Limited disclosure version

The limited disclosure version of Tyre $LCCO_2$ Calculation Guidelines does not contain the GHG emission coefficients from IDEAv2.

# Tyre $LCCO_2$ Calculation Guidelines

Ver. 3.0.1

December 2021

The Japan Automobile Tyre Manufacturers Association, Inc.

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## I. Introduction

Lifecycle assessment (LCA) is a method to quantitatively calculate, analyze, and evaluate a commercial product or service's impacts on the environment throughout its entire lifecycle from raw material procurement to the end of its life and recycling. To calculate $LCCO_2$, greenhouse gases (GHGs) emitted through the entire lifecycle are converted into $CO_2$. By visualizing GHG emissions, the manufacturers are expected to work to further reduce GHG emissions by cooperating with other companies in their supply chains, and conversely, consumers are expected to utilize the provided information to change their habits to those that release less carbon.

The LCA Subcommittee under the Environmental Experts Committee of the Japan Rubber Manufacturers Association put together the first LCA guidelines in the tyre and rubber industry in Japan in 1998 by quickly recognizing the trend at that time; "Tire Inventory Analysis Trials – LCA Analysis and Research Activities in the Rubber Industry" (hereinafter "1998 Guidelines") involve automobile tyres as calculation examples.
The Japan Automobile Tyre Manufacturers Association, Inc. (JATMA) put together Tire $LCCO_2$ Calculation Guidelines Ver. 2.0 (hereinafter "Guidelines Ver. 2.0") in 2012 based on the 1998 Guidelines.

Guidelines Ver. 2.0 were outsourced to Mizuho Information & Research Institute, Inc. as an expert organization and were prepared while referring to ISO14044, the Japanese Carbon Footprint system, PAS2050, BPX30-323, the GHG protocol, and the like. The preconditions and thinking behind the calculation procedure in Guidelines Ver. 2.0 were determined so as to satisfy ISO14040:2006 and ISO14044:2006, which are basic international LCA standards, except content of data collected individually and some other items such as sensitivity analysis. Following Guidelines Ver. 2.0 enabled calculations conforming to ISO14040:2006 and ISO14044:2006.
Approximately ten years have passed since the issuance of Guidelines Ver. 2.0 and the circumstances of the automobile industry have changed. These revised guidelines (hereinafter "Guidelines Ver. 3.0") were issued because we thought that guidelines that make it possible to calculate the $CO_2$ emissions based on the current situation would be necessary. Guidelines Ver. 3.0 include updated and more contents. The latest inventory data and data on representative tyre types were incorporated. Regarding calculation for the use stage from which the GHG emissions account for 80% or more of those in the entire tyre lifecycle, both setting conditions and results, including RRC values from the latest fuel consumption tests were included. And, calculation methods in the PCR[*1] that was prepared by the TIP[*2] under the World Business Council for Sustainable Development (WBCSD) were referred.
In addition, we received the critical review of the stakeholder committee organized by the Japan Life Cycle Assessment Facilitation Centre, and the Centre acknowledged that Guidelines Ver. 3.0 conform to ISO14040:2006 and ISO14044:2006.

*1: Abbreviation of "Product Category Rule" that was issued by UL LLC in 2017 <Reference ①>. The PCR is a guidance for preparing EPD (type III environmental declaration). In Japan, supplemental PCR is provided for in the EcoLeaf Program.

*2: Abbreviation of "Tire Industry Project." It consists of 11 tyre manufacturers around the world, including four JATMA member companies.

Guidelines Ver. 3.0 including the latest tyre LCA calculation methods and data should provide some assistance in calculating tyre LCA by interested parties.

Point to note 1:
Note that the raw materials, $CO_2$ emissions, and other data listed in Guidelines Ver. 3.0 are representative examples provided to aid in your understanding of the calculation.

Point to note 2:
Guidelines Ver. 3.0 (this edition) are a publicly released material. They are shown on the JATMA homepage and in other places.
JATMA has concluded a special license agreement with the Sustainable Management Promotion Organization in Japan and Guidelines Ver. 3.0 include the GHG emission coefficients from inventory database IDEAv2. Consequently, JATMA can disclose Guidelines Ver. 3.0 to parties who want to make calculations according to Guidelines Ver. 3.0 as long as they agree with the designated conditions. However, in special situations, we disclose Guidelines Ver. 3.0 to parties who have an end user license of inventory database IDEAv2 only after it has been confirmed that they possess a license.

Point to note 3
In Guidelines Ver. 3.0, GHG emissions are calculated for each stage, and there is a possibility of double counting in case each stakeholder will calculate the emission reduction effects individually.

March 2021

Environment Subcommittee
The Japan Automobile Tyre Manufacturers Association, Inc.

Environment Subcommittee members and related personnel involved in summarizing Guidelines Ver. 3.0

(Listed with the titles and divisions at the time of publishing)

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## II. Concept on $LCCO_2$ Calculation

### 1. Purpose

- To calculate GHG emissions in the lifecycles of tyres

Guidelines Ver. 3.0 summarize the basic methods to calculate GHG emissions in the lifecycles of tyres. This method can be used to quantitatively compare tyres with different rolling resistance coefficients (RRCs), such as conventional and fuel-efficient tyres in Japan.

### 2. Reference flow and Functional Units

The reference flow in Guidelines Ver. 3.0 is the lifecycle of a single tyre in each of the types listed below.

Tyres for passenger cars (PC) and trucks and buses (TB) sold in Japan

- Conventional PC tyre
- Fuel-efficient PC tyre
- Conventional TB tyre
- Fuel-efficient TB tyre

According to JATMA's grading system, the rolling resistance performance grade of fuel-efficient PC tyres should be A or higher (rolling resistance coefficient: 9.0 N/kN or less) and the wet grip performance grade should be within the range of a to d (wet grip performance G: 110% or more, 155% or less) <JATMA labeling system: Reference ②>. Fuel-efficient TB tyres refer to tyres with fuel-efficient specifications that the manufacturers determine.

The functional units of these tyres are their basic kinematical performance (e.g., bearing loads, transmitting power, and rolling with small resistance) and sufficient tyre life until they completely wear out.

Guidelines Ver. 3.0 exemplify that the tyre life of PC tyres is 30,000 km and that of TB tyres is 120,000 km.

### 3. Scope of Lifecycle to be Calculated (System Boundary)

A lifecycle consists of the following five stages:

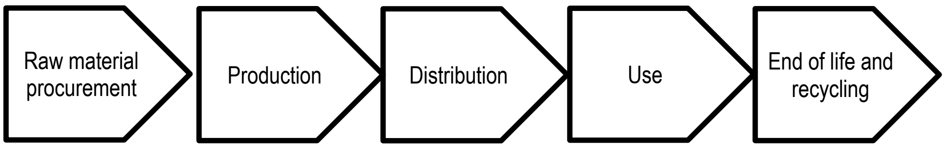



Fig. 1: Scope of a lifecycle

Raw material procurement includes mining and cultivation of rubber trees, which is where the raw material for fresh rubber comes from. The lifecycle ends at the end of life and recycling stage.

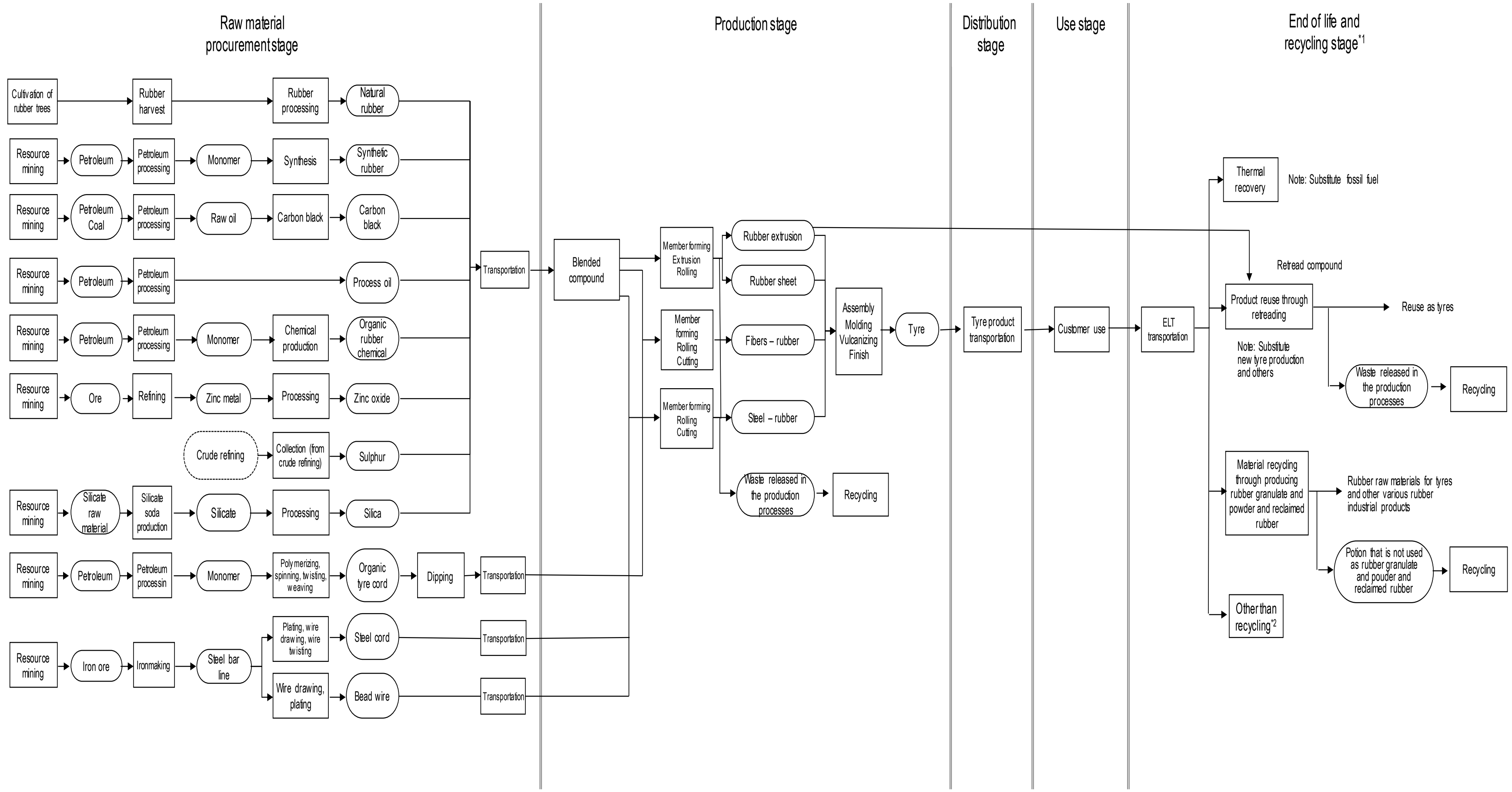



Fig. 2: Vehicle tyre lifecycle flow

*1: The flow at the end of life and recycling stage varies between PC and TB. PC tyres are recovered as heat. TB tyres are recovered as heat, they are reused through retreading, and they are processed to manufacture rubber granulate and powder and reclaimed rubber for material recycling (for tyres and other applications).
*2: The main application of "other than recycling" is export. There is no data on how exported tyres are discarded and recycled, so it has been assumed that they are simply incinerated (worst-case scenario).

4. Lifecycle Impact Assessment

1) Target greenhouse gases (GHG)

The table below lists the seven target gases.

Table 1: Target gases

| Code | Name |
|---|---|
| $CO_2$ | Carbon dioxide |
| $CH_4$ | Methane |
| $N_2O$ | Nitrous oxide |
| HFCs | Hydrofluorocarbons |
| PFCs | Perfluorocarbons |
| $SF_6$ | Sulfur hexafluoride |
| $NF_3$ | Nitrogen trifluoride |

* As of the issuance of Guidelines Ver. 3.0, there were not sufficient findings on whether tyres release HFCs, PFCs, $SF_6$, and $NF_3$ in their lifecycles and thereby they are not included in the emissions calculation. However, if the emissions of such gases can be individually identified and quantified, they should be included in calculations.

