



Carbon Footprint Assessment and GHG Mitigation Potential of Canned Tuna Spread Products in Thailand

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Article History: Received: 13 July 2025, Accepted: 22 August 2025, Published: 28 August 2025

Abstract

This study evaluated the carbon footprint (CFP) of tuna spread product produced by canned tuna factory in Thailand according to ISO 14067:2018 standards and Product Category Rules (PCRs) for processed and ready-to-eat food products. The assessment scope is cradle to gate, excluding secondary packaging of raw materials and products. The functional unit (FU) is defined as one can (net weight 85 grams) of tuna spread product. The carbon footprint of the tuna spread product is 408.08 gCO₂eq per FU. The proportion of greenhouse gas emissions comes from non-tuna ingredient, steam and hot water, tuna meat, and primary packaging, with values of 65.12, 11.40, 9.02, and 7.00 % respectively. GHGs reduction potentials are installing solar panels with power storage, increasing renewable energy consumption, changing to electric-powered ships and trucks, changing packaging to retort cup, implementing zero waste to landfill, and switching boiler fuel to biomass. Implementing all measures can reduce greenhouse gas emissions by up to 30.09% of the CFP of the classic style canned tuna spread product.

Keywords : Greenhouse gas emissions; Carbon footprint; Canned tuna spread; Tuna Industry; Thailand

Introduction

The processed tuna industry is a significant seafood processing industry in Thailand. Thailand is the world's number one exporter of canned tuna in 2023, primarily using imported tuna with a small fraction of tuna caught by Thai ship. The life cycle of canned processed tuna products, including the carbon footprint of the products, has been studied in several key countries for canned tuna exports, such as Spain, Ecuador, and Portugal including Thailand. Mungkung *et al.* (2012) [1] found that majority of greenhouse gas (GHGs) of canned tuna came from tuna

meat with significant GHGs from primary packaging. Hospido *et al.* (2006) [2] found that plastic pouch has lower environmental impacts than tin can, however consumers' acceptance should be considered as well as economic value and end of waste management. Poovarodom *et al.* (2012) [3] further explored impact of different packaging of canned tuna in sunflower oil and found that retort cup has lower GHG than plastic pouch and metal can. Avadí *et al.* (2015) [4] suggested that a bigger packaging could lower CFP; and aluminium can has lower GHG than tin can. Cortés *et al.* (2021) [5] suggested that, to reduce CFP, the company should consider increasing number of

products within its scope to share GHG emissions to other products. De Vlieghere *et al.* (2023) [6] suggested that using local contents and local supply chain can reduce GHG emissions.

From our investigation, we found that the processing of tuna meat into ready-to-eat products and premium pet food can significantly enhance product yield and augment the value of by-products. Additionally, other fish parts were sent elsewhere for various uses: fish bones have been utilized for fish meal, and fish entrails have been employed for animal feed. One of ready-to-eat products from Pattaya Food Industries Co., Ltd., a sandwich tuna spread is selected for this study based on its sale growth potential in Thailand with 1.5 million cans in 2023. With increasing awareness on carbon emission, Thailand is actively pursuing carbon reduction policies with the goal of achieving carbon neutrality by 2050 and net-zero greenhouse gas emissions by 2065. However, there is little to no study on an environmental impact of this product. Therefore, this study focuses on the impact on climate change and estimates the carbon footprint of the classic style canned tuna spread product. This study also explores GHGs reduction potential for the tuna processing industry to assess the possibility to achieve national policy to reduce greenhouse gas emissions by 30-40% by 2030.

Methodology

This study used the carbon footprint assessment method according to ISO 14067: 2018 [7] and followed Product Category Rules for Prepared and Ready to Eat Products [8].

Goal and Scope Definition

The main goals of this study are (1) to calculate the carbon footprint of the canned tuna spread product, (2) to identify GHGs reduction potential for the tuna processing industry.

A case study of canned tuna spread product (Classic Tuna Spread, Nautilus Brand) is presented based on data of year 2023 from a canned tuna factory in Thailand. The assessment scope is defined as cradle to gate, covering the process of obtaining raw materials, transportation, production process,

water production process, steam production process, wastewater treatment system, and waste management within the factory until the product is stored in the warehouse for shipment. Secondary packaging is not considered in this study. The system boundary is shown in Figure 1.

