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JAPIA
LCI Calculation Guidelines

Second Edition

Japan Auto Parts Industries Association

Life-Cycle Assessment Society of Japan

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LCI Calculation Guidelines
Second Edition

2016 April

JAPIA Japan Auto Parts Industries Association
Environmental Consciousness Committee,
LCA Subcommittee

Introduction to the Second Edition of JAPIA LCI Calculation Guidelines

This Second Edition is published in April 2016 as a revised version of the JAPIA LCI Calculation Guidelines issued first in March 2013. The First Edition included only the manufacturing phase of automotive parts in the scope of LCI study. The Second Edition has newly included methods for environmental impact assessment in the consumer use phase to identify the environmental impacts of the products manufactured by the JAPIA member companies throughout their life cycles.

Systematic methods for assessment of intermediate products in the consumer use phase are the first attempt for the automotive industry. This is expected to facilitate the visualization of environmental impacts of automotive parts and relevant business activities and the further development of environmental management at the individual JAPIA member companies.

Major revisions

- Newly included methods for calculating environmental loads in the consumer use phase
- Newly included Supplement 2

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Japan Auto Parts Industries Association, Environmental Consciousness Committee, LCA Subcommittee

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1. Introduction

In recent years, there has been growing interest in the environmental friendliness of industrial products. Automotive parts are no exception to this trend. In fact, concern for the environmental friendliness of auto parts is growing and therefore, it is of increasing importance to identify the environmental impacts of auto parts throughout their life cycles. Consequently, efficient studying of accurate numerical data is an urgent issue.

Supply chains for manufacturing of auto parts are complicated, including multiple tiers. Thus, even if life cycle assessment (LCA) is conducted for measurement of environmental loads in the manufacturing phase, it is practically very difficult to identify the environmental loads of auto parts under study in such conditions. In short, it involves possibilities of missing and/or erroneous data attributable to information transmission or the studying system to conduct the study by tracing the upstream supply chains without any direct business connections, thus leading to decreased accuracies of data.
By nature, LCA lacks such universality as available in the fields of physics and chemistry in terms of numeric values obtained from studies of individual unit processes and their interpretation as well as in terms of logical relationships between the individual unit processes. This means that verification based on the interpretation of numerical data collected from studies is impossible. This specific structure of LCA causes difficulty in conducting adequate studies based on tracing the supply chains.

With respect to the environmental load intensity of auto parts in the use phase, there have been no universal concepts established on the calculation of environmental load intensity of the intermediate products in the consumer use phase because they are not any end products and thus, visual identification has been impossible. Then, the Japan Auto Parts Industries Association (hereinafter referred to as JAPIA) member companies involved in manufacturing of auto parts have had great difficulty in demonstrating their own contribution to reduced environmental loads in the consumer use phase internally and externally.

Therefore, the JAPIA has developed a methodology to estimate the factors associated with the environmental impacts in the aspect of environmental impact assessment in the manufacturing phase of products (types and quantities of energy resources used (see Term No. 10), types and quantities of raw materials loaded, and types and quantities of substances likely to affect the environments to which the substances are emitted) from materials configuring the products and their masses and resultantly identify environmental impacts efficiently in order to take on the first challenge. Additionally, in order to take on the second challenge, we at JAPIA have developed a new methodology for calculation of environmental load intensity by organizing possible approaches for calculation of environmental load intensity in the consumer use phase of products (see “7. Basic concepts”). These two methodologies allow successful implementation of effective assessment of environmental load intensity in the manufacturing phase, including the supply chains of own products and also visualization of environmental loads in the consumer use phase, and thus, they are expected to facilitate the provision of useful information to both inside and outside of each member company.

2. Purpose

The Guidelines are intended to explain the approaches for comprehensively identifying the information contributing to assessment of environmental impacts of component parts used in motor vehicles and standardize the procedures for LCI data calculation for auto parts.
In practice, however, this is one of the standard approaches JAPIA has developed by improving the efficiency of Life Cycle Inventory analysis and therefore, **the Guidelines are not intended to preclude the individual JAPIA member companies from implementing the environmental impact assessment of their own products based on any other methods**.

3. Scope

The Guidelines are applicable to estimation of the usage of energy resources (see Term No. 10) and the emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), and other environmentally hazardous substances derived from the use of energy resources at individual phases of life cycle (manufacturing, transportation, consumer use, disposition, etc.) for every automotive part designed, manufactured, and/or marketed by JAPIA member companies. This Second Edition newly includes a description about the methods for estimation of environmental load intensity in the manufacturing phase, including materials manufacturing, purchased products manufacturing, and member company's internal manufacturing, and in the consumer use phase in which auto parts are mounted on motor vehicles. Furthermore, the Guidelines are also applicable to estimation of environmental load intensity in the manufacturing and consumer use phases of auto parts with respect to Product Environmental Impact Indicator (see Japan Auto Parts Industries Association Product Environmental Impact Indicator Guidelines).

4. Calculation of environmental load intensity of auto parts within the system boundaries (see Term No. 19)

In the Guidelines, the methods for calculation of environmental load intensity are defined for each phase of life cycle of individual auto parts. This Second Edition provides the calculation methods in the phases of manufacturing and consumer use.

4.1 Calculation of environmental load intensity in the manufacturing phase

For calculation of environmental load intensity of auto parts in the manufacturing phase within the system boundary proposed in the Guidelines, the environmental loads in the manufacturing phase of materials and the environmental loads in the phases of purchased products manufacturing and in-house manufacturing must be integrated. The environmental load intensity referred to in the Guidelines means the usage of energy resources in the individual phases, materials manufacturing, purchased products manufacturing and in-house manufacturing, and the emissions of environmentally hazardous substances derived from the use of the energy resources.

The basic calculation formula is shown below.

(Environmental load intensity of an auto part in the manufacturing phase within the system boundary defined by the Guidelines)

$= \Sigma (M_{at} \times m) + \Sigma (P_{NE} \times m) + \Sigma (P_E \times n)$

M_{at}: Base unit of environmental load in the manufacturing phase of materials
P_{NE}: Base unit of environmental load of any parts other than electronic components in the manufacturing phase (materials processing phase)
m: Mass of individual materials
P_E: Base unit of environmental load of electronic components in the manufacturing phase (including mounting process)
n: Number of terminal pins on an electronic component

In practice, <u>the formula shown above and the numerical values calculated based on the formula become valid only when there is a clear statement that the calculation is based on the Guidelines</u> presuming "7. Basic concepts" described later.

4.2 Calculation of environmental load intensity in the consumer use phase

For calculation of environmental load intensity of auto parts in the consumer use phase within the system boundary proposed in the Guidelines, the total amount of fuel or electric energy consumed in the practical use of motor vehicles, etc. must be allocated to individual auto parts. Methods of allocation depend on the function of individual auto parts and in fact, the following four (4) methods are used for the allocation.

Allocation method	Description
(1) Allocation according to mass (inertia)	The workload needed to accelerate the entire motor vehicle including auto parts in the vehicle-mounted condition is allocated according to the mass of individual auto parts. The necessary workload for accelerating a motor vehicle is determined based on the vehicle running pattern (vehicle use scenario in the life cycle of motor vehicle based on the JC08 mode cycle specifying the

	duration, traveling distance, and other parameters). This allocation is applied commonly to all auto parts.
(2) Allocation according to electric power consumption	Allocation according to the amount of electric power of an auto part consumed (lost) in the vehicle-mounted condition to meet the needs of vehicle functions or users (a driver and passengers). Calculated based on the practical use scenario of the predetermined life cycle for assessment of the part concerned. Applied commonly to all involved auto parts having the input of electric power. Typical applications) Headlights, meters, engine starters, electronic circuits
(3) Allocation according to direct use of power (shaft output) of prime mover	Allocation according to the workload of directly using (losing) the power (shaft output) generated in the engine in the vehicle-mounted condition to meet the needs of vehicle functions or users (a driver and passengers). Calculated based on the practical use scenario of the predetermined life cycle for assessment of the part concerned. Applied commonly to all auto parts having the input/output of power. Typical applications) Alternator (generator), air-conditioning system (compressors of any type other than electric-powered type), oil seals, torque converters, transmissions, bearings, other power transmission parts, wheels, brake disks/drums.
(4) Allocation in direct connection with the loss at the time of power generation by prime mover (engine, motor, etc.)	To the auto parts having the functions that directly affect the energy conversion efficiency (or thermal efficiency for internal combustion engine, or motor efficiency for motor) of prime mover, the improvable loss generated in the process of energy conversion by the prime mover is allocated according to the significance of influence of the auto part concerned on the loss of the prime mover. For the allocation according to the significance of influence, the influence of an individual auto part must be quantified. One of the methods for quantification is price ratio of individual auto parts. This allocation depends on the energy conversion efficiency, and thus it is dependent on the fuel consumption (electric power consumption) of the motor vehicle incorporating the prime mover in question. Typical applications) fuel injection control system, ignition plugs, muffler, engine ECU radiator

Calculating formula is shown below.

(Environmental load intensity of an auto part in the consumer use phase within the system boundary defined by the Guidelines)
$= (L_{am}\times M) + (L_{ae}\times I) + (L_{aw}\times P) + (L_{aa}\times A)$

L_{am}: Environmental load intensity per 1 kg of auto part
L_{ae}: Environmental load intensity per 1 A of auto part
L_{aw}: Environmental load intensity per 1 W of auto part
L_{aa}: Environmental load intensity due to the loss caused by energy conversion of prime mover on a motor vehicle incorporating the auto part subject to the calculation
M: Mass of auto part included in the calculation
I: Electric current consumption (loss) of auto part included in the calculation
P: Input (loss) workload to the auto part included in the calculation
A: Rate of allocation to the auto part included in the calculation

In practice, <u>the formula shown above and the numerical values calculated based on the formula become valid only when the compliance with the Guidelines is clearly expressed</u> presuming "7. Basic concepts" described later.

5. Typical calculation

Basic procedures are described below. This typical calculation includes the procedures for calculating the amount of energy resources used in the material and manufacturing phases of the auto part under study and the amount of such environmentally hazardous substances derived from the energy resources and discharged in the atmospheric air and water, and the procedures for calculating the amount of energy resources used in the consumer use phase and the amount of environmentally hazardous substances derived from the energy resources and discharged in the atmospheric air.

The numerical values, items, material names, product names, product numbers, and other data included in the Guidelines are intended for typical cases. For actual implementation of assessment, the items, numerical values, and other data included in the Guidelines Supplement 1 (hereinafter referred to as Manufacturing Phase Data Sheets) or the Guidelines Supplement 2 (hereinafter referred to as Consumer Use Phase Data Sheets) should be used.

5.1 Calculation of environmental load in the manufacturing phase

Steps	Description
(1) Studies on material composition of auto parts	For individual auto parts under study, the material composition is investigated and summarized by the material classification in (2) and (3).
(2) Calculation of environmental load in the material phase	Calculation in the manufacturing phase of materials
(3) Calculation of environmental load in the manufacturing phase	Calculation in the manufacturing phase of auto parts
(4) Integration of environmental loads	(2) + (3)

5.1.1 (1) Studies on material composition of auto parts

[Auto part under study]
Product No. 123456789 Product name ASSY

[Material composition]

(a) Electronic component (Part No. 999999000 Part name MOS IC)
2 pieces No. of terminal pins in each component 40 Total number of terminal pins 40*2=80

(b) Parts other than electronic components As listed in the table below.
* The table also includes the material composition of electronic components.

Configuration level	Product No.	Product name	Q'ty	Part weight [g]	Name of component material	Material weight [g]	Ref. STD. for material
0	123456789	ASSY	1	190			
1	0000000000	CASE	1	60			
					Plastics PP (Filled)	60	ISO1043
1	0000000000	COVER	1	20			
					Plastics PP (Filled)	20	ISO1043
1	0000000000	CIRCUIT	1	32			
2	999999000	MOS IC	2	1			
					Leadframe	0.5	
					Wire	0.2	
					Doped silicon	0.3	
2	0000000000	BOARD	1	29			
					Copper	5	
					Ink	1	
					Plastics EP (Filled)	21	ISO1043
					Solder H63A	2	JISZ3282
2	0000000000	RESISTOR	20	0.05			
					Ceramics	0.02	
					Electrolytic Nickel Plating	0.01	JISH8617
					Glass	0.01	
					Silver/Silver alloy	0.01	
1	0000000000	BRACKET	1	70			
					Electrolytic Zinc Plating	0.5	JISH8610
					Steel SPCE	69.5	JISG3141
1	0000000000	SCREW	4	2			
					Electrolytic Zinc Plating	0.05	JISH8610
					Steel SPCC	1.95	JISG3141

[Summary of materials]

Conversion from component material names to material classification for calculation of environmental load intensity of auto parts within the system boundary (material classification for LCI calculation) is based on the Manufacturing Phase Data Sheets “1. Cross-reference matrix in conversion between component material name and material classification for LCI calculation.”

