Tyre Generic Exposure Scenario

End of Life Tyre Guidance

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List of Abbreviations

BREF	Reference Document on Best Available Technique
CSA	Chemical Safety Assessment
DU	Downstream User
ELT	End-of-life tyre
ERC	Environmental Release Category
ESD	Emission Scenario Document
eSDS	Extended Safety Data Sheet
LCA	Life Cycle Analysis
M/I	Manufacture/Importer
PEC	Predicted Environmental Concentration
PROC	Process Category
RAR	Risk Assessment Report
RCR	Risk Characterization Ratio
STP	Sewage Treatment Plant
TDF	Tyre Derived Fuel
TGD	Technical Guidance Document

1.0 Summary

Waste operators are not considered downstream users (DU) under the REACH legislation; however, registrants of dangerous substances must cover the waste life stage for identified uses of the substances. Waste life operations relevant to end-of-life tyres (ELT) include storage, material recovery (i.e. shredding, grinding, pyrolysis) and energy recovery (i.e. cement kiln, power plants and electric arc furnaces). Material recovery can also occur as a part of energy recovery including silica and steel incorporated into cement clinker, ash generated during incineration and steel recovered in electric arc furnaces. The waste life scenarios are shown in Figure 1 as defined in the REACH guidance and in Figure 2 as adapted in this report to ELT. A waste life template for ELT has been prepared and presented in Section 4.0. Proposed process categories (PROC) and environmental release categories (ERCs) are presented in the template for each waste operation. In addition, waste treatment type codes are assigned, best available technique documents are identified and relevant EU directives are listed. More detailed information and citations are provided for each waste treatment category in the appendices.

Based on the REACH Chemical Safety Assessment (CSA) Technical Guidance Document (TGD) Chapter R.18 and Commission services interpretations, manufacturers and importers (M/I) are not required to register the use of a substance as a recovered substance because the life cycle of the 'original' substance ends when it ceases to be waste (Section 2.0). The primary purpose of the assessment of the waste life stage in the CSA is to define the substance-specific measures (if any) required to complement existing waste treatment related requirements (Section 3.0). M/I may choose to include general statements in the CSA regarding the various applications where recycled end-of-life tyres have be successfully and safely used outside of the waste life stage as discussed in Section 5.0.

Figure 1: Generic waste life stage of a substance (REACH CSA TGD Figure R.18-2).

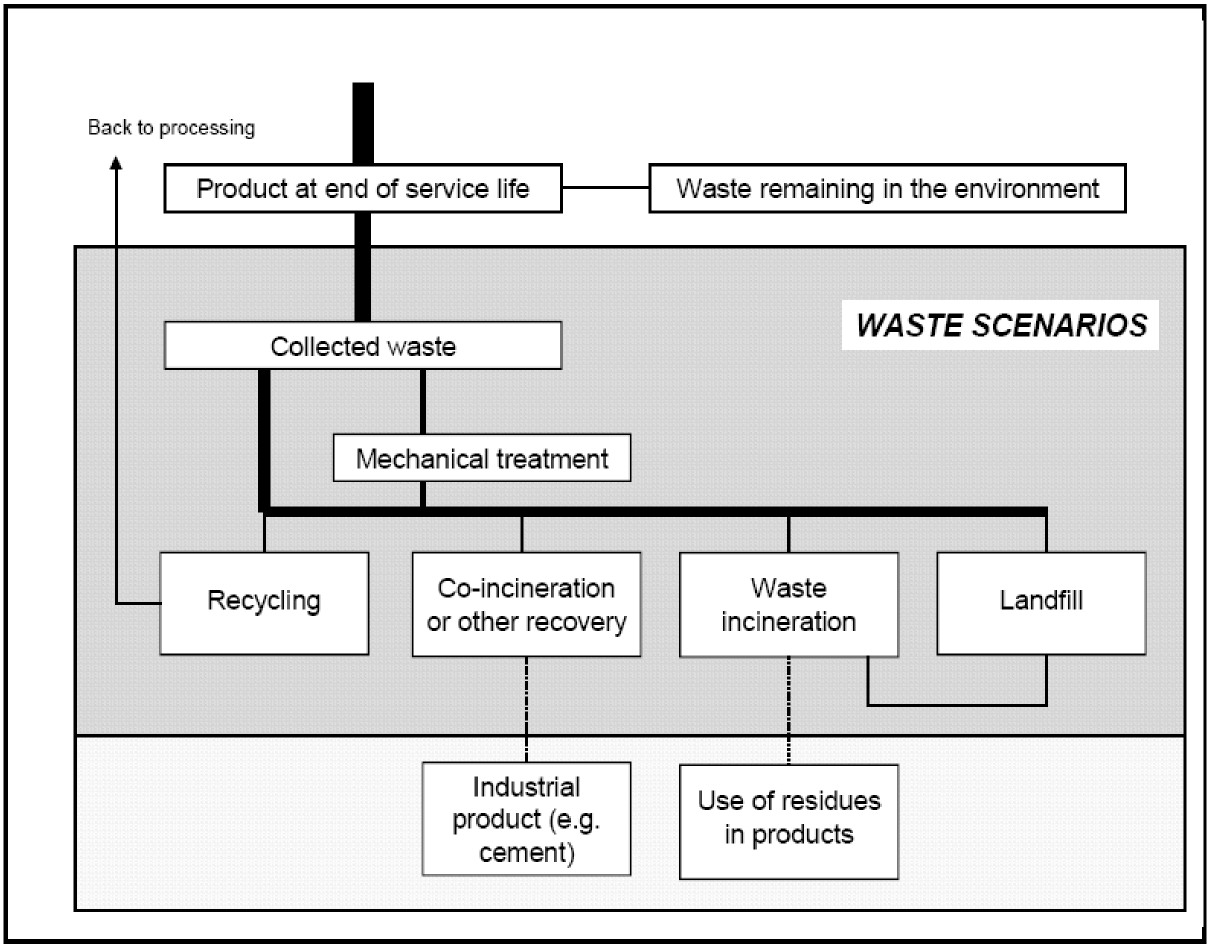
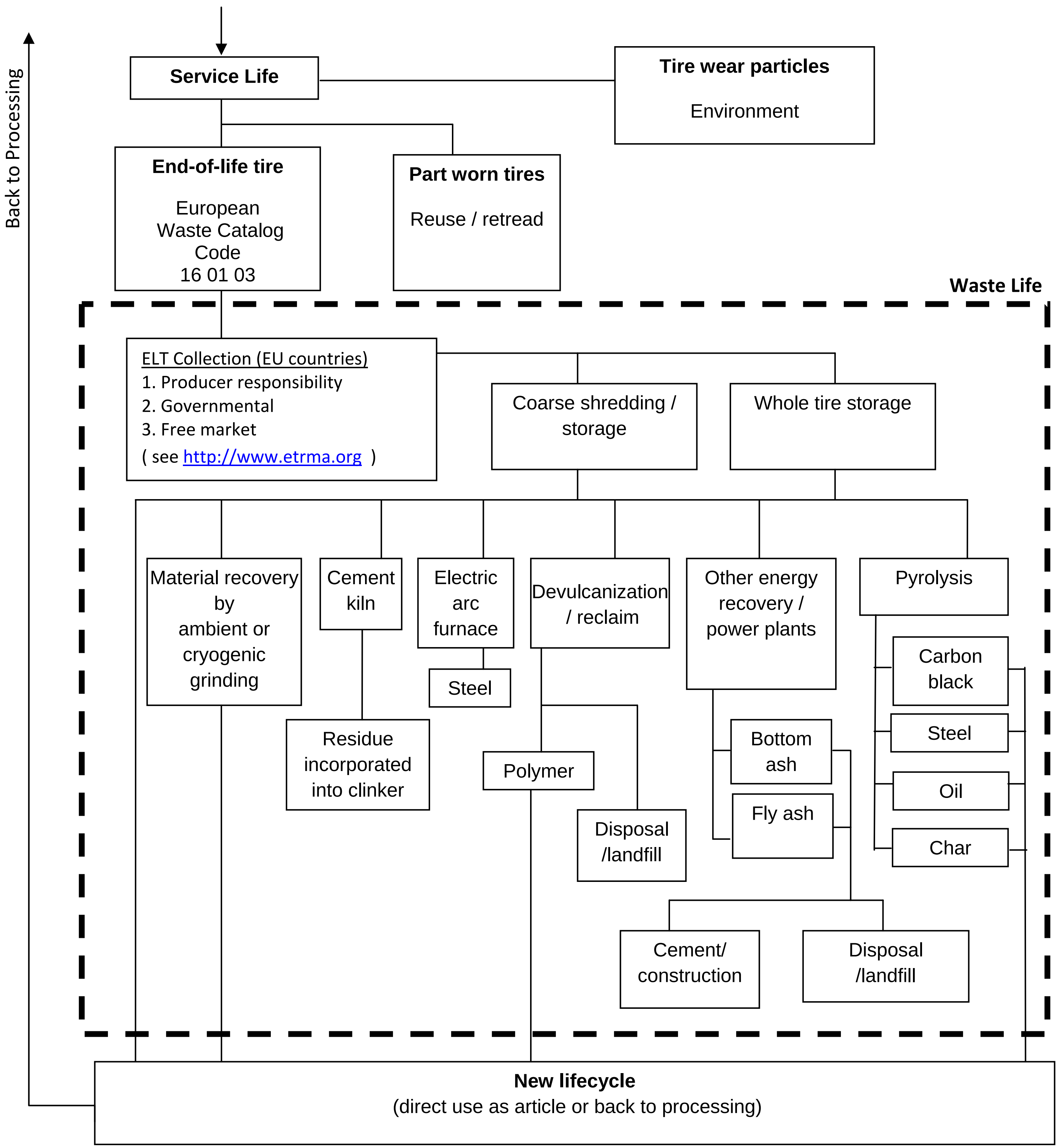


Figure 2: Waste life stage of a substance contained in a tyre. Dashed line denotes the scope of waste life stage under REACH.



2.0 Scope of Waste Life under REACH

The European Commission services (CA/24/2008) has clarified that:

> *"use of a substance as a recovered substance does not have to be covered in the exposure scenario of the 'original' substance (i.e. the substance that became waste and which is recovered from that waste) because the life cycle of the original substance ends when it ceases to be waste."*

The definition of waste with regard to tyres and the Waste Framework Directive has been reviewed by the UK Waste Tyres Task Group (Environment Council, 2003). The group concluded that tyres processed for material recovery are waste until the recovery has been completed. The group indicated that granulates used for safety surfaces (e.g. playgrounds) would likely be considered waste up until the point of deployment. At the point of deployment, a new life cycle is initiated. Tyres used in physical structures (e.g. civil engineering applications) are waste until incorporation in physical structure. Tyres that cease to be used in the structure revert back to waste tyre status.

In some cases, registration of the substance in the recycled product may not be required. The European Commission services (CA/24/2008) noted that:

> *"It is also possible that the recovery process results directly in an article, instead of a substance or preparation. This may be the case e.g. if collected and sorted polymer waste is directly melted in new articles. In this case, registration is only required if the article contains a substance with an intended release under certain conditions or if the Agency has taken a decision to require registration pursuant to Article 7(5)."*

In some applications like recycled rubber infill used for football pitches, the recycle rubber processed to specific standards based on size and shape and can be considered an article with no intended release. Therefore, registration may not be required for this application. In other applications (e.g. rubber modified asphalt) the manufacturer of the recycled product would need to make a determination regarding importance of chemical composition as compared to size and shape.

Based on the REACH CSA TGD and Commission services interpretations, M/I are not required to register the use of a substance as a recovered substance. In principle, many of the recycled uses will be similar to uses already covered under the general rubber goods exposure scenarios and a new assessment may not be required. In other instances, articles without intended releases may be exempt from registration. Although M/I are not required to include the uses for the new lifecycle in the 'original' substance assessment, general information regarding the beneficial and safe re-use has been provided in Section 5.0 of this report. M/I are encouraged to include general statements in the CSA regarding the various applications where recycled end-of-life tyres have be successfully and safely used after leaving the waste life stage.

3.0 M/I Requirements Relating to End-of-Life Tyres

Waste operators are not considered DU under the REACH legislation. Management of risk is primarily controlled by separate waste legislation and REACH exposure scenarios cannot be used to reduce or modify existing obligations. However, registrants of dangerous substances must cover the waste life stage for identified uses of the substances. As described in Chapters R.13.2.6 and Chapter R.18, the main requirement of the M/I is development of substance specific exposure scenarios that define the set operational conditions and risk management measures recommended to control or reduce exposure during waste disposal and recycling. Because waste operators are not downstream users under REACH, information provided in the waste life scenarios, including amount entering waste operations, secondary waste generated and predicted environmental concentrations (PECs), is not communicated down the supply chain.

