Product Category Rule (PCR) Guidance for Tires

From the range of Environmental Product Declarations of UL Solutions

VERSION 4.0 (TBD)

VALID THROUGH (July 2029)

www.ul.com/environment

Version overview

Version	Description	History
1	TIP_ULE_PCR_for_Tires_v14-3 for Phase 1a Pilot, Version by UL Solutions with input from external committee	October 2015
2	TIP_ULE_Quantis_PCR for Tires 2017-01-31, Version updated by Quantis after PCR pilot testing by committee members	January 2017
2.01	TIP_ULE_Quantis_PCR for Tires 2017-02-07, Version updated by Quantis	February 2017
3	TIP_ULE_Quantis_PCR for Tires 2017-03-31, Version updated by Quantis, with the following modifications: implementation of feedbacks received from other program operators (JEMAI and the International EPD® System), implementation of technical improvements, inclusion of bus specifications	March 2017
3.01	TIP_ULE_Quantis_PCR for Tires 2017-04-14, Version updated by Quantis with the implementation of technical improvements by committee members, submitted to open consultation and external review	April 2017
3.02	TIP_ULE_Quantis_PCR for Tires 2017-06-08, Version updated by Quantis with the implementation of comments from open consultation and external review (JEMAI and the International EPD® System), submitted to UL Solutions external review	June 2017
3.03	TIP_ULE_Quantis_PCR for Tires 2017-06-28, Version updated by Quantis with the implementation of comments from external review (UL Solutions), implementation of technical improvements (product grouping)	July 2017
3.04	TIP_ULE_Quantis_PCR for Tires 2017-11-01, Version updated by Quantis with implementation of updated rules for product grouping	November 2017
3.05	Version updated to align with updated approaches, information, and research, and to add consistency including: - Use stage calculation improvement related to vehicle efficiencies - Updated and added datasets for fuel combustion emissions related to different energy sources - Updated energy source distribution - Default datasets for raw materials - Updated data points related to tire and road wear particles - Updated impact assessment methods and categories	July 2022
4	TIP_ULE_PCR _for_Tires 2024-03-04, Version updated by WAP Sustainability with the following modifications: - Added off-the-road vehicle categories - Implemented hierarchy approach for allocation method - Updated region-specific ELT management data	TBD

Version	Description	History
	- Updated payload portion and payload utilization factors - Updated region-specific vehicle efficiencies and fuel mixes including updated default datasets for additional fuel types with a focus on trucks and buses - Updated fuel densities and LHVs for truck and bus fuels - Updated lists of impact indicators - Updated methodology for renewable materials, including how biogenic carbon is handled - Updated natural rubber background dataset - Updated background dataset emission factors	

Editor's Notes:

These Product Category Rules (PCR) are global in scope and serve both B2B and B2C applications, reflecting the global manufacturing, distribution networks, and use of these products. Updates to this PCR are anticipated as advances in scientific research and Environmental Product Declaration (EPD) application advance.

The PCR development committee was comprised of members from the following organizations:

- Bridgestone Corporation
- Continental AG
- Cooper Tire & Rubber Company (since merged with Goodyear)
- The Goodyear Tire & Rubber Company
- Hankook Tire & Technology Co., Ltd.
- Kumho Tire Company Inc.
- Manufacture Française des Pneumatiques Michelin
- Pirelli & C.
- Sumitomo Rubber Industries, Ltd.
- The Yokohama Rubber Co., Ltd.
- Toyo Tire Corporation

The PCR development committee was facilitated and supported by the following organizations:

- WBCSD
- WAP Sustainability
- maki Consulting GmbH

The first PCR external review was conducted by:

- Dr. Thomas Gloria, Industrial Ecology Consultants, Chair
- Dr. Amy Landis, Clemson University
- Dr. Stefan Hausberger, Graz University of Technology
- Dr. Michael Hauschild, Technical University of Denmark
- Mr. Mamoru Yanagisawa, Japan Gas Appliances Inspection Association
- Dr. JoongWoo Ahn, Sungshin University

The PCR external review report is available upon request at: ul.pcr@ul.com

The PCR was also submitted to review by other program operators, including:

- Mr. Akira Kataoka, JEMAI
- Mr. Kristian Jelse, The International EPD® System

A second PCR external review was conducted from April 2017 by:

- Dr. Thomas Gloria, Industrial Ecology Consultants
- Dr. Michael Hauschild, Technical University of Denmark
- Mr. Mamoru Yanagisawa, Japan Gas Appliances Inspection Association

[INSERT DETAILS ON REVIEW]

In addition, the PCR was reviewed by the Technical Committee of the International EPD® System in accordance with the General Program Instructions. The output of the review is that the current PCR is accepted, and can thus be adopted into the PCR library of the International EPD® System. The review panel members were:

- Maurizio Fieschi (review chair)
- Paola Borla
- Adriana Del Borghi
- Hüdai Kara
- Lars-Gunnar Lindfors
- Barbara Nebel
- Andrew Norton
- Claudia A. Peña

An addendum PCR, to be used with this document, has also been developed by the EcoLeaf program in Japan (Eco-Design Office, ecodesign@jemai.or.jp). This PCR document and the addendum PCR were reviewed by external panel.

Questions on the present document shall be addressed to Neha Verma (verma@wbcsd.org), WBCSD Tire Industry Project.

Table of Contents

1 General Information

The intended application of this Product Category Rules (PCR) document is to provide guidance for developing Environmental Product Declarations (EPDs) for tires and to pinpoint the underlying requirements of a Life Cycle Assessment (LCA) pursuant to ISO standards that address appropriate environmental aspects of the tire life cycle.

The user of this PCR will be manufacturers of tires and other interested parties and will enable EPDs that support comparable, informed, and objective evaluation of tires.

This document was developed under the UL Solutions EPD Program, operating in conformance with ISO 14025:2006 and the following international standards:

- ISO 14040, LCA - Principles and procedures
- ISO 14044, LCA - Requirements and guidelines

The rules and requirements of the UL EPD Program are defined in the UL General Program Instructions, available at: http://industries.ul.com/environment/transparency/product-category-rules-pcrs.

This PCR is valid for tires used in passenger vehicle, light truck, medium and heavy truck, pick-up, city and school bus, coaches, aircraft, off-the-road vehicles and motorcycle as further described in Section 2.1. This PCR is global in scope and presents a harmonized calculation procedure for tire-attributed vehicle use stage emissions.

Impacts reported in EPDs created using this PCR are only related to tires and shall not be used to compare to vehicle performance in other reported contexts beyond this PCR scope. This PCR shall not be used to represent the tire industry and/or individual tire company impacts on the whole given certain equations presented in this document could overestimate the environmental impact of tires (e.g. the amount of rubber in wear loss).

This Product Category Rules (PCR) document has been developed as part of the Tire Industry Project (TIP) of the World Business Council for Sustainable Development (WBCSD) with the aim to promote the development and the use of Environmental Product Declarations (EPD) for the tire industry around the world.

In order to address certain regional differences, this document provides different rules and options for users in different regions. The International EPD® System in Sweden has validated that this PCR document can be adopted into the PCR library of the International EPD® System. Addendum PCR, to be used with this document, has also been developed by the EcoLeaf program in Japan.

- Ecoleaf program: Eco-Design Office (ecodesign@jemai.or.jp)
- The International EPD® System: Mr. Kristian Jelse (kristian@environdec.com)

1.1 Committee Members

PCR version 3.04, published in November 2017.

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PCR version 3.05, published in June 2022.

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PCR version 4.0, published in June 2024.

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1.2 Acknowledgements

The committee would like to acknowledge the European Tyre and Rubber Manufacturers' Association (ETRMA) for the use of tire research and data to inform the development of this PCR.

1.3 Identification of Tire Product

This PCR covers commercially available, new, pneumatic tires, both tube type and tubeless, for use on conventional passenger cars, light trucks, medium to heavy trucks, pick-up, city and school buses, coaches, and similar vehicles normally operated on public roads and highways. This PCR also covers commercially available, special application light truck tires for operation on non-improved road surfaces, off-the-road tires, motorcycle tires, and aircraft tires. This PCR includes various sub-categories according to the following tire type:

- Passenger car/light truck
- Medium/heavy truck (Commercial),
- Bus
    - Pick-up bus,
    - City bus,
    - School bus,
    - Coach,
- Motorcycle,
- Off-the Road
    - Compactor,
    - Earth Mover,
    - Grader,
    - Loader and Dozer,
    - Mobile Crane,
    - Industrial,
    - Subterranean Haulage, and
- Aircraft tires

These tires are subject to the standards or technical approvals shown under Section 2.4.6. Additional rules around tire performance are provided for each tire sub-category.

1.3.1 UNSPSC Code

The following code covers the range of this rule: 25172500 (Tires and tire tubes)

1.4 Geographic Coverage

This PCR is global in scope and was developed in English. Regions of applicability include:

- China
- Europe
- Japan
- South Korea
- Latin America (including Mexico)
- North America
- Rest of World (ROW)
    - Middle East/ Africa
    - Oceania
    - Russia
    - Asia - Others
    - Taiwan

1.5 Period of Validity

This document is effective for five (5) years from the latest date of publication. If relevant changes in LCA methodology or other relevant considerations for the product category occur, the document will be revised.

1.6 Public Comment

In accordance with the UL Solutions General Program Instructions, this PCR is made freely available for public comment for at least one calendar month and open to all public comments. Identifiable sources are addressed and responses will be posted.

1.7 PCR Review Panel

The first PCR external review was conducted by:

- Dr. Thomas Gloria, Industrial Ecology Consultants, Chair
- Dr. Amy Landis, Clemson University
- Dr. Stefan Hausberger, Graz University of Technology
- Dr. Michael Hauschild, Technical University of Denmark
- Mr. Mamoru Yanagisawa, Japan Gas Appliances Inspection Association
- Dr. JoongWoo Ahn, Sungshin University

In addition, the PCR was also submitted to review by other program operators, including:

- Mr. Akira Kataoka, JEMAI
- Mr. Kristian Jelse, The International EPD® System

A second PCR external review of the document was conducted from April 2017 by:

- Dr. Thomas Gloria, Industrial Ecology Consultants
- Dr. Michael Hauschild, Technical University of Denmark
- Mr. Mamoru Yanagisawa, Japan Gas Appliances Inspection Association

In addition, the PCR was reviewed by the Technical Committee of the International EPD® System in accordance with the General Program Instructions. The output of the review is that the current PCR is accepted, and can thus be adopted into the PCR library of the International EPD® System. The review panel members were:

- Barbara Nebel (review chair)
- Paola Borla
- Adriana Del Borghi
- Hüdai Kara
- Lars-Gunnar Lindfors
- Barbara Nebel
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An addendum PCR, to be used with this document, has also been developed by the EcoLeaf program in Japan (Eco-Design Office, ecodesign@jemai.or.jp). This PCR document and the addendum PCR were reviewed by external panel.

1.8 Public Commenters

For the first open consultation, comments were received from:

- Japan Automobile Tyre Manufacturers Association (JATMA)

For the second open consultation (on the version 3.01), comments were received from:

- U.S. Tire Manufacturers Association (USTMA)

- European Tyre & Rubber Manufacturers' Association (ETRMA)

1.9 Other Tire Product Category Rules

Two existing PCRs for tires were reviewed and used to inform this PCR development process: The Taiwanese PCR for New Pneumatic Tyres (November 2013, developed by the Taiwan Rubber and Elastomer Industries Association) and the Korean PCR for Tires for passenger cars. Additionally, the Japan Automobile Tyre Manufacturers Association (JATMA) Tyre Life Cycle CO_2 Calculation Guidelines (April 2012) was used to inform this PCR.

1.10 LCA Study References

In developing this PCR, the committee reviewed several LCA studies of tires, including:

- Continental AG 2000. Life Cycle Assessment of a Car Tire.
- Corti and Lombardi 2004. End life tyres: Alternative final disposal processes compared by LCA. Energy 29 (2004) 2089–2108.
- Feraldi, Cashman et al. 2012. Comparative LCA of treatment options for US scrap tires: material recycling and tire-derived fuel combustion. The International Journal of Life Cycle Assessment. 03/2012; 18(3). DOI: 10.1007/s11367-012-0514-8
- Fiksel, Bakshi et al. 2011, Comparative life cycle assessment of beneficial applications for scrap tires. Clean Technologies and Environmental Policy. February 2011, Volume 13, Issue 1, pp 19-35
- Li, Xingfu, He Xu et al. Comparison of end-of-life tire treatment technologies: A Chinese case study. Tianjin: Elsevier, 2010, Waste management, Vol. 30, pp. 2235-2246.
- Van Beukering, P. J. H. and M. A. Janssen. 2000. A Dynamic Integrated Analysis of Truck Tires in Western Europe. Journal of Industrial Ecology 4(2): 93-115.

2 Goal and Scope

The intended application of this Product Category Rules (PCR) document is to give guidance for developing Environmental Product Declarations (EPD) for tires and to outline the requirements of a Life Cycle Assessment (LCA) report used to inform the EPD. The users of this PCR will be manufacturers of new tires and other interested parties. This PCR is valid for tires used in passenger vehicle, light truck, medium and heavy truck, pick-up, city and school bus, coaches, aircraft, off-the-road vehicles and motorcycle as further described in Section 2.1

This PCR addresses the cradle to end of life environmental impacts of tires and conforms with ISO 14025, Environmental labeling and declarations – Type III environmental declarations – Principles and procedures. The reporting of additional information as shown under Section 6.2 is permitted. The environmental impacts are calculated using attributional LCA methodology. The life cycle stages excluded from the scope are the following:

- Installation (corresponding to module A5, as described in Section 3.2);
- Transport of the assembled product to the consumer (corresponding to module A6, as described in Section 3.2), i.e., the transport of the vehicles on which the tire is mounted;
- Maintenance (corresponding to module B2, as described in Section 3.2), i.e., tire cleaning, inspection, inflation, rotation, balancing, and alignment;
- Repair (corresponding to module B3, as described in Section 3.2), i.e., repair of the tire over the reference service life. This includes routine patching and other standard repair processes;
- Removal (corresponding to module C1, as described in Section 3.2), i.e., the removal of the tire from the vehicle, including on-site sorting of materials;
- Capital equipment manufacture;
- Personnel impacts;
- Infrastructures;
- Vehicle & rim production, maintenance and end-of-life;
- Road production, maintenance and end of life.

Impacts reported in EPDs created using this PCR are only related to tires and shall not be used to compare to vehicle performance in other reported contexts or tire categories not covered in the PCR scope.

An EPD prepared under this PCR will present data that have been aggregated over the information modules.

Table 1. Tire product EPD types

EPD type	Declared Unit or Functional Unit	Life Cycle Stages/Information modules	Reference Service Life (RSL)	Primary audience
Cradle to factory gate + end of life	Declared unit	Modules A1-A3, C1-C3, as described in Section 3.2	Not specified	Business-to-business (B to B)
Cradle to grave	Functional unit	Modules A1-A6, B1-B4, C1-C3, as described in Section 3.2	RSL is required	Business-to-business (B to B) and/or Business-to-consumer (B to C)

The comparability of EPD of tire products will be in accordance with the requirements for comparability as described in ISO 14025, Section 5.6, "Type III environmental declarations are intended to allow a purchaser or user to compare the environmental performance of products on a life cycle basis. Therefore, comparability of Type III environmental declarations is critical. The information provided for this comparison shall be transparent in order to allow the purchaser or user to understand the limitations of comparability inherent in the Type III environmental declarations.

Type III environmental declarations not based on an LCA covering all life cycle stages, or based on different PCR, are examples of declarations that have limited comparability. Type III environmental declarations based on the same PCR but based on different impact and inventory results are examples of declarations that have limited comparability."

This PCR allows comparison only for the same size, same load index category (as per Table 38), and same tire-sub- categories according to Section 2.1 for passenger car and light truck. This PCR allows comparison only for the same size, same load index, and same tire sub-categories according to Section 2.1 for truck, bus, and off-the-road tires. In particular, dual tires are not comparable with a single wide based tire. Potential environmental impacts of tires should only be compared when mounted on the same category of vehicle.

If multiple plants are producing the same product, the average performance of the manufacturing plant locations shall be taken into account.

2.1 Tire Sub-Categories

Tire category definitions are provided to assist the user in identifying the most appropriate and applicable requirements within this global tire PCR. If the intended tire application is not specifically represented by a category and region provided, the user may select the most representative category or region. All tires referenced in Sections 2.1.1 - 2.1.20 shall be in conformance with ISO TC 31 Standards.

If the tire has been developed for a specific vehicle, this information may be reported in Section 6.1 and the results may be additionally reported under Section 6.2 as supplemental information.

2.1.1 Passenger Car Tire

A pneumatic tire for power-driven vehicles having at least four wheels, used for the carriage of passengers, and designed to seat no more than nine persons. Typically, these are vehicles classified in category M_1 of the World Forum for Harmonization of Vehicle Regulations. This category, for example, includes tires for passenger vehicles in North America designed to exceed 20 mph (32 km/h) and licensed for use on public roads (e.g. not golf cart tires).

2.1.2 Light Truck Tire

A pneumatic tire for power driven vehicles having at least four wheels used for the carriage of passengers and cargo (i.e. pick-up truck or light van). Typically, these are vehicles classified in category N_1 or the smaller vehicles in category N_2 of the World Forum for Harmonization of Vehicle Regulations.

Table 2. Gross Weight (metric tonnes) ranges for Vehicles in the Light Truck Category[1]

China		**Europe**	**Japan**		**South Korea**		**Latin America (LA)**	**North America (NA)**	**UN World Forum (N_1) / Rest of World (ROW)**
Small	< 1.8	< 3.50	Small size truck	≤3.5	Small size truck	≤ 3.50	≤ 3.50	≤ 6.35	≤ 3.50
Light truck	>1.8 < 6								

2.1.3 *Pick-up and Delivery Truck Tire*

A pneumatic tire for trucks used for local service or carriage of retail product. Typically, these are the larger vehicles classified in category N_2 of the World Forum for Harmonization of Vehicle Regulations.

Table 3. Gross Weight (metric tonnes) ranges for Vehicles in the Pick-up and Delivery Truck Category[1]

China		**Europe**	**Japan**		**South Korea**		**LA**	**NA**	**UN World Forum (N_2) / ROW**
Medium size truck	> 6 ≤ 14	> 3.5 ≤ 12	Medium size truck	≥ 3.5 ≤ 11	Medium size truck	> 3.50 < 10	> 3.50 < 12	> 6.35 ≤ 20	> 3.5 ≤ 12

2.1.4 *Long Haul Truck Tire*

A pneumatic tire for power driven vehicles with four or more wheels, used for carriage of cargo primarily on highways. Typically, these vehicles are classified in category N_3 of the World Forum for Harmonization of Vehicle Regulations.

[1] The sources are the following : China : MarkLines Data Center (https://www.marklines.com/en/vehicle_production/search_note), Europe : DIRECTIVE 2007/46/EC - ANNEX II (N1), Japan : Road Traffic Law, South Korea: Expert judgement, LA and NA : Estimated based on UN classifications and manufacturer information about common vehicles

Table 4. Gross Weight (metric tonnes) ranges for Vehicles in the Long Haul Truck Category[1]

China		Europe	Japan		South Korea		LA	NA	UN World Forum (N_2) / ROW
Large size truck	> 14	> 12	Large size truck	≥ 11	Large size truck	≥ 10	> 12	≥ 11.8	> 12

2.1.5 *Regional/City Truck Tire*

A pneumatic tire for power driven vehicles with four or more wheels, used for carriage of cargo on both highways and improved intra city roads. Typically, these vehicles are classified in category N_3 of the World Forum for Harmonization of Vehicle Regulations.

Table 5. Gross Weights (metric tonnes) ranges for Vehicles in the Regional / City Truck Category[1]

China		Europe	Japan		South Korea		LA	NA	UN World Forum (N_3) / ROW
Large size truck	> 14	> 12	Large size truck	≥ 11	Large size truck	≥ 10	> 12	≥6.35	> 12

2.1.6 *Mixed Service Truck Tire*

A pneumatic tire for power driven vehicles with four or more wheels, used for carriage of cargo on and off improved roads. Typically, these vehicles are classified in category N_3 of the World Forum for Harmonization of Vehicle Regulations.

Table 6. Gross Weights (metric tonnes) ranges for Vehicles in the Mixed Service Truck Category[1]

China		Europe	Japan		South Korea		LA	NA	UN World Forum (N_3) / ROW
Large size truck	> 14	> 12	Large size truck		Large size truck	> 10	> 12	≥ 11.8	> 12

				≥ 11					

2.1.7 *Pick-up Bus Tire*

A pneumatic tire for power driven vehicles with four or more wheels, used for local transport of passengers. Typically, these vehicles are classified in category M2 of the World Forum for Harmonization of Vehicle Regulations. Typical applications would be shuttle buses or community services. The buses are often minivans which are designed primarily for passengers with two or three rows of seating accessed via large (often sliding) doors. They have a greater height than sedan or station wagon counterpart. Their interior is often re-configurable with flexible or removable seating. In international markets, the minivan is classified as multi-purpose vehicle (MPV) or people carrier.

Table 7. Gross Weights (metric tonnes) ranges for Vehicles in the Pick-up Bus Category[2]

China	Europe	Japan	South Korea[3]	LA	NA	UN World Forum (M2) / ROW
< 5	< 5	>3.5 =<6	< 5	>3.5 and <12	<4.5	< 5

2.1.8 *City Bus Tire*

A pneumatic tire for power driven vehicles with four or more wheels, used for local transport of passengers. Typically, these vehicles are classified in category M3 of the World Forum for Harmonization of Vehicle Regulations. Typical applications are large and medium city buses as well as articulated buses. Their service is generally based on a regular operation along a route calling at agreed bus stops according to a published timetable. City buses can operate within the city as well as between the city and local suburban areas. City buses are designed to provide space for passengers to stand-up during the trip.

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[2] The sources are the following : China : same as Europe, Europe : https://www.hbefa.net/ and http://www.transportpolicy.net/index.php?title=EU:_Vehicle_Definitions, Japan : http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/sho_ene/jidosha_wg/2016/pdf/001_03_00.pdf, South Korea: same as Europe, LA : OEM literature, Law 9503 Compilado (Brazil), and DNIT: http://www.dnit.gov.br/download/rodovias/operacoes-rodoviarias/pesagem/qfv-2012-abril.pdf, and NA : Internal knowledge, manufacturer information, and APTA "An Analysis of Transit Bus Axle Weight Issues.

[3] For South Korea, the classification shall be based on length instead of weight as per national classification rules. As a proxy, the same values as Europe were used for gross weight ranges.

Table 8. Gross Weights (metric tonnes) ranges for Vehicles in the City Bus Category[2]

China	Europe	Japan	South Korea[3]	LA	NA	UN World Forum (M2) / ROW
> 5	> 5	>6	> 5	>3.5	>4.5	> 5

2.1.9 School Bus Tire

A pneumatic tire for power driven vehicles with four or more wheels, used for local transport of passengers and carrying students and school kids to and from school and related events. Typically, these vehicles are classified in category M3 of the World Forum for Harmonization of Vehicle Regulations. Typical applications are pick-up buses for school kids. This service is largely, but not exclusively, limited to the US.

Table 9. Gross Weights (metric tonnes) ranges for Vehicles in the School Bus Category[2]

China	Europe	Japan	South Korea[3]	LA	NA	UN World Forum (M3) / ROW
N/A	N/A	N/A	N/A	N/A	>8.2	> 5

2.1.10 Regional/Inter-city Coach Bus Tire

A pneumatic tire for power driven vehicles with four or more wheels, used for regional transport of passengers on both highways and improved intra city roads. Typically, these vehicles are classified in category M3 of the World Forum for Harmonization of Vehicle Regulations.

Regional and inter-city coach buses are used for excursions and for longer-distance services like inter-city. Unlike city busses, designed for shorter journeys, coaches often have a luggage compartment that is separate from the passenger cabin and are normally equipped with facilities required for longer trips, including comfortable seats and sometimes a toilet. In coach buses the passengers are required to have a seat for the journey.

Table 10. Gross Weights (metric tonnes) ranges for Vehicles in the Regional/Inter-city Coach Category[2]

China	Europe	Japan	South Korea[3]	LA	NA	UN World Forum (M3) / ROW
< 18	< 18	>14	< 18	> 10	>11.8	> 5

2.1.11 Long Haul Coach Bus Tire

A pneumatic tire for power driven vehicles with four or more wheels, used for transport of passengers, mainly on highways. Typically, these vehicles are classified in category M3 of the World Forum for Harmonization of Vehicle Regulations. Long-haul coach buses are often multi-axle buses that have more than the conventional two axles, usually three axles, or more rarely, four axles. Extra axles are usually added for legal weight restriction reasons, or to accommodate different vehicle designs such as articulation, or rarely, to implement trailer buses.

Long Haul coach buses are used for longer-distance services like international travel. Coaches often have a luggage compartment that is separate from the passenger cabin and are normally equipped with facilities required for longer trips, including comfortable seats and sometimes a toilet. In coach buses the passengers are required to have a seat for the journey.

Table 11. Gross Weights (metric tonnes) ranges for Vehicles in the Long Haul Coach Category[2]

China	Europe	Japan	South Korea[3]	LA	NA	UN World Forum (M3) / ROW
< 18	< 18	>14	< 18	> 10	>11.8	> 5

2.1.12 Motorcycle Tire

A pneumatic tire designed for a two or three wheeled vehicle powered by a motor. Typically these vehicles are classified in Category L of the World Forum for Harmonization of Vehicle Regulations.

2.1.13 Compactor Tire[4]

A pneumatic tire used in working conditions where equipment is used to compress material (earth, asphalt, other) by driving over it. Tire loads are relatively constant and speeds are low, typically 10km/h (5 mph). Travel distances vary depending on work situations. This category also includes tire rollers.

[4] Definitions for Sections 2.1.13 through 2.1.19 come from the Tire and Rim Association (T&RA) Yearbook.

Table 12. Gross Weights (metric tonnes) ranges for Vehicles in the Compactor Tire Category[5]

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥2.5 and ≤ 27	≥2.5 and ≤ 27	≥2.5 and ≤ 27	≥2.5 and ≤ 27	≥2.5 and ≤ 27	≥2.5 and ≤ 27	≥2.5 and ≤ 27

2.1.14 Earth Mover Tire

A pneumatic tire used in haulage cycles where equipment self-loads or receives a load from loading equipment, then transports this load to another location and returns unloaded. Transportation usually occurs over unimproved surfaces at speeds up to 65 km/h (40 mph) and short distances, up to 4 km (2.5 miles), one way. Equipment in this category is mainly haulage trucks and scrapers. This category also includes rigid dump trucks, wheel loaders, and backhoes.

