Tyre $LCCO_2$ Calculation Guidelines
Ver. 2.0

April 2012

The Japan Automobile Tyre Manufacturers Association, Inc.

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I. Introduction

LCA (lifecycle assessment) is a method used for quantitatively calculating, analyzing and evaluating the impact on the environment throughout the entire lifecycle from procurement of the raw materials for the commercial product or service, to discarding and recycling. With $LCCO_2$, greenhouse gasses (hereinafter referred to as GHG) emitted through the entire lifecycle are converted to CO2 for calculation. By visualizing GHG emission amounts, vendors will strive to reduce GHG emission amounts further by cooperating with other businesses that compose their supply chain, and conversely, consumers will transform their own consumer habits to one that consumes lower amounts of carbon, by utilizing information that is provided. The *Tyre Industry of Japan* took the lead in the tide relating to LCA at the time, has a track record in collecting and using the "*Tire Inventory Analysis Trials – LCA Analysis and Research Activities in the Rubber Industry*" (Issued November, 1998; hereinafter referred to as the 1998 Guidelines) that was an example calculation for automobile tyres conducted by the *Japan Rubber Manufacturers Association*, the Environmental Experts Committee and the LCA subcommittee.

Meanwhile, last year, standards and systems and the like related to LCA (ISO Environment Standard 14000 Series, PAS2050, BPX30-323, GHG protocol, Japan Carbon Footprint Institution) in Japan and elsewhere were widened and revised. Domestically as well, discussions have been advanced in the study committee (*Ministry of Economy, Trade and Industry*/survey and research relating to GHG emission amount calculating standards for organizations that compose the supply chain; From June, 2010; the *Ministry of the Environment*/committee for GHG emission amount calculation methods in the supply chain; From July, 2010) relating to LCA that is sponsored by related Ministries. Also, considering that the 1998 Guidelines that had been used by the tyre and rubber industry until now had been in use for more than a decade, we believed that the tyre LCA calculation methods needed to be reviewed. From 2010, JATMA, engineering committees and environmental committees have been considering these revisions.

Furthermore, the *Mizuho Information & Research Institute, Inc*. cooperated and was consigned the work as an expert positioned for fairness, and the propriety of a third party to these Guidelines, and to apply the Guidelines the latest domestic and international trends and knowledge they uncovered.

These Guidelines reference and follow standard contents such as ISO14044, the Japanese Carbon Footprint system, PAS2050, BPX30-323, and GHG protocol and the like, based on the 1998 Guidelines that have a track record for use. Particularly, ISO14040:2006 and ISO14044:2006 which are international standards are indicators for satisfying the standard contents such as the assumed conditions and calculation methods, excluding collection content of data implemented individually and issues such as some sensitivity analyses. It is possible to implement calculations that conform to those standards by using these Guidelines.

However, this is not intended completely to cover the reporting formats and report items (for example the setting of functional units and standard flow) pursuant to ISO14040:2006 and ISO14044:2006, so when considering complete compliance with ISO14040:2006 and ISO14044:2006, the pertinent standard contents shall be referenced.

These Guidelines are an activity report on the environment committee, and summarize the basic methods for tyre LCA calculating methods. Furthermore, these Guidelines should provide some assistance in calculating tyre LCA by interested parties.

[Notes]
These Guidelines (this edition) are publicly released material. They have been released on the JATMA homepage and others.
Note that the CO_2 emission amounts and various data, including the raw materials listed in these guidelines are representative data provided to aid in your understanding of the calculations.

April 2012

The Japan Automobile Tyre Manufacturers Association, Inc.
Technical Committee, Environment Subcommittee

Environment Subcommittee Members and Related Personnel Involved in Summarizing These Guidelines

(Listed with title at the time of publishing) (Honorifics omitted)

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II. Philosophy of $LCCO_2$ Calculations

1. Purpose

• To calculate greenhouse gas emission amounts in the lifecycle of tyres.

These Guidelines summarize the basic methods for calculating greenhouse gas emission amounts in the lifecycle of tyres.

In view of the diffusion of fuel efficient tyres that have been in the market over the last few years, there is a method for quantitatively comparing general tyres and fuel efficient tyres

2. Targeted Tyres

• PCR (Tyres for passenger vehicles)

• TBR (Tyres for trucks and busses)

3. Greenhouse Gasses Targeted for Calculation

The following seven types of gasses are targeted for calculation.

Table 1. Gasses Targeted for Calculation

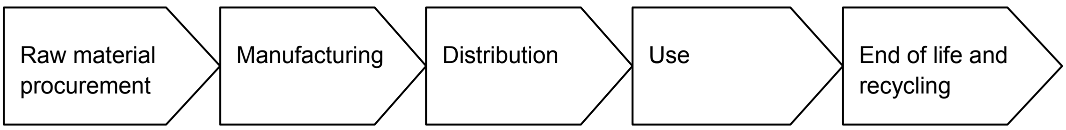
Symbol	Name
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Per fluorocarbons
SF_6	Sulfur hexafluoride
NF_3	Nitrogen trifluoride

Note: At the time of publishing these Guidelines, HFCs, PFCs, SF6 and NF3 were not adequately known to be emitted during the tyre lifecycle. For that reason, they are not allocated as emission amounts. However, if it is possible peculiarly to know these, it is necessary to allocate for them.

4. Scope of Lifecycle to be Calculated (System Boundary and Standard Flow)

The scope of the lifecycle consists of the next 5 steps:

Raw material procurement, manufacturing, distribution, use, and end of life and recycling.



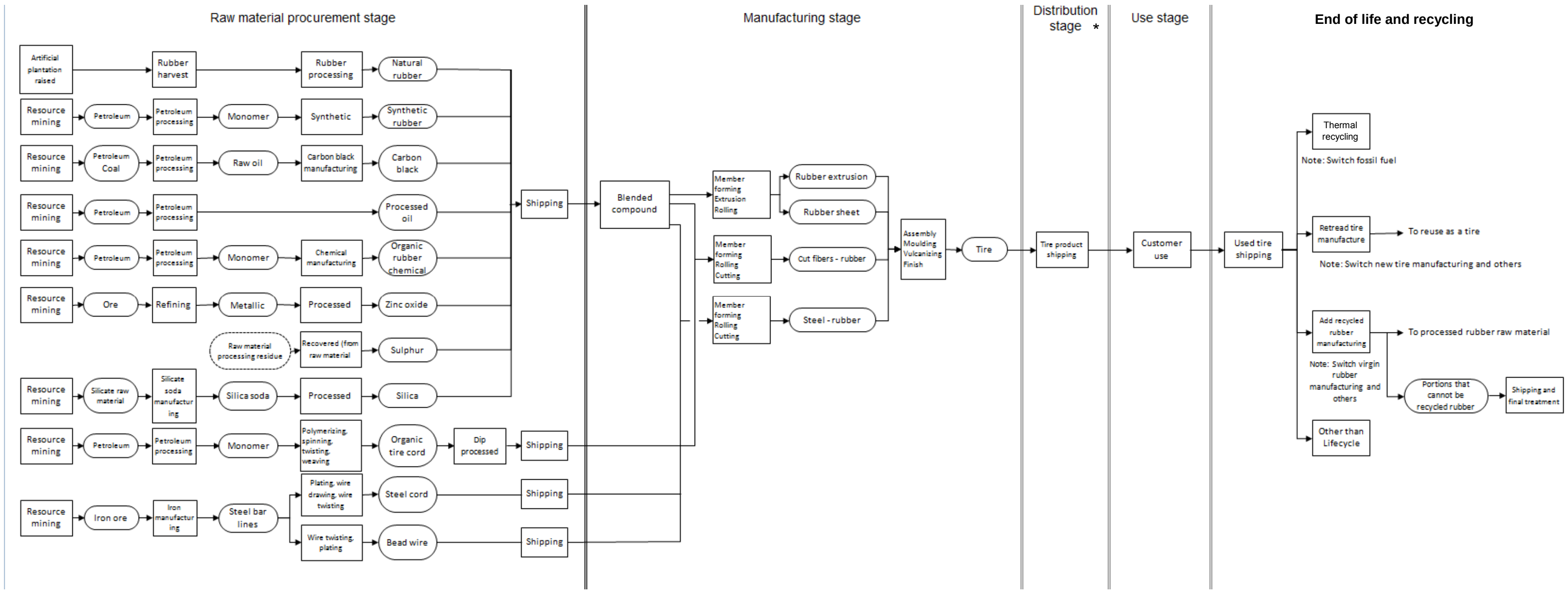


Fig. 1 Lifecycle diagram of vehicle tyres

Note: Set assuming distribution of replacement tyres in the distribution stage.

5. Calculation Units

Amount of greenhouse gasses emitted in the lifecycle of one tyre.

6. Inventory Types

From raw material mining to discarding (cradle to grave)

7. GWP (Global Warming Potential) Sources

Adopts a 100-year value in the Fourth IPCC Report (2007).