The guidance emphasizes evaluation of waste life-stage risks specific to the function and use of a substance. Therefore, the primary purpose of the chemical safety assessment is to determine the substance-specific measures (if any) required to complement existing waste related requirements. Exposure scenarios are expected to contain a number of waste treatment options (varying by local or national standards) with control of risk demonstrated in the M/I CSA. Examples of substance-specific risks during the waste life stage provided in the guidance (Chapter 13 Appendix 1) include:

- Dispersion of metals from incineration;
- Evaporation or leaching of PBT or vPvB substances;
- Break-down products during thermal treatment;
- Water soluble compounds; and
- Dust or fume generation during high energy stripping;

The duties of the M/I include:

- Collect available information on amount of waste resulting from identified use and use in articles. According to the European waste catalog, the waste stage of tyres is classified as “16 01 03 – end of life tyres”; and
- For dangerous substance (>10 t/y), inclusion of waste life stage in the chemical safety assessment (CSA) and extended safety data sheet (eSDS) including exposure estimation and measures for control of risk
    - Requirements of the EU waste legislation
    - Identification of risks unique to waste life stage (downstream users)
    - Waste quantities and concentration of substances
    - Identification of suitable waste management strategies including, if applicable, requirements for best available technique from EU BREF Documents (see REACH TGD Appendix R.18-1).
    - Preparation of initial Tier 1 exposure scenario including use of ERC (Section R.18.5 and appendix R.18.1) or other emissions estimates
    - Refinement of the exposure scenario if necessary
    - Incorporation of waste management advice and exposure scenarios in eSDS

4.0 Waste Life Scenarios for End-of-Life Tyres

End-of-life tyres (ELT) are defined as tyres which can no longer be used on vehicles including passenger cars, trucks, airplanes and motorcycle tyres (after retreading or regrooving). ELT are classified as non-hazardous waste (75/442/EEC amended by Directive 91/156/EC). Based on a review of waste processing of ELT, several beneficial energy recovery or material recovery waste scenarios have been identified for inclusion in the M/I generic exposure scenario (Basel Convention, 2002; ETRMA, 2007; WBCSD, 2008). These scenarios are illustrated in Figure 2, which parallels Figure R.18-2 in the REACH CSA TGD (reproduced in Figure 1).

The Directive on the Landfill of Waste (1999/31/EC) banned the landfill of certain whole and shredded tyres effective July 2003 and July 2006. Also, the End-of-Life Vehicle Directive (2000/53/EC) sets a target of 95% recovery by 2015 for vehicles below 3.5 tonnes and indirectly setting targets for a minor part of ELT in the EU (it is estimated that ELT coming from ELV as defined by 2000/53/EC represent a tonnage below 10% of total EU ELT). In Europe, three systems exist for collection of ELT, including the so called free-market (disposal like for any other non-hazardous waste), state/tax and a producer 'take back' approach termed producer responsibility. Recovery and recycling rates in Europe have increased appreciably in the last 15 years. A brief overview of the broad categories of end-of-life tyre management in Europe is provided in Table 1.

A generic Tier 1 template for the waste life scenarios has been prepared (Table 2). The template indicates whether energy and/or material recovery occurs, the waste treatment type(s), the estimated annual tonnage, regulatory framework, relevant available technique from EU BREF Documents, substances, process categories (PROCs) and environmental release categories (ERCs). In addition to the generic template, more detailed information for each scenario has been included as an appendix to this report. The detailed information includes the scenario description, key documents for more information, description of the regulatory framework, description of substance specific hazards, description of operational conditions and risk management measures, alternative emission factors, and environmental release category and process category assignments. A brief overview of each scenario is provided in the subsequent sections with reference to the appendix where more information can be found. It is also anticipated that some waste industries will make available refined emissions estimates to replace the conservative release estimates based on ERCs. Typically, emissions from facilities where tyre derived fuel substitution is used are expected to be similar to conventional fossil fuel combustion with the possible exception of zinc (U.S. EPA, 1997).

Information regarding the rate of use of additives in tyre manufacture can be found in Table 9 of the OECD Emission Scenario Document (ESD) for Rubber Additives (2004). A generalized recipe and final content in the ELT is also provided in Table 3. During the service life of a tyre, approximately 10-12% of the tyre is lost to the environment as tyre wear particles (Camatini et al., 2001, Blok 2005, OECD 2004). Therefore, the concentration of certain components not found in the tread such as textile coated steel wires is slightly greater in an ELT than in a new tyre. The calculated content based on recipe for tread and carcass presented in BLIC life cycle analysis (LCA) of a passenger tyre (Pré Consultants B.V., 2001), indicated 11.5% loss of mass during service life and 70% market share of silica tyres in Europe (LaFerre, 2009). Additional compositional information for new passenger and truck tyres is available in the Basel Convention Technical Guidelines in Table 2 (Basel Convention, 2002). Average ELT composition is also presented separately for carbon black and silica tread in Table 2.2 of BLIC 2004.

In sections 4.1 through 4.9 below, a brief description of the relevant ELT waste life scenarios is presented. Additional information can be found in Appendices A.1 through A.8.

4.1 Storage

ELTs are collected and stored prior to use in new applications or processing (grinding, shredding, etc.) for beneficial reuse. ELT can be stored as whole tyres, shreds or granules (Basel Convention, 2002). As a result of low water solubilities and incorporation of substances into the rubber matrix, chemical releases to air and water during storage are limited to specific chemical use categories and generally consist of transformation products (with the exception of zinc). Metals, particularly zinc, are the substances most likely to be detected in leachates from tyres in storage based on review of literature on leaching of shreds, chips, and whole tyres (MWH, 2004). However, leaching studies indicate that transformation products of vulcanization agents, anti-oxidants and plasticizer impurities may leach to a lesser degree (Nilsson et al., 2008; Kallqvist, 2005; Müller, 2007; Lim and Walker, 2009). More information can be found in Appendix A.1 and Table 2.

4.2 Recycling of ELT into Shreds

ELT are fed into a mobile or fixed shredder to generate a coarse material approximately 50-mm in size. Steel and textile are not typically removed, but a debeader can be used to remove the steel bead from truck tyres prior to shredding to reduce machine wear. The volume of tyre material is reduced by approximately a factor of 4 after shredding (Reschner, 2008; Basel Convention, 2002). The substances used in the manufacture of the tyre are bound in the rubber matrix and potentially released during shredding as dust. Particulate emissions from coarse shredders are lower than from the cryogenic or ambient fine granulation processes described in Sections 4.3 and 4.4. More information can be found in Appendix A.2 and Table 2.

4.3 Recycling of ELT into Ground Rubber, Rubber Crumb (Ambient)

ELT are ground to produce rubber crumb for use in a wide variety of consumer and civil engineering applications (e.g. artificial turf fields, playgrounds, asphalt, etc.). There are several processes that can be used to produce ground rubber crumb. In ambient grinding, vulcanized scrap rubber is first reduced to a 50-mm chip. These chips enter a granulator that, at ambient temperatures, processes the chips into rubber granules while removing the steel (via magnet) and fiber (via shaking screens and wind sifters). Depending on the desired product size, additional processing (secondary grinding) may be necessary to achieve smaller particle sizes (Reschner, 2008; Basel Convention, 2002). More information can be found in Appendix A.3 and Table 2.

4.4 Recycling of ELT into Ground Rubber, Rubber Crumb (Cryogenic)

Cryogenic grinding is an alternate technology used to produce rubber granules similar to that produced by ambient grinding. Because of the nature of crushing/shattering, the resulting particle size distribution is wider than with ambient grinding, and small particle sizes are achievable without additional processing. In cryogenic grinding, vulcanized scrap rubber is first reduced to 50 mm chips by processing in a shredder. The chips are then frozen to temperatures below -80˚C in a freezing tunnel. The resulting rubber is brittle and glass-like, and therefore can be shattered into small pieces in a hammer mill. As with ambient processing, the metals and fibers are then removed from the particles (Reschner, 2008; Basel Convention, 2002). More information can be found in Appendix A.4 and Table 2.

4.5 Recycling of ELT through Pyrolysis

Pyrolysis is the chemical conversion or breakdown of organic compounds by heating in the total or partial absence of oxygen. The reaction is not combustive and requires the input of a large amount of energy. Whole or shredded tyres are pyrolyzed using a series of heated reactors to isolate and reclaim carbon black, steel, and oils and solvents. Estimated yields of the end-products are variable based on process conditions, but are generally: 33% char, 35% oil, 12% metal, 20% gas (Sharma, et al. 1998). The non-condensable gas (composed of light hydrocarbons) is used to heat/fuel the pyrolysis reactor. The oil can be used to fuel the furnaces. Char and metal can be recovered as activated carbon and steel respectively. Economic feasibility, yield, and end-product quality have limited the application of this technology, but a full-scale facility located in England is proposed for completion in 2010 (PYReco, 2009; CIWMB. 2006). More information can be found in Appendix A.5 and Table 2.

4.6 Use of ELT as Supplementary Fuel in Production of Cement

ELT are used as a tyre derived fuel (TDF) as part of coprocessing in the cement industry. Coprocessing is defined as the use of waste materials in industrial processes with the main objective of substitution of primary fuel and raw materials. In the cement kiln, TDF (in the form of whole or shredded tyres) is used in the production of clinker, an intermediate product in cement manufacturing produced by decarbonizing, sintering and fast-cooling ground limestone. Product specific wastes are not generated because the fuel ashes are incorporated into the clinker. Silica and steel are used as secondary raw materials to replace glass sand and ferric oxide. The incineration process is regulated by national authorities with specified process control and waste admission requirements (Holcim, 2006). More information can be found in Appendix A.6 and Table 2.

4.7 Use of ELT as Supplementary Fuel in Energy Generation

ELT are used as a supplementary TDF for power generation or in waste-to-energy plants. Use of TDF for power generation is similar to co-processing in cement kilns with similar emissions controls, except that bottom ash and fly ash are generated. Zinc from tyres vaporizes in the furnace and condenses on fly ash particles and is concentrated in the fly ash portion relative to bottom ash (CIWMB, 1995b). Therefore, the two types of ash are characterized by different markets or options for reuse and disposal. Waste-to-energy facilities burn wood wastes, agricultural waste or municipal solid waste to produce steam and/or electricity. The incineration process is regulated by national authorities with specified process control and waste admission requirements (Holcim, 2006; Singh et al. 2009; CIWMB, 1992). More information can be found in Appendix A.7 and Table 2.

4.8 Use of ELT as Anthracite Substitute in Electric Arc Furnace

Carbon from ELT is used as an anthracite substitute for the purpose of reducing iron oxide and as a source of energy in electric arc furnaces used to make steel from scrap metal wastes. The carbon from ELTs is used as reactant, fuel and alloy element. The anthracite or ELT is dissolved in a molten metal bath and iron from the tyre is incorporated into the steel. Outputs from the process include metal, slag and dusts (Aliapur, 2006). Laboratory data also indicates that waste tyres can be coinjected with metallurlogical coke with resulting increased combustion efficiencies (Zaharia et al. 2009). Environmental emissions measured with and without use of tyres in the process indicate no significant changes in baseline emissions or occupational exposure. More information can be found in Appendix A.8 and Table 2.

4.9 Devulcanization/Reclaim

Devulcanization is the process of cleaving the sulfidic cross-links of vulcanized rubber. The process typically requires heat, chemicals and mechanical techniques (CIWMB, 2004). In principle, devulcanization could be used to produce a product substituting for virgin rubber. Reclaimed rubber is defined as devulcanized rubber that has regained its viscosity as well as the characteristics of the original compound. One company with a proprietary devulcanization technology has announced plans to sell devulcanized tyre rubber for use in shoe outsoles and goal of opening European manufacturing plants in the future (Green Rubber, 2009). Another company located in the Netherlands produces natural rubber reclaim and powders and butyl reclaim with a capacity of 25000 t/y (Rubber Resources, 2009). Devulcanized material (i.e. reclaimed rubber) is also used as raw material for new tyres manufacturing (see ETRMA 2009b). Imported reclaimed rubber is subject to registration (differently from EU reclaimed material). More information can be found in Appendix A.9 and Table 2.

Table 1: Used tyre management in Europe (ETRMA, 2009)

Parameter	Description of reuse or recovery	EU-15 (EU-15 + Norway and Switzerland)	Europe (EU-27 + Norway and Switzerland)	Percent of total (EU-15/EU-27)
Countries	--	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK (+Norway and Switzerland)	EU-15 Countries + Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic, Slovenia	--
Used tyre generation rate (tonnes)	Mass of used tyres generated in EU-15 and enlarged Europe	**2814000**	**3281000**	**100% / 100%**
Part-worn tyres -total (tonnes)	Part-worn tyres are either directly reusable[a], reusable after reprocessing or exported for reuse	**614000**	**631000**	**22% / 19%**
…Reuse (tonnes)	*Part-worn tyres reusable in Europe as a second hand-purchase as is or after regrooving*	*104000*	*104000*	*3.7% / 3.2%*
…Retreading (tonnes)	*Part-worn tyres reusable after replacement of worn-out tread*[b]	*342000*	*358000*	*12% / 11%*
…Export (tonnes)	*Part-worn tyres exported for reuse*	*168000*	*169000*	*6.0% / 5.2%*
End of life tyre - total (tonnes)	Tyre that is non-reusable in its original form and directed to waste management system for energy recovery or material recycling	**2091000**	**2472000**	**74% / 75%**
…Energy recovery (tonnes)	*ELT used as alternative or supplementary fuel at electric power stations or supplementary fuel in cement kilns*[c].	*953000*	*1199000*	*34% / 37%*
…Material recycling	*ELT recycled in whole, shredded or powder form for use in civil engineering, incorporation into other rubber based products and miscellaneous applications*	*1138000*	*1273000*	*40% / 39%*
Landfill or unknown (tonnes)	Landfill of whole tyres and shredded tyres was banned in the EU effective July 2003 and July 2006, respectively[d]	**126000**	**195000**	**4.5% / 5.9%**

[a]See council directive 89/459/EEC relating to minimum tread depth.
[b]See council directive 2006/443/EC regarding safety and quality control requirements for retreaded tyres.
[c]Silica and steel are used as supplementary raw materials in cement production.
[d]See council directive 1999/31/EC. Exemptions exist for use of whole tyres in engineering applications, bicycle tyres and tyres > 1.5 m diameter.

