Circular Manufacturing | Organized Session：OS: Circular Manufacutirng (4)

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[C-7] OS: Circular Manufacutirng (4)

Chair: Venkata Reddy Nallagundla (Indian Institute of Technology, Hyderabad, India)

Proceedings paper

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[C-7-02] Analysis of the Truck Disassembly Process and Assessment of the Environmental Impact Reduction Potential of Reused Parts

*Aoba Nohmura[1], Yusuke Nagai[1], Tatsuki Yamada[1], Akihiro Hayakawa[2], Shundai Nezu[2], Yuichi Takenaka[3], Mitsunobu Fujita[2], Masato Inoue[4], Takao Mori[1], Shuho Yamada[1] (1. Toyama Prefectural University, 2. NGP Co.,Ltd, 3. Japan Truck Refineparts Association, 4. Meiji University)

Currently in Japan, approximately 3.5 million vehicles reach the end of their service life annually. About 80% are recycled, while roughly 20% become shredder residue. However, in recent years, concerns have grown regarding limited landfill capacity and rising disposal costs, potentially leading to illegal dumping and improper treatment, causing environmental problems. Addressing these issues necessitates a recycling-oriented society focused on reducing natural resource consumption and minimizing environmental burden through material cycling. Utilizing recycled parts significantly reduces energy and resource consumption in new part manufacturing and decreases waste. Recycled parts include reused parts (recovered components with minimal processing for resale) and remanufactured parts (recovered components with worn parts replaced and reassembled). However, the environmental burden reduction effects of using recycled parts often lack clear data, especially for large trucks in long-distance transport, despite prior research on smaller trucks. This research aims to calculate the environmental burden emissions from manufacturing reused parts for large truck engines and Transmissions: T/M and evaluate the reduction achieved by their utilization through a process analysis until their sale. In this research, the environmental burden reduction effect from reused parts will be defined and evaluated in terms of converted CO2 emissions, calculated as the sum of various Greenhouse Gas (GHG) emissions multiplied by their respective Global Warming Potential (GWP). The reduction effect is considered to the difference between the GHG emissions from the production of new parts and the GHG emissions from the dismantling of used parts and the cleaning, inspection, and reconditioning of reused parts, assessed from part removal to storage. According to the results calculated in this research, the weight of the engine is approximately 990kg, and the T/M is approximately 360kg. The GHG emissions during the manufacturing of new engine parts are approximately 3,500 tons of CO2 equivalent, and those for a new T/M are approximately 950 kg-CO2eq. Subtracting the emissions from the production of reused parts, the reuse of engines and T/M shows a GHG emission reduction of over 99% for both, the impact of the production of reused parts is almost negligible. Note that this result may be an underestimate because the GHG emissions from the dismantling of a single truck were used to determine the reductions from engine and T/M reuse.

Analysis of the Truck Disassembly Process and Assessment of the Environmental Impact Reduction Potential of Reused Parts

Aoba NOHMURA [1], Yusuke NAGAI [1], Tatsuki YAMADA [1], Akihiro HAYAKAWA [2], Shundai NEZU [2], Yuichi TAKENAKA [3], Mitsunobu FUJITA [2], Masato INOUE [4], Takao MORI [5], Shuho YAMADA [5]

[1] Graduate School of Engineering, Toyama Prefectural University (TPU), Toyama, Japan

[2] NGP Co., Ltd., Tokyo, Japan

[3] Japan Truck Refineparts Association, Ishikawa, Japan

[4] Meiji University, Tokyo, Japan

[5] TPU, Toyama, Japan

Abstract

As a contribution to a circular economy, the use of recycled parts is important. This study aims to clarify the environmental impact reduction potential of reusing parts from large trucks by evaluating the reduction of greenhouse gases (GHG). The assessment was conducted from a life cycle assessment (LCA) perspective, targeting a heavy-duty truck over 20 tons. The truck disassembly process was analyzed to quantify the GHG emissions generated during the manufacturing of reused parts, specifically engines and transmissions. The GHG emissions from the manufacturing of new parts were compared with the emissions from the reused parts manufacturing process, which includes parts removal and cleaning. As a result, a significant GHG reduction effect of approximately 99% was shown for both the engine and the transmission. Future work will include considering the GHG emissions associated with the treatment of waste oil, fluorocarbons, and coolants, as well as evaluating the reduction potential of other reused parts besides the engine and transmission.