Table 13. Gross Weights (metric tonnes) ranges for Vehicles in the Earth Mover Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥ 50 and ≤ 700	≥ 50 and ≤ 700	≥ 50 and ≤ 700	≥ 50 and ≤ 700	≥ 50 and ≤ 700	≥ 50 and ≤ 700	≥ 50 and ≤ 700

2.1.15 Grader Tire

A pneumatic tire used in a working condition where equipment is used in construction and road maintenance. Tire loads are relatively constant during the work cycle. Equipment speeds are slow during working periods with maximum transportation speeds reaching 40 km/h (25 mph). Travel distances vary depending on work situations.

[5] Gross Vehicle Weights (GVW) data for Sections 2.1.13 through 2.1.19 come from OEM Manufacturer specifications and specification books.

Table 14. Gross Weights (metric tonnes) ranges for Vehicles in the Grader Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥6 and ≤271	≥6 and ≤271	≥6 and ≤271	≥6 and ≤271	≥6 and ≤271	≥6 and ≤271	≥6 and ≤271

2.1.16 Loader and Dozer Tire

A loader tire is a pneumatic tire used in a work cycle where the equipment is used to pick up material and relocate a short distance away. Tire loads fluctuate depending on the conditions involved when the equipment picks up the load. Transportation speeds are low, up to 10 km/h (5 mph), and distances are short, a maximum of 76 m (250 feet), one way.

A dozer tire is a pneumatic tire used in a working condition where equipment is used to move materials (usually earth) by pushing, dragging or grading. Tire loads are relatively constant and speeds are low, up to 10 km/h (5 mph). Travel distances vary depending on work situations.

Table 15. Gross Weights (metric tonnes) ranges for Vehicles in the Loader and Dozer Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥17 and ≤81	≥17 and ≤81	≥17 and ≤81	≥17 and ≤81	≥17 and ≤81	≥17 and ≤81	≥17 and ≤81

2.1.17 Mobile Crane Tire

A pneumatic tire on a mobile crane used for transport of the machine. When the crane is in operation, the machine load is taken up by the outrigger. This category includes truck cranes and wheel cranes.

Table 16. Gross Weights (metric tonnes) ranges for Vehicles in the Mobile Crane Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥77 and ≤346	≥77 and ≤346	≥77 and ≤346	≥77 and ≤346	≥77 and ≤346	≥77 and ≤346	≥77 and ≤346

2.1.18 Industrial Tire

A pneumatic tire used on vehicles such as counterbalanced lift trucks, container handlers, straddle carriers, aircraft tow tractors, pavers, mobile crushers, log stackers and rough terrain forklifts. This category also includes smooth terrain forklifts, module transporters, and reach stackers.

Table 17. Gross Weights (metric tonnes) ranges for Vehicles in the Industrial Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥1.5 and ≤666	≥1.5 and ≤666	≥1.5 and ≤666	≥1.5 and ≤666	≥1.5 and ≤666	≥1.5 and ≤666	≥1.5 and ≤666

2.1.19 Subterranean Haulage Tire

A pneumatic tire used in a haulage cycle where a machine receives a load from loading equipment, transports it to another location, and returns unloaded. Transportation usually occurs over unimproved surfaces at speeds up to 40 km/h (25 mph) and short distances, up to 5 km (3 miles), one way. Equipment in this category is mainly underground haulage trucks.

Table 18 .Gross Weights (metric tonnes) ranges for Vehicles in the Subterranean Haulage Tire Category

China	Europe	Japan	South Korea	LA	NA	UN World Forum (M3) / ROW
≥23 and ≤131	≥23 and ≤131	≥23 and ≤131	≥23 and ≤131	≥23 and ≤131	≥23 and ≤131	≥23 and ≤131

2.1.20 Aircraft Tire

A pneumatic tire designed for use on aircraft for landing, takeoff and taxiing.

2.2 System Function

The function of a tire is to provide friction between the ground and a vehicle to support a vehicle's safe movement. A tire is a ring-shaped covering that fits around the rim of a wheel and also serves to protect the wheel, improve a vehicle's acceleration, braking performance, driving performance and reduce the shock caused by surface irregularities. In this PCR, the term "new pneumatic tires" does not include retreaded tires.

This PCR uses functional and declared units, depending on the scope of the EPD. Section 3.1 discusses these units and defines them for the tire product category.

2.3 Definitions and Acronyms

For the purposes of this document, the following definitions and acronyms apply:

Background Process

A process other than a foreground process; a process not under direct operational control of a manufacturer with contributing data which may not be directly measured by the manufacturer.

CNG Compressed Natural Gas

Driving Cycle

Driving cycles are standardized driving conditions that duplicate the driving behavior and conditions experienced by a person operating a vehicle. Driving cycles are produced by different countries and organizations to assess vehicle performance attributes, such as fuel consumption and polluting emissions.

DU Declared Unit

Quantity of a tire for use as a reference unit description in an EPD not covering the full life cycle.

DQR Data Quality Rating

Methodology, criteria and matrix used to calculate the score estimating the quality of a data or of a dataset.

Drive tire

Drive-axle tires are the tires mounted and installed on the powered axle(s) of a commercial vehicle. May be used in conjunction with steer and trailer tires on commercial trucks.

Ecosphere flow

A flow directly to and from nature.

ELT End of Life Tire

A tire that can no longer be used for its original purpose; all tires including passenger car, truck, aircraft, motorcycle and off-road tires result in ELTs.

ETRMA European Tyre & Rubber Manufacturers' Association

ETRTO European Tyre and Rim Technical Organisation

Feedstock Energy

Heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value [ISO 14044].

Foreground Process

A process under operational control of the EPD owner. Foreground processes includes data collected by the owner of the EPD, e.g., raw materials amount and processing, energy consumed and waste generated during the manufacturing stage, direct emissions of the facility under operational control of the EPD owner.

FU Functional Unit

Quantified performance of a tire for use as a reference unit description in an EPD based on LCA [ISO 14025].

Information Module

Compilation of data to be used as a basis for a Type III Environmental Declaration, covering a unit process or a combination of unit processes that are part of the life cycle of a product [ISO 14025].

ISO International Organization for Standardization

JATMA Japan Automobile Tyre Manufacturers Association

KOTMA Korea Tire Manufacturers Association

LA Latin America

LCA Life Cycle Assessment

Calculation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14040].

LCI Life Cycle Inventory

Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle [ISO 14040].

LCIA Life Cycle Impact Assessment

Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product [ISO 14040].

Load Index

A numerical code associated with the maximum load a tire can carry at the speed indicated by its speed symbol under specified service conditions. The load index is unitless.

LPG Liquid Petroleum Gas

LHV Lower Heating Value

The amount of heat released by combusting a specified quantity of material (initially at 25°C or another reference state) and returning the temperature of the combustion products to 150°C. The lower heating value (LHV) (net calorific value (NCV) or lower calorific value (LCV)) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H_2O formed as a vapor. The energy required to vaporize the water therefore is not released as heat.

LHV calculations assume that the water component of a combustion process is in vapor state at the end of combustion, as opposed to the higher heating value (HHV) which assumes that all of the water in a combustion process is in a liquid state after a combustion process.

NA North America

PM Particulate matter

The term "particulate matter" (PM) includes both solid particles and liquid droplets found in air. Many manmade and natural sources emit PM directly or emit other pollutants that react in the atmosphere to form PM.

Particles less than 10 micrometers in diameter are called (PM_{10}).

Particles less than 2.5 micrometers in diameter are termed ($PM_{2.5}$) and are sometimes referred to as "fine" particles.

Process Energy

Energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself [ISO 14044].

Product Category

Group of products that can fulfill equivalent functions [ISO 14025].

TRAC

Rubber Association of Canada

RECICLANIP

Brazilian tire collection and recycling association

Regrooving

Process that extends the life of a tire by carving out the rubber in the grooves of a tire to create additional tread. Often performed before retreading and lowers a tire's profile thickness and reduces rolling resistance.

Retreading

Retreading also known as "recapping," or "remolding" is a re-manufacturing process for tires that replaces the tread on worn tires. Retreading is the process whereby partly-worn tires, receive an additional tread in order to extend their useful service life. It also includes modifying other parts of the tire, such as the outermost sidewall surface or the protective ply. In this PCR, retreading impacts shall only be considered for commercial truck tires and are optionally reported in supplemental information.

ROW Rest of the World

RSL Reference Service Life

Service life of a product which is known to be expected under a particular set, i.e. a reference set, of in-use conditions and which may form the basis of estimating the service life under other in-use conditions. The reference service life (RSL) of a tire is based on several types of tests to ensure the safety, durability, and mileage of the product.

RR Rolling resistance

Sometimes called rolling friction or rolling drag, rolling resistance is the force resisting motion when a tire rolls on a surface. It is mainly caused by non-elastic effects in that not all energy needed for deformation or movement of the tire is recovered when the pressure is removed.

RR_c Rolling resistance coefficient

The ratio of the rolling resistance of the tire (expressed in Newtons) to the load of the tire (expressed in Kilonewtons). The coefficient is dimensionless.

SI International System of Units

Metric units

Steer tire

Steer tires are the front two tires on a commercial truck and used to steer the vehicle.

Specific data

Data representative of a product, product group or construction service, provided by one supplier.

Technosphere flow

A flow related to economic activity; any flow not taken directly from the earth (ecosphere).

Tire Wear Loss

Tire wear loss is the weight of tire tread expected to be lost due to the friction between the tire and road surface.

Trailer tire

Trailer axle tires are mounted and installed on non-powered axles of the trailer of a commercial vehicle.

TRWP Tire and road wear particles

Tire and road wear particles (TRWP) are tiny particles that are produced by the friction between tires and the road surface, often referred to as abrasion. These particles are a mixture of tire tread and road pavement material.

Type III Environmental Declaration, Environmental Product Declaration (EPD)

Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information [ISO 14025].

Unit Process

Smallest portion of a product system for which data are collected when performing a life cycle assessment.

USTMA U.S. Tire Manufacturers Association

UTQG Uniform Tire Quality Grading

Established in the US by the National Traffic Safety Administration (NHTSA) in 49 CFR 575.14. A UTQG rating consists of a treadwear grade, traction grade, and temperature grade.

2.4 Description of company/organization and product

2.4.1 Description of company/organization

The EPD will set forth the name of the manufacturing company/organization as well as the place(s) of production. The EPD may include general information about the company/organization, such as the existence of quality systems, according to ISO 9001, or environmental management systems, according to ISO 14001 or any equivalent recognized standard, or any other management system in place.

2.4.2 Description of product and technical description

The EPD will provide a brief narrative description of the product or product line in a manner that enables the user to clearly identify the product.

2.4.3 Product identification

The EPD shall include product identification by brand name, by model name, and by simple visual representation, which may be by photograph or graphic illustration. Commercial tires shall be identified by steer, drive, or trailer position.

2.4.4 Specifications

Tire specifications shall be provided according to the following designation using appropriate references from the Tire and Rim Association (TRA), the European Tyre and Rim Technical Organization (ETRTO), the Tire and Rim Association of Australia (TRAA), the Japan Automobile Tyre Manufacturer's Association (JATMA), the Korea Tire Manufacturers Association (KOTMA), the Associacao Latino Americana de Pneus e Aros (ALAPA), the South African Bureau of Standards (SABS), or the ISO product specification (ISO TC 31), including pertinent physical properties and technical information.

Tire designation (some of the tire designations may be from the sidewall, brochure, or other technical specifications):

- Tire size
- Tire mass
- Intended use as identified in Tire Sub-Categories, Section 2.1
- Nominal section width
- Aspect ratio
- Casing construction (e.g. 1 ply, 2 ply, polyester, nylon, etc…, including steel ply/bels for commercial tires)
- Rim diameter
- Load index
- Speed rating
- Applicable mandatory regional labeling

2.4.5 Flow diagram

A graphical depiction (i.e. flow diagram) illustrating main production processes according to the scope of the declaration shall be provided.

2.4.6 Performance standards, labelling and regulation

The product assessed using this PCR shall be compliant with performance standards, labelling requirements and regulations specific to each region. The rolling resistance coefficient (RR_c) shall be based upon requirements of the test methods listed in Table 19. As this list is non-exhaustive, if a region is not identified please indicate the additional relevant testing method not already included in this list.

Table 19. Rolling resistance test method – non-exhaustive list

Region	**RR_c test method**
North America	ISO 28580 as regionally modified to account for local calibrations
Europe	ISO 28580 UN Regulation 117 Annex 6 respectively EU Regulation 1222/2009 + amendments
Japan	ISO 28580 as regionally modified to account for local calibrations
South Korea	ISO 28580 as regionally modified to account for local calibrations
China	ISO 28580 as regionally modified to account for local calibrations
Latin America (including Mexico)	ISO 28580 as regionally modified to account for local calibrations
ROW	ISO 28580 as regionally modified to account for local calibrations

2.4.7 Reference Service Life

The reference service life (RSL) will be set using an individual manufacturer's confidential/proprietary regimented testing system. The reference service life is discussed in more detail in Section 3.2.3.

3 Requirements for the Underlying LCA

3.1 Functional and declared units

The functional unit of a product provides the quantitative normalization for comparing products of equivalent function (functional unit) or equivalent specification (declared unit). A functional unit serves as the reference unit upon which the LCA study is performed and the results are presented in accordance with the ISO 14040 standard. For declarations covering the complete life cycle, a functional unit is defined. Where there is an applicable standard, that standard will be referenced per Section 2.4.6.

For declaration and reporting purposes only, it is required to report the functional and declared units and LCA results in SI units.

The declared and functional units for the various applications are provided in

Table 20.

Table 20. Functional and declared units[6]

Tire type	Declared Unit (cradle-to-gate + end of life)	Functional Unit[7] (cradle-to-grave)
Passenger car	n/a	1 tire driven 1,000 km (modules A1 – C3)
Light truck	n/a	1 tire driven 1,000 km (modules A1 – C3)
Medium/heavy truck Pick-up and Delivery Regional and City Long Haul Mixed Service	n/a	1 tire driven 1,000 km[8] (modules A1 – C3)
Pick-up service bus City bus School bus Coach	n/a	1 tire driven 1,000 km[9] (modules A1 – C3)
Compactor Earth Mover Grader Loader & Dozer Mobile Crane Industrial Subterranean Haulage	1 tire (modules A1 – A3, C1 – C3)[10]	n/a

[6] See Section 3.2 for information module definitions

[7] Assuming intended use and maintenance for safe distance traveled

[8] For medium/heavy trucks, the functional unit includes steer, drive, and trailer tires. When including retreading and regrooving for optional reporting as indicated in Section 6.2, the functional unit includes also: number of retreads indicated and retreading impacts according to Section 9.3

[9] For buses, when including retreading and regrooving for optional reporting as indicated in Section 6.2, the functional unit also includes number of retreads indicated and retreading impacts according to Section 9.3.

[10] There is not yet a standardized and agreed methodology to calculate the use phase of these specific tires.

Tire type	Declared Unit (cradle-to-gate + end of life)	Functional Unit[7] (cradle-to-grave)
Motorcycle	1 tire (modules A1 – A3, C1 – C3)[10]	n/a
Aircraft	1 tire (modules A1 – A3, C1 – C3)[10]	n/a

For declarations covering the complete life cycle, the reference flows needed to fulfill the functional unit are calculated based on the tire reference service life (RSL)[11]. More details on tire RSL are provided in Section 3.2.3.

Guidance - Reference flows

The performance of the studied tire is fulfilled by the production and use of a certain tire fraction, i.e., the reference flow.

The fraction of tire per functional unit (No per FU) is calculated based on the following equation (1):

$$(1)\ No\ per\ FU\ \left[\frac{unit}{FU}\right] = \frac{Dist\_FU\ [km/FU]}{Tire\_RSL\ [km]}$$

The parameters are the distance considered for the functional unit (Dist_FU) and the reference service life of the tire (Tire_RSL).

Let's assume two illustrative examples with the following specificities:

Illustrative examples	Dist_FU	Tire_RSL
Passenger car tire A	1,000 km	40,000 km
Truck tire B	1,000 km	230,000 km

Applying the parameters reported in the equation (1), the results are the following:

Illustrative example - Passenger car tire A

$$No\ per\ FU\ \left[\frac{unit}{FU}\right] = \frac{1{,}000\ [km/FU]}{40{,}000\ [km]} = 0.025\ [unit/FU]$$

Illustrative example - Truck tire B

$$No\ per\ FU\ \left[\frac{unit}{FU}\right] = \frac{1{,}000\ [km/FU]}{230{,}000\ [km]} = 0.0043\ [unit/FU]$$

[11] The guidance to calculate the references flows when including retreading and regrooving for optional reporting is provided in Section 9.3.

3.2 System boundaries

The tire life cycle is broken into the various “information modules” shown in Figure 1:

Each information module is described in more detail in the following sub-sections.

Retreading and regrooving processes shall not be included in the core section of the EPD, but may be included for commercial and bus tires as optional reporting as presented in Section 9.3 per the requirements in Section 6.2, only if primary data are available (except for regrooved tire RR_c and RR_c loss that shall be calculated using the default values provided).

Due to their small contribution (cut off criteria defined in Section 3.4), the system boundaries do not include the following modules:

- Installation (A5);
- Transport of the assembled product to the consumer (A6), i.e., the transport of the vehicles on which the tire is mounted;
- Maintenance (B2), i.e., tire cleaning, inspection, inflation, rotation, balancing, and alignment;
- Repair (B3), i.e., repair of the tire over the reference service life. This includes routine patching and other standard repair processes;
- Removal (C1), i.e., the removal of the tire from the vehicle, including on-site sorting of materials;
- Capital equipment manufacture;
- Personnel impacts.

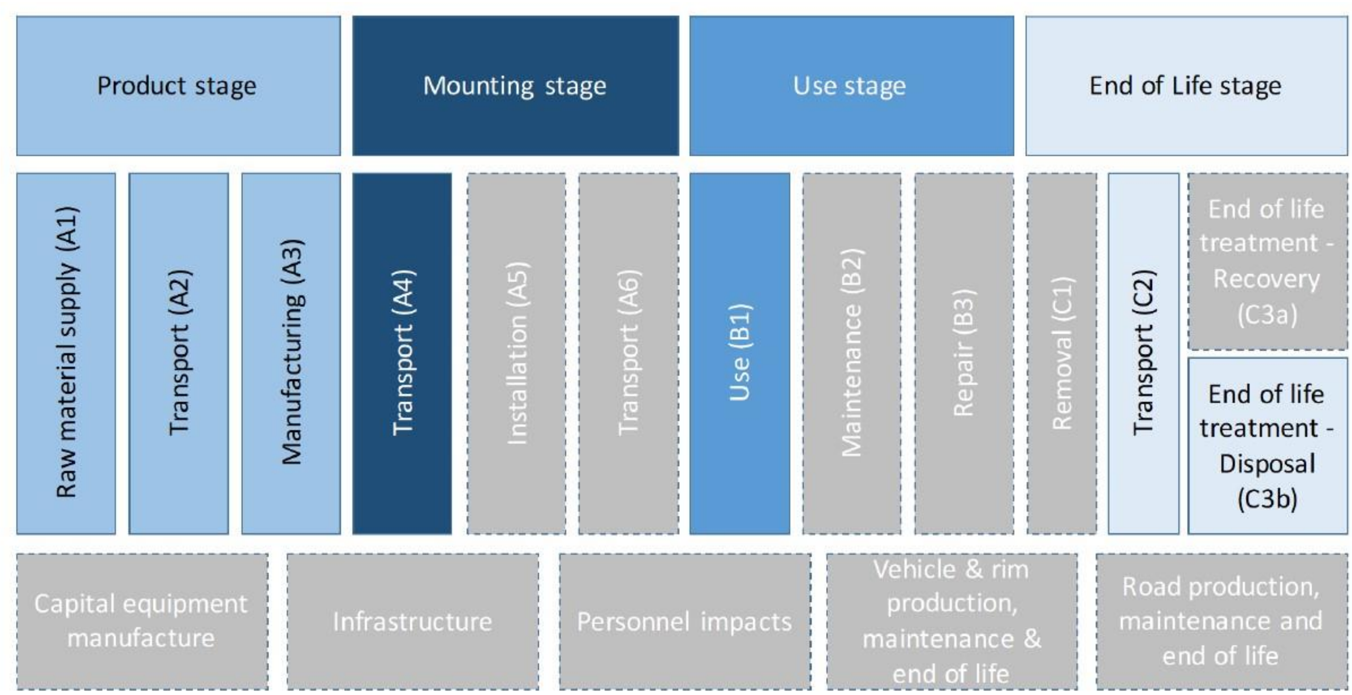
The exclusion of processes or activities due to cut-off criteria should be adapted depending on the vehicle technology considered, the geographical context and the time representativeness of the technologies (e.g., the maintenance module (B2) may become a significant contributor and should be included if the tire is mounted on an electric vehicle using a low-impact electricity mix).

The module “Infrastructure” is not included for foreground processes due to its small contribution to the overall impact and for simplification reasons. Production of infrastructure shall be excluded also for background generic processes, in order to ensure consistency between the foreground and background datasets and to ensure consistency between databases.

The modules “Vehicle & rim production, maintenance and end of life” and “Road production, maintenance and end of life” are excluded from the system boundaries, since their impacts are allocated to another system (i.e., vehicle life cycle).

Finally, the module “End of life treatment - Recovery module” (C3a) is excluded from the system boundaries due to recycled waste stream methodology applied in this PCR (cut-off rules defined in Section 4.3). This module includes the material flows intended for reuse, recycling, and energy recovery, and includes waste processing for recycling and energy recovery (e.g., shredding) and credits related to energy recovery and avoided primary material.

Figure 1. Tire life cycle system boundaries and information modules



Out of scope activities are indicated in the grey boxes

3.2.1 Product Stage (A1, A2, and A3)

The product stage is a set of information modules required to be included in all EPDs. Together, these represent the cradle-to-gate impacts of a tire. As illustrated in Figure 1, it includes the information modules A1 to A3. The system boundary with the ecosphere is set to include those processes that provide the material and energy inputs into the product system, processing, and transport processes up to the factory gate as well as the processing of any waste arising from those processes.

In the case of secondary materials input or energy recovered from incineration input (e.g., incineration of End of Life Tire (ELT)), the cut-off rule is applied according to Section 4.3. In other words:

- The impacts related to the collection of recyclable material (waste from a previous product system) and to its recycling process are allocated to the product using the recycled material;
- The impacts related to the collection of waste from a previous product system and to the energy production process are allocated to the product using the energy.

Processes in the product stage with more than one type of valuable output flow shall be treated by allocation, i.e., input to and emissions from such processes shall be divided between the output flows according to the chosen allocation criterion as described in Section 3.5.

3.2.1.1 Raw material supply (A1)

The raw material supply module (A1) includes all materials[12][13] and energy inputs, transportation stages, needed for the raw material supply stage, as well as end of life treatment of final residues produced during the raw material supply stage. However, production of capital goods, infrastructure, production of manufacturing equipment and personnel-related activities are not included.

As a first priority, companies should seek primary data (if available) from their supplier to model the raw material supply module (see section 4.1.1). If no primary data are available, the raw material supply module should be modelled using the default datasets presented in Appendix III (Section 10) for nine of the raw materials (synthetic rubber, natural rubber, carbon black, steel, textile polyester, textile nylon, silica, cobalt salt and plasticizers), unless better-quality data are available. In fact, those datasets were developed with the objective of being representative of a global technology for each specific raw material, and for a global geographical coverage (i.e., world coverage), except for the natural rubber which is representative of a specific geographical context for fresh latex cultivation (Thailand and Indonesia). If primary data or better-quality data (i.e., with a better geographical, technological or time representativeness) are available for one or several of those nine raw materials, specific datasets shall be developed. A justification of the replacement of the default dataset shall be provided in the background report. In addition, the data quality rating (DQR) of the specific dataset shall be calculated as per information provided in Section 4.1.2 and reported in the background report, and shall be better (i.e., with a lower score) than the DQR of the corresponding default dataset to justify a replacement.

The raw material supply module accounts for:

- Extraction and treatment of non-renewable primary materials (e.g., mining and refining processes)
- Production and treatment of renewable primary material (e.g., agricultural or forestry operations) (Section 4.4); including deforestation and land use change
- Processing of primary and secondary materials; Processing of secondary material from a previous product system (e.g., recycled tire) will be modelled using the cut-off rule, i.e. not including processes that are counted as waste processing in the previous product system (Section 4.3);
- Consumption of electricity, steam and heat from primary energy resources, also including their extraction, refining and transport;
- Consumption of energy recovered from a previous product system or produced from secondary fuels, but not including processes that are counted as waste processing in a previous product system (Section 4.3);
- Transportation up to the factory gate and internal, on-site transport;
- Consumption of ancillary materials or pre-products (e.g., lubricants);
- Waste processing or disposal, including any packaging waste.

3.2.1.2 Transport (A2)

The transport module (A2) includes the transportation of raw materials to the manufacturing site.

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[12] The raw materials included in the raw material supply module include only materials that are part of the tire (e.g., tube is considered as tire raw material, but tire pressure monitoring system (TPMS) is not considered as tire raw material)

[13] When semi-finished products are purchased from an external supplier, detailed data on the composition (i.e. raw materials that compose semi-finished product) have to be collected by the EPD owner and listed as « raw materials ».

3.2.1.3 Manufacturing (A3)

The manufacturing module (A3) concerns the manufacturing of raw materials into the finished tire, and includes all materials and energy inputs, transportation stages needed for the manufacturing stage, as well as end of life treatment of final residues produced during the manufacturing stage. However, production of capital goods, infrastructure, production of manufacturing equipment and personnel-related activities are not included.

The manufacturing module will account for:

- Consumption of electricity, steam and heat from primary energy resources, also including their extraction, refining and transport;
- Consumption of energy recovered from a previous product system or produced from secondary fuels, but not including processes that are counted as waste processing in a previous product system (Section 4.3)
- Internal transport;
- Consumption of ancillary materials or pre-products (e.g., lubricants);
- Production of co-products during the manufacturing process;
- Tire packaging production (material and manufacturing);
- Waste processing or disposal, including any packaging waste.

3.2.2 Mounting Stage (A4, A5, and A6)

The mounting stage (A4, A5 and A6) includes the information modules covering the activities from the tire factory to the final user, i.e. successive transport stages and installation onto the vehicle.

3.2.2.1 Transport (A4)

This module includes the transport of the tire from the factory to the place where the tire is mounted onto the vehicle. This includes the successive transport stages by the different modes of transport (truck, boat, train) to reach: car or truck makers, retailers, tire dealers and assembly centers. Module A4 may be optionally reported only when primary data are available to model impacts.

3.2.2.2 Installation (A5)

Impacts from installation of the tire onto the vehicle are considered outside the scope of this PCR.

3.2.2.3 Transport (A6)

Impacts from transport of the vehicle on which the tire is mounted to final customer are considered outside the scope of this PCR.