(CO2 : CH4 : N2O = 1 : 25 : 298; For other gasses, see the source.)

8. Calculation Precision

The calculations of $LCCO_2$ emission amounts in these Guidelines indicate the methods based on representative tyre information. Base the data used in $LCCO_2$ calculations on primary data. However, when it is not possible to apply primary data, apply secondary data based on settings indicated in these Guidelines. If more appropriate settings or data than what is provided in these Guidelines are obtained, use them to make more precise calculations.

9. Compliance with Standards

These Guidelines reference and follow standard contents such as ISO14044, the Japanese CFP system, PAS2050, BPX30-323, and GHG protocol and the like. Particularly, ISO14040:2006 and ISO14044:2006 which are international standards, are indicators for satisfying the standard contents such as the assumed conditions and calculation methods, excluding collection content of data implemented individually and issues such as some sensitivity analyses. It is possible to implement calculations that conform to those standards by using these Guidelines.
However, this is not intended completely to cover the reporting formats and report items (for example the setting of functional units and standard flow) pursuant to ISO14040:2006 and ISO14044:2006, so when considering complete compliance with ISO14040:2006 and ISO14044:2006, do not use the items outlined in this guidelines. Instead, reference the pertinent standard content.

III. Calculation Methods (Examples) at Each Stage

The following shows an example calculation using the calculation method at each stage and a representative tyre as a model.
The representative tyre is a general tyre of a volume retail tyre size and a fuel efficient tyre set based on a JATMA internal survey.

Table 2. Representative Tyre Sizes and Weights

Tyre class	Representative tyre size	Weight (kg)	
		General tyres	Fuel efficient tyres
PCR	195/65R15	8.6	8.2
TBR	275/80R22.5	56.2	54.5

1. Raw Material Stage

1) Raw Materials Configuration Ratio

The following shows an example of a representative raw material configuration ratio for each tyre. The configuration ratio was based on a JATMA internal survey.

Table 3. Representative Tyre Material Configuration Ratio (Example) (*)

Raw material name	PCR (195/65R15)		TBR (275/80R22.5)	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
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
Processed oil	8.0	9.6	2.0	1.8
Organic rubber chemical total	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
Fiber total	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 weight/new rubber weight ratio	2.06	2.18	2.17	2.13

(*): New rubber weight set as 100.

2) GHG Emission in Manufacture of Raw Materials

(1) GHG emission coefficient in the manufacturing of raw materials

The following table shows the GHG emission coefficient in the manufacture of each raw material.

Table 4. GHG Emission Coefficient in the manufacturing of Tyre Raw Materials

Raw material name	GHG emission coefficient ($kgCO_2e/kg$)	Source / background
New rubber	—	—
Natural rubber	6.39×10^{-1}	Allen, P. W., MRPRA (1979)
Synthetic rubber	2.40	JATMA created based on Synthetic Rubber Industry hearing.
Carbon black	3.20	Life Cycle Assessment Society of Japan (LCA) Forum (2011) *Data source: Carbon Black Association
Processed oil	1.61	Manufacture of MiLCA, lubricating oil (including grease) *Specific gravity as 0.88kg/L
Organic rubber chemical total	9.27	Manufacture of MiLCA, organic rubber chemical
Inorganic compounding agent	—	—
Zinc oxide	2.01	Manufacture of MiLCA, zinc oxide
Sulfur	7.09×10^{-3}	Manufacture of MiLCA, recovered sulfur (from crude refining)
Silica	2.06	Manufacture of MiLCA, silica gel
Fiber total	6.37	Created by JATMA based on Lifecycle Assessment Society of Japan (LCA) Forum (2011) *Data source: Japan Chemical Fibers Association
Steel cord	2.46	Manufacture of MiLCA, steel rope (including hard steel strand wires)
Bead wire	2.46	Manufacture of MiLCA, steel rope (including hard steel strand wires)

Note: MiLCA: Multiple interface Life Cycle Assessment; (Japan Environment Management Association for Industry; As of April 2012)

(2) Calculation of GHG emission amount in manufacture of raw materials

Use the following equation to find the GHG emission coefficient in the manufacture of the raw materials.

(GHG emission amount [kgCO2e] in manufacture of raw materials)

= Σ {(tyre weight (kg) x each raw material configuration ratio) x

(GHG emission coefficient [kgCO2e/kg] in manufacture of raw materials)}

Table 5. GHG Emission Amount in the Manufacture of Raw Materials

(Units: $kgCO_2e$/tyre)

Raw material name	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
New rubber	―	―	―	―
Natural rubber	1.0	1.1	12.7	12.9
Synthetic rubber	6.1	4.8	14.3	13.0
Carbon black	6.7	5.0	43.1	38.8
Processed oil	0.5	0.6	0.8	0.7
Organic rubber chemical total	3.1	4.6	24.0	19.7
Inorganic compounding agent	―	―	―	―
Zinc oxide	0.3	0.3	2.6	2.3
Sulfur	0.001	0.001	0.006	0.005
Silica	0.1	1.3	0.5	1.5
Fiber total	2.7	1.9	0.0	0.7
Steel cord	1.5	1.3	21.0	19.9
Bead wire	0.8	0.9	7.0	8.4
Total	22.8	21.7	126.2	117.9

3) GHG Emission in Shipping of Raw Materials

(1) Setting in shipping of raw materials

In the shipping of raw material, the distances in the table below are set as those for shipping.

Table 6. Setting in Shipping of Raw Materials Scenario

Raw material name	Shipping distance (km)	Basis for setting
Natural rubber	Land transportation before seaborne shipping: 500 km International seaborne: Southeast Asian route Land transportation after seaborne shipping: 500 km	• Transportation before and after international seaborne shipping on a 10-ton truck for 500 km one-way; loading ratio set at 50%. (Assumes shipping between Prefectures, and a distance of approximately Tokyo to Osaka.) • International seaborne shipping sets the GHG emission coefficient (conforms to Japan Rubber Manufacturers Association (1998)) pursuant to an estimation of natural rubber performance in Southeast Asia sealanes.
Synthetic rubber	Land transportation: 500 km	• Land transportation: For 500 km one-way. (Assumes shipping between Prefectures, and an approximately distance between Tokyo and Osaka.)
Carbon black		
Processed oil		
Organic rubber		

chemical total		
Zinc oxide		
Sulphur		
Silica		
Fiber total		
Steel cord		
Bead wire		

Table 7. GHG Emission Coefficient in the Shipping of Raw Materials

Raw material name	GHG emission coefficient ($kgCO_2e/kg$)	Remarks
Natural rubber	9.23×10^{-1}	• International seaborne shipping of natural rubber: Conforms to *The Japan Rubber Manufacturers Association* (1998)
Synthetic rubber	9.23×10^{-2}	• Land transportation of natural rubber and other raw materials: Truck: 10 tons Load ratio: 50% Fuel costs calculation format: Conforms to the Energy Saving Act $\ln x = 2.71 - 0.812 \ln (y/100) - 0.654 \ln z$ x: Amount of fuel used per cargo shipping amount (Unit l/ton k) y: Loading ratio (Unit: %) z: Maximum loading ratio of cargo vehicle (Unit: kg)
Carbon black	9.23×10^{-2}	
Processed oil	9.23×10^{-2}	
Organic rubber chemical total	9.23×10^{-2}	
Zinc oxide	9.23×10^{-2}	
Sulfur	9.23×10^{-2}	
Silica	9.23×10^{-2}	
Fiber total	9.23×10^{-2}	
Steel cord	9.23×10^{-2}	
Bead wire	9.23×10^{-2}	

(2) Calculation equation of GHG emission amount in shipping of raw materials

Use the following equation to find the GHG emission amount in the shipping of the raw materials.

(GHG emission amount [$kgCO_2e$] in the shipping of raw materials)
= (tyre weight [kg]) x Σ (each raw material configuration ratio) x
(GHG emission coefficient [$kgCO_2e/kg$] in the shipping of raw materials)

Table 8. GHG Emission Amount in the Shipping of Raw Materials

(Units: $kgCO_2e$/tyre)

Raw material name	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
New rubber	—	—	—	—
Natural rubber	1.50	1.61	18.41	18.65
Synthetic rubber	0.24	0.19	0.55	0.50

Carbon black	0.19	0.14	1.24	1.12
Processed oil	0.03	0.03	0.05	0.04
Organic rubber chemical total	0.03	0.05	0.24	0.20
Inorganic compounding agent	—	—	—	—
Zinc oxide	0.01	0.01	0.12	0.10
Sulfur	0.01	0.01	0.07	0.06
Silica	0.004	0.059	0.02	0.07
Fiber total	0.04	0.03	0.00	0.01
Steel cord	0.06	0.05	0.79	0.75
Bead wire	0.03	0.03	0.26	0.31
Total	2.15	2.20	21.75	21.82

4) GHG Emission Amount in the Overall Raw Material Stage

The following table shows the GHG emission amount in the overall raw material stage.
(GHG emission amount in the overall raw material stage)
= (GHG emission amount in the manufacture of raw materials)
+ (GHG emission amount in the shipping of raw materials)

Table 9. GHG Emission Amount in the Overall Raw Material Stage

(Units: $kgCO_2e$/tyre)

Class		PCR		TBR	
		General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
Raw material stage	Raw material manufacturing	22.8	21.7	126.2	117.9
	Raw material shipping	2.1	2.2	21.8	21.8
	Total	25.0	23.9	147.9	139.7

2. Manufacturing Stage

Calculate GHG emission amounts in the tyre manufacturing stage.