Table 2: End-of-life (ELT) tyre waste-life stage scenario template.

Waste Treatment Technique	Energy Recover	Material Recovery	Waste Treat-ment Types	Estimated Annual Tonnage (EU-27+2)	Regulatory Framework (EU Directive)	Relevant BREF for RMM and OC	Sub-stances	Process Categories	ERC	Report Appendix for Additional Information
ELT pre-processing storage	--	--	R13	2500000	OW	WTI	2,3,4,5,6.4	8a/8b	10a	Appendix A.1
Coarse shredding	--	Rubber/steel	R3/4/12	280000[a]	OW	WTI	1-7	8a/8b/21	3	Appendix A.2
Grinding (ambient)	--	Rubber/steel	R3/4/12	730000[a]	OW	WTI	1-7	8a/8b/24	3	Appendix A.3
Grinding (cryogenic)	--	Rubber/steel	R3/4/12	250000[a]	OW	WTI	1-7	8a/8b/24	3	Appendix A.4
Pyrolysis	Yes	CB/oil/steel	R3/4/5	60000[b]	IW/OW/LCP/IPPC	WI	1-7	8b/2/22	1 / 3	Appendix A.5
Energy recovery: cement kiln	Yes	Silica/steel	R1/4/5	820000	IW/OW/IPPC	WI, CL	1-7	8b/21/22	3 / (R.18) / 10a	Appendix A.6
Energy recovery: other	Yes	Ash	R1/11	380000	IW/OW/LCP/IPPC	WI	1-7	8b/21/22	3 / (R.18) / 10a	Appendix A.7
Electric arc furnace	Yes	Steel	R1/4	< 10000	IW/OW/IPPC	WI	1-7	8b/21/22	3 / (R.18)	Appendix A.8
Devulcanization/reclaim	--	Polymer	R3	< 25000[c]	OW/IPPC	WTI	1-7	8b/21/22	3	Appendix A.9

[a]Tonange excludes shredding or grinding as a pre-treatment under waste treatment type R12.
[b]A facility with 60000 t/y capacity with a completion date of 2010 has been proposed in UK.
[c]One facility in the Netherlands with a capacity of 25000 t/y was identified.

Legend

Waste Treatment Types:
- R1: Use principally as a fuel or other means to generate energy
- R3: Recycling/reclamation of organic substances which are not used as solvents
- R4: Recycling/reclamation of metals and metal compounds
- R5: Recycling/reclamation of other inorganic materials
- R11: Use of residual waste from any of the operations from R1 to R10
- R12: Exchange of waste for submission to any of the operations numbered R 1 to R 11
- R13: Storage of waste pending any of the operations from R1 to R12

Directives:
- IW: Directive 2000/76/EC (on incineration of waste)
- LCP: Directive 2000/53/EC (large combustion plants)
- OW: Directive 2006/12/EC (on waste) and 2008/98/EC (on waste and repealing certain Directives)
- IPPC: Directive 1996/61/EC and 2008/1/EC (integrated pollution prevention and control)

BREF (Best Available Techniques):
- WTI: Waste Treatment Industries
- CL: Cement and Lime Manufacturing Industries
- WI: Waste Incineration

Substances:
Note: (r) denotes reactive substance typically not present in original form in cured rubber
- 1: Mastication agents (r)
- 2: Vulcanization agents (r)
- 3: Antioxidants
- 4: Fillers
- 5: Plasticizers
- 6.2 Tackifier
- 6.4: Filler activator (r)
- 6.6: Bonding agent (r)
- 7.7: Hardener (r except resin)
- 7.12: Reinforcing agent (r except resin)

Process Categories:
- 2: Use in closed, continuous process with occasional controlled exposure (e.g. sampling)
- 8a: Transfer of substance or preparation (charging/ discharging) from/to vessels/large containers (non-dedicated)
- 8b: Transfer of substance or preparation (charging/ discharging) from/to vessels/large containers (dedicated)
- 21: Low energy manipulation of substances in form of massive metal or bound in other materials and/or articles
- 22: Potentially closed processing operations with minerals/metals at elevated temperature. Industrial setting
- 24: High (mechanical) energy work-up of massive metals or substances bound in materials and/or articles

ERC
- (R18) Tier 1 Emission Guidance for incineration found in R.18.5.2.2 of the Guidance for the implementation of REACH
- 1 Production of chemicals
- 3 Formulation in materials
- 10a Wide dispersive outdoor use of long-life articles with low release

Table 3: Representative recipe for new passenger tyre and final content in ELT. Percentages based on recipe presented in BLIC LCA of a passenger tyre, 11.5% loss of mass during service life and 70% market share of silica tread tyres in Europe.

Component	New passenger tyre representative recipe (%)	Used passenger tyre indicative content (%)	Notes
Natural and synthetic rubber	42.7%	41.9%	
Carbon Black	21.4%	21.9%	
Silica	6.9%	5.1%	
Sulphur	1.3%	1.4%	
ZnO	1.6%	1.6%	ZnO reacts during curing and Zn could be detected by analysis.
Oils	6.6%	5.9%	
Stearic Acid	0.9%	1.0%	
Accelerators	1.0%	--	Accelerators react during curing and are not present in final product in appreciable amounts. Some transformation products are found in the final product.
Antidegradants	1.5%	1.6%	The concentration of some antidegradants decreases over the service life the tyre (e.g. by reaction with ambient oxygen or ozone as part of the function of the substance).
Coated wires	11.5%	13.3%	
Textile fabric	4.7%	5.4%	Textile fabric is not a component of truck tyres.

5.0 Beneficial Reuse of Recycled Rubber

Manufacturers and importers (M/I) are not required to register the use of a substance as a recovered substance. However, the CSA should note that a number of environmentally sound uses for ELT have been identified and are routinely used. A Basel Convention technical guideline for management and use of ELT was adopted in December, 1999 and reprinted in 2002. A revised guideline is currently under preparation. The existing guideline identified many environmentally sound uses for ELT in the main categories of civil engineering applications and manufacture of consumer/industrial products. The ETRMA (former BLIC) life cycle analysis of a passenger tyre concluded that the recycling of a car tyre has a net environmental benefit as a result of the benefits of material recovery (Pré Consultants B.V., 2001). The European Committee for Standardization (CEN) has developed a technical specification CEN/TS 14243 defining specifications and test methods for tyre recycling and utilization of the tyre in the European market. The main categories of products that will be considered in the standard by size are cuts (>300 mm), shreds (20 mm – 400 mm), chips (10 mm – 50 mm), granulates (0.8 mm, to 20 mm), steel and textiles. The standards are expected to create new markets for tyre derived products and ensure uniform quality. The principal uses of ELT vary by size fraction and have been described by the European Tyre and Rubber Manufacturers Association and in the Basel Convention guidelines (ETRMA, 2007; Basel Convention, 2002).

5.1 Civil Engineering Applications

The UK Environment Agency and Department of Trade and Industry has funded the preparation of comprehensive engineering guidance and environmental impact assessment for re-use of tyres, including whole tyres, tyre bales and rubber crumb, in port, coastal and river engineering (HR Wallingford, 2005). It is estimated that 2 million tyres per annum may safely be used in coastal and river engineering over the next 5 to 10 years, particularly in the form of tyre bales. The hazard assessment noted that 30 years of data indicates that used tyre materials are not hazardous or dangerous to human health or the environment. The potential hazards identified included fire, leachates (metals, metallic compounds and benzothiazole compounds and derivatives) and airborne dust during grinding. With regard to leachates, potential consequences were determined to be negligible in most cases and mild in closed systems or stationary waters (where monitoring may be required). Risk to human health was considered to be low when regulatory provisions are in force best practices are used.

The safe use of whole tyres, shreds and granules in civil engineering applications is supported by ecotoxicity testing and leaching studies. In 1995 and 1996, ISO standard tests acute toxicity tests were performed at the request of BLIC (on powdered rubber from tyre tread at the Pasteur Institute (Basel Convention, 2002). The species considered included algae (ISO 8692), shellfish (ISO 6341), fish (ISO 7346-1) and earthworm (ISO 11268/1). Aquatic toxicity was not observed with the LC50 or EC50 greater than 13000 mg/L as compared to the threshold for classification of harmful aquatic organisms of 100 mg/L. Toxicity was not observed in the earthworm test. A literature review published by BLIC (2005) also suggested negligible environmental effects from leaching of used tyres used in roads or surface waters. Birkholz et al. leached 250g of both fresh and aged ground rubber from tyres in 1L of water and treated bacteria (*Vibrio fisheri),* algae, microcrustaceans (*Daphnia magna*), and fish (*Pimphales promelas*) with the resulting leachate. While leachates from the fresh ground rubber were toxic to all species investigated, aging of the ground rubber resulted in a nearly 60% reduction in toxicity. The authors concluded that while undiluted leachate from fresh tyre rubber may pose a moderate threat to aquatic toxicity, environmental aging will attenuate this toxicity such that the risk is not appreciable. Additional information regarding tyre leachates is available from studies of rubber crumb used as filler in artificial turf sports fields (ChemRisk, 2008).

5.2 Consumer / Industrial Products

ELT are used in a number of consumer and industrial products. A comprehensive assessment of the safe use of recycled granulate rubber in consumer products is available for use of recycled tyre rubber at playgrounds and synthetic turf fields. In 2008, a weight of evidence review of the health and ecological risks associated with the use of recycled rubber in consumer applications, particularly playgrounds and athletic fields, was completed on behalf of the Rubber Manufacture's Association (Chemrisk, 2008). An update to the review is currently in preparation. The human health pathways included in the assessment were oral intake, inhalation and dermal exposure and environmental leaching and ecotoxicity studies were considered. This review concluded that adverse health effects are not likely for children or athletes exposed to recycled tyre materials found at playgrounds or athletic fields. The literature also indicated that natural rubber sensitization or adverse allergic reactions are not likely from recycled tyre materials, since liquid latex is not used as raw material in making tyre compounds. Tyre compounds are made from, among other substances, natural rubber in bale form. Natural rubber in bale form does not contain the same level of active proteins, which may trigger allergenic responses, as found in liquid latex. Additionally, no adverse ecological health impacts are expected based on the published studies.

A number of leaching and ecotoxicity studies have been completed in the assessment of artificial turf fields constructed with recycled tyres. For example, ADEME, in coordination with ALIAPUR and Fieldturf Tarkett (a manufacturer of artificial turf field surfaces), assessed the environmental impact of the use of ground rubber in outdoor artificial turf fields (Moretto, 2007). Lysimeter synthetic rain percolates were collected weekly, combined, and analyzed at 1, 2, 3, 6, 9, and 11 months. The percolates were then used to treat *Daphnia magna* and *Pseudokirchneriella subcapitata* (soft water algae). Results from this study indicate that Daphnia magna and Pseudokirchneriella subcapitata (soft water algae) were not affected by the percolates from the rubber-infilled artificial turf fields.

Between 2005 and 2007, the Swiss Federal Authority of Sports (BASPO) performed field tests of simulated artificial turf surfaces using lysimeters originally designed for agricultural research (Müller 2008). The purpose of the testing was to study the substances that leach from synthetic sports surfaces under natural rainwater conditions over a period of one year.

Of four artificial turf surfaces considered, one consisted of truck tyre infill with quartz sand underlay, two contained EPDM infill and one did not contain infill material. The monitored parameters included total DOC, total dissolved organic nitrogen, inorganic nitrogen compounds, aniline, alkylate phenylenediamines, benzothiazole, PAHs, and zinc. The results of the tests indicated that zinc and PAH concentrations were not elevated when compared to the blank sample containing only gravel. These results are attributable to zinc retention by absorption in the underlayment layer and low amounts of leachable PAHs in the rubber compounds. Aromatic amine and benzothiazole compounds were initially detected in the range of 10 to 300 ppb, but typically rapidly decreased to below the detection limit by the end of the testing period. The conclusion of the study was that organic substances similar to that observed in roadway runoff are leached off by rainwater over a relatively short time period, but that state of the art synthetic sports surfaces are unlikely to have adverse surface water or groundwater effects.

