Location: Kings Lynn*
Box 2.20 Legislation relating to material / energy recovery and incineration

Tyres burnt in municipal incinerators or cement kilns are covered by the Municipal Waste Incinerator Directive (89/369/EEC). The objective of this Directive is to harmonise controls across Europe by setting standards that can be achieved with proven abatement technology and at a reasonable cost (BATNEEC). It sets emission limits that vary with the size of the plant, as well as operating and monitoring requirements. In the UK, those with an operating capacity of 1 tonne an hour or more are subject to Integrated Pollution Prevention and Control (IPPC); those with less than 1 tonne an hour are subject to Local Air Pollution Control.

The Hazardous Waste Incineration Directive (94/67/EC) was implemented in 1996 and specifies stricter standards for all incinerators of hazardous waste, including plant which burn hazardous waste as a fuel. Until recently, this did not cover plant burning tyres or other non-hazardous waste. However the Directive on Waste Incineration (2000/76/EC) covers the incineration of both hazardous and non-hazardous wastes, and requires strict emission limits similar to those currently in place for hazardous wastes (see below). The Directive sets strict requirements for the co-incineration of waste (such as that used in energy recovery, cement kilns and pyrolysis plants) to ensure that standards are maintained. Existing plants will need to comply within five years of the adoption date, and new plants 2 years after it is adopted.

Air emission limit values from incinerators.

*Daily average values (mg/m²):*

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Incineration of waste</th>
<th>Cement kilns co-incineration of waste</th>
<th>Combustion plants co-incineration of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>10</td>
<td>30</td>
<td>30-50</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen chloride</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen floride</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>50</td>
<td>50</td>
<td>200-850</td>
</tr>
<tr>
<td>NO and NO₂ expressed as NOₓ (existing plants)</td>
<td>200</td>
<td>800</td>
<td>200-400</td>
</tr>
<tr>
<td>NO and NO₂ expressed as NOₓ (new plants)</td>
<td>400</td>
<td>500</td>
<td>400</td>
</tr>
</tbody>
</table>
Box 2.21  Disposal: Landfill

Tyres are landfilled both whole and in shredded form. As well as being disposed of directly into landfill, tyres are used extensively for 'landfill engineering' (see Box 2.15). However, this method makes no attempt to recover any of the natural resources used in manufacture and is the least sustainable option. A tax is levied on all waste sent to landfill (Landfill tax) which is £13/tonne as of April 2002 for active waste (but is increasing by £1 per tonne per year up to £15/tonne in April 2004).

One of the most important pieces of legislation relating to tyres is the EU Landfill Directive (1999). This has major implications for the management and cost of waste disposal in the UK. Key aspects of the Directive are that it:

- requires a landfill site to be categorised into one of three types: hazardous, non-hazardous and inert (effectively ending the UK practice of co-disposal of hazardous and non-hazardous waste);
- requires the pre-treatment of certain (hazardous) waste streams; and
- bans the landfill of certain types of waste, including liquid waste and tyres.

The Directive would ban landfilling of whole tyres from 2003 and of shredded tyres from 2006. However, the forthcoming ban on landfilling of tyres will not apply to tyres used in landfill engineering.

The Directive states that existing landfill operators must submit a site conditioning plan to the competent authority (e.g. Environment Agency in England and Wales) setting out how they intend to comply with the various requirements of the Directive, including the tyre ban, subject to an absolute backstop of July 2009.

**Advantages**
- No processing required.
- Comparatively inexpensive.

**Disadvantages**
- No recovery of resources.
- Disposal to landfill be banned from 2006.

*Quantity of tyres sent to landfill in 1998: 97,259 tonnes (does not include tyres sent to stockpiles)*

*Number of facilities:* Numerous

*Location:* Nationwide

---

21
Box 2.22 Issues for tyre processing and disposal

1 What is the current environmental impact of tyre processing and disposal?

2 What percentage of the total environmental impact of the UK Tyre Industry is derived from tyre processing and disposal?

3 Is there sufficient processing capacity to deal with current and future predictions of post-consumer tyre arisings?

4 What would be the benefit in environmental terms of increasing the proportion of post-consumer tyres going to reuse and recycling options?

5 What are the economic/legislative drivers needed to encourage more reuse and recycling of post-consumer tyres?

3 Mass balance model of the UK Tyre Industry

Although much is known about the life of a tyre in the UK, the real scale of current and future problems is uncertain as post-consumer tyres are derived from a number of different sources (both recognised and illicit), and there is no comprehensive system of monitoring either their generation or their movement. Consequently, current figures are only estimates of the real situation. Also, the environmental burden that tyres represent is not adequately quantified. Without a comprehensive understanding of both the current and future problem, sensible decisions regarding the promotion of sustainable alternatives to landfill cannot be made.

To address this issue a series of ‘models’ have been developed to calculate the arisings of post-consumer tyres, and the natural resources used in their manufacture, use, treatment and disposal. These models also calculate the environmental impacts associated with these activities in terms of a limited number of environmental indicators. Together they form a complete ‘mass balance’ model of the UK Tyre Industry. A summary of the theory behind ‘mass balance’ studies is given in Appendix A.

3.1 Mass balance boundaries

The boundaries of the mass balance were clearly defined at the outset in order to make clear the data requirements and to ensure the input and output data could be reconciled.

The Tyre Industry was defined as the activities associated with vehicle tyres from manufacture through to disposal. Excluded were mass flows associated with the:

- manufacture of raw materials for tyre manufacture;
- conversion of products from tyre reprocessing, such as rubber crumb, into secondary products;
- transport of tyres to retailers, and from end-of-life to processing or disposal;
- packaging required for new or post-consumer tyres;
- peripheral industry supplies such as those associated with office activities.

Although transport and packaging are an integral part of raw material and tyre movements these issues are being addressed directly within other areas of Biffaward’s Mass Balance programme. To avoid double counting, these issues were not included within the scope of this work. Further details on the boundaries of the mass balance study and associated reasoning are given in Appendix A.

The environmental indicators adopted in the models are based on those proposed as ‘eco-efficiency’ indicators by the World Business Council for Sustainable Development for measuring the environmental performance of companies. In addition VOCs were added as an indicator as they were judged to be of particular significance in the Tyre Industry.

The components of the data collected are shown in Table 3.1.

Because of the different characteristics of the activities considered separate models were developed for each activity in the Tyre Industry as follows:

- The manufacture of new and retread tyres in the UK.
- The use of tyres in the UK.
- Post-consumer tyre arisings in the UK.
- The processing, treatment and disposal of post-consumer tyres in the UK.

The relationship between the models is illustrated on opposite page.

An overview of each model is given below, along with the main assumptions used and an outline of the outputs that can be obtained. Further detail, including a schematic of each model and a copy of the data input tables, is given in Appendices B-E. The sources of the data used to populate the data are given at the end of this section, with further detail relating to each model given in the relevant appendices.
Table 3.1 Input and output data components

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Energy consumption</td>
<td>- Product output</td>
</tr>
<tr>
<td>- Water consumption</td>
<td>- Energy recovery</td>
</tr>
<tr>
<td>- Oxygen consumption</td>
<td>- Carbon dioxide</td>
</tr>
<tr>
<td>- Primary material consumption</td>
<td>- Methane</td>
</tr>
<tr>
<td>- Recovered material consumption</td>
<td>- Nitrous oxide</td>
</tr>
<tr>
<td></td>
<td>- Volatile organic compounds</td>
</tr>
<tr>
<td></td>
<td>- PM10</td>
</tr>
<tr>
<td></td>
<td>- Particulates</td>
</tr>
<tr>
<td></td>
<td>- Solid waste: Inert</td>
</tr>
<tr>
<td></td>
<td>- Solid waste: Hazardous</td>
</tr>
<tr>
<td></td>
<td>- Solid waste: Non-hazardous</td>
</tr>
<tr>
<td></td>
<td>- Liquid waste</td>
</tr>
<tr>
<td></td>
<td>- Aqueous waste</td>
</tr>
</tbody>
</table>

3.2 The manufacture of new and retread tyres in the UK

Introduction

The Tyre Manufacture model calculates the resources used in, and the environmental impacts of, the manufacture of tyres in the UK. The data is calculated and presented on a national basis (UK wide).

The model permits a limited number of variables to be manipulated in order to test the effects on natural resources and the environment of changes in the number and types of tyre manufactured and the material composition of tyres.

To avoid double counting in the mass balance approach the model deals only with those resource uses and environmental impacts directly associated with manufacturing, it does not consider resource uses and environmental impacts associated with the manufacture of materials or products supplied to manufacturers. It does not, for example, consider the energy used in the manufacture of the steel reinforcement supplied to the manufacturer, it deals only with the energy used to turn the steel reinforcement as supplied to the manufacture into the material used in the tyre. Resources used in the manufacture of the steel reinforcement are part of the steel mass balance not part of the Tyre Industry mass balance.

Because the model deals with all tyres manufactured in the UK, those produced for export are included. Tyres imported into the UK do not have a ‘manufacturing’ impact in the UK and are therefore not included. The impacts of the manufacture of these are experienced elsewhere.

Notwithstanding this a broad indication of the impacts experienced worldwide as result of tyres used in the UK can be estimated by inputting the number of each type sold in the UK each year. It must be stressed that this approach will only provide an estimate of resource use and environmental impacts based on UK manufacturing practices, it cannot take account of differing manufacturing practices that may be adopted elsewhere.

Main assumptions

To facilitate the calculations a number of assumptions have been made. These are set out below.

The total number manufactured in the UK can be rationalised into the following main categories:
a Car tyres
Conventional new
Low profile new
Conventional retread
Low profile retread

b Small trucks
Conventional new
Conventional retread

Low profile new

Conventional new
Conventional retread

Low profile new

Conventional new (including buses and coaches)
Conventional retread
Low profile retread

These categories were agreed with the Tyre Mass Balance Advisory Group as representing a reasonable range of types and sizes for the purpose of modelling resource use and environmental impacts.

**Output from the model**
The output from the model is the annual total of the natural resources used by, and the environmental impacts of, the UK tyre manufacturing industry based on the number and type manufactured.

### 3.3 The use of tyres in the UK

**Introduction**
The Tyre Use model calculates the resources used in, and the environmental impacts of, the use of tyres on the road in the UK. The data is calculated and presented on a national basis (UK wide).

The model permits a limited number of variables to be manipulated in order to test the effects on natural resources and the environment of the use of tyres on the roads of the UK depending on the type and the distances covered.

The model identifies the fuel and oxygen used in overcoming the rolling resistance of the tyres and the associated emissions, together with the tonnage of rubber deposited on the roads. Fuel and oxygen used in overcoming rolling resistance have been quantified, rather than total fuel and oxygen used, as these quantities are directly related to the properties of the tyres and are within the influence of the manufacturing industry.

The model deals with all tyres used on the roads in the UK irrespective of where they were manufactured.

**Main assumptions**
The classifications of types adopted for these calculations are the same as those adopted in the manufacturing model described above.

<table>
<thead>
<tr>
<th>Fuel (assume 1 tonne)</th>
<th>Use of oxygen (tonnes)</th>
<th>Production of H_2O (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol (led, lead replacement and unleaded)</td>
<td>3.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Diesel</td>
<td>3.4</td>
<td>1.2</td>
</tr>
<tr>
<td>LPG</td>
<td>3.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

The rolling resistance of new tyres and equivalent retread tyres is the same.

Four fuel types are assumed to be used in the UK - leaded petrol or lead replacement petrol, unleaded petrol, diesel and gas. Oxygen used in fuel consumption is calculated assuming total combustion and total efficiency.

The fuel used by vehicles with low profile tyres is proportional to the number of vehicles fitted with low profile tyres.

**Output from the model**
The output from the model comprises the tonnages of:

- Fuel (led, lead replacement and unleaded petrol, diesel, gas) and oxygen used in overcoming tyre rolling resistance each year over a ten year period.

- Emissions (H_2O, VOC, CO, CO_2, CH_4, NOX and particulates) from the fuel used in overcoming rolling resistance each year over a ten year period.

- Tyre rubber deposited on the roads each year over a ten year period.

### 3.4 Post-consumer tyre arisings in the UK

**Introduction**
The Post-consumer Tyre Arisings model calculates the total number of post-consumer tyres coming off road going vehicles which will require treatment, processing or disposal in a given year. It estimates both the total number arising in a number of tyre categories and the total tonnage of material requiring treatment, processing or disposal.

The data is calculated and presented by DETR English Planning Regions, Wales, Scotland and Northern Ireland (12 areas in total) allowing regional variations in vehicle ownership, distance travelled and ELVs arising to be taken into account.

The model permits a limited number of variables to be manipulated in order to test the effects of changes in patterns of vehicle ownership, types and usage, and in purchasing practices, tyre life and weights.
Because the model calculates tyres coming off vehicles imports of post-consumer tyres for re-use or retreading are included, imports of post-consumer tyres destined solely for other treatments or disposal are not included.