Name of component material	Ref. STD. for material
Plastics PP (Filled)	ISO1043
Leadframe	
Wire	
Doped silicon	
Copper	
Ink	
Plastics EP (Filled)	ISO1043
Solder H63A	JISZ3282
Ceramics	
Electrolytic Nickel Plating	JISH8617
Glass	
Silver/Silver alloy	
Electrolytic Zinc Plating	JISH8610
Steel SPCE	JISG3141
Steel SPCC	JISG3141

⇨

Material classification for LCI calculation	Weight (g)
Polypropylene	80
Electronic component materials	1
Electronic component materials	0.4
Electronic component materials	0.6
Copper	5
Paints	1
Other thermosetting resins	21
Other special metals (Solders)	2
Ceramics	0.4
Nickel alloys	0.2
Glass	0.2
Electronic component materials	0.2
Zinc alloys	0.7
Cold-rolled carbon steel sheet/steel strip	69.5
Cold-rolled carbon steel sheet/steel strip	7.8

⇨

Material classification for LCI calculation	Weight (g)
Polypropylene	80
Electronic component materials	2.2
Copper	5
Paints	1
Other thermosetting resins	21
Other special metals (Solders)	2
Ceramics	0.4
Glass	0.2
Nickel alloys	0.2
Zinc alloys	0.7
Cold-rolled carbon steel sheet/steel strip	77.3

5.1.2 (2) Calculation of environmental load in the material phase

[Calculation of environmental load intensity of individual materials in the manufacturing phase]

The base unit of energy* resource consumption in the manufacturing phase of individual materials, the base unit of the substances of environmental concern discharged in the air and water due to the fuel combustion in the manufacturing phase of individual materials, and the base unit of environmentally hazardous substances discharged in the air and water due to the electric power generation are based on the Manufacturing Phase Data Sheets “2. Base unit of energy* resource consumption in the manufacturing phase of individual materials and the base unit of substances of environmental concern discharged in the air and water due to the fuel combustion, the base unit of energy* resource consumption in the processing phase of individual materials and the base unit of substances of environmental concern discharged in the air and water due to the fuel combustion” and “4. Base unit of substances of environmental concern discharged in the air and water due to the electric power generation by electric utilities.”

Material classification for LCA calculation	Weight (g)	×	Base unit of energy consumption in the manufacturing of individual materials: Electric power (Wh/g)	City gas (10E-3 m^3/g)	Kerosene (mL/g)	Light oil (mL/g)	Fuel oil A (mL/g)	Fuel oil C (mL/g)	Gasoline (mL/g)	LPG (g/g)	LNG (g/g)	Propane (g/g)	Coal (g/g)	Natural gas (g/g)	Crude oil (g/g)
Polypropylene	80		0.159	0.000	0.000	0.335	0.032	0.030	0.000	0.016	0.000	0.000	0.000	0.000	0.000
Electronic component materials	2.2		0.171	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Copper	5		0.729	0.000	0.002	0.000	0.001	0.091	0.000	0.004	0.000	0.000	0.120	0.000	0.000
Paints	1		0.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other thermosetting resins	21		0.310	0.000	0.000	0.000	0.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other special metals	2		0.171	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ceramics	0.4		34.360	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.279	0.000	0.000
Glass	0.2		0.353	0.005	0.001	0.000	0.004	0.322	0.000	0.006	0.000	0.000	0.000	0.000	0.000
Nickel alloys	0.2		5.410	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zinc alloys	0.7		2.800	0.001	0.000	0.000	0.013	0.007	0.031	0.000	0.000	0.000	0.000	0.000	0.000
Cold-rolled carbon steel sheet/steel strip	77.3		0.440	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.535	0.039	0.062
		Sum total	74.641	0.002	0.010	26.800	8.482	2.924	0.022	1.301	0.000	0.000	42.067	3.015	4.793

×	Base unit of environmentally hazardous substances discharged in the air and water due to the fuel combustion in the manufacturing of individual materials: CO_2(g/g)	NO_x(mg/g)	SO_x(mg/g)	PM(mg/g)	HC(mg/g)	HCl(mg/g)	BOD(mg/g)	COD(mg/g)
	1.002	0.913	0.225	0.028	3.168	0.000	0.024	0.045
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.592	1.370	5.920	0.620	0.000	0.000	0.000	0.360
	0.001	0.001	0.000	0.000	0.330	0.000	0.000	0.000
	0.109	0.122	0.163	0.005	0.000	0.000	0.000	1.490
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.662	1.282	0.004	0.000	0.000	0.000	0.000	0.000
	1.152	5.000	3.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1.170	0.350	3.870	0.035	0.000	0.000	0.000	0.000
	1.432	1.490	0.907	0.605	0.000	0.000	0.008	0.040
Total	197.418	199.388	124.445	52.226	253.770	0.032	2.538	39.782

Sum total of electric power consumption	×	Base unit of environmentally hazardous substances discharged in the air and water due to electric power generation: CO_2(g/Wh)	NO_x(mg/Wh)	SO_x(mg/Wh)	PM(mg/Wh)	HC(mg/Wh)	HCl(mg/Wh)	BOD(mg/Wh)	COD(mg/Wh)
74.641		0.425	0.170	0.130	0.006	0.000	0.000	0.000	0.000
	Total	31.722	12.689	9.703	0.481	0.000	0.000	0.000	0.012
	Sum total	229	212	134	53	254	0.032	2.54	39.8

5.1.3 (3) Calculation of environmental load in the manufacturing phase

[Calculation of environmental load intensity caused by the manufacturing and assembling of electronic components]

The base unit of energy* resource consumption in the manufacturing of electronic components, the base unit of the substances of environmental concern discharged in the air and water due to the fuel combustion in the manufacturing of electronic components, and the base unit of environmentally hazardous substance discharged in the air and water due to the electric power generation are based on the Manufacturing Phase Data Sheets “3. Base unit of energy* resource consumption in the manufacturing and assembling of electronic components and the base unit the substances of environmental concern discharged in the air and water due to the fuel combustion” and “4. Base unit of the substances of environmental concern discharged in the air and water due to the electric power generation by electric utilities.”

Total number of terminal pins in electronic component (n)
80

×

	Base unit of energy consumption in the manufacturing of individual electronic components												
	Electric power (Wh/pin)	City gas (10E-3 m^3/pin)	Kerosene (mL/pin)	Light oil (mL/pin)	Fuel oil A (mL/pin)	Fuel oil C (mL/pin)	Gasoline (mL/pin)	LPG (g/pin)	LNG (g/pin)	Propane (g/pin)	Coal (g/pin)	Natural gas (g/pin)	Crude oil (g/pin)
	7.6*n+482	0.014	0.000	0.000	0.016	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
Sum total	1090.000	1.133	0.000	0.000	1.302	0.000	0.000	0.392	0.000	0.000	0.000	0.000	0.000

×

	Base unit of environmentally hazardous substances discharged in the air and water due to fuel combustion in the manufacturing of individual electronic components							
	CO_2(g/pin)	NO_x(mg/pin)	SO_x(mg/pin)	PM(mg/pin)	HC(mg/pin)	HCl(mg/pin)	BOD(mg/pin)	COD(mg/pin)
	0.073	0.230	0.018	0.000	0.000	0.000	0.000	0.000
Total	5.840	18.400	1.440	0.000	0.000	0.000	0.000	0.000

Sum total of electric power consumption	1090.000

×

	Base unit of environmentally hazardous substances discharged in the air and water due to electric power generation							
	CO_2(g/Wh)	NO_x(mg/Wh)	SO_x(mg/Wh)	PM(mg/Wh)	HC(mg/Wh)	HCl(mg/Wh)	BOD(mg/Wh)	COD(mg/Wh)
	0.425	0.170	0.130	0.006	0.000	0.000	0.000	0.000
Total	463.250	185.300	141.700	7.031	0.000	0.000	0.000	0.174
Sum total	469	203.7	143.1	7.0	0.0	0.0	0.0	0.2

[Calculation of environmental load intensity in the manufacturing and assembling of parts other than electronic components]

The base unit of energy* resource consumption in the manufacturing of parts other than electronic components, the base unit of the substances of environmental concern discharged in the air and water due to the fuel combustion in the manufacturing of parts other than electronic components, and the base unit of environmentally hazardous substance discharged in the air and water due to the electric power generation are based on the Manufacturing Phase Data Sheets “2. Base unit of energy resources consumption in the manufacturing phase of individual materials and the base unit of the substances of environmental concern discharged in the air and water due to the fuel combustion, the base unit of energy* resource consumption in the processing phase of individual materials and the base unit of the substances of environmental concern discharged in the air and water due to the fuel combustion” and “4. Base unit of the substances of environmental concern discharged in the air and water due to the electric power generation by electric utilities.”

Material classification for LCA calculation	Weight (g)		Base unit of energy consumption in the processing of individual materials												
			Electric power (Wh/g)	City gas (10E-3 m^3/g)	Kerosene (mL/g)	Light oil (mL/g)	Fuel oil A (mL/g)	Fuel oil C (mL/g)	Gasoline (mL/g)	LPG (g/g)	LNG (g/g)	Propane (g/g)	Coal (g/g)	Natural gas (g/g)	Crude oil (g/g)
Polypropylene	80	×	3.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electronic component materials	2.2		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Copper	5		2.978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Paints	1		1.285	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other thermosetting resins	21		3.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other special metals	2		2.978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ceramics	0.4		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Glass	0.2		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nickel alloys	0.2		2.978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zinc alloys	0.7		2.978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cold-rolled carbon steel sheet/steel strip	77.3		1.562	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Sum total	467.561	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Base unit of environmentally hazardous substances discharged in the air and water due to fuel combustion in the processing of individual materials							
	CO_2(g/g)	NO_x(mg/g)	SO_x(mg/g)	PM(mg/g)	HC(mg/g)	HCl(mg/g)	BOD(mg/g)	COD(mg/g)
×	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			Base unit of environmentally hazardous substances discharged in the air and water due to electric power generation							
			CO_2(g/Wh)	NO_x(mg/Wh)	SO_x(mg/Wh)	PM(mg/Wh)	HC(mg/Wh)	HCl(mg/Wh)	BOD(mg/Wh)	COD(mg/Wh)
Sum total of electric power consumption	467.561	×	0.425	0.170	0.130	0.006	0.000	0.000	0.000	0.000
		Total	198.713	79.485	60.783	3.016	0.000	0.000	0.000	0.075
		Sum total	199	79	61	3	0.0	0.0	0.0	0.1

5.1.4 (4) Integration of environmental loads

(2) + (3)

	Energy consumption												
	Electric power (Wh)	City gas (10E-3 m^3)	Kerosene (mL)	Light oil (mL)	Fuel oil A (mL)	Fuel oil C (mL)	Gasoline (mL)	LPG (g)	LNG (g)	Propane (g)	Coal (g)	Natural gas (g)	Crude oil (g)
In the manufacturing of materials	74.6	0.0	0.0	26.8	8.5	2.9	0.0	1.3	0.0	0.0	42.1	3.0	4.8
In the manufacturing of electronic components	1090.0	1.1	0.0	0.0	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
In the manufacturing of parts other than electronic components	467.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1632.2	1.1	0.0	26.8	9.8	2.9	0.0	1.7	0.0	0.0	42.1	3.0	4.8

	Emissions of environmentally hazardous substances							
	CO_2 (g)	NO_x(mg)	SO_x(mg)	PM(mg)	HC(mg)	HCl(mg)	BOD(mg)	COD(mg)
In the manufacturing of materials	229.1	212.1	134.1	52.7	253.8	0.0	2.5	39.8
In the manufacturing of electronic components	469.1	203.7	143.1	7.0	0.0	0.0	0.0	0.2
In the manufacturing of parts other than electronic components	198.7	79.5	60.8	3.0	0.0	0.0	0.0	0.1
Total	896.9	495.3	338.1	62.8	253.8	0.0	2.5	40.0

5.2 Calculation of environmental load in the consumer use phase

[Auto part under study]
Product No. 123456789　Product name　ASSY

Steps	Description
(1) Allocation according to mass	Mass has been already identified in the preceding 5.1 (1).
(2) Allocation according to electric power consumption	Electric power consumption to be determined
(3) Allocation according to direct use of power	Power consumption (loss) to be determined
(4) Allocation in direct connection with loss at the time of driving force generation by prime mover (engine, motor, etc.)	The part is identified for direct involvement in the engine loss.
(5) Total of environmental loads	(1) + (2) + (3) + (4)

5.2.1 (1) Allocation according to mass

[Mass]
190 g

[Calculation of environmental load intensity according to mass]

1. The environmental load intensity per mass of 1 kg in the consumer use phase is based on the Consumer Use Phase Data Sheets “2. Numeric constants for calculation of environmental loads based on PE allocation - 2.1 Allocation according to mass.”