3.2.3 Use Stage (B1, B2, and B3)

The use stage (B1, B2 and B3) includes the information modules covering the period from the handover of the tire until it reaches its end of life. The use stage includes the use of tire products and services in their proper function. Maintenance and repair are part of the use stage but are excluded from system boundaries (discussed in Section 3.2). The duration of the use stage is dependent on the reference service life.

The reference service life (RSL) of a tire is based on several types of tests related to the performance of the product. Each company should use its own confidential/ proprietary regimented testing scheme to set the RSL for a specific tire, plus any regulatory required tests applicable for the intended region[14]. The results from the testing scheme are to be evaluated by the company and a decision made, using engineering judgment, to set the RSL conveyed in mileage wear out of the tire (example: mileage warranty or guarantee). The specified mileage should be determined for the intended region indicated in the EPD. Each company should generally describe the type(s) of tests utilized to determine the RSL including the testing type, which may also include information such as the severity of the test, etc. Example test types include:

- Laboratory abrasion testing of the tread compound
- Wheel testing of the tire for durability
- Road test of the tire for wear evaluation
- Loaded static & dynamic footprint
- Cut & chip

3.2.3.1 Use (B1)

The use module (B1) includes two contributors: (i) the fuel/energy consumption and related emissions attributable to the tire, and (ii) particle emissions related to tire and road abrasion. The amount of fuel/energy consumed shall be calculated according to specific methods for each tire sub-category outlined in Section 5.1. No other vehicle impacts shall be included. Additionally, the particle emissions generated by the abrasion of tire and road shall be reported according to the calculation methods outlined in Section 5.2. Only the tire particles encrusted with particles from the pavement, called tire and road wear particles (TRWP) are taken into account. Abrasion particles attributable to other systems (e.g. brakes, and other vehicle parts) are explicitly excluded from consideration. Road wear particles (RWP) are also excluded from the scope. In fact, while RWP result from the friction between tires and the road and, as such, are a direct consequence of using tires, these emissions are also influenced by other parameters, e.g., road surface, vehicle total weight, driving behaviour and ambient temperature. For this reason, the RWP emissions are assumed to be allocated to the vehicle use, and not to tire use.

3.2.3.2 Maintenance (B2)

Impacts from maintenance are considered outside the scope of this PCR.

3.2.3.3 Repair (B3)

Impacts from repair are considered outside the scope of this PCR.

3.2.4 End of life Stage (C1, C2, C3a, and C3b)

The end of life stage of the tire product starts when it is removed from the vehicle, does not provide any further operational function, and is at the end of the reference service life.

The mass to consider for end of life of the tire (ELT) is calculated as the mass of new tire minus tire wear loss (as calculated in Section 5.2). When a declared unit is assessed, the mass of new tire shall be used.

To model disposal pathways, the data presented in Table 21 shall be used, except for tires that have specific disposal pathways. For the latter, these specific disposal pathways shall be modelled when data are available.

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[14] There is no industry standard approach for determining the reference service life.

To calculate exported electrical energy and exported thermal energy, the default data presented in Table 22 shall be used.

Table 21. ELT management data for each region

	China	Europe	Japan	South Korea	LA	NA	ROW
Source[15]	Global ELT Management, 2019	Global ELT Management, 2019	Global ELT Management, 2019	Global ELT Management, 2019	Average Brazil and Mexico From Global ELT Management, 2019	USA from Global ELT Management, 2019	Average of all countries under study in Global ELT Management, 2019
TOTAL ELT Generated (from available sources)	100%	100%	100%	100%	100%	100%	100%
TOTAL Recovered	39%	89%	91.9%	87.9%	64.4%	72.1%	57.7%
TOTAL Recovered (including Civil Engineering and Landfill in Mining)	39%	92%	92%	87.9%	64.4%	80.9%	59.2%
Sub-total Material Recovery	39%	54%	18.9%	37.9%	38.6%	33.2%	42.3%
Sub-total Energy Recovery	0%	35%	73.0%	50.1%	25.9%	39.0%	15.5%
Sub-total Civil Engineering and Landfill in mining	0%	3%	0.1%	0.0%	0.0%	8.8%	1.5%
TOTAL Other (not recovered, landfill, stockpiled or unknown)	61%	8%	8%	12%	35.6%	19.1%	40.8%

[15] Global ELT Management- A global state of knowledge on regulation, management systems, impacts of recovery and technologies. WBCSD and the Tire Industry Project, December 2019. https://docs.wbcsd.org/2019/12/Global_ELT_Management–A_global_state_of_knowledge_on_regulation_management_systems_impacts_of_recovery_and_technologies.pdf

Table 22. Exported energy for ELT energy recovery

Category	Heat generation amount of tire (MJ/kg)	Source[16,17]
Passenger & Light Truck	28.4	Aliapur A, 2019
Medium/Heavy Truck	28.5	Aliapur B, 2019
Bus	28.4	Aliapur B, 2019
Motorcycle	28.5	Aliapur A, 2019
Off the Road	28.4	Aliapur B, 2019
Aircraft	28.4	Aliapur B, 2019

3.2.4.1 Removal (C1)

Impacts from removal are considered outside the scope of this PCR.

3.2.4.2 Transport (C2)

The end of life transport module (C2) includes the transportation of the tire to the end of life treatment facility. The impacts taken into account are related to the transport of tires to disposal site (incineration without energy recovery or landfill). Applying the cut-off rules (see Section 3.4), the impacts related to the transport of tires to energy recovery or recycling facilities are excluded from the system boundaries, since they are allocated to the next product using the recycled material or the energy.

3.2.4.3 End of life treatment - Recovery (C3a)

Impacts and credits from end of life recovery (reuse, recycling, or incineration with energy recovery) are not accounted for in this PCR.

3.2.4.4 End of life treatment - Disposal (C3b)

The end of life - Disposal module (C3b) includes the end of life treatment of tires being landfilled or incinerated without energy recovery. This module includes physical pre-treatment and management of the disposal site as well as impacts from landfilling and incineration without energy recovery. Environmental loads (e.g., emissions) from waste disposal in Module C3b are considered part of the product system under review, according to the “polluter pays principle”.

3.3 Aggregation of Information Modules

The Information modules as described in Figure 1shall not be aggregated into a total or sub-total of the life cycle stages A, B, or C but must be reported as separate information modules.

[16] Aliapur-Fiche technique Powergom Original A (Aliapur, 2019a) https://www.aliapur.fr/uploads/pdfs/fiche-technique-aliapur-powergom-a-en.pdf

[17] Aliapur-Fiche technique Powergom B (Aliapur, 2019b) https://www.aliapur.fr/uploads/pdfs/fiche-technique-aliapur-powergom-b-en.pdf

3.4 Cut-off rules

A process or activity that contributes 1% or less of the total mass and 1% or less of the total energy use may be omitted from the inventory analysis for any particular module, except that: Omissions of any material flows that may be below the 1% cut-off threshold based on mass or energy input but have a contribution to the required reported environmental indicators higher than 1% will be justified, if applicable, by a sensitivity analysis.

The sum of the excluded material flows must not exceed 5% of mass, energy or environmental relevance. Known module flows that are excluded from inventory calculations on the basis of cut-off thresholds should be documented in the EPD.

The exclusion of processes or activities due to cut-off rules may be adapted depending on the vehicle technology considered, the geographical context and the time representativeness of the technologies (e.g., the maintenance module (B2) may become a significant contributor if the tire is mounted on an electric vehicle using a low-impact electricity mix and should be considered).

3.5 Allocation rules

In a production process where more than one type of product is generated, it is necessary to allocate the environmental impacts (inputs and outputs) from the process to the different products in order to obtain product-based inventory data. Allocation rules should reflect the goal of the production process. For production of tire products, allocation should be avoided when possible by subdividing the unit processes into subprocesses that separately produce the studied product and co-products. Should no process subdivision be possible, and energy is one of the co-products, system expansion should be applied via direct substitution. This should only be applied when direct knowledge of the function, substituted production path, and eventual use of the energy co-product(s) exist and are identifiable. System expansion shall not be applied unless energy is one of the co-products. When allocation cannot be avoided, the following steps shall be completed to determine the appropriate method of allocation. The first step to decide on the allocation methodology is to calculate the ratio of the economic value of the co-products. The underlying logic behind the recommendation to use the ratio of economic value of co-products is that, in the case of high discrepancy in the market value of product coming from a common process, the product(s) with significantly higher economic value can be considered the driver(s) of the process. In other words, the production would not take place in the absence of the product with the highest economic value. The economic value of products should be calculated based on stable market prices. In the case of high price fluctuation, companies should calculate based on market prices averaged over a 3 year period, at minimum. The second step in determining the appropriate allocation methodology is to compare the economic value of co-products. If the calculated economic value ratio is equal to or lower than five, apply physical allocation between the studied product and the co-product(s). For this, the physical property used as the allocation factor should most accurately reflect the underlying physical relationship (e.g., mass, carbon content, chemical composition, etc.) between the studied product and co-product. [18] For additional information, see ISO 14044 Section 4.3.4.

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[18] Allocation rules taken from the Partnership for Carbon Transparency (PACT) Pathfinder Framework: Guidance for the Accounting and Exchange of Product Life Cycle Emissions Version 2.0. https://www.wbcsd.org/contentwbc/download/15625/226889/1

3.6 Transportation

Allocation associated with transport will be based on weight or volume, as appropriate for realistic modeling.

4 Data, Calculation and Reporting requirements

4.1 Data sources and data quality requirements

4.1.1 Data sources

All foreground technosphere data shall be primary data collected over the most recent calendar year of operation or measurement year. Companies shall seek primary data from first tier suppliers where available.

Primary data shall be collected by the manufacturer of the tire. It shall include the location of the manufacturer, the quantity and source location of all materials and energy used to manufacture the product, relevant emissions to air and water during manufacturing[19], relevant manufacturing waste produced and how it is managed (e.g., recycled, landfilled, incinerated) and the distance traveled to disposal. Primary data gathered from the sites where specific processes are carried out, shall be used for the core module. The requirement for primary data also includes actual product weights, amounts of raw materials, and amounts of waste. In cases where a product is manufactured in different locations (e.g., countries), results shall be calculated and reported on the basis of a weighted production average.

Secondary data may be used only when primary data are not available. When neither primary nor secondary data are available, tertiary data shall be used as proxy or substitution and derived from life cycle databases and peer reviewed literature on the basis of chemical composition. Generic datasets may be used for processes the manufacturer cannot influence, e.g., processes dealing with the production of input commodities, raw material extraction or electricity generation, or processes often referred to as upstream data or background processes. As a matter of principle, consistent and equivalent generic data shall be used, such as for background processes to support comparability of results.

For the raw material supply module, primary data from suppliers should be used where available. If primary data are not available, the default datasets presented in Appendix III (see Section 10) shall be used for nine of the raw materials (synthetic rubber, natural rubber, carbon black, steel, textile polyester, textile nylon, silica, cobalt salt and plasticizers), unless better-quality secondary data are available (i.e., with a lower DQR). In fact, the default datasets were developed with the objective of being representative of a global technology for each specific raw material, and for a global geographical coverage (i.e., world coverage), except for the natural rubber which is representative of a specific geographical context for fresh latex cultivation (Thailand and Indonesia). The other raw materials shall be modelled using secondary or tertiary data, as described above.

[19] "Relevant air and water emissions" refers to air and water emissions that have to be measured to calculate the impact assessment methods and inventory.

4.1.2 Data quality requirements

Data quality requirements shall be treated according to the following criteria and shall be documented in the Background Report according to ISO 14044[19] [20]

- Time representativeness:
  - Age of data:
    - The foreground data used shall not be older than two (2) years for primary data (e.g., specific mass of the tire, energy consumption for manufacturing process), i.e., shall have been collected over the most recent calendar year of operation or measurement year where the start date is not more than two (2) years prior. The measurement dates shall be disclosed in the LCA study. If primary data for more than one location are averaged for a unit process, a sensitivity analysis shall be performed using a plus or minus one standard deviation.
    - The foreground data shall not be older than ten (10) years for generic data (i.e., generic data calculated based on literature and default data provided in this PCR, e.g., specific load presented in Table 38).
    - For generic background datasets, the last version of LCI databases should be used.
  - Minimum length of time over which data should be collected: Primary data shall be based on one (1) year of typically averaged data; deviations shall be justified.
- Geographical coverage:
  - Primary data should be gathered from the sites where specific processes are carried out.
  - Where secondary data are used, the most relevant data shall be used, in the following order of preference, from most to least desired: same locality > global > other locality.
  - In case of using tertiary data from databases, where properly reviewed U.S. LCI database sets, EU ELCD, IDEA or other national or regional datasets are available, they shall be used for national data.
- Technology coverage: Where generic data are used, technological equivalence (specific technology or technology mix) shall be fulfilled, i.e., shall adhere to “Data deriving from the same chemical and physical processes or at least the same technology coverage (nature of the technology mix, e.g., weighted average of the actual process mix, best available technology or worst operating unit)”;
- Representativeness: The representativeness of the datasets with respect to time, location, and technology shall be documented, and deviations from the actual time, location, and technology relevant to the product shall be disclosed;
- Completeness: The LCI shall disclose the percent of the technosphere flows that are primary data based on number of product system flows.
- Precision
- Data sources:
  - All data sources shall be specified[21] . If consensus data are used for primary materials, it shall be documented. When generic data are used, they shall be documented as to the name of the database and the age of the data. Sources of data for transport models and

[20] For further insight on data quality, refer to the following sources: 1) Weidema, B. and M. Suhr Wesnaes. Data quality management for life cycle inventories, an example of using data quality indicators. Journal of Cleaner Production, 1996 , Vol. 4, no. 3-4, p. 167-174. 2) University of Leiden. Quality Assessment for LCA, CML Report

[21] For data used in the determination of a product RSL, evidence should be provided to a third party when requested upon EPD verification but shall not be disclosed in the EPD.

thermal energy production shall be documented. Any changes or alterations to information from the LCI libraries in the LCA software shall be documented with the reasons for making the alteration. For example, if the EU electric grid information on a substance from the EU ELCD was replaced by the average US electric grid information to make it relevant, then this action shall be documented.
    - Data sets taken from databases shall be identified as such in the Background Report, including the source and the year at which the dataset was last updated or pre-verified. The representativeness of the datasets with respect to time, location, and technology shall be documented, and deviations from the actual time, location, and technology relevant to the product shall be disclosed.
- Data gaps: The treatment of missing data and the use of data models shall be documented. When data from comparable processes must be used to cover gaps, the technological similarity shall be documented.

If specific datasets are modelled (based on primary data or secondary data) to replace one or more of the default datasets provided in Appendix III (see Section 0) for the nine raw materials (synthetic rubber, natural rubber, carbon black, steel, textile polyester, textile nylon, silica, cobalt salt and plasticizers), the DQR score shall be calculated for those specific datasets according to the specific rules listed in Appendix III Section 10.3. The specific dataset modelled can replace the corresponding default dataset only if its DQR score is better (i.e., lower) than the DQR score of the default dataset (provided in Appendix III Section 0), i.e, it represents a higher quality.

4.2 Transport

Transportation distances and methods shall be documented, as far as they are relevant. In addition, the average hauling distance for the distribution chain in the specific region or country can be used.

4.3 Recycled waste streams

Recycling and recycled content shall be modelled using the cut-off rule, also known as the recycled content rule. All materials recycled from unit processes (including those sent to energy recovery) are considered to have left the system boundary. Recycled content can only be modelled in the system where there is primary data showing that the percent of recycled content was specified in the purchase of materials. Where the product system has specified recycled content, all the environmental burdens of pre- and post- consumer recycling shall be included in the raw material portion of the inventory. The impact of recycling shall be calculated from the point of discard, either at the discarding facility or at the waste management center. Industrial recycling (e.g., prompt scrap[22]) is within the system boundary.

Where the manufacturer has an active recycling program in place for the replacement of the product, that information may be used for the product, but only to the extent which the manufacturer's program actually recycles tires. For example, if the manufacturer produces 100,000 tires per year, and recycles 10,000 tires per year, then 10% of the tires are removed from the life cycle waste calculations, and 90% of the

[22] "Prompt scrap" is scrap that it is produced from manufacturing products, and is available within months

tires are modelled in accordance with the average disposal pathway for tires in a region (e.g., landfill or incinerator).

4.4 Bio-based material

The biogenic carbon content of the bio-based material (e.g., natural rubber, textile made of natural fibers, bioethanol) shall be considered.

This biogenic carbon is the carbon that is taken up and incorporated in the biomass during growth (as the result of the photosynthesis effect) and which can be released during decomposition or combustion at the end of life[23].

For the modelling, the following considerations shall be applied:

- The captured carbon dioxide to take into account shall be calculated based on the amount of carbon present in the bio-based material according to its chemical composition;
- The further release of this biogenic carbon dioxide into the atmosphere shall be included in the same quantities, except in the following cases:
- Biogenic carbon that is still present in landfills after 100 years deposit is effectively treated as permanently stored. This follows the same guidance as fossil carbon in landfills post 100 years. The amount of biogenic carbon stored in landfills and other deposits/storage post 100 years must be reported.
- Biogenic carbon contained in recovered tires (those sent to recycling or incineration with energy recovery) is not considered to be released at end-of-life.
- For tires incinerated without energy recovery, the complete release of biogenic carbon shall be taken into account.
- The global warming potential to be considered for biogenic carbon is -1/+1 kg CO_2-eq/kg of biogenic carbon dioxide, for uptake and release, respectively. For biogenic methane, the characterization factor for fossil methane shall be used, per EF 3.1.
- No discounting for temporary carbon storage is taken into account, due to the relatively short period of storage.
- Direct land use change (dLUC) and its associated climate change contribution shall be accounted for following the EF2019 methodology. This methodology currently refers to guidelines of PAS 2050:2011 (BSI 2011) and the supplementary document PAS2050-1:2012 (BSI 2012) for horticultural products.
- Emissions associated with land management shall be quantified and included in background datasets, in line with SBTi FLAG Guidance. EF 2019 provides further guidance on quantification methods. Nitrogen modelling shall follow the alternative approach recommended by EF (Table 4) rather than use the IPCC 2006 emission factors.
- Uptakes and releases of biogenic carbon dioxide and/or methane shall be included in the assessment and reported separately for transparency. The biogenic carbon inputs and outputs

[23] The amount of biogenic carbon to be taken into account is only the amount of carbon included in the bio-based material. Neither the additional biogenic carbon uptake related to tree growing (carbon uptake above and below ground) nor the additional biogenic carbon uptake by the soil are taken into account.

shall balance for the finished product leaving the manufacturing facility (carbon uptake = carbon released during production via direct emissions or waste treatment + carbon contained in finished product).

- Only biogenic carbon that decomposes in the first 100 years after deposition in a landfill is considered to be released to the environment, the remainder is stored.
- Biogenic carbon contained in incinerated materials without energy recovery is assumed to be entirely released to the environment as carbon dioxide.
- Biogenic carbon contained in recovered materials is not assumed to be released to the environment.
- Due to lack of research, biogenic carbon contained in tire wear loss (TWL) particles shall be assumed to not degrade. When future research becomes available, this topic will be re-visited.

4.5 Renewable energy

Where the unit process is powered by methane from solid waste or wastewater, wind, biomass, hydro or solar power and no electricity leaves the facility (i.e., the system is not linked to a grid), renewable electricity produced from wind or solar may be accounted for within the system boundary.

Renewable electricity sources that are part of a country or regionally-specific grid mix shall be included in calculations if no renewable contractual instruments are allocated to the product.

If specific renewable, or “green”, power produced outside the facility is purchased using contractual instruments (Guarantees of Origin, Renewable Energy Certificates, Power Purchase Agreements, etc), the instruments may be used in LCI and LCIA calculations for the electricity for that unit process. However, all other upstream life cycle stages must then use a residual electricity mix that “subtracts” the contractual instruments used in regionally-specific grid mixes to avoid double-counting, unless otherwise justified. Where residual grid mixes are not available, they may be estimated by subtracting all renewable energy sources from the regional consumption mix.

Guarantees of Origin may be used to demonstrate that a specific electricity mix has been used. Also, other contractual instruments may be used, as long as reliability, traceability, and the avoidance of double counting are ensured, which is the case if the instrument guarantees that the electricity product (adopted from ISO 14067):

- conveys the information associated with the unit of electricity delivered together with the characteristics for the generator,
- is assured with a unique claim,
- is tracked and redeemed, retired or cancelled by or on behalf of the reporting entity,
- is as close as possible to the period to which the contractual instrument is applied and comprises a corresponding timespan, and
- is produced within the country, or within the market boundaries where consumption occurs if the grid is interconnected.

The Guarantees of Origin, RECs, PPAs, or similar shall be valid for at least the upcoming year and the manufacturer shall make a commitment to buy Guarantees of Origin for the full validity period of the EPD. If the electricity mix changes during the EPD validity (e.g., if the Guarantees of Origin are no longer valid) in a way that has an impact on the results or other contents of the EPD, the EPD Program Operator rules relating to changes, corrections, or amendments to published EPDs shall be followed. The EPD shall contain information on how electricity has been modelled for core processes, e.g., including how Guarantees of Origin (or similar) and/or residual electricity mixes have been used. The EPD must also contain information on how electricity has been modelled for upstream and downstream processes, if relevant. Residual electricity mixes must be used to model the electricity consumed across the portions of the product life cycle that are not represented by Guarantees of Origin or other contractual instruments (e.g., Renewable Energy Credits, Power Purchase Agreements).

CO_2 offsets shall be specified separately and not reported in inventory or impact assessment results. There shall be clear delineation between the product life cycle impacts and then any carbon offsets used to mitigate this impact. If there is a transparent path where chain of custody of renewable power can be traced by kWh and origin (not just CO_2e attributes), this information may be reported as additional information.

4.6 Electricity grid

The following applies in selecting the power mix:

- For the United States, regionally specific inventory data on electricity shall be based on subnational consumption mixes that account for physical power trade between the regions. If such regional data are not available (the database US LCI provides only production mix and not regional consumption mixes), the production mixes of the three continental interconnections (East, West, Texas) shall be used as a proxy, as well as those of Hawaï and Alaska. Those production mixes have to be modelled based on eGRID data https://www.epa.gov/energy/egrid. The sources for electricity and the calculation procedure shall be documented.
- On-site renewable electricity sources, when directly used by a facility to offset grid electricity purchases, may be included in calculations.
- Renewable electricity sources that are part of a country or region specific grid mix shall be included in calculations if no renewable contractual instruments (e.g. GOs, RECs, PPAs), are allocated to the product.
- If renewable contractual instruments are allocated to the product (e.g. GOs, RECs, PPAs), renewable electricity sources that are part of a country or region specific grid mix shall not be included in calculations. Instead, residual electricity mixes that “subtract” the renewable energy shall be used in regionally-specific grid mixes to avoid double-counting.
- For other regions than the United States, country-specific processes shall be used provided they are representative. For production facilities in several European countries, the applicable power mixes shall be assessed specifically for each country or combined, weighted by production volumes in the respective countries. The sources for electricity and the calculation procedure shall be documented.

4.7 Impact and inventory results

Table 23 through Table 28 present the environmental indicators to be reported in the EPD for each information module and assigned to the declared or functional unit of product.

4.7.1 *Impact categories – Entire Life Cycle*[24]

The impact categories to be reported are different depending on the region:

- For all regions, impact categories shall be calculated using the EF 3.1 impact assessment methods (Table 23)[25,26]. As of the time of publication of this PCR, the data used to calculate "Climate Change - Land Use and Land Use Change" are known to be uncertain and, therefore, when reporting results pertaining to this indicator the following disclaimer must be included; "*The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator."*
- For North America, impacts may optionally be reported using the TRACI 2.1 set of impact assessment methods (Table 24).

Regardless of region, indicators in

- Table 25 may be optionally reported. As of the time of publication of this PCR, these indicators are known to be uncertain and, therefore, when reporting results pertaining to these indicators the following disclaimer must be included; "*The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator."*

These indicators cover the entire life cycle.

Within the E.F. 3.1 methodology, the characterization factor for biogenic carbon shall be -1 kg CO2-eq/kg for uptake and +1 kg CO2-eq/kg for emission. For biogenic methane, the standard characterization factor shall be used.

Table 23. Impact categories for all regions

Impact category	**Method**	**Unit**	**Source**
Global Warming Potential, excluding Biogenic Carbon and Land Use Change	kg CO_2 -equiv	kg CO_2 equiv	IPCC 2021, GWP100a

[24] The version number of impact assessment methodology has to be updated before each publication of the PCR, using the latest version of LCIA available in LCA software.

25 As of 2023, this ensures consistency with the EC Product Environmental Footprint (PEF) guidelines: "COMMISSION RECOMMENDATION of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations"

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

[26] EF 3.0 method is described in this document: https://eplca.jrc.ec.europa.eu/permalink/PEF_method.pdf Differences between EF 3.0 and 3.1 methodologies are described here: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml.

Impact category	Method	Unit	Source
Climate Change- Total[27]	EF 3.1 Via IPCC 2021 GWP 100a	kg CO_2 equiv	EF 3.1 (adapted[27])
Climate Change- Fossil	EF 3.1 Via IPCC 2021 GWP 100a	kg CO_2 equiv	EF 3.1 (adapted[27])
Climate Change- Biogenic[27]	EF 3.1 Via IPCC 2021 GWP 100a	kg CO_2 equiv	EF 3.1 (adapted[27])
*Climate Change- Land Use and Land Use Change (LULUC)**	EF 3.1 Via IPCC 2021 GWP 100a	kg CO_2 equiv	EF 3.1 (adapted[27])
Acidification Potential	Accumulated Exceedance (Seppala et al. 2006, Posch et al, 2008)	mol H^+-equiv	EF 3.1
Eutrophication Potential, Freshwater	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	kg P-equiv	EF 3.1
Eutrophication Potential, Marine	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	kg N-equiv	EF 3.1
Eutrophication Potential, Terrestrial	Accumulated Exceedance (Seppala et al. 2006, Posch et al, 2008)	Mol N-equiv	EF 3.1
Photochemical Ozone Formation Potential	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe	kg NMVOC equiv	EF 3.1
Land Use*	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier,2018)	Pt	EF 3.1

[27] Note that EF 3.1 recommends a 0 value for biogenic carbon; however, for conformance with this PCR biogenic carbon uptake shall be modelled as a -1 value while biogenic carbon emission shall be modelled as a +1 value. Biogenic methane shall be modelled separately using the same characterization factor as fossil methane.