Keywords:

Life cycle assessment, Truck, Disassembly process analysis, Reuse parts, GHG reduction, Engine Transmission

1. INTRODUCTION

Since the 1990s, Japan has aimed to move away from a society of mass production, mass consumption, and mass disposal, and has promoted legal reforms to build a circular society. Since the 2000s, initiatives to promote the formation of a circular society have been undertaken, such as the implementation of the 3R (Reduce, Reuse, Recycle) and the Basic Law for Establishing the Recycling-Based Society and the Act on Recycling of End-of-Life Automobiles [1]. In particular, the Act on Recycling of End-of-Life Automobiles has contributed to promoting proper recycling by obligating each car owner, manufacturer, and related business operator to fulfill their respective roles [2]. Furthermore, in automobile recycling, the utilization of recycled parts can contribute to the realization of a circular society because it allows for the effective use of resources, the reduction of waste, and the reduction of energy and environmental burdens during the manufacturing of new parts.

Recycled parts are those that have been taken from an end-of-life vehicle, properly processed and inspected, and then remarketed. There are two types of recycled parts: reused parts and remanufactured parts. Reused parts are those that are resold after being visually and/or tester-inspected, cleaned, and beautified, without being disassembled or otherwise manipulated. Remanufactured parts, on the other hand, are resold after worn or degraded components are replaced with new ones, reassembled, and quality-tested using a tester. In previous research, the environmental impact reduction effect of using reused automobile parts has been investigated, including a study of the top 50 best-selling reused parts and a proposed model for predicting environmental load emissions [3]. There are also cases for remanufactured parts, such as an engine [4], AC compressors, starters, and alternators [5]. These previous studies have investigated recycled parts for trucks, with a focus on Kei trucks for reused parts and 2-ton trucks for remanufactured parts. However, the environmental impact reduction effect of using recycled parts for heavy-duty trucks, which are frequently used for long-distance transport, has not been sufficiently evaluated. This study aims to evaluate the environmental impact reduction effect of using reused parts from a life cycle assessment (LCA) perspective, while also calculating the environmental load emissions from their manufacturing. This paper investigates and analyzes the manufacturing process of the engine and transmission, which are among the most frequently sold reused parts, and evaluates the environmental impact reduction effect of their use.

2. DEFINITION OF ENVIRONMENTAL IMPACT REDUCTION EFFECTS

In this study, the environmental impact reduction effect is calculated by comparing the case of using new parts with the case of using reused parts. To evaluate the environmental impact reduction effect from the use of reused parts, this study focuses on global warming and calculates the reduction effect of greenhouse gas (GHG) emissions (unit: kg-CO_2e). Figure 1 shows the concept of the GHG reduction effect, and Equation *(1)* shows the calculation formula. GHG emissions from the manufacturing of reused parts are given as the sum of the GHG emissions from the process of separating parts from end-of-life vehicles (E_{dup}) and the GHG emissions from the cleaning, inspection, and beautification of the removed parts (E_{cib}). Furthermore, the GHG reduction amount (E_R) is determined by subtracting the GHG emissions from the manufacturing of reused parts from those of equivalent new parts (E_{npm}). However, this study does not consider the GHG emissions during the transportation and use of new and reused parts, as they are considered equivalent. Therefore, LCA is conducted on the target parts for the scope from resource extraction to product manufacturing for both new and reused parts.

In addition, converted CO_2 emissions are generally calculated by multiplying various GHG emissions by the global warming potential (GWP) and summing the results. Furthermore, these emissions are calculated by multiplying the emission intensity by the activity. This study uses the GHG emission intensity information described in the environmental load database IDEA ver. 3.1.0 [6]. To understand the GHG emissions associated with the manufacturing of new parts, this study disassembles parts removed from end-of-life vehicles and investigates detailed information such as material and weight. Furthermore, it investigates the amount of electricity consumed and materials used in the part removal and cleaning processes during the manufacturing of reused parts.

$$E_R = E_{\text{npm}} - \left(E_{\text{dup}} + E_{\text{cib}}\right) \qquad (1)$$