5.2.2 (2) Allocation according to electric power consumption

[Electric power consumption]
5 A (Running average)

[Operating time]
Equivalent to the hours of operation of the vehicle to which the auto part under study is mounted

[Calculation of environmental load intensity according to electric power consumption]
The environmental load intensity per second per ampere in the consumer use phase is based on the Consumer Use Phase Data Sheets “2. Numeric constants for calculation of environmental loads based on PE allocation - 2.2 Allocation according to electric power consumption.”

5.2.3 (3) Allocation according to direct use of power

[Power loss]
10 W (Running average)

[Operating time]
Equivalent to the hours of operation of the vehicle to which the auto part under study is mounted

[Calculation of environmental load intensity according to electric power consumption]
The environmental load intensity per second per watt in the consumer use phase is based on the Consumer Use Phase Data Sheets “2. Numeric constants for calculation of environmental loads based on PE allocation - 2.3 Allocation according to power (shaft output) consumption.”

5.2.4 (4) Allocation in direct connection with loss at the time of driving force generation by prime mover (engine, motor, etc.)

[Allocation ratio of engine loss]
1%

[Engine loss]
For the vehicle to which the auto part under study is mounted, the fuel consumption is assumed to be 17.6 km/L and the improvable engine loss 16%.

[Calculation of environmental load intensity allocated according to function]
Allocation ratio of loss at the time of engine output according to function is based on the Consumer Use Phase Data Sheets “2. Numeric constants for calculation of environmental loads based on PE allocation - 2.4 Allocation in direct connection with loss at the time of driving force generation by prime mover (engine, motor, etc.).”

5.2.5 (5) Total of environmental loads in the consumer use phase

(1) + (2) + (3) + (4)

6. Terms and definitions

Terms and definitions used in the Guidelines are listed in Table 1. For the other terms not listed in the table, refer to the JAPIA Product Environmental Impact Indicator Guidelines.

Table 1 Terms and definitions

No.	Term	Definition
1	Life Cycle Assessment (LCA)	Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle (ISO14040 Clause 3.2)[*1] Back Alt + ←
2	Life Cycle	Consecutive and interrelated stages of a product system, from raw material acquisition or natural resources production to final disposal (ISO14040 Clause 3.1)[*1] Back Alt + ←
3	Lifetime of a product and its component parts	Life cycle of a product and its component parts (see Term No. 7) Back Alt + ←
4	ISO14040: 2006	Environmental management - Life cycle assessment – Principles and framework Back Alt + ←
5	Product	Aggregation of smallest units performing one or more defined functions, which collects data for implementation of Life Cycle Assessment (see Term No. 1). The smallest units are combined with each other physically and energetically (see Term No. 10). A product conforms to “product system” defined in ISO14040 Clause 3.28[*1]. The term “product” includes a service system. Remarks: A product refers to not only the physically composed existing product but also a series of related flows involving environmental loads. Back Alt + ←
6	Component part	A portion of a physically composed product, requiring processing and changing for physical composition of the product. It is able to perform one or more defined functions in the product, and it can be considered to conform to the product system defined in ISO14040 even by itself and can become subject to Life Cycle Assessment. Back Alt + ←
7	Product and its component parts	A product and its component parts Back Alt + ←
8	System	Combined several products to perform one or more defined functions. The combination or a system can be also considered as a product. Back Alt + ←
9	Environmental load	Effects of human activities on the global environment, having the potential of causing interference with preservation of the environment and inhibiting the sustainable development by humans. In the Guidelines, the environmental load refers to use of energy resources (see Term No. 10) and emissions of environmentally hazardous substances. Back Alt + ←

10	Energy resources	Generic term for electric power, fossil fuel, and other fuels. Excludes solar radiation, waterpower, wind power, wave power, geothermal heat, and other renewable resources. Distinguished from the “energy” defined in physics, or the capacity for doing work to external objects or systems. For this reason, in the Guidelines, the expression “energy resources” is used. Back Alt + ←
11	Environmental hazardous substance	A substance which exerts or can exert adverse effects on humans and/or environments if discharged in the air, water, and/or soils. Includes greenhouse gases, exhaust gases, and substances of environmental concern. Back Alt + ←
12	Substances of environmental concern	Chemical substances defined among the interested parties as providing or possibly providing environmental loads. Back Alt + ←
13	Environmental impacts	Any changes to the environment, whether adverse or beneficial, wholly or partially resulting from an organization (ISO14001)[*2] Back Alt + ←
14	Base unit	Proportion of environmental load intensity to a certain unit quantitative value, e.g., the amount of energy resource needed to manufacture one kilogram of a material. (see Term No. 10). Back Alt + ←
15	MP base units integration	A methodology JAPIA has developed for assessment of environmental impacts of automotive parts throughout the life cycle. It estimates possible environmental impact of an auto part in the phases from material manufacturing through to product manufacturing by correlating the material (<u>M</u>aterial) with the product manufacturing process (<u>P</u>rocess) unambiguously and defining the intensity of the environmental load caused in the process which is correlated with the unit quantity characterizing the material as a coefficient. It allows approximate estimation of environmental load intensity including supply chains (see Term No. 25) by studying the material composition of the product and its component parts and summing up the environmental load intensities in the individual material processes. In practice, however, this method is based on the assumptions that the materials can be correlated with the processes unambiguously and therefore, the results obtained may not accurately reflect the actual conditions. In spite of the assumptions, this methodology should provide an effective means in the early stages of LCI analysis, focusing on the features of comprehensiveness and working efficiency. Back Alt + ←
16	Function	Various characteristics incorporated in a product and its component part Back Alt + ←
17	Performance	Same as “function” Back Alt + ←
18	Functional unit	Quantified performance of a product system for use as a reference unit in the Life Cycle Assessment (ISO14040 Clause 3.20)[*1]. Always includes quantified expressions, since it acts as a reference for comparison. Back Alt + ←
19	System boundary	A boundary between a product and its component parts, and the global environment or other products and their component parts. (ISO14040 Clause 3.32)[*1]。 Back Alt + ←

20	Allocation	Partitioning the input/output of substance or energy to/from the smallest unit for collection of data for implementation of Life Cycle Assessment between the products and their component parts under study. Back Alt+←
21	Assumptions	Prior conditions for implementing the LCA study Back Alt+←
22	Limitations	Restrictions on the interpretation of the study data which include assumptions and uncertainty. Back Alt+←
23	Critical review	Procedures to objectively evaluate the results of LCA and increase the reliability. (ISO14040 Clause 3.45) Back Alt+←
24	Manufacturing, Transportation, Consumer use, and Disposition	Manufacturing: A phase in which raw materials are processed to produce a material and the material is processed and changed to compose a product and its component parts. Transportation: A phase in which raw materials, the processed material, and a product and its component parts are transported. Use: A phase in which the product or the final product (e.g., motor vehicle) incorporating the product is offered for practical use. Disposition: A phase in which the product or the final product with the product incorporated is disposed of. Includes recycling. Back Alt+←
25	Supply chain	A chain of commercial transactions viewed from end users (own company), which is created for procurement of materials composing a product and its component parts or component parts. Back Alt+←
26	Life cycle impact assessment (LCIA)	Evaluating the significance of potential environmental impacts based on the results of life cycle inventory analysis (compilation and quantification of inputs and outputs of substance and/or energy for the product system under study throughout its life cycle) (ISO14040 Clause 3.4)[*1] Back Alt+←
27	Time-related coverage	Elapsed time from a request for data and the minimum length of time over which data should be collected. Back Alt+←
28	Geographical coverage	Geographical area from which data for the smallest units should be collected in the implementation of life cycle assessment to satisfy the goal of the study. Back Alt+←
29	Technology coverage	The extent of specific technology mix. Back Alt+←
30	Precision	Measure of the variability of the data values for each set of data expressed, e.g., variance. Back Alt+←
31	Completeness	The ratio of the number of units from which data collection was successfully attained actually to the units from which data collection was available among all the smallest units from which data was to be collected for the product under study for implementation of life cycle assessment. Back Alt+←

32	Representativeness	Qualitative assessment of the degree to which the acquired data reflects the true population of interest, e.g., showing to which electric power data refers, the national average or the average of electric power companies in a specific district. Back Alt + ←
33	Consistency	Qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis. Back Alt + ←
34	Reproducibility	Qualitative assessment of the extent to which the information about the methodology and data values would allow an independent LCA practitioner to reproduce the results reported in the study. Back Alt + ←
35	Material	Homogeneous substance constituting a component part or a product, made from natural resources. The term “homogeneous” means that the average of chemical components in the entire material is identical to the average of chemical components in any portion of the material. Back Alt + ←
36	Natural resources	Resources which exist in nature. Back Alt + ←
37	Electronic components	Refers, in the Guidelines, to semiconductor integrated circuits or semiconductor devices and resistors, capacitors, and printed-circuit boards intended primarily for processing of electronic signals. Excludes semiconductor lasers, light-emitting diodes, inductors, electronic circuitry transformers and coils, and semiconductor sensors. Back Alt + ←
38	Silicon chip & Compound semiconductor chip	Integrated circuit elements on boards made from silicon element crystals, compound semiconductor crystals. Back Alt + ←
39	No. of terminal pins	The number of metal terminals provided for electric current input/output in the semiconductor integrated circuits or semiconductor devices among the electronic components. Semiconductor integrated circuits or semiconductor devices refer to the electronic devices listed below. Examples: Diodes, small-signal transistors, power transistors, MOS micro, logic, MOS memory, and analog IC http://semicon.jeita.or.jp/icgb/pdf/icgb_4-5.pdf Back Alt + ←
40	Assembling	A process in which component parts are incorporated with each other.
41	Indirect materials	Substances used in the manufacturing process of materials and products and their component parts and not left remaining in the materials and products and their component parts. In the Guidelines, those substances left remaining in products and their component parts are defined to configure the products and therefore they are not referred to as indirect materials. Back Alt + ←
42	PE allocation (Potential energy allocation)	One of the techniques developed at JAPIA for assessment of environmental impacts of auto parts in the life cycles. The energies possessed by fuel and electric power (Potential Energy) are all calculated based on the (four) energy consumption patterns by auto parts in the vehicle-mounted condition and the rate of consumption. This features a standardized technique independent from the type of vehicle prime mover and fuel consumption, thus allowing efficient calculation of environmental load intensity. Back Alt + ←

7. Basic concepts

Back Alt + ←

In the assessment of environmental impacts of products, it is impractical to identify all the factors (type and amount of energy resources used, type and amount of raw materials loaded, type and amount of the substances affecting or likely to affect the environment into which the substances are discharged) associated with possible environmental impacts in all aspects. This suggests the necessity for selecting proper factors to be identified, taking into consideration the importance of respective factors and the significance of possible environmental impacts. In practice, however, for giving consideration to the importance and the significance of environmental impacts in early stages of environmental impact assessment, it is essential to identify the entire environmental impacts of the product and its component parts under study, this causing a contradiction at the end.