1) GHG Emission Coefficient by Energy

The following table shows the GHG emission coefficient of energy consumed in the tyre manufacturing stage.

Table 10. GHG Emission Coefficient of Energy

Class	GHG emission coefficient ($kgCO_2e$/Unit)	Units	Source
Benzene	2.81	$kgCO_2e/l$	MiLCA, burning, gasoline
Kerosene	2.76	$kgCO_2e/l$	MiLCA, burning, kerosene
Diesel fuel	2.89	$kgCO_2e/l$	MiLCA, burning, diesel fuel
A heavy oil	3.08	$kgCO_2e/l$	MiLCA, burning, A heavy oil
B • C heavy oil	3.34	$kgCO_2e/l$	MiLCA, burning, C heavy oil
Liquefied petroleum gas (LPG)	3.78	$kgCO_2e/kg$	MiLCA, burning, LPG
Liquefied natural gas (LNG)	4.23	kCO_2e/kg	MiLCA, burning, LNG
Fuel coal	2.37	$kgCO_2e/kg$	MiLCA, burning, fuel coal
City gas	3.00	$kgCO_2/Nm3$	MiLCA, burning, city gas 13A
Purchased electric power	0.484	$kgCO_2e/kWh$	MiLCA, generator, system electric power

Note: MiLCA: Multiple interface Life Cycle Assessment; (Japan Environment Management Association for Industry; As of April 2012)

2) GHG Emission Amounts in Manufacturing Stage

The following basic units were set according to the 2010 energy usage data and manufactured new rubber record of each JATMA member company.

(1) GHG emission amount (no distinction between PCR and TBR) per one kg of new rubber

Table 11. GHG Emission Amount (no distinction between PCR and TBR) per one kg of New Rubber

Class	Value	Units
Fuel-derived GHG emission amount per 1kg of new rubber	1.077	$kgCO_2e/kg$
Electric power-derived GHG emission amount per 1kg of new rubber	0.542	$kgCO_2e/kg$
GHG emission amount (no distinction between PCR and TBR) per one kg of new rubber	1.619	$kgCO_2e/kg$

(2) Used energy amount ratios per PCR and TBR unit weights in the manufacturing process are set as shown below (set according to results of survey of each company in JATMA)

Table 12. Used Energy Amount Ratios per PCR and TBR Unit Weights in the Manufacturing Process

Class	PCR	TBR
Fuel	100	65
Electric power	100	90

(3) Energy consumption coefficient per PCR and TBR, assuming a total manufacturing amount ratio of PCR and TBR is 1:1.

Table 13. Energy Consumption Coefficients per PCR and TBR

Class	PCR	TBR
Fuel energy	1.2	0.8
Electric power energy	1.05	0.95

(4) GHG emission amount per one kg of new rubber (per PCR and TBR)

PCR: (GHG emission amount per 1kg of new rubber)

= (Fuel-derived GHG emission amount per 1kg of new rubber) x 1.2
+ (Fuel-derived GHG emission amount per 1kg of new rubber) x 1.05
= 1.077 x 1.2 + 0.542 x 1.05 = 1.861 kgCO_2e/kg

TBR: (GHG emission amount per 1kg of new rubber)
= (Fuel-derived GHG emission amount per 1 kg of new rubber) x 0.8
+ (Fuel-derived GHG emission amount per 1 kg of new rubber) x 0.95
= 1.077 x 0.8 + 0.542 x 0.95 = 1.376 kgCO_2e/kg

(5) PCR and TBR actual tyre weight: Ratio of new rubber weight

Actual tyre weight from material configuration ratio of PCR and TBR: Set the ratio of new rubber weight as shown in the table below.

Table 14. PCR and TBR Actual Tyre Weight: Ratio of New Rubber Weight

Class	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
Actual weight/ new rubber weight ratio	2.06	2.18	2.17	2.13

(6) GHG emission amount per 1kg of actual tyre weight

(GHG emission amount per one kg of actual tyre weight)

= (GHG emission amount (per PCR and TBR) per one kg of new rubber)
÷ (actual tyre weight: Ratio of new rubber amount)

Table 15. GHG Emission Amount per 1kg of Actual Tyre Weight
(Units: $kgCO_2e$/1 kg of tyre)

Class	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
GHG emission amount per 1kg of actual tyre weight	0.903	0.854	0.634	0.646

(7) GHG emission amount per one tyre in manufacturing stage

(GHG emission amount per one tyre)
= (GHG emission amount per 1kg of actual tyre weight) x (weight per one tyre)

Table 16. GHG Emission Amount per One Tyre in Manufacturing Stage

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Weight per one tyre	8.6	8.2	56.2	54.5	kg/tyre
GHG emission amount per one tyre	7.8	7.0	35.6	35.2	$kgCO_2e$/tyre

3. Distribution Stage

Calculate GHG emission amounts in the tyre products distribution stage.

1) Scenario Setting for Tyre Product Shipping

Calculate GHG emission amounts in the tyre products distribution stage based on the following condition settings.

Table 17. Scenario Setting for Tyre Product Shipping

Class	Content	Remarks
Target	Shipping from production base in Japan to dealer shops	Sales processes are excluded due to lack of adequate knowledges.
Shipping distance	1,000 km, one-way shipping	Assumes a distance of more than half the length of the island of Honshu (1,600 km) as delivery destinations not limited to specific regions.
Shipping means	10-ton truck	JATMA setting value
Load ratio	50%	JATMA setting value

Fuel consumption calculation formula	Conforms to the Energy Saving Act	$\ln x=2.71-0.812 \ln (y/100)-0.654 \ln z$ x: amount of fuel consume per cargo shipping amount (l/ton-kilometers) y: Load ratio (%) z: Amount of fuel used per cargo shipping amount (kg)
GHG emission coefficient	0.185 $kgCO_2e/kg$	Set based on the conditions above.

2) GHG Emission Amounts in Distribution Stage

The following table shows the GHG emission amount at the distribution stage.

(GHG emission amount at the distribution stage)
= (weight per one tyre) x (GHG emission coefficient of shipping per one kg of actual tyre weight)

Table 18. GHG Emission Amount at the Distribution Stage

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Weight per one tyre	8.6	8.2	56.2	54.5	kg/tyre
GHG emission amount of shiping per one tyre	1.6	1.5	10.4	10.1	$kgCO_2e$/tyre

4. Usage Stage

At the tyre usage stage, GHG emission amounts are calculated as contribution portion of tyres attached to a running vehicle.

1) Setting for Tyre Usage Conditions

Tyre usage conditions are set in the table below.

Table 19. Setting for Tyre Usage Conditions

<table>
<tr><th rowspan="2">Class</th><th colspan="2">PCR</th><th colspan="2">TBR</th><th rowspan="2">Units</th><th rowspan="2">Basis for setting</th></tr>
<tr><th>General tyres</th><th>Fuel efficient tyres</th><th>General tyres</th><th>Fuel efficient tyres</th></tr>
<tr><td>Ratio of contribution of tyre to fuel consumption</td><td colspan="2">0.125 (1/8)</td><td colspan="2">0.25 (1/4)</td><td>—</td><td>JATMA survey result</td></tr>
<tr><td rowspan="2">Vehicle fuel consumption</td><td>10</td><td rowspan="2">Correction by rolling resistance difference</td><td>4</td><td rowspan="2">Correction by rolling resistance difference</td><td>km/l</td><td rowspan="2">JATMA setting based on statistics information</td></tr>
<tr><td>0.1</td><td>0.25</td><td>l/km</td></tr>
<tr><td>Vehicle fuel</td><td colspan="2">Benzene</td><td colspan="2">Diesel fuel</td><td>—</td><td>JATMA setting</td></tr>
<tr><td>Tyre rolling resistance coefficient</td><td>100</td><td>80</td><td>100</td><td>80</td><td>General tyres =100</td><td>JATMA survey result</td></tr>
<tr><td>No. of mounted tyres</td><td colspan="2">4</td><td colspan="2">10</td><td>tyres</td><td>JATMA setting</td></tr>
</table>

Tyre life	30,000	120,000	km/tyre	JATMA survey result (Lives of general tyres and fuel efficient tyres are unified for comparison)

2) GHG Emission Amounts in Usage Stage

(1) GHG emission coefficient of vehicle fuel

Table 20. GHG Emission Coefficient of Vehicle Fuel

Class	Value	Unit
Benzene GHG emission coefficient	2.81	$kgCO_2e/l$
Diesel fuel GHG emission coefficient	2.89	$kgCO_2e/l$

(2) Tyre-factor fuel consumption amount and GHG emission amount

Use the following equation to find the tyre-factor fuel consumption amount and GHG emission amount.