For ease of calculation it is assumed that post-consumer tyres arise in the same year that they are replaced. This fractionally over estimates arisings when vehicle numbers or tyre life are increasing and vice versa.

Main assumptions

To facilitate the calculations a number of assumptions have been made. These are set out below.

1 The total number of vehicles on the road in a region can be calculated from:
   a Cars The number of households in a region and the number of vehicles / household.
   b Small trucks The number of small trucks registered.
   c Large trucks The number of large trucks, including buses and coaches, registered.

2 The total number of ELVs in a region is proportional to the total number of vehicles of the same type on the road in the region. The total no. of ELVs is 1.8 m in 1998 (ACORD).

3 The total number of vehicles on the road can be rationalised into three main categories reflecting the broad similarities between tyres fitted on them:
   a Cars (Including light vans).
   b Small trucks
   c Large trucks (Including buses and coaches).

4 Tyres for each vehicle type can be placed into one of two main categories reflecting the differences in the manufacturing process and material composition:
   a Conventional (Cars, small trucks and large trucks).
   b Low profile (Cars and large trucks (large single tyre) only).

5 Tyres fitted to road going vehicles originate from one of three main sources. These tyres are assumed to have different lifespans as a result of their characteristics:
   a New manufacture
   b Retread 1
   c Part worn 2

Output from the model

The output from the model is the number and tonnage of arisings by the 9 English planning regions, Wales, Scotland and Northern Ireland by vehicle type and by tyre type for each year over a 15 year period from 1998 - 2012.

3.5 The processing, treatment and disposal of post-consumer tyres in the UK

Introduction

The Tyre Processing and Disposal model calculates the resource use (energy and oxygen), processed material outputs, wastes and emissions associated with the UK post-consumer tyre processing, treatment and disposal industries.

Fourteen processing, treatment and disposal routes are identified, categorised according to their position within the waste hierarchy. For each route the resource use, material outputs, wastes and emissions can be entered to facilitate the calculation of the UK wide total impact of the industries.

Main assumptions

The model uses the total tonnage of tyres processed in the UK in a given year apportioned by % by weight between fourteen post-consumer tyre destination processes identified by the Advisory Group.

Data is input on resource use, processed material outputs, wastes, emissions to air and energy recovered for each of the fourteen processing, treatment and disposal options. All of this data is input on a kg/tonne basis except for the energy data that is input on MJ/tonne of tyre processed.

Output from the model

The outputs from the model are the UK wide total tonnages of the following arising from the processing, treatment and disposal of post-consumer tyres in the UK:

- The energy and oxygen used.
- The material outputs.
- The wastes arising.
- The emissions generated.
- The energy recovered.

1 The lifespan entered for a retread is that for a single cycle of use, i.e. from new to first retreading, or from first regrooving to second regrooving.

2 The lifespan of a part worn tyre is measured from when it is fitted as a part worn tyre to when it is fully worn. Part worn tyres coming off ELVs are recorded as part of the 'post-consumer tyres from ELVs' calculation (see below)
3.6 Data sources, assumptions and confidence

In order to create the mass balance of the Industry the four models described above were populated with existing data for an identified base year – 1998. Where ever possible data was obtained from the direct sources within the UK. However where data was not available, sources from outside the UK were examined and where necessary assumptions made in order to indirectly calculate values to add to the models. For this reason levels of data quality varied. In order to assess the level of accuracy within the mass balance all data was classified in terms of data confidence as follows:

1. Highest confidence – data recognised as being accurate and robust and for which sources can be established.
2. Medium confidence – data based on expert judgement or assessment, not necessarily verifiable, but accepted by the Industry as being reasonable.
3. Lowest confidence – best estimates made by the Project Advisory Group and Project Team solely for the purpose of populating the database.

The main sources of data were Government and those organisations directly involved in the Tyre Industry. The major contributors are listed below:

- Used Tyre Working Group (UTWG).
- DETR (DETR no longer exists, responsibilities of the department are now within DEFRA, DfT and The Office of the Deputy Prime Minister).
- DTI.
- European Tyre Recycling Association (ETRA).
- NETCEN.
- British Rubber Manufacturers Association (BRMA).
- Imported Tyre Manufacturers Association (ITMA).
- Environment Agency.
- Direct correspondence with manufacturers and processors.

In a small number of cases no data could be found and the level of assumption required to populate the model was considered unreasonable. In these cases the model was left blank with no data.

Appendix F sets out all the data sources and the levels of confidence associated with them, and highlights those areas where data could not be found. The appendix also sets out the main assumptions made especially when having to calculate values. The aim has been to provide a transparent and accountable data set. In the future if better sources of data can be found these can be added to the model to achieve more accurate results.

Once the mass balance of the Tyre Industry had been established, the models were used to test various scenarios. Various changes were made to the model inputs in order to ‘create’ these scenarios. A summary of the changes is also set out in Appendix F.

4 Mass balance outputs

4.1 Summary mass balance

For each sector within the Tyre Industry, a summary mass balance was established, identifying those resource (including energy) inputs, and product and waste outputs. Wastes were split into solid/liquid waste and gaseous waste or ‘emissions’. These were combined to create a total mass balance of the Tyre Industry from which the major resource flows could be identified. These flows are summarised in Figure 4.1.

Overall there was a 4% discrepancy between inputs and outputs of mass, in favour of outputs. The data discrepancies reflect the inconsistency in some of the data collected and the assumptions used where data was missing or incomplete. These differences have been corrected for in Figure 4.1 based on confidence in the data used to calculate the flows. Table 4.1 indicates the values derived from actual data, and values obtained after correction. The assumptions used to make these corrections are set out in Appendix F, along with details of the size of the discrepancy between inputs and outputs in each component model.

Some of the key points from the resource flows are summarised as follows:

- Of the tyres manufactured in the UK, 391 kT (82%) are exported. Only 18% of tyres manufactured in the UK are used in the UK. The remaining demand for tyres is satisfied by imports, amounting to 432 kT of tyres.
- The greatest resource use is associated with tyre use, particularly the fuel used to overcome the rolling resistance of tyres. As a direct consequence, the greatest outputs are emissions (carbon dioxide and water vapour) resulting from fuel combustion.
- The stock of vehicles, and hence tyres on the road, increased over the year by 27 kT. Other changes in stock included an additional 32 kT held at tyre manufacturers/retailers, and an additional 23 kT stockpiled at reprocessors or disposed of illegally. Consequently, an additional 82 kT of resources were retained within the system during 1998.
Figure 4.1 Mass balance flows in the Tyre Industry
### Table 4.1 Summary of mass inputs and outputs used in the UK Tyre Industry (including imports and exports)

<table>
<thead>
<tr>
<th></th>
<th>Input (kT)</th>
<th></th>
<th>Output (kT)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Corrected</td>
<td>Actual</td>
<td>Corrected</td>
</tr>
<tr>
<td><strong>Tyre manufacture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource use</td>
<td>595</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Oxygen consumption</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Products</td>
<td>–</td>
<td>–</td>
<td>479</td>
<td>–</td>
</tr>
<tr>
<td>Recovered energy</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Solid and liquid waste</td>
<td>–</td>
<td>–</td>
<td>81</td>
<td>112</td>
</tr>
<tr>
<td>Emissions to air</td>
<td>–</td>
<td>–</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Tyres in use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK tyres manufactured</td>
<td>479</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Import of new/retread tyres and tyres on vehicles</td>
<td>432</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Export of new/retread tyres and tyres on vehicles</td>
<td>–</td>
<td>–</td>
<td>391</td>
<td>–</td>
</tr>
<tr>
<td>Addition to stock at retailers/manufacturers</td>
<td>–</td>
<td>–</td>
<td>32</td>
<td>–</td>
</tr>
<tr>
<td>UK replacement tyre sales</td>
<td>–</td>
<td>–</td>
<td>488</td>
<td>–</td>
</tr>
<tr>
<td>Resource use</td>
<td>9070</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>New tyres</td>
<td>488</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Oxygen consumption</td>
<td>30838</td>
<td>32440</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Solid and liquid waste (inc. post-consumer tyre arisings)</td>
<td>–</td>
<td>–</td>
<td>461</td>
<td>–</td>
</tr>
<tr>
<td>Emissions to air</td>
<td>–</td>
<td>–</td>
<td>41510</td>
<td>–</td>
</tr>
<tr>
<td>Addition to stock on roads</td>
<td>–</td>
<td>–</td>
<td>27</td>
<td>–</td>
</tr>
<tr>
<td><strong>Tyre processing and disposal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-consumer tyre casings from UK road vehicles</td>
<td>397</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Whole post-consumer tyre casings from 1997</td>
<td>5</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Imports of post-consumer tyres</td>
<td>20</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Export of post-consumer tyres</td>
<td>–</td>
<td>–</td>
<td>47</td>
<td>–</td>
</tr>
<tr>
<td>Resource use</td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Oxygen consumption</td>
<td>126</td>
<td>151</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Casings for retread manufacture</td>
<td>–</td>
<td>–</td>
<td>73</td>
<td>–</td>
</tr>
<tr>
<td>Recovered energy</td>
<td>–</td>
<td>–</td>
<td>64</td>
<td>–</td>
</tr>
<tr>
<td>Other products</td>
<td>–</td>
<td>–</td>
<td>98</td>
<td>96</td>
</tr>
<tr>
<td>Solid and liquid waste</td>
<td>–</td>
<td>–</td>
<td>102</td>
<td>–</td>
</tr>
<tr>
<td>Emissions to air</td>
<td>–</td>
<td>–</td>
<td>169</td>
<td>–</td>
</tr>
<tr>
<td>Addition to sand stock at tyre collectors/reprocessors</td>
<td>–</td>
<td>–</td>
<td>23</td>
<td>–</td>
</tr>
</tbody>
</table>

- Solid waste resulting from tyre use is due to tyre wear. The rubber loss during 1998 results from loss from the whole stock of tyres on the road (between 815 and 974 kT), not just those added in 1998.
- Only a small amount of material (< 2%) is recycled within the system, in the form of retread tyres.
- A proportion of recycled tyres used whole (in applications such as use in silage clamps) will return as ‘post-consumer tyre arisings’ in subsequent years. The number of tyres re-entering the reprocessing/disposal chain in this manner during 1998 was estimated to be 5 kT.
- A large proportion of the post-consumer tyre arisings (41%) are not reprocessed but disposed of in landfill, stockpiles or illegally dumped.
- The UK is a net exporter of post-consumer tyres.

Although this summary data and black box view is useful, it is important to understand the mass flows and mass stocks within each sector of the Tyre Industry. In the following sections, tyre stocks and mass flows within each individual sector are described in more detail.

### 4.2 Tyre stocks

There are three aspects to the stock of tyres in the Tyre Industry.

#### Tyres on the road

The number of vehicles on the road in the UK is steadily increasing as outlined in Figure 2.4. The number of vehicles (cars, buses and other commercial vehicles) registered by the end of 1997 was 24.5 million. The number of vehicles registered by the end of 1998 was 25.0 million. Assuming an average of 5 tyres associated with cars and 8 tyres associated with small and large trucks, this gives a total net gain of 1.81 million tyres on the road during 1998.
As the tyres within this ‘stock’ are of various ages and therefore in various states of wear, and as tyres produced in previous years weigh more than tyres produced now, it is not possible to give accurate predictions of the total tonnage on the road in 1998. However, if it is assumed that tyre weights are the same as new tyres, stock tonnage will vary between 815 and 974 kT depending on whether the tyres have undergone little or large amounts of wear. The net gain in stock on the roads in 1998 can be worked out by the following:

\[
\text{Additional weight of tyres on the road} = \text{weight of tyres going into system} - \text{weight of tyres leaving system} - \text{weight of particulate rubber removed from tyres}
\]

As can be seen in Figure 4.2 this equated to 27 kT.

**Post-consumer tyres in illegal stockpiles**

The locations of known stockpiles are given in Figure 2.7. The numbers present at each site range from 3,000 - 5,000,000 (assuming all car tyres this is between 0.02 - 33 kT at each site; assuming all truck tyres, this increases to between 0.16 – 270 kT at each site). The total estimate for all the sites lies between 30 and 50 million tonnes (300-500 kT). At 17 of the sites the tyres are mixed with other wastes, making recovery very difficult.

Up to date information on the number that are stockpiled and illegally dumped is patchy. There is limited data for some regions, for instance it is estimated that 2 kT per annum are illegally dumped in Essex (personal communication – Essex County Council). It was beyond the scope of this project to carry out a survey to collect more accurate data. However the mass balance model indicates that in 1998 alone, 23 kT of tyres were stockpiled. This will have added to the already large stock already in existence in stockpiles and illegal dumps.

N.B. It is possible that some of the 23 kT of tyres regarded as illegal stockpiles are actually located in legitimate stockpiles on sites belonging to collection companies or reprocessors.