In order to avoid such situations, JAPIA has developed a methodology to comprehensively determine environmental impacts through a sequence of procedural steps by simplifying the interrelation between various factors, which govern environmental impacts of a product and its component parts under study, and studying the individual factors in advance without sorting out any factors according to their importance and the significance of environmental impacts. The methodology for determining auto parts for their environmental impacts in the manufacturing phase of life cycle is denoted “MP base units integration (see Term No. 15),” and the methodology for identifying auto parts for their environmental impacts in the consumer use phase is referred to as “PE allocation (see Term No. 42).” Adoption of these methodologies should allow valid assessment of environmental impacts in their early stages, ensuring comprehensiveness and completeness for the products under study.

7.1 Defining the scope of study in the Guidelines

For determination of quantitative values of environmental impacts, it is necessary to define the product and its component parts to be studied and the scope of study on the environmental impacts which the product and its component parts under study provide or can provide.

The scope definition is carried out based on the International Standard ISO14040: 2006 (see Term No. 4) for Life Cycle Assessment (LCA) (see Term No. 1). In the scope definition in LCA, the following items (1) through (12) are specified by the International Standard to be considered and clearly described.

(1) the functions of the product (see Term No. 5) and the system (see Term No. 8) the product composes;
(2) the functional unit (see Term No. 18);
(3) the product to be studied;
(4) the system boundaries (see Term No. 19) of the product under study;
(5) allocation procedures (see Term No. 20);
(6) the methodology of Life Cycle Impact Assessment (LCIA) (see Term No. 26) and subsequent interpretation to be used;
(7) data requirements;
(8) assumptions (see Term No. 21);
(9) limitations (see Term No. 22);
(10) initial data quality requirements;
(11) type of critical review (see Term No. 23), if any;
(12) type and format of the report required for the study.

In the scope definition or the fundamental step in the Guidelines, considerations given are as listed below. In practice, however, where considerations given in the implementation of assessment in accordance with the Guidelines differ from those listed below, they must be stated separately, although the validity of the study implemented is not impaired in terms of adherence to the Guidelines.

(1) The functions of the product and the system the product composes

Capabilities incorporated in motor vehicles, etc. to facilitate the appropriate actions for fulfillment of the functions of motor vehicle, etc. in accordance with the requirements of users or to meet the user needs.

(2) The functional unit

(2.1) In the case of a product

The "functions (see Term No. 16) of actuating a motor vehicle, etc. (transportation equipment) properly" are defined as a unit. The applicable product is considered to be mounted on a motor vehicle, etc. and to provide its characteristics for the motor vehicle in accordance with the needs of the user of the motor vehicle. Where a single system product performs for N (two or more) motor vehicles, the functional unit of a product is considered "the function of actuating N motor vehicles properly." Where *n* (two or more) pieces of the same product perform for one motor vehicle, etc., the functional unit of each product is considered "the function of actuating one motor vehicle properly with *n* pieces of product."

(2.2) In the case of a component part

The "function of actuating one product properly" is defined as a unit. The applicable component part is considered to be incorporated in a product and to provide its characteristics for the product in accordance with the intent of the design personnel of the product. Where *n* (two or more) pieces of same component part perform for one product, the function unit of each component part is considered "the function of actuating one product properly with *n* pieces of component parts."

(3) The product to be studied

Those products and their component parts or the systems configured with the products, which are under discussion among the member companies about environmental friendliness.

(4) The system boundaries of the product

The system boundaries of a product (see Term No. 5) mean the boundaries between the product and the environment or other products. The scope of study for LCA refers to the extent of study on the impacts or potential impacts on the environment associated with the product. In other words, the system boundaries of product may be equivalent to assumptions of determining quantitatively the resources and energy resources introduced in the individual phases of manufacturing, transportation, consumer use, and disposition of the physically constructed product and the substances discharged (Figure 1).

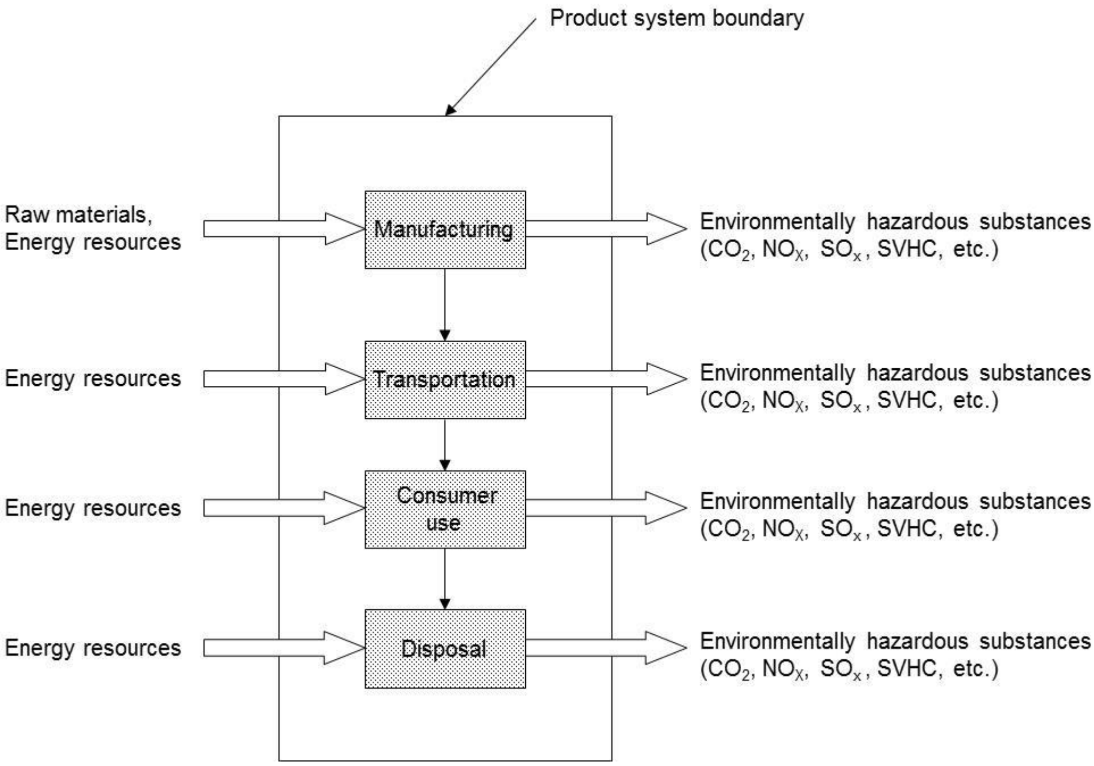

Figure 1 System boundaries of product in its life cycle

Usually, parts configuration, manufacturing processes, and use conditions vary with different products, and therefore the boundaries differ between individual products. For understanding the differences in the boundaries between products, it is necessary to actually investigate the products concerned for physical configurations, manufacturing processes, and use conditions, and set appropriate boundaries for individual products. Then, in order to achieve the purpose of the Guidelines, "identifying the information efficiently and comprehensively, which contributes to environmental impacts assessment," the procedures for setting the boundaries are defined as listed below as common to individual products and their component parts.

[The boundaries based on the physical configuration of the product and its component parts (see Term No. 7)]
Includes all physical configurations of product and its component parts specified by Product/Part No. under study but excludes any software and drawings.

[The boundaries in the lifetime of individual products and their component parts (see Term No. 3)]
The Second Edition only focuses on the manufacturing phase and the consumer use phase of the above described product and its component parts under study (Figure 2).

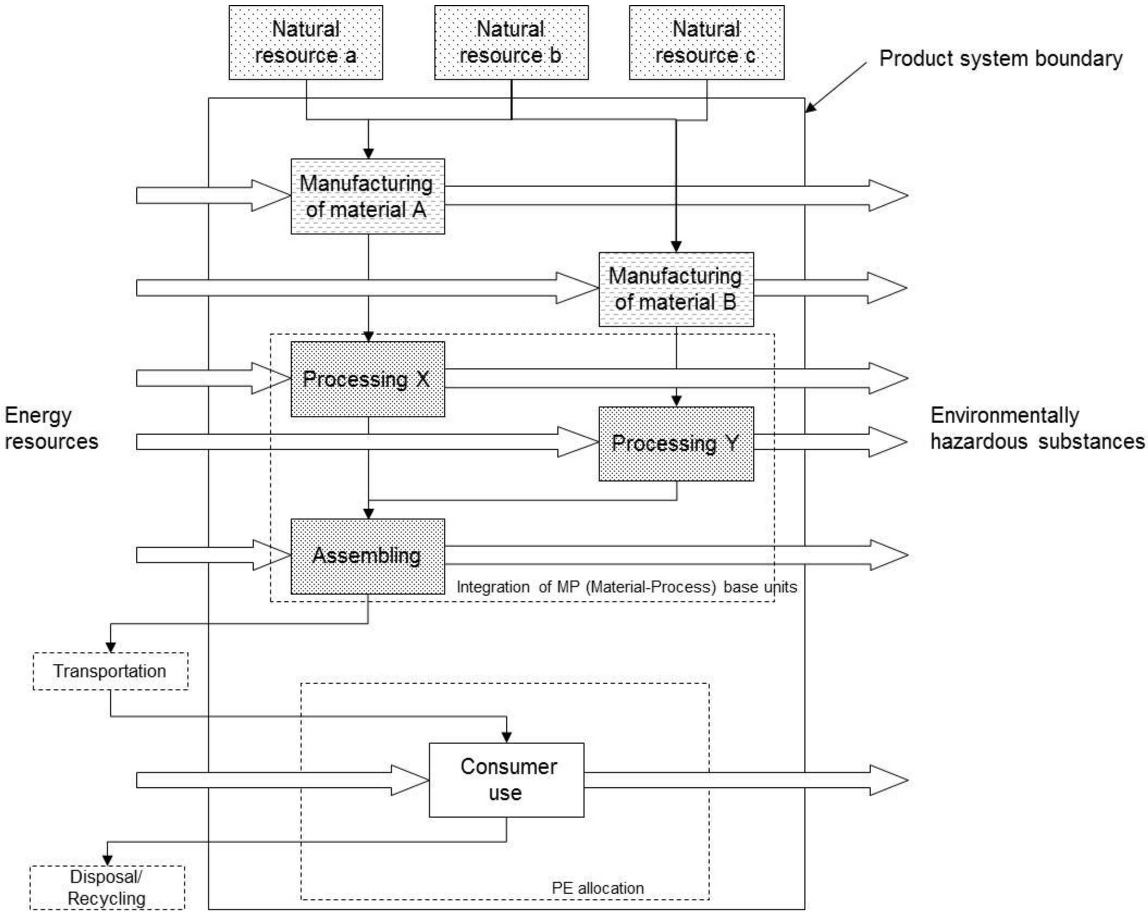

Figure 2 System boundaries covered in the Guidelines

(4.1) Manufacturing phase
The manufacturing phase of a product and its component parts is roughly divided into two; one, the manufacturing process of the materials, which physically configure individual products and their component parts, and the other, the process of physically configuring the products and their component parts by using the materials.

Regarding the former manufacturing process of materials, materials are manufactured from natural resources as a rule in the specific processes to the individual materials. Thus, once the materials are identified, possible environmental impacts in the relevant manufacturing process may be uniquely determined based on the manufacturing methods.
Regarding the latter manufacturing process of products and their component parts, approximate environmental impacts may be simply identified in theory without preliminary investigation of manufacturing processes of individual products by assuming fairly definite manufacturing processes, depending on the individual component parts and products. This is applicable to not only internal processes but also the processes performed at the other companies engaged in manufacturing of purchased products. The methods for processing and assembling individual materials which configure products and their component parts vary according to the final requirements for product functions and characteristics. However, by introducing the assumptions that the processes applied to the same materials are fixed and unvarying in any cases, it becomes possible to identify the rough outline of environmental impacts without the need for field surveys. This approach for identifying the environmental impacts of the manufacturing processes is designated “MP base units integration (see Term No. 15).” The methods for setting the manufacturing processes for the products and their component parts and the assumptions are described later.

(4.2) Consumer use phase
Results of allocation of inputs of fuel or energy to a vehicle loaded with the auto parts under study and outputs of environmental load from the vehicle in proportion to the burden share the

individual auto parts should be liable to bear are defined as environmental load intensities for the auto parts in the consumer use phase. The "burdens the auto parts should bear" refer to the weighted values derived logically from the functions of auto parts during the allocation of environmental loads in the consumer use phase of automobiles.