(Tyre-factor fuel consumption amount)
= (fuel consumption amount per 1 km for one tyre) x (tyre travel life)
= (fuel consumption of vehicle) x (tyre contribution ratio) ÷ (number of tyres)
x (tyre rolling resistance correction) x (tyre travel life)

Tyre-factor GHG emission amount
= (tyre-factor fuel consumption amount) x (GHG emission coefficient of vehicle fuel)

Table 21. Tyre-factor Fuel Consumption Amount and GHG Emission Amount

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Tyre-factor fuel consumption amount per 1 km for 1 tyre	3.13×10^{-3}	2.50×10^{-3}	6.25×10^{-3}	5.00×10^{-3}	l/km • tyre
Tyre-factor fuel consumption amount (Per tyre life)	93.8	75.0	750.0	600.0	l/tyre
Tyre-factor GHG emission amount (Per tyre life)	263.4	210.8	2,167.5	1,734.0	$kgCO_2e$/tyre

5. End of Life & Recycling Stage

Calculate GHG emission amounts in the end of life & recycling stage.

1) End of Life and Recycling Ratios by Usage of Used Tyres

The following graphs show the ratio of discarding and recycling for PCR and TBR tyres based on the 2010 used tyre usage type statistics from a JATMA survey.

PCR tyre is recycled for thermal usage (thermal recycling), TBR tyre is recycled for thermal usage (thermal recycling), product reuse (retreading), and material reuse (material recycling).

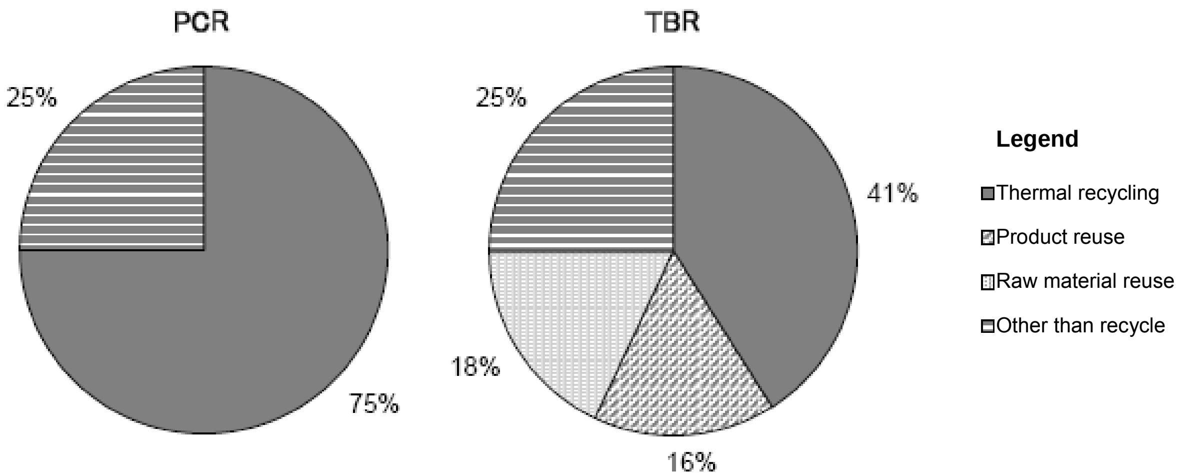


Fig. 2. End of Life & Recycling Ratios by Usage of Used Tyres

2) GHG Emission Amounts in Shipping of Used Tyres

(1) Condition settings for shipping of used tyres

GHG emission amount in shipping of used tyre is calculated based on the following condition settings.

Table 22. Condition Settings for Shipping of Used Tyres

Class	Content	Remarks
Target	Shipping from branch where used tyres are brought (dealers and the like) to disposal treatment facility	—
Shipping distance	100km, one-way shipping	Assumes shipping within Prefectures and distances from Prefecture border to another
Shipping means	2-ton truck	JATMA setting value
Load ratio	50%	JATMA setting value
Fuel calculation equation	Conforms to the Energy Saving Act	$\ln x = 2.71 - 0.812 \ln (y/100) - 0.654 \ln z$ x: amount of fuel used per cargo shipping amount (unit l/tons kg) y: Load ratio (unit %) z: Amount of fuel used per cargo shipping amount (unit kg)
GHG emission coefficient	0.0529 $kgCO_2e/kg$	Set based on the conditions above.

Used tyres wear rate	PCR: 15% TBR: 18%	Set using tyre specifications calculations and others (See Table 25. Tyre Wear Rate)

(2) GHG emission amount in shipping of used tyres

Use the following equation to find the GHG emission amount in the shipping of used tyres.

(GHG emission amount in the shipping of used tyres)
= (weight per one used tyre)
x (GHG emission coefficient of per one kg of actual tyre weight)

Table 23. GHG Emission Amount in Shipping of Used Tyres

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Used tyre weight	7.3	7.0	46.1	44.7	kg
GHG emission amount in shipping of used tyres	0.39	0.37	2.44	2.36	$kgCO_2e$/tyre

3) GHG Emission and Emission Reduction Effect in Thermal Recycling

(1) GHG emission in thermal use (thermal recycling)

a) Carbon content in new tyres

The carbon content of tyres is calculated according to composition ratios of tyre raw materials and carbon content ratio of each raw material. Also, consider recyclable raw materials (natural rubber) as a carbon-neutral raw material and exclude it from the carbon content.
Also, when using used tyres for heat (thermal recycling), sometimes a process for cutting the tyres is required. However, compared to burning tyres, the GHG emission amount is extremely small so that was excluded (approximately 1/1,000).

Table 24 Carbon Content in New Tyres

Raw material name	Carbon Amount (Considering Carbon Neutral)				Carbon Quantity ratio (See *1)	Carbon Neutral (See *2)
	PCR		TBR			
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres		
New rubber	—	—	—	—	—	—
Natural rubber	0.0	0.0	0.0	0.0	0.88	0
Synthetic rubber	54.9	48.2	20.7	19.1	0.90	1
Carbon black	47.5	39.2	49.4	44.9	0.95	1
Processed oil	7.2	8.6	1.8	1.6	0.90	1
Organic Rubber Chemical (See *3)	5.6	9.2	7.0	5.8	0.70	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
Fiber total	6.5	5.2	0.0	0.3	0.65	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	121.7	110.5	78.9	71.7	—	—
Carbon Content Ratio in Tyres	0.59	0.51	0.36	0.34	—	—

* 1: The carbon quantity ratio in each raw material is estimated based on the basic molecular structure.
* 2: Carbon neutral = 0; Not carbon neutral = 1; Raw materials contains no carbon = N
* 3: Each type has organic rubber chemicals but the carbon quantity ratio was set to 0.7.

b) Reduction amount caused by tyre wear

Set the reduction amount % for all wear from tyre specifications manual calculations.

Table 25. Tyre Wear Rate

Class	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
Wear rate	15%		18%	

c) Change in material configuring components and carbon content after tyre wear

Only the rubber content is worn in tyres, so this was reduced by proportional distribution using that which excludes steel and fiber weights.

Table 26. Change in Carbon Content by Wear Amount

Class		PCR		TBR	
		General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
New Tyre	Configuring weight	206.0	218.4	217.0	212.5
	Wear component weight	173.0	186.8	173.0	167.3
	Carbon content	121.5	111.4	78.1	72.3
	Carbon content rate	59%	51%	36%	34%
Used Tyre	Configuring weight	175.1	185.6	177.9	174.3
	Wear component weight	142.1	154.0	133.9	129.1
	Carbon content	101.1	92.0	61.1	55.4
	Carbon content rate	58%	50%	34%	32%
Reduction amount rate	Configuring weight	15%	15%	18%	18%
	Wear component weight	18%	18%	23%	23%
	Carbon content	17%	17%	22%	23%

d) GHG emission amount per 1kg of used tyres when burning

Use the following equation to find the GHG emission amount per 1kg of tyre when burning used tyres.

(GHG emission amount per 1kg of used tyres when burning)

= (carbon content in used tyres) x 44 ÷ 12

Table 27. GHG Emission Amount per 1kg of Used Tyres when Burning

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
GHG emission amount per 1kg of used tyres when burning	2.127	1.833	1.247	1.173	$kgCO_2e$/ kg tyre

e) GHG emission amount per one tyre when burning used tyres

Use the following equation to find the GHG emission amount per one tyre when burning used tyres.