The functional unit is 1 can of tuna spread product (net weight 85 grams). The inventory of tuna spread production in 2023 is approximately 400,000 cans accounting for less than 0.1% of total production of the factory in that year. Mass allocation is used to distribute utilities and environmental burdens among different products.

Inventory Analysis

This study collected primary data from the company records, including data on domestic and international fish catching, raw materials and packaging, production process and waste management. Carbon emissions for fish catching are not available, therefore emission factors of fuel consumption in tuna fishing [10] were used instead. Sea transportation data was obtained from Captain Statement, Movement Document of the Department of Fisheries, and distances from Searates [11]. Loading factors for sea transportation are assumed to be 100% and distance of single trip is used since shipping vessels exchange goods at different ports along the way. Emissions from land transport were assessed based on vehicle types, distances, and loading factors. Land transportation data of each raw material was obtained from company records and Google Map. Loading factors for land transportation are calculated based on number of shipments and order volume of the same year. One-way empty loading, 0%, was assumed since company has no back hauling policy.

Data on raw materials and packaging were collected from the company's database. Primary data on the production process obtained from the company includes the use of tap water, electricity, steam production, and wastewater treatment system within the factory. Waste management data was considered based on disposal methods and location of disposal contractors. Inventory data is shown in Table 1.

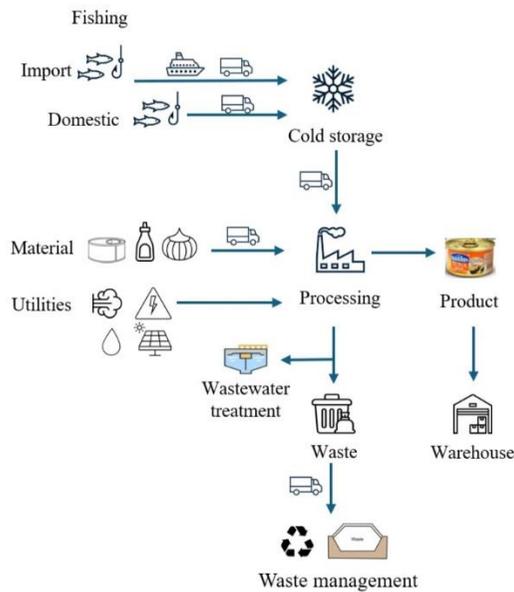


Figure 1 System boundary of the carbon footprint assessment of the tuna spread product

Table 1 Inventory data for the tuna spread processing

Input	Unit	Value per FU	Transport distance (km)
Ingredients			
Raw tuna (Import)	g	13.70	5,900 - 16,522 ^(a)
			48-52 ^(b)
Raw tuna (domestic)	g	3.30	5 - 1,005 ^(c)
			9-12 ^(d)
Mayonnaise (egg-based)	g	39.95	88
Water chestnut	g	22.10	120
Onion	g	5.95	12
Iron lid	g	3.00	13
Aluminum can	g	6.00	13
Utilities			
Electricity (mixed grid)	kWh	2.17×10^{-2}	
Electricity (solar power)	kWh	1.29×10^{-3}	
Water	liter	1.57	
Steam^(e)	kg of steam	0.11	
wastewater	liter	1.21	

Note: (a) Transport distance from tuna landing port to Bangkok Port (ship),
 (b) Transport distance from Bangkok Port to cold storage (road),
 (c) Transport distance from domestic tuna landing port to cold storage (road),
 (d) Transport distance from cold storage to factory (road),
 (e) utilize Sub-bituminous coal and heavy oil grade A

Greenhouse gas emissions coefficients used in this study were considered according to the guidelines for selecting greenhouse gas emissions coefficients from Thailand Greenhouse Gas Management Organization (Public Organization) (TGO) in the following order: 1) TGO database, 2022 [12] 2) environmental database of basic materials and energy in Thailand 3) peer reviewed

research paper and thesis conducted in Thailand 4) SimaPro software Version 8.3 and Background processes were taken directly from Ecoinvent Version 3.0 production process database. IPCC 2013 GWP 100a V1.03 calculation method was selected to align with the national database. Emission factors used in this study are shown in Table 2 and Table 3.