For allocation, four (4) approaches are available, "allocation according to mass (inertia)," "allocation according to electric power consumption," "allocation according to power (shaft output) consumption," and "allocation associated with energy efficiency of prime mover." For every auto part, one or more allocation approaches are applicable. However, the "allocation according to mass (inertia)" is applicable to all auto parts.
The burdens allocated based on these approaches depend on the use conditions and fuel consumption of the vehicles on which individual auto parts are mounted. This means that even auto parts of similar types and similar functions may differ from each other in the allocated burden and allocation ratio depending on the type, characteristics, and performance of the vehicles on which they are mounted. In practice, however, assuming certain use conditions and fuel consumption, it becomes possible to estimate the representative values of environmental load intensity in the consumer use phase without studying any actual working conditions and specifications of vehicles on which auto parts are mounted. This allocation of environmental load intensity to auto parts in the consumer use phase of a motor vehicle defined based on the relationship between auto part functions and the motor vehicle is designated "PE allocation" (see Term No. 42). Allocation to auto parts, concepts of allocation ratio, and setting methods are described later.

The values estimated based on the above-described assumptions and the quantified values for environmental impacts assessment based on the on-the-spot surveys may differ from each other. However, the differences from the on-the-spot surveys must be accepted in practice, assuming that the values from the on-the-spot surveys would be partially or wholly taken into account and resolved at the end through repetition and review of the study on base units (see Term No. 14).

(5) Allocation (see Term No. 20) procedures
[Manufacturing phase]
Assessment is conducted following the prior setting of certain manufacturing processes, and thus there is no need for allocation as a rule.

[Consumer use phase]
Assessment is conducted based on the PE allocation by allocating the environmental load intensity of the entire motor vehicle, on which the auto parts under study are mounted. Regarding auto parts, only the results of allocation to auto parts in the entire motor vehicle are defined as being included in the system boundaries and therefore, for a single product, there is no need of additional allocation in the consumer use phase. Where the product under study constitutes a part of the system of auto parts and allocation is conducted to the entire system based on the PE allocation and then the results need to be further allocated to the product in the system boundaries, valid allocation must be conducted according to either parameter, physical or economic.

(6) Life Cycle Impact Assessment (LCIA) methodology and subsequent interpretation method
The study conducted based on the Guidelines refers to life cycle inventory analysis (LCI) up to the stages of compiling and quantifying the inputs/outputs of substances and energy resources to/from products and their component parts throughout the life cycles. The Life Cycle Impact Assessment (LCIA) implemented based on the LCI results is out of the scope of the Guidelines. Therefore, the impact assessment methodology and subsequent interpretation are not referred to in the Guidelines.

(7) Data requirements
Regarding the data needed for discussion of environmental friendliness of products, evaluation is conducted.

(8) Assumptions (see Term No. 21)

[Manufacturing phase]

In the MP base units integration applied in the manufacturing processes of products and their component parts, assessment is conducted based on the assumptions that the products and their component parts, even if they differ from each other, undergo the same fabrication process for incorporation in the end products.

For example, where the material X is used in both products A and B, for the processing to the material X, the process related to the material X in the Standard LCI Data Calculation Methodology established by JAPIA is assumed to be applied even if the actual manufacturing processes and manufacturing sites differ between the products A and B. Making these assumptions allows identification of approximate values in the early stages of LCI data survey without need for any field survey.

Typically, it is impractical for the member companies to trace the supply chains without any direct business connections and conduct the LCA study directly. Consequently, for data collection, there is no other way but to rely on the direct business connections for the survey. Additionally, the whole circumstances in which LCA study only relies on the direct business traders for the survey results are common to all business operators constituting supply chains. This leads to increased possibility of data unavailability and/or data errors, although adoption of the assumptions helps avoid damage to the data collection quality. In actuality, however, the actual processes may not be reflected in some cases and therefore, the quality of data collected is inconsistent with the quality of data collection.

MP base units integration will be described later in 7.2.

[Consumer use phase]

In the PE allocation applied in the allocation of environmental loads in the consumer use phase, assessment is based on the use conditions and fuel consumption of the vehicles on which the products under study are mounted. Where those conditions can be clearly identified, allocation is attained based on the conditions. If the conditions are difficult to identify, environmental load intensities are calculated based on the typical estimations of use conditions and fuel consumption defined in the Guidelines.

Details of methodology of PE allocation are described later in 7.3.

(9) Limitations (see Term No. 22)

Limitations are defined to prevent possible over-interpretation of conclusions derived from the study data. Assessment based on either method, MP base units integration or PE allocation, is conducted for the issues described above and therefore, it does not allow any interpretation based on the details not included in the issues. The Guidelines also define similar limitations.

(10) Initial data quality requirements

The ISO14040 standard states that the following items are preferably specified as requirements. The Guidelines specify as listed below.

(10.1) Time-related coverage (see Term No. 27)

[Manufacturing phase]

In accordance with the data acquisition requirements listed in the base units (see Term No. 14) defined by JAPIA. The information about materials composing the product and its component parts under study is specified to remain unchanged without being affected by the effects of elapsed time.

[Consumer use phase]

The vehicle running conditions and fuel consumption conditions defined by JAPIA are specified to remain unchanged without being affected by the effects of elapsed time.

(10.2) Geographical coverage (see Term No. 28)

[Manufacturing phase]

In accordance with the data acquisition requirements listed in the base units (see Term No. 14) defined by JAPIA. The information about materials composing the product and its component parts under study is specified to remain unchanged without being affected by any geographical effects.

[Consumer use phase]
The vehicle running conditions defined by JAPIA are specified to remain unchanged without being affected by any geographical effects.

(10.3) Technology coverage (see Term No. 29)
[Manufacturing phase]
In accordance with the data acquisition requirements listed in the base units (see Term No. 14) defined by JAPIA. It is specified that the coverage is only determined based on the information about materials composing the product and its component parts under study, and it omits any effects of other technical backgrounds.
[Consumer use phase]
The vehicle running conditions, fuels, and other forms defined by JAPIA are specified to remain unchanged without being affected by any effects of technical backgrounds. In response to any changes in technical backgrounds, the conditions will be reviewed.

(10.4) Precision (see Term No. 30)
[Manufacturing phase]
In accordance with data accuracy listed in the base units (see Term No. 14) defined by JAPIA. The accuracy of information about materials composing the product and its component parts under study is based on the numerical values the member companies have identified.
[Consumer use phase]
Decrease in the accuracy can result due to the difference between the vehicle running conditions defined by JAPIA and the actual use conditions of individual motor vehicles.

(10.5) Completeness (see Term No. 31)
[Manufacturing phase]
In accordance with the degree of completion of input of the information about materials composing the product and its component parts under study, which the member companies have identified.
[Consumer use phase]
Assessment is attainable based on the vehicle running conditions and fuel consumption conditions defined by JAPIA and therefore, the completeness of the study is considered assured.

(10.6) Representativeness (see Term No. 32)
[Manufacturing phase]
In accordance with temporal and geographical coverages.
[Consumer use phase]
In accordance with temporal and geographical coverages.

(10.7) Consistency (see Term No. 33)
[Manufacturing phase]
Assessment is attained based on the MP base units integration and therefore, the consistency of the study is always assured.
[Consumer use phase]
Assessment is attained based on the PE allocation and therefore, the consistency of the study is always assured.

(10.8) Reproducibility (see Term No. 34)
[Manufacturing phase]
Assessment results based on the MP base units integration rely on only the information about materials composing the product and its component parts under study as a rule and therefore, a high degree of reproducibility is expected.
[Consumer use phase]
Assessment results based on the PE allocation rely on only the existing product information (e.g., mass, performance) and therefore, a high degree of reproducibility is expected.

(11) Type of critical review (see Term No. 23), if any

A critical review becomes necessary to provide comparative assertions to external interested parties. Therefore, it is unnecessary as a rule when discussion is made within individual member companies about the environmental friendliness of products and their component parts. Where comparative assertions are provided externally about results of the LCA study conducted in accordance with the Guidelines, the review by the internal experts in the member companies should be conducted. The experts who conduct the review should be in a position independent from the LCA study concerned and familiar with the ISO14040 and the Guidelines and they should have the necessary scientific and technical expertise.

(12) Type and format of the report required for the study

The study should have been based on the Guidelines, and the issues required by ISO14040 to be reported other than study results are listed in the Guidelines, and therefore their description and reporting may be omitted. Where results of the LCA study conducted based on the Guidelines are used in comparative assertions to external interested parties, a report including all the issues specified in ISO14040 should be prepared.

LCA is a methodology of step iteration. MP base units integration (see Term No. 15) and PE allocation (see Term No. 42) are intended to be conducted in the early stages of LCA. Therefore, as additional information is collected during the study, partial or total adoption of any methodology other than MP base units integration and PE allocation may become required. In this case, the scope of study must be corrected in some cases.

7.2 Framework for calculating the environmental impacts of a product and its component parts in the manufacturing phase

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Calculation of environmental impacts in the manufacturing phase in the product system boundaries is attained in two steps, calculation in the manufacturing process of materials composing individual products and their component parts physically, and calculation in the manufacturing process of the products and their component parts made up from the materials.

7.2.1 Calculation in the manufacturing process of materials

Materials composing products and their component parts are widely diverse, amounting to thousands or more in terms of type. It is thus inefficient to ensure the correspondence between the usage of natural resources (see Term No. 36) and the usage of energy resources required for manufacturing all types of materials for data collection, and therefore the types of materials are narrowed down. The method for narrowing the number of material types is based on the Data Sheets.

7.2.2 Calculation in the manufacturing process of component parts and products

Calculation is based on the MP base units integration described in the preceding section "(8) Assumptions." This methodology conducts assessment of the product and its component parts in the manufacturing phase on the assumptions that the fabrication process of materials composing the products is equally applied independently from the applied section of the product and its component parts and the type of the product and its component parts. The use of energy resources in the manufacturing phase of product and its component parts is assumed to depend on the type and mass of the materials composing the product and its component parts. However, in the case of products and their component parts including electronic components, it is assumed that only the electronic components depend on the other factors.

7.2.2.1 Calculation in the manufacturing process of electronic components (see Term No. 37)

Calculation is made on the assumptions that in the MP base unit integration, materials and fabrication processes are uniquely interrelated with each other and that the usage of energy resources depends on the type and mass of individual materials contained in the product and its component parts. This is applied to the machine parts (products and their component parts, the structure of which is formed by materials and which perform the functions primarily due to kinetic or chemical actions).

On the other hand, in the case of materials composing those products and their component parts which fulfill the functions in response to electronic signals as typified by semiconductor integrated circuits, the relation between the masses and the functions has not been exactly identified. Especially in the case of integrated circuits (IC) and large-scale integrated circuits (LSI), the masses of the products and their component parts (silicon chips or compound semiconductor chips) (see Term No. 38), which fulfill their functions are almost entirely composed of the element silicon or compound semiconductors. However, the functions of the integrated circuits depend on the chip area, circuit integration density, and other factors rather than the mass of silicon or compound semiconductors. Additionally, the manufacturing process of semiconductor integrated circuits reportedly consumes a much greater amount of energy resources compared to typical mechanical products and their component parts. This suggests that for calculation, semiconductor integrated circuits must be separated from the machine parts which depend on the component materials and their masses with regard to the functions and performance; otherwise large deviations from the actual conditions could result.

The functions of semiconductor integrated circuits depend on the chip area and other factors, although it is very difficult to study the chip area and other factors of the purchased semiconductor integrated circuits. Therefore, the Guidelines have established the parameters substituting for the chip area and other factors to determine the functions of the integrated circuits. As a method to estimate the silicon chip area or the functions (capabilities) of semiconductor integrated circuit components based on only the external appearances or the written specifications of product and its component parts, measurement of the number of terminal pins (see Term No. 39) in the semiconductor integrated circuit components is available. The methodology of estimating the size of function based on the number of terminal pins has been adopted by the Japan Electronics and Information Technology Industries Association (JEITA)[Note 1] and then JAPIA has decided to also use this methodology. Available functions depend on the chip area, and the amount of the energy resources used by the semiconductor integrated circuit components in the manufacturing phase depends on the chip area. This relation is posted in the Life Cycle Assessment (LCA) Society of Japan Database[Note 2].