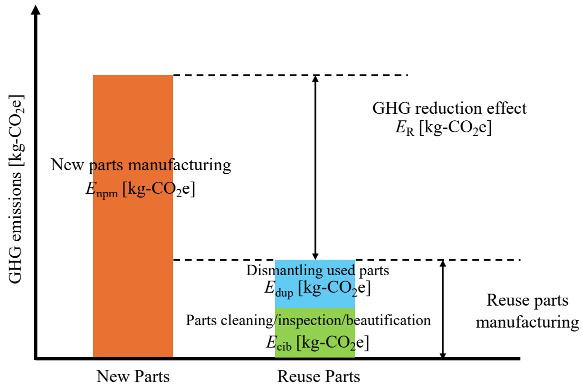

Fig. 1: Conceptual diagram of GHG reduction effect

3. CREATION OF A TRUCK DISASSEMBLY PROCESS MODEL

In this study, the disassembly process of a heavy-duty truck exceeding 20 tons was investigated to create a process model for the disassembly process, in order to visualize the equipment and resources used, as well as the work standards, in each part removal process for manufacturing reused parts, and to track various information leading to part removal. The IDEF0: Integration DEFinition 0 [7] functional modeling method is used for modeling the disassembly process. IDEF0 is a method for hierarchically and in detail modeling the flow of decisions, actions, and activities within a system in a top-down manner. As shown in Fig. 2, the basic unit of IDEF0 representation consists of four elements for one function name: Input, Control, Output, and Mechanism. In the modeling of the disassembly process, the function name is defined as the work process, Input as the resources and power used, Control as the work standard for the process, Output as what is emitted by the process, and Mechanism as the workers and equipment used.

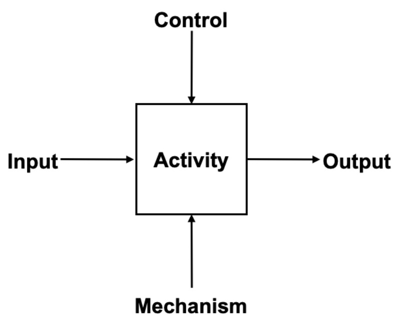

Fig. 2: IDEF0 box format

The truck disassembly process consists of a total of 28 steps. Table 1 shows the details of the processes and the process IDs for identification. Additionally, a part of the truck disassembly process model created using IDEF0 is shown in Fig. 3.

Table 1: Details of the truck disassembly process

Process ID	Process name
DP 0	Truck entering
DP 1	Check CP (Computer) and other status
DP 2	Wing van body removal
(DP 2.1) [*1]	Wing van body disassembly
DP 3	Check powertrain components
DP 4	Treatment and recovery of CFCs and airbag
DP 5	Collection of waste oil and LLC [*2]
DP 6	Dismantle cabin
DP 6.1	Air deflector removal
DP 7.1.1	Frame transport
DP 7.1.2	Harness removal
DP 7.2.1	Removal of engine bay chassis components
DP 7.2.2	Dismantle engine
DP 7.3	Other chassis components removal
DP 7.4.1	Dismantle propeller shaft
DP 7.4.2	Propeller shaft disassembly
DP 7.5.1	Front-wheel (F.) dismantle axle
DP 7.5.2	F. Wheels removal
DP 7.5.3	F. Dismantle suspensions
DP 7.5.4	F. Drum brake disassembly
DP 7.6.1	Rear-wheel (R.) welding to a chassis with 2 axles
DP 7.6.2	R. Wheels removal
DP 7.6.3	R. Chassis removal
DP 7.6.4	R. Diff [*2] oil recovery
DP 7.6.5	R. Dismantle suspensions
DP 7.6.6	R. Extract axle shafts
DP 7.6.7	R. Diff removal
DP 7.6.8	R. Drum brake disassembly

*1 Body is replaceable, so it is not considered in this study.

*2 LLC stands for Long Life Coolant.

*3 Diff stands for Differential Gear.