**New tyres stored at retailers**

As detailed in Section 2.3 there are a large number of retailers distributed throughout the UK. The mass balance study indicated a total stockpile of 32 kT in tyre retail stores. It was not possible within the scope of the project to determine the number of new tyres held by retailers that were manufactured before 1998. However it is reasonable to assume that the majority will only be stored for short periods of time, preventing the build up of large stockpiles in these areas.

**4.3 Tyre manufacturing mass balance**

Figure 4.3 shows the flows of resources into and out of the new and retread manufacturing industry. More
detailed information regarding raw material and energy use, and product and waste outputs is given in Figure 4.4 and Figure 4.5 respectively. Unfortunately no data was available on the recycled component of new or retread manufacture.

The resource use is primarily recognisable raw materials used to manufacture tyres, however, there is a significant, input of energy (expressed in tonnes of oil equivalents). The main outputs are new and retread tyres, with some solid waste (primarily buffings from post-consumer tyres as they are prepared for retreading), liquid waste and relatively small quantities of emissions (volatile organic compounds and oxides of nitrogen).

Given that UK tyre manufacture does not supply the whole of the UK market; the remaining demand being satisfied by imports, it was important to understand the resource use and waste outputs for all the tyres required by the UK. Figure 4.6 compares the mass balance for actual UK tyre manufacture with ‘UK equivalent’ tyre manufacture which takes into consideration the resource requirements for those manufactured outside the UK, but imported for use within the UK. The assumption made is that the same proportion of inputs and outputs are required for manufacturing tyres outside the UK as inside. The term ‘UK equivalent’ has been used to highlight the fact that not all the raw material and energy inputs are required within the UK, and not all the wastes/emissions are released into the UK, but it is UK tyre use that is driving the need.

**Figure 4.3** Mass flows in the UK tyre manufacturing industry

**Figure 4.4** Quantity of resource use in UK tyre manufacturing
It is clear from Figure 4.6 that almost double the number of resources and impacts are associated with manufacturing all the tyres required in the UK compared to those actually manufactured in the UK.

4.4 Tyre use mass balance

Figure 4.7 shows the flows of resources associated with using tyres in the UK, again highlighting the inputs and outputs. More detailed information regarding resource use and waste outputs are given in Figure 4.8 and Figure 4.9 respectively.

The total inputs and outputs are much greater for tyre use than for their manufacture. Resource use other than tyres is dominated by fuel use to overcome rolling resistance and oxygen (obtained from the atmosphere) to aid in the combustion of the fuel. As a direct result of this, the main outputs are the by-products of combustion released in the form of gaseous wastes. The correlation between gaseous emissions from vehicles and public health has led to many changes both in the quality (and type) of fuel used and in the design of vehicles (including the introduction of catalytic converters). However, atmospheric pollution from vehicles, and their associated health impacts, is still a major issue in congested areas.

A relatively minor output in comparison to gaseous emissions is the abrasion of rubber tread during use. Loss of rubber from tyres contributes to the quantities of sediment and zinc found in highway runoff and the atmosphere. The total length of public roads in Great Britain in 1999 was 371,914 km. This equates to an average abrasion of 172 kg of rubber per km of road, although rubber loss will be greater on motorways where the traffic volume is greater, and in braking areas around junctions. Larger particles fall onto the road surface and are washed into the drainage system during wet weather.
Figure 4.7 Mass flows in tyre use in the UK

Figure 4.8 Quantity of resource use during tyre use in the UK
Finer rubber particles are transported by aerial dispersion into the atmosphere. Zinc found in tyre rubber can be detected in both highway runoff and in background atmospheric dust samples. As zinc is an essential element for humans, it is of less concern than other contaminants found in highway runoff and the atmosphere. As achievements continue in reducing the impacts of other more harmful contaminants, however, greater effort could be directed towards reducing the concentrations of contaminants like zinc.

No products are gained through tyre use, although there is an indirect benefit in that tyres associated with vehicles provide mobility to the general population to access employment, services and recreation sites, and to industry in the provision of raw materials and distribution of products (and wastes).

4.5 Tyre arisings

Figure 4.10 and Figure 4.11 show the quantity of post-consumer tyres arising, by weight and by number of units respectively, in 1998. The figures are further broken down to give an indication of the quantity of each category of tyre arising.

The variation between the two figures reflects the wide variation in weight between tyres in different categories. Post-consumer car tyre casings have an average weight of 6.5kg, and post-consumer large truck tyre casings 51kg. However, it should be noted that there are no distinct threshold weights between categories, and only average weights for each category have been used (weighted according to the relative proportions of different sizes in each category). The wide variation in weight, and the fact that some organisations monitor tonnages while other monitor the numbers of tyres, has led to problems in recording the exact number arising in any particular year, as experienced by the Used Tyre Working Group.

The model developed for the purpose of this project avoids this issue by predicting the number of tyres expected to arise as a result of the number currently in use, rather than from collating data on the number of tyres arising in any one particular location. The model
has the added benefit of being able to predict future post-consumer tyre arisings based on readily available statistics (DETR, 2000) relating to predicted vehicle ownership and mileage travelled.

The results from the model are very dependant on the average mileage figures inputted for any vehicle category, and on the average weight in any tyre category, both of which are hard to pinpoint. However the best available information was used at the time of model development, and predicted post-consumer tyre arisings for 1998 using the model (396,839 tonnes) were in the same order of magnitude as those presented by the Used Tyre Working Group (388,487 tonnes after exports have been deducted).

The breakdown of tyre arisings by region/country within the UK is given in Figure 4.12. Figures range from 10,932 tonnes in Northern Ireland, to 51,179 in the South East of England, and are a reflection of population density and affluence.

### 4.6 Tyre processing and disposal mass balance

Figure 4.13 shows the flows of mass in the tyre processing and disposal industry, again highlighting the inputs and outputs. More detailed information regarding resource use and waste outputs are given in Figure 4.14 and Figure 4.15 respectively.

Tyre processing and disposal also has its own characteristics in terms of the type of resources required, and the products/waste produced. The main ‘resource’ inputs are post-consumer tyre casings, with some fuel and oxygen use required during combustion processes. The outputs vary greatly in the range of ‘products’ from whole tyres that have been reused in engineering projects to individual component materials such as steel and crumbed rubber. Solid waste primarily comprises tyres going to landfill or illegally dumped, with emissions resulting from the combustion of tyres in energy recovery operations.

### 4.7 Environmental impact of the UK Tyre Industry

It should be noted that this is a mass balance study and not a life cycle analysis. Identifying the quantities of materials consumed and produced, although important in terms of resource use and depletion of non-renewable resources, may give a false impression in terms of the environmental impacts of wastes and emissions. It is a combination of the concentration and physical/chemical characteristics of a contaminant that determines its environmental impact.

Table 4.2 below summarises some of the material flows in the Tyre Industry that have a significant environmental impact, and generic actions that can be taken or are being taken to reduce the impacts.

At present the greatest impacts result from the use of non-renewable resources, and emissions resulting from the energy required to overcome rolling resistance. Further details on the environmental impacts of tyres can be obtained from ‘Tyres in the Environment’ (Environment Agency, 1998).

The sustainability issues that arise from the above analysis of mass flows in the Industry are discussed in Section 5.

### 5 Issues and future scenarios

#### 5.1 Introduction

The outputs from the mass balance models give a comprehensive review of the resource inputs and waste/emissions of the Tyre Industry for 1998, broken down by each sector of operation. As a result, some of the issues posed in Chapter 2 relating to current practice and the relative environmental impact of each sector of operation have been addressed. However, predictions regarding issues that the Industry may have to face in the future are also important. To address this, the models were programmed with sets of data that represented possible...
Figure 4.12 Quantity of post-consumer tyre arisings by region (tonnes)
Figure 4.13 Mass flows in UK tyre processing and disposal

Figure 4.14 Quantity of resource use in UK tyre processing and disposal
### Figure 4.15 Quantity of outputs in UK tyre processing and disposal

### Table 4.2 Environmental implications of the Tyre Industry

<table>
<thead>
<tr>
<th>Material</th>
<th>Impact</th>
<th>Actions to avoid / Reduce impact</th>
</tr>
</thead>
</table>
| Resource use during manufacture, use and reprocessing and disposal | • Depletion of oil reserves  
• Depletion of iron ore  
• Depletion of zinc oxide | • Increase recycled content of tyres  
• Extend life of tyres  
• Increase energy efficiency of processing |
| Atmospheric emissions during manufacture, use and reprocessing/disposal | • Quality of atmosphere  
• Human health (respiratory problems) | • Remove potential pollutants from manufacturing process  
• Increase energy efficiency  
• Improve technology to reduce emissions  
• Improve fuel quality or use low emission alternatives |
| Tyre abrasion during use | • Quality of water courses  
• Quality of atmosphere | • Reduce abrasion rate of tyres (extend life of tyres)  
• Maintain tyre pressures |
| Stockpiles of post-consumer tyres after use | • Fire risk  
• Quality of atmosphere  
• Quality of watercourses  
• Quality of soil and vegetation  
• Human health  
• Unsightly | • Increase reprocessing capacity for post-consumer tyres  
• Encourage development of recycled products and markets  
• Greater enforcement of regulations regarding illegal dumping |
future scenarios. Some of the scenarios were chosen to give a realistic view of the future situation, other scenarios were chosen deliberately to give an extreme view of one aspect of the Tyre Industry, to clearly demonstrate the benefits/disbenefits of an imbalance created in any particular direction.

The scenarios that were investigated are highlighted below, along with the results of the modelling activities. Future situations were modelled first (predicting the number of post-consumer tyre arisings and capacity for reprocessing/disposal), followed by future possible scenarios which may minimise resource use, minimise post-consumer tyre arisings, or encourage the use of reprocessing options which lie at the top of the waste hierarchy.

Figure 5.3 indicates that according to current Industry predictions there could be a heavy reliance in coming years on energy recovery, and recycling with energy recovery, to deal with post-consumer tyre arisings. The reprocessing plants for these technologies tend to be small in number, large in size (e.g. cement kilns) and deal with large tonnages of tyres. Reuse includes only retreading, and this is currently not expected to increase over coming years because of the poor market for passenger car retreads in the UK. Recycling tends to be carried out on a much smaller scale and there is a wide range of technologies that can be adopted to deal with tyres. It is therefore much more difficult to predict the increase in capacity. There is however much potential for development in this capacity.

In terms of sustainability, large processing plants with economies of scale in dealing with post-consumer tyres may be less desirable than a larger number of small plants, which are not necessarily as efficient in dealing with tyres, but do reduce transport costs and impacts (in line with

**Scenario 1: Future predicted quantities of post-consumer tyre arisings**

The tyre arisings model was programmed with data from DETR relating to future vehicle ownership and use in the UK. The outputs from the model are shown in Figures 5.1 and 5.2 below.

The trend is for an increase in post-consumer tyre arisings of approximately 30% over the 14 year period to 2012. The growth in post-consumer tyre arisings will be smaller if transport growth is less than currently predicted, for instance if:

- There is a greater modal shift from road to public transport than predicted.
- There is a greater movement of goods from road to rail and water transport than predicted.
- There are fewer and shorter car journeys undertaken by the population than predicted.

Post-consumer tyre arisings could also increase at a slower rate if there was greater uptake in the use of retreaded tyres. It should be noted, however, that the main driver for tyre retreading is the market for retreaded tyres, which is currently poor.

The split indicates that despite truck tyres being much smaller in numbers they make up a large proportion of the arisings in terms of tonnage. It is important for planning purposes for the Industry to be aware of the composition of the arisings. Many reprocessing technologies cannot use truck tyres, or require tyres to be shredded before use. Truck tyres will be more expensive and difficult to deal with.

![Figure 5.1 Predicted quantity of post-consumer tyre arisings in the UK (tonnes)](image-url)
Scenario 2: Processing capacity and quantity of post-consumer tyre arisings

Future capacities for various processing options were gathered direct from industry sources and compared with predicted post-consumer tyre arisings.

Figures 5.3, 5.5 and 5.6 present reprocessing capacities predicted from current capacities, planned new infrastructure and growth predicted by the Tyre Industry. These are therefore best case capacities which will only come on line if markets are stable and economic and permits and planning permissions are granted.

Figure 5.3 shows the changes in predicted capacity for each processing or disposal option for 1998, 2003, 2006 and 2012. Making predictions beyond 2006 proved difficult and should be viewed with caution.

As can be seen, landfill as an option disappears by 2006, with the biggest increases appearing in the energy and recycling with energy recovery.

Figure 5.5 compares post-consumer tyre arisings to capacity again, but here the potential capacity is broken down by existing capacity, planned new infrastructure and capacity which is under trial such as additional cement kilns burning tyres.