Table 2 Secondary data on input emission factors for materials and energy

Item	EF Source
Material	
Raw tuna catching	Parker <i>et al.</i> (2015) [10]
Diesel oil (for sea transportation) ^(a)	Ecoinvent Version 3.0
Diesel oil (for land transportation) ^(b)	TGO, 2022
Mayonnaise (egg-based)	Saget <i>et al.</i> (2021) [13]
Water chestnut	Jirajitmeechai <i>et al.</i> (2025) [14]
Onion	TGO, 2022
Iron lid (tin free steel)	TGO, 2022
Aluminium can (aluminum plate with deep drawing, steel press) ^(c)	TGO, 2022 and Ecoinvent Version 3.0
Aluminum Sulphate (PAC)	TGO, 2022
Utility	
Electricity (Mixed grid)	TGO, 2022
Electricity (Solar power)	Khan <i>et al.</i> (2024) [15]
Tap water	TGO, 2022
Fuel oil	TGO, 2022
Heavy oil	TGO, 2022
Lignite coal	TGO, 2022
Sub-bituminous coal	TGO, 2022
Stationary Combustion	TGO, 2022
Waste management	
Municipal solid waste landfill (Compaction)	Liamsanguan <i>et al.</i> (2008) [16]
Open dumping	TGO, 2022

Note: EF = GHG Emission factor

(a) Diesel oil used in fishing vessels occurs outside Thailand.

(b) Diesel oil used in fishing vessels occurs within Thailand.

(c) EF of aluminum can is calculated from aluminum plate with EF from TGO (2022) and EF of can forming with deep drawing process from Ecoinvent Version 3.0.

Table 3 Secondary data on input emission factors for transport

Type of transport	Source	Item
transoceanic ship with reefer	Ecoinvent Version 3.0	Raw tuna
10-wheel truck	TGO, 2022	Raw tuna
4-wheel vehicle	TGO, 2022	Onion, water chestnut, waste
6-wheel vehicle	TGO, 2022	Can, mayonnaise, waste

Results and Discussion

The results of GHG emissions of the Classic Tuna Spread product are presented in Figure 2, grouped into 6 categories. The majority of GHG emissions come from non-tuna ingredients, 65.12%, followed by from processing, 16.60%, tuna meat, 9.02%, packaging, 7.00%, transportation, 1.99%, and waste disposal, 0.27%. GHGs from non-tuna ingredients were investigated further; it found that 39.55 grams of mayonnaise contribute highest GHG emissions, 167.22 gCO₂eq, since it is the main ingredient of tuna spread. Carbon footprint of Mayonnaise mainly comes from vegetable oil, in which reference study used sunflower oil [13]. Considering emission factors of different vegetable oil, changing of vegetable oil type may significantly affect the carbon footprint of Mayonnaise [9].

The second highest GHG emission is from 22.10 grams of water chestnuts, the second highest content of all ingredients, contribute 96.47 gCO₂eq. GHG emissions from production processes mainly come from hot water and steam utilization, 46.51 gCO₂eq. It should be noted that sub-bituminous coal is used as fuel for the boiler; CO₂ emission from fossil fuel combustion could not be avoided. Electricity used in the process comes from two sources, one is from the electricity grid of Provincial Electricity Authority (PEA), and another is from 301.72 kW roof-top solar panel accounting for 5.39% of total electricity power consumption. Land transportation of raw materials and sea transportation of tuna fish account for 1.99% of total GHG emissions. The diesel fuel consumption for fishing vessels was determined using the fuel intensity associated with tuna catching in the Atlantic, Pacific, and Indian Oceans [10], with SimaPro software Version 8.3 GHG emissions factor applied to diesel for imported tuna and TGO's GHG emission factor for domestic tuna fishing. Total GHG emission for tuna landing at ports in Thailand is

36.80 gCO₂eq. Another major GHG emission comes from primary packaging, 28.56 gCO₂eq. Emission factor of aluminum can produce in Thailand is not available, therefore emission factor of aluminum can was calculated from emission factor of aluminum sheet and single stroke deep drawing process from SimaPro software. The lid of the aluminum can is made of tin free steel; an emission factor from TGO is used. Secondary packaging of raw materials was either sent back to producers or to recyclers for reuse or recycle, hence it is not covered in this study. Waste from tuna cutting such as bones, guts and blood were sent to produce fish meal and pet food, however, fatty sludge from wastewater treatment system, bottom ash and fly ash from boiler were sent to landfill.