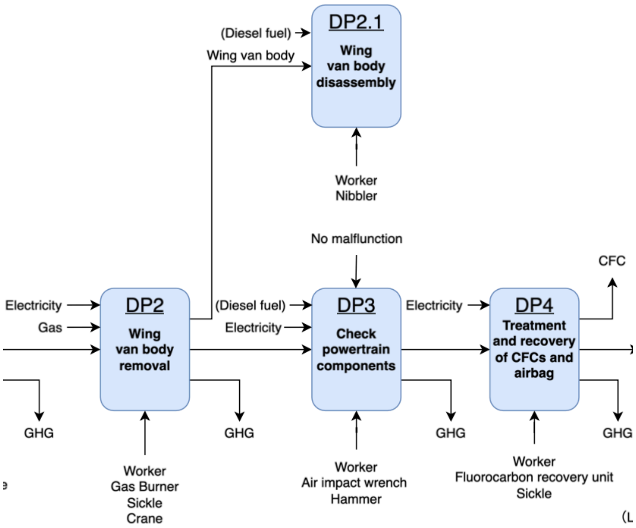

Fig. 3: Part of the truck disassembly process

4. GHG REDUCTION EFFECTS THROUGH THE USE OF REUSED PARTS (E_{R})

4.1 Inventory analysis of parts subject to investigation and calculation of GHG emissions from manufacturing of new parts (E_{npm})

In this study, a disassembly investigation was conducted on the target engine (total displacement 9839 cc) and transmission (T/M: Smoother Gx: 12-speed), and the weight, materials, and processing methods of their components were investigated. As a result of the investigation, Table 2 shows the weights of the engine and T/M and their calculated GHG emissions. In addition, the breakdown of the material composition by weight for the engine and T/M is shown in Figures 4 and 5, and the GHG emissions for the engine and T/M and their material breakdown are shown in Figures 6 and 7. As a supplement, in Figures 4-7, the material "Plastics" includes PP, PE, PA6, glass fiber, and unknown plastics. Unknown plastics refer to those whose material could not be identified during the disassembly investigation because the material markings stipulated by ISO and JIS were not confirmed on the plastic products. For the calculation of GHG emissions for unidentifiable plastics, the average emission intensity for all plastics in IDEA ver. 3.1.0 was used as a representative value. Furthermore, the material "Other" includes paper, carbon, circuit boards (found only in engines), and harnesses. In addition, within the category of "Other," harnesses were treated separately due to their relatively complex composition. As a representative case, the door harness of a passenger car was investigated, and its GHG emission factor was set at 8.30 kg-CO2e per 1 kg for the calculation. Also, a material breakdown of "0.0%" on the graphs in Figures 3-6 indicates that the proportion of that material is less than 0.05%.

Table 2: Engine and T/M weight and GHG emissions

Subject parts	Weight [kg]	GHG emissions [kg-CO_2e]
Engine	989	3.52×103
T/M	364	903