Figure 5.6 compares post-consumer tyre arisings to best case capacity on a regional basis.
the proximity principle). As transport was not included in the mass balance, it is difficult to compare economies of scale with the proximity principle, but further work to identify the optimum balance between these two important issues is obviously required. The principles of the waste hierarchy are that efforts should be focussed on minimising, reusing and recycling waste (those activities at the top of the waste hierarchy), rather than energy recovery and disposal (those at the bottom). While the first priority is to find alternatives to landfill (with energy recovery being an obvious choice), ultimately, the danger is that the recycling markets will not be able to develop because of the dominance of energy recovery. Incentives to minimise waste in the longer term may also be reduced. Figure 5.4 demonstrates the balance that is required between energy recovery, reuse/recycling and minimisation when determining how to address the issue of post-consumer tyres in a sustainable way.

Figure 5.4 Competing options for post-consumer tyres

Figure 5.5 shows the estimated increase in arisings in future years compared to existing and planned capacity to process post-consumer tyres. It is clear that with existing infrastructure there is a serious shortfall in capacity to process arisings on an annual basis. This is before thought is given to addressing the large numbers that are currently stored in existing illegal stockpiles.

Estimates of the capacity of planned new infrastructure have been gathered, and these indicate that the UK could have sufficient capacity to deal with used tyres. However, there is great uncertainty as to whether all the predicted capacity will actually come on line in the future, or whether it will come on line soon enough to be in place when the landfill directive is implemented in 2003. If none of the planned new infrastructure comes on line there will be a huge shortfall in capacity in both 2003 and 2006, a great deal larger than the shortfall in existence in 1998. Therefore there is the risk that the Tyre Industry will not be prepared for the implementation of the landfill directive and a large number will be illegally dumped or stockpiled.

To address both the shortfall in capacity and maintain a balance of processing solutions as indicated in Figure 5.4, there is a need to develop more recycling applications, products and markets (such as civil engineering applications for whole tyres and new markets for crumb rubber).

Figure 5.6 introduces the additional problem of the geographical location of arisings and markets. When post-consumer tyre arisings were compared to capacity on a regional planning scale, as shown in Figure 5.5, it can be

Figure 5.5 Predicted capacity to process post-consumer tyres (categorised by probability) compared with predicted post-consumer tyre arisings in the UK
Figure 5.6 Ability (best case scenario) of English planning regions, Wales, Scotland and Northern Ireland to process post-consumer tyre arisings

Figures on map indicate predicted post-consumer tyre arisings (kT)

<table>
<thead>
<tr>
<th>Year</th>
<th>1998</th>
<th>2003</th>
<th>2006</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity &lt; 80% of arisings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity between 80% and 100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity between 100% and 120%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity &gt; 120% of arisings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
seen that the ability of each region to process post-consumer tyres varies greatly. In 1998 only five of the regions had the capacity to deal with their arisings with a large concentration of capacity in the Midlands and North. In 2003 the southern regions are still lacking in capacity and with the implementation of the landfill directive very little of the country has the ability to deal with their own arisings. There is the risk that the processing plants in place will not be able to source the tonnages required to reach efficiency and will therefore be short lived or that tyres will have to be transported for large distances with associated environmental impacts. The proximity principle will not be achieved.

Therefore three main issues need to be considered by the Tyre Industry:

1. Will adequate processing capacity be in place in 2003/2006 when the landfill directive takes effect?

2. Will a balance be maintained between recycling and energy recovery reprocessing technologies with the implementation of the landfill directive?

3. Will the reprocessing facilities be suitably located in order to source the numbers of tyres required to be economic, and to achieve the proximity principle?

Increasing the proportion of retreads manufactured results in significant savings in raw materials and energy use. However, the proportion of retreads manufactured is driven primarily by market forces and, at present, a combination of poor public image and strong competition from budget imports is reducing sales of retreads.

As tyre use has the greatest impact of all the Industry sectors, any changes made to decrease resource use and/or emissions in this area will have significant effects on the total mass balance of the Industry. Rolling resistance is an obvious choice, and efforts are already being made by manufacturers to produce ‘energy efficient’ tyres with low rolling resistance. Greater education of the overall impacts of the use of energy efficient tyres would drive this market forward, especially with regard to savings in carbon emissions.

Although the savings in resource use by increasing the durability of a tyre are not as great as those resulting from reducing the rolling resistance, the reduction in post-consumer tyre arisings makes this a favourable option. Sale of these tyres will be market driven and, although ‘longer life’ tyres are a major selling point in America, the same is not currently true in the UK.

### Scenarios 3, 4 and 5: Ways to minimise resource and/or post-consumer tyre arisings

A doubling in retread manufacture in the UK from 52kT to 104kT retreads is as follows:

- Saves 15kT of rubber, 16 kT steel, 8 kT carbon black and 10kT of electricity (oil equivalents) per year.
- Increases solid waste by 8 kT per year (mainly due to greater amounts of particulates produced during retreading).
- If all the additional retreaded tyres were produced in the UK an additional 46kT of post-consumer tyre casings would be recycled each year.

A 10% reduction in the rolling resistance of a tyre had the following main effects:

- Saves 907kT fuel per year.
- Reduces emissions of VOCs by 14 kT, carbon dioxide by 2,878 kT, carbon monoxide by 83 kT and oxides of nitrogen by 20kT per year.
- Has no impact on post-consumer tyre arisings.

A 10% increase in life span of a tyre had the following main effects:

- Reduces rubber loss by 6 kT per year.
- Reduces post-consumer tyre arisings by 32 kT per year.
Scenario 6: Changes in type of processing option for post-consumer tyres

The impacts of allowing all post-consumer tyre arisings to be processed by one single option within the waste hierarchy were modelled.

By using the actual figures for 1998 as a baseline (in terms of the proportions of post-consumer tyres going to the various reprocessing and disposal options) and then assuming that the same number of tyres were processed using one option only, changes in the resource use, products, wastes and emissions can clearly be seen. The changes are presented in Figure 5.7. and are summarised below:

- **Reuse** increases raw material use by 78kT, energy use by 27kT and waste by 4kt. This is balance by an increase in products of 411kT and a reduction in carbon dioxide emissions of 126kT.

- **Recycling** decreases energy use by 5kT, solid waste by 1kt and carbon dioxide emissions by 126kT. Products are increased by 192kT.

- **Recovery (material)**: saves 15 kT in raw materials (rubber/steel), increases the quantity of products (rubber, steel, gas and oil) by 126 kT, reduces solid waste by 144 kT and reduces carbon dioxide emissions by 120 kT, increases energy use by 4kT, decreases energy recovery by 2kT.

- **Recove (energy)**: saves 15 kT in raw materials (rubber/steel) and reduces solid waste by 144 kT, but increases carbon dioxide emissions by 478kT, decreases energy use by 6kT, increases energy recovery by 243kT.

- **Landfill**: saves 15 kT in raw materials (rubber/steel), reduces the quantity of products by 251 kT, increases the amount of solid waste by 250 kT, but reduces the emissions of carbon dioxide by 478 kT.

Note: If the same calculation is carried out using 2003 and 2006 post-consumer tyre arisings figures, proportions stay the same but total inputs and outputs increase by 10% for 2003 and 17% for 2006.
The diversion of post-consumer tyres into reuse, recycle and or material recovery results in greater resource savings, or conversion of resource into useable products, with reduced emissions compared to the 1998 scenario. Although energy is gained during energy recovery operations, emissions associated with this are greater. For landfill, there is no benefit; all the resource goes to waste. This clearly demonstrates the sustainability benefits of promoting reuse and recycling (including material recovery) over energy recovery and landfill, and adds further support for the application of the waste hierarchy.

5.2 Influences on the recovery market

The scenarios tested above all provide an insight into how the number of arisings can be reduced, and where the Tyre Industry can make gains in sustainability in terms of efficient resource management and environmental impact. However, what cannot be ignored are the other criteria of sustainability; economics and social impacts. Both have a large influence over current (and future) practices. Some of the main economic and social influences relating to the Tyre Industry, particularly with regard to reprocessing and disposal, are summarised as follows:

Markets stability and investment costs

Many novel technologies exist to recycle post-consumer tyre arisings. However, set up costs for what are usually small to medium scale enterprises are high and it is difficult to obtain funding, especially when either the technologies or the economics are unproven. Competition for post-consumer tyres in some areas, and high transport costs in more rural areas leads to raw material supply problems. Longer-term markets and price stability for products are needed to encourage investment and create employment especially in rural or deprived areas; this is lacking for many products at present.

Disposal costs

Currently all reprocessors charge a gate fee and landfilling is becoming more expensive. This rise in cost has led to growth in unregulated markets, with more tyres being disposed of illegally. This puts added pressure on responsible tyre disposal companies to compete with illegal operations and remain profitable. The cost of disposal needs to be recognised and accepted, supported if necessary by greater enforcement (see below).

Regulation and monitoring

Illegal dumping is increasing (EA reference 2001 – Fran Lowe) because transport and disposal costs have increased steeply, and competition from low priced new tyres has made reuse less viable (ENDS 306). Greater regulation and enforcement is required to prevent illegal disposal. This issue is currently being addressed by the Environment Agency in the form of a national campaign to raise awareness, both within and outside the EA, of the environmental burdens of tyres. An understanding of those areas that have the greatest shortfall in reprocessing capacity, and which will be prone to more illegal operations, will enable EA to focus their efforts where they are needed most.

Tyre care

TyreCheck 2000 has found that 1 in 10 tyres on the UK roads are likely to be illegal, this equates to 13 million tyres on a national scale. The checks have also revealed that only 54% of tyres were correctly inflated to recommended levels (www.tyretradenews.co.uk). This has implications for the tyre disposal industry for two reasons:

- Tyres recovered below the legal tread depth are more likely to be in poor condition and unsuitable for retreading.

- Tyres incorrectly inflated increase fuel use and have a reduced lifespan, increasing the rate of post-consumer tyre arisings. Driver/passenger safety is also compromised.

Education of vehicle owners regarding these issues, and in car technology to inform owners immediately when pressure starts to drop will not only increase safety, but also reduce fuel use and extend tyre life.

Logistics

The logistics and costs required to collect post-consumer tyre arisings from around the country from a large number of sources and deliver them to the limited number of large reprocessing sites are enormous. For example, WTS collect 12 million post-consumer car casings and 0.5 million post-consumer truck casings annually (two hundred and twenty thousand casings a week). This requires approximately one hundred thousand collections by truck from all over the country. The minimum collection size is 100 car tyres and 20 truck tyres, with the average collection size being 160 tyres. The cost and environmental burden of this is great and efforts are already made by collection services to reduce the cost and environmental impact of the transport of tyres, as outlined in Box 5.1. It also raises the question of whether the small number of large centralised reprocessing plants should be balanced with a larger number of small local reprocessing facilities (see waste planning).
Waste planning and the waste hierarchy

The large number of sources of post-consumer tyres distributed all round the UK means it is difficult to regularly source large numbers for reprocessing. It also means disposal costs in outlying areas tend to be considerably higher and the incentives to fly-tip in these areas are great. An added complication is instability in the various reuse/recycling markets and the limited number of areas where these markets are located. The suspension of operations e.g. at the SITA ‘electricity from waste’ plant has had a large impact on the disposal options for post-consumer tyres, resulting in a significant increase in the number going back to landfill.

There is a greater need for information to be incorporated into the waste planning process. This will enable new reprocessing facilities to be encouraged in areas where shortfalls in capacity are expected, and/or where excessive transport costs may result in greater fly-tipping. It will also prevent excessive build up of capacity in areas where it is not required. As indicated above, careful consideration needs to be given to the proximity principle to address these issues without compromising competition and profitability.

6 Conclusions and Recommendations

6.1 Conclusions

Lack of consistent and available information for the whole Tyre Industry has hindered understanding of current and future issues. There has also been a lack of awareness of how issues in one sector of the Industry can influence sustainable change in other sectors. This mass balance study has given the Tyre Industry a detailed baseline of information on current practice, from which certain current and future issues have been identified. This information has been shared with all sectors of the Industry. There is a need, however, for greater cross communication, reporting and co-operation within the Industry, including consistent data collection.

In the past the inability to predict the quantity and location of post-consumer tyre arises means that the Industry has had to be reactive rather than being able to plan ahead. The results from the predictive model have shown that with the introduction of the Landfill Directive, there will be a continued shortfall in national processing/disposal capacity. More importantly, this shortfall will not be evenly distributed across the UK. Certain regions (such as the Midlands) already have an over capacity, while others (such as the Southeast) are in serious deficit.

In conjunction with lack of reprocessing capacity a serious problem to the UK is that of illegal dumping of post-consumer tyres. Under the Duty of Care regulations the Tyre Industry should ensure that tyres it produces or handles are properly disposed of. However tyre collection takes place where post-consumer tyres are not disposed of in a responsible manner - adding them to illegal stockpiles or flytipping. This undermines the businesses of responsible collectors and reprocessors.