Impact category	Method	Unit	Source
Ozone Depletion Potential	1999 WMO assessment	kg CFC-11 equiv	EF 3.1
Resource use, minerals and metals*	CML 2002 (Guinee et al, 2002) and (van Oers et al, 2002)	kg Sb equiv	EF 3.1
Resource use, fossils*	CML 2002 (Guinee et al, 2002) and (van Oers et al, 2002)	MJ	EF 3.1
Particulate matter	PM method recommended by UNEP (UNEP 2016)	Disease incidence	EF 3.1
Water scarcity*	Available WAter REmaining (AWARE) as recommended by UNEP, 2016	m^3 water-equiv	EF 3.1

*When reporting results for these indicators, the following disclaimer must be made: *"The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator."*

Table 24. Optional impact categories for North America (TRACI 2.1)

Impact category	Unit per FU/DU	Source
Acidification Potential	kg SO_2 -equiv	US EPA TRACI v2.1 (1.05 Nov 2018) (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts)
Eutrophication Potential	kg N -equiv	
Smog Creation Potential	kg O_3 -equiv	
Ozone Depletion Potential	kg CFC-11 -equiv	
Fossil Depletion Potential	MJ surplus	
Particulate matter	kg PM2.5 -equiv	

Table 25: Optional Indicators for all regions (EF 3.1)

Impact category	Method	Unit per FU/DU	Source
Ionizing Radiation- Human* Health	Human health effect model as developed by Dreicer et al. (1995) and published in Frischknecht et al. (2000)	kBq U^{235}	EF 3.1
Ecotoxicity- Freshwater*	Based on USEtox2.1 model (Fantke et al.2017, Rosenbaum et al. 2008), as in Saouter et al. (2018)	CTUe	
Human Toxicity- Cancer*	Based on USEtox2.1 model (Fantke et al.2017, Rosenbaum et al. 2008), as in Saouter et al. (2018)	CTUh	
Human Toxicity- Non-Cancer*	Based on USEtox2.1 model (Fantke et al.2017, Rosenbaum et al. 2008), as in Saouter et al. (2018)	CTUh	

4.7.2 Indicators Describing Particulate Matter – Use stage

The indicators to be reported for all the regions are presented in Table 23. These indicators cover only the use stage rather than the entire life cycle. These indicators are additionally included within the full life cycle impacts reported in the previous section.

Particulate matter in the form of PM_{10} and $PM_{2.5}$ generated during the product use stage shall be reported as a separate inventory element and are calculated based on equations provided in Sections 5.1and 5.2.

Table 26. Indicators describing particulate matter – Inventory for the use stage

Indicator	**Unit per FU/DU**	**Source**
Particulate Matter (PM_{10})*	[kg]	Calculation of Sections 5.1and 5.2
Particulate Matter ($PM_{2.5}$)	[kg]	Calculation of Sections 5.1and 5.2

**The indicator PM_{10} is related to all the particles below 10 mm, and therefore includes $PM_{2.5}$*

4.7.3 Indicators Describing Resource Use - Entire Life Cycle

The indicators to be reported for all the regions are presented in Table 27. These indicators cover the entire life cycle.

- The total use of renewable primary energy is calculated using the Cumulative Energy Demand (CED) methodology, as per the sum of the five CED renewable energy indicators, i.e., “biomass”, “geothermal, converted”, “solar, converted”, “potential (in barrage water), converted” and “kinetic (in wind), converted”;
- The total use of non- renewable primary energy is calculated using the Cumulative Energy Demand (CED) methodology, as per the sum of the three CED non-renewable energy indicators, i.e., “fossil”, “nuclear” and “primary forest”;
- The use of fresh water resources shall be interpreted as water withdrawal (and not as water consumed) and is calculated from the inventory, as per the sum of the following fresh water flows: groundwater, surface water (river and lake), water for cooling. Turbined water, rain water and salt water shall not be taken into account.

Table 27. Indicators describing the use of resources

Indicator	**Unit per FU/DU**	**Source**
Total use of **RENEWABLE** primary energy	MJ, net calorific value	Sum of 5 CED renewable energy indicators
Total use of **NON-RENEWABLE** primary energy	MJ, net calorific value	Sum of the 3 CED non-renewable energy indicators
Water use (consumptive)	m^3	LCI results

4.7.4 *Other Indicators Describing Different Waste Categories and Output Flows – Tire End of life*

The following indicators derived from the product LCI describing different waste categories and output flows shall be calculated. Those indicators cover only the tire at its end of life rather than the entire life cycle.

The first indicator quantifies the total mass of the tire once it reaches its end of waste state, while the other recovery indicators quantify the material flows once they have both reached the end of waste state and left the system boundary. The "materials for energy recovery" parameter does not include materials for waste incineration without energy recovery. Waste incineration without energy recovery is regarded as a waste processing process and remains within the system boundary.

Table 28. Indicators describing end of life treatment and end of life output flows

Indicator	Unit per FU/DU	Source
Tire end of life treatment	kg	Calculation based on new tire mass minus TWL
Components for reuse	kg	Calculation based on i) tire mass at its end of life and ii) Table 21 provided in Section 3.2.4
Materials for recycling	kg	
Materials for energy recovery	kg	
Exported energy (materials for energy recovery)[28]	MJ, net calorific value per energy carrier	Calculation based on i) the indicators „Materials for energy recovery and ii) Table 22 provided in Section 3.2.4

4.7.5 *Indicators Describing Flows of Biogenic Carbon Throughout the Tire Life Cycle*

As discussed in Section 4.4, flows of biogenic carbon throughout the life cycle of a tire must be accounted for in an LCA model utilizing this PCR. The following indicators shall be used to illustrate the flows of biogenic carbon throughout the life cycle of a tire.

Note: the unit for reporting the following indicators is kg CO_2-eq. As such, all biogenic carbon and methane must be converted to this unit for reporting.

Table 29: Indicators describing flows of biogenic carbon throughout the modeled system.

Indicator	Unit per FU/DU	Source
Inputs of Biogenic Carbon to the Modeled System		

[28] The indicators « Materials for energy recovery » and « Exported energy (materials for energy recovery) » represent the same information on a mass basis and on an energy basis respectively.

Indicator	Unit per FU/DU	Source
Biogenic carbon contained in product	kg CO_2-eq	Calculation based on the amount of carbon present in the bio-based material according to its chemical composition.
Outputs of Product Biogenic Carbon from the Modeled System		
Biogenic carbon emitted from landfilling of product within 100 years of EOL	kg CO_2-eq	Calculation based on the amount of carbon present in the bio-based material according to its chemical composition less the amount that **does not** degrade over 100 years following EOL.
Biogenic carbon emitted from incineration of product without energy recovery.	kg CO_2-eq	Calculation based on the amount of carbon present in the bio-based material according to its chemical composition. Assumption of 100% release on incineration.
Biogenic carbon contained in product sent to reuse/recycling or incineration with energy recovery.	kg CO_2-eq	Calculation based on the amount of carbon present in the bio-based material according to its chemical composition.
Biogenic carbon contained in product stored in landfill longer than 100 years after EOL.	kg CO_2-eq	Calculation based on the amount of carbon present in the bio-based material according to its chemical composition less the amount that **does** degrade over 100 years following EOL.

5 Use Stage Calculations

While tires do not directly consume any energy, tire performance will affect the energy consumed by the vehicle on which a tire is used. To address this, the use stage energy calculations in this PCR are based on the tire rolling resistance coefficient, tire mass and dimension, relevant tire load, assumed vehicle efficiency or fuel consumption, and number of tires mounted on the vehicle. As a reminder, calculated impacts are only related to tires within the scope of this PCR and shall not be used to compare to vehicle performance.

This section provides the concepts and framework for calculating the use stage energy consumption and emissions of tires for the period in which a vehicle is in operation. Section 5.1 details the calculations for energy consumption and associated emissions for all regions. Section 5.2 details the calculations for particles emissions related to tire abrasion. All the calculations refer to the entire life of the tire, and shall be calculated per functional unit by using reference flows presented in Section 3.1.

The use stage calculation determines the amount of energy used and emissions produced by a tire of the reference service life of the specific tire module. To allow meaningful comparisons, these calculations assume proper tire rotation, alignment on vehicle, and specified air pressure is maintained throughout the tire lifetime. Moreover, it is assumed that there is no impact of some parameters like temperature, speed, and road.

Generic operational models are provided that balance sufficient detail with streamlined calculations to determine a tire's use stage energy consumption. These models provide for meaningful comparisons between tires with different performance characteristics.

The use stage energy and emissions calculation procedures account for the contributions of tires to vehicle energy consumption as well as tire abrasion that occurs during a tire’s use stage. The results allow comparison, once incorporated into the life cycle assessment, of the environmental impact of different tires.

5.1 Use stage energy calculation guidelines

The energy consumption attributable to a tire, given in MJ of energy per tire, shall be calculated according to the following equation (Equation 1) and is directly related to the tire’s rolling resistance coefficient (RRc) and to the tire's acceleration resistance. Ultimately these calculations shall be reported in terms of the functional units listed in Section 3.1, Table 20.

$$Total\ Energy\ Consumption \left[\frac{MJ}{tire}\right] = Energy\ Consumption\ Related\ to\ RR \left[\frac{MJ}{tire}\right] + Energy\ Consumption\ Related\ to\ Acceleration\ Resistance \left[\frac{MJ}{tire}\right]$$

Equation 1. Total Energy Consumption Attributable to Tire

Note, for Internal Combustion Engine Vehicle (ICEV), the impact of the rolling resistance and the inertia of tires are considered only when the vehicle is under torque. In the case of Battery Electric Vehicle (BEV), this formula also considers the energy that is not recovered by the vehicle due to the rolling resistance and the inertia of tires when the vehicle is not under torque. As the perimeter of this formula is not the same for ICEV and BEV, it is not recommended to compare the impact assessments for tires mounted on ICEV and BEV.

5.1.1 Energy consumption due to rolling resistance

The energy consumption of a tire due to its rolling resistance, given in MJ of energy per tire, shall be calculated according to the following equation.

$$Energy\ consumption\ related\ to\ RR \left[\frac{MJ}{tire}\right] = RRC_{new}\left[\frac{kg}{t}\right] * \left(1 - \frac{RRC_{loss\%}[-]}{2}\right) * relevant\ tire\ load[t] * RSL_{tire}[km] * \frac{g[m.s^{-2}]}{\eta_1[-].\eta_2[-]} * \left(\frac{d_{mot}}{d}[-] + \left(1 - \frac{d_{mot}}{d}[-]\right).\eta_3[-]\right) * \frac{1}{1}\left[\frac{kJ}{N \cdot km}\right] * \frac{1}{10^3}\left[\frac{MJ}{kJ}\right]$$

Equation 2. Energy Consumption Due to Rolling Resistance

For this calculation, the following parameters are needed:

Table 30. Parameters to be used for

Equation 2

Parameter	Unit	Description	Default value
RRc_{new}	kg/t	Rolling Resistance coefficient	According to ISO 28580
$RRc_{loss\%}$	%	Reduction of the RR_c of a used tire (at the end of its RSL) compared to a new one	Passenger car and light truck: 20%[29] Medium/Heavy truck: refer to Section 5.1.5 Bus: refer to Section 5.1.5

[29] Validated by the European Tyre and Rim Technical Organisation (ETRTO)

Parameter	Unit	Description	Default value
Relevant Tire Load	t	Relevant tire load	Passenger car and light truck: refer to Section 5.1.6.1. Medium/Heavy truck: refer to Section 5.1.6.2 Bus: refer to Section 5.1.6.2
RSL_{tire}	km	Reference Service Life	N/A
g	m/s^2	Standard acceleration due to gravity	9.81
η_1	-	Efficiency n°1 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_2	-	Efficiency n°2 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_3	-	Efficiency n°3 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
d_{mot}/d	-	% of driving cycle with engine torque demand	Refer to Section 5.1.9

5.1.2 Energy consumption due to acceleration resistance

The marginal energy consumption of a tire, given in MJ of energy per tire, shall be calculated according to the following equations and is directly related to the inertia force (due to the tire's mass and inertia moment), and to the cycle positive accelerations (braking stages are engine idling).

$$Energy\ consumption\ related\ to\ Acceleration\ Resistance \left[\frac{MJ}{tire}\right] = \frac{Inertia\ Force\ of\ the\ tire\ [N]}{\eta_1[-].\eta_2[-]} * RSL_{tire}[km] * \left(\frac{d_{mot}}{d}[-] + \left(1 - \frac{d_{mot}}{d}[-]\right).\eta_3[-]\right) * \frac{1}{1}\left[\frac{kJ}{N \cdot km}\right] * \frac{1}{10^3}\left[\frac{MJ}{kJ}\right]$$

Equation 3. Energy Consumption Due to Acceleration Resistance

$$Inertia\ Force\ of\ the\ tire\ [N] = (Weight_{new}[kg] - TWL\ [kg]\ /2 + InertiaMoment\ [kg.m^2]/OuterRadius\ [m]\ ^2) * \gamma[m.s2]$$

Equation 4. Inertia Force of the Tire

$$InertiaMoment\ [kg * m^2] = 0.8 * (Weight_{new}[kg] - TWL\ [kg]/2) * OuterRadius\ [m]^2 + 0.2 * (Weight_{new}[kg] - TWL\ [kg]/2\ ) * SeatRadius\ [m]^2$$

Equation 5. Inertia Moment of the Tire

For these calculations, the following parameters are needed:

Table 31. Parameters to be used for Equation 3

Parameter	Unit	Description	Default value
RRc_{new}	kg/t	Rolling Resistance coefficient	According to ISO 28580
$RRc_{loss\%}$	%	Reduction of the RR_c of a used tire (at the end of its RSL) compared to a new one	Passenger car and light truck: 20%[30] Medium/Heavy truck: refer to Section 5.1.5 Bus: refer to Section 5.1.5
Relevant Tire Load	t	Relevant tire load	Passenger car and light truck: refer to Section 5.1.6.1. Medium/Heavy truck: refer to Section 5.1.6.2 Bus: refer to Section 5.1.6.2
RSL_{tire}	km	Reference Service Life	N/A
g	m/s^2	Standard acceleration due to gravity	9.81
η_1	-	Efficiency n°1 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_2	-	Efficiency n°2 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_3	-	Efficiency n°3 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
d_{mot}/d	-	% of driving cycle with engine torque demand	Refer to Section 5.1.9

[30] Validated by the European Tyre and Rim Technical Organisation (ETRTO)

5.1.3 Energy consumption due to acceleration resistance

The marginal energy consumption of a tire, given in MJ of energy per tire, shall be calculated according to the following equations and is directly related to the inertia force (due to the tire's mass and inertia moment), and to the cycle positive accelerations (braking stages are engine idling).

$$Energy\ Consumption\ related\ to\ Acceleration\ Resistance\ \left[\frac{MJ}{tire}\right] = \frac{Inertia\ Force\ of\ the\ Tire\ [N]}{n_1[-] \cdot n_2[-]} * RSL_{tire}[km] * \left(\frac{d_{mot}}{d}[-] + \left(1 - \frac{d_{mot}}{d}[-]\right) \cdot n_3[-]\right) * \frac{1}{1}\left[\frac{kj}{N \cdot km}\right] * \frac{1}{10^3\left[\frac{MJ}{kJ}\right]}$$

Equation 6. Energy Consumption Due to Acceleration Resistance

$$Inertia\ Force\ of\ the\ tire\ [N] = (Weight_{new}[kg] - TWL\ [kg]\ /2 + InertiaMoment\ [kg.m^2]/OuterRadius\ [m]^2) * \gamma[m.s2]$$

Equation 7. *Inertia Force of the Tire*

$$InertiaMoment\ [kg * m^2] = 0.8 * (Weight_{new}[kg] - TWL\ [kg]/2) * OuterRadius\ [m]^2 + 0.2 * (Weight_{new}[kg] - TWL\ [kg]/2\ ) * SeatRadius\ [m]^2$$

Equation 8. *Inertia Moment of the Tire*

For these calculations, the following parameters are needed:

Table 32 Parameters to be used for Equation 6, Equation 7, and Equation 8

Parameter	Unit	Description	Default value
η_1	-	Efficiency n°1 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_2	-	Efficiency n°2 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8
η_3	-	Efficiency n°3 depending on vehicle technology	Refer to Section 5.1.4 and 5.1.8

Parameter	Unit	Description	Default value
d_{mot}/d	-	% of driving cycle with engine torque demand	Refer to Section 5.1.9
RSL_{tire}	km	Reference Service Life	N/A
$Weight_{new}$	kg	Weight of a new tyre	N/A
TWL	kg	Tire Wear Loss	Refer to Section 5.2.1
OuterRadius	m	Distance from the center of the rim to the top of the tire tread	N/A
SeatRadius	m	Distance from the center of the rim to where the tire is seated on the rim	N/A
γ	m/s^2	Positive acceleration value of the considered cycle	Passenger car and light truck: refer to Table 33 Medium/heavy truck: refer to Table 33 Bus: refer to Table 34

Table 33. Positive Accelerations by Vehicle Category - Passenger Car and Truck tires[31]

	Passenger car and Light truck		**Medium/heavy truck**			
	Passenger car	**Light truck**	**Pick-up and Delivery**	**Regional and City**	**Long Haul**	**Mixed Service**
γ (m/s^2)	0.16	0.16	0.09	0.09	0.03	0.09

[31] Driving cycle references: Passenger car and light truck: Class 3 cycle, UNEC: Available as PCR supplemental file. Medium/heavy truck (pick/up and delivery, regional and city, long haulage and mixed service: Based on internal tests done by Manufacture Française des Pneumatiques Michelin.

Table 34. Positive Accelerations by Vehicle Category – Bus tires[32]

	Bus						
	Pick up bus	**City bus, Small**	**City bus, Medium**	**City bus, Large**	**School Bus**	**Coach, Regional (Inter-city)**	**Coach, Long haulage**
γ (m/s²)	0.23	0.23	0.23	0.23	0.23	0.12	0.12

5.1.4 Additional information for energy consumption formulas

$\eta 1$, $\eta 2$, $\eta 3$ are efficiencies, with different meanings and values depending on vehicle technology.

$dmot/d$ is the part of driving cycles with engine torque demand, as a tire does not consume fuel when the engine does not require power.

Equation 2 and Equation 3 are able to cover all vehicle technologies. For PHEV, these equations should be applied for multiple sources (e.g., electric + gasoline) and the result should be a weighted average based on a ratio between thermal and electric operating mode, using an energy source distribution ratio of:

- 60% for electric[33]
- 40% for gasoline or diesel[34]

Table 35. Physical meaning of η_1, η_2 and η_3 used in Equation 2 and Equation 3 according to energy source and fuel type

Energy source	**Fuel type**	η_1	η_2	η_3
Gasoline	Gasoline	Engine thermodynamic efficiency	Transmission efficiency	N/A ($\eta_3 = 0$)
Diesel	Diesel	Engine thermodynamic efficiency	Transmission efficiency	N/A ($\eta_3 = 0$)

[32] Buses: Based on calculation done by Manufacture Française des Pneumatiques Michelin using the different cycles available in VECTO (“Suburban”, “Urban”, and “Heavy Urban” for Pick-up and City buses, “Interurban” for regional and long haulage coach.

[33] Source: IEA Global EV Outlook 2020 which can be found here: https://www.iea.org/reports/global-ev-outlook-2020

[34] Based on assumption

Energy source	Fuel type	η_1	η_2	η_3
Flex Fuel (E25)	Flex Fuel (E25)	Engine thermodynamic efficiency	Transmission efficiency	N/A (η_3 = 0)
Flex Fuel (E85)	Flex Fuel (E85)	Engine thermodynamic efficiency	Transmission efficiency	N/A (η_3 = 0)
Gaseous - CNG	Gaseous - CNG	Engine thermodynamic efficiency	Transmission efficiency	N/A (η_3 = 0)
Gaseous - LPG	Gaseous - LPG	Engine thermodynamic efficiency	Transmission efficiency	N/A (η_3 = 0)
Gasoline hybrid	Gasoline	Engine thermodynamic efficiency	Transmission efficiency	Energy recovery efficiency
Diesel hybrid	Diesel	Engine thermodynamic efficiency	Transmission efficiency	Energy recovery efficiency
Fuel cell	Hydrogen	Electric motor x fuel cell efficiency	Battery efficiency	Energy recovery efficiency
All-electric	Electricity	Electric motor efficiency	Battery efficiency	Energy recovery efficiency

5.1.5 Rolling Resistance Loss – Medium, Heavy Truck and Bus Tires

Equation 9 presents the rolling resistance loss calculation for medium and heavy truck tires, as well as for bus tires.[35]

$$RRc_{loss\%}\ [\%] = 0.224 * (Tread\ Depth\ [cm] - TWI\ Height\ [cm])$$

Equation 9. Rolling Resistance Loss Calculation for Medium, Heavy Truck and Bus Tires

For this calculation, the following parameters are needed:

[35] Equation for RRc loss for medium/heavy truck and bus tires comes from tests done by Manufacture Française des Pneumatiques Michelin of both truck and bus tires buffed at the treadwear indicator for tires ranging in size from 17.5 to 22.5. The equation proposed is a statistical analysis that considers the first order parameter of wearable tread depth (Tread Depth to the bottom of the groove-TWI Height).

Table 36. Parameters to be used for Equation 6

Parameter	Unit	Description	Default value
Tread Depth	cm	Average of the tread depth at each groove (measured from the top of the tread down to the bottom of the groove)	N/A
TWI Height	cm	Height of the treadwear indicator	N/A

5.1.6 Relevant Tire Load

5.1.6.1 Passenger Car and Light Truck Tires

Equation 10 presents the relevant tire load calculation for passenger car and light truck tires and is related to one tire.

$$Relevant\ Tire\ Load\ [t] = \frac{VehicleWeight[t]}{\#\ Tires\ to\ support\ load\ [-]}$$

Equation 10. Passenger car and light truck Tires Relevant Load Calculation

For this calculation, the following parameters are needed:

Table 37. Parameters to be used for Equation 7

Parameter	Unit	Description	Default value
VehicleWeight	t	Weight of the vehicle	Refer to Table 38, which presents the vehicle weights to be used per the listed load index ranges
# Tires to support load	-	Number of tires to support vehicle weight	4

Table 38. Load Indices and Related Vehicle Weights[36]

Category	Load Index (all regions)	Vehicle Weight [t]
1	50-74	0.750
2	75-85	1.180
3	86-98	1.540
4	99-111	1.950
5	112-128	2.860
6 (only applicable in Korea)	129-135	5.240

5.1.6.2 Medium and Heavy (Commercial) Truck Tires, Bus Tires

Equation 11 presents the relevant tire load calculation for medium, heavy trucks and buses and is related to one tire.

$$\begin{aligned} Relevant\ Tire\ Load\ [t] &= Load\ Capacity\ [kg] * R_{factor}[-] \\ &* \left[(1 - Payload\ Portion\ [\%]) + Payload\ Portion\ [\%] * Payload\ Utilization\ Factor[\%]\right] \\ &* \frac{1}{1000}\ [\frac{t}{kg}] \end{aligned}$$

Equation *11*. Commercial Truck Tire and Bus Tire Load Calculation

For this calculation, the following parameters are needed:

[36] To develop this table, average vehicle weights were simulated using the load index of the tire for 73 different vehicles that are popular in the US. The vehicles selected range from small passenger cars (such as a smart car) to large light trucks (such as an F-350 Super Duty). A list of the curb weights was compiled for each vehicle and compared to the average vehicle weight that would be selected using the proposed load index ranges for the tire. Average vehicle weights were optimized to produce the lowest percent error possible for this selection of 73 vehicles. While developed based on US data, this list was also found to be consistent with vehicle weights and load indices for the other regions considered in this PCR.

Table *39*. Parameters to be used for Equation 8 for Commercial Truck Tire

Parameter	Unit	Description	Default value
Load Capacity	kg	Maximum load a tire can support at a recommended cold inflation pressure which corresponds to the load index of the tire, as per specification in Section 2.4.4	Standard values
R_{factor}	-		0.85 (based on ISO 28580)
Payload Portion	[%]	Portion of the total loaded vehicle weight attributable to payload	For steer tires, payload portion is 0. For drive and trailer tires, refer to Table 40, which presents the payload portion If no assignment exists for a particular region, use Europe numbers by default
Payload Utilization Factor	[%]	Portion of total travels of the truck for which the truck has a full payload	Refer toTable 41, which presents the payload utilization factor If no assignment exists for a particular region, use Europe numbers by default

Table 40. Payload Portion Factors by Truck Class

<table>
<tr><th rowspan="2">Medium/Heavy Truck Class</th><th colspan="7">Payload Portion[37]</th></tr>
<tr><th>NA</th><th>LA</th><th>Europe</th><th>Japan</th><th>China</th><th>South Korea</th><th>ROW</th></tr>
<tr><td>Long Haul</td><td>60%</td><td rowspan="4">70%</td><td>65%</td><td>65%</td><td>65%</td><td rowspan="2">77%</td><td>67%</td></tr>
<tr><td>Regional and City</td><td>50%</td><td rowspan="3">60%</td><td rowspan="3">60%</td><td rowspan="3">60%</td><td>63%</td></tr>
<tr><td>Mixed Service</td><td>60%</td><td>60%</td><td>65%</td></tr>
<tr><td>Pick-up and Delivery</td><td>30%</td><td>60%</td><td>57%</td></tr>
</table>

Table 41. Payload Utilization Factors by Truck Class

<table>
<tr><th rowspan="2">Medium/Heavy Truck Class</th><th colspan="7">Payload Utilization[38]</th></tr>
<tr><th>NA</th><th>LA</th><th>Europe</th><th>Japan</th><th>China</th><th>South Korea</th><th>ROW</th></tr>
<tr><td>Long Haul</td><td>75%</td><td>75%</td><td>75%</td><td>40%</td><td>75%</td><td>54%</td><td>74%</td></tr>
<tr><td>Regional and City</td><td>75%</td><td>75%</td><td rowspan="3">50%</td><td>40%</td><td rowspan="3">50%</td><td>50%</td><td>48%</td></tr>
<tr><td>Mixed Service</td><td rowspan="2">50%</td><td rowspan="2">50%</td><td>40%</td><td rowspan="2">42%</td><td>49%</td></tr>
<tr><td>Pick-up and Delivery</td><td>31%</td><td>49%</td></tr>
</table>

[37] The sources for Payload portion are the following: NA and LA : based on manufacturer information, Europe : ACEA - Commercial Vehicles and CO_2, Japan : assumed same as Europe, China : assumed same as Europe, South Korea: The 2017 'National Transportation DB', Ministry of Land, Infrastructure and Transport , ROW : calculated as the average of all the countries

[38] The sources for Payload utilization factors are the following: NA /LA: assumed same as Europe, Europe: AEA - Reduction and Testing of Greenhouse. Gas (GHG) Emissions from Heavy Duty. Vehicles – Lot 1: Strategy, Japan: 2021 statistical data of Japanese government, e-Stat. https://www.e-stat.go.jp/dbview?sid=0003442538" from " Japan: Report of Ministry of Economy, Trade and Industry summarized by Japan Institute of Logistics System, China : assumed same as Europe, South Korea : The 2017 'National Transportation DB', Ministry of Land, Infrastructure and Transport, ROW : calculated as the average of all the countries

Table 42. Parameters to be used for Equation 8 for Bus Tire

Parameter	Unit	Description	Default value
Load Capacity	kg	Maximum load a tire can support at a recommended cold inflation pressure which corresponds to the load index of the tire, as per specification in Section 2.4.4.	Standard values
R_{factor}	-		0.85 (based on ISO 28580)
Payload Portion	[%]	Portion of the total loaded vehicle weight attributable to payload	Refer to Table 40, which presents the payload portion If no assignment exists for a particular region, use Europe numbers by default
Payload Utilization Factor	[%]	Portion of total travels of the bus for which the bus has a full payload	Refer to Table 41, which presents the payload utilization factor If no assignment exists for a particular region, use Europe numbers by default

Table 43. Payload Portion Factors by Bus Class

Bus Class	Payload Portion[39]						
	NA	LA	Europe	Japan	China	South Korea	ROW
Pick-up bus	20%	60%	43%	43%	43%	43%	42%
City bus	30%	70%	43%	43%	43%	43%	44%
School bus	33%	N/A	N/A	N/A	N/A	N/A	N/A
Coach, regional haulage	33%	75%	23%	23%	23%	23%	34%
Coach, long haulage			35%	35%	35%	35%	41%

Table 44. Payload Utilization Factors by Bus Class

Bus Class	Payload Utilization[40]						
	NA	LA	Europe	Japan	China	South Korea	ROW
Pick-up bus	25%	25%	19%	19%	19%	19%	21%
City bus	35%	35%	19%	19%	19%	19%	24%
School bus	30%	N/A	N/A	N/A	N/A	N/A	N/A
Coach, regional haulage	65%	65%	36%	36%	36%	36%	46%

[39] The sources for Payload portion are the following: NA : Internal knowledge, manufacturer information, and the APTA report "An Analysis of Transit Bus Axle Weight Issues", LA : OEM literature, Law 9503 Compilado (Brazil), and DNIT: http://www.dnit.gov.br/download/rodovias/operacoes-rodoviarias/pesagem/qfv-2012-abril.pdf (Based on average of data for typical vehicles in Brazil and region), Europe : HBEFA https://www.hbefa.net/, Japan, China, and South Korea: assumed same as Europe, ROW : calculated as the average of all the countries.