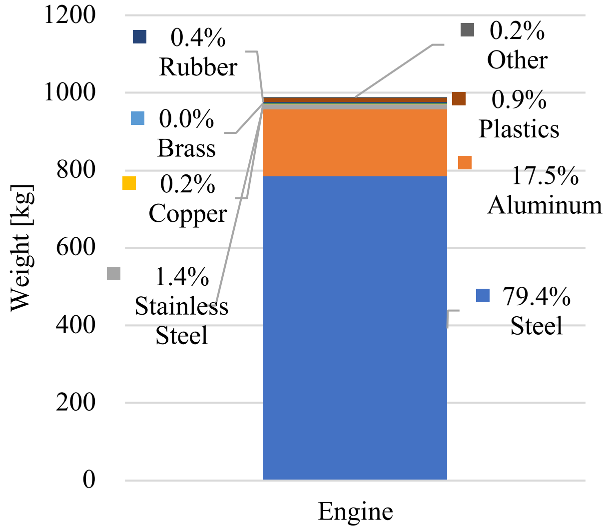

Fig. 4: Breakdown of materials within the weight of the engine

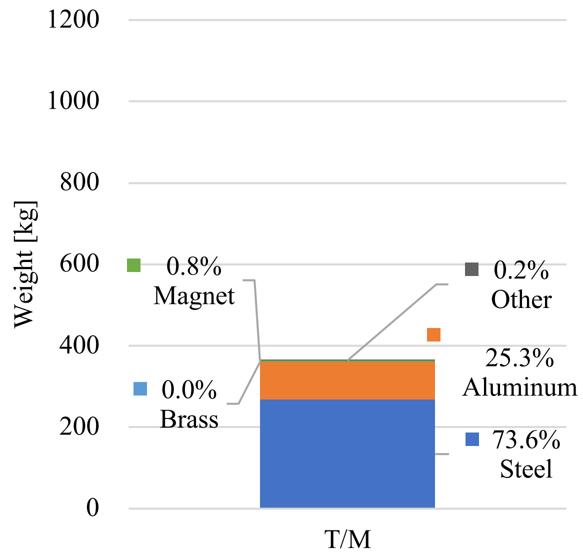

Fig. 5: Breakdown of materials within the weight of the T/M

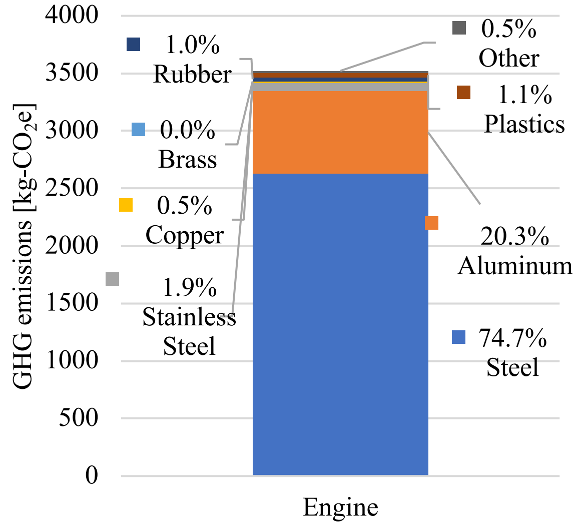

Fig. 6: Breakdown of materials within the GHG emissions of the engine

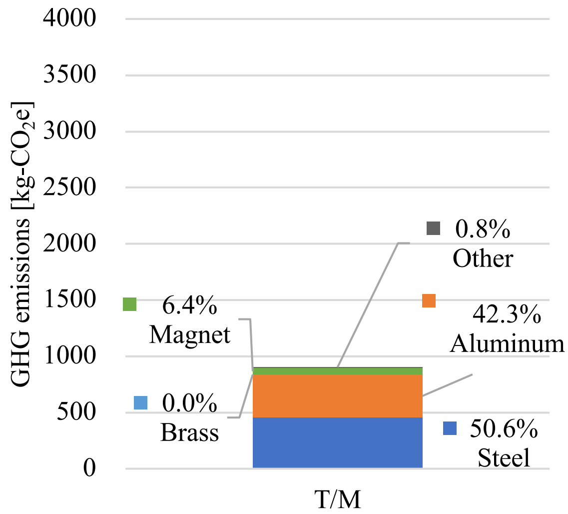

Fig. 7: Breakdown of materials within the GHG emissions of the T/M

4.2 GHG emissions from dismantling used parts

In this study, an investigation of a reused parts manufacturing plant for the engine and T/M, which are frequently sold as reused parts, was conducted, and it was confirmed that the processes shown in Table 1 are being carried out. The GHG emissions from dismantling used parts are determined from the GHG emissions of the equipment used, based on the information obtained from this factory investigation during truck disassembly. The equipment used in the disassembly process is mainly electrically operated equipment (such as compressors for air tools and overhead cranes) and gas-fueled equipment (gas burners). To calculate the GHG emissions from the use of electrically operated equipment, it is necessary to know the amount of power consumed. This study investigated actual power consumption using a power logger and calculated it based on usage time. For gas-fueled equipment, the consumption of liquefied oxygen and LPG (liquefied petroleum gas) used with gas burners was measured. Table 3 shows the power consumption, the consumption of oxygen and LPG, and the resulting GHG emissions obtained from this investigation. Here, the consumption of oxygen and LPG was estimated based on various truck disassembly processes. To determine the consumption of oxygen and LPG for the dismantling of the subject truck of this study, a correlation was established between the consumption of oxygen and LPG and the vehicle weight (the sum of the body weight, the weight of the unloaded cargo bed, and the weight when filled with engine oil, fuel, and LLC) using data from four non-target trucks. Figure 8 shows this correlation plot. Furthermore, the vehicle weight data used to estimate the consumption of oxygen and LPG during the dismantling process of the subject truck is 10710 kg, as specified in the manufacturer's documentation [8].

