CARBON FOOTPRINT ASSESSMENT OF INTERNAL TRANSPORTATION OF LEAD FACTORY AND GUIDELINE TO REDUCE CARBON FOOTPRINT

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Received: August 5, 2021; **Revised:** October 11, 2021; **Accepted:** October 29, 2021

Abstract

Greenhouse Gas emission is a cause of global warming problem. Carbon footprint from the manufacture of a product indicates the amount of greenhouse gas emitted from the manufacture of that product. This research work has two objectives, namely, 1) to assess the carbon footprint of internal transportation of lead factory, and 2) to find ways to reduce carbon footprint and greenhouse gas that is emitted from internal transportation of lead factory that recycles used batteries in order to get lead that is the raw material for the manufacture of lead ingot, the total weight of with is 1,000 kilograms.

The findings from the study show that the carbon footprint of the internal transportation of raw material in the preparation of the raw material is higher than the carbon footprint from other transportation process. It is found out that the carbon footprints are 143.23, 112.33, 78.46 kg CO_2e per product ton for 2018, 2019 and 2020, respectively. It is also found out that the carbon footprints of the internal transportation in the factory for the production of lead ingot are lowest, or 0.22, 0.97, 0.90 kg CO_2e per product ton in 2018, 2019 and 2020, respectively.

As for the transportation for the preparation of raw material for producing pure lead and supportive process, it is discovered that the carbon footprints from the production of rough lead are the highest ones in all the three years, followed by the carbon footprint from the preparation of raw material for lead with calcium.

Concerning the carbon footprints from the transportation of raw materials, sorted by products, it is found out that the carbon footprint from the transportation of raw material for the production of pure lead is the highest of all.

Keywords: Carbon Footprint; Life Cycle Assessment; Transportation

Introduction

The change of economic driving factor from agricultural sector to industrial sector has led to the great expansion of industry, which is beneficial to Thai economy. However, industrial expansion has been causing environmental problems at the same time. Without proper measures, environmental problems, such as climate change and global warming, tend to increase. The Intergovernmental Panel on Climate Change (IPCC) had estimated the emission of carbon dioxide in the future and discovered that the amount of carbon dioxide gas in the future will rank between 541 and 970 ppm around 2100 (IPCC, 2001).

Lead industry is an important basic industry because lead is used in a high amount, next to iron, copper, zinc and aluminum. Around 10 percent of lead is used for producing bullets, cable core cover, and lead for welding and molding. The other 90 percent is used as raw material for the production of batteries in car and motorcycle industries (Department of Primary Industries and Mines, 2013). Lead industry is a supply chain that is important to the growth of automotive industry which is a key industry that generates economic value to the country from employment, creates added value and plays essential roles in developing supportive industries and related businesses in the supply chain. Thailand is famous for automotive production. Thus, automotive industry has been continuous growing. However, automotive product is a factor that causes environmental problems concerning the use of natural resources, energy and pollution. Hence, automotive manufacturers want to develop clean vehicles that saves energy in order to decrease pollutions and resource consumption. Thailand Automotive Institute has set the strategy to enhance competitiveness of Thai automotive industry, which is to strengthen the entrepreneurs in the supply chain of Thai automotive industry to be strong manufacturers capable of and prompted for adapting to changes in the future, in terms of economy, social and environment, through the development of efficiency and productivity by developing clean vehicles that save energy and green manufacturing technology (Thailand Automotive Institute, 2012).

Therefore, it is necessary to conduct this research project on Carbon footprint assessment of internal transportation of lead factory and guideline to reduce carbon footprint.

Research Objectives

1. To assess the carbon footprint of internal transportation of lead factory.
2. To find ways to reduce carbon footprint and greenhouse gas that is emitted from internal transportation of lead factory.

Literature Review

Lead Industry

Lead industry or lead production industry is an important fundamental industry for the development of the country. Lead is one of the earliest metals known to mankind since ancient times. It is very important and useful to human beings. Lead is a heavy metal and is the most abundant substance in the world. It is a very heavy, gray, and hard liquid. Lead used in industry is divided into two types. The first type is Inorganic lead, such as lead oxide, which is greatly used for manufacturing battery and automotive coloring, and lead chromate, which is used for paint manufacturing paint. The second type is organic lead, including Tetra methyl lead and Tetraethyl lead, which are substances that make engines run smoothly (Antiknock compound). Of all nonferrous metals, lead is in the fifth rank of the most consumed metal, after iron, copper, zinc and aluminum. It is mainly used as raw material for the manufacture of batteries for the automobiles, communication device and electrical appliance industries, all of which are accounted for more than 90 percent of the total use of lead (Office of Primary Industries, 2013). The rest is the use for the production of rolled lead sheets or casted lead cover of the cable, ammunitions, lead alloys, ingredient in gasoline and color pigments. Since almost all the lead is used in the manufacture of automotive batteries, it can be said that the importance and the expansion of the lead industry is in the same direction as the expansion of the automotive industry. As for lead production in Thailand, two manufacturing technologies are applied. The first technology is the production of lead from ore (Primary Process) and lead production from battery plates (Secondary Process or Recycling). Pollutions caused by lead manufacturing process is air pollution from exhaust air or smoke, fuel exhaust and acid fume, lead dust, particles from the separation of plates, lead dust smelting, furnaces, cleaning pans, mixing pans and ingot castings.