(GHG emission amount per one tyre when burning used tyres)

= (GHG emission amount per one tyre when burning used tyres) x (used tyre weight)

Table 28. GHG Emission Amount per One Tyre When Burning Used Tyres

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Used tyre weight	7.3	7.0	46.1	44.7	kg
GHG emission amount when burning used tyres	15.5	12.8	57.5	52.4	$kgCO_2e$/ tyre

(2) GHG emission reduction effect in thermal use (thermal recycling)

By recovering energy by using used tyres as a heat source, it is believed that consumption of fossil fuels is substituted and GHG emissions are reduced. Calculate this reduction effect.

a) Substituted amounts of fossil fuel with thermal use (thermal recycling) of used tyres

The paper manufacturing industry can be given as a main user of heat from used tyres. In view of statistical data from that industry, it was inferred that it is appropriate to substitute C weight oil for used tyres.

Table 29. Heat Generation Amount of Tyre and GHG Emission Coefficient for C Heavy Oil

Item	Value	Units
Heat generation amount of tyre	33.2	MJ/kg
GHG Emission Coefficient for C Heavy Oil	0.080	$kgCO_2e$/MJ

b) GHG emission reduction effect through thermal use (thermal recycling) of used tyres

Use the following equation to find the GHG emission reduction effect through thermal use of used tyres.

(GHG emission reduction effect through thermal use of used tyres)
= (heat generation amount of tyre) x (GHG emission coefficient for C heavy oil)
x (thermal recovery efficiency coefficient) x (used tyre weight)

Note: Thermal recovery efficiency coefficient: Compared to the thermal use of fossil fuels, there is the possibility that thermal recovery is low when using used tyres for heat. However, at present, we have not attained adequate knowledge, so the thermal recovery rate was set at 0.9.

Table 30. GHG Emission Reduction Effect Through Thermal Use of Used Tyres

Class	PCR		TBR		Units
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres	
Used tyre weight	7.3	7.0	46.1	44.7	kg/tyre
GHG reduction effect	-17.4	-16.6	-109.9	-106.6	$kgCO_2e$/tyre

(3) GHG emission (overall) in thermal use (thermal recycling)

Use the following equation to find the GHG emission amount (overall) in thermal use (thermal recycling). For details on the summary results, see “Table 46. GHG Emission Amount and Emission Reduction Effect in the End of Life & Recycling Stage.”

(GHG emission amount in thermal use (thermal recycling))
= (GHG emission amount in shipping of used tyres)
+ (GHG emission amount per one tyre when burning used tyres)
- (GHG emission reduction effect through thermal use of used tyres)

4) GHG Emission and Emission Reduction Effect in Reused Products

The following points can be given as GHG emissions in product reuse (retreading of TBR).

[GHG emission]
- Manufacture of retread compound raw materials
- Shipping of retread compound raw materials
- Compounding of retread compound raw material
- Production of retreaded tyres

[GHG emission reduction effect]
- Substitute new tyre manufacturing with retreaded tyres (reduction effect)

(1) GHG emission in products for reuse (retreading)

a) GHG emission amount in manufacture of retread compound raw material

(i) GHG emission amount in retread compound raw material composition ratio and manufacture

The retread compound raw material composition ratio was set as shown in the table below using data from each company in JATMA.
Use the following equation to find the GHG emission amount in the manufacturing of retread compounds.

(GHG emission amount in manufacture of retread compound raw material)
= Σ {(Weight of each raw material in the retread compound)
x GHG emission coefficient of each raw material)}

Table 31. GHG Emission Amount in Retread Compound Raw Material Composition Ratio and Manufacture

Class	Composition ratio	GHG emission coefficient [$kgCO_2e/kg$]	GHG emission amount [$kgCO_2e$]
Natural rubber	70	6.39×10^{-1}	44.73
Synthetic rubber	30	2.40	72.00
Carbon black	48	3.20	153.60
Processed oil	7	1.61	11.27
Organic rubber chemical	7	9.27	64.89
Zinc oxide	3	2.01	6.03
Sulfur	2	7.09×10^{-3}	0.01
Silica	0	2.06	0.00
Total	167	—	352.53
Actual weight/new rubber ratio	1.67		

Therefore, the following table shows the GHG emission amount per 1kg of retread compound.

(GHG emission amount per 1kg of retread compound)
= GHG emission amount ÷ composition ratio weight

= 352.53 ÷ 167 = <u>2.11 $kgCO_2e/kg$</u>

(ii) Retread compound weight
Calculate assuming the ratio of number of general tyres and studless tyres is 8:2.
When the weight of a general tyre is 15kg, and that of a studless tyre is 19kg:

15 x 0.8 + 19 x 0.2 = <u>16 kg</u>
(iii) GHG emission amount of retread compound in the raw material stage (per one retreaded tyre)

(GHG emission amount in retread compound in the raw material stage)
= (GHG emission amount per 1kg of retread compound)
x weight of retread compound = 2.11 x 16 = <u>33.78 $kgCO_2e$/tyre</u>

Table 32. GHG Emission Amount in Retread Compound in the Raw Material Stage

Class	Value	Units
GHG emission amount per one tyre	33.78	$kgCO_2e$/tyre

b) GHG emission amounts in shipping of retread compound raw materials

The same thinking as shipping of tyre raw materials (Table 8. GHG Emission Amount in the Shipping of Raw Materials) was applied to GHG emission when shipping retread compound raw materials. Use the following equation to find the GHG emission coefficient when shipping retread raw materials and GHG emission amount.

(GHG emission amount [kgCO2e] in the shipping of retread compound raw materials)
= (retread compound raw material weight [kg])
x Σ {(composition ratio of each raw material)
x (GHG emission coefficient [$kgCO_2e/kg$] in the shipping of raw materials)}

Table 33. GHG Emission Amount in Retread Compound Raw Material Composition Ratio and Shipping

Class	Composition ratio	GHG emission coefficient [$kgCO_2e/kg$]	GHG emission amount [$kgCO_2e$]
Natural rubber	70	9.23×10^{-1}	64.61
Synthetic rubber	30	9.23×10^{-2}	2.77
Carbon black	48	9.23×10^{-2}	4.43
Processed oil	7	9.23×10^{-2}	0.65
Organic rubber chemical	7	9.23×10^{-2}	0.65
Zinc oxide	3	9.23×10^{-2}	0.28
Sulfur	2	9.23×10^{-2}	0.18
Total	167	—	73.56

Use the following equation to find the GHG emission coefficient when shipping 1kg of retread compound raw material.

(GHG emission coefficient when shipping 1kg of retread compound raw material)
= 73.56 ÷ 167 = 0.440

Therefore, use the following equation to find the GHG emission amount in shipping retread raw material.

(GHG emission amount when shipping retread compound raw material)
= (retread compound weight total)
x (GHG emission coefficient when shipping 1kg of retread compound raw material)
= 16 x 0.440 = 7.05 $kgCO_2e$/tyre

Table 34. GHG Emission Amount When Shipping Retread Compound Raw Material

Class	Value	Units
Retread compound raw material weight total	16	kg
GHG emission coefficient when shipping 1kg of retread compound raw material	0.440	$kgCO_2e/kg$
GHG emission amount when shipping retread compound raw material	7.05	$kgCO_2e$/tyre

c) GHG emission amount when compounding retread compounds

(i) GHG emission amount when compounding retread compound (per new rubber)

• Consumed energy when compounding retread compound is considered to be electric power, and calculated as shown below.

• GHG emission amount through consumed electric power in the production stage per 1kg of new rubber is 0.542$kgCO_2e/kg$, as shown in ”Table 11. GHG emission amount (no distinction between PCR and TBR) per one kg of new rubber” (GHG emission amount derived from electric power).

• Multiply 0.95 of TBR energy consumption coefficient (electric power) to this.

• Furthermore, multiply 0.35 which is the rate of electric power used in the compounding process to the total electric power used in all processes (according to JATMA data) to calculate the GHG emission amount per 1kg of new rubber at the retread compound compounding.