Table 3: Input material usage and GHG emissions in truck disassembly

Input		Usage	GHG emissions [kg-CO_2e]
Electricity	Air tools (Compressor)	1.51 kWh	0.819
	Crane	1.07 kWh	0.579
Oxygen		4.97 kg	0.787
LPG		1.29 kg	6.07

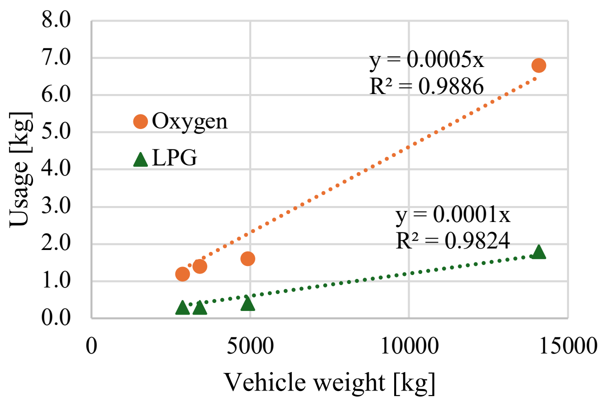

Fig. 8: Correlation between oxygen and LPG consumption and the vehicle weight, based on dismantling of four non-target trucks

Table 3 shows the quantified GHG emissions for the entire truck disassembly process. In this process, the GHG emissions from each step involving electricity and gas (oxygen and LPG) were calculated based on the usage time of air tools, cranes, and gas burners. The results are summarized in Figure 9. As a result, it was found that the truck disassembly step with the highest GHG emissions was DP7.6.5, "R. suspension removal". This was mainly because the nuts fastening the rear wheel suspension were seized. While the front wheel suspension, which was of the leaf spring type, could be disassembled relatively easily, the rear wheel suspension was an air suspension type with a more complex structure. Moreover, since the four nuts on both sides were seized, repeated heating with a gas burner was required to expand them, followed by removal with an air tool. Each nut had to be heated for more than one minute. This prolonged use of the gas burner led to longer operation times compared to other processes and consequently resulted in higher GHG emissions.

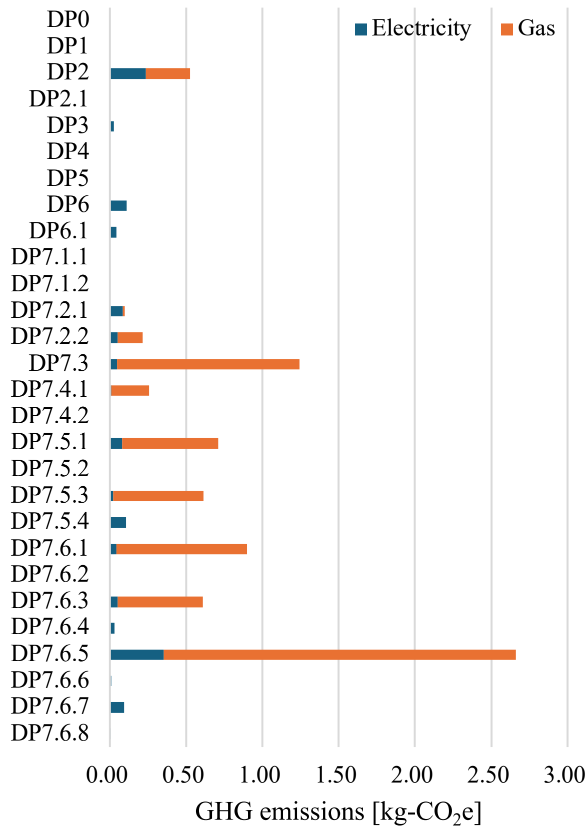

Fig. 9: GHG emissions from electricity and gas consumption in each process

In addition, since the data shown in Table 3 represent the total input of energy and materials for the entire truck disassembly process, it is necessary to allocate them to the target parts. Therefore, the GHG emissions from power consumption and oxygen and LPG consumption in Table 3 were allocated based on the weight ratio of the target parts to the total truck weight. Table 4 presents the weight ratio of the engine and T/M to the total truck weight, and Table 5 presents the allocated power consumption and GHG emissions from oxygen and LPG consumption. The GHG emissions for the engine and T/M shown in Table 5 are regarded as E_{dup}, i.e., the GHG emissions from dismantling used parts.