Carbon Footprint (CF)

The International Organization for Standardization (ISO) defines the carbon footprint as the total amount of carbon dioxide and other greenhouse gases such as methane, and nitrous oxide, emitted from products or services. For Thailand, the representative agency is Thailand Greenhouse Gas Management Organization (Public Organization), which has defined the carbon footprint that as the amount of greenhouse gases emitted by each product throughout the product life cycle from the acquisition of raw materials, transportation, assembly of parts, use and post-production management. It is calculated in the form of carbon dioxide equivalents (Thailand Greenhouse Gas Management Organization Public Organization, 2007). The International Organization for Standardization (ISO) has developed a specific standard on Carbon Footprint (ISO 14067) by specifying principles, requirements and guidelines for the quantitative assessment and communication of greenhouse gas emission of a product (Carbon Footprint of Products, CFP), which consists of 2 parts, namely, Part 1: Carbon Footprint Analysis (Quantification), and Part 2: Communication, which refers to the communication of carbon foot data, printed with carbon label.

Concerning the types of Carbon Footprints, Thailand has set up carbon footprint to reduce greenhouse gas emissions in the forms of corporate carbon footprint and carbon footprint of the product. The Carbon Footprint for Organization (CFO or Corporate Carbon Footprint; CCF) is one way to visualize the amount of greenhouse gas emissions from an organization's operations, leading to the determination of management guidelines for reducing greenhouse gas emissions effectively, at the factory level, industrial level and national level (Thailand Greenhouse Gas Management Organization, Public Organization, 2007).

As for the level of product carbon footprint assessment, carbon footprint assessment is divided into 3 levels according to the assessment objectives. The first level is product level, which is the use of carbon footprint information communicated directly to consumers by showing on the product label. The second level is service level; for example, airlines declare their carbon footprint of services so that passengers can compare the impact of travel. The third level is the enterprise level. The carbon footprint is calculated and published in the annual report or corporate environmental report in order to build the image as an organization that helps reduce greenhouse gas emissions. Each type of carbon footprint has calculation method that is different from others.

As for transportation, the greenhouse gas emission is calculated with the amount of fuel used for transportation multiplied with the emission factor of the type of fuel used. In case where the amount of fuel is unknown, the carbon factor is calculated by multiplying the distance with the amount of the goods loaded on the vehicle, before multiplying the outcome with the emission factor for the type of vehicle used for the transportation.

Research Methodology

The research uses the framework of Life Cycle Assessment, in accordance with Standard of Environmental management, Life Cycle Assessment: Principles and Frameworks (ISO 14040: 2006) and Standard of Environmental Management, Life Cycle Assessment: Requirements and guidelines (ISO 14044: 2006) and calculates the carbon footprint of product in accordance with the direction for carbon footprint assessment of a product, 7th Edition (December, 2020), developed by the Board of Carbon Footprint Technique of Thailand, in the collaborative project by Thailand Greenhouse Gas Management Organization (Public Organization), as mentioned before in the reviewed theory. The research work consists the following steps: 1) Determination of Objectives and Product Selection; 2) Determination of Goals and Scope of Study; 3) Analysis for Making Environs List; 4) Environment Impact Assessment [(4.1) Carbon Footprint Calculation and (4.2) Carbon Footprint Report]; and 5) Data Analysis and Interpretation of Outputs from the Study.

The researcher, has set the functions in accordance with the objectives of the research and the use of products by the manufacturer and users. In addition, function units of lead ingots are set in accordance with characteristics of product and the objective for the use by the manufacturer and the users. In addition, there is the comparison of levels of greenhouse gases emission of several products as follows: 1) pure lead ingot, 2) lead alloy with calcium, 3) lead alloy with tin, 4) lead alloy with antimony and 5) function units of lead ingot with 12 cm width, 9 cm thickness and 61.5 cm length, weighing 50 kilograms, with the total container weight of 1,000 kilograms, with the function of material for the production of battery plates and lead for welding.