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Appendix A.1: Storage of ELT

Appendix A.1: Storage of ELT

Parameter	Description
ELT Scenario	Storage of ELT prior to processing or use in new application
Waste Treatment Type (2008/98/EC)	R13: Storage of waste pending any of the operations numbered R 1 to R 12
Estimated annual ELT tonnage (EU 27+2)	2472000 (ETRMA, 2009)
Scenario Description	End of life tires are collected and stored prior to use in new application or processing (grinding, shredding, etc.) for beneficial reuse. Whole tires, shreds and granules are stored prior to recovery or initiation of a new life cycle (Basel Convention, 2002).
Key Document(s) for more General Information about Scenario	BASEL Convention Technical Guidelines on the Identification and Management of Used Tyres (2002) The Prevention and Management of Scrap Tire Fires, (IAFC and STMC, 2000) End of Life Tire Management: Storage Options (MWH, 2004)
Description of Key Document(s)	Describes storage options, best practices, and emissions during storage or in cases of accidents.
Regulatory Framework	Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives) ELV Directive (2000/53/EC), but only applicable to a small amount of passenger (PSR) and commercial van (CVR) ELT tyres from ELV below 3.5 tons.
Description of Regulatory Framework	The EU directives on waste require that member states take the necessary measures to ensure that waste is recovered without risk to water, air or soil, or to plants or animals and without adversely affecting the countryside or places of special interest. Waste processing must not cause a nuisance through noise or odors. For example, in the UK, environmental permits for processing of tires by shredding or pulverizing are generally required by the Environmental Permitting (England and Wales) Regulations 2007 unless an exemption is granted (generally for processing waste at the site where it is produced). . As a minimal technical requirement for treatment the ELV Directive requires "appropriate storage for used tires, including prevention of fire hazards and excessive stockpiling" (Annex I). No information on regulations pertaining to duration of storage was identified for EU. In U.S., to avoid stockpiling, tires are permitted to remain stored for up to 30 days prior to processing or use in new applications (MWH, 2004)
Description of Substance Specific Hazards	Storage of ELT could result in three types of emissions of specific substances: chemical volatilization during storage, leaching into contact water, and emissions in the event of tire fires (MWH, 2004). As a result of low water solubilities and properties of the rubber matrix, chemical releases to water during storage are limited to specific chemical use categories and generally consist of transformation products (with the exception of metals). Based on a review of leaching studies (Nilsson et al., 2008; Kallqvist, 2005; Müller, 2007; Lim and Walker, 2009), and the OECD Emission Scenario Document for the Rubber Industry (2004), the following chemical classes should be considered for environmental release during storage: • Vulcanization agents (example: Zn, benzothiazole compounds, cyclohexylamine, dicyclohexylamine) • Anti-aging agents and anti-degradants (example: aniline, phenylenediamine compounds) • Plasticizers (example: trace PAH compounds) Chemical emissions to air by volatilization are expected to be negligible (NIPH, 2006; Moretto, 2007).

Parameter	Description
Key Operational and Risk Management Measures	The Best Available Techniques for Waste Treatment Industries (EC, 2006a) provides generic techniques for waste storage and techniques to reduce water use and prevent water contamination. The ELV Directive requires impermeable surfaces for appropriate areas and equipment for the treatment of water, including rainwater, in compliance with health and environmental regulations. Similar requirements are anticipated for large outdoor tire storage facilities. Although tires cannot spontaneously combust, tire fires represent a significant potential hazard for tire storage based on the difficulty in controlling the resulting fires. Best practices have been presented in the document: *The Prevention and Management of Scrap Tire Fires* (IAFC, STMC, NFTA, 2000)
Environmental Release Category	ERC 10A - Wide dispersive outdoor use with low release
Environmental Release Category Notes	ERC10A was selected because ELT collection and temporary storage points are widely distributed throughout Europe.
Alternative Emission Factor Data Description	Volatilization of constituents of tyre matrix under atmospheric conditions. Data includes identification of products in headspace, identification of volatiles at facilities using rubber products from tyres.
Alternative Emission Factor Data Details	Although direct measurements are not available, emissions of volatile and semi-volatile compounds from stockpiled tyres are expected to be negligible. VOCs identified at turf fields (indoor and outdoor) or other locations using applications for ELTs include common industrial substances frequently detected in ambient air including: formaldehyde, benzene, toluene, xylenes, benzoic acid, limonene, styrene, benzothiazole, aniline, cyclohexane, cyclohexanone, 1,2-dichlorobenzene, ethylbenzene, isopropylbenzene, methylisobutylketone, naphthalene, acetaldehyde, trichloroethylene and phenol. Risk assessments based on air concentrations for these VOCs in the vicinity of these rubber products suggested human health risk was negligible from inhalation of VOCs associated with off-gassing from ground rubber (NIPH, 2006; Moretto, 2007). In a study comparing VOC and SVOC ambient air concentrations above a warm field containing recycled ELTs (27 ˚C ambient temperature); there was no statistical difference between concentrations at the field and background concentrations (Lim, L. and R. Walker, 2009). Similar VOCs were detected in air at scrap-tyre shredding facilities based on GC/MS; levels were not quantified (Chien, et al. 2003). Stockpiled whole tyres, because of lower exposed surface area, are expected to off-gas less than ground rubber. An analysis of headspace from tyre crumbs (at 60 ˚C) indentified benzothiazole, butylated hydroxyanisole (BHT derivative), n-hexadecane and 4-(t-octyl) phenol (Mattina, et al. 2007).
Alternative Emission Factor Data Description	Compounds leaching from tyres during storage following contact with water (e.g. rainwater, water used for fire control, etc.)

Parameter	Description
Alternative Emission Factor Data Details	Metals, particularly zinc, are the substances most likely to be detected in leachates of tyres during storage based on review of literature on leaching of shreds, chips, and whole tyres (MWH, 2004). The metal most likely to be detected in whole tyre leachate above background levels is zinc from ZnO used as an accelerator activator. Emission rates of organic compounds are expected to be appreciably lower than that of zinc. Cadmium and lead are identified as trace contaminants of ZnO but are expected to be negligible constituents of leachate in most cases. Although exposed surface area differs (surface to volume ratio) for whole tyres vs. ground tires or TWP, the profile of possible emissions is expected to be similar for ELT in storage as that of the in-use portion of the tire life cycle. Zn emissions from stockpiled tires to water can be reduced by use of a cover to prevent contact with rainwater or by indoor storage. As a worst case, emission factors can be derived from studies examining the emission of substances from tires in continuous contact with water. Fenner et al. (2003) measured the release rate of zinc, cadmium, lead, and nickel into natural fresh and seawater for a 22 g strip of rubber cut from the walls of 4-year old used tires. The release of lead was negligible and not quantified. The release of zinc corresponded to an emission factor of 3×10^{-8} (freshwater) to 3×10^{-7} (seawater) g Zn/g tyre/day. The corresponding emission factor for a three month period was 3×10^{-6} (freshwater) to 3×10^{-5} (seawater) g Zn/g. Collins et al. (1995) identified zinc as the primary tyre leachate for sea water in contact with whole tyres. After 3 months, the emission factor was 1×10^{-4} to 5×10^{-5} based on 10 mg/tyre leachable Zn and total Zn content of100 to 200 g/tyre. The low emission factor is attributable to the limited surface for leaching, consisting of the outer 2 mm of the tyre. Nelson et al. (1994) did not observe an analytical difference between de-ionized control water and tyre leachate with 5 g tyre plugs for 117 organic compounds (detection limit 1 ppb) after a study period of 40 days. The emission rate of zinc in this study was 4×10^{-6} g Zn/g tyre for the 40 day period. The emission rate of zinc from whole tyres in a separate aquarium study with fresh water was 2×10^{-6} g Zn/g tyre for a 30 day exposure period.
Occupational Exposure Assessment	Potential occupational exposures for tyre storage include dermal contact during manual transfer of whole tyres similar to dermal contract occurring during professional use of tyres.
Process Categories Relevant to ELT Material Handling	*Material transfer of whole tyres*: PROC 8a/b:Transfer of substance or preparation (charging/ discharging) from/to vessels/large containers (non-dedicated/dedicated)

Parameter	Description
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. Chien, Y-C, C., et al. 2003. Assessment of occupational health hazards in scrap-tire shredding facilities. Science of the Total Environment, 309: 35-46. Collins, K. J., et al. 1995. A review of waste tyre utilization in the marine environment. Chem. Ecol., 10(3-4): 205-216. EC (European Commission). 2006a. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Waste Treatment Industries. August 2006. ETRMA. 2008a. End of life tyre treatment data in 2007. http://www.etrma.org IAFC and STMC. 2000. International Association of Fire Chiefs and The Scrap Tire Management Council. Guidelines for prevention and management of scrap tire fires. Washington, DC. Kallqvist, T., Environmental risk assessment of artificial turf systems. 2005, Norwegian Institute for Water Research: Oslo. p. 1-19. Lim, L. and R. Walker, An assessment of chemical leaching, releases to air and temperature at crumb-rubber infilled synthetic turf fields, New York State Department of Environmental Conservation and Department of Health, Editor. 2009. Mattina, M.I., et al., Examination of crumb rubber produced from recycled tires. 2007, The Connecticut Agricultural Experiment Station. Department of Analytical Chemistry. Moretto, R., Environmental and health assessment of the use of elastomer granules (virgin and from used tyres) as filling in third-generation artificial turf. 2007, ADEME/ALIAPUR/FIELDTURF TARKETT. p. 1-27. MWH. 2004. End-of-life tyre management: storage options. Final report for the Ministry for the Environment. July 2004. Müller, E., Results of a field study on environmental compatibility of synthetic sports surfaces. 2007, Swiss Federal Authority of Sports (BASPO). Nilsson, N.H., B. Malmgren-Hansen, and U.S. Thomsen, Mapping, emissions and environmental and health assessment of chemical substances in artificial turf. 2008, Danish Ministry of the Environment. NIPH (Norwegian Institute of Public Health and the Radium Hospital), Artificial turf pitches – an assessment of the health risks for football players. 2006, Norwegian Institute of Public Health and the Radium Hospital: Oslo. p. 1-34. OECD. 2004. Emission Scenario Document on Additives in the Rubber Industry. Emission Scenario Document #6.

Appendix A.2: Recycling of ELT into Shreds

Appendix A.2: Recycling of ELT into Shreds

Parameter	**Description**
ELT Scenario	Recycling of ELT into Shreds
Waste Treatment Type (2008/98/EC)	R3: Recycling/reclamation of organic substances which are not used as solvents R4: Recycling/reclamation of metals and metal compounds R12: Exchange of waste for submission to any of the operations numbered R 1 to R 11. (including preliminary operations prior to recovery including shredding, repackaging, separating, blending or mixing prior to submission to any of the operations numbered R1 to R11).
Estimated annual ELT tonnage (EU 27+2)	End-of life tyres are shredded for use as construction fill, to increase the ease of transport or as the first step prior to granulation by ambient or cryogenic granulation process. The majority of tyres used in material recycling are pre-processed by shredding. Of the total amount, approximately 22% is not processed further (Pré Consultants B.V., 2001). Based on a total material recycling rate of 1.3 million tons per year, the amount of tyres processed by coarse shredding with no additional treatment is approximately 280,000 tons/year (ETRMA, 2009).
Scenario Description	ELT are fed into a mobile or fixed shredder to generate a coarse material approximately 50-mm in size. Steel and textile are not typically removed, but a debeader can be used to remove the steel bead from truck tyres prior to shredding to reduce machine wear. The volume of tyre material is reduced by approximately a factor of 4 after shredding (Reschner, 2008; Basel Convention, 2002).
Key Document(s) for more General Information about Scenario	Best Practices in Scrap Tyres and Rubber Recycling: Ambient versus Cryogenic Grinding (CWC,1998) Scrap Tyre Recycling; A Summary of Prevalent Disposal and Recycling Methods (Reschner, 2008)
Description of Key Document(s)	Documents provide comparisons of characteristics of and outputs from ambient and cryogenic grinding in the manufacture of crumb rubber.
Regulatory Framework	Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The EU directives on waste require that member states take the necessary measures to ensure that waste is recovered without risk to water, air or soil, or to plants or animals and without adversely affecting the countryside or places of special interest. Waste processing must not cause a nuisance through noise or odors. For example, in the UK, environmental permits for processing of tyres by shredding or pulverizing are generally required by the Environmental Permitting (England and Wales) Regulations 2007 unless an exemption is granted (generally for processing waste at the site where it is produced). .