Co-ordinated efforts are needed to address these issues. On one hand efforts need to be made to encourage the development of new technologies, give stability to emerging markets, inform the planning process to ease the approval process and inform the Regulators to ease the consent process. This will help to increase investor confidence. In parallel to this there needs to be control of illegal operations, education of vehicle dismantlers, garage services, tyre distributors and retreaders to ensure the collector is legitimate and education of the general public regarding tyre use and disposal. Only then will sufficient capacity be created within the short time-scale available.

While there is an excess of post-consumer tyre arises over capacity, tyres will tend to be perceived as a waste rather than a valued resource. Large scale operations that can remove this waste quickly and cheaply will be favoured over smaller scale more costly reprocessing options, as shown by the rapid increase of energy recovery operations. Investment is needed in post-consumer tyre reprocessing options that are higher up the waste hierarchy and meet economies of scale by being placed to deal with local capacity. In this way more sustainable use of resources is met, including reducing the large costs.
and impacts associated with transporting tyres vast distances, and also discourage illegal dumping.

Having detailed information on the resource use and waste outputs within the Industry allows actions to be focused in areas where the greatest sustainable benefit can be achieved. Concentrating on solutions for post-consumer tyres is vital now because of the immediate challenge of the Landfill Directive. However the overall sustainability of the Tyre Industry needs to be improved to reduce the use of natural resources, and to minimise waste by reducing the number of post-consumer tyres arising which then reduces the immediate in hand problem.

For the Tyre Industry, it was found that the greatest resource use is in the fuel required to overcome the rolling resistance of a tyre, combined with the large number of vehicles in use and the increasing distances travelled by road. Improvements in tyre manufacturing can reduce the rolling resistance, but efforts can also be focussed outside of the Tyre Industry itself. For example, efforts to reduce movement of people by road have been initiated through integrated transport planning. Similar efforts are now required for the movement of freight. Advances in vehicle and fuel technologies can assist fuel economy, increase tyre life and enable drivers to monitor tyre pressures on a regular basis.

6.2 Recommendations

This report has identified current and future challenges and threats within the UK Tyre Industry. Although some of these are already being addressed there is presently no co-ordinated strategic framework of actions which is effectively dealing with these issues. Given increasing emphasis not just on the minimisation and recycling of waste but also on sustainable resource management throughout the life of a given material, if the Tyre and Vehicle Industry does not effect more sustainable change in its practices, further legislation and greater regulation of the Industry may result.

There is a need to manage current and future threats more effectively, thereby avoiding the need for further legislation/regulation. Five primary recommendations are made therefore that will achieve improvements in tyre sustainability (see below). These address the problems faced by the Tyre Industry while taking account of the sustainability principles of waste minimisation, the waste hierarchy and the proximity principle. Each recommendation has an associated list of actions that will create positive change. It is acknowledged that within each list some actions are contentious, some are conflicting and others may simply not be practicable at this time. The aim at this stage is to raise awareness of the range of options available to the Industry, not to define in detail what the Industry should do.

To decide upon, and implement, an actual package of measures that will effect sustainable change within the Tyre Industry, Stakeholders, Government and the Regulators need to work together to identify a 'National Strategy' of sustainability objectives and actions. Those responsible for undertaking each action need to be clearly identified and their commitment to achieving these actions obtained. Targets should be agreed for the accomplishment of each action, and the degree of success reported on an annual basis. In this manner sustainable change can be achieved through co-operation rather than regulation. Whatever the package of measures adopted, however, the Industry must be able to monitor, re-evaluate and achieve continuous improvement.

**Improve sustainability in the UK Tyre Industry through integrated product policy development**

1. Establish stakeholder partnership arrangements across full supply chain (vehicle manufacturers, tyre manufacturers, tyre component manufacturers, tyre collectors and tyre reprocessors, secondary product manufacturers) to improve product sustainability.


3. Make mandatory the use of existing in-car technology to aid monitoring of tyre inflation/tyre wear.


5. Improve design for ‘low energy’ tyres with lower rolling resistance.

6. Increase the recycled component of tyres.

7. Design tyres to facilitate retreading.

8. Establish targets to optimise resource use and waste outputs from tyre manufacturing and reprocessing.

9. Design vehicles which reduce the abrasion rate of tyres.

10. Provide clear labelling and information of tyre characteristics for consumers (e.g. tyre life, grip etc).

11. Disseminate sustainability improvements through environmental/sustainability reports.

### Implement comprehensive, consistent and permanent resource flow monitoring and reporting procedures

1. Define standardised method of calculation of post-consumer tyre arisings (based on tyres in use as opposed to sales?).
2. Establish systematic tracking of tyre movements, including tagging of tyres.
3. Record both the weight and units of tyres handled at all stages within the life-cycle.
4. Encourage the use of responsible (audited) tyre collection companies.
5. Implement continual programme of information dissemination to inform strategy and action development (including use of environmental/sustainability reports).

### Implement waste planning initiatives that maintain balance of centralised reprocessing with regional reprocessing, and target capacity to need

1. Annual review of reprocessing capacity on a national and regional level and identify those areas with greatest need for rapid increase in reprocessing capacity.
2. Develop and implement a national strategy for increasing reprocessing capacity, which balances large scale and small scale reprocessing facilities, and targets capacity to need on a regional basis. Disseminate to Local, Regional and National Planning Authorities.
3. Improve the planning approval process by streamlining and educating of the need for targeted reprocessing facilities.

### Promote and encourage investment in prioritised new recycling technologies and markets

1. National review of composition of existing reprocessing capacity against the need for reprocessing (see above) and the objectives of national waste strategies that encourage movement up the waste hierarchy.
2. Identify and encourage development of recycle and material recovery ‘product’ markets e.g. by standardisation of products and encouragement of use in engineering applications.
3. Establish alternative sources of funding for development of new recycling technologies and markets, especially in rural areas where transport costs are high and illegal dumping is of concern (e.g. regeneration funds).
4. Stabilise markets (and market price) e.g. by setting minimum cost of disposal for tyres and preventing over-dominance of market by energy recovery operations.
5. Control current potential growth in energy recovery (which lies close to the bottom of the waste hierarchy) to further recycle, reuse and minimisation.
6. Consider levy to be used for market and product development initiatives.

### Implement Environment Agency national ‘Duty of Care Awareness/Compliance’ campaign

1. Stronger enforcement of current legislation to reduce illegal dumping (including additional funding?).
2. Increase punishment for offenders.
3. Education campaign for general public to ensure tyres are returned to responsible organisations.
4. Education campaign for general public to ensure tyres are properly inflated and maintained.
5. Comprehensive review/audit of existing illegal dumps and stockpiles.
6. Clarification of who is responsible for ‘removal costs’ of existing dumps and stockpiles.
7. Clarification, and consistent interpretation, of waste regulations.
7 References


Scott P J (1993). Study of location of major UK tyre deposits. ETSU.


UNECE (1987). Recycling of used tyres and rubber wastes. UNECE


Websites (available at time of printing)

Energy Power Resources: www.eprl.co.uk

Environment Agency: www.environment-agency.gov.uk

International Rubber Research and Development Board: www.irrdb.org

Gas Association of New Zealand: www.ganz.org.uk

National Tyre Distributors Association (NTDA): www.ntda.co.uk

NETCEN: www.aeat.co.uk/netcen/airqual

Retread Manufacturers Association (RMA): www.retreaders.org.uk/index

Scrap Tire News: www.scraptirenews.com

Tyre Trade News: www.tyretradenews.co.uk

Used Tyre Working Group: www.tyredisposal.co.uk

Waste Tyre Solutions: www.wastetyres.com
Appendix A: Mass balance study concept and boundaries

The mass balance concept

The information given below is taken from ‘Mass Balance UK: Mapping UK Resource and Material Flows’ (Linstead and Ekins 2001). This publication was written by Forum for the Future as a guide to data co-ordination for the series of Biffaward Mass Balance projects.

The purpose of a mass balance study is to follow and quantify the flow of a material or materials in a defined situation and over a period of time. This allows the identification of points in the life cycle where resource use is most inefficient and tacks the types and quantities of waste produced. The fundamental theory behind the mass balance is that mass can be transformed but not created or destroyed, therefore within a closed system total mass is constant.

Irrespective of where the system boundaries are set, the mass of inputs, mass of outputs and change in mass of the system should balance. Data is required on the initial mass or stock of tyres, the movement of mass into the Tyre Industry, the mobilisation of mass within the Tyre Industry through manufacture, the loss of mass through disposal or dispersion to the natural environment and the movement of mass out of the Industry.

In addition, from the point of view of tracking resource efficiency and the cycling of materials within the Industry the mass of material that is recycled or recovered needs to be accounted for. The data needs to be collected for a set accounting period, in this study this was one year from January to December 1998. This allows changes in flows to be tracked over time as well as geographical and economical space.

Mass balance boundaries

<table>
<thead>
<tr>
<th>Issue</th>
<th>Boundary</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyre types.</td>
<td>Includes car / truck / bus vehicle tyres.</td>
<td>The main driver for the project was the impact of the landfill directive. The directive includes car, truck, bus, motorbike, solid industrial and agricultural up to a certain size. Those covered by the directive but excluded from the report represent only a very small proportion of the overall tyres requiring disposal.</td>
</tr>
<tr>
<td></td>
<td>Excludes motorcycle, bicycle, motor sport and industrial tyres.</td>
<td></td>
</tr>
<tr>
<td>Energy.</td>
<td>Includes fuel used to overcome rolling resistance of tyre during tyre use. Includes energy use for manufacturing and disposal processes.</td>
<td>The flow of energy is normally only included in a mass balance in so far as a certain mass of fossil fuel or biomass is mobilised to generate energy. However energy is an important product from many of the tyre disposal processes and it was though important to include for illustration purposes.</td>
</tr>
<tr>
<td></td>
<td>Energy was included in this mass balance by converting energy consumption and recovery figures to a tonnage of oil equivalent. The conversion factor was obtained from the DETR Digest of Energy Statistics (2000).</td>
<td></td>
</tr>
<tr>
<td>Water.</td>
<td>Included as a product from a direct combustion process such as fuel combustion. Excluded as a input (resource use) and output (aqueous waste /steam).</td>
<td>Water consumption data was requested along with data on aqueous waste production. However the data set obtained was incomplete and therefore could not be included in the model. It would be desirable to collect data on water consumption in the future.</td>
</tr>
<tr>
<td>Oxygen.</td>
<td>Included in the mass balance if their was a direct combustion process e.g. burning fuel in cars to overcome the rolling resistance of tyres. Excluded when the energy utilised by a process came from the national grid.</td>
<td>Including oxygen consumed producing electricity for the national grip would have been accounting for mass flows in the energy sector and therefore double counting.</td>
</tr>
<tr>
<td>Packaging.</td>
<td>Excluded.</td>
<td>Though to be double counting with any mass balance study of the packaging industry.</td>
</tr>
<tr>
<td>Transport.</td>
<td>Includes the use of tyres once on vehicle. Excludes mass flows associated with transport of tyres to retailer and after tyre is removed from vehicles.</td>
<td>Beyond the scope of data collection.</td>
</tr>
<tr>
<td>Other periphery activities in the Tyre Industry.</td>
<td>Excluded.</td>
<td>Beyond the scope of the project.</td>
</tr>
</tbody>
</table>
Appendix B: Details of manufacturing model

**Basis of the calculations**

The calculations are based on three key data sets:

- The number of each type of tyre manufactured.
- The resources used in the manufacture of each type of tyre.
- The wastes and emissions associated with the manufacture of each tyre type.

The total resources used by tyre manufacture in the UK is the product of:

\[ \text{The total number of each tyre type manufactured} \times \text{The resources used in the manufacture of each tyre type} \]

The total environmental impact of tyre manufacture in the UK is the product of:

\[ \text{The total number of each tyre type manufactured} \times \text{The wastes and emissions associated with the manufacture of each tyre type} \]

**Variables**

The following input data can be varied to quantify the resource use and environmental impacts of a range of tyre manufacturing outputs.

**Material Resources use**

<table>
<thead>
<tr>
<th>Material Resources use</th>
<th>Retarders</th>
<th>Waxes</th>
<th>Tackifying resins</th>
<th>Hardeners</th>
<th>Dessicants - calcium oxide</th>
<th>Peptisers</th>
<th>Colouring pigments - iron oxide</th>
<th>Flame retardents</th>
<th>Steel</th>
<th>Nylon</th>
<th>Rayon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole post-consumer casings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synthetic rubber - SBR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural rubber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber preservatives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulcanising agents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fillers - carbon black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasticisers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anti - oxidants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activators - zinc oxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stain protectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Energy use (MJ)**

- Electricity
- Solid fuel
- Fuel oils
- Gas
- Oxygen for combustion (tonnes)

**Emissions to air**

- H₂O
- VOC
- CO₂
- CH₄
- N₂O
- Particulates

**Wastes**

- Solid waste - inert
- Solid waste - hazardous
- Solid waste - non hazardous
- Liquid waste
- Aqueous waste
Appendix C: Details of tyre use model

Basis of the calculations
The number of cars on the road is calculated from the number of households and rates of car ownership.