Data Collection and Analysis on Transportation Inside the Factory

Data concerning types and quantities of fuels are obtained from the collection of data concerning diesel fuel consumption in the factory to support the production process, by recording the data of diesel fuel sorted with vehicle types and the units that use the vehicles. In this study, greenhouse gas emissions from transportation are assessed by multiplying transport fuel data by the greenhouse gas emissions by the type of fuel used for internal transportation, transportation of slag, transport of products and production support activities.

As for the transportation of products to the customer's factory, in case of delivery by the company's vehicle, the calculation is based on the amount of fuel used for transportation, multiplied by the greenhouse gas emissions by the type of fuel used, which is diesel. In case where the transportation is hired, the average distance will be multiplied by the amount of cargo loaded. Afterward, the output is multiplied by the greenhouse gas emissions. Transportation will be calculated based on the distance of a round trip. The out-going trips is the delivery of all the target products and the in-coming trip has no product. Then, the output is multiplied by the greenhouse gas emissions by vehicle type. As this is cradle-to-gate evaluation, it is calculated until the point of exit from the factory.

Concerning the transportation of raw materials to the factory, the transportation will be calculated based on the distance of a round trip. The out-going trips is the delivery of all the target products and the in-coming trip has no product. Then, the output is multiplied by the greenhouse gas emissions by vehicle type. As this is cradle to grave evaluation, it is calculated until the point of exit from the deliverer’s factory or delivery point or warehouse, depending on the delivery requirement by each deliverer.

I, the researcher, have set the situation of the transportation to be the use of normal vehicle in round trip. The out-going trip is fully loaded (100% loaded), the in-coming trip has no load (or 0% loaded).

Concerning the transportation of plastic scraps from the production process, the company sells plastic scraps to customers by having customers come to buy at the factory and carrying out the transportation of plastic scraps by the customers’ cars. I, the researcher, will collect such data but will not use such data for calculating greenhouse gas emission in this study. The reference is the specification for automotive battery product group. Amended for the first time on September 30, 2016, Clause, the collection of data for each step through the product life cycle, production process, scope of data collection, management of waste from production processes, described that the methods of waste disposal, such as burying and burning, should be considered in accordance with the truth, and should include the transportation of waste to be disposed, by using the distance from the manufacturer to the destination where the waste is managed. If the waste is sold for use, it is assumed that there is no greenhouse gas emission from the waste management, i.e., the emission factor of the waste disposal is zero.

There are two methods to calculate the amount of the greenhouse gas from the transportation of raw materials, products and waste (kg CO_2e), as follows:

= Transportation Load (Unit) x Greenhouse Gas Emission Coefficient from Transportation Load; or

= Amount of Diesel Used in the Transportation (Unit) x Greenhouse Gas Emission Coefficient from Fuel Production and Fuel Combustion (kg CO_2e/ Unit).

Results

The assessment of carbon footprint from the transportation of raw materials, chemicals and other materials relating to and supporting the manufacture with greenhouse gas emission directly inside the factory is shown in Table 1.

Table 1: Carbon Footprint from Transportation of Raw Material

Process	Carbon Footprint (kg CO_2e) per Product Ton)		
	2018	2019	2020
Raw Material Preparation	143.23	112.33	78.46
Rough Lead Manufacture	10.20	25.06	25.35
Lead Alloy Manufacture	1.48	1.82	3.12
Pure Lead Manufacture	0.22	0.97	0.90
Manufacture Support Process	0.1886	0.2535	0.2243
Total	**155.32**	**140.44**	**108.06**

From the table, it is apparent that concerning the carbon footprint for the internal transportation of raw material, the carbon footprints of raw material preparation are greater than those of other processes, which are 143.23, 112.33, 78.46 kg CO_2e per product ton, in 2018, 2019 and 2020, respectively. It is also apparent that the carbon footprints of pure lead manufacture are the lowest of all, or 0.22, 0.97, 0.90 kg CO_2e per product to in 2018, 2019 and 2020, respectively.

The proportion of the transportation from raw material preparation, rough lead manufacture to supporting process, in order to attain carbon footprint from transportation, sorted by products, are shown in Table 2.

Table 2: Proportion of Transportation from Raw Material, Rough Lead Manufacture and Supportive Process

Product	2018		2019		2020	
	CF	%	CF	%	CF	%
Pure Lead	115.23	0.75	98.28	0.71	68.90	0.66
Lead with Tin	4.70	0.03	8.00	0.06	3.22	0.03
Lead with Antimony	6.74	0.04	3.35	0.02	0.99	0.01
Lead with Calcium	26.95	0.18	28.00	0.20	30.94	0.30
Total	**153.62**		**137.64**		**104.04**	

for the proportion of the transportation from the material preparation, the manufacture of rough lead and the supportive process, it is found out that the material preparation for pure lead product has the highest carbon footprint for all the three years, followed by the material preparation for lead with calcium Product.