Parameter	Description
Description of Substance Specific Hazards	The substances used in the manufacture of the tyre are bound in the rubber matrix and potentially released during shredding as dust. The substances can generally be classified as reactive substances with minimal content remaining in the final tread or unreactive substances. Reactive substances transformed after curing is complete typically include mastication agents, vulcanization agents and filler activators. Anti-oxidants react with ozone or ambient oxygen during the service life and are present at the end-of-life in concentrations lower than the initial concentration. Other substances expected to be present in the tyre and the end-of-life include fillers, plasticizers, tackifiers, Zn from the accelerator activator ZnO and other Zn compounds and Co from cobalt salts used as bonding agents. Solvents and mold release agents are unreactive substances typically not incorporated into the rubber matrix. Hardeners and reinforcing agents in resin form are generally unreactive but reactive substances such as HMT or resorcinol are included in these categories. Some chemicals are associated with transformation products or impurities as indicated below: • Vulcanization agents (example: benzothiazole compounds, cyclohexylamine, dicyclohexylamine) • Anti-aging agents and anti-degradants (example: aniline, phenylenediamine compounds) • Plasticizers (example: trace PAH compounds)
Key Operational and Risk Management Measures	Typical processing rates for shredding equipment are 2000 to 6000 kg/hour. The most common machine is a rotary shear shredder with counter-rotating shafts powered by electric motors. The BREF for Waste Treatment Industries provides techniques for reducing emissions from shredding activities and techniques to reduce emissions from washing processes (Reschner, 2008; EC, 2006a).
Environmental Release Category	ERC 3 – Formulation in materials
Environmental Release Category Notes	REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations.
Alternative Emission Factor Data Description	Particulate emission during shredding
Alternative Emission Factor Data Details	Particulate emissions from shredders are lower than from the subsequent cryogenic or ambient granulation process. A lifecycle analysis considering ambient and cryogenic grinding of rubber in Italian facilities indicated the potential of particulate emissions for ambient grinding (i.e. mechanical pulverization) but not pre-shredding (Corti and Lombardi, 2004). A particulate emission factor (PM-10) for shredding of 9×10^{-7} (9×10^{-5} %) has been recommended for portable tyre shredders (State of Indiana, 2003).
Occupational Exposure Assessment	Whole or shredded tyres are shredded at ambient temperatures resulting in possible release of fugitive dust during the grinding processes. The processes included are sorting of whole tyres and handling of shreds. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds or packaging and inhalation of fugitive dust during material transfer or processing (Basel Convention, 2002). Although lower concentrations are expected for coarse shredding only, dust levels at shredding facilities including granulation ranged from 1.55 to 2.31 mg/m^3 (total particulate) and 0.57 to 0.80 mg/mg^3 (respirable particulate) during processing (Chien, et al. 2003). Some common industrial VOCs were detected in air at scrap-tyre shredding facilities based on GC/MS; levels were not quantified (Chien, et al. 2003).
Process Categories Relevant to ELT Material Handling	*Material transfer of whole tyres and tyre shreds*: PROC 8a/8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers (dedicated/non-dedicated) *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles

Parameter	Description
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. Chien, Y-C, C., et al. 2003. Assessment of occupational health hazards in scrap-tire shredding facilities. Science of the Total Environment, 309: 35-46. Corti, A. and Lombardi, L. 2004. End of life tyres: Alternative final disposal processes compared by LCA. Energy, 29: 2089-2108. CWC (Clean Washington Center), 1998a. Best practices in scrap tires and rubber recycling: ambient versus cryogenic grinding. Seattle, Washington. EC (European Commission). 2006a. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Waste Treatment Industries. August 2006. ETRMA, 2008a. End of life tyre treatment data in 2007. http://www.etrma.org Pré Consultants B.V., 2001. Life cycle assessment of an average European car tyre. Third Party Report Commissioned by BLIC. Reschner, K. 2008. Scrap tire recycling. A summary of prevalent disposal and recycling methods. Berlin, Germany. http://www.entire-engineering.de/en1.htm State of Indiana. 2003. New source construction permit and minor source operating permit. Office of Air Quality. Rumpke of Indiana, LLC (Portable Source). Operation Permit No.: MSOP 071-16792-05226.

Appendix A.3: Recycling of ELT into Ground Rubber, Rubber Crumb (Ambient)

Appendix A.3: Recycling of ELT into Ground Rubber, Rubber Crumb (Ambient)

Parameter	**Description**
ELT Scenario	Recycling of ELT into Ground Rubber, Rubber Crumb (Ambient)
Waste Treatment Type (2008/98/EC)	R3: Recycling/reclamation of organic substances which are not used as solvents R4: Recycling/reclamation of metals and metal compounds R12: Exchange of waste for submission to any of the operations numbered R 1 to R 11. (including preliminary operations prior to recovery including shredding, repackaging, separating, blending or mixing prior to submission to any of the operations numbered R1 to R11).
Estimated annual ELT tonnage (EU 27+2)	80% of tyres subject to material recycling are processed by ambient grinding including coarse shredding only (i.e. no further processing) (Pré Consultants B.V., 2001). Based on a total material recycling rate of 1.3 million tons per year, the amount of tyres processed by ambient grinding to produce rubber crumb or granulate is approximately 730000 tons/year (ETRMA, 2009). An additional 280000 tons/year are processed by coarse shredding only (see coarse shredding scenario).
Scenario Description	ELT are ground to produce rubber crumb for use in a wide variety of consumer and civil engineering applications (e.g. artificial turf fields, playgrounds, asphalt, etc.). There are several processes that can be used to produce ground rubber crumb. In ambient grinding, vulcanized scrap rubber is first reduced to a 50-mm chip. These chips enter a granulator that, at ambient temperatures, processes the chips into rubber granules while removing the steel (via magnet) and fiber (via shaking screens and wind sifters). Depending on the desired product size, additional processing (secondary grinding) may be necessary to achieve smaller particle sizes (Reschner, 2008; Basel Convention, 2002).
Key Document(s) for more General Information about Scenario	Best Practices in Scrap Tyres and Rubber Recycling: Ambient versus Cryogenic Grinding; Cryogenic Processing (CWC,1998) Scrap Tyre Recycling; A Summary of Prevalent Disposal and Recycling Methods (Reschner, 2008)
Description of Key Document(s)	Documents provide comparisons of characteristics of and outputs from ambient and cryogenic grinding in the manufacture of crumb rubber.
Regulatory Framework	Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The EU directives on waste require that member states take the necessary measures to ensure that waste is recovered without risk to water, air or soil, or to plants or animals and without adversely affecting the countryside or places of special interest. Waste processing must not cause a nuisance through noise or odors. For example, in the UK, environmental permits for processing of tyres by shredding or pulverizing are generally required by the Environmental Permitting (England and Wales) Regulations 2007 unless an exemption is granted (generally for processing waste at the site where it is produced).

Parameter	Description
Description of Substance Specific Hazards	The substances used in the manufacture of the tyre are bound in the rubber matrix and potentially released during ambient processing as dust. The substances can generally be classified as reactive substances with minimal content remaining in the final tread and unreactive substances. Reactive substances transformed after curing is complete typically include mastication agents, vulcanization agents and filler activators. Anti-oxidants react with ozone or ambient oxygen during the service life and are present at the end-of-life in concentrations lower than the initial concentration. Other substances expected to be present in the tyre and the end-of-life include fillers, plasticizers, tackifiers, Zn from the accelerator activator ZnO and other Zn compounds and Co from cobalt salts used as bonding agents, Solvents and mold release agents are unreactive substances typically not incorporated into the rubber matrix. Hardeners and reinforcing agents in resin form are generally unreactive but reactive substances such as HMT or resorcinol are classified in these categories. Some chemicals are associated with transformation products or impurities as indicated below: • Vulcanization agents (example: benzothiazole compounds, cyclohexylamine, dicyclohexylamine) • Anti-aging agents and anti-degradants (example: aniline, phenylenediamine compounds) • Plasticizers (example: trace PAH compounds)
Key Operational and Risk Management Measures	Typical processing rates for cryogenic facilities are 500 to 1000 kg/hour. Following granulation by the grinding mill, fiber is removed using air separation and metals are removed using magnetic separators. Sieving is used to separate the granulate into specific size fractions. The BREF for Waste Treatment Industries provides techniques for reducing emissions from shredding activities and techniques to reduce emissions from washing processes (EC, 2006a).
Environmental Release Category	ERC 3 – Formulation in materials
Environmental Release Category Notes	REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations.
Alternative Emission Factor Data Description	Particulate emission during ambient grinding
Alternative Emission Factor Data Details	A lifecycle analysis considering ambient grinding of rubber in Italian facilities indicated a particulate emission rate of 0.03% (Corti and Lombardi, 2004). A dust emission factor of 0.4 kg/hour has been stated, which corresponds to a total dust emission rate of approximately 0.01% to 0.02% based on a processing rate of 500 to 1000 kg/hour (Basel Convention, 2002; Reschner, 2008). The BLIC LCA of a passenger tyre indicates an average emission factor of 0.002% for coarse dust and 0.00002% for PM-10 based on an average for 80% ambient and 20% cryogenic (Pré Consultants B.V., 2001).
Occupational Exposure Assessment	Whole or shredded tyres are ground at ambient temperatures resulting possible release of fugitive dust during the grinding processes. The processes included are sorting of whole tyres or handling of shreds, feed of the raw material into the grinder by conveyor belt, grinding, and packaging of granulate. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds or packaging and inhalation of fugitive dust during material transfer or processing (Basel Convention, 2002). Dust levels at shredding facilities ranged from 1.55 to 2.31 mg/m^3 (total particulate) and 0.57 to 0.80 mg/mg^3 (respirable particulate) during processing (Chien, et al. 2003). Some common industrial VOCs were detected in air at scrap-tyre shredding facilities based on GC/MS; levels were not quantified (Chien, et al. 2003).
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/granules/whole tyres*: PROC 8a/8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers (dedicated/non-dedicated) *Processing of whole tyres by grinding*: PROC 24 - High (mechanical) energy work-up of massive metals or substances bound in materials and/or articles

Parameter	Description
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. Chien, Y-C, C., et al. 2003. Assessment of occupational health hazards in scrap-tire shredding facilities. Science of the Total Environment, 309: 35-46. Corti, A. and Lombardi, L. 2004. End of life tyres: Alternative final disposal processes compared by LCA. Energy, 29: 2089-2108. CWC (Clean Washington Center), 1998a. Best practices in scrap tires and rubber recycling: ambient versus cryogenic grinding. Seattle, Washington. EC (European Commission). 2006a. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Waste Treatment Industries. August 2006. ETRMA, 2008a. End of life tyre treatment data in 2007. http://www.etrma.org Pré Consultants B.V., 2001. Life cycle assessment of an average European car tyre. Third Party Report Commissioned by BLIC. Reschner, K. 2008. Scrap tire recycling. A summary of prevalent disposal and recycling methods. Berlin, Germany. http://www.entire-engineering.de/en1.htm

Appendix A.4: Recycling of ELT into Ground Rubber, Rubber Crumb (Cryogenic)

Appendix A.4: Recycling of ELT into Ground Rubber, Rubber Crumb (Cryogenic)

Parameter	**Description**
ELT Scenario	Recycling of ELT into Ground Rubber, Rubber Crumb (Cryogenic)
Waste Treatment Type (2008/98/EC)	R3: Recycling/reclamation of organic substances which are not used as solvents R4: Recycling/reclamation of metals and metal compounds R12: Exchange of waste for submission to any of the operations numbered R 1 to R 11. (including preliminary operations prior to recovery including shredding, repackaging, separating, blending or mixing prior to submission to any of the operations numbered R1 to R11).
Estimated annual ELT tonnage (EU 27+2)	20% of tyres subject to material recycling are processed by cryogenic grinding (Pré Consultants B.V., 2001). Based on a total material recycling rate of 1.3 million tons per year, the amount of tyres processed by cryogenic grinding is approximately 250,000 tons/year (ETRMA, 2009).
Scenario Description	ELT are ground to produce rubber crumb to be used in a wide variety of consumer and civil engineering applications (e.g. artificial turf fields, playgrounds, asphalt, etc.). There are several processes that can be used to produce ground rubber crumb. In cryogenic grinding, vulcanized scrap rubber is first reduced to 50 mm chips by processing in a shredder. The chips are then frozen to temperatures below -80˚C in a freezing tunnel. The resulting rubber is brittle and glass-like, and therefore can be shattered into small pieces in the hammer mill. As with ambient processing, the metals and fibers are then removed from the particles. Because of the nature of crushing/shattering, the resulting particle size distribution is wider than with ambient grinding, and small particle sizes are achievable without additional processing (Reschner, 2008; Basel Convention, 2002).
Key Document(s) for more General Information about Scenario	Best Practices in Scrap Tyres and Rubber Recycling: Ambient versus Cryogenic Grinding; Cryogenic Processing (CWC,1998) Scrap Tyre Recycling; A Summary of Prevalent Disposal and Recycling Methods (Reschner, 2008)
Description of Key Document(s)	Documents provide comparisons of characteristics of and outputs from ambient and cryogenic grinding in the manufacture of crumb rubber.
Regulatory Framework	Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The EU directives on waste require that member states take the necessary measures to ensure that waste is recovered without risk to water, air or soil, or to plants or animals and without adversely affecting the countryside or places of special interest. Waste processing must not cause a nuisance through noise or odors. For example, in the UK, environmental permits for processing of tyres by shredding or pulverizing are generally required by the Environmental Permitting (England and Wales) Regulations 2007 unless an exemption is granted (generally for processing waste at the site where it is produced).