2) Global warming potential used for lifecycle impact assessment

The 100-year values specified in the Fifth IPCC Report (2013) were adopted as the global warming potential (GWP).

(To $CO_2$: 1, $CH_4$: 28, $N_2O$: 265)

5. Calculation Accuracy

Guidelines Ver. 3.0 show methods to calculate $LCCO_2$ emissions from tyres based on information on representative tyre types. Though the primary data, which is the measured or estimated value in each company, should be used for $LCCO_2$ calculation as a basic rule, if such primary data cannot be applied, the setting values in Guidelines Ver. 3.0 can be applied. If more appropriate settings or data than what is provided in Guidelines Ver. 3.0 can be obtained, it is recommended to use them for more accurate calculation.

6. Consistency with the Standards

Guidelines Ver. 3.0 were determined while referring to ISO14040:2006 and ISO14044:2006. The preconditions and thinking behind the calculation procedure in Guidelines Ver. 3.0 were determined so as to satisfy ISO14040:2006 and ISO14044:2006, except data collected individually and some other items such as sensitivity analysis. Following Guidelines Ver. 3.0 enables calculations conforming to ISO14040:2006 and ISO14044:2006.

However, Guidelines Ver. 3.0 do not include all the reporting formats and report items included in ISO14040:2006 and ISO14044:2006 (e.g., sensitivity analysis of results and uncertainty analysis), so if you need complete compliance with ISO14040:2006 and ISO14044:2006, refer to them in addition to the items in Guidelines Ver. 3.0.

## III. Calculation Methods in Each Stage (Inventory Analysis)

The following describes the calculation method for each stage and calculation examples using the representative tyre types as models.

The representative tyre size was determined using JATMA tyre sales data in Japan by tyre size as of 2019 and the weights were determined based on a JATMA internal survey.

The determination process of each representative tyre size:

The size of most sold PC tyres was that for light vehicles. However, the weight of tyres in that size is far lighter than the average weight of PC tyres as a whole, so we decided that it is not adequate as the representative tyre size. Therefore, 195/65R15 was selected because the weight is closer to the average weight and the sales volume is the largest next to it.

As the representative TB tyre size, among tyres for which the size was indicated in accordance with the ISO standards, 275/80R22.5 with a rim diameter of 22.5 inches was selected because the sales number was large.

The rolling resistance performance grade of fuel-efficient PC tyres in Table 3 is A or higher (rolling resistance coefficient: 9.0 N/kN or less) according to the JATMA labeling system <Reference ②> and the wet grip performance grade is within the range of a to d (wet grip performance G: 110% or more, 155% or less). Fuel-efficient TB tyres refer to tyres with the fuel-efficient specifications determined by the manufacturers.

Table 2: Representative tyre size

| Tyre type | Representative tyre size |
|---|---|
| PC | 195/65R15 |
| TB | 275/80R22.5 |

Table 3: Representative tyre weights

(Unit: kg)

| Tyre types | | Weight |
|---|---|---|
| PC | Conventional tyre | 8.6 |
| | Fuel-efficient tyre | 8.2 |
| TB | Conventional tyre | 56.2 |
| | Fuel-efficient tyre | 54.5 |

1. Raw Material Procurement Stage

1) Raw material configuration ratios

The table below lists the example representative raw material configuration ratios for the representative tyre types. The configuration ratios were determined based on a JATMA internal survey.

Table 4: Representative tyre raw material configuration ratios (weight ratios)*

| Raw material | | PC (195/65R15) | | TB (275/80R22.5) | |
|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| New rubber | | 100.0 | 100.0 | 100.0 | 100.0 |
| | Natural rubber | 39.0 | 46.4 | 77.0 | 78.8 |
| | Synthetic rubber | 61.0 | 53.6 | 23.0 | 21.2 |
| Carbon black | | 50.0 | 41.3 | 52.0 | 47.3 |
| Process oil | | 8.0 | 9.6 | 2.0 | 1.8 |
| Total of organic rubber chemicals | | 8.0 | 13.1 | 10.0 | 8.3 |
| Inorganic compounding agent | | 7.0 | 22.8 | 9.0 | 9.9 |
| | Zinc oxide | 3.0 | 3.4 | 5.0 | 4.4 |
| | Sulfur | 3.0 | 2.5 | 3.0 | 2.7 |
| | Silica | 1.0 | 16.9 | 1.0 | 2.8 |
| Total of fibers | | 10.0 | 8.0 | 0.0 | 0.4 |
| Steel cord | | 15.0 | 14.1 | 33.0 | 31.5 |
| Bead wire | | 8.0 | 9.5 | 11.0 | 13.3 |
| Total | | 206.0 | 218.4 | 217.0 | 212.5 |
| Actual tyre weight/ new rubber weight ratio | | 2.06 | 2.18 | 2.17 | 2.13 |

*Determined with the new rubber weight regarded as 100

2) GHG emission in raw material production

① GHG emission coefficients for raw material production

The table below lists the GHG emission coefficients for raw material production.

Table 5: GHG emission coefficients for tyre raw material production

(Unit: kg$CO_2$e/kg)

| Raw material | | GHG emission coefficient | Source and background |
|---|---|---|---|
| New rubber | | — | — |
| | Natural rubber | $6.71 \times 10^{-1}$ | Allen, P. W., the Malaysian Rubber Producers Research Association<br>“Energy accounting: natural versus synthetic rubber”<br>Rubber development vol. 32, No. 4, 1979 |
| | Synthetic rubber | 3.71 | Weighted average of the emission coefficients for styrene-butadiene rubber and butadiene rubber (IDEA) with the quantity of synthetic rubber shipped for tyres and tubes (statistics by the Japan Rubber Manufacturers Association, data in 2018) |
| Carbon black | | *** | JLCA database, carbon black (2017) |
| Process oil | | *** | IDEA, lubricating oil (including grease)<br>*The unit was converted using 0.88 kg/l of the specific gravity surveyed by JATMA. |
| Total of organic rubber chemicals | | *** | IDEA, organic rubber chemical |
| Inorganic compounding agent | | — | — |
| | Zinc oxide | *** | IDEA, zinc oxide |
| | Sulfur | *** | IDEA, recovered sulfur |
| | Silica | *** | IDEA, silica gel |
| Total of fibers | | 7.16 | Weighted average of the emission coefficients for polyester tyre cords, nylon tyre cords, and rayon (IDEA) with the consumption ratios (statistics by JATMA, data in FY2018) |
| Steel cord | | *** | IDEA, steel ropes (including hard steel stranded wire) |
| Bead wire | | *** | IDEA, steel ropes (including hard steel stranded wire) |

* IDEA: LCI database IDEA version 2.3 (December 27, 2019)
  Research Laboratory for IDEA under the Japanese National Institute of Advanced Industrial Science and Technology
  Sustainable Management Promotion Organization in Japan

② Calculation of GHG emissions per tyre in raw material production

The GHG emissions per tyre in raw material production are calculated with the following equation. (GHG emissions in raw material production (kg$CO_2$e/tyre)) = Σ{(tyre weight (kg)) × (each raw material configuration ratio) × (GHG emission coefficient for raw material production (kg-$CO_2$e/kg))}

Table 6: GHG emissions in raw material production

(Unit: $kgCO_2e$/tyre)

| Raw material | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| New rubber | — | — | — | — |
| Natural rubber | 1.1 | 1.2 | 13.4 | 13.6 |
| Synthetic rubber | 9.4 | 7.5 | 22.1 | 20.2 |
| Carbon black | *** | *** | *** | *** |
| Process oil | *** | *** | *** | *** |
| Total of organic rubber chemicals | *** | *** | *** | *** |
| Inorganic compounding agent | — | — | — | — |
| Zinc oxide | *** | *** | *** | *** |
| Sulfur | *** | *** | *** | *** |
| Silica | *** | *** | *** | *** |
| Total of fibers | 3.0 | 2.2 | 0.0 | 0.7 |
| Steel cord | *** | *** | *** | *** |
| Bead wire | *** | *** | *** | *** |
| Total | 26.3 | 23.8 | 137.3 | 129.3 |

3) GHG emission in raw material transportation

① Setting for raw material transportation

It has been determined that raw materials are transported for the distances specified in the table below.

Table 7: Raw material transportation scenarios

| Raw material | Transportation distance | Remarks |
|---|---|---|
| Natural rubber | Land transportation before marine transportation: 500 km<br>International marine transportation: From the country of origin (Southeast Asian countries) to Japan via Singapore (1st hub), Shanghai (2nd hub), etc.<br>Land transportation after marine transportation: 500 km | • Transportation before and after international marine transportation: A 10-ton truck for 500 km one-way; load ratio set at 50%. (The assumed distance is the approximate distance between Tokyo and Osaka.)<br>• Feeder boats for international marine transportation should be 2,000 TEU and mother ships should be 10,000 TEU or more.<br>(JATMA survey results (2019)) |
| Synthetic rubber | Land transportation: 500 km | • The assumed distance is the approximate distance between Tokyo and Osaka.<br>• Means of transportation: A 10-ton truck with a load ratio of 50% |
| Carbon black | | |
| Process oil | | |
| Total of organic rubber chemicals | | |
| Zinc oxide | | |
| Sulfur | | |
| Silica | | |
| Total of fibers | | |
| Steel cord | | |
| Bead wire | | |

Table 8: GHG emission coefficients for raw material transportation

(Unit: $kgCO_2e/kg$)

| Raw material | GHG emission coefficient | Remarks |
|---|---|---|
| Natural rubber | $2.97 \times 10^{-1}$ | JATMA survey results (2019)<br>• For marine transportation, GHG emissions for the representative 18 routes were surveyed.<br>• For land transportation, the GHG emissions were calculated as follows: Fuel consumption × GHG emission coefficient／load weight<br>Fuel consumption calculation equation: Conforms to the Act on the Rationalization etc. of Energy Use in Japan<br>$\ln x = 2.71 - 0.812 \ln (y/100) - 0.654 \ln z$<br>x: Fuel consumption per cargo transportation volume (unit: l/(ton·km))<br>y: Load ratio (unit: %)<br>z: Maximum load of the cargo vehicle (unit: kg)<br>GHG emission coefficient for light oil: *** $kgCO_2e/l$<br>(IDEA, light oil combustion energy) |
| Synthetic rubber | *** | The afore-mentioned equation for land transportation was used. |
| Carbon black | *** | |
| Process oil | *** | |
| Total of organic rubber chemicals | *** | |
| Zinc oxide | *** | |
| Sulfur | *** | |
| Silica | *** | |
| Total of fibers | *** | |
| Steel cord | *** | |
| Bead wire | *** | |

② Equation to calculate GHG emissions per tyre in raw material transportation

The GHG emissions per tyre in raw material transportation are calculated with the following equation.

(GHG emissions in raw material transportation ($kgCO_2e$/tyre))
= Σ{(tyre weight (kg)) × (each raw material configuration ratio) ×
(GHG emission coefficient for raw material transportation ($kgCO_2e/kg$))}

Table 9: GHG emissions in raw material transportation

(Unit: $kgCO_2e$/tyre)

| Raw material | | PC | | TB | |
|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| New rubber | | — | — | — | — |
| | Natural rubber | 0.48 | 0.52 | 5.92 | 6.00 |
| | Synthetic rubber | *** | *** | *** | *** |
| Carbon black | | *** | *** | *** | *** |
| Process oil | | *** | *** | *** | *** |
| Total of organic rubber chemicals | | *** | *** | *** | *** |
| Inorganic compounding agent | | — | — | — | — |
| | Zinc oxide | *** | *** | *** | *** |
| | Sulfur | *** | *** | *** | *** |
| | Silica | *** | *** | *** | *** |
| Total of fibers | | *** | *** | *** | *** |
| Steel cord | | *** | *** | *** | *** |
| Bead wire | | *** | *** | *** | *** |
| Total | | 1.15 | 1.13 | 9.39 | 9.28 |

4) GHG emissions in the entire raw material procurement stage

The table below lists the GHG emissions in the entire raw material procurement stage.