(GHG emission amount per new rubber when compounding retread compound)
= (GHG emission amount from consumed electric power per 1kg of new rubber) x (TBR energy consumption coefficient) x (energy consumption coefficient in compounding process)
= 0.542 × 0.95 × 0.35
= 0.180 $kgCO_2e$/1kg of new rubber

Table 35. GHG Emission Amount When Compounding Retread Compound (Per New Rubber)

Class	Value	Units
GHG emission amount from consumed electric power per 1kg new rubber in production stage	0.542	$kgCO_2e/kg$
TBR energy consumption coefficient	0.95	—
Used electric power rate in compounding process share of all processes	0.35	—
GHG emission amount per 1kg new rubber when compounding retread compound	0.180	$kgCO_2e/kg$

(ii) GHG emission amount per actual weight of retread when compounding retread compound

• Rebate to GHG emission amount per 1kg of retread with a ratio of actual weight/new rubber)

• By multiplying the actual weight of retread rubber, find the GHG emission amount when compounding retread compound

(GHG emission amount when compounding retread compound)
= (GHG emission amount per 1kg new rubber when compounding retread compound) ÷ (actual weight/new rubber ratio) x (actual weight retread rubber)

= 0.180 ÷ 1.67 × 16

= 1.725 $kgCO_2e$/tyre

Table 36. GHG Emission Amount per Actual Weight of Retread When Compounding Retread Compound

Class	Value	Units
GHG emission amount per 1kg new rubber when compounding retread compound	0.180	$kgCO_2e/kg$
Actual weight/new rubber ratio	1.67	—
Actual weight of retread rubber	16	kg
GHG emission amount per retread actual weight	1.725	$kgCO_2e$/tyre

d) GHG emission amount when producing retreaded tyres

(i) Energy consumption amount and GHG emission amount per one tyre when producing retreaded tyres

Use the following equation to find the GHG emission amount when producing retreaded tyres at a retread plant, according to data from 3 JATMA member companies.

(GHG emission amount when producing retreaded tyres at a retread plant)
= (Consumption amount of C heavy oil) x (GHG emission coefficient of C heavy oil)
+ (electric power consumption amount) x (electric power GHG emission coefficient)
= 5.5 × 3.34 ＋ 12 × 0.484
= 24.18 $kgCO_2e$/tyre

Table 37. Energy Consumption Amount and GHG Emission Amount per One Tyre When Producing Retreaded Tyres

Class		Value	Units
Consumption amount	C heavy oil	5.5	l/tyre
	Electric power	12.0	kWh/tyre
GHG emission coefficient	C heavy oil	3.34	$kgCO_2e/l$
	Electric power	0.484	$kgCO_2e/l$
GHG emission amount	C heavy oil	18.37	$kgCO_2e$/tyre
	Electric power	5.81	$kgCO_2e$/tyre
GHG emission amount per one tyre producing retread		24.18	$kgCO_2e$/tyre

e) GHG emission amount in products for reuse (retreading)

The GHG emission amounts in products for reuse (retreading) according to the above, are shown below.

Table 38. GHG Emission Amount When Reusing Products

Class	Value	Units
Retread compound raw material manufacturing stage	33.8	$kgCO_2e$/tyre
Retread compound raw material shipping stage	7.0	$kgCO_2e$/tyre
Retread compound compound stage	1.7	$kgCO_2e$/tyre
Retread tyre production stage	24.2	$kgCO_2e$/tyre
GHG emission amount total by reusing products (retreading)	66.7	$kgCO_2e$/tyre

(2) GHG emission reduction effect in products for reuse (retreading)

By retreading used tyres for reuse, it is believed that that the raw material production of new tyres, raw material shipping and new tyre production are substituted. With this, it is possible to obtain the GHG emission reduction effect shown in the table below.

Table 39. GHG Emission Reduction Effect Through Product Reuse (Retreading)

Class	TBR		Units
	General tyres	Fuel efficient tyres	
GHG emission amount substitute reduction amount in raw material production	-126.2	-117.9	$kgCO_2e$/tyre

GHG emission amount substitute reduction amount in raw material shipping	-21.8	-21.8	$kgCO_2e$/tyre
GHG emission amount substitute reduction amount in new tyre manufacturing	-35.6	-35.2	$kgCO_2e$/tyre
GHG emission reduction amount by retreaded tyre	-183.5	-174.9	$kgCO_2e$/tyre

See: Table 5. GHG Emission Amount in the Manufacture of Raw Materials
Table 8. GHG Emission Amount in the Shipping of Raw Materials
Table 16. GHG Emission Amount per One Tyre in Manufacturing Stage

(3) GHG emission (overall) in product reuse (retreading)

Use the following equation to find the GHG emission amount (overall) in product reuse (retreading). For details on the summary results, see "Table 46. GHG Emission Amount and Emission Reduction Effect in the End of Life and Recycling Stage."

(GHG emission (overall) in product reuse (retreading))
= (GHG emission in product reuse (retreading))
- (GHG emission reduction effect through product reuse (retreading))

5) GHG Emission in Reuse of Materials

(1) GHG emission in material reuse (material recycling)

a) GHG emission amount in production stage of material reuse (material recycling)

(i) GHG emission amount per 1 kg of rubber powder in rubber powder manufacturing stage

Recycled tyre material is mainly reused as rubber powder and recycled rubber (reclaimed). Calculated the GHG emission about from the energy used when reprocessing used tyres into rubber powder and recycled rubber at the recycled rubber plant and the energy used in discarding and shipping and the final disposal of portions that cannot be used in the recycling process.
Obtained energy data in the material reuse (material recycling) from the recycled rubber plant.
Use the following equation to find the GHG emission amount in the rubber powder manufacturing stage.

(GHG emission amount per 1 kg of rubber powder in rubber powder manufacturing stage)
= (electric power consumption amount per 1 kg of rubber powder in rubber powder manufacturing stage)
x (electric power GHG emission coefficient)
= 0.660 x 0.484 = 0.319 $kgCO_2e/kg$

Table 40. GHG Emission Amount per 1 kg of Rubber Powder in Rubber Powder Manufacturing Stage

Class	Value	Units
Electric power consumption amount per 1 kg of rubber powder in rubber powder manufacturing stage	0.660	kWh/kg

Electric power GHG emission coefficient	0.484	$kgCO_2e/kWh$
GHG emission amount per 1 kg of rubber powder in rubber powder manufacturing stage	0.319	$kgCO_2e/kg$

(ii) GHG emission amount per 1 kg of recycled rubber in recycled rubber manufacturing stage

Use the following equation to find the GHG emission amount in the recycled rubber manufacturing stage.

(GHG emission amount per 1 kg of recycled rubber in recycled rubber manufacturing stage)
= (Electric power consumption amount per 1 kg of recycled rubber in recycled rubber manufacturing stage)
x (electric power GHG emission coefficient)
+ (C heavy oil consumption amount per 1 kg of recycled rubber in recycled rubber manufacturing stage)
x (GHG emission coefficient for C heavy oil)
= 1.44 x 0.484 + 0.07 x 3.34 = <u>0.931 $kgCO_2e/kg$</u>

Table 41. GHG Emission Amount per 1 kg of Recycled Rubber in Recycled Rubber Manufacturing Stage

Class		Value	Units
Consumption amount	Electric power consumption amount per 1 kg of recycled rubber in recycled rubber manufacturing stage	1.44	kWh/kg
	C heavy oil consumption amount per 1 kg of recycled rubber in recycled rubber manufacturing stage	0.07	l/kg
GHG emission coefficient	Electric power GHG emission coefficient	0.484	$kgCO_2e/kWh$
	GHG Emission Coefficient for C Heavy Oil	3.34	$kgCO_2e/l$
GHG emission amount (per unit)	GHG emission amount of electric power consumption per 1 kg of recycled rubber in recycled rubber manufacturing stage	0.697	$kgCO_2e/kg$
	GHG emission amount of consumed C heavy oil per 1 kg of recycled rubber in recycled rubber manufacturing stage	0.234	$kgCO_2e/kg$
	GHG emission amount per 1 kg of recycled rubber in recycled rubber manufacturing stage	0.931	$kgCO_2e/kg$

b) GHG emission amount (per unit) relating to shipping and final disposal

Energy consumed for final disposal and its shipping, of unusable portions of used tyres for recycled rubber.

(i) GHG emission coefficient relating to shipping and final disposal

Shipping conditions: within the prefecture, a distance between prefectural borders, 100km by 2-ton truck (1 way), load ratio 50%.

(GHG emission coefficient for shipping of 1kg of unusable portions of used tyres for recycled rubber)

= (diesel fuel consumption amount per ton-km) x (GHG emission coefficient of diesel fuel) x (shipping distance)

= 0.183 × 2.89 × 100 ÷ 1000= 0.0529 kgCO_2e/kg

* ln x = 2.71 - 0.812 ln (y/100) - 0.654 ln z
x: Amount of fuel used per cargo shipping amount (unit/ton-km),
y: Load rate (unit: %)
z: Maximum load amount of cargo vehicle (Unit: kg)

(ii) GHG emission coefficient relating to final disposal

The GHG emission coefficient relating to final disposal was set as shown below.

(GHG emission coefficient relating to final disposal*) = 3.83×10-3 kgCO_2e/kg
*Source MiLCA, landfill process (industrial waste)

Table 42. GHG Emission Coefficient Relating to Shipping and Final Disposal

Class	GHG emission coefficient	Units
GHG emission coefficient of shipment	5.29×10^{-2}	kgCO_2e/kg
GHG emission coefficient of final disposal	3.83×10^{-3}	kgCO_2e/kg

c) GHG emission amount in material reuse (material recycling)

(i) Weight setting in material recycling
The used tyres for material recycling weigh less due to wear.
The weight of used tyre weighs less because of wear. Furthermore, it is separated into the rubber part that is recyclable and the cord and steel part that is un-recyclable to "recycled rubber". The weight of used tyres for material recycling is set as the below table.