The fuel used by a vehicle in overcoming rolling resistance is expressed as a % of the total fuel used by a vehicle (based on data provided tyre manufacturers). The emissions associated with overcoming rolling resistance are directly proportional to the fuel used.

Accordingly the total of each type of emission arising from overcoming the rolling resistance of tyres is the sum of the products of the following formula for each tyre and fuel type:

\[
\text{Total tonnage of fuel burned} \times \% \text{ of total fuel used in overcoming rolling resistance} \times \left( \frac{\text{tonnage of emission}}{\text{tonne of fuel burned}} \right).
\]

The tonnage of tyre rubber deposited on the roads in a given year is the sum of the products of the following formula for each vehicle and tyre type:

\[
\text{The total number of each tyre type on the road} \times \text{the average distance covered by the vehicle in a year} \times \left( \frac{\text{the weight of a new tyre} - \text{the weight of a post-consumer tyre}}{\text{the average life of the tyre}} \right).
\]

Variables
The following data may be varied in the model:

- Quantity and type of fuel used by each vehicle type.
- Number of households.
- Number of cars / household.
- Number of small and large trucks on the road.
- Annual % change in car / truck ownership by vehicle type.
- Average no. of road tyres / vehicle exc. spares by vehicle type.
- Low profile tyres as a % of total tyres on road by vehicle type.
- % of fuel used to overcome rolling resistance by tyre type.
- Weight of new tyre (kg) by tyre type.
- Weight of post-consumer tyre (kg) by tyre type.
- Average annual vehicle use (km) by vehicle type.
- Average lifespan of tyres (km) by tyre and vehicle type.
- Oxygen used tonnes / tonne of fuel by fuel type.
- \( \text{H}_2\text{O} \) tonnes/tonne of fuel used by fuel type.
- VOC tonnes/tonne of fuel used by fuel type.
- CO tonnes/tonne of fuel used by fuel type.
- \( \text{CO}_2 \) tonnes/tonne of fuel used by fuel type.
- \( \text{CH}_4 \) tonnes/tonne of fuel used by fuel type.
- \( \text{N}_2\text{O} \) tonnes/tonne of fuel used by fuel type.
- Particulates tonnes/1000 tonne of fuel used by fuel type.
Appendix D: Details of post-consumer tyre arisings model

**Basis of the calculations**

The calculations are based on two key data:

- The number of vehicles on the road.
- The number of ELVs arising.

Total number of waste tyre arisings in any year is the sum of:

- The total number of tyres routinely replaced in a year +
- The total number of tyres taken from ELVs

**Routine replacement**

The total number of tyres routinely replaced on a vehicle in a year can be calculated from:

\[
\text{The number of road wheels on the vehicle} \times \text{the average annual distance travelled by the vehicle} / \text{the average life of the tyre (in km)}.
\]

The total number of tyres routinely replaced in a region in a year can be calculated from:

\[
\text{The total number of vehicles on the road in the region} \times \text{The total number of tyres routinely replaced on a vehicle in a year}
\]

**Post-consumer tyres from ELVs**

The total number of tyres arising from ELVs in a year can be calculated from:

The total number of ELVs arising x (the total number of road wheels on the vehicle + 1)

It is acknowledged that at the point of final disposal ELVs often do not have a full complement of wheels / tyres with spare. However, for the purpose of this model tyres removed from ELVs prior to disposal are assumed to have been on the vehicle at disposal. For the purposes of the ‘Processing, Treatment and Disposal of Post-consumer Tyres in the UK’ model these same tyres are categorised by their destination i.e. re-used as part worn or used as an input material for retreading.

**Tonnages of post-consumer tyre arisings**

The tonnage of tyres arising is calculated from:

\[
\text{The total number of tyres arising by tyre type} \times \text{the average weight of each post-consumer tyre type}.
\]

**Variables**

The following data can be varied to ‘model’ a wide range of ‘what if’ scenarios:

- No. of households per region.
- No. of cars per household by region.
- No. of small and large trucks by region.
- % changes in numbers of cars, small and large truck per year.
- No. of wheels per vehicle by vehicle type.
- No. of ELVs of each vehicle type by region.
- % change in number of ELVs of each vehicle type per year.
- Average distance travelled by each vehicle type
- Change in distance travelled by each vehicle type per year.
- Proportions of different tyre types fitted to each vehicle type (conventional, low profile, new, retread or part worn).
- Weight of post-consumer tyres by type.
- Average lifespan of tyre in kms.
Appendix E: Details of tyre processing and disposal model

Basis of the calculations

The UK total resource use, processed material outputs, wastes, emissions to air and energy recovered is the sum of the products of:

The total tonnage of tyres arising in a given year x the proportion of the total processed in each process x the resource use, processed material outputs, wastes, emissions to air and energy recovered by each process.

Varying the total tonnage of tyres and the proportions going to via each route allows the effects of different processing, treatment and disposal options to be modelled.

Variables

The following data can be varied to ‘model’ a wide range of ‘what if’ scenarios.

- The total tonnage of post-consumer tyres processed in the UK.
- The proportion of post-consumer tyres going via each of the 14 possible processing, treatment or disposal routes.
- 16 different processed material outputs by each of the 14 possible processing, treatment or disposal routes.
- 5 different wastes by each of the 14 possible processing, treatment or disposal routes.
- 6 different emissions to air by each of the 14 possible processing, treatment or disposal routes.
- Energy recovered (as electricity or heat) by each of the 14 possible processing, treatment or disposal routes.
Appendix F: Data sources and confidence levels

Data sources and assumptions for mass balance models

Tyre weight categories

One of the main points of controversy when calculating post-consumer tyre arisings is reaching agreement on what tyre weights and tyre categories to use. In terms of the mass balance it was important to determine what categories and weights would be used early on in the project as the values would be used in most parts of the model. The Used Tyre Working Group used two categories in their 1998 calculations: car and truck. In discussion with the Used Tyre Working Group it was determined that further refinement was required in the truck category.

Through data provided by the UTWG it was determined that the weights being used for new and post-consumer car tyre casings was acceptable even when including heavier four by four and light commercial vehicle tyres. Four by fours and light commercial vehicles are a small proportion of the total number of vehicles in this category. Therefore when a proportional average is taken the average weight remains the same. To use a greater number of categories would have proven to difficult since the other data used in the models is not available down to this level of detail.

For trucks data was collected from tyre manufacturers and the UTWG for new tyre weights and post-consumer tyre weights. On this basis it was determined to split the truck category into small truck (3.5-7.5 tonnes in weight) and large truck (>7.5 tonnes in weight). The use of three categories allows a greater level of refinement to be included in the mass balance models and allows more confidence in the post-consumer tyre arising tonnages coming out of the model.

The final categories used and the associated new and post-consumer tyre weights are set out in the table below:

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>New tyre weight (kg)</th>
<th>Post-consumer tyre weight (kg)</th>
<th>Weight loss (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>8</td>
<td>6.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Commercial vehicle 3.5-7.5 tonnes</td>
<td>23</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Commercial vehicle and bus &gt; 7.5 tonnes</td>
<td>57</td>
<td>50</td>
<td>7</td>
</tr>
</tbody>
</table>

Tyre categories used in the mass balance models

Model limitations

Many small limitations in the model due are set out in the individual discussion of each model below. However there are some limitations that apply to all the models. The models do not:

- examine the impact of producing the raw materials for tyre manufacture;
- include any analysis of the impact of transport involved in moving the tyres around to be sold, processed, disposed of etc;
- include any analysis of subsidiary activities such as resources used in office activities.

Oxygen consumption and water emissions

Oxygen was included as a resource use and water as an emission in the models where a direct combustion process was involved. This included burning of fuel in tyre use and burning of tyres in incinerators and cement kilns. Oxygen use and water emissions were not counted when the combustion process was indirect such as in the generation of electricity to power a process. This would have meant including impacts in the Tyre Industry which were actually part of the power generating industry.

Reconciliation of the mass balance flows

In the flow diagrams illustrating the mass balance flows in the Tyre Industry any discrepancies have been corrected so that the inputs and outputs balance. The following explains where the adjustments were made and why:

- **Tyre manufacturing**: the inputs to this part of the mass balance were greater than the outputs. The emissions to air and waste figures were adjusted to make the flows balance. The decision was made because of the poor data quality in these areas.
- **Tyres in use**: the outputs were greater than the inputs in this section of the mass balance. In this model the largest flows were the oxygen consumption and emissions to air. Emissions to air were calculated based on data modelled by NETCEN, however the oxygen consumption was calculated based an idealised combustion equation. Therefore it was judged that oxygen was the source of the discrepancy and this was adjusted to make the flows balance.
- **Tyre processing**: the outputs were greater than the inputs in this section of the mass balance. Oxygen was
determined to be the source of the discrepancy. Tyres burnt for energy recovery consume oxygen and produce water and carbon dioxide. An idealised combustion equation was used to calculate the values but uncertainty existed because a tyre is a more complex fuel that petrol, diesel etc. The oxygen figure was adjusted the make the flows balance.

**Key to data confidence**

Tables are displayed below for each of the models setting out data sources and colour coded according the level of confidence given to this data. The key below explains the colour coding used:

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>High confidence</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>Medium confidence</td>
</tr>
<tr>
<td>LOW</td>
<td>Low confidence</td>
</tr>
<tr>
<td>NOT APPLICABLE</td>
<td>Not applicable used as a descriptor when no data could be obtained.</td>
</tr>
</tbody>
</table>

'Not applicable' has been used as a descriptor when no data could be obtained.
### Tyre manufacturing model

#### Data sources

<table>
<thead>
<tr>
<th>New tyre manufacture</th>
<th>Car</th>
<th>Small truck</th>
<th>Large truck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of tyres manufactured (000s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated from BRMA, ITMA and IRSG data.</td>
<td>Calculated from BRMA, ITMA and IRSG data.</td>
<td>Calculated from BRMA, ITMA and IRSG data.</td>
<td>Calculated from BRMA, ITMA and IRSG data.</td>
</tr>
<tr>
<td><strong>Average weight of new tyre (kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UTWG figure used.</td>
<td>Calculated from new tyre weights provided by UK tyre manufacturers.</td>
<td>Calculated from new tyre weights provided by UK tyre manufacturers.</td>
<td>Calculated from new tyre weights provided by UK tyre manufacturers.</td>
</tr>
<tr>
<td><strong>Average weight of post-consumer tyre (kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td><strong>Whole post-consumer casings (No.)</strong></td>
<td>Not applicable.</td>
<td>Not applicable.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Other raw materials</strong></td>
<td>Data provided in confidence by tyre manufacturer. Data has been aggregated.</td>
<td>Data provided in confidence by tyre manufacturer. Data has been aggregated.</td>
<td>AMAT Ltd.</td>
</tr>
</tbody>
</table>
### Tyre manufacturing model (Continued)

#### Data sources

<table>
<thead>
<tr>
<th>Retread tyre manufacture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of tyres manufactured (000s)</strong></td>
</tr>
<tr>
<td>Car</td>
</tr>
<tr>
<td>Conventional</td>
</tr>
<tr>
<td>Calculated from BRMA and RMA.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average weight of new retreaded tyre (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed to be same as new manufactured tyre.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average weight of post-consumer retreaded tyre (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed to be same as new manufactured tyre.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Whole post-consumer casings (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTWG.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other raw materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed that the raw materials and proportions used in new manufacture were the same in retread manufacture bar ing the use of textile and steel.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed energy requirements were 30% of that to make a new tyre, from RMA web site.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOCs and particulates calculated from US EPA emission factors making assumptions re amount of rubber removed during manufacture.</td>
</tr>
</tbody>
</table>
Notes and Assumptions

New tyre manufacture

- The most detailed breakdown on manufacturing production available was the split between car and truck tyre manufacture. Therefore it was assumed that an equal number of small truck and large truck new tyres were produced.
- The proportion of conventional to low profile tyres was calculated based on the proportion of tyre sales that were low profile in 1998.
- Due to wastage the raw material input should be more than 100%, however the only data available for new tyre manufacture was the percentage composition of a vehicle tyre. The model does not therefore properly account for the amount of resources used.
- The raw material inputs for new tyre manufacture is only based on one car tyre type and one truck tyre type so the data is not truly representative of the UK Tyre Industry.
- A figure of 11.7GJ per tonne of new tyres produced was used to calculate the energy use figure, taken from an academic paper. Data provided by a tyre manufacturer could not be used because a total energy use figure was given which included non tyre manufacture. However the tyre manufacturer did indicate that electricity was the energy source and therefore no utilisation of oxygen was included.
- No reliable data on waste was found for tyre manufacture. A tyre manufacturer provided us with the total amount of waste produced by the factory including manufacture of racing tyres and processed materials (compound and calendering). These figures were used to provide an average value for amount of waste produced per tonne of primary materials used, however it must be recognised that the data quality is very low.
- Some of the figures given were in terms of volume not weight. It was assumed that these wastes were water based and therefore that 1 litre was the equivalent of 1 kilogram.
- Emissions of VOCs from new tyre manufacture were calculated by dividing total VOC emissions in the UK in 1998 (NETCEN) by total UK tyre manufacture (BRMA)
- Emissions of particulates from new tyre manufacture were calculated using US EPA emission factors assuming that 5% of the tyre weight is removed during grinding sidewall.
- Particulate data assumes that particulates have not already been included in the waste figures. This may mean some double counting has been included since particulates are generally mainly collected in air filters.