[40] The sources for Payload utilization factors are the following: NA : Internal knowledge, manufacturer information, and the APTA report "An Analysis of Transit Bus Axle Weight Issues", LA: assumed same as Europe, Europe : http://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles-1, Japan, China, and South Korea: assumed same as Europe, ROW : calculated as the average of all the countries

Coach, long haulage			67%	67%	67%	67%	66%

5.1.7 Vehicle Fuel Types

The default energy source distribution across the different regions is provided in Table 35 for passenger cars and light trucks, in Table 36 for medium and heavy trucks, and in Table 37 for buses.

5.1.7.1 Passenger Car and Light Truck Tires

Table 45. Passenger Car and Light Truck Energy Sources Distribution (Energetic Percentage) by Region

	Energetic Distribution (for 1 MJ consumed)[41]				
Region[42]	Gasoline	Diesel	Flex-fuel (E25)	Gasoline hybrid	Gaseous - LPG
North America (NA)	100.00%	0.00%	0.00%	0.00%	0.00%
Latin America (LA)	47.49%	13.18%	39.33%	0.00%	0.00%
Europe	38.03%	61.97%	0.00%	0.00%	0.00%
Japan	83.42%	0.00%	0.00%	16.58%	0.00%
China	88.05%	11.95%	0.00%	0.00%	0.00%
South Korea	41.22%	39.40%	0.00%	0.00%	19.39%
Rest of the World (ROW)	78.09%	21.91%	0.00%	0.00%	0.00%

5.1.6.2 Medium/Heavy Truck

[41] The distribution across the different energy sources was calculated based on number of vehicles distribution and on the corresponding vehicle efficiency. Energy sources contributing with more than 10% to energetic distribution by region were included in the average energetic distribution for LCI modeling purposes and normalized to 100%.

[42] The source for distribution by region is IEA Mobility Model : Energy intensity is obtained based on the following formula: [annual mileage * number of units * fuel economy]. This analysis is based on the Mobility Model developed by the International Energy Agency [2019], all rights reserved, but the resulting analysis has been prepared by Michelin and does not necessarily reflect the views of the International Energy Agency.

Table 46. Medium and Heavy Truck Fuel Types

	Energetic Distribution (for 1 MJ consumed)[43]	
Region[44]	Gasoline	Diesel
North America (NA)	18.9%	81.1%
Latin America (LA)	0%	100%
Europe	0%	100%
Japan	0%	100%
China	35.9%	64.1%
South Korea	0%	100%
Rest of the World (ROW)	0%	100%

5.1.7.1 Pick-up Services/City/School Bus and Coaches

Table 47. Bus Fuel Types

	Energetic Distribution (for 1 MJ consumed)[45]			
Region[46]	Gasoline	Diesel	Flex-fuel (E25)	CNG

[43] The distribution across the different energy sources was calculated based on number of vehicles distribution and on the corresponding vehicle efficiency. Energy sources contributing with more than 10% to energetic distribution by region were included in the average energetic distribution for LCI modeling purposes and normalized to 100%.

[44] The source for distribution by region is IEA Mobility Model: Energy intensity is obtained based on the following formula: [annual mileage * number of units * fuel economy]. This analysis is based on the Mobility

[45] The distribution across the different energy sources was calculated based on number of vehicles distribution and on the corresponding vehicle efficiency. Energy sources contributing with more than 10% to energetic distribution by region were included in the average energetic distribution for LCI modeling purposes and normalized to 100%.

[46] The source for distribution by region is IEA Mobility Model: Energy intensity is obtained based on the following formula: [annual mileage * number of units * fuel economy]. This analysis is based on the Mobility Model developed by the International Energy Agency [2019], all rights reserved, but the resulting analysis has been prepared by Michelin and does not necessarily reflect the views of the International Energy Agency.

	Energetic Distribution (for 1 MJ consumed)[45]			
North America (NA)	0%	87.9%	0%	12.1%
Latin America (LA)	10.6%	76.3%	13%	0%
Europe	0%	100%	0%	0%
Japan	0%	100%	0%	0%
China	23.8%	76.2%	0%	0%
South Korea	0.0%	79.4%	0%	20.6%
Rest of the World (ROW)	39.3%	60.7%	0%	0%

5.1.8 Vehicle Efficiencies

The default vehicle efficiencies for the different energy sources are provided in Table 48 for all tire sub-categories.

If a manufacturer can demonstrate via supporting documentation that a tire will be used on an alternative vehicle technology, the specific vehicle efficiencies may be used as detailed in 9.1and provided as additional environmental information.

Table 48. Vehicle Efficiencies by Energy Source[47]

Energy source	Fuel type	η_1	η_2	η_3
Gasoline	Gasoline	37%	90%	0%
Diesel	Diesel	Passenger Car and Light Truck: 42%	90%	0%

[47] Passenger Car and Light Truck: JC Guibet, Fuels and Engines, 1999; Mallet, E., "Impact of tire rolling resistance on fuel consumption: current status and perspectives", 2nd International VDI Conference Eurotyre, 2016; Siemens Amesim simulation tool with IFP Drive library.

Medium/heavy truck and bus: JC Guibet, Fuels and Engines, 1999; Pachernegg, S.J.; "A Closer Look at the Willans-Line," SAE 690182, 1969; VECTO https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en

Energy source	Fuel type	η_1	η_2	η_3
		Medium/Heavy trucks: 46% Bus: 46%		
Flex Fuel (E25)	Flex Fuel (E25)	37%	90%	0%
Gaseous- CNG	Gaseous- CNG	Bus: 45%	Bus: 90%	0%
Gaseous - LPG	Gaseous - LPG	45%	90%	0%
Gasoline hybrid	Gasoline	37%	90%	50%

Efficiency is the same for all tire sub-categories except if specified in the table

5.1.9 Part of driving cycle with engine torque demand

Table 49. Part of driving cycle with engine torque demand[48]

	Passenger car and Light Truck	**Medium/Heavy Truck**	**Bus**
d_{mot}/d	80%	80%	80%

5.1.10 Energy source and combustion direct emissions

To model the energy consumption attributable to the tire, the split per MJ by energy source as presented in Table 31 shall be applied. The corresponding direct emissions relate to only fuel combustion emissions, exclude other emission types, and are as follows:

[48] Passenger Car and Light Truck : JC Guibet, Fuels and Engines, 1999; Mallet, E., "Impact of tire rolling resistance on fuel consumption : current status and perspectives", 2nd International VDI Conference Eurotyre, 2016; Siemens Amesim simulation tool with IFP Drive library
Medium/heavy truck and bus : JC Guibet, Fuels and Engines, 1999; Pachernegg, S.J.; "A Closer Look at the Willans-Line," SAE 690182, 1969; VECTO https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en

- Tire and Road Wear Particles emissions have to be excluded since they are modelled separately (Section 5.2.2)
- Brake and other abrasion emissions except TRWP, given they are out of scope as noted in Sections 3.2.3.1and 5.2.2.

The energy consumption and direct emissions per MJ for each type of energy source shall be modelled using the datasets presented in Table 50 and Table 51 and fuel density presented in Table 52. Detailed air emissions to be used for the modeling are presented in Appendix IV in Section 11 If primary data are available for combustion direct emissions, this should be reported as additional environmental information as per Section 9.

Table 50. Default datasets to be used for fuel consumption and combustion emissions (Passenger car)[49]

	Passenger car				
Type of fuel	Gasoline	Diesel	Flex-fuel (E25)	Gaseous – LPG	Gasoline Hybrid
Source	Ecoinvent v3.6		Based on ecoinvent v3.6	Ecoinvent v3.6	Ecoinvent v3.6
Default dataset	Transport, passenger car, large size, petrol, EURO 5	Transport, passenger car, large size, diesel, EURO 5	Based on Transport, passenger car, large size, petrol, EURO 5	Transport, passenger car, medium size, liquefied petroleum gas (LPG), EURO 5	Transport, passenger car, large size, petrol, EURO 5
Geography	RER (Europe)	RER (Europe)	RER (Europe)	RER (Europe)	RER (Europe)
Time period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period

[49] The default datasets were selected based on the technological representativeness, the geographic coverage, the time-related representativeness, and the completeness (substances coverage for each impact category required). The database ecoinvent v3.6 was selected for passenger cars and trucks, since the emissions are calculated based on TREMOVE 2007 and COPERT 2006 (models internationally recognized and supported by the European Environment Agency and the JRC), and since they represent the most recent datasets (2012). The database US LCI was selected for buses, since the emissions are calculated based on EPA's MOVES 2010a (MOVES is the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator), since it offers a wider choice of buses technologies, and since it includes the most recent datasets for buses (2010).

Table 51. Default datasets to be used for fuel consumption and combustion emissions (Truck and Bus)[50]

	Truck		Bus			
Type of fuel	Gasoline	Diesel	Diesel	Flex-fuel (E25)	Gasoline	CNG
Source	U.S. Life Cycle Inventory Database	Ecoinvent v3.6	U.S. Life Cycle Inventory Database	U.S. Life Cycle Inventory Database	U.S. Life Cycle Inventory Database	U.S. Life Cycle Inventory Database
Default dataset	Transport, combination truck, short-haul, gasoline powered	Transport, freight, lorry >32 metric ton, EURO6	Transport, transit bus, diesel powered	Based on Transport, transit bus, gasoline powered	Transport, transit bus, gasoline powered	Transport, transit bus, CNG powered
Geography	RNA (Northern America)	RER (Europe)	RNA (Northern America)	RNA (Northern America)	RNA (Northern America)	RNA (Northern America)
Time period	2010-01-01 to 2010-01-01	2009-01-01 to 2013-12-31 Valid for the entire period	2010-01-01 to 2010-01-01	2010-01-01 to 2010-01-01	2010-01-01 to 2010-01-01	2010-01-01 to 2010-01-01

[50] The default datasets were selected based on the technological representativeness, the geographic coverage, the time-related representativeness, and the completeness (substances coverage for each impact category required). The database ecoinvent v3.6 was selected for passenger cars and trucks, since the emissions are calculated based on TREMOVE 2007 and COPERT 2006 (models internationally recognized and supported by the European Environment Agency and the JRC), and since they represent the most recent datasets (2012). The database US LCI was selected for buses, since the emissions are calculated based on EPA's MOVES 2010a (MOVES is the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator), since it offers a wider choice of buses technologies, and since it includes the most recent datasets for buses (2010).

Table 52. Fuel Densities and Lower Heating Values (LHV)[51]

Fuel Type	LHV (MJ/L)	LHV (MJ/kg)	Density (kg/L)
Diesel	35.80		0.835
Gasoline	32.36		0.749
Ethanol	21.10		0.789
Flex fuel (E25)	28.56		0.743
Flex fuel (E85)	23.13		0.781
Gaseous - CNG		45.1	0.000840
Gaseous - LPG	26.35		0.557
Hydrogen		120.1	0.0225

5.2 Tire abrasion calculation guidelines

Particles generated by the abrasion of tire and road are part of non-exhaust vehicle emissions (in addition to wear particles of brakes, clutches and chassis). Particles of tire tread are always mixed with pavement particles, (Kreider et al. 2010); therefore, this PCR refers to these particles as tire and road wear particles (TRWP), not as tire debris or tire wear particles. Only particles that include a tire abrasion component are included in the scope of this PCR, i.e. TRWP. The particles that do not include a tire abrasion component are excluded from the scope of this PCR. In other terms, it means that the particles originating exclusively from the pavement, and particles originating from other vehicle systems (including but not limited to brakes, clutch, and chassis emissions) are excluded from the scope of this PCR.

[51] LHV and densities from Argonne National Laboratory GREET v. 1.3.0.14168 model, with the exception of diesel density, taken from https://www.dieselnet.com/standards/eu/fuel_reference.php

Ethanol LHV and densities taken from: https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html.

E25 LHV taken from Argonne National Laboratory, Improving Ethanol-Gasoline Blends by Addition of Higher Alcohols, 2012: https://www.energy.gov/eere/vehicles/articles/improving-ethanol-gasoline-blends-addition-higher-alcohols

E25 density from Khierallaa et al, (2011) Effect of Ethanol−Gasoline Blends on Fuel Properties Characteristics of Spark Ignition Engines

CNG density taken from ecoinvent documentation

CNG LHV taken from IEA Mobility Model

LPG LHV and density taken from IEA Mobility Model

Hydrogen LHV and density taken from IEA Mobility Model

5.2.1 Tire Wear Loss

If available, companies shall use their own internal Computer Aided Design (CAD) tire mold modeling capabilities to determine the Tire Wear Loss (TWL).

If a company does not have the capability to use CAD modeling, then the following equations shall be used to calculate an estimate for TWL. The TWL is determined by calculating the mass of tread compound above the Tread Wear Indicator (TWI) on the tire, based on the assumption that the tire is completely worn down to the TWI before it is replaced. In many regions it is common practice to change tires before the TWI is reached, causing the total amount of tread released into the environment to be lower in comparison to the amount considered in calculations of this PCR.

$$TWL[kg] = \frac{1}{1000}\left[\frac{kg}{g}\right] * (Tread\ Depth\ [cm] - TWI\ Height\ [cm]) * \text{Tread Lenght}[cm] * \text{Density}\left[\frac{g}{cm3}\right] * (\text{Contact Width}[cm] * (1 - \text{Void Ratio}\ [-]) + \alpha\ [cm])$$

Equation 12. Tire Wear Loss Calculation - Passenger Car, Truck and Bus Tires

$$\text{Tread Lenght}[cm] = (2 * \text{Outer Radius}\ [cm] - \text{Tread Depth}\ [cm]) * \pi$$

Equation 13. Tread Length Calculation - Passenger Car, Truck and Bus Tires

For these calculations, the following parameters are needed:

Table 53. Parameters to be used for Equation 12 and Equation 13

Parameter	Unit	Description	Default value
Tread Depth	cm	Average of the tread depth at each groove (measured from the top of the tread down to the treadwear indicator)	N/A
TWI Height	cm	Height of the treadwear indicator	N/A
Tread Length (TL)	cm	Tread length as measured around the circumference of	N/A

Parameter	Unit	Description	Default value
		the tire at the center-line	
Density	g/cm^3	Density of the tread compound	N/A
Contact Width	cm	The flat portion of the tread that contacts the road, this can be obtained from the footprint measurement at 85% load	As a proxy, can be estimated as “Tread Width of the original new tire”
α	cm	Calculated as: ((Tread Width of the worn tire until Tread Wear Indicator) – (Tread Width of the original new tire))/2	if α is not calculated, below default values can be used: Passenger car and light truck tire: 2 cm Medium/heavy truck tire: 0cm Bus tire: 0 cm
Void ratio	[-]	Part of tread volume that does not contain rubber, from the tire engineering specification	N/A
Outer Radius	cm	Distance from the center of the rim to the top of the tire tread	N/A

5.2.2 Tire Road Wear Particle Emissions[52]

Equation 14 presents the calculations for determining Tire and Road Wear Particle (TRWP) emissions using the Tire Wear Loss (TWL) calculated in Equation 12, based on the composition of TRWP which is 50% tire tread and 50% embedded pavement.[53]

$$TRWP\,[kg] = \frac{TWL\,[kg]}{50\%}$$

Equation 14. Tire Road Wear Particle Emissions Calculation[54]

Of the TRWP, particles above 10 µm represent at least 98% of the mass of particles emitted, leaving less than 2% mass for particles below 10 µm (PM_{10}). Equation 15 presents the calculation for determining PM_{10} amount within TRWP emissions. The amount of PM_{10} includes all the particles below 10 µm, and therefore includes also $PM_{2.5}$.

$$PM_{10,air}\,[kg] = TRWP\,[kg] * 2\%$$

Equation 15. PM_{10} Emissions Calculation

Of the TRWP <10 µm, 69.2% are greater than 2.5µm.

Equation 16 presents the calculation for determining $PM_{2.5}$ amount within TRWP emissions.

$$PM_{2.5,air}[kg] = PM_{10,air}[kg] * 30.8\%$$

Equation 16. $PM_{2.5}$ Emissions Calculation

[52] Emissions and equations are based on research by Panko et al. 2009.

[53] Based on Kovochich et al, 2021; Unice et al, 2013; Kreider et al, 2010.

[54] Based on visual observation of PM_{10} TRWP from electron microscope pictures. As applied in this formula, all TRWP are approximately 50% tread rubber and 50% embedded pavement particles. At this time of publication of v1 of this PCR, this is the best available data point for approximation of PM_{10}.

Table 54. Tire and Road Wear Particle Emissions

TRWP Particle size (Panko et al. 2009)	TRWP Emissions Compartment
> 10 µm, 98% of TRWP by mass	1% road surface retention 61% to soil 18% removed through stormwater management 18% to surface water 16% to sediment 2% to estuary (Unice et al 2019)
< 10 µm, 2% of TRWP by mass	100% to air (Panko et al 2009)
2.5 to 10 µm, 69.2% of TRWP < 10 µm by mass	
<2.5 µm, 30.8% of TRWP < 10 µm by mass	

5.3 Units

The following units shall be used for the life cycle calculations:

- SI units
- Preferred basic units:
  - kg (kilograms)
  - km (kilometers)
  - MJ (mega Joule) for thermal energy
  - MJ (mega Joule) for electrical energy (kWh can also be used with 1 kWh = 3.6 MJ)

6 Content of the EPD

All Type III environmental declarations in a product category will include the parameters as identified in this PCR.

6.1 General information to be declared

The following general information will be declared:

- Name and address of the manufacturer(s);
- Product identification by name (including model name) and a simple visual representation of the tire product to which the EPD is developed;
- EPD type and region of applicability;
- Tire designation information in Section 2.4.4;
- Retreadability;
- Tire labelling information, if any (graphic optional);
- Rolling Resistance coefficient value (As used in Section 0);
- Description of the product's use, tire category, and the functional or declared unit of the product to which the data relates;
- Tire reference service life (RSL) (except if confidential);
- Name and contact information of program operator;
- PCR identification;
- Date the declaration was issued and period of validity;
- General specification for the material composition of the product as identified will be given (mass and % contribution by mass);
    - Synthetic rubber
    - Natural rubber
    - Steel
    - Textiles
    - Silica
    - Carbon black
    - Other materials (e.g., chemicals)
- LCA software used and version number;
- LCI databases used, version number. In addition, the contribution of each specific database (e.g., Ecoinvent, ELCD, USLCI, GaBi, IDEA) to the global warming potential shall be indicated;
- Statement that environmental declarations from different programs (ISO 14025) may not be comparable;
- Statement that calculated impacts are only related to tires within the scope of this PCR and shall not be used to compare to vehicle performance;
- Where an EPD declares an average performance for a number of manufacturing plant locations;
- The site(s), manufacturer or group of manufacturers or those representing them for whom the results of the LCA are representative;
- Information on where explanatory material may be obtained;
- A diagram of the life cycle stages included in the LCA; and
- Completion and inclusion of Table 55 (below):

Table 55. Demonstration of verification

This PCR review, was conducted by: < name and organization of the chair, and information on how to contact the chair through the Program Operator >
Independent verification of the declaration and data, according to ISO 14025
(Where appropriate) Third party verifier: < name of the third party verifier >

6.2 Declaration of Environmental Impacts

Impact category indicators shall include, but not be limited to, those specified in Table 23, for each reported module and for the entire life cycle, for all regions. EPDs representing North America may additionally report indicators specified in Table 24, for each reported module and for the entire life cycle. All regions may additionally report indicators specified in Table 25, for each reported module and for the entire life cycle.

The indicators describing particles emissions, presented in Table 26, shall be included for each reported module of the use stage only, for all regions.

The indicators describing resource use, presented in Table 27, shall be included for each reported module and for the entire life cycle, for all regions.

The indicators describing waste and resource recovery, presented in Table 28, shall be included for each reported module in the end of life stage only, for all the regions.

The indicators describing biogenic carbon uptake and release, presented in Table 29, shall be included for the entire life cycle, for all the regions.

Additional environmental information, scenarios and technical information related to environmental aspects may be included per Section 9, Appendix II).

6.3 Inclusion of several similar products in the same EPD

This PCR allows including similar tires from the same company in the same EPD. The following requirements shall be met:

- The tires shall be:

  - Of the same tire sub-category as described in Section 5.1.6 of the present document,
  - Of the same load index category for passenger car and light truck tires (as per Table 38) and of the same load index for truck and bus tires,
  - Of a similar tireline.
- The difference between the mandatory impact indicators shall be lower than ±10%. The impact indicators to be published in the EPD shall be calculated as the average of the impact indicators of the different tires grouped within the same EPD.

6.4 Validity of an EPD

The validity of the EPD is set at five years after which the declaration must necessarily be revised and reissued.

7 References

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8 Appendix I – Project Documentation/Background Report

Project documentation (or Background Report) shall include the following information, which shall be provided to the verifier to demonstrate conformance with ISO 14025:

- Input and output environmental data of the unit processes that are used for the LCA calculations;
- The documentation (measurements, calculations, estimates, sources, correspondence, traceable references to origin, etc.) that provides the basis from which the process data for the LCA is formulated;
- The documentation on data quality requirements;
- Documentation demonstrating that the verification and review requirements of ISO 14025 have been followed.

This includes documentation for:

- The material specification to which the tire product conforms;
- Energy consumption figures;
- Emission data to air, water and soil;
- Waste production;
- Data that demonstrates the information is complete. If applicable standards or quality regulations are available, reference should be made to them;
- Referenced literature and databases from which data have been extracted;
- Demonstrating that the tire products can meet the desired function(s) and deliver desired performance;
- Substantiating the chosen life cycle of the tire products;
- In cases where applicable, data used to carry out the sensitivity analyses
- Substantiating the percentages or figures used for the calculations in the waste scenario;
- Substantiating the percentages and figures (e.g., number of cycles) used for the calculations in the allocation procedure;
- Information showing how averages of different reporting locations have been calculated in order to obtain generic data;

- Substantiating any qualitative information in the additional environmental information;
- Procedures used to carry out the data collection (questionnaires, instructions, informative material, confidentiality agreements, etc.);
- The characterization factors, normalization factors and weighting factors used;
- The criteria and substantiation used to determine the system limits and the selection of input and output flows;
- Substantiating the other choices and assumptions; and
- The results, comments and recommendations from a critical review per ISO 14025.

9 Appendix II – Additional Environmental Information

9.1 Vehicle-Specific Use Stage Impacts

9.1.1 Information to be reported for specific vehicles

If tires are designed for a specific vehicle or vehicle categories (primarily in term of technology), life cycle stage impacts may be reported based on category-specific parameters or Original Equipment Manufacturer (OEM) specific data or in this section in addition to the default average reported impacts.

When reporting results on the basis of a category specific vehicle technology type for use stage parameters, the following data shall be reported:

- Vehicle type
- Vehicle load
- Number of tires
- Vehicle efficiencies: use default values provided in Table 48 and Table 56
- Fuel required including electrical grid mix if relevant
- Fuel parameters if required
- Parameters for energy consumption due to acceleration resistance, with option to use default values in Section 5.1.2.

When reporting results on the basis of a category specific OEM vehicle for use stage parameters, the following data shall be reported:

- Vehicle type
- Vehicle load
- Number of tires
- Vehicle efficiencies, or use default values provided in Table 48 and Table 56
- Fuel required including electrical grid mix if relevant
- Fuel parameters if required
- Parameters for energy consumption due to acceleration resistance, with option to use default values in Section 5.1.2
- Payload portion (if commercial) or relevant load on tire in operation – based on maximum load and provide adjustment for the payload utilization described in Section 5.1.4.

9.1.2 Use stage calculations for specific vehicles

9.1.2.1 Vehicle Efficiencies

The default vehicle efficiencies for the different energy sources are provided in Table 48 for the different types of energy sources.

Table 56. Vehicle Efficiencies by Energy Source[48]

Energy source	Fuel type	η_1	η_2	η_3
Flex Fuel (E85)	Flex Fuel (E85)	37%	90%	0%
Gaseous - CNG	Gaseous - CNG	45%	90%	0%
Diesel hybrid	Diesel	Passenger Car and Light Truck: 42% Medium/Heavy trucks: 46% Bus : 46%	90%	50%
Fuel cell	Hydrogen	55%	90%	50%
All-electric	Electricity	90%	90%	50%

Efficiency is the same for all tire sub-categories except if specified in the table.

9.1.2.2 Energy source and combustion direct emissions

The energy consumption and corresponding direct emissions per MJ for each type of energy source shall be modelled using the datasets presented in Table 50 and Table 57 and fuel density and LHV presented in Table 52. Detailed combustion air emissions to be used for the modelling (when relevant) are presented in Appendix IV - Default datasets for fuel combustion emissions.

As indicated in Table 50, for some types of energy source there are no direct emission, or their direct emissions relate with other types of vehicles which already exist in. The modelling principles to be applied for those specific vehicles are presented below.