Table 4: Weight ratio of engine and T/M in the whole truck

Target parts	Weight [kg]	Weight ratio
Engine	989	13.6 %
T/M	364	5.0 %
The whole truck	7.29×10^3	100.0 %

Table 5: GHG emissions from dismantling the engine and transmission

Target parts	GHG emissions [kg-CO_2e]		
	Electricity	Gas	Total
Engine	0.190	0.929	1.12
T/M	0.0698	0.342	0.412
The whole truck	1.40	6.85	8.25

4.3 GHG emissions from cleaning and beautification processes E_{cib}

In the production of reused parts, the cleaning process is performed either after dismantling from the truck or prior to sale. In addition, the beautification process is carried out concurrently with cleaning. The inspection process, on the other hand, is conducted during truck disassembly by checking diagnostic trouble codes (DTCs) with a diagnostic tool and visually inspecting operation. For this reason, this study assumes that no GHG emissions are associated with the inspection process. Therefore, only the GHG emissions from the cleaning (including beautification) process are calculated.

In this study, the GHG emissions from the cleaning process for the truck engine and T/M are calculated using data from cleaning comparable parts as a representative value. Since they are prone to stubborn stains from mud and dust picked up during driving or from engine oil leaks, high-pressure washers were used for the cleaning process. The inputs to this process include alkaline detergent and washing water, as well as kerosene and electricity used for the high-pressure washer. The consumption of detergent and kerosene was calculated by measuring the weight of their containers before and after cleaning. The amount of washing water was calculated by multiplying the washer's rated discharge rate (1300 L/hour) by its usage time. Power consumption was measured using a power logger. The data obtained from the investigation of the engine and T/M cleaning processes are shown in Table 6, and the GHG emissions calculated from these data are presented in Table 7. The results showed that the GHG emissions were 25.8 kg-CO_2e for engine cleaning and 9.99 kg-CO_2e for T/M cleaning. The GHG emissions from the consumption of input materials for cleaning the engine and T/M cleaning correspond to the GHG emissions from the cleaning process, E_{cib}.

Table 6: Amount of input used when cleaning target parts

Target parts	Alkaline cleaner [kg]	Kerosene [kg]	Washing water [kg]	Electricity [kWh]
Engine	2.43	3.75	0.620	5.61
T/M	0.848	1.51	0.268	2.30

Table 7: GHG emissions from inputs during cleaning of target parts

Target parts	GHG emissions [kg-CO_2e]			
	Alkaline cleaner	Kerosene	Washing water	Electricity
Engine	7.90	14.8	0.0847	3.05
T/M	2.76	5.94	0.0365	1.25

4.4 Calculation of GHG emission reduction effect E_R

The GHG emission reduction effect (E_R) from the use of the reused engine and T/M was calculated using Equation *(1)*, based on the GHG emissions from new parts manufacturing (E_{npm}) calculated in Section 4.1, the GHG emissions from dismantling used parts (E_{dup}) calculated in Section 4.2, and the GHG emissions from the cleaning process (E_{cib}) calculated in Section 4.3. The results are shown in Figure 10. The GHG emission reductions for the engine and T/M of a heavy-duty truck exceeding 20 tons were 3.50×10^3 kg-CO_2e and 892 kg-CO_2e, respectively. The reduction ratios were approximately 99.2% for the engine and 98.9% for the T/M, indicating a reduction of about 99% for both. The major reason for this high reduction is that the GHG emissions from new parts manufacturing are significantly larger than those from reused parts manufacturing. This suggests that utilizing reused parts is important for reducing environmental impact.