For the semiconductor integrated circuit components incorporated in the product and its component parts under study, the chip area, the manufacturing processes, and other details may be identified in some cases, although the calculation based on the measurement of the number of terminal pins at early stages of LCA study should be effective for efficient understanding of environmental loads.

In addition, also regarding the resistors, capacitors, and used in electronic circuits similarly to the above-described semiconductor integrated circuit components, the calculated values based on the MP base units focusing on machine work may largely deviate from the actual conditions. Therefore, the base units for these component parts are separately established.

The cross-reference between the total number of terminal pins, the total number of resistors, the total number of capacitors, and the area of PCB on the semiconductor integrated circuit components incorporated in the product and its component parts and the usage of energy resources in the manufacturing phase is based on the Data Sheets.

Note 1 JEITA LCA methodology for semiconductor integrated circuits: A methodology developed by the JEITA Semiconductor Environment Safety Committee for life cycle inventory calculation based on the estimation of chip area from the geometry of IC and the number of pins (http://semicon.jeita.or.jp/committee/committee 2_4_1.html)

Note 2 Life Cycle Assessment Society of Japan (JLCA) Database: The accomplishment of the five-year First Term LCA Project promoted and implemented by the Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO) from FY 1998 to FY 2002. This database includes the data for inventory analysis, impact assessment, and literature (http://lca-forum.org/).

7.2.2.2 Handling of soldering process of electronic components

Usually, electronic components are soldered (mounted) to the printed circuit board (PCB). Typical soldering in volume production is based on the flow solder bath or reflow soldering. This means that the soldering constitutes batch processing of the complete set of printed circuit boards (PCBs). The study on the area of PCB allows calculation of usage of energy resources in the flow or reflow soldering per area. However, increasing the number of study items is not appropriate for the purpose of the LCA study in the early stages. Consequently, the Guidelines have established the assumptions listed below.

It is difficult to estimate the area of a PCB from the material composition of the product and its component parts under study. It is also difficult to estimate the area from the total number of terminal pins in the electronic components. However, it can be said that there is correlation between the total number of terminal pins and the area of a PCB. The area of a PCB does not necessarily increase in proportion to the total number of terminal pins, although it tends to increase with increasing number of electronic components mounted on the PCB or increasing total number of terminal pins due to the increasing number of terminal pins in the electronic components. Therefore, the usage of energy resources in the batch process is expected to increase as a result of allocation according to the area of a PCB.

Then, the base units of PCB per area in the soldering (mounting) process depending on the number of terminals in the manufacturing of semiconductor integrated circuit components described above are to be established.

The cross-reference for the amount of the energy resources used and other parameters in the soldering stage of a PCB on the electronic components incorporated in the product and its component parts are based on the Data Sheets.

7.2.2.3 Calculation in the manufacturing process of parts other than electronic components

In the manufacturing process of the products and their component parts other than electronic components, involvement of the fabrication processes established specific to individual materials composing the products and their component parts under study is assumed, and therefore, the amount of the energy resources used in the fabrication process are assumed to depend on the mass of individual materials composing the products and their component parts under study.

The cross-reference between materials and the usage of energy resources in the fabrication process is based on the Data Sheets.

7.2.2.4 Exceptional treatment of mass of electronic components in their impacts assessment

For assessment in the manufacturing phase of products and their component parts including electronic components, the values obtained from calculation in the manufacturing phase of electronic components and the values obtained from calculation in the manufacturing phase of parts other than electronic components are integrated. The electronic components are made up from several materials, although the environmental loads of electronic components in the manufacturing phase are assessed based on other factors than the type and mass of the materials. Therefore, in order to avoid duplication, the material composition and the mass of electronic components should be excluded in principle from the whole for assessment. However, considering that the mass of electronic components is relatively smaller than that of other machine parts, as is the number of person-hours needed to extract the fraction equivalent to the materials of electronic components from the Material Composition Table, any duplication of the assessment based on the base unit for electronic components and the assessment based on the MP base units is allowable in the integration. However, this does not apply when the assessments can be separated from each other.

7.2.2.5 Handling of fraction defective and yield rate

The values of fraction defective and yield rate of product and its component parts affect the Life Cycle Impact Assessment (LCIA). In the MP base unit integration, specific processes are defined to uniquely correspond to specific materials. The amount of the energy resources used in the individual

processes are allocated based on the quantity of manufactured (post-manufacturing) products and their component parts and therefore, there is no need to give special consideration to fraction defectives and yield rates in the calculation of the amount of the energy resources used in the fabrication process.
On the other hand, the MP base unit integration has not defined any required material masses for the established fabrication process. This is because the MP base unit integration is primarily intended to efficiently and comprehensively identify the environmental loads of the entire system by simplifying the assumptions for calculation and thus, this methodology adopts the assumption that a single material is fed through a sequence of processes for processing. Therefore, it does not have any meaning to additionally include other secondary assumptions. Based on the concept of ISO that LCA is iterative, it is considered more efficient to take into consideration the conditions of fraction defective and yield rate in the LCA in the stages after the early stage.

In practice, however, where sufficient person-hours are available for the study to take into account the fraction defective and yield rate, the quantity of usage of materials should be additionally increased from the values. In this case, in response to the increased quantity of usage of materials, the entire environmental load intensity is to be increased.

7.2.2.6 Handling of items related to transportation

In the procurement of materials and purchased products, their transportation causes loads on the environment. However, compared to the transportation of completed products, which may need restrictions on the placement, the transportation of materials and/or parts is easily estimated to provide extremely higher load efficiency and therefore, the values are considered to have little effect on the assessment of product and its component parts in the early stage. Therefore, they are excluded from the study scope. In addition, in the Guidelines, transportation of finished products is defined as being outside of the system boundaries (see Term No. 19).

7.2.2.7 Handling of items related to assembling (see Term No. 40)

The "assembling" in the Guidelines refers to the process of combining component parts with each other. Typically, the information about materials composing the product and its component parts does not contain any information about assembling, and accordingly, the MP base unit integration does not allow any assessment of environmental load intensity in the assembling process. However, the amount of usage of energy resources in the assembling process is typically considered smaller than that in the materials fabrication process. Therefore, it is excluded from the study scope, while prioritizing the improvement of efficiency of assessment. However, this does not apply where the base unit of assembling process can be identified.

7.2.2.8 Handling of indirect materials (see Term No. 41)

For the materials used in the manufacturing processes of a product and its component parts and not included in the list of materials composing the product and its component parts, the assessment based on the MP base unit integration cannot be applied. Prioritizing the improvement of efficiency of assessment, the Guidelines exclude those materials from assessment. This does not apply where the quantity of usage of indirect materials and their intensities of environmental impacts can be identified.

7.3 Framework for calculating the environmental impacts of a product and its component parts in the consumer use phase

Environmental impacts in the system boundaries of the product in the consumer use phase are calculated based on the four methods of allocation: "allocation according to mass (inertia)," "allocation according to electric power consumption," "allocation according to power (shaft output) consumption," and "allocation associated with energy efficiency of prime mover," as discussed in the previous section, and they are summed up for determination of the sum total (Figure 3).

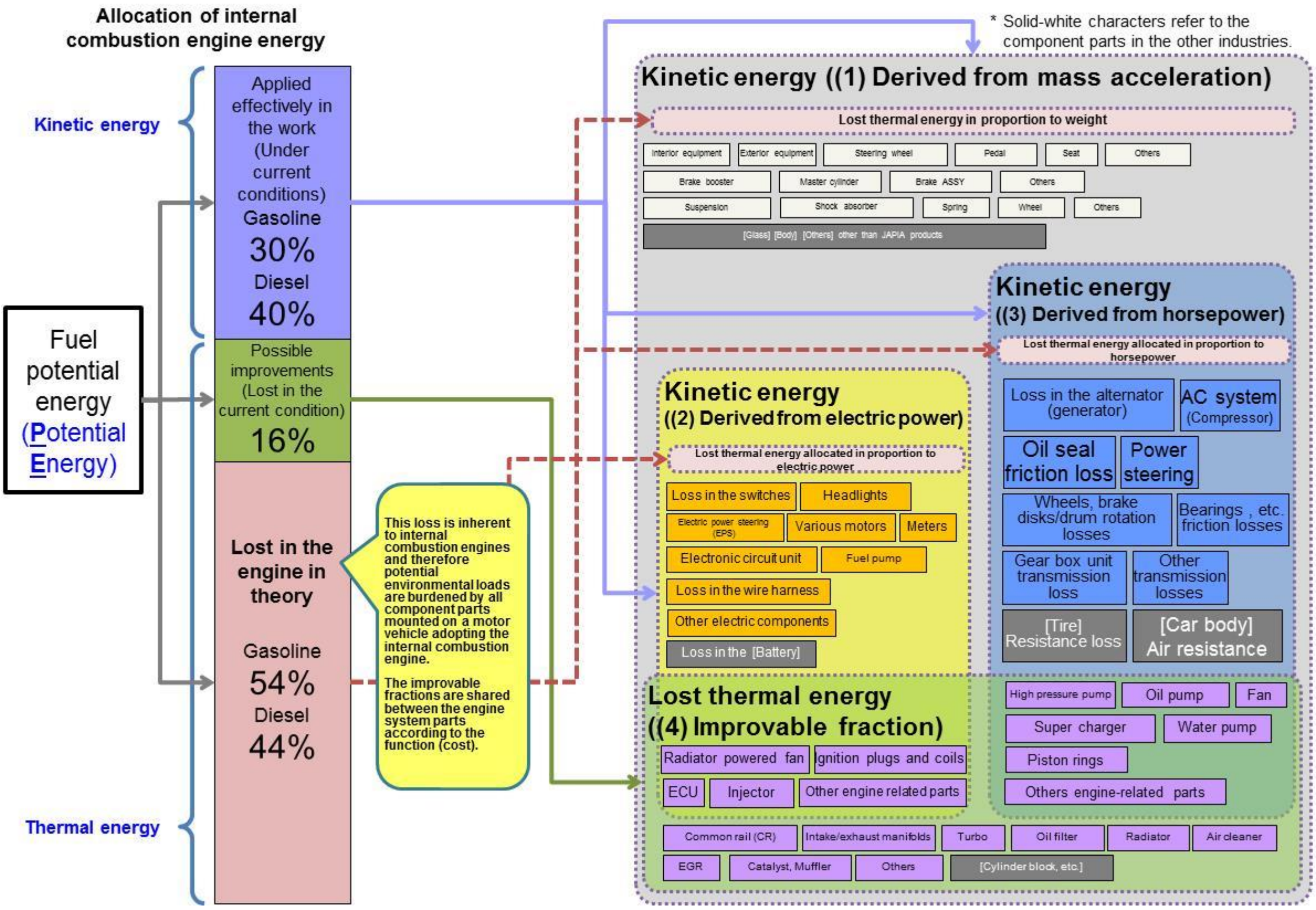

Figure 3 Typical tree diagram for environmental impacts of a gasoline/diesel engine vehicle in the consumer use phase

7.3.1 Calculation based on allocation according to mass (inertia)

The dynamic output generated by the prime mover in a motor vehicle is consumed partially in the running of the vehicle. The workload needed to run a heavy load depends on the travel pattern of motor vehicle. The factors that constitute the resistance and resultant loss (environmental load) in the running of motor vehicle include (a) rolling resistance, (b) air resistance, (c) grade resistance, and (d) acceleration resistance.