(GHG emissions in the entire raw material procurement stage)

= (GHG emissions in raw material production) + (GHG emissions in raw material transportation)

Table 10: GHG emissions in the entire raw material procurement stage

(Unit: $kgCO_2e$/tyre)

| Class | | PC | | TB | |
|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| Raw material procurement stage | Raw material production | 26.3 | 23.8 | 137.3 | 129.3 |
| | Raw material transportation | 1.1 | 1.1 | 9.4 | 9.3 |
| | Total | 27.4 | 24.9 | 146.7 | 138.6 |

2. Production Stage

The GHG emissions in the tyre production stage are calculated as follows.

1) GHG emission coefficients by energy

The table below lists the GHG emission coefficients for energy consumed in the tyre production stage.

Note that water used in manufacturing processes has been excluded because its impact is small.

Table 11: GHG emission coefficients for energy

| Class | GHG emission coefficient | Unit | Source[*1, 2] |
|---|---|---|---|
| Gasoline | *** | $kgCO_2e/l$ | IDEA, gasoline combustion energy |
| Kerosene | *** | $kgCO_2e/l$ | IDEA, kerosene combustion energy |
| Light oil | *** | $kgCO_2e/l$ | IDEA, light oil combustion energy |
| Heavy oil A | *** | $kgCO_2e/l$ | IDEA, heavy oil A combustion energy |
| Heavy oil C | *** | $kgCO_2e/l$ | IDEA, heavy oil C combustion energy |
| Liquefied petroleum gas (LPG) | *** | $kgCO_2e/kg$ | IDEA, LPG combustion energy |
| Liquefied natural gas (LNG) | *** | $kgCO_2e/kg$ | IDEA, LNG combustion energy |
| Steam coal | *** | $kgCO_2e/kg$ | IDEA, steam coal combustion energy |
| City gas | *** | $kgCO_2e/Nm^3$ | IDEA, city gas 13A combustion energy |
| Purchased electric power | *** | $kgCO_2e/kWh$ | IDEA, electric power, average in Japan, FY2017 |

* 1: IDEA: LCI database IDEA version 2.3 (December 27, 2019)
Research Laboratory for IDEA under the Safety Science Research Section of the Japanese National Institute of Advanced Industrial Science and Technology
Sustainable Management Promotion Organization in Japan

* 2: The coefficients specified in IDEA are for all processes including mining.

2) GHG emissions in the production stage

It is difficult to directly obtain GHG emission data from JATMA member companies' factories in Japan for each tyre type. Therefore, the GHG emissions per kg of new rubber for each tyre type were calculated by using ① the average GHG emissions per kg of new rubber of all factories (average of all PC and TB), ② energy consumption ratios per kg of new rubber for each tyre type in the production process at each member company, and ③ new rubber production weight ratios for each tyre type. New rubber refers to new natural rubber and synthetic rubber that are used in tyre production, and all the energy related to tyre production is calculated in units of energy per kg of new rubber.

① GHG emissions per kg of new rubber (average of all PC and TB)

The GHG emissions per kg of new rubber at JATMA member companies' tyre factories in Japan were calculated as follows: The consumptions of fuel and electric power that were actually used in 2018 were converted into GHG emissions; they were divided by the actual new rubber amount in the same year; and the values were added. That is to say, the obtained value is the average value of GHG emissions per unit weight of new rubber for all PC and TB.

Table 12: GHG emissions per kg of new rubber (average of all PC and TB)

(Unit: $kgCO_2e/kg$)

| Class | GHG emissions |
|---|---|
| Fuel-derived GHG emissions per kg of new rubber | 0.981 |
| Electric power-derived GHG emissions per kg of new rubber | 0.684 |
| GHG emissions per kg of new rubber | 1.665 |

② Table 13 lists the energy consumption ratios per new rubber weight in the production process of conventional PC, fuel-efficient PC, conventional TB, and fuel-efficient TB tyres. They were determined based on results of surveys at JATMA member companies in 2019. The energy consumption for a conventional PC tyre is used as the reference and the ratios of the fuel energy amount and electric power energy amount per unit weight of new rubber used to produce each tyre type are shown.

Table 13: Energy consumption ratios per unit weight of new rubber in the production process of PC and TB (= GHG emission ratios per unit weight of new rubber for each tyre type)

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| Fuel | 100 | 105 | 108 | 109 |
| Electric power | 100 | 108 | 73 | 76 |

③ Table 14 lists the new rubber production weight ratios for each tyre type when the entire new rubber production weight is 100, which are calculated as follows. According to the 2019 JATMA statistics data,the ratio of the total production weight of new rubber for PC tyres to that of TB tyres was 2:1, and the ratio of the total production weight of new rubber for conventional PC tyres to that of fuel-efficient PC tyres was 1:4. And, the ratio of the total production weight of new rubber for conventional TB tyres to that of fuel-efficient TB tyres was assumed as 1:1.

Table 14: New rubber production weight ratios for PC and TB tyres

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| New rubber production weight ratio | 13 | 53 | 17 | 17 |

The procedure for calculating the GHG emission rate for each tyre type to the GHG emissions per kg of new rubber (average of all PC and TB) listed in Table 12 is explained below, using fuel-derived emissions for conventional PC tyres as an example.

When the rate of emissions for conventional PC tyres to the fuel-derived GHG emissions per kg of new rubber (0.981 $kgCO_2e/kg$) is assumed as *a*, from the ratios in Table 13, the fuel-derived GHG emissions per kg of new rubber for each tyre type are expressed with the following equations.

Fuel-derived GHG emissions per kg of new rubber for conventional PC tyres = $a \times$ fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)
Fuel-derived GHG emissions per kg of new rubber for fuel-efficient PC tyres = $1.05 \times a \times$ fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)
Fuel-derived GHG emissions per kg of new rubber for conventional TB tyres = $1.08 \times a \times$ fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)
Fuel-derived GHG emissions per kg of new rubber for fuel-efficient TB tyres = $1.09 \times a \times$ fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)

The fuel-derived GHG emissions per kg of new rubber (average of all PC and TB) listed in Table 12 can be regarded as the weighted average of the fuel-derived GHG emissions per unit weight of new rubber for each tyre type. Accordingly, the following equation is obtained by using the values in Tables 12, 13, and 14.

Fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)
= 0.981 $kgCO_2e/kg$
$= (a \times 0.981 \times 13 + 1.05 \times a \times 0.981 \times 53 + 1.08 \times a \times 0.981 \times 17 + 1.09 \times a \times 0.981 \times 17) / (13 + 53 + 17 + 17)$
$= 0.981 \times a \times (1 \times 13 + 1.05 \times 53 + 1.08 \times 17 + 1.09 \times 17) / 100$

From the above equation, the rate of fuel-derived GHG emissions per kg of new rubber for conventional PC tyres : $a$ is calculated to be 0.95.
In addition, the rate of fuel-derived GHG emissions per kg of new rubber for fuel-efficient PC tyres is as follows: $a \times 1.05 = 1.00$
The rates of electric power-derived GHG emissions per new rubber weight for each tyre type were calculated in the same way. Table 15 lists the results.

Table 15: Rate of GHG emissions for each tyre type to the GHG emissions per kg of new rubber (average of all PC and TB)

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| Fuel | 0.95 | 1.00 | 1.02 | 1.03 |
| Electric power | 1.04 | 1.13 | 0.76 | 0.79 |

④ GHG emissions per kg of new rubber for each tyre type
(GHG emissions per kg of new rubber)
= (fuel-derived GHG emissions per kg of new rubber (average of all PC and TB)) × (rate of fuel-derived GHG emissions for each tyre type) + (electric power-derived GHG emissions per kg of new rubber (average of all PC and TB)) × (rate of electric power-derived GHG emissions for each tyre type)

Table 16: GHG emissions per kg of new rubber

(Unit: $kgCO_2e/kg$)

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| Fuel-derived GHG emissions per kg of new rubber (a) | 0.981 | | | |
| Rate of GHG emissions for fuel (b) | 0.95 | 1.00 | 1.02 | 1.03 |
| Electric power-derived GHG emissions per kg of new rubber (c) | 0.684 | | | |
| Rate of GHG emissions for electric power (d) | 1.04 | 1.13 | 0.76 | 0.79 |
| GHG emissions per kg of new rubber (a × b) + (c × d) | 1.644 | 1.748 | 1.526 | 1.556 |

⑤ Actual tyre weight/new rubber weight ratio for PC and TB

Based on the PC and TB tyre raw material configuration ratios (Table 4), the actual tyre weight/new rubber weight ratio was set as listed below.

Table 17: Actual tyre weight/new rubber weight ratio for PC and TB

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| Actual tyre weight/new rubber weight ratio | 2.06 | 2.18 | 2.17 | 2.13 |

⑥ GHG emissions per kg of actual tyre weight

(GHG emissions per kg of actual tyre weight)

= (GHG emissions per kg of new rubber (for each of PC and TB))

／(actual tyre weight/new rubber weight ratio)

Table 18: GHG emissions per kg of actual tyre weight

(Unit: $kgCO_2e$/1 kg of tyre)

| Class | PC | | TB | |
|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre |
| GHG emissions per kg of actual tyre weight | 0.799 | 0.802 | 0.703 | 0.731 |

⑦ GHG emissions per tyre in the production stage
(GHG emissions per tyre)
= (GHG emissions per kg of actual tyre weight) × (single tyre weight)

Table 19: GHG emissions per tyre in the production stage

| Class | PC | | TB | | Unit |
|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| Single tyre weight | 8.6 | 8.2 | 56.2 | 54.5 | kg/tyre |
| GHG emissions per tyre | 6.9 | 6.6 | 39.5 | 39.8 | kg$CO_2$e/tyre |

3. Distribution Stage

The GHG emissions in the tyre product distribution stage are calculated as follows.

1) Tyre product transportation scenarios

The GHG emissions in tyre product transportation are calculated based on the conditions specified below.

Table 20: Tyre product transportation scenarios

| Class | Details | Remarks |
|---|---|---|
| Scope | Transportation from a production base in Japan to a dealer shop, etc. | |
| Transportation distance | 550 km, one way | JATMA setting value<br>Results of surveys on transportation distances for JATMA member companies in 2019 |
| Means of transportation | 10-ton truck | JATMA setting value |
| Load ratio | 50% | JATMA setting value |
| Fuel consumption calculation equation | Conforms to the Act on the Rationalization etc. of Energy Use in Japan | $\ln x = 2.71 - 0.812 \ln (y/100) - 0.654 \ln z$<br>x: Fuel consumption per cargo transportation volume (unit: l/t·km)<br>y: Load ratio (unit: %)<br>z: Maximum load of the truck (unit: kg) |
| GHG emission coefficient for light oil | *** $kgCO_2e/l$ | IDEA, light oil combustion energy |
| GHG emission coefficient for transportation per kg of actual tyre weight | 0.104 $kgCO_2e/kg$ | Fuel consumption × GHG emission coefficient／load weight |

2) GHG emissions in the distribution stage

The table below lists the GHG emissions in the distribution stage.

(GHG emissions in the distribution stage) = (single tyre weight)
× (GHG emission coefficient for transportation per kg of actual tyre weight)

Table 21: GHG emissions in the distribution stage

| Class | PC | | TB | | Unit |
|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| Single tyre weight | 8.6 | 8.2 | 56.2 | 54.5 | kg/tyre |
| GHG emission coefficient for transportation per kg of actual tyre weight | 0.104 | | | | $kgCO_2e/kg$ |
| GHG emissions per tyre in transportation | 0.9 | 0.9 | 5.8 | 5.7 | $kgCO_2e$/tyre |

4. Use Stage

For the tyre use stage, among GHG emissions to be released from a traveling vehicle with the tyres mounted, the contribution of the tyres is divided for calculation.

1) Tyre use conditions

Table 22 lists the tyre use conditions used to calculate GHG emissions.

Note that the RRC values for the representative tyre size are only examples and they are not the average values in the market.

(JATMA researches and releases the average RRC value for PC tyres in Japanese market once every four years <Reference ③>.)

The vehicle fuel consumption values were also measured on a vehicle used for experiments and they are not average values in the market.

(Average vehicle fuel consumption values in the market are shown on the website of the Japanese Ministry of Land, Infrastructure, Transport and Tourism <Reference ④>.)