Parameter	Description
Description of Substance Specific Hazards	The substances used in the manufacture of the tyre are bound in the rubber matrix or potentially released during cryogenic processing as dust. The substances can generally be classified as reactive substances with minimal content remaining in the final tread and unreactive substances. Reactive substances transformed after curing is complete typically include mastication agents, vulcanization agents and filler activators. Anti-oxidants react with ozone or ambient oxygen during the service life and are present at the end-of-life in concentrations lower than the initial concentration. Other substances expected to be present in the tyre and the end-of-life include fillers, plasticizers, tackifiers, Zn from the accelerator activator ZnO and other Zn compounds and Co from cobalt salts used as bonding agents, Solvents and mold release agents are unreactive substances typically not incorporated into the rubber matrix. Hardeners and reinforcing agents in resin form are generally unreactive but reactive substances such as HMT or resorcinol are included in these categories. Some chemicals are associated with transformation products or impurities as indicated below: • Vulcanization agents (example: benzothiazole compounds, cyclohexylamine, dicyclohexylamine) • Anti-aging agents and anti-degradants (example: aniline, phenylenediamine compounds) • Plasticizers (example: trace PAH compounds)
Key Operational and Risk Management Measures	Typical processing rates for cryogenic facilities are 1800 to 2700 kg/hour. Fiber is removed using air separation and metals are removed using magnetic separators. The chips are frozen to temperatures below -80 ˚C and processed with a hammer mill to create 0.2 to 10 mm particles (CWC, 1998a,b; Reschner, 2008). Approximately 0.5 to 1 kg liquid N_2 per kg of tyre is used. The BREF for Waste Treatment Industries provides techniques for reducing emissions from shredding activities and techniques to reduce emissions from washing processes (EC, 2006a).
Environmental Release Category	ERC 3 – Formulation in materials
Environmental Release Category Notes	REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations.
Alternative Emission Factor Data Description	Particulate emission during cryogenic grinding
Alternative Emission Factor Data Details	Particulate emissions from cryogenic processes are expected to be lower than for ambient processes. A lifecycle analysis considering ambient and cryogenic grinding of rubber in Italian facilities indicated the potential of particulate emissions for ambient grinding but not cryogenic grinding (Corti and Lombardi, 2004). Cryogenic grinding provides a high product yield, corresponding to low environmental losses. A dust emission factor of 0.4 kg/hour has been stated which corresponds to a total dust emission rate of approximately 0.01% based on a processing rate of 1800 to 2700 kg/hour (Basel Convention, 2002; Reschner, 2008). The BLIC LCA of a passenger tyre indicates an average emission factor of 0.002% for coarse dust and 0.00002% for PM-10 based on an average for 80% ambient and 20% cryogenic (Pré Consultants B.V., 2001).
Occupational Exposure Assessment	Whole or shredded tyres are ground at low temperatures resulting possible release of fugitive dust during the grinding processes. The processes included are sorting of whole tyres or handling of shreds, feed of the raw material into the grinder by conveyor belt, grinding, and packaging of granulate. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds or packaging and inhalation of fugitive dust during material transfer or processing (Basel Convention, 2002). Dust levels at shredding facilities ranged from 1.55 to 2.31 mg/m^3 (total particulate) and 0.57 to 0.80 mg/mg3 (respirable particulate) during processing (Chien, et al. 2003). Some common industrial VOCs were detected in air at scrap-tyre shredding facilities based on GC/MS; levels were not quantified (Chien, et al. 2003).

Parameter	Description
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/granules/whole tyres*: PROC 8a/8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers (dedicated/non-dedicated) *Processing of whole tyres by grinding*: PROC 24 - High (mechanical) energy work-up of massive metals or substances bound in materials and/or articles
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. Chien, Y-C, C., et al. 2003. Assessment of occupational health hazards in scrap-tire shredding facilities. Science of the Total Environment, 309: 35-46. Corti, A. and Lombardi, L. 2004. End of life tyres: Alternative final disposal processes compared by LCA. Energy, 29: 2089-2108. CWC (Clean Washington Center), 1998a. Best practices in scrap tires and rubber recycling: ambient versus cryogenic grinding. Seattle, Washington. CWC (Clean Washington Center), 1998b. Best practices in scrap tires and rubber recycling: cryogenic processing. Seattle, Washington. EC (European Commission). 2006a. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Waste Treatment Industries. August 2006. ETRMA, 2008a. End of life tyre treatment data in 2007. http://www.etrma.org Pré Consultants B.V., 2001. Life cycle assessment of an average European car tyre. Third Party Report Commissioned by BLIC. Reschner, K. 2008. Scrap Tire Recycling. A summary of prevalent disposal and recycling methods. Berlin, Germany. http://www.entire-engineering.de/en1.htm

Appendix A.5: Recycling of ELT through Pyrolysis

Appendix A.5: Recycling of ELT through Pyrolysis

Parameter	**Description**
ELT Scenario	Recycling of ELT through pyrolysis
Waste Treatment Type (2008/98/EC)	R3: Recycling/reclamation of organic substances which are not used as solvents R4: Recycling/reclamation of metals and metal compounds R5: Recycling/reclamation of other inorganic materials
Estimated annual ELT tonnage (EU 27+2)	Currently operating full-scale pyrolysis facilities were not identified in Europe. A facility with a 60,000 t/year capacity has been proposed in the UK with an estimate completion date of 2010 (PYReco, 2009).
Scenario Description	Pyrolysis is the chemical conversion or breakdown of organic compounds by heating in the total or partial absence of oxygen. The reaction is not combustive and requires the input of a large amount of energy. Whole or shredded tyres are pyrolyzed using a series of heated reactors to isolate and reclaim carbon black, steel, and oils and solvents. Estimated yields of the end-products are variable based on process conditions, but are generally: 33% char, 35% oil, 12% metal, 20% gas (Sharma, et al. 1998). The non-condensable gas (composed of light hydrocarbons) is used to heat/fuel the pyrolysis reactor. The oil can be used to fuel the furnaces. Economic feasibility, yield, and end-product quality have limited the application of this technology, but a full-scale facility is proposed for completion in 2010 (PYReco, 2009; CIWMB. 2006).
Key Document(s) for more General Information about Scenario	BASEL Convention Technical Guidelines on the Identification and Management of Used Tyres (2002) Scrap Tyre Recycling: A Summary of Prevalent Disposal and Recycling Methods (Reschner, 2008) Sharma, et al. 1998. Disposal of Waste Tyres for Energy Recovery and Safe Environment- Review CIWMB. 2006. Technology Evaluation and Economic Analysis of Waste Tyre Pyrolysis, Gasification and Liquefaction.
Description of Key Document(s)	Describe the pyrolysis process and provide data or estimates of releases from tyre pyrolysis facilities.
Regulatory Framework	Directive 1996/61/EC and 2008/1/EC (on Integrated Pollution Prevention and Control) Directive 2000/76/EC (on incineration of waste) Directive 2001/80/EC (on large combustion plant) Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The purpose of Directive 2000/76/EC is to limit negative effects on environment from incineration and co-incineration of waste. The directive requires an approved permit and establishes operating conditions and air emission limit values. Directives 2006/12/EC and 2008/98/EC provide a legal framework for the treatment of waste and define categories of waste, disposal operations and recovery operations. Directive 2001/80/EC establishes emissions limits for large combustion plants with rated thermal input exceeding 50 MW (possibly relevant when recovered oil is used in furnace). Directive 1996/61/EC and 2008/1/EC require best available techniques for industrial emissions with respect to environmental protection of air, water and soil for energy facilities with rated thermal input exceeding 50 MW.

Parameter	Description
Description of Substance Specific Hazards	Because most of the products of pyrolysis of tyres are useful (e.g. the oil is used to fuel the furnace, the gas is used to heat the reactor, the char can be converted to activated carbon, and the metal is reclaimed as steel), there are few environmental emissions from pyrolysis. PAHs have been identified as a potential emission from pyrolysis plants (Chen, et al. 2007) from the use of the polymer rubber. Low molecular weight hydrocarbons and some benzene-based VOCs are also generated in the light oil fraction of the pyrolysis gas and attributed to the polymer, but the extent these are recycled as fuel versus subjected to emission from the facility is unclear. Besides PAHs and VOCs, the other primary emissions from tyre pyrolysis plants include criteria air pollutants (CO, NO_x, SO_x, and particulate matter) (CIWMB, 2006).
Key Operational and Risk Management Measures	Pyrolysis operational conditions include high temperatures (ranging from ~200 to 800 ˚C) and oxygen-free or oxygen deficient atmospheres. Because the primary emissions from pyrolysis are through air emissions, wet scrubbers, dust filters, and/or flares can be used to minimize emissions (Chen, et al. 2007; CIWMB, 2006). Incineration (recycled into the pyrolysis reaction as fuel) or treatment by flare is typically used to control emissions (CIWMB, 1995a). The waste incineration BREF recommends a combination stage with energy recovery and flue-gas treatment and recovery substances that are not combusted (EC, 2006b).
Environmental Release Category	*Shredding*: ERC 3 – Formulation in materials *Pyrolysis*: ERC 1 – Production of chemicals
Environmental Release Category Notes	REACH CSA Chapter R.18 recommends ERC 1 for regeneration / refining of waste oils and for operations similar to chemical production. REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations.
Alternative Emission Factor Data Description	Emissions from pyrolysis are minimal based on characteristics of reaction/process
Alternative Emission Factor Data Details	Because the pyrolysis reactions occur in the absence of oxygen, lower environmental emissions of NO_2 and SO_2 occur with pyrolysis of tyres than with incineration. Furthermore, the pyrolysis is performed in closed vessels, and thus volumes of air, vapor and grit/dust emissions associated with the incinerator are not present (Sharma, et al. 1998). Pyrolytic units are expected to contribute minimally to air pollution because the gas generated under the process is burned as fuel for the process (CIWMB, 1996) In the presence of a flare, with complete combustion, products of pyrolytic gas are water, CO_2, CO, SO_2 and NOx (CIWMB, 1996).
Alternative Emission Factor Data Description	VOCs generated during pyrolysis
Alternative Emission Factor Data Details	Benzene-derived VOCs are generated during pyrolysis of SBR, IR and waste tyres, although the emission rate and specific chemicals liberated are dependent upon the starting material and operational conditions. These VOCs include benzene, toluene, ethylbenzene, 2-ethyenyl-cyclohexane, styrene, 1-methyl-4-(1-methylethyl)-benzene and limonene. Of these, approximate generation estimates are available in ppmv per 10 mg tyre for: styrene (35); limonene (20); m-xylene (0.25), 1,2,4-trimethylethylbenzene (0.25); 1-methyl-3-ethyl-benzene (0.65). The emission range for all VOCs generated during pyrolysis is ~1-50 ppmv/10 mg tyre (Kwon and Castaldi, 2009). Although the pyrolytic gas is typically recycled to be used as fuel for the reaction, if necessary a worst case release estimate could be calculated for specific environmental controls with known efficiencies for treating VOCs. If incineration (recycling into pyrolysis process) is chosen, emission rates in accordance with the recommendation in R.18 for incineration can be applied.
Alternative Emission Factor Data Description	Emissions of PAHs from pyrolysis plants equipped with wet scrubber and flare

Parameter	Description
Alternative Emission Factor Data Details	PAHs may be generated during the pyrolysis reaction from the combustion of rubber (SBR, IR or NR) into low-carbon hydrocarbons, which undergo a series of reactions to form PAHs with different rings, or at increasing temperature from the Diels-Alder aromatization reaction (from alkenes and dienes generated from alkane pyrolysis) (Chen, et al. 2007; Kwon and Castaldi, 2009). Chen, et al. 2007 measured PAH emissions from a facility that used a wet scrubber (WSB) and a flare as environmental controls. The total emission rate for PAHs from the facility was 42.3 g/day and 4.0 mg/kg tyre.
Alternative Emission Factor Data Description	Emission of criteria air pollutants during pyrolysis
Alternative Emission Factor Data Details	Emission of criteria air pollutants during pyrolysis has been quantified by CIWMB (1995a) based on reporting from 3 facilities. In ton emissions/ton tyres, emissions were: SO_x = 0.004, NO_x = 0.005 and PM = 0.0002.
Occupational Exposure Assessment	Occupational exposures associated with pyrolysis include dermal contact during material handling of the whole or shredded tyres.
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/whole tyres*: PROC 8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers at dedicated facilities *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles *Operation of pyrolysis unit*: PROC 2 - in closed, continuous process with occasional controlled exposure (e.g. sampling)
References	BASEL Convention. 2002. Technical Guidelines on the Identification and Management of Used Tyres. Chen, S-J., et al. 2007 Emissions of polycyclic aromatic hydrocarbons (PAHs) from the pyrolysis of scrap tires. Atmospheric Environment 41: 1209-1220 CIWMB (California Integrated Waste Management Board). 1995a. Environmental factors of waste tire pyrolysis, gasification and liquefaction. CIWMB (California Integrated Waste Management Board). 1996. Effects of waste tires, waste tire facilities, and waste tire projects on the environment. CIWMB (California Integrated Waste Management Board). 2006. Technology evaluation and economic analysis of waste tire pyrolysis, gasification and liquefaction. EC (European Commission). 2006b. Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration. August 2006 Kwon, E. and M.J. Castaldi. 2009. Fundamental Understanding of the Thermal Degradation Mechanisms of Waste Tires and their Air Pollutant Generation in a N2 Atmosphere. Environ. Sci. Technol. 43: 5996-6002 PYReco. 2009. Welcome to PYReco. http://www.pyreco.com/Default.asp Reschner, K. Scrap tire recycling: A summary of prevalent disposal and recycling methods. Sharma, V.K. et al. 1998. Disposal of waste tyres for energy recovery and safe environment- review. Energy Conservation Management. 39: 511-528.