(a) The rolling resistance of a motor vehicle increases in proportion to the normal force against the road surface. The normal force means the product of the mass of the entire motor vehicle and the gravitational acceleration acting perpendicularly to the road surface, and the rolling resistance is the product of the normal force and the rolling resistance coefficient (RRC). The rolling resistance is the work performed by tires, and the energy is not reserved in the form of kinetic energy but converted to thermal energy. The Tire $LCCO_2$ Calculation Guidelines developed by the Japan Automobile Tire Manufacturers Association (JATMA) (http://www.jatma.or.jp/environment/pdf/lcco2guideline.pdf) define that tires contribute to fuel consumption (L/km) by 12.5% in the case of passenger cars on the assumption that the fuel consumption of simulated motor vehicles equipped with general-purpose tires is 0.1 L/km (10 km/L). There is no definite data shown to support this value. However, based on the preconditions that the tire rolling resistance is all caused by the tires independently from normal force, it is considered that one-eighth (12.5%) of fuel consumption of a motor vehicle is attributed to tires (even considering that the normal force and rolling resistance coefficient (RCC) act as intervening variable parameters to govern the rolling resistance as the physical phenomena).
The normal force depends on mass, although allocating the environmental load from the rolling resistance as being according to mass can cause double counting of allocation to tires based on the above-described concepts of JATMA and allocation to auto parts other than tires. Additionally, if rolling resistance is considered to be derived completely from mass in order to avoid double counting, allocation of the environmental load from rolling resistance to tires is eliminated, and the approach

for allocating the environmental load in the consumer use phase of motor vehicles to tires as one of the auto parts becomes insignificant. Therefore, **rolling resistance should not be subject to the "allocation according to mass (inertia)."** The loss caused by the rolling resistance is categorized as described later in 7.3.3 Allocation according to power (shaft output) consumption, and it should be all allocated to tires.

(b) Air resistance depends on the geometry of a car body. Therefore, **air resistance is not subject to the allocation according to mass of auto parts**. However, in case where auto parts affect the geometry of car body as exterior automotive trim, the air resistance should be subject to 7.3.3 Allocation according to power (shaft output) consumption.

(c) Grade resistance is regarded temporarily as one of the resistances as a result of conversion of prime mover output to potential energy, although it is highly likely to be canceled at the end in consideration of the operating hours of motor vehicle throughout its lifetime (The converted potential energy is further converted to the kinetic energy for running on a downhill road. From the standpoint of lifetime operating time of motor vehicle, the initial altitude and the end-of-life altitude of the motor vehicle are estimated to be identical with each other. Even if they are different from each other, the environmental load intensity caused by the workload due to the differences is estimated to be very little compared to the environmental load intensity throughout the lifetime). Consequently, **there is no need to take into account any grade resistance.**

(d) Acceleration resistance only refers to the outcome of conversion of mechanical energy, similarly to the grade resistance. However, the kinetic energy converted from the thermal and other energies by the prime mover is preserved in the entire motor vehicle once then the kinetic energy fraction left out from recovery during the deceleration by the regenerative system is converted to thermal energy by the friction brake and dissipated at the end. Therefore, **only the acceleration (speed increasing) resistance is considered to be derived from mass (inertia).** For motor vehicles equipped with the regenerative control system, the fraction corresponding to the regenerative energy is taken into account for allocation.

The workload for accelerating a motor vehicle may be determined from a difference between the kinetic energies at the time of start and end of acceleration. The lifetime workload for acceleration of a motor vehicle (the amount of energy lost) is a difference between the integrated value of differences between the kinetic energies at the time of start and end of acceleration and the integrated value of regenerated energies. From the chronological viewpoint, acceleration is always followed by regeneration, although acceleration and regeneration may be considered to take place concurrently with each other when considering the environmental load throughout the lifetime operating hours of motor vehicle. In practice, however, the regenerated kinetic energy must be assumed to be used completely for acceleration of motor vehicle after regeneration (Figure 4).

(Energy loss due to the acceleration resistance throughout the lifetime operating time)
= Σ {(Kinetic energy at the start of acceleration) - (Kinetic energy at the end of acceleration)}
– Σ (Energy regenerated and re-used for acceleration throughout the lifetime operating time)

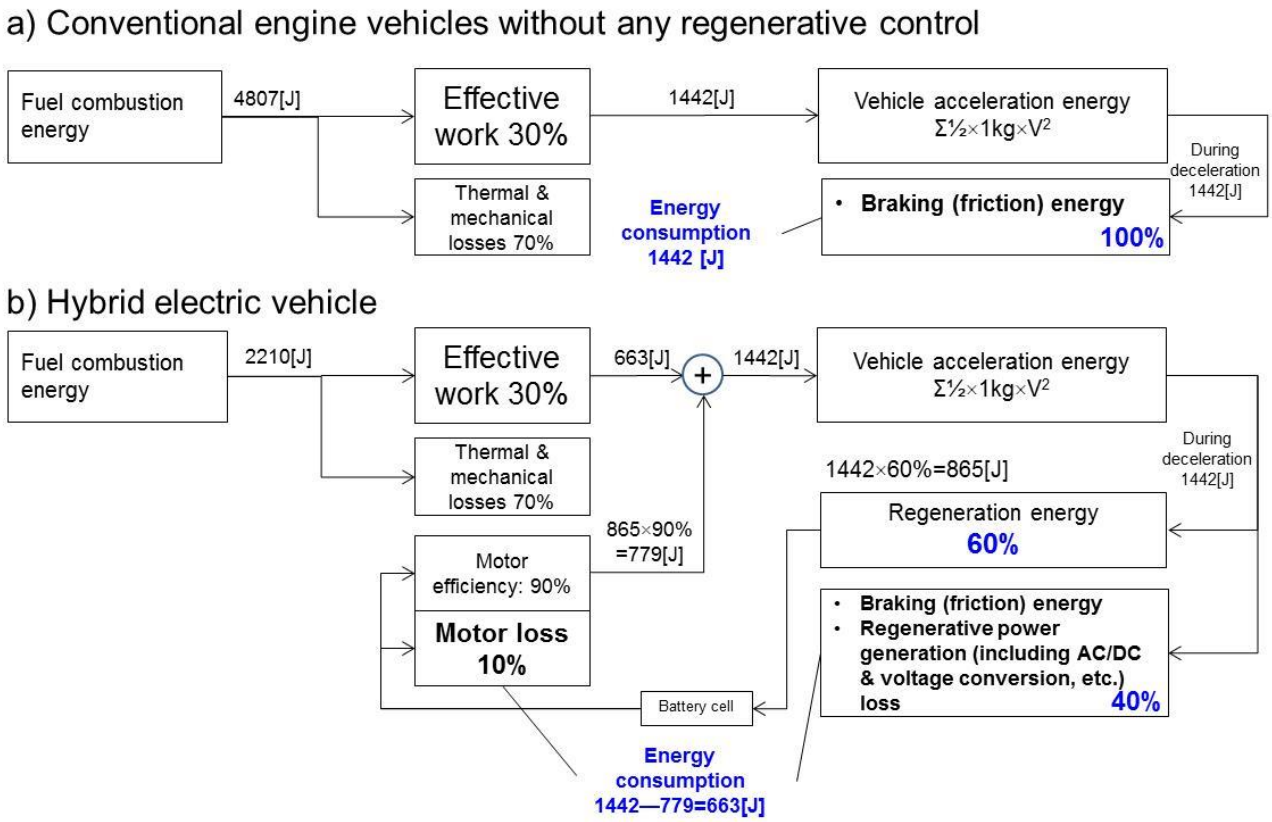

Figure 4 Acceleration energy balance per weight (kg) in the JC08 mode driving

Kinetic energy is proportional to the square of speed and the mass. Identifying the acceleration pattern throughout the lifetime operating time of motor vehicle, the workload for accelerating the entire motor vehicle may be considered partly borne by the auto parts according to their masses. Additionally, when the energy burden is to be generated by the prime mover, energy conversion loss occurs in the prime mover. Therefore, this energy loss inherent in the energy burden must be also allocated as environmental load. This means that **the allocation according to mass (inertia) includes the sum of the environmental load fraction corresponding to the kinetic energy and the accompanying energy loss.** However, the energy loss included in the allocation should focus on the loss derived theoretically from the configuration of the prime mover (the intrinsic loss independent from the functions and characteristics of parts configuring the prime mover, e.g., the thermal energy which cannot be converted thermodynamically to any kinetic energy among the entire input thermal energy in the case of a heat engine).
Based on this concept, the environmental load intensity based on the allocation according to mass of auto parts could be determined independently from the total mass and fuel consumption properties of the motor vehicle on which the auto parts under study are mounted, provided that the acceleration pattern and the amount of energy lost in the prime mover to produce the entire energy required for acceleration can be identified.

It is considered very difficult to identify the driving patterns of individual automobiles during their lifetime operating time and therefore, JAPIA has specified the driving pattern that seems typical. In addition, in the case of those motor vehicles equipped with the regenerative system which consumes all the regenerated kinetic energy in the running, the regeneration efficiency affects the allocated environmental load intensity and therefore, the efficiency has also been specified. The details are included in the Consumer Use Phase Data Sheets attached to the Guidelines.

7.3.2 Calculation based on allocation according to electric power consumption

The dynamic output (shaft output) generated by the automobile prime mover is partially converted to electric power by the generator and supplied to the auto parts which use or transmit electric power. The auto parts supplied with the electric power consume electric power to express the functions of the auto parts. The electric power-transmitting auto parts transmit the electric power while causing electric power loss. Thus, the burden of environmental loads derived from electric power consumption may be considered to correspond to the workload based on the electric power consumption and transmission loss of the auto parts. Furthermore, where the energy burden is to be generated by the prime mover, energy conversion loss occurs in the prime mover and therefore, also the energy loss necessarily accompanying the energy burden must be allocated as one of the environmental loads. This means that the **allocation according to electric power consumption includes the sum of the energy due to the electric power consumption and its accompanied energy loss.** In practice, however, the energy loss allocated should cover the loss fraction derived theoretically from the configuration of prime mover. This is similar to the case of allocation according to mass.

Based on this concept, the burden allocated depends on only the energy consumption of auto parts consuming the electric power and the energy lost in the prime mover for generation of that energy. Thus, the environmental loads can be determined irrespective of the generator efficiency and the fuel consumption of the motor vehicle on which the auto parts are mounted.

In the case of those automobiles equipped with a regenerative system to use the regenerated kinetic energy for any purposes other than driving (automobiles incorporating the regenerative function but not constituting any hybrid electric vehicles), the environmental load intensity derived from the electric power consumption of the entire automobile varies. The amount of regenerated energy is uniquely determined based on the vehicle total weight and running conditions, and the total amount of electric power used in the vehicle is determined based on the total quantity of the electric power-using parts mounted on the vehicle. However, there is not necessarily a correlation between the two, and then, it is impracticable to preliminarily allocate the regenerated energy according to the unit electric power consumption and unit loss electric power of auto parts. Consequently, it is left out of consideration to allocate to the auto parts the fraction of reduced environmental load derived from the energy regenerated by the regenerative system (Figure 5).

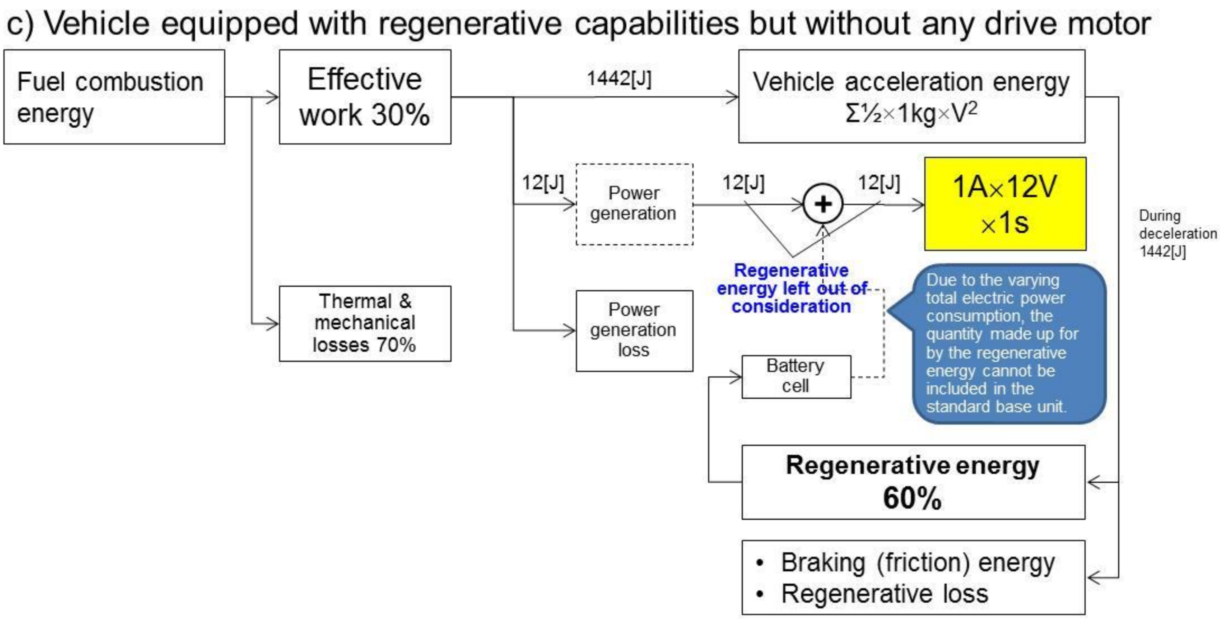

Figure 5 Relation between regenerative energy and electric per 1 A-sec. power (12 V power source) in JC08 mode driving

It is considered very difficult to identify individual operating hours in the lifetime operating time of individual automobiles and therefore, JAPIA has specified the operating time of motor vehicles and their functions considered typical to ensure the consistency with other allocation approaches. The details are included in the attached Consumer Use Phase Data Sheets.