Table 22: Tyre use conditions used to calculate GHG emissions

| Class | PC | | | TB | | Unit | Remarks |
|---|---|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre A | Fuel-efficient tyre B | Conventional tyre | Fuel-efficient tyre | | |
| Tyre size | 195/65R15 | | | 275/80R22.5 | | — | |
| Tyre rolling resistance coefficient (RRC) | 10.5 | 8.9 | 6.5 | 9.0 | 5.6 | N/kN | Determined by JATMA[*1] |
| (Tyre rolling resistance index) | 100 | 85 | 62 | 100 | 62 | % | General tyre = 100 |
| Vehicle fuel consumption | 15.25 | 15.68 | 16.37 | 4.0 | 4.4 | km/l | JATMA survey result[*2] |
| | 0.0656 | 0.0638 | 0.0611 | 0.250 | 0.227 | l/km | |
| Contribution ratio of tyres to fuel consumption | 0.179 | 0.156 | 0.119 | 0.26 | 0.18 | — | |
| Vehicle fuel | Gasoline | | | Light oil | | — | |
| Number of mounted tyres | 4 | | | 10 | | tyre | |
| Tyre life | 30,000 | | | 120,000 | | km/tyre | JATMA survey result[*3] |

*1: Two specific types of tyres with different structures, tread patterns, etc. were used as fuel-efficient PC tyres A and B. The actual tyre raw material configuration ratio of each type differs from the values listed in Table 4. However, tyre raw material configuration ratios are company secrets, so they were assumed to be the same this time.

*2: The values for fuel-efficient PC tyres A and B were measured values in WLTC mode fuel consumption tests performed in 2020 or calculated values based on such measured values. In the tests, the two types of tyres that JATMA selected were mounted onto the same vehicle (a sedan with an 1800-cc gasoline engine).

JATMA surveyed the rolling resistance coefficients for all types of PC tyres that were sold by the member companies in Japan in 2006 along with the numbers of the tyres. The rolling resistance coefficient for conventional PC tyres is the average for those tyres except fuel-efficient tyres. The ratio of the rolling resistance coefficient for fuel-efficient tyres to that for conventional tyres was used to calculate the vehicle fuel consumption and contribution ratio to fuel consumption for conventional tyres.

The values for TB are measured and calculated values obtained when member companies performed tests using actual vehicles in 2009. The member companies selected tyres of conventional and low-rolling resistance specifications (fuel-efficient tyres) as test tyres.

*3: Determined based on the Research and Analysis Report on the Use Periods of Tyres (Japanese Ministry of the Environment, 2016 and 2017) and the National Greenhouse Gas Inventory Report of Japan (Center for Global Environmental Research, National Institute for Environmental Studies, Japan, 2020).

Fig. 3 shows that when tyres with different rolling resistance coefficients are mounted, the vehicle fuel consumption varies and the contribution ratio of the tyres to the fuel consumption also changes. As shown in Fig. 3, the vehicle fuel consumption (l/km) can be divided into the fuel consumption originating in the tyre rolling resistance and that originating in other causes of resistance (constant regardless of the differences in the tyre RRC). The contribution ratio of tyres to fuel consumption is defined as the ratio of the fuel consumption originating in the tyre rolling resistance to the vehicle fuel consumption.

Vehicle fuel consumption (l/km) = fuel consumption originating in the tyre rolling resistance (l/km) + fuel consumption originating in causes of resistance other than the tyre rolling resistance (l/km)
Contribution ratio of the tyres to fuel consumption = fuel consumption originating in the tyre rolling resistance (l/km)／vehicle fuel consumption (l/km)

In addition, the fuel consumption originating in the tyre rolling resistance (l/km) changes in proportion to the tyre rolling resistance coefficient (RRC). That is to say, it is calculated by multiplying the tyre rolling resistance coefficient by a constant (value obtained by dividing the fuel consumption originating in tyre rolling resistance coefficient by the tyre rolling resistance coefficient). Accordingly, the vehicle fuel consumption can be expressed with the following equation.

Vehicle fuel consumption (l/km) = tyre rolling resistance coefficient × constant + fuel consumption originating in causes of resistance other than the tyre rolling resistance (l/km)

By assigning the rolling resistance coefficient and vehicle fuel consumption values for fuel-efficient tyres A and B listed in Table 22, the fuel consumption originating in the tyre rolling resistance (tyre rolling resistance coefficient × constant) and the fuel consumption originating in causes of resistance other than the tyre rolling resistance are calculated.

Vehicle fuel consumption for fuel-efficient PC tyre A = 8.9 × constant + fuel consumption originating in causes of resistance other than the tyre rolling resistance
= 0.0638 (l/km)
Vehicle fuel consumption for fuel-efficient PC tyre B = 6.5 × constant + fuel consumption originating in causes of resistance other than tyre rolling resistance
= 0.0611 (l/km)

Figure 3 shows examples for fuel-efficient PC tyres A and B listed in Table 22. From the difference of 0.0027 (l/km) in the fuel consumption between the two types and the difference in the RRC (8.9 − 6.5 = 2.4 (N/kN)), the fuel consumption per RRC (N/kN) (constant in the afore-mentioned equation) is as follows: 0.0027／2.4 = 0.00113 (l/km). By multiplying this value by the rolling resistance coefficient for each tyre type, the fuel consumption originating in the tyre rolling resistance (① and ② in Fig. 3) is calculated. In addition, the fuel consumption originating in causes of resistance other than the tyre rolling resistance is calculated with the following equations.

Fuel consumption originating in the tyre rolling resistance of fuel-efficient PC tyre A (①)

= 0.0027／2.4 × 8.9 = 0.0100 (l/km)

Fuel consumption originating in the tyre rolling resistance of fuel-efficient PC tyre B (②)

= 0.0027／2.4 × 6.5 = 0.00731 (l/km)

Fuel consumption originating in causes of resistance other than the tyre rolling resistance

= vehicle fuel consumption for fuel-efficient PC tyre A − (①) = 0.0638 − 0.0100 = 0.0538 (l/km)

Accordingly, the contribution ratio of fuel-efficient PC tyre A on a vehicle is calculated by dividing the fuel consumption originating in the tyre rolling resistance (Fig. 3 ①) by the vehicle fuel consumption (l/km) as shown in the following equation.

Contribution ratio of fuel-efficient PC tyre A to fuel consumption = fuel consumption originating in the tyre rolling resistance (①)／vehicle fuel consumption (l/km)

= 0.0100／0.0638

= 0.156

The contribution ratio of fuel-efficient PC tyre B to fuel consumption is calculated with the following equation as well.

Contribution of fuel-efficient PC tyre B to fuel consumption = fuel consumption originating in the tyre rolling resistance (②)／vehicle fuel consumption (l/km)

= 0.00731／0.0611

= 0.119

In addition, given that conventional PC tyre with a RRC of 10.5 are mounted on the vehicle used in this experiment, the vehicle fuel consumption and the contribution ratio of the tyres to the fuel consumption are calculated with the following equations.

Fuel consumption of the vehicle with conventional PC tyres = fuel consumption originating in the tyre rolling resistance + fuel consumption originating in causes of resistance other than the tyre rolling resistance

= 0.0027／2.4 × 10.5 + 0.0538

= 0.0656 (l/km)

Contribution ratio of the conventional PC tyres to fuel consumption = fuel consumption originating in the tyre rolling resistance／vehicle fuel consumption

= 0.0027／2.4 × 10.5／0.0656

= 0.179

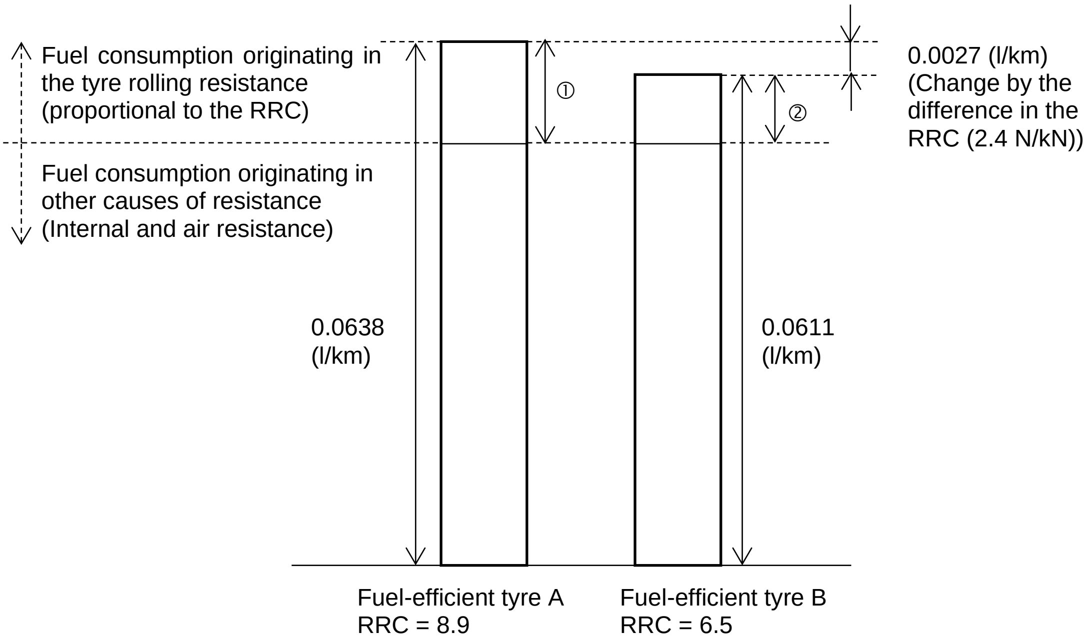



Fig. 3: Changes in the fuel consumption when different types of tyres are installed

In addition, experimental values for conventional TB tyre and fuel-efficient TB tyre were used to calculate the contribution ratio of the tyres to the fuel consumption in a same procedure. Table 22 lists the calculation results.

2) GHG emissions in the use stage

① GHG emission coefficients for vehicle fuels

Table 23: GHG emission coefficients for vehicle fuels

(Unit: $kgCO_2e/l$)

| Class | GHG emission coefficient | Source |
|---|---|---|
| Gasoline | *** | IDEA, gasoline combustion energy |
| Light oil | *** | IDEA, light oil combustion energy |

② Tyre-derived fuel consumption (l/km) and GHG emissions

Tyre-derived fuel consumption (l/km) and GHG emissions are calculated with the following equations.

(Tyre-derived fuel consumption (l/km))
= (fuel consumption per tyre and per km (l/km)) × (tyre life)
= (vehicle fuel consumption) × (contribution ratio of the tyres to fuel consumption) ⁄ (number of tyres) × (tyre life)

(Tyre-derived GHG emissions) = (tyre-derived fuel consumption (l/km)) × (GHG emission coefficient for the vehicle fuel)

Table 24: Tyre-derived fuel consumptions (l/km) and GHG emissions

| Class | PC | | | TB | | Unit |
|---|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre A | Fuel-efficient tyre B | Conventional tyre | Fuel-efficient tyre | |
| Tyre-derived fuel consumption per tyre and per km (l/km) | *** | *** | *** | *** | *** | l/km·tyre |
| Tyre-derived fuel consumption (l/km) (per tyre life) | *** | *** | *** | *** | *** | l/tyre |
| Tyre-derived GHG emissions (per tyre life) | 250.5 | 212.3 | 155.1 | 2,326.9 | 1,447.9 | $kgCO_2e$/tyre |

3) Another method of calculating GHG emissions in the use stage (reference)

The equations presented in the PCR <Reference ①> prepared by the WBCSD TIP can also be used as a method to calculate GHG emissions in the use stage. While the contribution ratio of tyres to fuel consumption is calculated in the JATMA Guidelines, in the PCR, tyres' kinetic energy is calculated and the combustion energy required for that kinetic energy is calculated by using the vehicle efficiency. "Vehicle efficiency" refers to the ratio of the energy to be transferred to tyres' kinetic energy from the combustion energy excluding thermal loss and mechanical transfer loss.

The energy calculation in the use stage specified in the PCR consists of the following equations. For gasoline vehicles, "energy consumption" refers to the amount of combustion energy of the fuel.

(Total Energy Consumption [MJ/tyre]) = (energy consumption related to rolling resistance) + (energy consumption related to accelerating resistance)

Where, the energy consumption related to the rolling resistance is calculated with the following equation.