Table 43. Weight Setting Relating to Material Recycling

Class		TBR		Units
		General tyres	Fuel efficient tyres	
New Tyre	New tyre weight	56.2	54.5	kg/tyre
	Rate of recyclable parts	80	79	%
	Recyclable part weight in new tyres	44.80	42.91	kg/tyre
Wear	Wear rate	18	18	%
	Wear amount	10.12	9.81	kg/tyre
	Used tyre weight	46.08	44.69	kg/tyre
	Weight of portions of used tyres that can be recycled	34.69	33.10	kg/tyre
Rubber powder	Yield to rubber powder from used tyres	90	90	%
	Weight that can be recycled to rubber powder	31.22	29.79	kg/tyre

	Unusable portions of used tyres for recycled rubber	14.86	14.90	kg/tyre

(ii) GHG emission amount in material recycling

Use the following equation to find the GHG emission amount in the material recycling.

(GHG emission amount in material recycling)
= (GHG emission amount when producing rubber powder and recycled rubber)
+ (GHG emission amount when shipping and in final disposal)
= (Weight of the recyclable part to rubber powder)
x {(GHG emission amount per 1 kg of rubber powder in rubber powder manufacturing stage)
+ (GHG emission amount per 1 kg of recycled rubber in recycled rubber manufacturing stage)}
+ (Unusable portions of used tyres for recycled rubber)
x (GHG emission coefficient when shipping) + (GHG emission coefficient in final disposal)

Table 44. GHG Emission Amount in Material Reuse (Material Recycling)

Class	TBR		Units
	General tyres	Fuel efficient tyres	
GHG emission amount when producing rubber powder and recycled rubber	39.0	37.2	kgCO_2e/tyre
GHG emission amount when shipping and in final disposal	0.8	0.8	kgCO_2e/tyre
GHG emission amount in material reuse (material recycling)	39.9	38.1	kgCO_2e/tyre

(2) GHG emission reduction effect amount by material reuse (material recycling)

By implementing material recycling, it is possible to consider substituting the production of compounded rubber. Use the following equation to find the GHG reduction effect through material recycling, considering the yield of rubber powder obtained through used tyres.

(GHG reduction effect by material reuse (material recycling))
= (weight of portions of used tyres that can be recycled)
x (yield to rubber powder from used tyres)
x (GHG emission coefficient of compounded rubber)

Table 45. GHG Reduction Effect in Material Recycling

Class	TBR		Units
	General tyres	Fuel efficient tyres	
Weight of portions of used tyres that can be recycled	34.69	33.10	kg/tyre
Yield to rubber powder from used tyres	90	90	%
Recovered recycled rubber	31.22	29.79	kg/tyre
GHG emission coefficient of compounded rubber *	2.65	2.56	kgCO_2e/kg
GHG emission reduction effect by material recycling	-82.79	-76.20	kgCO_2e/tyre

* Coefficient obtained for GHG emission coefficient (raw material production and shipping) of each raw material (natural rubber, synthetic rubber, carbon black, process oil, organic rubber chemicals, and inorganic compounding agent) included in the compounded rubber, by weighting through multiplication of few material composition ratio. See: Table 3. Representative Tyre Material Configuration Rate (Example)
Table 4. GHG emission coefficient in the manufacture of tyre raw materials
Table 7. GHG Emission Coefficient in the Shipping of Raw Materials

(3) GHG emission (overall) in material reuse (material recycling)

Use the following equation to find the GHG emission amount (overall) in material reuse (material recycling). For details on the summary results, see "Table 46. GHG Emission Amount and Emission Reduction Effect in the End of Life & Recycling Stage."

(GHG emission (overall) in material reuse (material recycling)
= (GHG emission amount in material reuse (material recycling))
- (GHG emission reduction effect by material reuse (material recycling))

6) GHG Emission Amount and Emission Reduction Effect in End of Life & Recycling Stage

(1) Ratio by recycling type

The graphs below show the recycling ratio of used tyres, according to JATMA statistics.

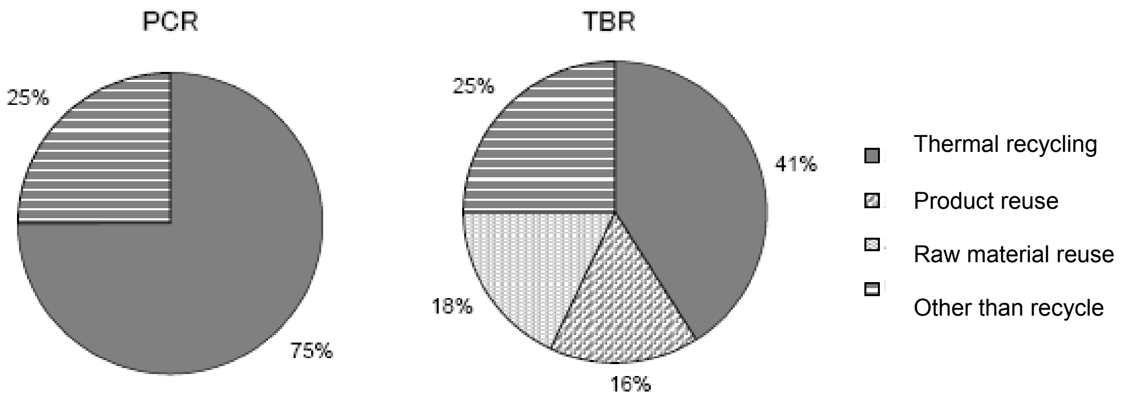


Fig. 3. Recycling Ratio of Used Tyres

(2) GHG emission and emission reduction effect in the end of life & recycling stage

Implemented weighting for GHG emission amount for each recycling method according to the recycling ratio. The table below shows the emission reduction effect according to the GHG emission amount and emission reduction effect in the end of life & recycling stage.

Table 46. GHG Emission Amount and Emission Reduction Effect in the End of Life & Recycling Stage

(Units: $kgCO_2e$/tyre)

Class	PCR		TBR	
	General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres

Lifecycle ratio	Thermal recycling	75%		41%	
	Product reuse	—		16%	
	Raw material reuse	—		18%	
	Other than Lifecycle	25%		25%	
GHG emission amount	Recovery shipment	0.4	0.4	2.4	2.4
	Thermal recycling	11.7	9.6	23.6	21.5
	Product reuse	0.0	0.0	10.7	10.7
	Raw material reuse	0.0	0.0	7.2	6.9
	Simple burning	3.9	3.2	14.4	13.1
Emission reduction effect	Thermal recycling	-13.1	-12.5	-45.1	-43.7
	Product reuse	0.0	0.0	-29.4	-28.0
	Raw material reuse	0.0	0.0	-14.9	-13.7

6. GHG Emission Amount in Lifecycle

The following table shows the total for the GHG emission amount in the lifecycle, based on representative tyres.

Table 47. GHG Emission Amount (Details) in the Lifecycle

(Units: $kgCO_2e$/tyre)

Class			PCR		TBR	
			General tyres	Fuel efficient tyres	General tyres	Fuel efficient tyres
Raw material stage		Raw material manufacturing	22.8	21.7	126.2	117.9
		Raw material shipping	2.1	2.2	21.8	21.8
Manufacturing stage		Manufacturing	7.8	7.0	35.6	35.2
Distribution stage		Shipping	1.6	1.5	10.4	10.1
Usage Stage		Use	263.4	210.8	2,167.5	1,734.0
End of life & recycling stage	Emission amount	Recovery shipment	0.4	0.4	2.4	2.4
		Thermal recycling	11.7	9.6	23.6	21.5
		Product reuse	0.0	0.0	10.7	10.7
		Raw material reuse	0.0	0.0	7.2	6.9
		Simple burning	3.9	3.2	14.4	13.1
Total of GHG emission amount			313.7	256.4	2,419.6	1,973.6
End of life & recycling stage	Reduction effect	Thermal recycling	-13.1	-12.5	-45.1	-43.7
		Product reuse	0.0	0.0	-29.4	-28.0
		Raw material reuse	0.0	0.0	-14.9	-13.7
GHG emission amount in lifecycle (considering reduced effect)			300.6	243.9	2,330.3	1,888.1