7.3.3 Calculation based on allocation according to power (shaft output) consumption Back Alt + ←

The dynamic output (shaft output) generated by a prime mover of motor vehicle will be partially supplied to the auto parts performing the 1) mechanical work, 2) transmission of shaft output, and/or

3) conversion of shaft output to electric power. The auto parts performing the mechanical work use the supplied kinetic energy to complete the work and resultantly express their own functions. The auto parts transmitting the shaft output transmit the kinetic energy, providing irrecoverable losses due to friction (heat, sound, deformation) and rotation energy. The auto parts converting the shaft output to electric power convert the kinetic energy to electric energy, providing conversion loss. Therefore, the burden of environmental loads caused by use of power (shaft output) may be considered equivalent to the workload, transmission loss, and conversion loss of the auto parts involved. For example, it corresponds to the workload determined based on the oil discharge and pressure for mechanical oil pumps, the transmission loss caused by internal friction and/or rotation work for the transmissions, the rotation workload and friction workload for the wheels and brake disks/drums, and the electric power conversion loss for the generators. For the exterior automotive trim, the air resistance or the mechanical work against the air constitutes the burden of environmental loads. Additionally, where the burden energy is to be generated by a prime mover, the energy conversion loss occurs in the prime mover, and therefore, the energy loss necessarily accompanying the burden energy must be also allocated as an environmental load. This means that **the allocation according to use of shaft output includes the sum of the power energy used and the accompanying energy loss**. However, the energy loss allocated should focus on the loss derived theoretically from the configuration of the prime mover. This is the case with the allocation according to mass.
Based on this concept, the burden allocated depends only on the workload, transmission loss, and conversion loss of auto parts under study and the energy lost in the prime mover to generate the energy making up for the corresponding energy. As a result, the environmental loads can be determined independently from the fuel consumption of the motor vehicles on which the auto parts are mounted.

It is considered very difficult to identify individual use conditions in the lifetime operating time of individual automobiles, and therefore, JAPIA has established the use conditions of motor vehicles considered typical to ensure consistency with the other allocation approaches. The details are included in the attached Consumer Use Phase Data Sheets.

7.3.4 Calculation based on allocation associated with energy conversion efficiency in prime mover

In the consumer use phase of motor vehicles, the prime mover converts the thermal energy generated by the combustion of fuel or the electric energy to kinetic energy. The conversion efficiency of the prime mover is always below 100%, thus causing a loss (the fraction not converted to the intended kinetic energy but left remaining in the form of thermal energy). Especially in a heat engine which burns fuels to convert the thermal energy to kinetic energy, the intrinsic loss always occurs due to the theoretical thermal efficiency. This loss is unavoidable so long as a heat engine is adopted, and thus the loss may be considered an environmental load caused directly by the prime mover. Therefore, the Guidelines have described that the fraction of the theoretical loss caused by the prime mover (thermal energy not converted to kinetic energy) should be allocated as environmental load of the auto parts under study according to their energy consumption patterns.
However, the actual energy loss differs from the above-described theoretical energy loss. **This difference in the energy loss will be considered the improvable loss in the future (the loss fraction expected to be extracted as kinetic energy in the future due to the improved conversion efficiency by the involved auto parts) and it is allocated according to the auto parts which directly govern the energy conversion efficiency of the prime mover.**
However, the total thermal energy loss caused by the prime mover depends on the sum total of kinetic and other energies required by the motor vehicles, and therefore, the total amount of the required energy must be predetermined. This means that the prerequisite amount of fuel consumed per unit travel distance (fuel consumption) should be specified. The total amount of energy needed for the performance of the motor vehicle concerned is uniquely determined based on the mass of the entire motor vehicle, the body geometry, the energy consumption of individual on-board equipment, tire performance, and other factors, and the amount of fuel needed to create the energy (fuel consumption) depends on the energy conversion efficiency of the prime mover mounted in the motor vehicle.

(Automobile fuel consumption: Total fuel potential chemical energy required by the prime mover for running a unit distance)
× (Actual energy conversion efficiency of prime mover)
= (Mass-based energy: Mass of the entire automobile) + Σ (Electric power-based energy: Equipment using electric power)
+ Σ (Power-based energy: Equipment using power, Air resistance, Friction, Tire rolling resistance)

(Automobile fuel consumption: Total fuel potential chemical energy required by the prime mover for running a unit distance)
× {(Prime mover theoretical energy conversion efficiency) – (Prime mover actual energy conversion efficiency)}
= (Future improvable energy loss: Thermal energy fraction not converted to kinetic energy at present)

For allocation of energy loss to auto parts, the ratio of allocation must be defined. The allocation rate of environmental load to auto parts, which have functions that affect the actual energy efficiency of the prime mover, must be determined on the basis of what degree of influence the individual auto parts have in determining the energy efficiency of the prime mover mounted on the motor vehicle concerned. The degree of influence may be identified by varying functions of the involved auto parts. Thus, standardization is essential for quantifying the correlation between the functions and the degree of influence and resultantly calculating the allocation ratio. However, it is thought to be very difficult to standardize the correlation between the functions defined by various physical parameters such as mass, electric power, and workload described above and the energy loss. Then, the degree of influence of individual auto parts is considered to be reflected in the economic values or prices.
For the burden allocated to the involved auto parts in the prime mover, the environmental load output as loss in the prime mover during the use of automobile equipped with the auto parts should be defined using the ratio of the prices of the auto parts to the cost price of the prime mover. Based on this concept, the burden allocated depends on the theoretical energy efficiency, E_{th}, of the prime mover in the automobile equipped with the auto parts under study (or the theoretical thermal efficiency for the engine), the actual energy efficiency, E_{re}, of prime mover, the cost of manufacture, C_{en}, of the prime mover, and the selling price, P_{pt}, of the auto parts to automobile manufacturers. This may be expressed as follows:

(Environmental load allocated to individual auto parts which have functions affecting the energy efficiency of the prime mover)
= (Future improvable energy loss: Thermal energy not converted to kinetic energy at present) $\div C_{en} \times P_{pt}$
= (Automobile fuel consumption: Total fuel potential chemical energy required by the prime mover for running a unit distance)
$\times (E_{th}-E_{re}) \div C_{en} \times P_{pt}$

For determination of energy loss for allocation, the energy conversion efficiency of the automobile prime mover, and the cost of manufacture of the automobile prime mover acting as the denominator of allocation ratio must be studied. It is easy to imagine that the studies are very difficult to complete. Accordingly, JAPIA has specified the automobile fuel consumption, the prime mover energy conversion efficiency, and the cost of manufacture of prime mover that are considered typical. The details are included in the attached Data Sheets.

7.3.5 Calculation of environmental load intensity in the consumer use phase

The environmental load intensity of the individual auto parts under study in the consumer use phase may be determined as the sum total of environmental load intensities based on the four (4) allocation methods described above.

The guidelines for making decision on which calculation methods should be applied for the auto parts under study among the four methods are provided in the attached Consumer Use Phase Data Sheets.

8. References

*1 ISO14040 2006 Environmental management - Life cycle assessment - Principles and framework
*2 ISO14001 2004 Environmental management systems - Requirements with guidance for use

Revision No.	Date of revision	Description of revision
First edition	May 1, 2013	• Newly established
Ver. 1.1	May 1, 2014	• 6. Terms and definitions: Corrected definition of the term “Electronic component.” • 7.2.2.1 Calculation in the manufacturing phase of electronic component: Newly included description about the need for giving consideration to the environmental load intensity depending on the number of resistors and capacitors mounted, and the area of printed circuit boards (PCBs). • Some changes in the wording, etc.
Second edition	Apr. 30, 2016	• Newly included description about calculation in the consumer use phase. • Some changes in the wording, etc.

The Guidelines have been developed by the Subcommittee members listed below.

Environmental Consciousness Committee LCA Subcommittee Members (In no particular order)

Chairperson	Akira Tanahashi	Denso Corporation
Members	Naomasa Ikeda	Aisin Seiki Co., Ltd.
	Satoshi Imaizumi	Aisin Seiki Co., Ltd.
	Shinichi Otani	Aisin Seiki Co., Ltd.
	Tomoyuki Tsunekawa	Aisin Seiki Co., Ltd.
	Yasuhiro Harada	Aisin Seiki Co., Ltd.
	Minoru Hirata	Aisin Seiki Co., Ltd.
	Yasumine Kanamori	Akebono Brake Industry Co., Ltd.
	Tatsuya Okabe	NOK Corporation
	Masayuki Kishimoto	NOK Corporation
	Tadayoshi Tajima	Calsonic Kansei Corporation
	Tomoaki Hasegawa	Calsonic Kansei Corporation
	Toshinobu Ueoka	Keihin Corporation
	Tsuyoshi Tomita	KYB Corporation
	Yasutaka Hara	KYB Corporation
	Hiroshi Matsumoto	KYB Corporation
	Takayuki Yasuma	Koito Manufacturing Co., Ltd.
	Akihisa Yamada	Koito Manufacturing Co., Ltd.
	Hiroyuki Ito	Sanden Holdings Corporation
	Yoshihiro Saito	Sanden Holdings Corporation
	Kazushige Watanabe	Sanden Holdings Corporation
	Takeo Onuma	Sanden Holdings Corporation
	Minoru Takeda	JTEKT Corporation
	Keitoku Higashiyama	JTEKT Corporation
	Tomohiro Haruta	JTEKT Corporation
	Masaki Okajima	JTEKT Corporation
	Shinji Okise	Stanley Electric Co., Ltd.

Members	Hideki Kitamura	Stanley Electric Co., Ltd.
	Shotaro Suzuki	Sumitomo Wiring Systems, Ltd.
	Norio Kanbara	Sumitomo Rico Company Ltd.
	Yoshitaka Goto	Denso Corporation
	Atsuhiro Hara	Denso Corporation
	Yoshinori Watanabe	Denso Corporation
	Katsuhisa Kobayashi	Toyo Denso Co., Ltd.
	Yoshihiro Fujiwara	Toyo Denso Co., Ltd.
	Naoto Kato	Toyota Industries Corporation
	Makoto Murayama	Toyoda Gosei Co., Ltd.
	Yasuharu Kondo	Toyota Boshoku Corporation
	Katsuhiko Hokazono	Toyota Boshoku Corporation
	Hiroshi Fukawa	NSK Ltd.
	Teruhisa Miyamoto	NSK Ltd.
	Yoshio Inoue	NGK Spark Plug Co., Ltd.
	Hidetoshi Ogawa	NGK Spark Plug Co., Ltd.
	Hisato Kashima	NGK Spark Plug Co., Ltd.
	Wataru Nagasaki	Bosch Corporation
	Yukio Morita	Bosch Corporation
	Atsushi Yamamoto	Mikuni Corporation
	Masatoshi Kishida	Yazaki Corporation
	Junya Korenaga	Yazaki Corporation
Secretariat	Kiyonori Sekiguchi	The Japan Auto Parts Industries Association
	Masatoshi Tsutsui	The Japan Auto Parts Industries Association
	Natsuya Saito	The Japan Auto Parts Industries Association

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Minato-ku, Tokyo 108-0074
Tel.: 03-3445-4215 Fax.: 03-3447-5372
Email: saito-natsuya@japia.or.jp
http://www.japia.or.jp/