(Energy consumption related to rolling resistance) = (tyre rolling resistance coefficient) × (1 − (reduction rate of rolling resistance of ELT compared to a new one)/2) × (tyre load) × (tyre life) × (gravitational acceleration)/(vehicle efficiency)

Meanwhile, the energy consumption related to accelerating resistance is expressed as the following equation.

(Energy consumption related to accelerating resistance) = (tyre inertia force)/(vehicle efficiency) × (tyre life)

The differences in terms are supplemented here. While "tyre life" is used in Guidelines Ver. 3.0, in the PCR, "Reference Service Life" is used.

GHG emissions can be calculated as follows: First divide the total energy consumption related totyre by the fuel's lower heating value coefficient (e.g., Table 39 in the PCR) to calculate the fuel amount; and then multiply the fuel amount by the GHG emission coefficient (e.g., Table 11 in Guidelines Ver. 3.0).

As described above, the equations in the PCR involve parameters different from those in Guidelines Ver. 3.0. As long as adequate parameter values are used, users can use either method for calculation.

Note that because the PCR does not contain sufficient example data for the stages other than the use stage, Guidelines Ver. 3.0 only describes calculation for the use stage.

5. End of Life and Recycling Stage

The GHG emissions in the end of life and recycling stage are calculated as follows.

1) Ratios of disposal and recycling of ELT by application

Fig.4 shows the ratios of disposal and recycling of PC and TB ELT by application based on the 2019 statistics of ELT in a JATMA survey.

PC ELT is recovered as heat. TB ELT is recovered as heat, is reused through retreading, and is processed to manufacture rubber granulate and powder and reclaimed rubber for material recycling.

The majority in “other than recycling” is export. There is no data on how exported tyres are discarded and recycled, so it has been assumed that they are simply incinerated (worst-case scenario).

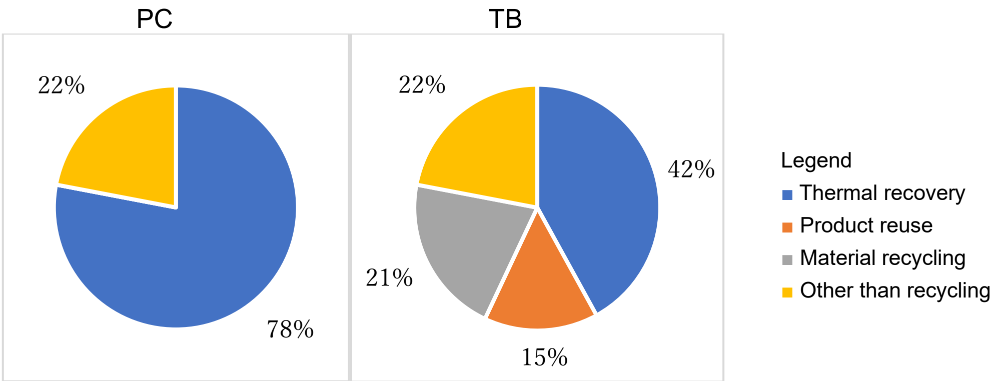



Fig. 4: Ratios of disposal and recycling of ELT by application

2) GHG emissions in ELT transportation

① ELT transportation conditions

Table 25 lists the conditions used to calculate GHG emissions in ELT transportation.

Table 25: ELT transportation conditions

| Class | Details | Remarks |
|---|---|---|
| Scope | Transportation from a branch to which ELT are brought (dealers and the like) to a waste treatment facility | — |
| Transportation distance | 100 km, one way | The assumed distance is from the prefecture border to another border as transportation within a prefecture. |
| Means of transportation | 2-ton truck | JATMA setting value |
| Load ratio | 50% | JATMA setting value |
| Fuel consumption calculation equation | Conforms to the Act on the Rationalization etc. of Energy Use | $\ln x = 2.71 - 0.812 \ln (y/100) - 0.654 \ln z$<br>x: Fuel consumption per cargo transportation volume (unit: l/t·km)<br>y: Load ratio (unit: %)<br>z: Maximum load of the cargo vehicle (unit: kg) |
| GHG emission coefficient for light oil | *** $kgCO_2e/l$ | IDEA, light oil combustion energy |
| GHG emission coefficient for ELT transportation | 0.0547 $kgCO_2e/kg$ | Fuel consumption × GHG emission coefficient ⁄ load weight |

② GHG emissions in ELT transportation

The GHG emissions per ELT in transportation are calculated with the following equation.

(GHG emissions in ELT transportation)

= (ELT weight) × (GHG emission coefficient for ELT transportation)

Table 26: GHG emissions per ELT in transportation

| Class | PC | | TB | | Unit | Remarks |
|---|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | | |
| New tyre weight (a) | 8.6 | 8.2 | 56.2 | 54.5 | kg | From Table 3 |
| Wear rate (b) | 15 | | 18 | | % | *1 |
| ELT weight (a) × (1 − b) | 7.3 | 7.0 | 46.1 | 44.7 | kg | |
| GHG emission coefficient for ELT transportation (c) | 0.0547 | | | | $kgCO_2e/kg$ | From Table 25 |
| GHG emissions in ELT transportation (a) × (1 − b) × (c) | 0.40 | 0.38 | 2.52 | 2.44 | $kgCO_2e$/tyre | |

*1: The weight reduction (%) when a tyre has completely worn out was determined by calculations based on the tyre specifications.

3) GHG emissions and emission reduction effects in thermal recycling

① GHG emissions in thermal recycling

a) Carbon content in new tyres

The carbon content of tyres is calculated according to the tyre raw material configuration ratios and the carbon content ratio of each raw material. Note that the renewable raw material (natural rubber) was excluded from the carbon content because it was regarded as a carbon-neutral raw material.

In addition, when ELT are used as a heat source (thermal recovery), sometimes a process for cutting the tyres is required. However, compared to burning tyres, the GHG emissions in cutting are extremely small (approximately 1/1,000), so it was excluded.

Table 27: Carbon content in new tyres*1

| Raw material | Carbon content (considering carbon neutral) | | | | Carbon content ratio*2 | Caron neutral*3 |
|---|---|---|---|---|---|---|
| | PC | | TB | | | |
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | | |
| New rubber | — | — | — | — | — | — |
| Natural rubber | 0.0 | 0.0 | 0.0 | 0.0 | 0.88 | 0 |
| Synthetic rubber | 54.3 | 47.7 | 20.5 | 18.9 | 0.89 | 1 |
| Carbon black | 49.0 | 40.5 | 51.0 | 46.4 | 0.98 | 1 |
| Process oil | 6.7 | 8.1 | 1.7 | 1.5 | 0.84 | 1 |
| Total of organic rubber chemicals*4 | 5.4 | 8.8 | 6.7 | 5.6 | 0.67 | 1 |
| Inorganic compounding agent | — | — | — | — | — | N |
| Zinc oxide | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | N |
| Sulfur | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | N |
| Silica | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | N |
| Total of fibers | 6.2 | 5.0 | 0.0 | 0.2 | 0.62 | 1 |
| Steel cord | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | N |
| Bead wire | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | N |
| Total | 121.6 | 110.0 | 79.8 | 72.5 | — | — |
| Ratio of carbon in a tyre*5 | 0.590 | 0.504 | 0.368 | 0.341 | — | — |

*1: Weight indexes when the new rubber weight is regarded as 100. Calculated by multiplying the raw material configuration ratios in Table 4 by the carbon content ratios.

*2: The carbon content ratio for each raw material was estimated by JATMA based on the basic molecular structure.

*3: Carbon neutral = 0; Not carbon neutral = 1; Raw material containing no carbon = N

*4: The values for the organic rubber chemical were calculated from the basic molecular structure of a representative vulcanizing accelerator and antioxidant.

*5: Calculated by dividing the total carbon content in this table by the total weight index when the new rubber weight is regarded as 100 shown in Table 4 (206.0 for conventional PC tyres).

b) Changes in material components and carbon content after tyres have worn out

Because only the rubber is worn in tyres, the weights of the total of fibers, steel cord, and bead wire were reduced from the total material weight of new tyre first, and then, the wear component weight of ELT was calculated proportionally according to the wear rate in Table 26.

Table 28: Changes in carbon content due to weight reduction by wear

| Class | | PC | | TB | | Remarks |
|---|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| New tyre | Total material weight (a) | 206.0 | 218.4 | 217.0 | 212.5 | *1 |
| | Wear component weight (b) | 173.0 | 186.8 | 173.0 | 167.3 | *2 |
| | Carbon content (c) | 121.6 | 110.0 | 79.8 | 72.5 | Calculated using Table 27 |
| | Carbon content rate (d) | 59.0% | 50.4% | 36.8% | 34.1% | |
| ELT | Total material weight (e) | 175.1 | 185.6 | 177.9 | 174.3 | (a) × (1 − wear rate*3) |
| | Wear component weight (f) | 142.1 | 154.0 | 133.9 | 129.1 | (b) − (a - e) |
| | Carbon content (g) | 101.0 | 91.6 | 61.8 | 56.0 | *4 |
| | Carbon content rate | 57.7% | 49.3% | 34.7% | 32.1% | (g)/(e) |

*1: Weight index when the new rubber weight is regarded as 100 shown in Table 4

*2: Values obtained by excluding the weight of total of fibers, steel cord, and bead wire from the total material weight (a)
(= rubber compound weight index)

*3: Specified in Table 26

*4: Total carbon content in the wear components in a new tyre (total of natural rubber, synthetic rubber, carbon black, process oil, and total of organic rubber chemicals in Table 27) × ((f)/(b)) + carbon content in the steel cord, bead wire, and total of fibers in a new tyre

c) GHG emissions per kg of ELT when burned

The GHG emissions per kg of ELT when burned are calculated with the following equation.

(GHG emissions per kg of ELT when burned)

= (carbon content rate for an ELT) × 44／12

Table 29: GHG emissions per kg of ELT when burned

| Class | PC | | TB | | Unit |
|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| Carbon content rate for an ELT (from Table 28) | 57.7 | 49.3 | 34.7 | 32.1 | % |
| GHG emissions per kg of ELT when burned | 2.114 | 1.808 | 1.273 | 1.179 | $kgCO_2e/kg$ |

d) GHG emissions per ELT when burned

The GHG emissions per ELT when burned are calculated with the following equation.

(GHG emissions per ELT when burned)

= (GHG emissions per kg of ELT when burned)

× (ELT weight)

Table 30: GHG emissions per ELT when burned

| Class | PC | | TB | | Unit |
|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| GHG emissions per kg of ELT when burned | 2.114 | 1.808 | 1.273 | 1.179 | $kgCO_2e/kg$ |
| ELT weight | 7.3 | 7.0 | 46.1 | 44.7 | kg |
| GHG emissions per ELT when burned | 15.5 | 12.6 | 58.7 | 52.7 | $kgCO_2e$/tyre |

② GHG emission reduction effects in thermal recovery

By recovering energy by using ELT as a heat source, it can be thought of as being substituted for the consumption of fossil fuels and GHG emissions are reduced. This reduction effects are calculated as follows.

a) Fossil fuel substituted as a result of thermal recovery of ELT

The paper manufacturing industry is a main user of heat from ELT. By interviewing paper manufacturing companies, it has been found that ELT is mainly used in place of heavy oil C. So this guidelines assume that ELT is a substitute for heavy oil C.

b) GHG emission reduction effects through thermal recovery of ELT

The GHG emission reduction effects through thermal recovery of ELT are calculated with the following equation.

(GHG emission reduction effects through thermal recovery of ELT)

= (GHG emission coefficient for heavy oil C) × (caloric value of a tyre) × (ELT weight)

Table 31: GHG emission reduction effects through thermal recycling of ELT

| Class | PC | | TB | | Unit | Remarks |
|---|---|---|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | | |
| GHG emission coefficient for heavy oil C | *** | | | | $kgCO_2e/MJ$ | *1 |
| Caloric value of a tyre | *** | | | | MJ/kg | *2 |
| ELT weight | 7.3 | 7.0 | 46.1 | 44.7 | kg | From table 26 |
| GHG emission reduction effects | −20.4 | −19.4 | −128.5 | −124.6 | $kgCO_2e$/tyre | |

*1: IDEA, heavy oil C combustion energy

*2: IDEA, gross calorific value of a waste tyre

③ GHG emissions in thermal recovery (overall)

GHG emissions in thermal recovery (overall) are calculated with the following equation.