Retread tyre manufacture

- The most detailed breakdown on manufacturing production available was the split between car and truck tyre manufacture. Therefore it was assumed that an equal number of small truck and large truck retread tyres were produced.
- The assumption was made that no low profile retread car passenger tyres were produced in 1998 and therefore the model does not take account of the introduction of retread low profile tyres in future years.
- The proportion of conventional to low profile tyres was calculated based on the proportion of tyre sales that were low profile in 1998.
- Figures for whole used casings used in retread manufacture were taken from the 1998 UTWP report.
• It is known that many used tyre casings will be discarded in the selection process of retreading. However due to lack of information it was assumed that the number used was equal to the number manufactured.

• No waste data could be found for retread manufacture and therefore these are not included in the mass balance.

• Emissions of VOCSs and particulates from retread manufacture were calculated using US EPA emission factors assuming that 5% of the post-consumer tyre casing weight is removed in preparing the casing for tread replacement. Calculations also assume that the amount of rubber added to the post-consumer tyre casing during retread manufacture is equivalent to the difference between a new tyre casing and a post-consumer tyre casing plus 5%.

**Both new and retread manufacture**

Much of the data for waste and emissions could not be obtained. Those values included are low in data confidence due to the large number of assumptions that had to be made. It was however decided that it was important to try and include values for particulates and VOCs. The following facts suggested that they were the most significant pollutants from tyre and retread manufacture:

• Tyre manufacture is a part B process. Local authorities have to monitor particulates and solvents but no other emissions.

• NETCEN who calculate the national emission inventory only look at VOC emissions from tyre manufacture.

• The US EPA have emission factors for tyre manufacture but only for particulates and VOCs.
<table>
<thead>
<tr>
<th></th>
<th>Vehicle type</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tyres in use model</strong></td>
<td><em>Data sources</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total fuel used</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LPG.</td>
<td>DTI Digest of Energy Statistics 2000.</td>
<td>Split between small truck and large truck calculated using fuel consumption data from a TRL study on HGV drive cycles.</td>
</tr>
<tr>
<td></td>
<td><strong>No. of households.</strong></td>
<td>Sum of DETR figures for regions including 1999 figure for NI.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td></td>
<td><strong>No. of cars / household.</strong></td>
<td>Sum of DETR figures including NI statistics calculated by dividing number of households by number of cars registered.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td></td>
<td><strong>No. of cars / trucks.</strong></td>
<td>Calculated from no of household and no car/household.</td>
<td>Calculated from DETR and Transport Commissioners figures. NI figure from Northern Ireland Statistics and Research Agency.</td>
</tr>
<tr>
<td></td>
<td><strong>Annual % change in vehicles on road consumer.</strong></td>
<td>Weighted average calculated from data in post-consumer tyre arisings model.</td>
<td>Weighted average calculated from data in post-consumer tyre arisings model.</td>
</tr>
<tr>
<td></td>
<td><strong>Average no. of road tyres / vehicle exc. spares.</strong></td>
<td>Project Team: own knowledge.</td>
<td>Calculated from DETR registration data and tyre weights supplied by UTWG and tyre manufacturers.</td>
</tr>
<tr>
<td></td>
<td><strong>Low profile tyres as a % of total tyres on road.</strong></td>
<td>Calculated from BRMA &amp; ITMA tyre sales figures.</td>
<td>Not applicable.</td>
</tr>
</tbody>
</table>
## Tyres in use model (Continued)

### Data sources

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Car</th>
<th>Small truck</th>
<th>Large truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of new tyre (kg).</td>
<td>UTWG figure used.</td>
<td>Calculated from new tyre weights provided by UK tyre manufacturers.</td>
<td>Calculated from new tyre weights provided by UK tyre manufacturers.</td>
</tr>
<tr>
<td>Weight of post-consumer tyre (kg).</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td>Average annual vehicle use (km).</td>
<td>Calculated from DETR vehicle km and registration data.</td>
<td>Calculated from DETR vehicle km and registration data.</td>
<td>Calculated from DETR vehicle km and registration data.</td>
</tr>
<tr>
<td>Fuel Use Emissions</td>
<td>Leaded petrol</td>
<td>Unleaded petrol</td>
<td>Diesel</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------</td>
<td>-----------------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>VOC tonnes/tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
</tr>
<tr>
<td><strong>CO tonnes/tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
</tr>
<tr>
<td><strong>CO2 tonnes/tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
</tr>
<tr>
<td><strong>CH4 tonnes/tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
</tr>
</tbody>
</table>
### Fuel Use Emissions

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Leaded petrol</th>
<th>Unleaded petrol</th>
<th>Diesel</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N₂O tonnes/tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Calculated from emissions tests on a VW Golf quoted at <a href="http://www.ganz.org.nz">www.ganz.org.nz</a></td>
</tr>
<tr>
<td><strong>Particulates tonnes/1000 tonne of fuel used.</strong></td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Emissions from leaded and unleaded petrol were assumed to be the same. Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Total emissions for 1998 (NETCEN) divided by the total number of tonnes of fuel consumed by car and truck road transport (see above).</td>
<td>Calculated from emissions tests on a VW Golf quoted at <a href="http://www.ganz.org.nz">www.ganz.org.nz</a></td>
</tr>
</tbody>
</table>
Notes and Assumptions

This model does not take account of the changing balance of fuel use e.g. the increased use of LPG in future years and does not take account of the change in emissions due to changes in the vehicle fleet in future years e.g. increased proportion having catalytic converter.

Total fuel used
The split in fuel consumption between small truck and large truck was calculated using fuel consumption data from a TRL study on HGV drive cycles.

Emissions
- Particulates do not include black smoke emissions.
- Emissions for petrol and diesel were calculated on the basis of total emissions for 1998 divided by the total number of tonnes of fuel consumed by car and truck road transport.
- Emissions from unleaded and leaded petrol were assumed to be the same.

Low profile tyres as a % of total tyres on road
- Calculated from BRMA tyre sales figures. Assumes that sales of low profiles reflect proportion of low profile tyres on road.

% of fuel used to overcome rolling resistance
- Average value used calculated from figures obtained from a number of sources.
- Assumption was made that the rolling resistance of new tyres and equivalent retreads is the same.

LPG
- Oxygen and water emissions calculated on the basis of a 50/50 split of propane and butane.
- Emissions data equivalent to that used for diesel and petrol was not available and therefore emissions were calculated from emissions tests on a VW Golf quoted at www.ganz.org.nz, no data was available for methane. Because of the small amount of LPG fuel involved compared to petrol and diesel this was considered to be an adequate source of data.
- An assumption was made that half of LPG is used by cars and half by trucks because no other data exists.
<table>
<thead>
<tr>
<th>Tyre type</th>
<th>New</th>
<th>Retread</th>
<th>Part worn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average life of tyres in kms: Conventional car tyre</strong></td>
<td>Medium figure taken from those quoted in Tyre Recycling after 2000: Status and Options, ETRA, 2000.</td>
<td>Retread assumed to have same lifespan as a new tyre. No better data has been found.</td>
<td>Part worn assumed to have half lifespan of a new tyre. No other data available.</td>
</tr>
<tr>
<td><strong>Average life of tyres in kms: Low profile car tyre</strong></td>
<td>Assumed to be the same as a conventional tyre.</td>
<td>Retread assumed to have same lifespan as a new tyre. No better data has been found.</td>
<td>Part worn assumed to have half lifespan of a new tyre. No other data available.</td>
</tr>
<tr>
<td><strong>Average life of tyres in kms: Conventional small truck tyre</strong></td>
<td>Medium figure taken from those quoted in Tyre Recycling after 2000: Status and Options, ETRA, 2000.</td>
<td>Retread assumed to have same lifespan as a new tyre. No better data has been found.</td>
<td>Part worn assumed to have half lifespan of a new tyre. No other data available.</td>
</tr>
<tr>
<td><strong>Average life of tyres in kms: Conventional large truck tyre</strong></td>
<td>Medium figure taken from those quoted in Tyre Recycling after 2000: Status and Options, ETRA, 2000.</td>
<td>Retread assumed to have same lifespan as a new tyre. No better data has been found.</td>
<td>Part worn assumed to have half lifespan of a new tyre. No other data available.</td>
</tr>
<tr>
<td><strong>Average life of tyres in kms: Low profile large truck tyre</strong></td>
<td>Assumed to be the same as a conventional tyre.</td>
<td>Retread assumed to have same lifespan as a new tyre. No better data has been found.</td>
<td>Part worn assumed to have half lifespan of a new tyre. No other data available.</td>
</tr>
<tr>
<td><strong>Average weights of post-consumer tyres in kgs: Conventional car tyre</strong></td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td><strong>Average weights of post-consumer tyres in kgs: Low profile car tyre</strong></td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td><strong>Average weights of post-consumer tyres in kgs: Conventional small truck tyre</strong></td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td><strong>Average weights of post-consumer tyres in kgs: Conventional large truck tyre</strong></td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
<tr>
<td><strong>Average weights of post-consumer tyres in kgs: Low profile large truck tyre</strong></td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
<td>Calculated from post-consumer tyre weights provided by Paul Hallett UTWG.</td>
</tr>
</tbody>
</table>
### Waste tyre sources model (Continued)

#### Data sources

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Car</th>
<th>Small truck</th>
<th>Large truck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of households 1998 (000s)</strong></td>
<td>DETR, NI is 1999 Figure.</td>
<td>Not applicable.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Annual % change in no. of households</strong></td>
<td>Calculated from DETR.</td>
<td>Not applicable.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>No. of cars/household</strong></td>
<td>DETR, NI statistic calculated by dividing number of households by number of cars registered.</td>
<td>Not applicable.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>No. of vehicles on road</strong></td>
<td>Not applicable.</td>
<td>Calculated from DETR and Transport Commissioners figures.</td>
<td>Calculated from DETR and Transport Commissioners figures.</td>
</tr>
<tr>
<td><strong>Annual % change in cars / household</strong></td>
<td>Calculated from DETR.</td>
<td>Not applicable.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Annual % change in vehicles on road</strong></td>
<td>Calculated from annual % change in no. of households and annual % change in cars / household.</td>
<td>Assumption, no data currently found.</td>
<td>Assumption, no data currently found.</td>
</tr>
<tr>
<td><strong>Average no. of road tyres exc. spares</strong></td>
<td>Project Team: own knowledge.</td>
<td>Calculated from DETR registration data and tyre weights supplied by UTWP and tyre manufacturers.</td>
<td>Calculated from DETR registration data and tyre weights supplied by UTWP and tyre manufacturers.</td>
</tr>
<tr>
<td><strong>Low profile tyres as a % of total fitted</strong></td>
<td>Calculated from BRMA &amp; ITMA tyre sales figures.</td>
<td>Not applicable.</td>
<td>Calculated from BRMA &amp; ITMA tyre sales figures.</td>
</tr>
<tr>
<td><strong>Average annual kms</strong></td>
<td>Calculated from DETR vehicle km and registration data.</td>
<td>Calculated from DETR vehicle km and registration data.</td>
<td>Calculated from DETR vehicle km and registration data.</td>
</tr>
<tr>
<td><strong>Annual % change in annual kms</strong></td>
<td>Calculated from DETR assuming implementation of 10 Transport Plan. 1999 will be overestimated due to having to apply same percentage annually.</td>
<td>Calculated from DETR assuming implementation of 10 Transport Plan. 1999 will be overestimated due to having to apply same percentage annually.</td>
<td>Calculated from DETR assuming implementation of 10 Transport Plan. 1999 will be overestimated due to having to apply same percentage annually.</td>
</tr>
<tr>
<td><strong>ELV arisings</strong></td>
<td>Calculated: the total ELV arisings figure in the EA Strategic Waste Management Assessment 2000 reports was broken down regionally by number of households.</td>
<td>Percentage of trucks scrapped in 1998 calculated from SMMT registration and vehicles in use data, probably overestimates but no better data available.</td>
<td>Percentage of trucks scrapped in 1998 calculated from SMMT registration and vehicles in use data, probably overestimates but no better data available.</td>
</tr>
</tbody>
</table>
### Waste tyre sources model (Continued)

**Data sources**

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Car</th>
<th>Small truck</th>
<th>Large truck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual % change in ELV arisings</strong></td>
<td>Assumes increases in line with increases in number of vehicles.</td>
<td>Fixed the same as change in number of vehicles on road which is an assumed figure, not better data currently found.</td>
<td>Fixed the same as change in number of vehicles on road which is an assumed figure, not better data currently found.</td>
</tr>
<tr>
<td><strong>% of tyres replaced with new tyres</strong></td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
</tr>
<tr>
<td><strong>% of tyres replaced with retreads</strong></td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
</tr>
<tr>
<td><strong>% of tyres replaced with part worn tyres</strong></td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
<td>Calculated from UTWG figures.</td>
</tr>
<tr>
<td><strong>% of part worn tyres that are retreads</strong></td>
<td>Assumption based on retread market share.</td>
<td>Assumption based on retread market share.</td>
<td>Assumption based on retread market share.</td>
</tr>
<tr>
<td><strong>% of tyres from ELVs that are low profile</strong></td>
<td>Calculated from BRMA &amp; ITMA tyre sales figures.</td>
<td>Not Applicable.</td>
<td>Calculated from BRMA &amp; ITMA tyre sales figures.</td>
</tr>
<tr>
<td><strong>% of tyres from ELVs that are retreads</strong></td>
<td>Assumption based on market share.</td>
<td>Assumption based on retread market share.</td>
<td>Assumption based on retread market share.</td>
</tr>
</tbody>
</table>
Notes and Assumptions

Average lifespans
● Retread tyres were assumed to have same lifespan as conventional tyres. The Tire Retread Information Bureau advised in a personal communication that generally, a retreaded tyre (car or truck) will last as long as a comparable new tire. However, the exact life span will depend on how the tyre is used. No comparison data was found.