Appendix A.6: Use of ELT as Supplementary Fuel in Production of Cement

Appendix A.6: Use of ELT as Supplementary Fuel in Production of Cement

Parameter	**Description**
ELT Scenario	Use of ELT as Supplementary Fuel in Production of Cement
Waste Treatment Type (2008/98/EC)	R1: Use principally as a fuel or other means to generate energy R4: Recycling/reclamation of metals and metal compounds R5:Recycling/reclamation of other inorganic materials
Estimated annual ELT tonnage (EU 27+2)	500000 t/year in 2002 (Holcim, 2006) 699000 t/year in 2003 (CEMBURAEU, 2006)[a] 810000 t/year in 2004 (CEMBURAEU, 2006)[a] 820000 t/year in 2008 (ETRMA, 2009)[b]
Scenario Description	ELT are used as a tyre derived fuel (TDF) as part of coprocessing in the cement industry. Coprocessing is defined as the use of waste materials in industrial processes with the main objective of substitution of primary fuel and raw materials. In the cement kiln, TDF (in the form of whole or shredded tyres) is used in the production of clinker, an intermediate product in cement manufacturing produced by decarbonizing, sintering and fast-cooling ground limestone. Product specific wastes are not generated because the fuel ashes are incorporated into the clinker. Silica and steel are used as secondary raw materials to replace glass sand and ferric oxide. The incineration process is regulated by national authorities with specified process control and waste admission requirements (Holcim, 2006).
Key Document(s) for more General Information about Scenario	Guidelines on co-processing Waste Materials in Cement Production (Holcim, 2006)
Description of Key Document(s)	Document provides guiding principles for the conditions where co-processing can be applied.
Regulatory Framework	Directive 2000/76/EC (on incineration of waste) Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The purpose of Directive 2000/76/EC is to limit negative effects on environment from incineration and co-incineration of waste. The directive requires an approved permit and establishes operating conditions and air emission limit values. Directives 2006/12/EC and 2008/98/EC provide a legal framework for the treatment of waste and define categories of waste, disposal operations and recovery operations.
Description of Substance Specific Hazards	For emissions to air, the European Waste Incineration Directive (2000/76/EC) defines acceptable emissions based on total emission limit values. Total emission limit values (mg/Nm^3) have been established for total dust, HCl, HF, NO_x, Cd + Tl, Hg, Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V, dioxins and furans, SO_2 and TOC. Cement kiln emissions to water are considered to be limited in scope and usually limited to surface water runoff and cooling water (EC, 2001). Emission data for air and water are available from the European Pollutant Emission Register. A recent health impact assessment completed in the UK concluded that the proposed combustion of tyres in a cement plant was unlikely to cause adverse impacts (Cook and Kemm, 2004). With regard to specific substances, a potential increase in zinc emissions with no impact on health and small decrease in most other trace metals was noted. A pilot test program conducted by the U.S. EPA (1997) concluded that with the exception of zinc, emissions from tyre derived fuel are expected to be similar to conventional fossil fuels in properly designed and maintained combustion devices.

Parameter	Description
Key Operational and Risk Management Measures	Operational conditions and risk management measures are described in Directive 2000/76/EC, the Best Available Techniques for Waste Incineration (EC, 2006b), the Best Available Techniques in the Cement and Lime Manufacturing Industries (EC, 2001 and the Best Available Techniques in the Cement, Lime and Magnesium Oxide Manufacturing Industries (EC draft May 2009). In general a gas retention time of 8 seconds above 1200 ˚C is achieved in the rotary kiln with an oxidizing gas atmosphere. Organic pollutants are completely destroyed and treatment technologies are used to remove gaseous substances including HF, HCl, and SO_2. The fuel ashes are used in the clinker for simultaneous energy recovery and recycling.
Environmental Release Category	*Shredding*: ERC 3 – Formulation in materials *Kiln*: Not assigned in REACH CSA TGD Chapter R.18 for this waste treatment type (see below for current REACH guidance and more information) *Cement/clinker*: ERC 10a - Wide dispersive outdoor use with low release
Environmental Release Category Notes	REACH CSA TGD Chapter R.18 proposes Tier 1 air emissions factors of 0.01% for organic substances and 0.2% for metals except Hg. However, the process conditions including the type of kiln and residence time of gases in the kiln result in a very high removal efficiency rate of > 99.9999% (EC, 2009). Therefore, emissions will be appreciably lower than that proposed in REACH CSA TGD Chapter R.18. Compliance with Directive 2000/76/EC is assumed. REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations. Use of ERC 10a is recommended for outdoor use of residual incorporated into cement based REACH Chapter R.18 recommendation for incinerator slag.
Alternative Emission Factor Data Description	European Pollutant Emission Register
Alternative Emission Factor Data Details	Cement clinker production emission data is available for 989 facilities and 30 pollutants for EU-25. The use of bulk tyres raises zinc air emission levels (Holcim, 2006). The database indicates that the total zinc emission to air and direct emission to water for all facilities is 58.7 t/year and 2.88 t/year, respectively. An additional 0.81 t/year of zinc is directed to off-site waste water treatment (European Pollutant Emission Register, 2009)
Alternative Emission Factor Data Description	Emission monitoring during combustion of alternative fuels
Alternative Emission Factor Data Details	As part of the commenting on the cement manufacturing industry, BREF, the German national expert group submitted air emission data for a modern dry kiln process system utilizing tyres at a rate representing 20% of energy consumption demonstrating compliance with the emission limits of 2000/76/EC (Germany, 2006)
Occupational Exposure Assessment	Whole or shredded tyres are incinerated at high temperature resulting in complete combustion of tyres and oxidation of the steel beads. The processes included are sorting of whole tyres or handling of shreds, feed of the raw material into the kiln by conveyor belt, and incineration. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds and inhalation of fugitive dust during raw material transfer or processing (Basel Convention, 2002)
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/whole tyres*: PROC 8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers at dedicated facilities *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles *Operation of kiln*: PROC 22 - Potentially closed processing operations with minerals/metals at elevated temperature. Industrial setting

Parameter	Description
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. CEMBURAEU (The European Cement Association). 2006. Cement & Lime BREF Revision. CEMBUREAU Contribution. 2003 and 2004 statistics on the use of alternative fuels & materials in the clinker production in the European cement industry. Cook and Kemm. 2004. Health impact assessment of proposal to burn tyres in a cement plant. Environmental Impact Assessment Review. 24: 207-216. EC (European Commission). 2001. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries. December 2001. EC (European Commission). 2006b. Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration. August 2006 EC (European Commission). 2009. Draft Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques in the Cement, Lime and Magnesium Oxide Manufacturing Industries. ETRMA, 2008b. End of Life Tyres – Alternative Fuel. http://www.etrma.org European Pollutant Emission Register. 2009. European Environment Agency (EEA). Copenhagen, Denmark. http://eper.ec.europa.eu Germany, 2006. German contribution to the review of the Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries. Part II: Cement manufacturing industries. National Expert Group. Holcim. 2006. Guidelines on co-processing waste materials in cement production. The GTZ-Holcim Public Private Partnership. Eschborn, Germany and Zürich, Switzerland. U.S. EPA. Air emission from scrap tire combustion. Office of Research and Development. Washington, DC. EPA-600/R-97-115.

[a]Rubber and ELT combined.
[b]Calculated based on a material recycling rate of 25% or 3281000 t/year x 0.25 = 820000 t/year (ETRMA, 2008b, 2009).

Appendix A.7: Use of ELT as Supplementary Fuel in Energy Generation

Appendix A. 7: Use of ELT as Supplementary Fuel in Energy Generation

Parameter	**Description**
ELT Scenario	Use of ELT as Supplementary Fuel in Energy Generation (excluding cement kilns)
Waste Treatment Type (2008/98/EC)	R1: Use principally as a fuel or other means to generate energy R11: Use of waste from any of the operations number R1 to R10 (e.g. bottom ash)
Estimated annual ELT tonnage (EU 27+2)	379000 t/year in 2008 based on the fraction of energy recovery not attributable to cement kilns (ETRMA, 2009)[a]
Scenario Description	ELT are used as a supplementary tyre derived fuel (TDF) for power generation or in waste-to-energy plants. Use of TDF for power generation is similar to co-processing in cement kilns with similar emissions controls, except that ash is generated. Waste-to-energy facilities burn wood wastes, agricultural waste or municipal solid waste to produce steam and/or electricity. Coprocessing is defined as the use of waste materials in industrial processes with the main objective of substitution of primary fuel and raw materials. The incineration process is regulated by national authorities with specified process control and waste admission requirements (Holcim, 2006; Singh et al. 2009; CIWMB, 1992).
Key Document(s) for more General Information about Scenario	Air emissions from scrap tyre combustion (EPA, 1997) Tyres as fuel supplement: feasibility study (CIWMB, 1992) Waste tyre rubber as a secondary fuel for power plants (Singh et al., 2009)
Description of Key Document(s)	EPA (1997) and CIWMB (1992) and provide general information on incineration of ELT. Singh et al. 2009 present pilot data showing the successful application of end-of-life tyres in reburning (staging process downstream of burner area to reduce NO_x emissions by use of an auxiliary fuel) and co-firing (supplementation of primary fuel with a secondary fuel).
Regulatory Framework	Directive 1996/61/EC and 2008/1/EC (on Integrated Pollution Prevention and Control) Directive 2000/76/EC (on incineration of waste) Directive 2001/80/EC (on large combustion plant) Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The purpose of Directive 2000/76/EC is to limit negative effects on environment from incineration and co-incineration of waste. The directive requires an approved permit and establishes operating conditions and air emission limit values. Directives 2006/12/EC and 2008/98/EC provide a legal framework for the treatment of waste and define categories of waste, disposal operations and recovery operations. Directive 2001/80/EC establishes emissions limits for large combustion plants with rated thermal input exceeding 50 MW. Directive 1996/61/EC and 2008/1/EC require best available techniques for industrial emissions with respect to environmental protection of air, water and soil for energy facilities with rated thermal input exceeding 50 MW.
Description of Substance Specific Hazards	Zinc from tyres vaporizes in the furnace and condenses on fly ash particles and is concentrated in the fly ash portion relative to bottom ash (CIWMB, 1995b). For emissions to air, the European Waste Incineration Directive (2000/76/EC) defines acceptable emissions based on total emission limit values. Total emission limit values (mg/Nm3) have been established for total dust, HCl, HF, NO_x, Cd + Tl, Hg, Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V, dioxins and furans, SO_2. A pilot test program conducted by the U.S. EPA (1997) concluded that with the exception of zinc, emissions from tyre derived fuel are expected to be similar to conventional fossil fuels in properly designed and maintained combustion devices. Sources of non-cooling waste water are limited and include process water if a wet flue gas treatment system is used and waste water from collection storage and treatment of bottom ash. Best available treatment techniques for waste water and air emissions are available (EC, 2006b).

Parameter	Description
Key Operational and Risk Management Measures	Operational conditions for combustion and waste to energy facilities are described in Directive 2000/76/EC and the Best Available Techniques for Waste Incineration (EC, 2006b). In general, a waste to energy facility consists of drying and degassing (at 100 to 300 ˚C), pyrolysis and gasification (at 250 to 700 ˚C) and oxidation of the combustion gases at flue gas temperatures of 800 and 1450 °C. Flue-gas cleaning is used to remove volatile heavy metals and inorganic matter and several technologies such as electrostatic precipitators are used to reduce particulate emissions. The Waste Incineration BREF provides treatment guidelines for the solid residues (i.e. ash) generated by combustion. The general considerations include the content of organic compounds and metals in the residues, the leachability of metals in the residues and physical suitability of the residues for reuse or disposal.
Environmental Release Category	*Shredding*: ERC 3 – Formulation in materials *Incineration*: Not assigned in REACH CSA TGD Chapter R.18 for this waste treatment type (see below for current REACH guidance) *Ash/slag*: ERC 10a - Wide dispersive outdoor use with low release
Environmental Release Category Notes	REACH CSA TGD Chapter R.18 proposes Tier 1 air emissions factors of 0.01% for organic substances and 0.2% for metals except Hg. Compliance with Directive 2000/76/EC is assumed. REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations. Use of ERC 10a is recommended for outdoor use of incineration slag.
Alternative Emission Factor Data Description	Source test data for utility facilities using TDF
Alternative Emission Factor Data Details	Data summarized by the U.S. EPA (1997) indicate that particulate and NO_x emissions decrease with increasing TDF content and that a clear trend for SO_x emissions was not observed. Detailed emissions data is available in Appendix A of U.S. EPA (1997) for dedicated tyre to energy plant, coal fired power plants, wood fired power plant, cement kiln, lime kiln, pulp and paper mills and industrial boilers. For the dedicated waste to energy facility (100% tyre use), the zinc emission rate was 5×10^{-5} kg emission/kg tyre based on feed rate of 350 to 400 tyres per hour and the 1988 data. SO_x and NO_x emission rates were 7×10^{-4} and 2×10^{-3} kg emission/kg tire and the particulate emission rate was 0.0002. The air pollution control devices were: • NO_x: Selective non-catalytic reduction (ammonia injection) • PM: Fabric filter with Gore-Tex® bags. • SO_x: Wet scrubber with lime injection.
Alternative Emission Factor Data Description	Characterization of fly ash and bottom ash from waste to energy facilities using tires as a supplemental fuel or primary fuel source
Alternative Emission Factor Data Details	Total zinc concentrations measured in the ash of two waste-to-energy facilities were approximately 700 to 1000 mg/kg for bottom ash and 22000 to 26000 mg/kg for fly ash. Soluble zinc was present in much lower levels, with levels of 26 to 48 mg/kg in bottom ash and 12 to 490 mg/kg in fly ash. Approximately 10 to 12% of the tire is converted to ash (CIWMB, 1995b).
Occupational Exposure Assessment	Whole or shredded tyres are incinerated at high temperature resulting in complete combustion of tyres (and oxidation of the steel beads if present). The processes included are sorting of whole tyres or handling of shreds, feed of the raw material into the kiln by conveyor belt, and incineration. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds and inhalation of fugitive dust during raw material transfer or processing (Basel Convention, 2002)
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/whole tyres*: PROC 8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers at dedicated facilities *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles *Operation of incinerator*: PROC 22 - Potentially closed processing operations with minerals/metals at elevated temperature. Industrial setting

Parameter	Description
References	Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. CIWMB (California Integrated Waste Management Board). 1992. Tires as a fuel supplement: feasibility study. CIWMB (California Integrated Waste Management Board). 1995b. Final ash quantification and characterization study – co-firing and dedicated combustion of waste tires. Prepared by R.W. Beck. Sacramento, California. EC (European Commission). 2006b. Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration. August 2006 ETRMA. 2008a. End of life tyre treatment data in 2007. http://www.etrma.org ETRMA, 2008b. End of Life Tyres – alternative Fuel. http://www.etrma.org Holcim. 2006. Guidelines on co-processing waste materials in cement production. The GTZ-Holcim Public Private Partnership. Eschborn, Germany and Zürich, Switzerland. Pré Consultants B.V., 2001. Life cycle assessment of an average European car tyre. Third Party Report Commissioned by BLIC. Singh et al. 2009. Waste tyre rubber as a secondary fuel for power plants. Fuel, 88: 2473-2480. U.S. EPA. 1997. Air emission from scrap tire combustion. Office of Research and Development. Washington, DC. EPA-600/R-97-115.