To compare CFP of this study with other studies, the GHG emission per FU from different studies as shown in Table 4 are converted to GHG emission per one kilogram of edible content in the products as shown in Figure 3. It is found that raw tuna products, pouched loin tuna and bagged frozen loin tuna, have lower GHG emissions than most of cooked tuna products. Among cooked tuna products, GHG emissions vary depending on type of liquid filled in the products and containers. The ready to eat product in this study, canned tuna spread even without considering post-consumer waste, has higher GHG per kilogram edible product than all canned tunas. This was caused by small portion of tuna meat, 20%, mixed with non-tuna ingredients, 80%, that have higher GHG emissions such as mayonnaise (47%), water chestnut (26%), and onion (7%). Among different landed fish, there are 0.36 kgCO₂eq per kg sardine landed [17] and 1.14 kgCO₂eq per kg tuna landed [10]. Although landed sardine has lower GHG emission than landed tuna, canned sardine with olive oil has highest GHG emissions per kg sardine meat, in which aluminium canned contributes highest to total GHG emissions of the product [18].

Potential for Reducing Greenhouse Gas Emissions of Classic Tuna Spread product

The potential for reducing greenhouse gas emissions of canned tuna products, as shown in Figure 4, is assessed based on research findings and company data.

(1) The study of Moultak *et al.* (2017) [20] shows that switching type of transportation to electric-powered ships and trucks can reduce greenhouse gas emissions by 40%. Additionally, utilizing electricity generated from clean energy

sources, such as solar power, can further reduce emissions by up to 89.80%. With this GHG reduction rate from utilizing electric-powered vessels in fishing activities, greenhouse gas emissions could be reduced up to 8.10% of total GHG emissions from canned tuna spread product. Transitioning all transportation to electric-powered vehicles that utilize renewable energy may result in an additional 1.78% of total GHG emissions reduction.

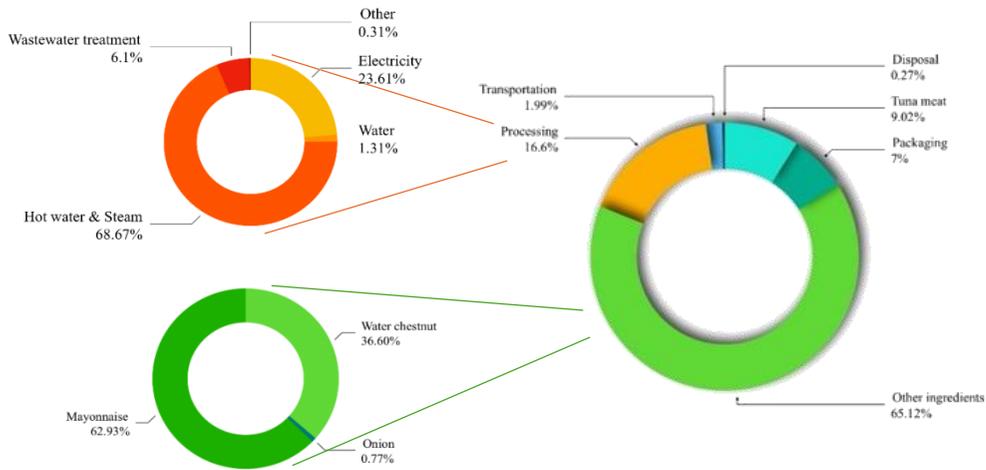


Figure 2 The proportion of greenhouse gas emissions of the Classic Tuna Spread product