Average weights of post-consumer tyres
● The calculated weights for the small and large truck tyres were based on three actual weights in each category. The calculated weight for the car tyre was based on 214 actual weights

Annual percentage change in small and large trucks on road
● No forecasts could be found to calculate this information. Therefore an assumption was made that there would be a 1% growth annually. This figure was chosen as the closest round figure to the forecast growth in car traffic.

Percentage of tyres replaced by new, retread and part worn tyres
● The market share of each type was calculated using replacement tyre sales and vehicle registrations for 1998 from the 1999 UTWG report. It was assumed that all tyres that went to be re-used as a part worn were re-used in 1998.

Percentage of part worn tyres that are retreads
● Assumption was that the percentage of part worns that were retreads was the same as the retread market share. This may be an overestimate but more accurate information was not available.

Percentage of tyres from ELVs that are retreads
● Assumption was that the percentage of tyres from ELV’s that were retreads would be the same as the retread market share.

Low profile tyres as a % of total fitted
● Calculated from BRMA & ITMA tyre sales figures. Assumes that sales of low profiles reflect proportion of low profile tyres fitted.

Percentage of tyres from ELVs that are low profile
● Assumes same proportion as low profile tyres as a percentage of total fitted.

Annual percentage change in annual kms
Figures were calculated from road forecasts assuming DETR 10 Year Transport Plan is implemented. Where a category included more than one class in the transport plan the growth rates were weighted according to number of vehicles registered in each class. The same growth factor had to be used for small and large truck categories as greater detail was not available. It is thought that the amount of traffic in 1999 will be underestimated as traffic growth would have been higher then before implementation of 10 year plan began in 2000.
## Tyre processing and disposal model

### Data sources

<table>
<thead>
<tr>
<th>Input resources</th>
<th>Output products and materials</th>
<th>Waste</th>
<th>Emissions</th>
<th>Energy recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Landfill engineering</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no output other than tyres.</td>
<td>Project team: Assumed no waste as being reused whole in stationary positions.</td>
<td>Project team: Assumed no emissions as being reused whole in stationary positions.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Coral reefs</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no output other than tyres.</td>
<td>Project team: Assumed no waste as being reused whole in stationary positions.</td>
<td>Project team: Assumed no emissions as being reused whole in stationary positions.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Crash barriers</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no output other than tyres.</td>
<td>Project team: Assumed no waste as being reused whole in stationary positions.</td>
<td>Project team: Assumed no emissions as being reused whole in stationary positions.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Other applications of whole tyres</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no output other than tyres.</td>
<td>Project team: Assumed no waste as being reused whole in stationary positions.</td>
<td>Project team: Assumed no emissions as being reused whole in stationary positions.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td><strong>Regroove</strong>&lt;br&gt;No data available.</td>
<td>No data available.</td>
<td>No data available.</td>
<td>No data available.</td>
<td>No data available.</td>
</tr>
<tr>
<td><strong>Retread</strong>&lt;br&gt;Figures taken from tyre manufacturing model using the same assumptions.</td>
<td>Figures taken from tyre manufacturing model using the same assumptions.</td>
<td>Figures taken from tyre manufacturing model using the same assumptions.</td>
<td>Figures taken from tyre manufacturing model using the same assumptions.</td>
<td>Figures taken from tyre manufacturing model using the same assumptions.</td>
</tr>
<tr>
<td><strong>Shredding</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed same as for crumbing.</td>
<td>Project team: Assumed same as for crumbing.</td>
<td>Project team: Assumed same as for crumbing.</td>
<td>Project team: Assumed same as for crumbing.</td>
</tr>
<tr>
<td><strong>Crumbling</strong>&lt;br&gt;Project team: Assumed no input other than tyres.</td>
<td>ETRA.</td>
<td>ETRA.</td>
<td>ETRA.</td>
<td>ETRA.</td>
</tr>
<tr>
<td><strong>Pyrolysis</strong>&lt;br&gt;Coalite Ltd and Beven Recycling: PC.</td>
<td>Coalite Ltd and Beven Recycling: PC.</td>
<td>Coalite Ltd: PC.</td>
<td>Coalite Ltd: PC.</td>
<td>Coalite Ltd: PC.</td>
</tr>
<tr>
<td><strong>Microwave technology</strong>&lt;br&gt;AMAT Technology: PC.</td>
<td>AMAT Technology: PC.</td>
<td>AMAT Technology: PC.</td>
<td>AMAT Technology: PC.</td>
<td>AMAT Technology: PC.</td>
</tr>
<tr>
<td>Tyre processing and disposal model (Continued)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data sources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input resources</th>
<th>Output products and materials</th>
<th>Waste</th>
<th>Emissions</th>
<th>Energy recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incineration with energy recovery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no input products due to incineration.</td>
<td>Environment Agency and NETCEN.</td>
<td>Environment Agency.</td>
<td>ETRA.</td>
</tr>
<tr>
<td><strong>Use as fuel in cement kiln</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETRA.</td>
<td>NETCEN.</td>
<td>NETCEN.</td>
<td>ETRA.</td>
<td></td>
</tr>
<tr>
<td><strong>Incineration without energy recovery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project team: Assumed same as incineration with energy recovery.</td>
<td>Project team: Assumed same as incineration with energy recovery.</td>
<td>Project team: Assumed same as incineration with energy recovery.</td>
<td>Project team: Assumed same as incineration with energy recovery.</td>
<td></td>
</tr>
<tr>
<td><strong>Landfill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project team: Assumed no input other than tyres.</td>
<td>Project team: Assumed no output other than tyres.</td>
<td>Project team: Assumed no waste as being reused whole in stationary positions.</td>
<td>Project team: Assumed no emissions as being reused whole in stationary positions.</td>
<td>Not applicable.</td>
</tr>
</tbody>
</table>
Notes and Assumptions

- This model covers the resource flows associated with the tyre destination once it has been removed from a vehicle.
- The input of total post-consumer tyre arisings is the tonnage coming out of the waste tyre sources model LESS Exports of Post-consumer Casings PLUS Imports of Post-consumer Casings.
- Where processes always or sometimes require shredding before processing the additional impacts have not been included, this includes tyres that are shredded while on vehicles as automotive shredder residue. The model does not include the impacts of turning whole tyres into bales or other whole tyre use applications in terms of energy and resource use. These considerations were beyond the scope of the project.
- Any possible leaching from coral reefs and landfill sites have been ignored
- No data was available for crumbing where textile and steel had been removed therefore all calculations based on assumption that all crumbing involves the removal of steel only.
- Any possible leaching from coral reefs and landfill sites have been ignored
- No data was available for crumbing where textile and steel had been removed therefore all calculations based on assumption that all crumbing involves the removal of steel only.

Shredding
- No data could be obtained for emissions from shredding. They were therefore assumed to be equivalent to those from crumbing.
- No data was available for the amount of tyres that were shredded with steel and textile recovered. Therefore it was assumed that all tyres that were shredded did not have steel and textile removed.

Crumbling
- No data was available for the amount of crumbing that is carried out to remove both steel and textile. Therefore it was assumed that all tyre crumbed only had steel removed.

Regrooving
- No data available

Retreading
- Figure for buffed rubber calculated on the assumption that 5% of the weight of the tyre will be buffed to prepare the tyre.
- Figure for retreaded tyres calculated on the assumption that the tonne of post-consumer tyres processed were all car tyres weighing 6.5kg and that once they were processed would weight 8kg.
- Emission and energy values were taken from the tyre manufacturing model and the same assumptions apply.
- No data was available for the waste produced by retreading.
- Particulate emissions assumes that these are released to air and not collected as waste, it also assumes that no double counting is occurring between particulate emissions and buffed rubber as a product.

Pyrolysis
- The data used was an average of that provided by Beven Recycling and Coalite Ltd except in the case of energy inputs where only Coalite’s provided data that was compatible with the units being used in the model.

Microwave technology
- Data was obtained for both car and truck tyres, however the model does not allow for this level of detail and therefore an average of these values was used.
- The gas produced by this process is not re-used. It will be emitted in a controlled manner. Some of the gas constituents are included in the emissions data.
- A figure for methane emissions was not available.

Incineration with energy recovery
- Data for VOCs was from Environment Agency pollution inventory. The figure quoted was <1t for 1998, therefore it was assumed that the emission was exactly this.

Incineration without energy recovery
- Data for incineration with energy recovery was used as a proxy for incineration without energy recovery.

Cement kilns
- A figure for VOC emissions was not available.
- The figures for oxygen utilisation and water emissions were calculated on the basis of a typical tyre being 46.5% rubber compound and that this compound was 46% natural rubber and 60% synthetic rubber. The oxygen and water associated with burning the rest of the tyre was not calculated.
Abstract

Lack of consistent and available information for the whole Tyre Industry has hindered understanding of current and future issues that need to be addressed to improve sustainability. There has also been a lack of awareness of how one sector of the Industry can influence sustainable change in the other sectors. This report sets out the current situation regarding the manufacture, use, reprocessing and disposal of tyres within the UK. It identifies current and future challenges and recommends options to achieve more sustainable changes.

In order to quantify the current situation in the Tyre Industry mass balance models were developed to generate post consumer tyre arisings by region, and resource use and environmental impacts of tyre manufacture, tyre use and tyre reprocessing. Post consumer tyre arisings were generated for base year of 1998 and predicted for future years. These were compared with estimated future reprocessing capacities. The other mass balance models gave data on the resource use from tyre manufacture, use and reprocessing.

It was found that (for 1998), 18% of tyres produced in the UK were used in the UK; 9070kT of fuel were consumed just to overcome the rolling resistance between tyres and the road surface; 40,000kT of air emissions were released resulting from fuel combustion; post consumer tyre arisings will increase by approximately 30% by 2012. Regarding disposal, 41% of the post consumer tyre arisings in 1998 were not reprocessed but disposed of in landfill, stockpiles or illegally dumped.

Five primary recommendations are presented that will achieve improvements in tyre sustainability. Each recommendation has an associated list of actions that can create positive sustainable change.

- Improve sustainability in the UK Tyre Industry through Integrated Product Policy development.
- Implement comprehensive, consistent and permanent resource flow monitoring and reporting procedures.
- Implement waste planning initiatives that maintain balance of centralised reprocessing with regional reprocessing, and target capacity to need.
- Promote and encourage investment in prioritised new recycling technologies and markets.
- Implement Environment Agency national ‘Duty of Care Awareness/Compliance campaign’.

Related publications

VR3  The status of post-consumer tyres in the European Union by V L Shulman (European Tyre Recycling Association). 2002 (price £40, code EX)

TRL200  Re-use of scrap tyres in highway drainage by J Carswell and E J Jenkins. 1996 (price £25, code E)

CT100.2  Vehicle tyres - design and safety update (2000-2002) Current Topics in Transport: selected abstracts from TRL Library’s database (price £20)

CT130.1  Rubber in bituminous pavements update (1998-2001) Current Topics in Transport: selected abstracts from TRL Library’s database (price £20)

Prices current at September 2002

For further details of these and all other Viridis and TRL publications, telephone Publication Sales on 01344 770783, or visit TRL on the Internet at www.trl.co.uk.