[a]Calculated as the balance of energy recovery not attributed to cement kilns (ETRMA, 2008a,b).

Appendix A.8: Use of ELT as Anthracite Substitute in Electric Arc Furnace

Appendix A.8: Use of ELT as Anthracite Substitute in Electric Arc Furnace

Parameter	**Description**
ELT Scenario	Use of ELT as Anthracite Substitute in Electric Arc Furnace
Waste Treatment Type (2008/98/EC)	R1: Use principally as a fuel or other means to generate energy R4: Recycling/reclamation of metals and metal compounds (i.e. steel)
Estimated annual ELT tonnage (EU 27+2)	One facility in France was identified with an annual capacity of 7000 tonnes (Aliapur, 2006)
Scenario Description	Carbon from ELT is used as an anthracite substitute for purpose of reducing iron oxide and as a source of energy in electric arc furnaces used to make steel from scrap metal wastes. The carbon from ELTs is used as reactant, fuel and alloy element. The anthracite or ELT is dissolved in a molten metal bath. Iron from the tyre is incorporated into the steel. Outputs from the process include metal, slag and dusts (Aliapur, 2006). Laboratory data indicates that waste tyres can be coinjected with metallurlogical coke with resulting increased combustion efficiencies (Zaharia et al. 2009).
Key Document(s) for more General Information about Scenario	Charging tyres in the EAF as a substitute to carbon (Gorez et al. 2003) End-of-life tyres in electric arc furnaces: an industrial success story (Aliapur, 2006)
Description of Key Document(s)	Gorez et al. (2003) and (Aliapur, 2006) describe the successful use of ELT for energy and material recovery in electric arc furnaces.
Regulatory Framework	Directive 1996/61/EC and 2008/1/EC (on Integrated Pollution Prevention and Control) Directive 2000/76/EC (on incineration of waste) Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives)
Description of Regulatory Framework	The purpose of Directive 2000/76/EC is to limit negative effects on environment from incineration and co-incineration of waste. The directive requires an approved permit and establishes operating conditions and air emission limit values. Directives 2006/12/EC and 2008/98/EC provide a legal framework for the treatment of waste and define categories of waste, disposal operations and recovery operations. Directive 1996/61/EC and 2008/1/EC require best available techniques for industrial emissions with respect to environmental protection of air, water and soil for energy facilities with rated thermal input exceeding 50 MW.
Description of Substance Specific Hazards	Environmental emissions measured with and without use of tyres indicate no significant changes in baseline emissions of SO_2, Zn, Pb, Cd, PAH, benzene, toluene, xylene and dioxins. A similar conclusion was obtained for occupation exposure furnace operators including consideration of heavy metals, nitrosamines and formaldehyde (Gorez et al. 2003).
Key Operational and Risk Management Measures	The ELT substitution rate in an electric arc furnace is 1.7 kg tyre per kg carbon and tyres can be substituted up to 8-12 kg/t steel Tyre pieces 10 cm in size are added under controlled conditions (Gorez et al. 2003). Post-combustion parameters must be optimized to ensure CO combustion occurs in the furnace (Aliapur, 2006). Generic operational conditions for combustion and waste to energy facilities are described in Directive 2000/76/EC and the Best Available Techniques for Waste Incineration (EC, 2006b).
Environmental Release Category	*Shredding*: ERC 3 – Formulation in materials *Furnace*: Not assigned in REACH CSA TGD Chapter R.18 for this waste treatment type (see below for current REACH guidance)
Environmental Release Category Notes	REACH CSA TGD Chapter R.18 proposes Tier 1 incineration air emissions factors of 0.01% for organic substances and 0.2% for metals except Hg. Compliance with Directive 2000/76/EC is assumed. REACH CSA Chapter R.18 recommended ERC 3 for shredding operations, which are similar to milling of solid materials as a process step within production of granulates for solid preparations.
Alternative Emission Factor Data Description	Comparative emission study with and without use of ELT

Parameter	Description
Alternative Emission Factor Data Details	Environmental emissions were measured with and without use of tyres in the furnace. There were no significant differences in the parameters monitored including SO_2, Zn, Pb, Cd, PAH, benzene, toluene, xylene and dioxins (Gorez et al. 2003).
Occupational Exposure Assessment	Whole or shredded tyres are introduced at high temperature into the electric arc furnace resulting in complete combustion of tyres and oxidation of the steel beads. The processes included are sorting of whole tyres or handling of shreds, feed of the raw material into the kiln by conveyor belt, and incineration. Potential occupational exposures include dermal contact during manual sorting of whole tyres/shreds and inhalation of fugitive dust during raw material transfer or processing (Basel Convention, 2002; Gorez et al. 2003)
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/whole tyres*: PROC 8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers at dedicated facilities *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles *Operation of furnace*: PROC 22 - Potentially closed processing operations with minerals/metals at elevated temperature. Industrial setting
References	Aliapur. 2006. End-of-life tyres in electric arc furnaces: an industrial success story. Lyon cedex, France. Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. Gorez et al. 2003. Charging s in the EAF as a substitute to carbon. Rev. Metall./Cah. Inf. Tech., 100, 17-24. EC (European Commission). 2006b. Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration. August 2006 Zaharia, M. et al. 2009. Recycling of rubber tires in electric arc furnace steelmaking: Simultaneous combustion of metallurgical coke and rubber tyre blends. Energy and fuels, 23: 2467-2474.

Appendix A.9: Reclaim of Rubber through Physical or Chemical Processes for Incorporation in Virgin Rubber Products

Appendix A.9: Reclaim of Rubber through Physical or Chemical Processes for Incorporation in Virgin Rubber Products

Parameter	**Description**
ELT Scenario	Reclaim of rubber through physical or chemical processes for incorporation in virgin rubber products
Waste Treatment Type (2008/98/EC)	R3: Recycling/reclamation of organic substances which are not used as solvents
Estimated annual ELT tonnage (EU 27+2)	< 25,000 tonnes per annum, based on maximum capacity of large scale reclaim facility in Maastricht, Netherlands (Rubber Resources, 2009).
Scenario Description	Devulcanization is the process of cleaving the sulfidic cross-links of vulcanized rubber. The process typically requires heat, chemicals and mechanical techniques (CIWMB, 2004; Adikari et al., 2000, Basel Convention, 2002). In principle, devulcanization could be used to produce a product substituting for virgin rubber. Reclaimed rubber is defined as devulcanized rubber that has regained its viscosity as well as the characteristics of the original compound. Devulcanized material (i.e. reclaimed rubber) is also used as raw material for new tyres manufacturing (see ETRMA 2009b). Imported reclaimed rubber is subject to registration (differently from EU reclaimed material). In chemical reclaim, which represents the majority of reclaim industries (Adikari et al., 2000), chemical agents, including organic disulfides and mercaptans, inorganics, or other chemicals, are used to devulcanize rubber. Rubber particles are batch-mixed with these chemical reagents in a reactor at controlled temperature and pressure, upon which the resulting product is filtered and undesirable components are removed. In physical reclaim, the crosslinked rubber breaks down in the presence of energy, including mechanical, thermo-mechanical, cryo-mechanical, microwave, and ultrasonic. • *Mechanical/thermomechanical reclaim*: Milling is carried out at high temperature resulting in a decrease in molecular weight attributed to shearing at high temperatures. • *Cryomechanical reclaim:* Milling is carried out in the presence of liquid nitrogen to create a fine powder. See cryogenic grinding description provided in Appendix A.4. • *Microwave method*: Controlled dose of microwave energy at specified frequency and energy level is applied to the rubber to cleave the carbon-carbon bonds. Microwave requires polar rubber compounds in order to create enough energy to break the bonds (thus microwave reclaim applications are limited). • *Ultrasonic method*: Ultrasonic devulcanization is a continuous process whereby rubber particles are fed into an extruder, which mechanically manipulates, heats and softens the rubber. As the rubber passes through the extruder, it is subject to ultrasonic energy.
Key Document(s) for more General Information about Scenario	Reclamation and recycling of waste rubber (Adhikari et al., 2000); Evaluation of Waste Tyre Devulcanization Technologies (CIWMB, 2004)
Description of Key Document(s)	Describes methods for rubber reclaim, including available reclaim technologies (mechanical and chemical), discussion of benefits and/or disadvantages of available technology, applications for reclaimed rubber, and chemicals of concern for environmental emissions from devulcanization.
Regulatory Framework	Directive 2006/12/EC (on waste) Directive 2008/98/EC (on waste and repealing certain Directives) Directive 1996/61/EC and 2008/1/EC (Integrated Pollution Prevention and Control)
Description of Regulatory Framework	Directives 2006/12/EC and 2008/98/EC provide a legal framework for the treatment of waste and define categories of waste, disposal operations and recovery operations. Directive 1996/61/EC and 2008/1/EC require best available techniques for industrial emissions with respect to environmental protection of air, water and soil for energy facilities with rated thermal input exceeding 50 MW.

Parameter	Description
Description of Substance Specific Hazards	Based on the process descriptions for microwave, ultrasonic, and chemical reclaim processes, heat, pressure, energy, and/or mechanical manipulation are required to accomplish the devulcanization. Although little information is available on emissions from waste tyre devulcanization technologies, a qualitative understanding of the process allowed for identification of potential chemicals of concern. Exposures and/or emissions are likely to occur as a consequence of heating of the rubber. Emissions are likely to be greater with chemical reclaim processes than physical reclaim because of use of exogenous chemicals in the reaction process. CIWMB (2004) has identified some chemical families as potential compounds emitted during devulcanization activities. Chemical families identified included plasticizers (impurities in oils and parent compounds), polymers (impurities, including monomers), antioxidants, retarders and metal fume including zinc.
Key Operational and Risk Management Measures	CIWMB identified the following as important RMM for environmental emissions from devulcanization facilities: Treatment of vapors with thermal oxidation, metals and particulate deposited in baghouse, scrubbers to remove sulfur compounds associated with reactants (disulfides) and waste water treatment for liquid waste from scrubber. If the process is ultrasonic, vapor phase carbon could be used to treat the vapors. The BREF for Waste Treatment Industries provides techniques for reducing emissions from various waste treatment techniques (EC, 2006a).
Environmental Release Category	*Shredding/devulcanization*: ERC 3 – Formulation in materials
Environmental Release Category Notes	ERC3 is proposed for shredding and other dismantling activities related to ELV, home appliances and electronic waste and is applicable to milling of solid materials as a process step within the production of granulates for solid preparations, and thus is appropriate for mechanical applications of rubber reclaim. It is also used as the ERC for plastic recycling (and R3 waste types), which may be the most appropriate for chemical reclaim processes.
Alternative Emission Factor Data Description	Very little information on devulcanization plant emissions is available in the public literature (CIWMB, 2004).
Alternative Emission Factor Data Details	Facilities are assumed to operate with necessary and appropriate RMM. Filters to control dust emissions and gas scrubbers to control SO_2 emissions may be required. Liquid effluents may require treatment.
Occupational Exposure Assessment	Potential occupational exposures include dermal contact during loading of rubber (shreds, crumb, etc.) and inhalation of fugitive dusts or vapors in the processing (CIWMB, 2004).
Process Categories Relevant to ELT Material Handling	*Material transfer of tyre shreds/whole tyres*: PROC 8b - Transfer of substance or preparation (Charging/discharging) to/from vessels/large containers at dedicated facilities *Processing of whole tyres by shredding*: PROC 21 - Low energy manipulation of substances bound in materials and/or articles *Devulcanization under heated conditions*: PROC 22 - Potentially closed processing operations with minerals/metals at elevated temperature. Industrial setting

Parameter	Description
References	Adhikari, B., De, D. and S. Maiti. Reclamation and recycling of waste rubber. 2000. Prog. Polym. Sci. 25, 909-948. Basel Convention. 2002. Basel Convention Technical Guidelines on the Identification and Management of Used Tyres. Basel Convention on the Control of Transboundary Movements on Hazardous Wastes and Their Disposal. No. 10. CIWMB (California Integrated Waste Management Board). 2004. Evaluation of waste tyre devulcanization technologies. EC (European Commission). 2006a. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Waste Treatment Industries. August 2006. ETRMA. 2009b. Guidelines for recovered rubber. Version 1.1. REACH, 1907/2008/EC. http://www.etrma.org. Green Rubber. 2009. Press Release. The Timberland Company and Green Rubber Inc. Announce Partnership to Reduce the Critical Environmental Hazard of Waste Tires. Rubber Resources, 2009. Rubber resources. Maastricht Plant. http://www.rubber-resources.com/upload/File/Brochures/03_PlantMaastricht.pdf