[48] Passenger Car and Light Truck : JC Guibet, Fuels and Engines, 1999; Mallet, E., "Impact of tire rolling resistance on fuel consumption : current status and perspectives", 2nd International VDI Conference Eurotyre, 2016; Siemens Amesim simulation tool with IFP Drive library

Medium/heavy truck and bus : JC Guibet, Fuels and Engines, 1999; Pachernegg, S.J.; "A Closer Look at the Willans-Line," SAE 690182, 1969; VECTO https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en

Vehicles without combustion direct emissions – additional modelling indications:

All electric vehicles

The impacts related to all-electric vehicles shall be modelled applying the following considerations:

1) Modelling the energy consumption of the vehicle (indirect emissions):

- The amount of electricity consumed (kWh) shall be modeled using the relevant electricity mix as described in section 4.6, i.e. using country-specific or region-specific electricity mix. Residual grid mixes are not required to be used as customer purchasing habits are unknown.

2) Modelling the direct emissions of the vehicle:

- There are no direct emissions related with the operation of the all-electric vehicle, therefore there is no combustion emission dataset to be used and the combustion emissions shall be set to 0.

Only tire and road wear particle emissions have to be considered as described in section 5.2.2.

Hydrogen / Fuel cell vehicles

The operation of hydrogen/fuel cell vehicles results in the production of water and heat only (no other combustion (tailpipe) emissions). The impacts related to hydrogen/fuel cell vehicles shall be modelled applying the following considerations:

1) Modelling the energy consumption of the vehicle (indirect emissions):

- The amount of hydrogen consumed shall be modeled using the fuel density and LHV in Table 52 and modelled using datasets from public databases as described in section 4.1.1, considering the relevant technology used for hydrogen production.

2) Modelling the direct emissions of the vehicle:

- There are no other direct emissions than heat and water related to the operations of the hydrogen / fuel cell vehicle. As water and heat emissions are not characterized in the included LCIA categories (i.e., those emissions have no influence on the impact results), there is no combustion emission dataset to be used and the combustion emissions shall be set to 0, as for the all-electric vehicle.

Only tire and road wear particle emissions have to be considered as described in section 5.2.2.

- Vehicles for which existing combustion emission datasets are used (gasoline or diesel) – additional modelling indications

Plug-in hybrid electric vehicles (PHEV) - gasoline or diesel

It is assumed that those vehicles operate 60% on electric and 40% on thermal power from gasoline or diesel combustion. The impacts related to plug-in hybrid vehicles shall be modelled applying the following considerations:

1) Calculating the split between electric and thermal mode

- The total energy consumption is calculated according to
- Equation 1 in Section 5.1. This total energy consumption is split between 60% electric and 40%

$$Energy\ consumption\ on\ electric\ operating\ mode\ \left[\frac{kWh\ electricity}{tire}\right] = 60\%\ \times Total\ energy\ consumption\ \left[\frac{MJ}{tire}\right] \times \frac{1}{3.6}\left[\frac{kWh}{MJ}\right]$$

$$Energy\ consumption\ on\ thermal\ operating\ mode\ \left[\frac{MJ\ fuel}{tire}\right] = 40\%\ \times Total\ energy\ consumption\ \left[\frac{MJ}{tire}\right]$$

thermal operating mode.

2) Modelling the energy consumption of the vehicle (indirect emissions):

- For the electric operating mode, the amount of electricity consumed (kWh) shall be modeled using the relevant electricity mix as described in section 4.6, i.e. using country-specific or region-specific electricity mix.
- For the thermal operating mode, the amount (kg) of fuel consumed (gasoline or diesel) shall be calculated using the fuel density and LHV in Table 52 and modelled using datasets from public databases as described in section 4.1.1.

3) Modelling the direct emissions of the vehicle:

- For the electric mode, there are no direct emissions related with the electric operation of the plug-in hybrid vehicle, therefore there is no combustion emission dataset to be used and the combustion emissions shall be set to 0, as for the all-electric vehicle.
- For the thermal mode, the direct emissions per kg of fuel consumed shall be modelled using the relevant fuel combustion emissions datasets (gasoline or diesel) as reported in Appendix IV - Default datasets for fuel combustion emissions.

Tire and road wear particle emissions have to be considered as described in section 5.2.2
Hybrid vehicles - gasoline or diesel Hybrid vehicles operate with thermal power from gasoline or diesel combustion and electric power from a battery. The total energy consumption is calculated according to Equation 1 in Section 5.1. For hybrid vehicles, as a part of energy is recovered into the battery with a given efficiency, the contribution of the tire on the energy recovered is calculated based on 3 vehicles efficiency factors, as presented in Table 35. The energy recovered due to hybrid system is especially reflected by the factor η3 "*Energy recovery efficiency*". Therefore, as the total energetic need calculated with Equation 1 includes these global vehicle efficiency factors, it reflects the global energetic consumption (entirely covered by fuel, gasoline or diesel). The impacts related to hybrid vehicles shall be modelled applying the following considerations: 1) Modelling the energy consumption of the vehicle (indirect emissions): • The amount (kg) of fuel consumed (gasoline or diesel) shall be calculated using the fuel density and LHV in Table 52 and modelled using datasets from public databases as described in section 4.1.1. 2) To model the direct emissions of the vehicle: The direct emissions per kg of fuel consumed shall be modelled using the relevant fuel combustion emissions datasets (gasoline or diesel) as reported in table Appendix IV - Default datasets for fuel combustion emissions. Tire and road wear particle emissions have to be considered as described in section 5.2.2.

Table 57. Default datasets to be used for fuel consumption and combustion emissions[55]

Type of fuel	**Flex-fuel (E85)**	**Gaseous - CNG**	**All electric**	**Fuel cell**	**Diesel Hybrid**	**Gasoline Plug-in Hybrid**	**Diesel Plug-in Hybrid**
Source	Based on ecoinvent v3.6	Ecoinvent v3.6	N/A	N/A	Ecoinvent v3.6	Ecoinvent v3.6	Ecoinvent v3.6
Fuel combustion default dataset	Based on Transport , passenger car, large size, petrol, Euro 5	Transport, passenger car, large size, natural gas, EURO 5	N/A	N/A	Transport, passenger car, large size, diesel, EURO 5	Transport, passenger car, large size, petrol, EURO 5	Transport, passenger car, large size, diesel, EURO 5
Geography	RER (Europe)	RER (Europe)	N/A	N/A	RER (Europe)	RER (Europe)	RER (Europe)
Time period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	N/A	N/A	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period

[55] The default datasets were selected based on the technological representativeness, the geographic coverage, the time-related representativeness, and the completeness (substances coverage for each impact category required). The database ecoinvent v3.6 was selected, since the emissions are calculated based on TREMOVE 2007 and COPERT 2006 (models internationally recognized and supported by the European Environment Agency and the JRC), and since they represent the most recent datasets (2012).

9.2 Variation Across Vehicle Technologies and Weights

It is understood in the development of this PCR that use stage impacts are related to the vehicle onto which a tire is mounted. The use stage reporting requires consideration of a representative vehicle. However, many tires may be mounted on different vehicle types. Therefore, this supplemental reporting section is designed to allow disclosure of some of the variability that exists for different vehicle types.

This should be exhibited as a graph on which the x-axis shows a range of relevant loads that includes the load required to be reported in Equation 10 or Equation 11. The y-axis should show either the total energy consumption as per

Equation 1 or Global Warming Potential impacts. Different vehicle technologies and/or energy sources may be represented by separate lines on the graph which are drawn using a minimum of three (3) points (including the upper end and lower end). A different vehicle technology shall be characterized and reported as described in Section 10.1 including any additional relevant information such as the electric grid mix used if relevant. One line on the graph must include the average energy and vehicle technology for the region based on Section 0 of the PCR. The reported value used for the main reporting section of the PCR must be highlighted in some way on the graph, such as with a distinct point.

9.3 Retreading and Regrooving Impacts

Impacts from retreading and regrooving may be reported as supplemental environmental information for commercial and bus tires, only if primary data are available, except for regrooved tire RR_c and RR_c loss, which shall be calculated using Equation 17 and Equation 18. Retreading shall only include the retreading portion from a new casing and not an existing casing. Retreading and regrooving of commercial and bus tires shall be considered and modelled as tire “maintenance processes” which permit extending the total service life of the tire.

Data to be collected for reporting retreading and regrooving impacts are reported in Table 57 below.

The impacts to take into account for retreading and regrooving include modules A1-A4 when relevant (i.e., A1 - Raw materials supply for retreading process, A2 - Transport of those materials to the manufacturing plant, A3 - Manufacturing), module A4 (i.e. Transport of retreaded or regrooved tire to first client), and module B1 calculated as described in "Section 5.2" (i.e. fuel consumption related to rolling resistance, fuel consumption related to acceleration resistance, tire and road wear particles emissions).

The total impacts of retreading and regrooving shall be calculated by multiplying the impacts of one retread and one regroove by the number of retreads and regrooves, and shall be added to the life cycle impacts of the originally new tire. Finally, the total impacts (new tire + retreading + regrooving) shall be reported per functional unit (1000 km), using the extended service life life. Guidance to calculate the extended service life and the updated reference flows when taking into account retreading and regrooving is provided below.

The impacts of retreading and regrooving shall be distributed among the different modules they correspond to (see Table 57), and shall be presented in addition to the impacts of the originally new tire, as presented in the example in Table 59: the information should be presented in three ways:

- The impacts of the new tire only (as required by the PCR);
- The impacts of the retreaded and regrooved portion of the life cycle only;
- The impacts of the total life cycle of the tire including both the new tire and the retreading and regrooving portions.

Table 58. Data to be collected for retreading and regrooving reporting and module where the impacts of retreading and regrooving have to be reported

Data to be collected and reported	Description	Corresponding module
Number of retreads and regrooves	Maximum number of retreads and regrooves as stated on the tire	Entire life cycle
Raw materials (only for retreading)	Mass and type of materials used for one retread	Module A1 – Raw material supply
Raw materials delivery (only for retreading)	Transport of raw materials to manufacturing plant	Module A2 - Transport
Energy, water and ancillary material consumption for retreading and regrooving	Energy consumption, water withdrawal, amount and composition of solid waste	Module A3 - Manufacturing
Retreaded and regrooved tire delivery	Transport of retreaded or regrooved tire to first client	Module A4 - Transport
Retreaded and regrooved tire RR_c	Retreaded tire RR_c (when newly retreaded)	Module B1 – Use stage
Regrooved tire RR_c	Regrooved tire RR_c (when newly regrooved) The default value to be used for regrooved tire RR_c shall be calculated according to Equation	Module B1 – Use stage
Retreaded tire RR_c loss rate	RR_c loss during the reference service life of a retreaded tire. Retreaded tire RR_c loss shall be considered equivalent to new tire RR_c loss rate	Module B1 - Use stage

Data to be collected and reported	Description	Corresponding module
Regrooved tire RR_c loss	RR_c loss during the reference service life of a regrooved tire. The default value to be used for regrooved tire RR_c loss shall be 0.39 [kg/t]	Module B1 - Use stage
Retreaded and regrooved tire wear loss	To be calculated according to Section 5.2.1	Module B1 – Use stage
New tire reference service life	Tire reference service life before retreading or regrooving (as described in the core report)	Entire life cycle, Module B1 – Use stage
Extended service life after one retreading and after one regrooving	Additional mileage of the tire after one retreading or after one regrooving	Entire life cycle, Module B1 – Use stage

Equation 17 presents the calculation for determining the RR_c of a newly regrooved tire[56].

$$RRC_{regrooved\ new}\left[\frac{kg}{T}\right] = RRC_{worn}\left[\frac{kg}{T}\right] + \Delta RRC_{regrooved}\left[\frac{kg}{T}\right]$$

Equation 17. Newly Regrooved Tire RR_c Calculation

The default parameter to be used in the equation is the following

$$\Delta RRC_{regrooved}\left[\frac{kg}{T}\right] = 0.165\left[\frac{kg}{T}\right]$$

Equation 18 presents the calculation for determining the RR_c loss of a regrooved tire during its reference service life.

[56] Equation for RRc and RRc loss for regrooved tires comes from tests done by Manufacture Française des Pneumatiques Michelin.

$$RRC_{regrooved\,worn}\left[\frac{kg}{T}\right] = RRC_{regrooved\,new}\left[\frac{kg}{T}\right] - RRC_{loss\ regrooved}\left[\frac{kg}{T}\right]$$

Equation 18. Regrooved Tire RR_c loss Calculation

The default parameter to be used in the equation is the following:

$$RRC_{loss\ regrooved}\left[\frac{kg}{T}\right] = 0.39\left[\frac{kg}{T}\right]$$

Guidance - Reference flows when including regrooving and retreading

When reporting regrooving and retreading processes as additional environmental information, the fraction of tires per functional unit (No per FU) is calculated based on equation (1):

$$(1)\ No\ per\ FU\left[\frac{unit}{FU}\right] = \frac{Dist\_FU\ [km/FU]}{Tire\_RSL\ [km]}$$

The following parameters are used:

1. The total service life (Tire_RSL) is calculated according to equation (2):

   $$Tire_{RSL}[km] = New_{Tire_{RSL[km]}} + RG_{Tire_{RSL[km]}} * \#RG + RT_{Tire_{RSL[km]}} * \#RT\_PCT$$

   The total reference service life of a tire, as expressed in equation (2), is calculated as the sum of (i) the tire service life when new (New_Tire_RSL), (ii) its additional service life once regrooved (RG_Tire_RSL) considering the number of regrooves (#RG), and (iii) its additional service life once retreaded (RT_Tire_RSL) considering the number of retreads (#RT).

2. The tire carcass impacts as well as the new tread impacts are allocated over the total tire reference service life, i.e., allocated on a mileage basis.

3. The regrooving and retreading impacts are assigned to the total tire reference service life of the regrooved and retreaded tire, respectively.

Let's assume one illustrative example with the following specificities:

Illustrative examples	#RG and #RT	Tire_RSL
New	N/A	230,000 km
Regrooved	2	57,500 km
Retreaded (drive position)	2	220,000 km

Note: For commercial tires, only new and regrooved tire can be used in the steer position. However, steer retreaded tire may be used in the drive position, since steer and drive tires are of the same dimensions, and hence can be replaced on the same truck.

Applying the parameters reported in the

Equation 1, the fraction of tire per functional unit is calculated as follows:

Illustrative example - Truck tire retreaded and regrooved

$$No\ per\ FU \left[\frac{unit}{FU}\right] = \frac{1{,}000\ [km/FU]}{785{,}000\ [km]} = 0.0023\ [unit/FU]$$

The following data shall be reported:

- Number of time retreads
- Extended service life after one retreading
- Mass and type of raw materials used for one retread (based on materials categories used for producing a new tire)
- RR_c of a retreaded tire
- Position in which the retreaded tire is used (steer, drive, or trailer position) (only for commercial tires)
- Number of times regrooved
- Extended service life after one regrooving
- RR_c of a regrooved tire
- Position in which the regrooved tire is used (steer, drive, or trailer position) (only for commercial tires)

Table 59. Example of Results Presentation for Regrooving and Retreading Optional Reporting

		Total Life Cycle			Product stage									Mounting Stage			Use Stage			End of life stage					
EUROPE	Unit per FU	Total			A1 - Raw Material Supply			A2 - Transport			A3 - Manufacturing			A4 - Transport			B1 - Use			C2 - Transport			C3b- Disposal		
		"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total	"New" portion	"Reg. & Retr."	Total
Global Warming Potential	kg CO2 eq																								
Acidification Potential	molc H+ eq																								
Eutrophication Potential (freshwater aquatic)	kg P eq																								
Photochemical Ozone Formation Potential	kg NMVOC eq																								
Ozone Depletion Potential	kg CFC-11 eq																								
Abiotic Depletion Potential	kg Sb eq																								
Particulate Matter (PM10)	kg																								
Particulate Matter (PM2.5)	kg																								
Total use of renewable primary energy (primary energy	MJ, net calorific																								
Total use of NON-RENEWABLE primary energy	MJ, net calorific																								
Use of freshwater resources	m3																								
Tire end of life treatment	kg																								
Components for reuse	kg																								
Materials for recycling	kg																								
Materials for energy recovery	kg																								
Exported electrical energy (waste to energy)	MJ, net calorific																								
Exported thermal energy (waste to energy)	MJ, net calorific																								

10 Appendix III – Default datasets for raw materials supply

10.1 Introduction

Default datasets are provided for nine of the raw materials. In some cases, the default dataset can be used as proxies for other raw materials, as presented in Table 60.

Table 60. List of raw material and description of use

Raw material (name of the dataset)	Description of use: can be used as a proxy for other raw materials
Synthetic rubber, S-SBR	Yes, for other types of synthetic rubber
Natural rubber, TSR 20 (from fresh latex from TH)	Yes, for other fresh latex production countries
Carbon black	No
Steel wire	No
Silica	No
Textile – Nylon	No
Textile – Polyester	No[57]
Plasticizers	No
Cobalt salts	No

If no primary data are available for raw materials, the default datasets presented in the present section shall be used. If primary data or better-quality data (i.e. with higher technological, geographical or time representativeness) are available for one or several of those nine raw materials, specific datasets shall be developed. A justification of the replacement of the default dataset shall be provided in the background report. In addition, the data quality rating (DQR) of the specific dataset shall be calculated as per information provided below and reported in the background report, and shall be better than the DQR of the corresponding default dataset (i.e., with a lower score). The datasets for silica and carbon black are

[57] It is required to develop specific datasets for other types of textile, based on the textile – polyester dataset

recommended as default datasets. If the practitioner has access to better data such as more recent versions of ecoinvent, these should be used in place of the specified default datasets.

Those default datasets were developed with the objective of being representative of a global technology for each specific raw material, and for a global geographical coverage (i.e., world coverage), except for the natural rubber which is representative of a specific geographical context for fresh latex cultivation (Thailand and Indonesia). The DQR of default datasets were evaluated to reflect this global technology and geographical representativeness.

Those default datasets are described in the following documents:

- The detailed information (metadata) are presented in the following section 11.2 for each dataset;
- The DQR methodology, criteria and calculation description is presented in the section 11.3 below.
- The impact and resource indicators as per section 4.7 are presented in section 11.4 below as are the entire inventories for each dataset and the DQR results for each dataset.

10.2 Metadata

10.2.1 Synthetic rubber, S-SBR

Raw material	**Synthetic Rubber**
Name of specific product	**Solution Styrene Butadiene (S-SBR)**
Source	IISRP (2014) Solution Styrene Butadiene Rubber. Inventory data and LCIA results.
Year of data	2012
Life cycle steps excluded (due to unavailability of information)	None
Final life cycle steps included	- Raw materials (Styrene, Butadiene). - Solvent and chemical reagent. -Manufacturing (electricity and thermal energy)
Geographical area	Global
Overall dataset quality	DQR = 2.5: Good quality

10.2.2 Natural Rubber, TSR 20 (from fresh water from TH)

Raw material	**Natural Rubber**
Name of specific product	**Natural rubber, Technically Specified Rubber (TSR 20) (from fresh latex from TH/ID)**
Source	Usubharatana P, Phungrassami H 2018: natural rubber cultivation FAOstat[58] : average yield of natural rubber from 2019 to 2021 in TH/ID Jawjit, W. et. Al. 2010: natural rubber transformation into TSR 20
Year of data	Natural rubber cultivation: 2014 - 2016 Land use change reference: 1999 - 2001 Fresh latex yield: average 2019 - 2021 Fresh latex transformation into TSR 20: 2009
Life cycle steps excluded (due to unavailability of information)	None
Final life cycle steps included	- Fresh latex production (agricultural inputs and for hevea trees planting and cultivation, direct emissions on field, excluding LUC and carbon sequestration in biomass and soil). -Transport (from plantation to rubber mill). -Manufacturing into TSR (electricity and heat).
Geographical area	Thailand and Indonesia for fresh latex cultivation Global for transformation into TSR 20
Overall dataset quality	DQR = 3: Good quality

58 FAOstat available at: http://www.fao.org/faostat/en/#data/QC

10.2.3 Carbon black

Raw material	**Carbon black**
Name of specific product	**Carbon black**
Source	Ecoinvent 3.10: Carbon black {GLO}| production |Cut-off, U
Year of data	Background data based on: - literature and expert judgment: 2007, 2010 - data from a large chemical factory located in Germany: collected from 2011 to 2015
Life cycle steps excluded (due to unavailability of information)	- Solid waste treatment
Final life cycle steps included	- Raw materials (production and transport to carbon black manufacturing plant) - Manufacturing (energy and water consumption, wastewater treatment).
Geographical area	Global (but based on input data from EU)
Overall dataset quality	DQR = 3.3: Fair quality

Additional comment for the choice of dataset: The carbon black technology has not significantly changed for several years (expert judgement from industrial associations). As a consequence, it is estimated that data from 2009 to 2015 can represent a good estimation of the current carbon black technology. For information, a detailed inventory was available for carbon black production in Japan based on data collected in 2015. However, due to the previous statement on the evolution of carbon black production technology, it was decided to prioritize geographical representativeness over time representativeness. However, it also has to be noticed that the ecoinvent dataset, even if adapted to be representative of a global production, was developed based on literature data but also based on input data from a factory in Germany, especially for the yield. The yield is quite high, with a consequently low emission factor for the production of carbon black compared to other sources. This might not be entirely representative for the global production (which explains the DQR score for this dataset), and therefore any dataset more representative of the geographical or technological context shall be used.

10.2.4 Steel wire

Raw material	Steel wire
Name of specific product	**Steel wire (diameter of less than 1 mm)**
Source	Worldsteel: Steel wire rod/GLO Ecoinvent 3.10: Wire drawing, steel {GLO}| market for | Cut-off, U
Year of data	Steel wire rod: 2022 Wire drawing: 2002
Life cycle steps excluded (due to unavailability of information)	- Extra drawing from 1-2 mm diameter to < 1 mm diameter - Potential surface coating
Final life cycle steps included	- Steel extraction and production of rod - Transport of raw material to manufacturing site - Steel manufacturing to obtain a wire of 1 mm diameter (Electricity and thermal energy, machinery, chemicals)
Geographical area	Global
Overall dataset quality	DQR = 2.33: Good quality

10.2.5 Silica

Raw material	Silica
Name of specific product	**High grade amorphous silica**
Source	Ecoinvent 3.10: Activated silica {GLO}|production |Cut-off, U
Year of data	2015-2016

Life cycle steps excluded (due to unavailability of information)	None
Final life cycle steps included	- Raw material (sodium silicate, produced out of Silica Sand) - Reactant (sulfuric acid) - Water - Production plant - Thermal energy & electricity
Geographical area	Global
Overall dataset quality	DQR = 2.67: Good quality

10.2.6 Textile - Nylon

Raw material	**Textile - Nylon**
Name of specific product	**Nylon 6-6 fabric**
Source	PlasticsEurope: Polyamide (Nylon) 6.6/EU-27 Ecoinvent 3.10: processing - Synthetic yarn production, from staple fibres/GLO U - Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U
Year of data	Nylon 6-6: 2011-2012 Processing (yarning and weaving): 2013
Life cycle steps excluded (due to unavailability of information)	- Twisting processes - Additional treatment of the cord (oil addition) - Treatment of the fabric (dipping in RFL (Resorcinol – Formaldehyde – Latex) solution)

Final life cycle steps included	- Raw material (Nylon 6-6 granulates) - Yarning process (Electricity and thermal energy, waste generated) - Weaving process (Electricity, chemicals and waste generated)
Geographical area	Global
Overall dataset quality	DQR = 3.67: Fair quality

10.2.7 Textile – Polyester

Raw material	**Textile - Polyester**
Name of specific product	**Polyester fabric**
Source	Ecoinvent 3.10: - Fibre, polyester {GLO}| market for fibre, polyester| Cut-off, U, updated with polyethylene terephthalate {GLO}| production, granulate, bottle grade - Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U
Year of data	Polyester granulates: 2015 Yarning process: 2001, 2013 Weaving process: 2013
Life cycle steps excluded (due to unavailability of information)	- Twisting processes - Additional treatment of the cord (oil addition) - Treatment of the fabric (dipping in RFL (Resorcinol – Formaldehyde – Latex) solution)

Final life cycle steps included	- Raw material (Polyethylene terephthalate granulates) - Electricity and thermal energy required by the fully oriented yarning process - Waste generated by the yarning process
Geographical area	Global
Overall dataset quality	DQR = 3: Good quality

Additional comment for the choice of dataset: It was decided to use the data for PET granulate bottle grade as background dataset for the yarning process instead of the PET granulate amorphous, even if the PET bottle grade represents a higher grade, and therefore an additional step, than the PET amorphous production. In fact after comparison of the two datasets, the PET bottle grade (2015) represents lower impacts than the PET amorphous (2000), and represents therefore better the current situation.

10.2.8 Plasticizers

Raw material	**Plasticizers**
Name of specific product	**Treated distillate aromatic extracted (TDAE)**
Source	Public - literature: American Petroleum Institute Petroleum HPV Testing Group (2002), Robust summary of information on substance group: aromatic extracts
Year of data	2002
Life cycle steps excluded (due to unavailability of information)	None

Final life cycle steps included	- Raw material (Light fuel oil). - Electricity and thermal energy required for the production process.
Geographical area	Global
Overall dataset quality	DQR = 3.33: Fair quality

10.2.9 Cobalt salts

Raw material	**Cobalt salts**
Name of specific product	**Cobalt salts**
Source	The Cobalt Development Institute (CDI): synthesis of cobalt salts Ecoinvent v3.10: cobalt production, via "The Environmental Performance of Refined Cobalt - Life Cycle Inventory and Life Cycle Assessment of Refined Cobalt - Summary Report", CDI & ERM, November 2016.
Year of data	Cobalt metal: 2012 Synthesis of cobalt salts: 2006
Life cycle steps excluded (due to unavailability of information)	- Energy required for the synthesis of cobalt salt - Chemical reactants required for the synthesis of cobalt salt
Final life cycle steps included	- Cobalt metal production - Organic components production
Geographical area	Global
Overall dataset quality	DQR = 3: Good quality

10.3 Data quality rating methodology

The data quality rating (DQR) is calculated based on the last update of the PEF methodology[59]. This data quality rating methodology was used to calculate the DQR score of each default dataset described above and shall be used to calculate the DQR of any specific dataset developed to replace the default datasets. The DQR of specific dataset shall be better (so, with a lower score) than the DQR of default dataset to allow the replacement of default dataset by specific dataset.

Three quality criteria are used (technological representativeness, geographical representativeness, time representativeness) and shall be subject to the scoring procedure described in section 11.3.1.

10.3.1 DQR criteria and scoring

The scoring of each of the DQR criteria is described in the table below and shall be used for calculating the DQR of any specific dataset used to replace default dataset. The scoring for each criteria was adapted from the PEF methodology secondary datasets evaluation.