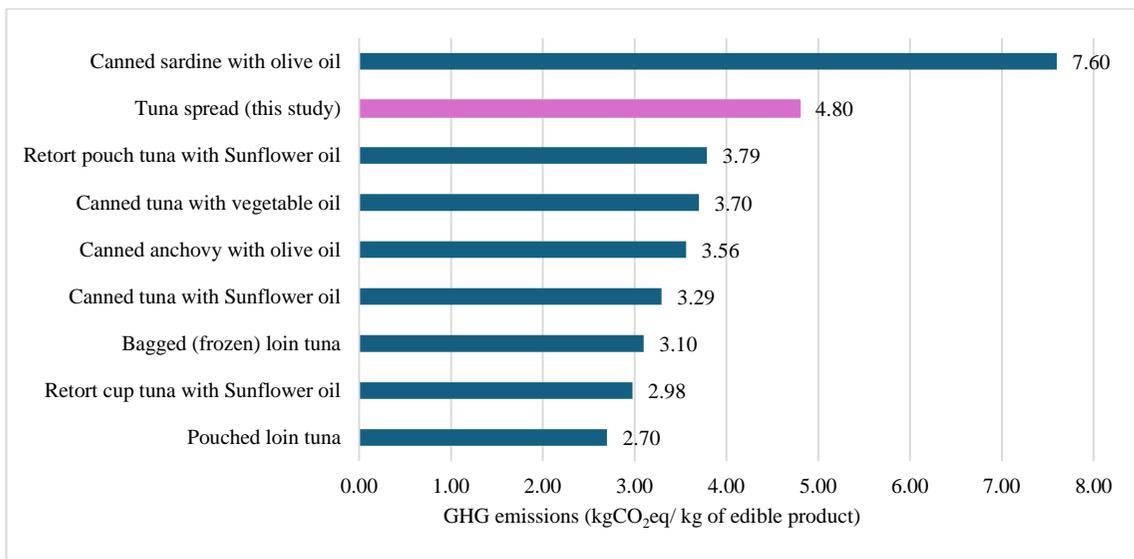


Figure 3 The greenhouse gas emissions of processed seafood products

Table 4 The greenhouse gas emissions of processed seafood products

Reference / Country	Targeted species	FU	System boundaries	GHG emissions (kgCO ₂ eq/FU)
This study / Thailand	tuna yellowfin (<i>Thunnus albacares</i>), skipjack (<i>Katsuwonus pelamis</i>) and albacore tuna (<i>Thunnus alalunga</i>)	1 can of product	Cradle to gate	0.408
Poovarodom <i>et al.</i> (2012) [3] / Thailand	tuna	Chrome-coated steel can, with an aluminum lid (net weight 85g)	Cradle to grave	0.280
		Retort pouch (net weight 85g)	Cradle to grave	0.322
		Retort cup (net weight 80g)	Cradle to grave	0.253
Almeida <i>et al.</i> (2015) [18] / Portugal	European pilchard (<i>Sardina pilchardus</i>)	1 kg of edible, canned sardine with olive oil	Cradle to gate	7.6
Avadi <i>et al.</i> , (2015) [4] / Ecuador	tuna yellowfin (<i>Thunnus albacares</i>), skipjack (<i>Katsuwonus pelamis</i>) and bigeye (<i>Thunnus obesus</i>)	1 kg of canned tuna in vegetable oil	Cradle to gate	3.7
		1 kg of pouched loins	Cradle to gate	2.7
		1 kg of bagged (frozen) loins	Cradle to gate	3.1
Laso <i>et al.</i> (2017) [19] / Spain	Anchovy (<i>Engraulis encrasicolus</i>)	1 can of fish in extra virgin olive oil (aluminum can, 30g of anchovy and 20 g of extra virgin olive oil (EVOO))	Cradle to gate	0.178

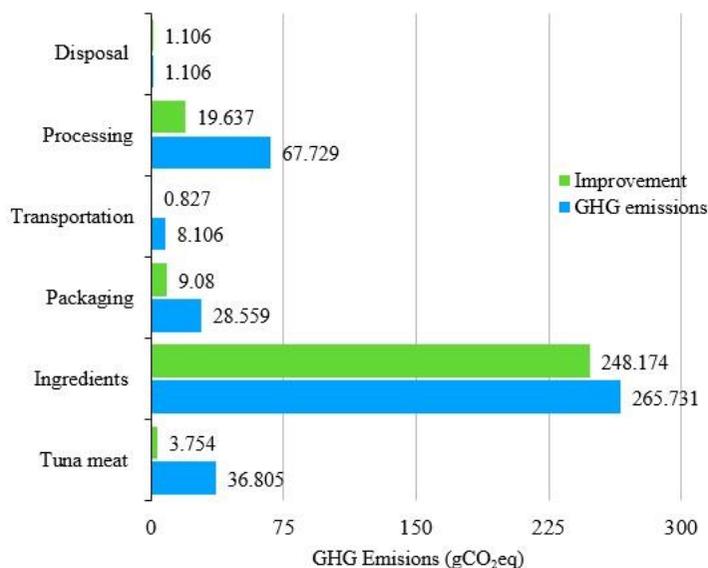


Figure 4 Potential for reducing greenhouse gas emissions of canned tuna spread products

(2) According to Thailand's PDP2018 Revision 1 plan, increasing the proportion of electricity generation from renewable energy sources will enable the use of electricity to reduce greenhouse gas emissions by 24.51% in B.E. 2580, in which can reduce GHG emissions from cold storage room by 0.205% of the total GHG emissions.