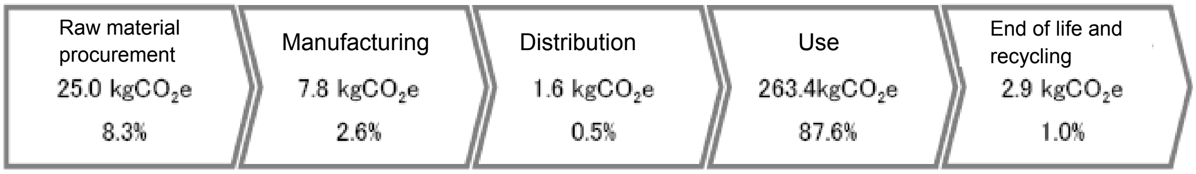
Table 48. GHG Emission Amount (By Stage) in the Lifecycle

(Units: $kgCO_2e$/tyre)

Class	PCR				TBR			
	General tyres		Fuel efficient tyres		General tyres		Fuel efficient tyres	
Raw material stage	25.0	8.3%	23.9	9.8%	147.9	6.3%	139.7	7.4%
Manufacturing stage	7.8	2.6%	7.0	2.9%	35.6	1.5%	35.2	1.9%
Distribution stage	1.6	0.5%	1.5	0.6%	10.4	0.4%	10.1	0.5%
Usage Stage	263.4	87.6%	210.8	86.4%	2,167.5	93.0%	1,734.0	91.8%
End of life & Recycling stage	2.9	1.0%	0.7	0.3%	-31.1	-1.3%	-30.9	-1.6%
Emission	15.9	5.3%	13.1	5.4%	58.2	2.5%	54.5	2.9%
Emission reduction effect	-13.1	-4.3%	-12.5	-5.1%	-89.3	-3.8%	-85.4	-4.5%
Total	300.6	100.0%	243.9	100.0%	2,330.3	100.0%	1,888.1	100.0%

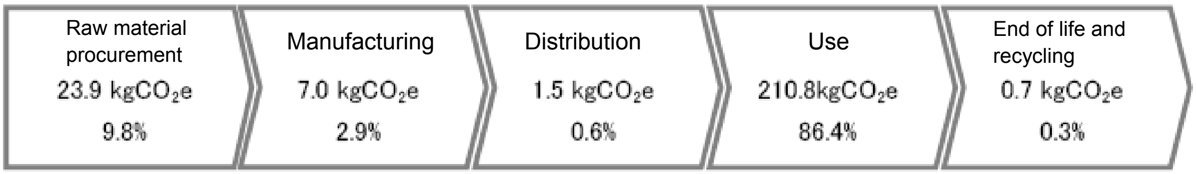
[PCR]

Lifecycle GHG emission amount per one general tyre = 300.6 $kgCO_2e$



* GHG emission amount in the end of life & recycling stage: Emission = 15.9 $kgCO_2e$; Reduction effect = -13.1 kgCO2e

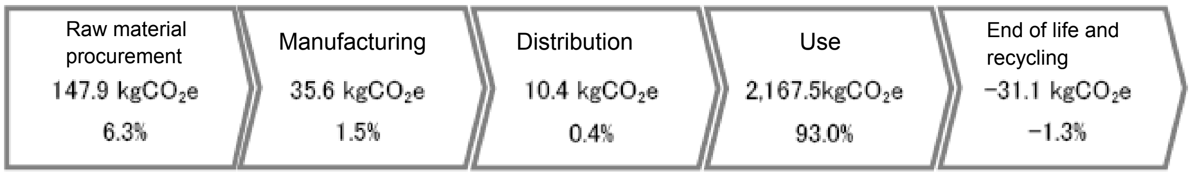
Lifecycle GHG emission amount per one fuel efficient tyre = 243.9 $kgCO_2e$



* GHG emission amount in the end of life & recycling stage: Emission = 13.1 $kgCO_2e$; Reduction effect = -12.5 kgCO2e

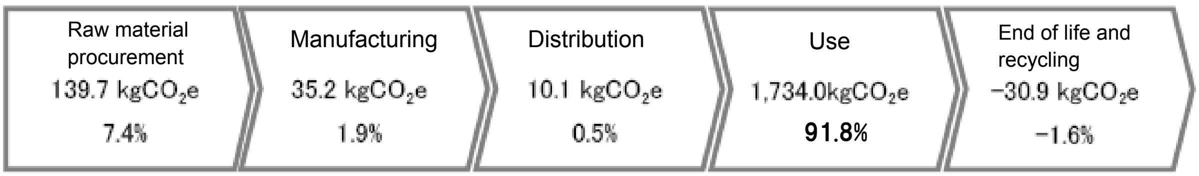
[TBR]

Lifecycle GHG emission amount per one general tyre = 2,330.3 $kgCO_2e$



* GHG emission amount in the end of life & recycling stage: Emission = 58.2 $kgCO_2e$; Reduction effect = -89.3 $kgCO_2e$

Lifecycle GHG emission amount per one fuel efficient tyre = 1,888.1 $kgCO_2e$



* GHG emission amount in the end of life & recycling stage: Emission = 54.5 $kgCO_2e$; Reduction effect = -85.4 kgCO2e

Fig. 4 GHG Emission Amount (Drawing) in the Lifecycle

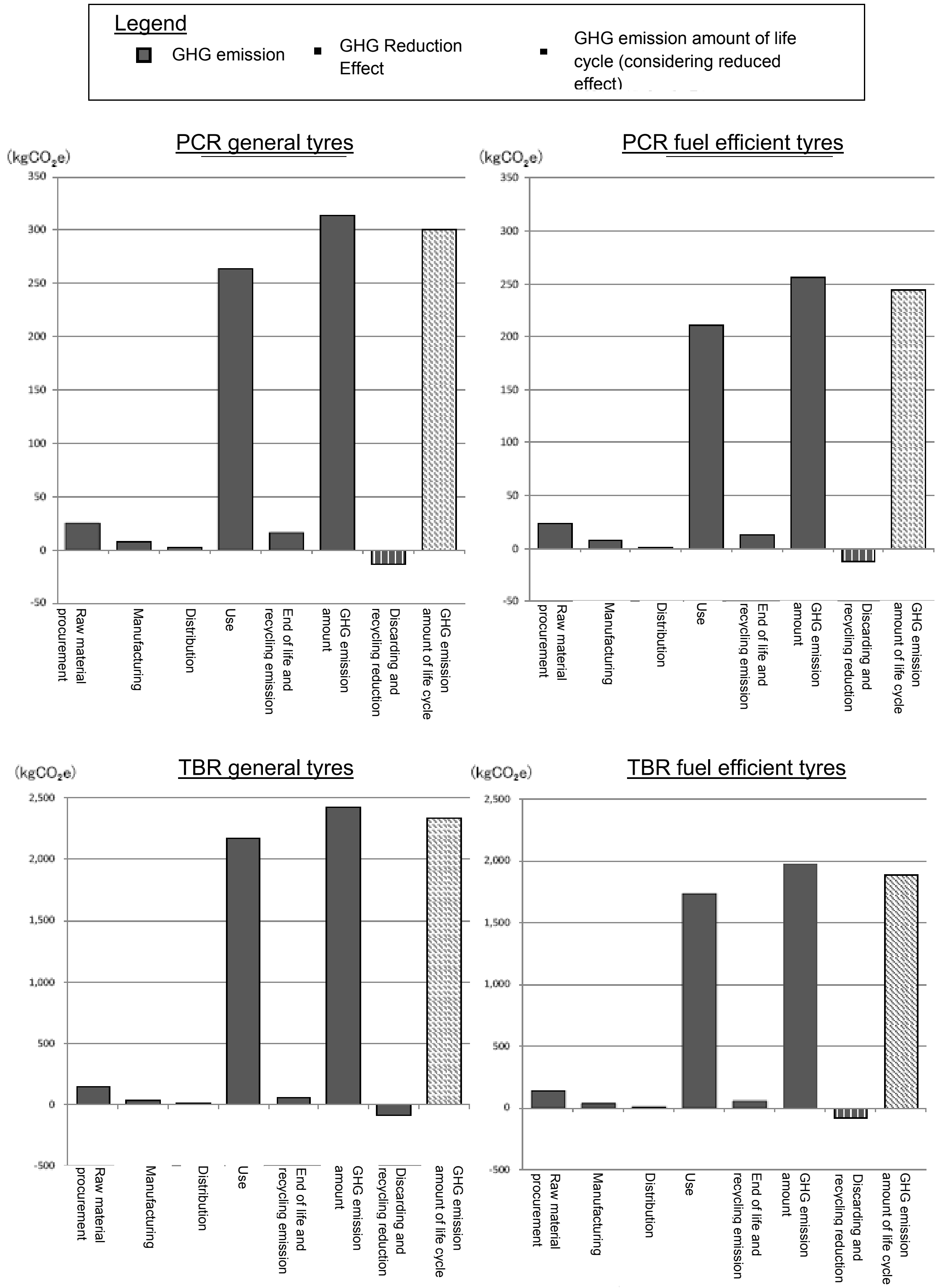


Fig. 5 GHG Emission Amount (Graphs) in the Lifecycle