For details on the summary results, refer to “Table 46: GHG emissions and emission reduction effects in the end of life and recycling stage.”

(GHG emissions in thermal recovery)

= (GHG emissions in ELT transportation)

\+ (GHG emissions per ELT when burned)

− (GHG emission reduction effects through thermal recovery of an ELT)

4) GHG emissions and emission reduction effects in product reuse through retreading

GHGs are emitted in product reuse through retreading as listed below.

[GHG emissions]

• Manufacturing of retread compound raw materials
• Transportation of retread compound raw materials
• Mixing of retread compounds
• Retread tyre production

Note: "Compound" refers to rubber that was manufactured by combining and blending various raw materials (natural rubber, synthetic rubber, carbon black, process oil, organic rubber chemicals, and inorganic compounding agents).

[GHG emission reduction effects]

• Retread tyres are a substitute for new tyre manufacturing (reduction effect).

As preconditions, the life and rolling resistance of retread tyre were regarded as the same as new one. However, the calculation should be adjusted based on actual conditions.

① GHG emissions in product reuse through retreading

a) GHG emissions in retread compound raw material manufacturing

(i) Retread compound raw material configuration ratios and GHG emissions in manufacturing

The GHG emissions in retread compound manufacturing are calculated with the following equation.

(GHG emissions in retread compound manufacturing)
= Σ{(weight of each raw material in the retread compound)
× (GHG emission coefficient for the raw material)}

Table 32: Retread compound raw material configuration ratios and GHG emissions in manufacturing

| Class | Configuration ratio (kg) | GHG emission coefficient ($kgCO_2e/kg$) | GHG emissions ($kgCO_2e$) |
|---|---|---|---|
| Natural rubber | 70 | $6.71 \times 10^{-1}$ | 46.97 |
| Synthetic rubber | 30 | 3.71 | 111.30 |
| Carbon black | 48 | *** | *** |
| Process oil | 7 | *** | *** |
| Organic rubber chemical | 7 | *** | *** |
| Zinc oxide | 3 | *** | *** |
| Sulfur | 2 | *** | *** |
| Silica | 0 | *** | 0 |
| Total | 167 | — | 375.35 |
| Total raw material weight/ new rubber ratio | 1.67 | | |

*The configuration ratios were determined based on JATMA survey.

Accordingly, the GHG emissions per kg of retread compound are as shown below.
(GHG emissions per kg of retread compound)
= GHG emissions／total material weight (kg)
= 375.35／167 = 2.25 $kgCO_2e/kg$

(ii) Retread compound weight
The ratio of the number of summer tyres to that of winter tyres was set to 1:1 based on an inquiry to Japan Retreaders' Association for calculation.
Based on a JATMA internal survey, the weights were set as follows: Summer tyres: 15 kg; winter tyres: 19 kg
$15 \times 0.5 + 19 \times 0.5 = 17.0$ kg

(iii) GHG emissions per tyre in the retread compound raw material stage
(GHG emissions in the retread compound raw material stage)
= (GHG emissions per kg of retread compound)
× retread compound weight
= $2.25 \times 17.0 = 38.21$ $kgCO_2e$/tyre

Table 33: GHG emissions per tyre in the retread compound raw material stage

(Unit: $kgCO_2e$/tyre)

| Class | GHG emissions |
|---|---|
| GHG emissions per tyre | 38.21 |

b) GHG emissions in retread compound raw material transportation
GHG emissions in retread compound raw material transportation are considered in a same way as that for tyre raw material transportation (Table 9: GHG emissions in raw material transportation). The GHG emission coefficient and GHG emissions in retread compound raw material transportation are calculated with the following equations.
(GHG emissions in retread compound raw material transportation ($kgCO_2e$))
= Σ{(weight of each retread compound raw material)
× (GHG emission coefficient for transportation of the raw material)}

Table 34: Retread compound raw material configuration ratios and GHG emissions in transportation

| Class | Configuration ratio (kg) | GHG emission coefficient ($kgCO_2e/kg$) | GHG emissions ($kgCO_2e$) |
|---|---|---|---|
| Natural rubber | 70 | $2.97 \times 10^{-1}$ | 20.79 |
| Synthetic rubber | 30 | *** | *** |
| Carbon black | 48 | *** | *** |
| Process oil | 7 | *** | *** |
| Organic rubber chemical | 7 | *** | *** |
| Zinc oxide | 3 | *** | *** |
| Sulfur | 2 | *** | *** |
| Total | 167 | — | 30.05 |

The GHG emission coefficient for transportation per kg of retread compound raw material is calculated with the following equation.
(GHG emission coefficient for transportation per kg of retread compound raw material)
= 30.05／167 = 0.180
Accordingly, the GHG emissions per tyre in retread compound raw material transportation are calculated with the following equation.
(GHG emissions per tyre in retread compound raw material transportation)
= (retread compound raw material weight)
× (GHG emission coefficient for transportation per kg of retread compound raw material)

Table 35: GHG emissions per tyre in retread compound raw material transportation

| Class | Value | Unit |
|---|---|---|
| Retread compound raw material weight | 17.0 | kg |
| GHG emission coefficient for transportation per kg of retread compound raw material | 0.180 | $kgCO_2e/kg$ |
| GHG emissions per tyre in retread compound raw material transportation | 3.06 | $kgCO_2e$/tyre |

c) GHG emissions in mixing of retread compounds
(i) GHG emissions in mixing of retread compounds (per new rubber)
Retread compounds are usually mixed at tyre factories and the main energy used in the mixing process is electric power. The GHG emissions are calculated as follows.
The GHG emissions per kg of new rubber for TB tyres from electric power used in the production stage are calculated by multiplying electric power-derived GHG emissions, which are shown in Table 12 (0.684 $kgCO_2e/kg$), by the rate of electric power-derived GHG emissions for TB, which is shown in Table 15 (average of conventional and fuel-efficient tyres: 0.775). In addition, the electric power-derived GHG emissions are the value for all production processes, so the emissions in the mixing process are calculated by multiplying by 0.39, which is the ratio of the electric power used in the mixing process to that in all processes (results of a survey of JATMA member companies in 2019). Table 36 lists the values.

(GHG emissions per kg of new rubber in mixing of retread compounds)
= (GHG emissions per kg of new rubber from the electric power used in the production stage)
× (rate of electric power-derived GHG emissions for TB tyres) × (ratio of the electric power used in the mixing process to that in all processes)

Table 36: GHG emissions in mixing of retread compounds (per kg of new rubber)

| Class | Value | Unit |
|---|---|---|
| GHG emissions per kg of new rubber from the electric power used in the production stage (average of all PC and TB) | 0.684 | $kgCO_2e/kg$ |
| Rate of electric power-derived GHG emissions for TB tyres (average of conventional and fuel-efficient tyres) | 0.775 | — |
| Ratio of the electric power used in the mixing process to that in all processes | 0.39 | — |
| GHG emissions per kg of new rubber in mixing of retread compounds | 0.207 | $kgCO_2e/kg$ |

(ii) GHG emissions per tyre in mixing of retread compounds
The GHG emissions per tyre in mixing of retread compounds are calculated by dividing the GHG emissions per kg of retread compound by the retread compound /new rubber weight ratio, and then multiplying the result by the retread compound weight.
(GHG emissions per tyre in mixing of retread compounds)
= (GHG emissions per kg of new rubber in mixing of retread compounds)
∕(retread compound /new rubber weight ratio) × (retread compound weight)

Table 37: GHG emissions per tyre in mixing of retread compounds

| Class | Value | Unit |
|---|---|---|
| GHG emissions per kg of new rubber in mixing of retread compounds | 0.207 | $kgCO_2e/kg$ |
| Retread compound /new rubber weight ratio | 1.67 | — |
| Retread compound raw material weight | 17.0 | kg |
| GHG emissions per tyre in mixing of retread compounds | 2.105 | $kgCO_2e/tyre$ |

d) GHG emissions in retread tyre production

The GHG emissions per retread tyre in production are calculated with the following equation.

(GHG emissions in retread tyre production)

= (consumption of energy per retread tyre in production) × (GHG emission coefficient for the energy)

Table 38: GHG emissions per retread tyre in production

| Class | Energy consumption in retread tyre production (a)*1 | GHG emission coefficient ($kgCO_2e$/unit) (b)*2 | GHG emissions ($kgCO_2e$) (a × b) |
|---|---|---|---|
| Heavy oil A (l) | 4.02 | *** | *** |
| Kerosene (l) | 0.01 | *** | *** |
| Light oil (l) | 0.35 | *** | *** |
| Gasoline (l) | 0.06 | *** | *** |
| Natural gas ($Nm^3$) | 0.11 | *** | *** |
| Electric power (kWh) | 11.71 | *** | *** |
| GHG emissions per retread tyre in production | — | — | 21.26 |

*1: The energy consumption in retread tyre production was determined based on a JATMA survey.

*2: The GHG emission coefficients are the same as those in Table 11 (that for natural gas, which was not included in Table 11, was determined based on the natural gas combustion energy in IDEA).

e) GHG emissions per tyre in product reuse through retreading

The GHG emissions per tyre in product reuse through retreading are as shown in the table below from the afore-mentioned calculation.

Table 39: GHG emissions per tyre in product reuse through retreading

(Unit: $kgCO_2e$/tyre)

| Class | GHG emissions |
|---|---|
| Retread compound raw material production stage | 38.2 |
| Retread compound raw material transportation stage | 3.1 |
| Retread compound mixing stage | 2.1 |
| Retread tyre production stage | 21.3 |
| Total GHG emissions per tyre in product reuse through retreading | 64.6 |

② GHG emission reduction effects in product reuse through retreading
It can be assumed that reusing ELT through retreading can substitute for raw material production, raw material transportation, and production of new tyre. The GHG emission reduction effects per tyre in product reuse through retreading were calculated while referring to the GHG emissions per new tyre in each stage shown in Tables 6, 9, and 19. Table 40 lists the calculation results.

Table 40: GHG emission reduction effects per tyre in product reuse through retreading

(Unit: $kgCO_2e$/tyre)

| Class | TB | |
|---|---|---|
| | Conventional tyre | Fuel-efficient tyre |
| GHG emission reduction in raw material production | −137.3 | −129.3 |
| GHG emission reduction in raw material transportation | −9.4 | −9.3 |
| GHG emission reduction in new tyre production | −39.5 | −39.8 |
| Total GHG emission reduction per tyre in product reuse through retreading | −186.2 | −178.4 |

③ GHG emissions in product reuse through retreading (overall)
The GHG emissions in product reuse through retreading (overall) are calculated with the following equation. For details on the summary results, refer to “Table 46: GHG emissions and emission reduction effects in the end of life and recycling stage.”
(GHG emissions in product reuse through retreading (overall))
= (GHG emissions in product reuse through retreading)
− (GHG emission reduction effects in product reuse through retreading)

5) GHG emissions and emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

① GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber
a) GHG emissions in the production stage in material recycling through manufacturing rubber granulate and powder and reclaimed rubber (per unit weight)
(i) GHG emissions per kg of rubber granulate and powder in the rubber granulate and powder production stage
In material recycling of tyres, they are mainly reused as rubber granulate and powder and reclaimed rubber.
The GHG emissions when ELT is reprocessed into rubber granulate and powder and reclaimed rubber at reclaimed rubber factories were calculated from their energy consumption.
The energy data on material recycling through manufacturing rubber granulate and powder and reclaimed rubber was obtained from the Japan Reclaimed Rubber Manufacturers Association in 2019.
The GHG emissions in the rubber granulate and powder production stage are calculated with the following equation.
(GHG emissions per kg of rubber granulate and powder in the production stage)
= (electric power consumption per kg of rubber granulate and powder in the production stage)
× (GHG emission coefficient for electric power)

Table 41: GHG emissions per kg of rubber granulate and powder in the production stage

| Class | Value | Unit | Source/background |
|---|---|---|---|
| Electric power consumption per kg of rubber granulate and powder in the production stage | 0.660 | kWh/kg | Interviewed the Japan Reclaimed Rubber Manufacturers Association |
| GHG emission coefficient for electric power | *** | $kgCO_2e/kWh$ | IDEA, electric power, average in Japan, FY2017 |
| GHG emissions per kg of rubber granulate and powder in the production stage | *** | $kgCO_2e/kg$ | |

(ii) GHG emissions per kg of reclaimed rubber in the production stage

The GHG emissions in the reclaimed rubber production stage are calculated with the following equation.