(3) The company decided to install rooftop solar panels in 2023 covering 33% of the total roof area, in which solar panels could produce electricity with a maximum power generation about 30% of total electricity consumption and be consumed by the plant during the daytime. In 2024, the company utilized electricity from photovoltaics about 8.64% of total electricity consumption of the whole year. If the company had decided to maximize rooftop solar panel installation equipped with energy storage sources, with additional consideration of the PDP2018 Revision 1 plan, the greenhouse gas emissions would be reduced by up to 61.92% in B.E. 2580, in which accounted for 1.91% of the total GHG emissions. The greenhouse gas emission coefficient from solar cells produced in China with a lifespan of 30 years and used in

tropical humid areas with a value of 33.9 gCO₂eq/kWh was selected [13].

(4) Poovarodom *et al.* (2012) [3] compared CFP of tuna with different packaging and found that by changing packaging from metal can to plastic pouch and retort cup can reduce carbon footprint by 58.6% and 68.2%, respectively. By switching from aluminum cans to retort cups, CFP would be decreased by up to 4.77% of the total GHG emissions.

(5) Switching fuel from sub-bituminous coal to parawood pallet biomass can reduce greenhouse gas emissions by up to 76.73%, which contributes to 8.75% of the total GHG emissions.

(6) Jirajitmeechai *et al.* (2015) [14] demonstrated that changing disposal method from landfilling to utilizing water chestnut peel for making soil conditioner can significantly reduce carbon dioxide emissions by 18.2%, in which accounted for 4.30% of the total GHG emissions.

(7) Utilizing waste (fat sludge) as energy, along with using the methane gas produced from wastewater treatment plant, can reduce greenhouse gas emissions by up to 100%.

Table 5 Potential for Reducing Greenhouse Gas Emissions of Classic Tuna Spread product

Mitigation and Reduction Measures	Potential GHG reduction (%)*	Reduction contribution to CFP (%)	Reference
Change to electric-powered ships and trucks	40% (electricity from normal grid mix) / 89.80% (electricity from renewable energy)	8.10% (electric-powered fishing ships) 1.78% (electric-powered ships and trucks for raw material transportation)	Moultak <i>et al.</i> (2017) [20]
Increase renewable energy in grid mix	24.51% (B.E. 2580) (cold storage room)	0.21%	Thailand's PDP2018 Revision 1 plan
Increase electricity from photovoltaics	61.92% (B.E. 2580, with power storage) (production)	1.91%	Khan <i>et al.</i> (2024) [15], and Thailand's PDP2018 Revision 1
Change packaging	58.6% (plastic pouch) / 68.2% (retort cup)	4.77% (retort cup)	Poovarodom <i>et al.</i> (2012) [3]
Replace with biomass fuel	76.73% (parawood sawdust)	8.75%	Jirajitmeechai J., (2025) in publishing process (thesis) [21]
Zero waste to landfill	18.2% (chestnut peel) 100% (fat sludge)	4.30% 0.27%	Jirajitmeechai <i>et al.</i> , (2025) [14]
All measures		30.09%	

Note: *compared with current practice, in 2023 (B.E. 2566)

Conclusions

The carbon footprint of the tuna spread product is 408.08 gCO₂eq per can with major contribution from ingredients and processing, respectively. With the current practice, all fish meat and bones have been utilized as products or raw materials for other industries. Additional greenhouse gas reduction measures that can be implemented immediately by manufacturers with small impact to customers are changing boiler fuel from coal to biomass, installing roof top solar panels, implementing better waste management, and maintaining zero waste to landfill policy. These immediate measures can reduce GHG by 15.23%. Further R&D is required before changing packaging from aluminum can to retort cup or plastic pouch, since this may require process adjustment as well as customer acceptance. As for changing internal combustion engine (ICE) vehicles to electric powered, the company may start to integrate electric powered vehicles into the fleet and request suppliers to take similar measures to reduce GHG emission. One significant GHG emissions is from power supply, it highly depends on national power development plan. If it can be expedited, further GHG reduction could be achieved. Implementing all measures together can reduce greenhouse gas emissions by up to 30.09 % of the total GHG emissions, resulting in a carbon footprint of 285.26 gCO₂eq per can.

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