[59] Zampori, L. and Pant, R., *Suggestions for updating the Product Environmental Footprint (PEF) method*, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 00653-4, doi:10.2760/265244, JRC115959.

Table 61. How to assign the values to DQR criteria when using specific dataset.

Rating	Time representativeness TiR	Technology representativeness TeR	Geographical representativeness GeR
1	The data refers to the most recent annual administration period with respect to the EPD publication date(*)	The technology used for the raw material under study is exactly the same as the one in scope of the dataset	The process modelled for the raw material under study takes place in the country the dataset is valid for
2	The data refers to maximum 2 annual administration periods with respect to the EPD publication date (*)	The technology used for the raw material under study is included in the mix of technologies in scope of the dataset	The process modelled for the raw material under study takes place in the geographical region (e.g. Europe) the dataset is valid for
3	The data refers to maximum 4 annual administration periods with respect to the EPD publication date (*)	The technologies used for the raw material under study are only partly included in the scope of the dataset	The process modelled for the raw material under study takes place in one of the geographical regions the dataset is valid for
4	The data refers to maximum 6 annual administration periods with respect to the EPD publication date (*)	The technologies used for the raw material under study are similar to those included in the scope of the dataset	The process modelled for the raw material under study takes place in a country that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement
5	The data refers to more than 6 annual administration periods with respect to the EPD publication date (*)	The technologies used for the specific raw material are different from those included in the scope of the dataset	The process modelled for the raw material under study takes place in a different country than the one the dataset is valid for

The scoring for technology, geographical and time representativeness is based on the table 24 (DQR of secondary datasets).

(*)*According to the PEF guidelines, the time representativeness is evaluated based on the time validity of the dataset. However, it was decided in the frame of this PCR to evaluate time representativeness based on time of data gathering (based on data sources used to develop the dataset) rather than time of validity* *of the dataset. This allows to increase the accuracy of time representativeness evaluation, but also allows a fair comparison with the DQR of specific datasets potentially developed to replace default datasets.*

10.3.2 DQR formula

The overall data quality is calculated using the three data quality criteria:

$$DQR = \frac{TeR + GeR + TiR}{3}$$

According to the PEF methodology, the overall DQR reflects five quality levels, from poor to excellent, which are presented in Table 61 below.

Table 62. Overall data quality level of datasets according to the achieved data quality rating

Overall data quality rating (DQR)	**Overall data quality level**
DQR ≤ 1.5	“Excellent quality”
1.5 < DQR ≤ 2.0	“Very good quality”
2.0 < DQR ≤ 3.0	“Good quality”
3 < DQR ≤ 4.0	“Fair quality”
DQR >4	“Poor quality”

10.4 LCIA Results and Details of the Foreground Flows

This section aims to display the LCIA results and the details of the foreground flows for the nine raw materials.

Table 63. Raw materials Life Cycle Impact Assessment (LCIA) results

ID	Name	Quantity	Unit	IPCC AR6	EF 3.1 (Adapted)			
				Global Warming Potential, excluding Biogenic Carbon and Land Use Change	Climate Change-Total	Climate Change-Fossil	Climate Change-Biogenic	Climate Change-Land Use and Land Use Change (LULUC)
				kg CO2 eq	kg CO2 eq	kg CO2 eq	kg CO2 eq	kg CO2 eq
1	**Synthetic rubber (S-SBR)**	**1**	**kg**	**4.76E+00**	**4.77E+00**	**4.76E+00**	**8.99E-03**	**1.30E-03**
2	**Natural rubber, TSR 20 (from fresh latex from TH)**	**1**	**kg**	**1.12E+00**	**-1.93E+00**	**1.12E+00**	**-3.30E+00**	**2.50E-01**
2.a	Natural rubber cultivation, fresh latex, fresh weight with DRC 30%, at farm / ID	1.35	kg	2.76E-01	-7.13E-02	2.73E-01	-1.00E+00	6.59E-01
2.b	Natural rubber cultivation, fresh latex, fresh weight with DRC 30%, at farm / TH	1.99	kg	2.42E-01	-1.06E+00	2.39E-01	-9.78E-01	-3.22E-01
2.c	Natural rubber processing, transformation into TSR 20, at plant / TH/ID	1	kg	2.71E-01	2.72E-01	2.71E-01	6.94E-04	2.00E-04
3	**Steel wire**	**1**	**kg**	**2.54E+00**	**2.54E+00**	**2.54E+00**	**-8.08E-03**	**7.52E-03**
3.a	Steel wire rod, GLO, Worldsteel	1	kg					
3.b	Wire drawing, steel {GLO}| processing | Cut-off, U	1	kg					
4	**Textile - Nylon**	**1**	**kg**	**1.01E+01**	**1.01E+01**	**1.01E+01**	**1.10E-02**	**4.15E-03**
4.a	Polyamide (Nylon) 6.6, EU-27, PlasticsEurope	1.03	kg					
4.b	Synthetic yarn production, from staple fibres/GLO U	1.02	kg					
4.c	Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U	1	kg					
5	**Textile – Polyester**	**1**	**kg**	**5.19E+00**	**5.21E+00**	**5.18E+00**	**2.57E-02**	**3.74E-03**
5.a	Fibre, polyester {GLO}| market for fibre, polyester | Cut-off, U	1.02	kg					
5.b	Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U	1	kg					
6	**Plasticizers**	**1**	**kg**	**1.16E+00**	**1.16E+00**	**1.16E+00**	**2.31E-03**	**6.63E-04**
6.4	Heat, district or industrial, natural gas {GLO}| market group for | Cut-off, U	0.03	MJ					
6.b	Electricity, low voltage {GLO}| market group for | Cut-off, U	2.15	MJ					
6.c	Light fuel oil {RoW}| production | Cut-off, U	1	kg					
7	**Cobalt salt**	**1**	**kg**	**9.66E+00**	**9.82E+00**	**9.62E+00**	**1.48E-01**	**5.50E-02**
7.a	Chemical, organic {GLO}| production | Cut-off, U	0.8	kg					
7.b	Cobalt {GLO}| production | Cut-off, U	0.2	kg					

	EF 3.1						
ID	Acidification Potential	Eutrophication Potential, Freshwater	Eutrophication Potential, Marine	Eutrophication Potential, Terrestrial	Photochemical Ozone Formation Potential	Land Use*	Ozone Depletion Potential
	mol H+ eq	kg P eq	kg N eq	mol N eq	kg NMVOC eq	Pt	kg CFC11 eq
1	**1.51E-02**	**7.48E-05**	**2.47E-03**	**2.69E-02**	**1.69E-02**	**2.47E+00**	**1.18E-07**
2	**4.20E-02**	**5.39E-03**	**9.05E-03**	**1.83E-01**	**3.62E-03**	**4.76E+03**	**1.15E-08**
2.a	1.21E-02	1.61E-03	2.55E-03	5.28E-02	5.50E-04	1.87E+03	2.66E-09
2.b	1.20E-02	1.61E-03	2.53E-03	5.28E-02	4.25E-04	1.12E+03	1.86E-09
2.c	1.72E-03	7.04E-06	5.69E-04	6.24E-03	2.03E-03	1.84E-01	4.20E-09
3	**7.39E-03**	**8.57E-05**	**1.31E-03**	**1.32E-02**	**4.65E-03**	**2.72E+00**	**3.33E-09**
3.a							
3.b							
4	**3.29E-02**	**4.01E-04**	**7.92E-03**	**7.58E-02**	**2.42E-02**	**7.66E+00**	**3.07E-08**
4.a							
4.b							
4.c							
5	**2.05E-02**	**2.76E-04**	**3.89E-03**	**3.96E-02**	**2.53E-02**	**4.38E+00**	**1.56E-05**
5.a							
5.b							
6	**5.23E-03**	**2.28E-05**	**7.75E-04**	**8.38E-03**	**7.76E-03**	**5.94E-01**	**5.41E-08**
6.4							
6.b							
6.c							
7	**9.47E-02**	**9.16E-04**	**9.85E-03**	**8.70E-02**	**4.10E-02**	**2.74E+01**	**2.43E-07**
7.a							
7.b							

	EF 3.1							
ID	Resource use, minerals and metals*	Resource use, fossils*	Particulate matter	Water scarcity*	Ionizing Radiation- Human* Health	Ecotoxicity- Freshwater*	Human Toxicity- Cancer*	Human Toxicity- Non-Cancer*
	kg Sb eq	MJ	disease inc.	m3 depriv.	kBq U-235 eq	CTUe	CTUh	CTUh
1	**1.85E-07**	**1.41E+01**	**1.65E-07**	**3.55E-01**	**4.98E-02**	**1.57E+01**	**2.77E-08**	**1.38E-08**
2	**4.19E-07**	**3.00E+00**	**3.24E-07**	**4.55E+01**	**1.45E-02**	**1.71E+01**	**4.03E-09**	**9.59E-08**
2.a	1.24E-07	5.93E-01	8.77E-08	7.78E+00	2.42E-03	5.11E+00	1.20E-09	2.85E-08
2.b	1.21E-07	4.57E-01	8.71E-08	1.76E+01	1.70E-03	4.96E+00	1.19E-09	2.84E-08
2.c	1.10E-08	1.30E+00	3.28E-08	2.42E-02	7.82E-03	3.71E-01	4.10E-11	9.33E-10
3	**2.71E-06**	**2.64E+01**	**2.49E-07**	**1.03E+00**	**3.16E-02**	**8.76E+00**	**1.05E-08**	**7.45E-09**
3.a								
3.b								
4	**2.52E-05**	**1.50E+02**	**2.63E-07**	**5.19E+01**	**1.23E+00**	**4.85E+02**	**1.52E-08**	**1.04E-06**
4.a								
4.b								
4.c								
5	**3.12E-06**	**2.49E+01**	**2.01E-07**	**1.17E+00**	**1.36E-01**	**1.82E+01**	**1.87E-09**	**2.71E-08**
5.a								
5.b								
6	**1.43E-07**	**4.13E+00**	**4.22E-08**	**8.46E-02**	**2.58E-02**	**2.33E+00**	**1.95E-10**	**5.09E-09**
6.4								
6.b								
6.c								
7	**1.94E-03**	**7.56E+01**	**1.06E-06**	**8.81E+01**	**2.50E+00**	**1.45E+02**	**4.56E-08**	**4.49E-07**
7.a								
7.b								

	TRACI 2.1						CED		Water inventory
ID	Acidification	Eutrophication	Smog	Ozone depletion	Fossil fuel depletion	Respiratory effects	**Non renewable, energy**	**Renewable, energy**	**Fresh water use**
	kg SO2 eq	kg N eq	kg O3 eq	kg CFC-11 eq	MJ surplus	kg PM2.5 eq	MJ	MJ	m3
1	**1.29E-02**	**1.04E-03**	**1.56E-01**	**1.29E-07**	**1.35E+01**	**1.94E-03**	**1.05E+02**	**1.38E+00**	**1.12E-02**
2	**2.70E-02**	**4.80E-02**	**6.14E-02**	**1.32E-08**	**1.23E+00**	**2.51E-03**	**1.11E+01**	**2.32E+01**	**4.88E+00**
2.a	7.67E-03	1.44E-02	8.31E-03	2.96E-09	2.66E-01	6.67E-04	2.32E+00	6.89E+00	3.26E-01
2.b	7.60E-03	1.43E-02	7.05E-03	2.04E-09	1.83E-01	6.50E-04	1.63E+00	6.86E+00	2.23E+00
2.c	1.54E-03	1.25E-04	3.62E-02	5.13E-09	5.09E-01	3.13E-04	4.68E+00	2.56E-01	9.66E-04
3	**6.16E-03**	**1.30E-03**	**7.68E-02**	**4.30E-09**	**1.24E+00**	**1.51E-03**	**2.78E+01**	**1.77E+00**	**3.44E-01**
3.a									
3.b									
4	**2.87E-02**	**5.56E-03**	**3.55E-01**	**4.65E-08**	**1.94E+01**	**4.54E-03**	**1.69E+02**	**4.85E+00**	**1.22E+00**
4.a									
4.b									
4.c									
5	**1.78E-02**	**3.73E-03**	**2.30E-01**	**1.40E-05**	**1.11E+01**	**3.72E-03**	**9.89E+01**	**3.73E+00**	**3.41E-02**
5.a									
5.b									
6	**4.33E-03**	**3.65E-04**	**4.86E-02**	**5.92E-08**	**7.59E+00**	**8.36E-04**	**5.63E+01**	**7.60E-01**	**3.26E-03**
6.4									
6.b									
6.c									
7	**7.67E-02**	**1.42E-02**	**5.01E-01**	**2.61E-07**	**2.17E+01**	**9.51E-03**	**2.21E+02**	**2.73E+02**	**2.07E+00**
7.a									
7.b									

Table 64. Raw materials foreground data

Synthetic rubber, S-SBR

Confidential data.

Natural rubber, TSR 20 (from fresh latex from TH/ID)

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Natural rubber, TSR 20 (from fresh latex from TH/ID)		kg	1.00	100%	

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Natural rubber cultivation, fresh latex, at farm / TH		kg	1.19		Production-volume weighted average
Natural rubber cultivation, fresh latex, at farm / ID		kg	0.81		Production-volume weighted average
Natural rubber processing, transformation into TSR 20, at plant / GLO		kg	1.00		

Sub components for Natural rubber

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Natural rubber processing, transformation into TSR 20, at plant / GLO		kg	1.00	100%	

Electricity/heat	Sub-compartment	Unit	Quantity		Comments
Electricity, low voltage {GLO}| market group for | Cut-off, U		kWh	0.20		220 kWh per ton STR 20 (Jawjit 2010)
Diesel, burned in building machine {GLO}| processing | Cut-off, U		MJ	1.00		1000 MJ/ton STR 20 (Jawjit 2010)
LPG		kg	0.03		1252 MJ LPG / ton STR 20 (Jawjit 2010) LHV: 49,3 MJ/kg LPG
Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Cut-off, U - diesel consumption (GLO) for TIP		tkm	0.06		60 km per round trip from farm to processing mill, with diesel vehicle (Jawjit 2010)

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Natural rubber cultivation, fresh latex, fresh weight with DRC 30%, at farm / TH		**kg**	**5,000.00**	**91%**	**>> mass is 36%, economic allocation is 91% to fresh latex (including cup lump)**
Natural rubber cultivation, para-rubber wood, at farm / TH		kg	8,889.00	9%	>> mass is 64%, economic allocation is 9% to para-rubber wood

Resources	Sub-compartment	Unit	Quantity		Comments
Carbon dioxide, in air	in air	kg	5.54E+03		(2,2,1,1,1,na)
Energy, gross calorific value, in biomass		MJ	4.40E+04		(2,2,1,1,1,na)
Occupation, permanent crop, TH	land	m2a	1.00E+04		(2,1,1,1,1,na)
Transformation, from annual crop, TH	land	m2	1.11E+03		(2,1,1,1,1,na)
Transformation, from permanent crop, TH	land	m2	5.51E+02		(2,1,1,1,1,na)
Transformation, to permanent crop, TH	land	m2	5.57E+03		(2,1,1,1,1,na)
Surface water		m3	1.22E+04		(2,1,1,1,1,na)
Rain water		m3	2.82E+04		(2,1,1,1,1,na)

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Fruit tree seedling, for planting {GLO}| market for fruit tree seedling, for planting | Cut-off, U		p	1.80E+01		(2,1,1,1,1,na)
Planting tree {GLO}| market for planting tree | Cut-off, U		p	0.00E+00		(2,1,1,1,1,na) - (18) Assumed to be covered from diesel input
Establishing orchard {GLO}| market for establishing orchard | Cut-off, U		p	0.00E+00		(2,1,1,1,1,na) - (18) Assumed to be covered from diesel input
Orchard, rooting up trees (WFLDB)/GLO U		ha	4.00E-02		(2,1,1,1,1,na)
Urea {RoW}| market for urea | Cut-off, U		kg	2.34E+02		(2,1,1,1,1,na)
Inorganic phosphorus fertiliser, as P2O5 {RoW}| nutrient supply from phosphate rock, beneficiated | Cut-off, U		kg	1.34E+02		(2,1,1,1,1,na)
Inorganic potassium fertiliser, as K2O {RoW}| nutrient supply from potassium chloride | Cut-off, U		kg	1.06E+02		(2,1,1,1,1,na)
Manure, solid, cattle {GLO}| market for | Cut-off, U		kg	7.48E+01		(2,1,1,1,1,na)
Manure, liquid, swine {GLO}| market for | Cut-off, U		kg	9.74E+00		(2,1,1,1,1,na)
Poultry manure, dried {GLO}| market for | Cut-off, U		kg	[illegible]		[illegible]
Diesel, burned in agricultural machinery {WFLDB}/GLO U		MJ	[illegible]		[illegible]
[redacted]		kg	[illegible]		[illegible]
[redacted]		kg	[illegible]		[redacted]
[redacted]		kg	[illegible]		[redacted]
[redacted]		g	[illegible]		[illegible]
[redacted]		g	[illegible]		[illegible]

Wastes	Sub-compartment	Unit	Quantity		Comments
Agricultural residue to treatment		kg	122		Usubharatana P, Phungras

Emissions to air	Sub-compartment	Unit	Quantity		Comments
Ammonia	low, pop,	kg	2.09E+01		(2,2,1,1,1,na) - Calculated
Dinitrogen monoxide	low, pop,	kg	2.51E+00		(2,2,1,1,1,na) - Calculated
Methane, biogenic	low, pop,	kg	2.42E-01		(2,2,1,1,1,na) - Calculated
Carbon dioxide, fossil	low, pop,	kg	7.88E+01		(2,2,1,1,1,na) - Calculated
Carbon dioxide, LUC	low, pop,	kg	-1.77E+03		(2,2,1,1,1,na) - Calculated
Glyphosphate	low, pop,	g	1.63E+02		(2,2,1,1,1,na) - From EF20
Glyphosphate	low, pop,	g	7.94E+01		(2,2,1,1,1,na) - From EF20

Emissions to water	Sub-compartment	Unit	Quantity		Comments
Nitrate	groundwater	kg	1.89E+02		(2,2,1,1,1,na) - Calculated
Phosphorus	river	kg	1.71E+00		(2,2,1,1,1,na) - Calculated
Phosphate	river	kg	1.03E+00		(2,2,1,1,1,na) - Calculated
Phosphate	groundwater	kg	1.84E-01		(2,2,1,1,1,na) - Calculated
Cadmium	river	kg	2.32E-04		(2,2,1,1,1,na) - Calculated
Cadmium	groundwater	kg	4.54E-05		(2,2,1,1,1,na) - Calculated
Chromium	river	kg	2.16E-02		(2,2,1,1,1,na) - Calculated
Chromium	groundwater	kg	2.04E-02		(2,2,1,1,1,na) - Calculated
Copper	river	kg	2.92E-02		(2,2,1,1,1,na) - Calculated
Copper	groundwater	kg	3.23E-03		(2,2,1,1,1,na) - Calculated
Lead	river	kg	6.31E-03		(2,2,1,1,1,na) - Calculated
Lead	groundwater	kg	1.83E-04		(2,2,1,1,1,na) - Calculated
Mercury	river	kg	4.61E-05		(2,2,1,1,1,na) - Calculated
Mercury	groundwater	kg	9.38E-07		(2,2,1,1,1,na) - Calculated
Nickel	river	kg	1.55E-02		(2,2,1,1,1,na) - Calculated
Zinc	river	kg	3.45E-02		(2,2,1,1,1,na) - Calculated
Zinc	groundwater	kg	1.96E-02		(2,2,1,1,1,na) - Calculated
Glyphosphate	river	g	1.81E+01		(2,2,1,1,1,na) - From EF20
Glyphosphate	river	g	8.82E+00		(2,2,1,1,1,na) - From EF20

Emissions to soil	Sub-compartment	Unit	Quantity		Comments
Cadmium	agricultural	kg	6.03E-03		(2,2,1,1,1,na) - Calculated
Chromium	agricultural	kg	4.39E-02		(2,2,1,1,1,na) - Calculated
Copper	agricultural	kg	-1.36E-02		(2,2,1,1,1,na) - Calculated
Lead	agricultural	kg	-3.99E-03		(2,2,1,1,1,na) - Calculated
Mercury	agricultural	kg	4.63E-05		(2,2,1,1,1,na) - Calculated
Nickel	agricultural	kg	-3.12E-03		(2,2,1,1,1,na) - Calculated
Zinc	agricultural	kg	2.40E-02		(2,2,1,1,1,na) - Calculated
Glyphosate	agricultural	g	1.63E+03		(2,2,1,1,1,na) - From EF20
Glyphosate	agricultural	g	7.94E+02		(2,2,1,1,1,na) - From EF20

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Agricultural residue to treatment			**1.00**		**Assumed to be entirely in**

[redacted]
sami H (2018)
value - EMEP/EEA (2016)
value - IPCC (2006)
value - EF2019
value - EF2019
value - PAS-2050
19, 9% emitted to air, 1% to water, remainder to soil
19, 9% emitted to air, 1% to water, remainder to soil
value - SQCB-NO3
value - Prasuhn (2006)
value - Prasuhn (2006)
value - Prasuhn (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
19, 9% emitted to air, 1% to water, remainder to soil
19, 9% emitted to air, 1% to water, remainder to soil
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
value - Freiermuth (2006)
19, 9% emitted to air, 1% to water, remainder to soil
19, 9% emitted to air, 1% to water, remainder to soil
cinerated

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Natural rubber cultivation, fresh latex, fresh weight with DRC 30%, at farm / ID		**kg**	3,024.95	**91%**	**>> mass is 36%, economic allocation is 91% to fresh latex (including cup lump)**
Natural rubber cultivation, para-rubber wood, at farm / ID		kg	5,377.76	9%	>> mass is 64%, economic allocation is 9% to para-rubber wood

Resources	Sub-compartment	Unit	Quantity		Comments
Carbon dioxide, in air	in air	kg	3434.08		(2,2,1,1,1,na)
Energy, gross calorific value, in biomass		MJ	26636		(2,2,1,1,1,na)
Occupation, permanent crop, ID	land	m2a	1.00E+04		(2,1,1,1,1,na)
Transformation, from annual crop, ID	land	m2	6.39E+02		(2,1,1,1,1,na)
Transformation, from forest, intensive, ID	land	m2	2.74E+03		(2,1,1,1,1,na)
Transformation, from grassland/pasture/meadow, ID	land	m2	4.29E+01		(2,1,1,1,1,na)
Transformation, from permanent crop, ID	land	m2	9.23E+00		(2,1,1,1,1,na)
Transformation, to permanent crop, ID	land	m2	3.43E+03		(2,1,1,1,1,na)
Surface water		m3	1.07E+03		(2,1,1,1,1,na)
Rain water		m3	5.59E+04		(2,1,1,1,1,na)

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Fruit tree seedling, for planting {GLO}| market for fruit tree seedling, for planting | Cut-off, U		p	1.09E+01		(2,1,1,1,1,na)
Planting tree {GLO}| market for planting tree | Cut-off, U		p	0.00E+00		(2,1,1,1,1,na) - (18) Assumed to be covered from diesel input
Establishing orchard {GLO}| market for establishing orchard | Cut-off, U		p	0.00E+00		(2,1,1,1,1,na) - (18) Assumed to be covered from diesel input
Orchard, rooting up trees (WFLDB)/GLO U		ha	2.42E-02		(2,1,1,1,1,na)
Urea {RoW}| market for urea | Cut-off, U		kg	1.41E+02		(2,1,1,1,1,na)
Inorganic phosphorus fertiliser, as P2O5 {RoW}| nutrient supply from phosphate rock, beneficiated | Cut-off, U		kg	8.10E+01		(2,1,1,1,1,na)
Inorganic potassium fertiliser, as K2O {RoW}| nutrient supply from potassium chloride | Cut-off, U		kg	6.42E+01		(2,1,1,1,1,na)
Manure, solid, cattle {GLO}| market for | Cut-off, U		kg	4.52E+01		(2,1,1,1,1,na)
Manure, liquid, swine {GLO}| market for | Cut-off, U		kg	5.89E+00		(2,1,1,1,1,na)
Poultry manure, dried {GLO}| market for | Cut-off, U		kg	4.82E+00		(2,1,1,1,1,na)
Diesel, burned in agricultural machinery (WFLDB)/GLO U		MJ	1.47E+01		(2,1,1,1,1,na)
Crop, default, heavy metals uptake (WFLDB)/GLO U		kg	0.00E+00		(2,2,1,1,1,na)
Packaging, for fertilisers or pesticides {GLO}| packaging production for solid fertiliser or pesticide, per kilogram of packed product | Cut-off, U		kg	4.21E+02		(2,2,1,1,1,na)
Packaging, for fertilisers or pesticides {GLO}| packaging production for liquid fertiliser or pesticide, per kilogram of packed product | Cut-off, U		kg	9.07E-01		(2,2,1,1,1,na)
Glyphosate {GLO}| market for | Cut-off, U		g	1.09E+03		(2,2,1,1,1,na)
Pyridine-compound {GLO}| market for | Cut-off, U		g	5.34E+02		(2,2,1,1,1,na)

Wastes	Sub-compartment	Unit	Quantity		Comments
Agricultural residue to treatment		kg	73.8		Usubharatana P, Phungrassami H (2018)

Emissions to air	Sub-compartment	Unit	Quantity		Comments
Ammonia	low, pop,	kg	1.26E+01		(2,2,1,1,1,na) - Calculated value - EMEP/EEA (2016)
Dinitrogen monoxide	low, pop,	kg	1.52E+00		(2,2,1,1,1,na) - Calculated value - IPCC (2006)
Methane, biogenic	low, pop,	kg	1.47E-01		(2,2,1,1,1,na) - Calculated value - EF2019
Carbon dioxide, fossil	low, pop,	kg	4.77E+01		(2,2,1,1,1,na) - Calculated value - EF2019
Carbon dioxide, LUC	low, pop,	kg	2.19E+03		(2,2,1,1,1,na) - Calculated value - PAS-2050
Glyphosphate	low, pop,	g	9.84E+01		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil
Glyphosphate	low, pop,	g	4.80E+01		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil

Emissions to water	Sub-compartment	Unit	Quantity		Comments
Nitrate	groundwater	kg	3.03E+01		(2,2,1,1,1,na) - Calculated value - SQCB-NO3
Phosphorus	river	kg	3.54E+00		(2,2,1,1,1,na) - Calculated value - Prasuhn (2006)
Phosphate	river	kg	4.60E+00		(2,2,1,1,1,na) - Calculated value - Prasuhn (2006)
Phosphate	groundwater	kg	8.24E-01		(2,2,1,1,1,na) - Calculated value - Prasuhn (2006)
Cadmium	river	kg	1.40E-04		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Cadmium	groundwater	kg	2.75E-05		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Chromium	river	kg	1.30E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Chromium	groundwater	kg	1.23E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Copper	river	kg	1.77E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Copper	groundwater	kg	1.96E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Lead	river	kg	3.82E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Lead	groundwater	kg	1.11E-04		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Mercury	river	kg	2.79E-05		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Mercury	groundwater	kg	5.67E-07		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Nickel	river	kg	9.35E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Zinc	river	kg	2.09E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Zinc	groundwater	kg	1.18E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Glyphosphate	river	g	1.09E+01		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil
Glyphosphate	river	g	5.34E+00		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil

Emissions to soil	Sub-compartment	Unit	Quantity		Comments
Cadmium	agricultural	kg	3.65E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Chromium	agricultural	kg	2.66E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Copper	agricultural	kg	-8.21E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Lead	agricultural	kg	-2.41E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Mercury	agricultural	kg	2.80E-05		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Nickel	agricultural	kg	-1.89E-03		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Zinc	agricultural	kg	1.45E-02		(2,2,1,1,1,na) - Calculated value - Freiermuth (2006)
Glyphosate	agricultural	g	9.84E+02		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil
Glyphosate	agricultural	g	4.80E+02		(2,2,1,1,1,na) - From EF2019, 9% emitted to air, 1% to water, remainder to soil

Steel wire

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Steel wire		**kg**	**1.00**	**100%**	

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Steel wire rod, GLO, Worldsteel		kg	1.00		
Wire drawing, steel {GLO}| processing | Cut-off, U		kg	1.00		

Silica

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Activated silica {GLO}| production | Cut-off, U		**kg**	**1.00**	**100%**	**The activated silica produced is a negatively charged colloidal particle which is grown to a desired point, The solution is diluted to prevent further growth, Activated silica is mainly used as a coagulant aid in water treatment,▯Production Volume Amount: 400000000▯**

Resources	Sub-compartment	Unit	Quantity		Comments
Water, cooling, unspecified natural origin, GLO	in water	m3	1.11E-02		(2,3,1,4,3,na)▯Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of water for cooling extracted per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The reported amounts of water extracted as groundwater and surface water (river) are assumed to be used entirely for cooling purposes,▯
Water, river, GLO	in water	m3	5.81E-04		(2,3,1,4,3,na)▯Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of groundwater and surface water (river) extracted per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of groundwater and surface water (river) extracted in the year 2015 was 19950000 tonnes and 21488100 tonnes respectively (Gendorf, 2016, Umwelterklärung, www,gendorf,de),▯
Water, well, GLO	in water	m3	5.61E-04		(2,3,1,4,3,na)▯Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of groundwater and surface water (river) extracted per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of groundwater and surface water (river) extracted in the year 2015 was 19950000 tonnes and 21488100 tonnes respectively (Gendorf, 2016, Umwelterklärung, www,gendorf,de),▯

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Chemical factory, organics {GLO}| market for | Cut-off, U		p	2.70E-10		(2,3,1,4,3,na)▯Calculated based on literature data published by the industry, For this activity, no information was readily available concerning infrastructure and land-use, Therefore, the infrastructure is estimated based on data from two chemical factories, the BASF site of Ludwigshafen and the chemical factory in Gendorf (which are both located in Germany), which produce a wide range of chemical substances, Based on this data, the following assumptions are made: the built area amounts to about 4,2 ha, the plant has an average output of 50'000 t/a and a lifespan of fifty years, The estimated infrastructure amount is therefore 4,00 E-10 units per kg of produced chemical,▯▯References:▯Althaus H,-J,, Chudacoff M,, Hischier R,, Jungbluth N,, Osses M, and Primas A, (2007) Life Cycle Inventories of Chemicals, ecoinvent report No, 8, v2,0, EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH,▯Gendorf (2000) Umwelterklärung 2000, Werk Gendorf, Werk Gendorf, Burgkirchen,▯
Sodium silicate, solid {RER}| market for sodium silicate, solid | Cut-off, U		kg	4.54E-01		(3,5,5,5,5,na)▯Stoichiometric calculation,▯
Sodium silicate, solid {RoW}| market for sodium silicate, solid | Cut-off, U		kg	9.19E-01		(3,5,5,5,5,na)▯Stoichiometric calculation,▯
Sulfuric acid {RER}| market for sulfuric acid | Cut-off, U		kg	1.64E-01		(3,5,5,5,5,na)▯Stoichiometric calculation,▯
Sulfuric acid {RoW}| market for sulfuric acid | Cut-off, U		kg	9.39E-01		(3,5,5,5,5,na)▯Stoichiometric calculation,▯
Tap water {GLO}| market group for | Cut-off, U		kg	1.76E-02		(2,3,1,4,3,na)▯Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of tap water per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of tap water consumed in the year 2015 was 55100 tonnes (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The resulting amount of tap water is 0,023 kg/kg of chemical product produced, The 5-year average (2011 - 2015, weighted by production volume) is 0,026 kg/kg,▯

Electricity/heat	Sub-compartment	Unit	Quantity		Comments
Electricity, medium voltage {GLO}| market group for | Cut-off, U		kWh	2.81E-01		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of electricity per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of electricity consumed in the year 2015 was 3498800 GJ (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The resulting amount of electricity is 0,406 kWh/kg (year 2015) of chemical substance produced, The 5-year average (2011 - 2015, weighted by production volume) is 0,416 kWh/kg (1,5 MJ/kg), Cross-reference: the amount of chemicals produced (excluding intermediate products) in the EU-28 in the year 2011 was 327 million tonnes (Eurostat, http://ec,europa,eu/eurostat/statistics-explained/index,php/Chemicals_production_statistics, accessed 20170126), The chemical and petrochemical industry sector consumed 2,33 EJ of energy in 2011 (European Commission - Joint Research Centre, 2014, BAT on Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector), The resulting energy (both heat and electricity) consumed per kg of chemicals produced in 2011 is thus 7,13 MJ/kg, This is higher than the value calculated using data published by Gendorf – 3,85 MJ/kg, but that is to be expected as the intermediate products are not accounted for,⍰
Heat, district or industrial, natural gas {GLO}| market group for | Cut-off, U		MJ	1.45E+00		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of heat used per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of heat in the year 2015 was 523500 GJ (Gendorf, 2016, Umwelterklärung, www,gendorf,de) of which 90% was obtained from natural gas and 10% from steam, The resulting amount of heat from natural gas is 2,02 MJ/kg of chemical product produced, The 5-year average (2011 - 2015, weighted by production volume) is 2,15 MJ/kg, Cross-reference: the amount of chemicals produced (excluding intermediate products) in the EU-28 in the year 2011 was 327 million tonnes (Eurostat, http://ec,europa,eu/eurostat/statistics-explained/index,php/Chemicals_production_statistics, accessed 20170126), The chemical and petrochemical industry sector consumed 2,33 EJ of energy in 2011 (European Commission - Joint Research Centre, 2014, BAT on Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector), The resulting energy (both heat and electricity) consumed per kg of chemicals produced in 2011 is thus 7,13 MJ/kg, This is higher than the value calculated using data published by Gendorf – 3,85 MJ/kg, but that is to be expected as the intermediate products are not accounted for,⍰
Heat, from steam, in chemical industry {RER}| market for heat, from steam, in chemical industry | Cut-off, U		MJ	2.02E-02		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of heat used per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of heat in the year 2015 was 523500 GJ (Gendorf, 2016, Umwelterklärung, www,gendorf,de) of which 90% was obtained from natural gas and 10% from steam, The resulting amount of heat from steam is 0,22 MJ/kg of chemical product produced, The 5-year average (2011 - 2015, weighted by production volume) is 0,20 MJ/kg, Cross-reference: the amount of chemicals produced (excluding intermediate products) in the EU-28 in the year 2011 was 327 million tonnes (Eurostat, http://ec,europa,eu/eurostat/statistics-explained/index,php/Chemicals_production_statistics, accessed 20170126), The chemical and petrochemical industry sector consumed 2,33 EJ of energy in 2011 (European Commission - Joint Research Centre, 2014, BAT on Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector), The resulting energy (both heat and electricity) consumed per kg of chemicals produced in 2011 is thus 7,13 MJ/kg, This is higher than the value calculated using data published by Gendorf – 3,85 MJ/kg, but that is to be expected as the intermediate products are not accounted for,⍰
Heat, from steam, in chemical industry {RoW}| market for heat, from steam, in chemical industry | Cut-off, U		MJ	1.15E-01		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of heat used per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of heat in the year 2015 was 523500 GJ (Gendorf, 2016, Umwelterklärung, www,gendorf,de) of which 90% was obtained from natural gas and 10% from steam, The resulting amount of heat from steam is 0,22 MJ/kg of chemical product produced, The 5-year average (2011 - 2015, weighted by production volume) is 0,20 MJ/kg, Cross-reference: the amount of chemicals produced (excluding intermediate products) in the EU-28 in the year 2011 was 327 million tonnes (Eurostat, http://ec,europa,eu/eurostat/statistics-explained/index,php/Chemicals_production_statistics, accessed 20170126), The chemical and petrochemical industry sector consumed 2,33 EJ of energy in 2011 (European Commission - Joint Research Centre, 2014, BAT on Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector), The resulting energy (both heat and electricity) consumed per kg of chemicals produced in 2011 is thus 7,13 MJ/kg, This is higher than the value calculated using data published by Gendorf – 3,85 MJ/kg, but that is to be expected as the intermediate products are not accounted for,⍰

Emissions to water	Sub-compartment	Unit	Quantity		Comments
Water, GLO		m3	1.15E-02		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The amount of water released back to the environment consists of the amount of process water treated in the internal WWTP and then released back to the environment and the amount of cooling water released back to the environment, In addition, water is also released by the chemical reaction (0,0003 m3 per kg of activated silica produced) and is assumed to be released into water in the environment,⍰

Waste to treatment	Sub-compartment	Unit	Quantity		Comments
Wastewater, average {CH}| market for wastewater, average | Cut-off, U		m3	6.17E-08		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of wastewater (which is later on treated in the municipal WWTP) per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of wastewater which is later on treated in the municipal WWTP in the year 2015 was 1200 tonnes (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The resulting amount of wastewater is 2,7E-06 m3/kg of chemical product produced,⍰Production Volume Amount: 1080⍰
Wastewater, average {Europe without Switzerland}| market for wastewater, average | Cut-off, U		m3	5.70E-07		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of wastewater (which is later on treated in the municipal WWTP) per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of wastewater which is later on treated in the municipal WWTP in the year 2015 was 1200 tonnes (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The resulting amount of wastewater is 2,7E-06 m3/kg of chemical product produced,⍰Production Volume Amount: 1080⍰
Wastewater, average {RoW}| market for wastewater, average | Cut-off, U		m3	1.19E-06		(2,3,1,4,3,na)⍰Calculated based on literature data published by the industry, This value is a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www,gendorf,de), (Gendorf, 2015, Umwelterklärung, www,gendorf,de), (Gendorf, 2014, Umwelterklärung, www,gendorf,de), The amount of wastewater (which is later on treated in the municipal WWTP) per kg of chemical substance produced is calculated using literature data published by the Gendorf factory based in Germany, which produces a wide range of chemical substances, The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www,gendorf,de) and 740000 tonnes of intermediate products, The amount of wastewater which is later on treated in the municipal WWTP in the year 2015 was 1200 tonnes (Gendorf, 2016, Umwelterklärung, www,gendorf,de), The resulting amount of wastewater is 2,7E-06 m3/kg of chemical product produced,⍰Production Volume Amount: 1080⍰

Textile - Nylon

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Textile - Nylon		**kg**	**1.00**	**100%**	

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Polyamide (Nylon) 6,6, EU-27, PlasticsEurope		kg	1.03		
Synthetic yarn production, from staple fibres/GLO U		kg	1.02		
Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U		kg	1.00		

Textile – Polyester

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Textile, polyester {GLO}		**kg**	**1.00**	**100%**	

Materials/fuels	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Fibre, polyester {GLO}| market for fibre, polyester | Cut-off, U		kg	1.02		
Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U		kg	1.00		

Plasticizers

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Plasticizers		**kg**	**1.00**	**100%**	

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Heat, district or industrial, natural gas {GLO}| market group for | Cut-off, U		MJ	0.03		
Electricity, low voltage {GLO}| market group for | Cut-off, U		MJ	2.15		
Light fuel oil {RoW}| production | Cut-off, U		kg	1.00		

Cobalt salt

Products	Sub-compartment	Unit	Quantity	Economic allocation	Comments
Cobalt salt		**kg**	**1.00**		

Materials/fuels	Sub-compartment	Unit	Quantity		Comments
Chemical, organic {GLO}| production | Cut-off, U		kg	0.80		
Cobalt {GLO}| production | Cut-off, U		kg	0.20		

Table 65: Data Quality Rating (DQR)

ID	Materials	Ti_R Time representativeness	Te_R Technology representativeness	Ge_R Geographic representativeness	Overall data quality rating (DQR)	Overall data quality level
1	Synthetic rubber (S-SBR)	5.0	1.5	1.0	2.50	Good quality
2	Natural rubber, TSR 20 (from fresh latex from TH)	5.0	2.0	2.0	3.00	Good quality
3	Carbon black	5.0	2.0	3.0	3.33	Fair quality
4	Steel wire	3.0	3.0	1.0	2.33	Good quality
5	Activated silica	5.0	2.0	1.0	2.67	Good quality
6	Textile - Nylon	5.0	3.0	3.0	3.67	Fair quality
7	Textile – Polyester	5.0	3.0	1.0	3.00	Good quality
8	Plasticizers	5.0	2.0	3.0	3.33	Fair quality
9	Cobalt salt	5.0	3.0	1.0	3.00	Good quality

Some additional notes for the LCA user:

Natural rubber transformation

The ecoinvent *process Liquefied petroleum gas {GLO}| market group for liquefied petroleum gas | Cut-off, U* is used to account for the production of LPG (per kg of fuel). Additionally, to account for the direct emissions of LPG combustion at the processing plant, we add the direct emissions to air per kg LPG consumed, as shown in the inventory of the ecoinvent dataset *Transport, passenger car, medium size, liquefied petroleum gas, EURO 5 {GLO}| transport, passenger car, medium size, liquefied petroleum gas (LPG), EURO 5 | Cut-off, U* (1 km uses approx. 0.06 kg LPG). Hence, the LPG inventory is a combination of the two parts - LPG manufacturing & direct emissions of LPG combustion.

Steel wire

The dataset used for drawing is from ecoinvent 3.10 and the RoW data are used and renamed as GLO. When accessed via SimaPro, the Worldsteel dataset for Steel wire rod may lead to different results, specifically negative water scarcity. The provided values shall be used instead.

Textile – Nylon

When accessed via SimaPro, the PlasticsEurope dataset for Polyamide 6,6 may lead to different results, specifically negative water scarcity. The provided values shall be used instead.

Disclaimer - use of databases

A user would need to have access to ecoinvent 3.10, Industry data 2.0, and WFLDB databases in order to be able to replicate the inventories listed in the 9 raw material datasets.

11 Appendix IV - Default datasets for fuel combustion emissions

The datasets to be used for air emissions related to fuel combustion of the vehicles presented in Table 45, Table 46, and

Table 47 are described in Table 66 , which presents air emissions per kg of fuel consumed, and per m3 of fuel consumed for natural gas. The entire inventory and the detailed information on each dataset are respectively available at https://ecoquery.ecoinvent.org and at https://www.lcacommons.gov/. Note that datasets have been adapted to remove potential doublecounting of TRWP and break emissions.

Table 66. Fuel Consumption and Air per kg of Fuel Consumed, Passenger car

	Transport, passenger car, large size, petrol, EURO 5	**Transport, passenger car, large size, diesel, EURO 5**	**Transport, passenger car, large size, flex fuel (E25), EURO 5**	**Transport, passenger car large size, flex fuel (E85), EURO 5**	**Transport, passenger car, large size, natural gas, EURO 5**	**Transport, passenger car, medium size, liquefied petroleum gas (LPG), EURO 5**
Source	Ecoinvent v3.6,	Ecoinvent v3.6,	Based on ecoinvent v3.6, dataset: Transport, passenger car, large size, petrol, EURO 5	Based on ecoinvent v3.6, dataset: Transport, passenger car, large size, petrol, EURO 5	Ecoinvent v3.6	Ecoinvent v3.6
Geography	RER (Europe)	RER (Europe)	RER (Europe)	RER (Europe)	RER (Europe)	RER (Europe)
Time period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2012-12-31 Valid for the entire period	2012-01-01 to 2019-12-31	2012-01-01 to 2019-12-31
Fuel Consumption	**kg/kg petrol**	**kg/kg diesel**	**kg/kg E25**	**kg/kg E85**	**m3/m3 CNG**	**kg/kg LPG**
Petrol, low-sulfur	1.00E+00		7.39E-01	1.43E-01		
Diesel, low-sulfur		1.00E+00				
Ethanol			2.61E-01	8.57E-01		
CNG					1.00E+00	
LPG						1.00E+00
Air emissions	**kg/kg of fuel**	**kg/kg of fuel**	**kg/kg of fuel**	**kg/kg of fuel**	**kg/m^3 of natural gas**	**kg/kg of fuel**
1-Pentene	6.19E-06	0.00E+00	6.19E-06	6.19E-06		4.25E-07
2-Methyl pentane	1.01E-04	0.00E+00	1.01E-04	1.01E-04		1.28E-04
Acetaldehyde	2.73E-06	3.07E-05	2.73E-06	2.73E-06		2.90E-06
Acetone	2.22E-06	1.40E-05	2.22E-06	2.22E-06		2.36E-06

	Transport, passenger car, large size, petrol, EURO 5	Transport, passenger car, large size, diesel, EURO 5	Transport, passenger car, large size, flex fuel (E25), EURO 5	Transport, passenger car large size, flex fuel (E85), EURO 5	Transport, passenger car, large size, natural gas, EURO 5	Transport, passenger car, medium size, liquefied petroleum gas (LPG), EURO 5
Acrolein	6.92E-07	1.70E-05	6.92E-07	6.92E-07		7.34E-07
Ammonia	3.00E-05	1.60E-05	3.00E-05	3.00E-05	1.36E-04	3.22E-05
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Benzaldehyde	8.02E-07	4.09E-06	8.02E-07	8.02E-07		8.50E-07
Benzene	5.48E-05	9.41E-06	5.48E-05	5.48E-05	3.54E-05	6.42E-05
Butane	1.03E-04	5.23E-07	1.03E-04	1.03E-04		1.27E-04
Cadmium	1.00E-08	1.00E-08	1.00E-08	1.00E-08		1.07E-08
Carbon dioxide, fossil	3.18E+00	3.14E+00	2.35E+00	4.54-01	2.01E+00	2.98E+00
Carbon dioxide, biogenic			4.98E-01	1.63E+00		
Carbon monoxide, fossil	5.46E-03	9.07E-04	5.46E-03	5.46E-03	8.32E-03	1.15E-02
Chromium	5.00E-08	5.00E-08	5.00E-08	5.00E-08		5.36E-08
Chromium IV	1.00E-10	1.00E-10	1.00E-10	1.00E-10		1.07E-10
Chromium VI						
Copper	1.70E-06	1.70E-06	1.70E-06	1.70E-06		1.82E-06
Cyclohexane	4.15E-06	3.09E-06	4.15E-06	4.15E-06		
Dinitrogen monoxide	1.30E-04	5.00E-05	1.30E-04	1.30E-04	3.48E-05	1.39E-04
Ethane	1.59E-05	1.57E-06	1.59E-05	1.59E-05		1.78E-05
Ethylene oxide	2.66E-05	5.21E-05	2.66E-05	2.66E-05		2.82E-05
Formaldehyde	6.20E-06	5.70E-05	6.20E-06	6.20E-06		6.57E-06
Heptane	2.70E-06	9.50E-07	2.70E-06	2.70E-06		2.86E-06
Lead	1.50E-09	8.26E-14	1.50E-09	1.50E-09		1.61E-09
Mercury	7.00E-11	2.00E-11	7.00E-11	7.00E-11	9.99E-09	7.51E-11
Methane, fossil	2.45E-04	2.86E-05	2.45E-04	2.45E-04	6.39E-04	2.34E-04
Methyl ethyl ketone	1.82E-07	5.70E-06	1.82E-07	1.82E-07		1.93E-07
m-Xylene	4.44E-05	2.90E-06	4.44E-05	4.44E-05		5.48E-05
Nickel	7.00E-08	7.00E-08	7.00E-08	7.00E-08		7.51E-08
Nitrogen oxides	4.44E-04	9.73E-03	4.44E-04	4.44E-04		5.85E-04
NMVOC, non-methane volatile organic compounds, unspecified origin	9.29E-04	2.52E-04	9.29E-04	9.29E-04	9.09E-05	1.03E-03
o-Xylene	1.06E-05	1.28E-06	1.06E-05	1.06E-05	2.42E-04	1.28E-05
PAH, polycyclic	3.48E-08	1.85E-07	3.48E-08	3.48E-08		3.73E-08

	Transport, passenger car, large size, petrol, EURO 5	**Transport, passenger car, large size, diesel, EURO 5**	**Transport, passenger car, large size, flex fuel (E25), EURO 5**	**Transport, passenger car large size, flex fuel (E85), EURO 5**	**Transport, passenger car, large size, natural gas, EURO 5**	**Transport, passenger car, medium size, liquefied petroleum gas (LPG), EURO 5**
aromatic hydrocarbons						
Particulates, < 2.5 um	1.41E-05	2.75E-05	1.41E-05	1.41E-05	5.31E-06	1.83E-06
Particulates, > 2.5 um, and < 10um						
Pentane	1.19E-04	1.90E-07	1.19E-04	1.19E-04		1.49E-04
Propane	7.62E-05	5.23E-07	7.62E-05	7.62E-05		9.67E-05
Propylene oxide	1.39E-05	1.71E-05	1.39E-05	1.39E-05		1.48E-05
Selenium	1.00E-08	1.00E-08	1.00E-08	1.00E-08		1.07E-08
Styrene	3.68E-06	1.76E-06	3.68E-06	3.68E-06		3.90E-06
Sulfur dioxide	2.00E-05	2.00E-05	2.00E-05	2.00E-05		2.15E-06
Toluene	1.03E-04	3.28E-06	1.03E-04	1.03E-04	2.03E-05	1.27E-04
Zinc	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-04	1.07E-06

Table 67. Fuel Consumption and Air per kg of Fuel Consumed, Truck and Bus

	Transport, freight, lorry >32 metric ton, EURO6	Transport, combination truck, short-haul, gasoline powered	Transport, transit bus, diesel powered	Transport, transit bus, gasoline powered	Transport, transit bus, flex fuel (E25) powered	Transport, transit bus, CNG powered
Source	Ecoinvent v3.6,	U.S. Life Cycle Inventory Database	U.S. Life Cycle Inventory Database	U.S. Life Cycle Inventory Database	Based on U.S. Life Cycle Inventory Database: Transport, transit bus, gasoline powered	U.S. Life Cycle Inventory Database
Geography	RER (Europe)	RNA (Northern America)	RNA (Northern America)	RNA (Northern America)	RNA (Northern America)	RNA (Northern America)
Time period	2009-01-01 to 2013-12-31 Valid for the entire period	2009-01-01 to 2009-12-31	2009-01-01 to 2009-12-31	2009-01-01 to 2009-12-31	2009-01-01 to 2009-12-31	2009-01-01 to 2009-12-31
Fuel Consumption	**kg/kg diesel**	**kg/kg petrol**	**kg/kg diesel**	**kg/kg petrol**	**kg/kg E25**	**m3/m3 CNG**
Petrol, low-sulfur		1.00E+00		1.00E+00	7.39E-01	
Diesel, low-sulfur	1.00E+00		1.00E+00			
Ethanol					2.61E-01	
CNG						1.00E+00
LPG						
Air emissions	**kg/kg of fuel**	**kg/kg of fuel**	**kg/kg of fuel**	**kg/kg of fuel**	**kg/kg of fuel**	**kg/m³ of natural gas**
1-Pentene						
2-Methyl pentane						
Acetaldehyde	3.91E-06					
Acetone						
Acrolein	1.51E-06					
Ammonia	9.79E-06	7.15E-05	4.63E-05	8.82E-05	8.82E-05	0.00E+00
Arsenic	1.00E-10					
Benzaldehyde	1.17E-06					
Benzene	5.99E-08					
Butane	1.28E-07					
Cadmium	8.70E-09					
Carbon dioxide, fossil	3.00E+00	3.06E+00	3.10E+00	3.39E+00	2.50E+00	2.34E+00
Carbon dioxide, biogenic					5.30E-01	

	Transport, freight, lorry >32 metric ton, EURO6	Transport, combination truck, short-haul, gasoline powered	Transport, transit bus, diesel powered	Transport, transit bus, gasoline powered	Transport, transit bus, flex fuel (E25) powered	Transport, transit bus, CNG powered
Carbon monoxide, fossil	2.73E-03	2.96E-01	1.13E-02	1.48E-01	1.48E-01	1.10E-01
Chromium	3.00E-08					
Chromium IV						
Chromium VI	6.00E-11					
Copper	2.12E-08					
Cyclohexane						
Dinitrogen monoxide	1.63E-04	1.07E-04	6.94E-06	1.50E-04	1.50E-04	2.98E-04
Ethane	2.57E-08					
Ethylene oxide						
Formaldehyde	7.18E-06					
Heptane	2.57E-07					
Lead	5.21E-08					
Mercury	5.30E-09					
Methane, fossil	2.10E-06	9.34E-04	4.87E-05	1.82E-04	1.82E-04	6.87E-05
Methyl ethyl ketone						
m-Xylene	8.38E-07					
Nickel	8.80E-09					
Nitrogen oxides	1.37E-03	5.49E-02	6.01E-02	2.42E-02	2.42E-02	9.00E-03
NMVOC, non-methane volatile organic compounds, unspecified origin	6.95E-05	1.40E-02	1.79E-03	6.19E-03	6.19E-03	
o-Xylene	3.42E-07					
PAH, polycyclic aromatic hydrocarbons	7.82E-08	1.37E-02	1.75E-03	6.04E-03	6.04E-03	2.98E-03
Particulates, < 2.5 um	1.24E-05	3.18E-04	1.46E-03	3.93E-05	3.93E-05	1.97E-05
Particulates, > 2.5 um, and < 10um		3.45E-04	1.50E-03	4.27E-05	4.27E-05	1.97E-05
Pentane	5.13E-08					
Propane	8.55E-08					
Propylene oxide						
Selenium	1.00E-10					
Styrene	4.79E-07					
Sulfur dioxide	1.63E-05	5.69E-05	4.93E-05	6.30E-05	6.30E-05	

	Transport, freight, lorry >32 metric ton, EURO6	Transport, combination truck, short-haul, gasoline powered	Transport, transit bus, diesel powered	Transport, transit bus, gasoline powered	Transport, transit bus, flex fuel (E25) powered	Transport, transit bus, CNG powered
Toluene	8.55E-09					
Zinc	1.74E-06					