(GHG emissions per kg of reclaimed rubber in the production stage)
= (electric power consumption per kg of reclaimed rubber in the production stage)
× (GHG emission coefficient for electric power)
+ (heavy oil A consumption per kg of reclaimed rubber in the production stage)
× (GHG emission coefficient for heavy oil A)

Table 42: GHG emissions per kg of reclaimed rubber in the production stage

| Class | | Value | Unit | Source/background |
|---|---|---|---|---|
| Consumption | Electric power consumption per kg of reclaimed rubber in the production stage | 1.44 | kWh/kg | Interviewed the Japan Reclaimed Rubber Manufacturers Association |
| | Heavy oil A consumption per kg of reclaimed rubber in the production stage | 0.07 | l/kg | Same as above |
| GHG emission coefficient | GHG emission coefficient for electric power | *** | $kgCO_2e/kWh$ | IDEA, electric power, average in Japan, FY2017 |
| | GHG emission coefficient for heavy oil A | *** | $kgCO_2e/l$ | IDEA, heavy oil A combustion energy |
| GHG emissions (per unit weight) | GHG emissions per kg of reclaimed rubber from electric power used in the production stage | *** | $kgCO_2e/kg$ | |
| | GHG emissions per kg of reclaimed rubber from heavy oil A used in the production stage | *** | $kgCO_2e/kg$ | |
| | GHG emissions per kg of reclaimed rubber in the production stage | *** | $kgCO_2e/kg$ | |

c) GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

(i) Weights in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

The weights of ELT used for material recycling through manufacturing rubber granulate and powder and reclaimed rubber have been reduced due to wear. In addition, ELT is divided into the part mainly consisting of rubber that can be reused as rubber granulate and powder and reclaimed rubber and the part that cannot be reused as recycled rubber (cord and steel parts). The weights in material recycling were determined as shown in the table below.

Table 43: Weights in material recycling

| Class | | TB | | Unit | Remarks |
|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | | |
| New tyre | New tyre weight (a) | 56.2 | 54.5 | kg/tyre | From Table 3 |
| | Proportion of the recyclable part (b) | 80 | 79 | % | *1 |
| | Weight of the recyclable part in a new tyre (a) × (b) | 44.80 | 42.91 | kg/tyre | |
| ELT | Wear rate (c) | 18 | 18 | % | From Table 26 |
| | Wear amount (a) × (c) | 10.12 | 9.81 | kg/tyre | |
| | ELT weight (a) − (a × c) | 46.08 | 44.69 | kg/tyre | |
| | Weight of the recyclable part in an ELT (a × b) − (a × c) | 34.69 | 33.10 | kg/tyre | |
| Rubber granulate and powder and reclaimed rubber | Yield to rubber granulate and powder and reclaimed rubber from an ELT (d) | 90 | 90 | % | Interviewed the Japan Reclaimed Rubber Manufacturers Association*2 |
| | Reclaimed rubber yield ((a × b) − (a × c)) × (d) | 31.22 | 29.79 | kg/tyre | |

*1: Proportion of the recyclable part: Percentage of natural rubber, synthetic rubber, carbon black, process oil, organic rubber chemicals, and inorganic compounding agents

*2: Parts that cannot be processed into rubber granulate and powder and reclaimed rubber are recycled mainly in the cement and steelmaking industries.

(ii) GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

The GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber are calculated with the following equation.

(GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber)

= (GHG emissions in rubber granulate and powder and reclaimed rubber production)

= (reclaimed rubber yield) × {(GHG emissions per kg of rubber granulate and powder in the production stage) + (GHG emissions per kg of reclaimed rubber in the production stage)}

Table 44: GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

| Class | TB | | Unit |
|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | |
| Reclaimed rubber yield | 31.22 | 29.79 | kg/tyre |
| GHG emissions per kg of rubber granulate and powder in the production stage | *** | | $kgCO_2e/kg$ |
| GHG emissions per kg of reclaimed rubber in the production stage | *** | | $kgCO_2e/kg$ |
| GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber | 45.8 | 43.7 | $kgCO_2e$/tyre |

② GHG emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

It can be assumed that material recycling through manufacturing rubber granulate and powder and reclaimed rubber can substitute for the production of compounds for tyres and various industrial rubber products (e.g., rubber belts, rubber hoses, and rubber plates). Considering the yield of rubber granulate and powder and reclaimed rubber produced from ELT, the GHG emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber is calculated with the following equation.

(GHG emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber)
= (weight of the recyclable part in an ELT)
× (yield to rubber granulate and powder and reclaimed rubber from an ELT)
× (GHG emission coefficient for the compound)

Table 45: GHG emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber

| Class | TB | | Unit |
|---|---|---|---|
| | Conventional tyre | Fuel-efficient tyre | |
| Weight of the recyclable part in an ELT (a) | 34.69 | 33.10 | kg/tyre |
| Yield to rubber granulate and powder and reclaimed rubber from an ELT (b) | 90 | 90 | % |
| Reclaimed rubber yield (a × b) | 31.22 | 29.79 | kg/tyre |
| GHG emission coefficient for the compound* | 2.27 | 2.16 | $kgCO_2e/kg$ |
| GHG emission reduction effects in material recycling | −70.76 | −64.20 | $kgCO_2e$/tyre |

*Coefficient that can be obtained by multiplying the GHG emission coefficient for each raw material contained in the compound in the production by the raw material configuration ratio and then dividing by the total compound weight. The values for conventional TB and fuel-efficient TB tyres shown in Tables 4 and 5 were used to calculate each value.

③ GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber (overall)

The GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber (overall) are calculated with the following equation. For details on the summary results, refer to "Table 46. GHG emissions and emission reduction effects in the end of life and recycling stage."

(GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber (overall))
= (GHG emissions in material recycling through manufacturing rubber granulate and powder and reclaimed rubber)
− (GHG emission reduction effects in material recycling through manufacturing rubber granulate and powder and reclaimed rubber)

6) GHG emissions and emission reduction effects in the end of life and recycling stage

① GHG emissions and emission reduction effects in the end of life and recycling stage

The GHG emissions and emission reduction effects through recycling in the end of life stage were calculated by weighting the GHG emissions for each recycling method according to the recycling ratio in Fig. 4. The table below lists the calculated values.

Table 46: GHG emissions and emission reduction effects in the end of life and recycling stage

(Unit: $kgCO_2e$/tyre)

| Class | | PC | | TB | | Remarks |
|---|---|---|---|---|---|---|
| | | Conventional tyre | Fuel-efficient tyre | Conventional tyre | Fuel-efficient tyre | |
| Recycling ratio | Thermal recovery | 78% | | 42% | | Fig. 4 |
| | Product reuse | — | | 15% | | |
| | Material recycling | — | | 21% | | |
| | Other than recycling | 22% | | 22% | | |
| GHG emissions | Transportation | 0.4 | 0.4 | 2.5 | 2.4 | Table 26 |
| | Thermal recovery | 12.1 | 9.8 | 24.6 | 22.1 | GHG emissions in Table 30 × thermal recovery ratio |
| | Product reuse | — | — | 9.7 | 9.7 | GHG emissions in Table 39 × product reuse ratio |
| | Material recycling | — | — | 9.6 | 9.2 | GHG emissions in Table 44 × material recycling ratio |
| | Incineration | 3.4 | 2.8 | 12.9 | 11.6 | GHG emissions in Table 30 × ratio of other than recycling |
| Emission reduction effects | Thermal recovery | −15.9 | −15.2 | −54.0 | −52.3 | GHG emission reduction in Table 31 × thermal recovery ratio |
| | Product reuse | — | — | −27.9 | −26.8 | GHG emission reduction in Table 40 × product reuse ratio |
| | Material recycling | — | — | −14.9 | −13.5 | GHG emission reduction in Table 45 × material recycling ratio |

6. Lifecycle GHG Emissions

The table below lists the total GHG emissions for the representative types of tyres in their lifecycles.

Table 47: Lifecycle GHG emissions (details)

(Unit: $kgCO_2e$/tyre)

<table>
<tr><th colspan="3" rowspan="2">Class</th><th colspan="3">PC</th><th colspan="2">TB</th></tr>
<tr><th>Conventional tyre</th><th>Fuel-efficient tyre A</th><th>Fuel-efficient tyre B</th><th>Conventional tyre</th><th>Fuel-efficient tyre</th></tr>
<tr><td colspan="2" rowspan="2">Raw material procurement stage</td><td>Raw material production</td><td>26.3</td><td colspan="2">23.8</td><td>137.3</td><td>129.3</td></tr>
<tr><td>Raw material transportation</td><td>1.1</td><td colspan="2">1.1</td><td>9.4</td><td>9.3</td></tr>
<tr><td colspan="2">Production stage</td><td>Production</td><td>6.9</td><td colspan="2">6.6</td><td>39.5</td><td>39.8</td></tr>
<tr><td colspan="2">Distribution stage</td><td>Transportation</td><td>0.9</td><td colspan="2">0.9</td><td>5.8</td><td>5.7</td></tr>
<tr><td colspan="2">Use stage</td><td>Use</td><td>250.5</td><td>212.3</td><td>155.1</td><td>2,326.9</td><td>1,447.9</td></tr>
<tr><td rowspan="5">End of life and recycling stage</td><td rowspan="5">Emissions</td><td>Transportation</td><td>0.4</td><td colspan="2">0.4</td><td>2.5</td><td>2.4</td></tr>
<tr><td>Thermal recovery</td><td>12.1</td><td colspan="2">9.8</td><td>24.6</td><td>22.1</td></tr>
<tr><td>Product reuse</td><td>—</td><td colspan="2">—</td><td>9.7</td><td>9.7</td></tr>
<tr><td>Material recycling</td><td>—</td><td colspan="2">—</td><td>9.6</td><td>9.2</td></tr>
<tr><td>Simple incineration</td><td>3.4</td><td colspan="2">2.8</td><td>12.9</td><td>11.6</td></tr>
<tr><td colspan="3">Total GHG emissions</td><td>301.5</td><td>257.6</td><td>200.4</td><td>2,578.4</td><td>1,687.0</td></tr>
<tr><td rowspan="3">End of life and recycling stage</td><td rowspan="3">Reduction effects</td><td>Thermal recovery</td><td>−15.9</td><td colspan="2">−15.2</td><td>−54.0</td><td>−52.3</td></tr>
<tr><td>Product reuse</td><td>—</td><td colspan="2">—</td><td>−27.9</td><td>−26.8</td></tr>
<tr><td>Material recycling</td><td>—</td><td colspan="2">—</td><td>−14.9</td><td>−13.5</td></tr>
<tr><td colspan="3">Lifecycle GHG emissions (considering reduction effects)</td><td>285.6</td><td>242.5</td><td>185.2</td><td>2,481.6</td><td>1,594.4</td></tr>
</table>

Table 48: Lifecycle GHG emissions (by stage)

(Unit: $kgCO_2e$/tyre)