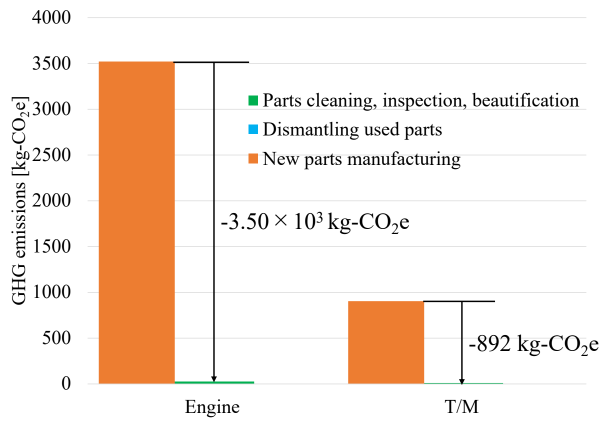

Fig. 10: Reduction of GHG emissions through the reuse of engine and transmission

5. CONCLUSION

This study aims to evaluate the potential for reducing environmental impacts through the reuse of parts from heavy-duty trucks, focusing on the GHG emission reduction effect of reused engines and transmissions from an LCA perspective. Based on a survey of a reused parts manufacturing plant, a process model for truck disassembly was developed. The input materials and equipment used in the disassembly and cleaning processes were identified, along with the materials with high consumption and associated GHG emissions. Furthermore, through a disassembly investigation, the materials, weights, and processing methods of the components were specified, and the GHG emissions from the manufacturing of new parts were calculated.

The GHG emissions from part removal were estimated using the weight ratio of the parts to the total truck weight and were combined with the GHG emissions from the cleaning process to calculate the emissions from reused parts manufacturing. The GHG emission reduction effect was then calculated by comparing the GHG emissions from the manufacturing of new and reused parts. As a result, reductions of 3.50×10^3 kg-CO_2e for the engine and 892 kg-CO_2e for the T/M were obtained, corresponding to a GHG emission reduction of approximately 99% for both.

Future work should include the consideration of GHG emissions associated with the treatment of waste oil, fluorocarbons, and coolants discharged during truck disassembly. In addition, this study evaluated the reduction effect only for the engine and T/M of a heavy-duty truck. However, since almost all truck parts, except for certain components such as the frame, can be reused, clarifying the GHG emission reduction effect of other reused parts also remains an important future task.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Hamamoto M (2023) Circularity in Municipal Solid Waste Management in Japan [Translated from Japanese]. Studies on environmental symbiosis, No. 16, pp 1-12, (Accessed July 7, 2025)

[2] Ministry of Economy, Trade and Industry (n.d.) What is the Automobile Recycling Law [Translated from Japanese]. https://www.meti.go.jp/policy/mono_info_service/mmon/automobile/automobile_recycle/about/recycle/rerecyc.html, (Accessed June 22, 2025)

[3] Takahashi S, Iwasaki M, Fujita M, Mori T, Suzuki R, Suzuki Y, Tamaki M, Sugimoto J, Ishizuka K, Obata K, Suzuki S, Kobayashi K, Tani H, Hayakawa H, Inoue M (2016) Calculation and public examples of greenhouse gas emission reduction assessment - 50 major parts of automobile reuse. In: Proceedings of the 11th Annual Meeting of the Japan LCA Society D3-01, p. 318.

[4] Kobayashi S, Okamoto T, Fujita M, Mori T, Hayakawa A, Sugimoto J, Inoue M (2018) Reduction Effect of Rebuilt Engine for Automobiles on Carbon Dioxide Emissions. In: Proceedings of the Design and Systems Conference, 2018.28, No. 2604, DOI:10.1299/jsmedsd.2018.28.2604

[5] Yamada S, Horiuchi Y, Inoue M, Fujita M, Hayakawa A, Mori T (2024) Assessment of greenhouse gas reduction through the utilization of remanufactured automotive parts, and consideration of the guidelines for product designs (Case studies of AC compressors, starters, and alternators). Transactions of the Japan Society of Mechanical Engineers, Vol. 90, No. 940, DOI:10.1299/transjsme.24-00109

[6] National Institute of Advanced Industrial Science and Technology, Safety Science Research Division, IDEA Lab (2021) LCI Database IDEA, Version 3.1.0

[7] Fujino K, Yoshida T, Hattori T, Kaneko S, Sawa D, (1996). IDEF0-Based Analysis of On-Site Labor Safety Management and Information Management Strategies [Translated from Japanese]. In: Proceedings of the Construction Management Research, Vol. 4, 1996, pp 59-68, DOI:10.2208/procm.4.59

[8] Isuzu Motors Limited. G Cargo/Tractor: Main Specifications (n.d.) https://www.isuzu.co.jp/product/giga/lineup/g_cargo/pdf/g_cargo_shogen.pdf, (Accessed June 29, 2025).