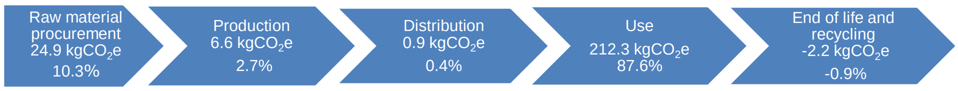
| Class | PC | | | | | | TB | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Conventional tyre | | Fuel-efficient tyre A | | Fuel-efficient tyre B | | Conventional tyre | | Fuel-efficient tyre | |
| Raw material procurement stage | 27.4 | 9.6% | 24.9 | 10.3% | 24.9 | 13.4% | 146.7 | 5.9% | 138.6 | 8.7% |
| Production stage | 6.9 | 2.4% | 6.6 | 2.7% | 6.6 | 3.5% | 39.5 | 1.6% | 39.8 | 2.5% |
| Distribution stage | 0.9 | 0.3% | 0.9 | 0.4% | 0.9 | 0.5% | 5.8 | 0.2% | 5.7 | 0.4% |
| Use stage | 250.5 | 87.7% | 212.3 | 87.6% | 155.1 | 83.7% | 2,326.9 | 93.8% | 1,447.9 | 90.8% |
| End of life and recycling stage | 0.0 | 0.0% | −2.2 | −0.9% | −2.2 | −1.2% | −37.4 | −1.5% | −37.5 | −2.4% |
| Emissions | 15.9 | 5.6% | 13.0 | 5.4% | 13.0 | 7.0% | 59.4 | 2.4% | 55.0 | 3.5% |
| Emission reduction effects | −15.9 | −5.6% | −15.2 | −6.3% | −15.2 | −8.2% | −96.8 | −3.9% | −92.6 | −5.8% |
| Total | 285.6 | 100.0% | 242.5 | 100.0% | 185.2 | 100.0% | 2,481.6 | 100.0% | 1,594.4 | 100.0% |

[PC]

Lifecycle GHG emissions per conventional tyre = 285.6 $kgCO_2e$

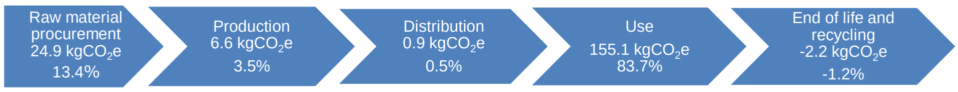

*GHG emissions in the end of life and recycling stage: emission = 15.9 $kgCO_2e$, reduction effects = −15.9 $kgCO_2e$

Lifecycle GHG emissions per fuel-efficient tyre A = 242.5 $kgCO_2e$




*GHG emissions in the end of life and recycling stage: emission = 13.0 $kgCO_2e$, reduction effects = −15.2 $kgCO_2e$

Lifecycle GHG emissions per fuel-efficient tyre B = 185.2 $kgCO_2e$



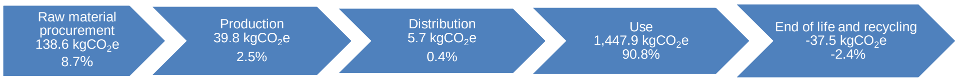

*GHG emissions in the end of life and recycling stage: emission = 13.0 $kgCO_2e$, reduction effects = −15.2 $kgCO_2e$

[TB]

Lifecycle GHG emissions per conventional tyre = 2,481.6 $kgCO_2e$

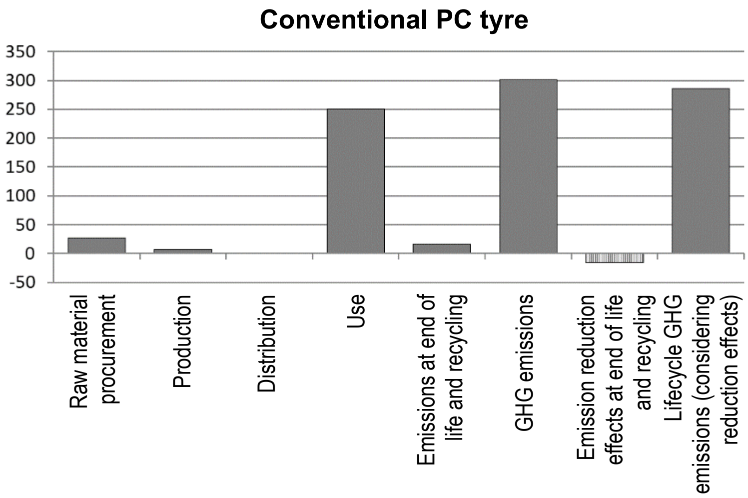

*GHG emissions in the end of life and recycling stage: emission = 59.4 $kgCO_2e$, reduction effects = −96.8 $kgCO_2e$

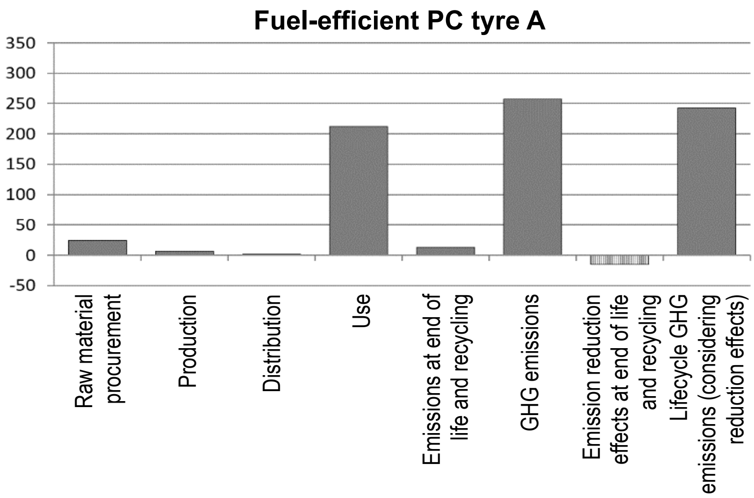
Lifecycle GHG emissions per fuel-efficient tyre = 1,594.4 $kgCO_2e$




*GHG emissions in the end of life and recycling stage: emission = 55.0 $kgCO_2e$, reduction effects = −92.6 $kgCO_2e$

Fig. 5: Lifecycle GHG emissions (figure)



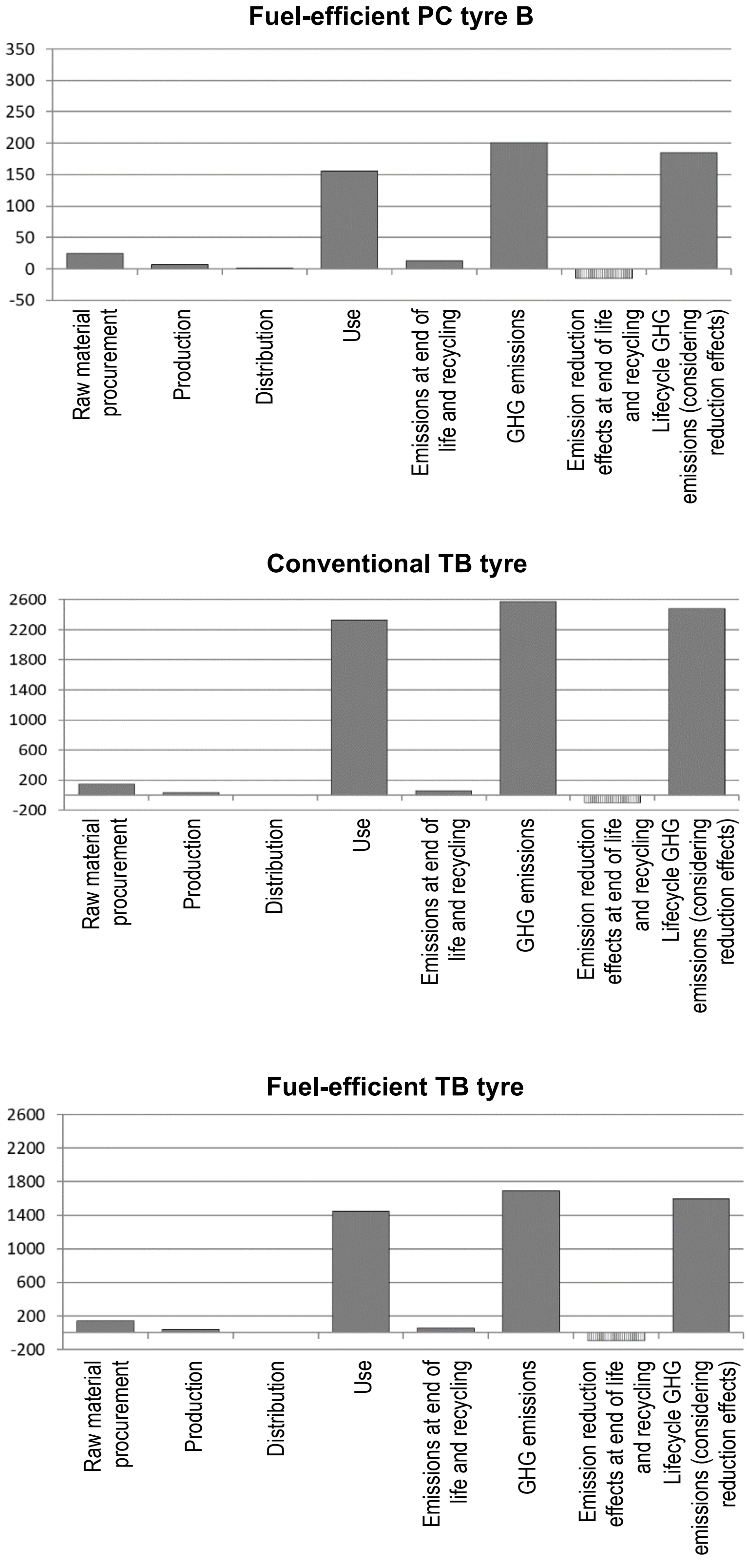



Fig. 6: Lifecycle GHG emissions (graphs)

In Guidelines Ver. 3.0, the life of each tyre was considered to be the same and assessment was performed per tyre. However, when tyres for which the life varies are compared, comparison per tyre is not adequate. In such a case, tyres may be compared using unit distance as an example. In that case, calculate $LCCO_2$ for each tyre with a different tyre life as described in Guidelines Ver. 3.0 and convert the results into emissions per unit distance for comparison.

GHG emissions per unit travel distance = $LCCO_2$ from the tyre × unit travel distance／tyre life

7. Future Tasks

• Guidelines Ver. 3.0 do not involve sensitivity analysis of results and uncertainty analysis that are report items in accordance with ISO14040:2006 or ISO14044:2006. This analysis is a task for the future.

• The GHG emission coefficient for natural rubber in Table 5 is based on an old document (1979). Because there is no better assessment as of now, the coefficient was considered adequate. However, we understand the value needs to be updated.

8. References


① PCR:
https://www.ul.com/news/tire-industry-project-announces-first-pcr-tires-industry-developed-ul

② JATMA labeling system:
https://www.jatma.or.jp/english/labeling/outline.html

③ Average RRC value in the market for PC tyres (JATMA survey results):
https://www.jatma.or.jp/english/tyrerecycling/pdf/news1211e.pdf

④ Average vehicle fuel consumption values in the market (Japanese Ministry of Land, Infrastructure, Transport and Tourism):
https://www.mlit.go.jp/k-toukei/nenryousyouhiryou.html (Japanese)

Ⅳ. Critical Review Statement

# CERTIFICATE

CERTIFICATE NUMBER: CR2020001

**The Japan Automobile Tyre Manufacturers Association, Inc.**

**LCAF certifies**

## Tyre LCCO2 Calculation Guidelines Ver. 3.0

**is in accordance with requirements of the following standards**
**as a result of the critical review panel conducted on December 22, 2020**

**ISO 14040: 2006**
Environmental management -Life cycle assessment -Principles and framework

**ISO 14044: 2006**
Environmental management -Life cycle assessment -Requirements and guidelines

A Certificate on December 22, 2020

Japan Life Cycle Assessment Facilitation Centre (LCAF) President

Atsushi Inaba

Dr. Atsushi INABA

Chairperson of Critical Review Panel

Atsushi Inaba

Dr. Atsushi INABA

LCAF Japan Life Cycle Assessment Facilitation Centre

V. Revision History

| Version | Revision Date | Description |
|---|---|---|
| 1.0 | November 1998 | “Tire Inventory Analysis Trials – LCA Analysis and Research Activities in the Rubber Industry” issued by The Japan Rubber Manufacturers Association |
| 2.0 | April 2012 | “Tyre $LCCO_2$ Calculation Guidelines Ver.2.0” Issued |
| 3.0 | March 2021 | “Tyre $LCCO_2$ Calculation Guidelines Ver.3.0” Issued |
| 3.0.1 | December 2021 | Corrected GHG emission coefficients for “Process oil production” and “Total of Fibers production” and recalculated values accordingly. |