The calculation of the proportion of carbon footprint from the transportation for the manufacture of mixed lead conducted in order to get carbon footprint from the transportation for each product is shown in Table 3.

Table 3: Proportion of Carbon Footprint from Transportation for Manufacture of Mixed Lead

Product	2018		2019		2020	
	CF	%F	CF	%F	CF	%F
Lead with Tin	0.18	0.12	0.37	0.20	0.29	0.09
Lead with Antimony	0.26	0.18	0.16	0.09	0.09	0.03
Lead with Calcium	1.04	0.70	1.30	0.71	2.75	0.88
Total	**1.48**		**1.82**		**3.12**	

Concerning carbon footprint from transportation for the manufacture of mixed lead, it is apparent that the carbon footprint from transportation for the manufacture of lead with calcium product is the highest.

The footprints from the transportation of raw material, sorted by products in Tables 1 – 3 are used for calculating the carbon footprint from the transportation of raw material, sorted by products, as shown in Table 4.39. It is shown that the carbon footprint from the transportation of raw material, sorted by products, of pure lead product is the highest of all.

Table 4: Carbon Footprint from Transportation of Raw Material, Sorted by Product

Product	Carbon Footprint (kg CO_2e per Product Ton)		
	2018	2019	2020
Pure Lead	115.45	99.26	69.80
Lead with Tin	4.88	8.37	3.50
Lead with Antimony	7.00	3.51	1.08
Lead with Calcium	27.99	29.30	33.69
Total	**155.32**	**140.44**	**108.06**

2.3 The Carbon footprints from internal transportation in the factory for the transportation of raw material, chemical and product are shown in tables 5 - 8, as follows.

Table 5: Carbon Footprint from Internal Transportation in the Company in 2018

Product	FU Liter/ Product Ton	Emission Factor kg CO_2e / Liter	CF kg CO_2e/ton
Pure Lead	5.1741	2.7080	14.01
Lead with Tin	5.0016	2.7080	13.54
Lead with Antimony	5.0016	2.7080	13.54
Lead with Calcium	5.0016	2.7080	13.54

Table 6: Carbon Footprint from Internal Transportation in the Company in 2019

Product	FU Liter/ Product Ton	Emission Factor kg CO_2e / Liter	CF kg CO_2e/ton
Pure Lead	5.7254	2.7080	15.50
Lead with Tin	5.1710	2.7080	14.00
Lead with Antimony	5.1710	2.7080	14.00
Lead with Calcium	5.1710	2.7080	14.00

Table 7: Carbon Footprint from Internal Transportation in the Company in 2020

Product	FU Liter/ Product Ton	Emission Factor kg CO_2e / Liter	CF kg CO_2e/ton
Pure Lead	5.3771	2.7080	14.56
Lead with Tin	5.2715	2.7080	14.28
Lead with Antimony	5.2715	2.7080	14.28
Lead with Calcium	5.2715	2.7080	14.28

Data in Table 7: Carbon Footprint from Internal Transportation in the Company in 2018, are combined with data in Table. Carbon Footprint from Internal Transportation in the Company in 2019, and Table 4.45: Carbon Footprint from Internal Transportation in the Company in 2020, and summarized as the carbon footprints from internal transportation of the Company, sorted by products each year.

Table 8: Carbon Footprints from Internal Transportation of the Company

Product	Carbon Footprint (kg CO_2e per Product Ton)		
	2018	2019	2020
Pure Lead	14.01	15.50	14.56
Lead with Tin	13.54	14.00	14.28
Lead with Antimony	13.54	14.00	14.28
Lead with Calcium	13.54	14.00	14.28
Total	54.64	57.51	57.39

Conclusion and Discussion

The assessment of carbon footprint of internal transportation in the factory of lead product is the consideration of the amount of greenhouse gas emitted throughout the life cycle of lead ingot product. The results from the assessment of carbon footprint of internal transportation in the factory of lead ingot product, sorted by product types, processes and life cycles are the following carbon footprints.

The findings from the research reveal that the most greenhouse gas is emitted from the production and transportation of raw material, chemical and product in the Company. The phase of raw material acquisition has greenhouse gas emitted from the transportation and carbon footprint that comes with the raw material.

Concerning the rate of greenhouse gas emission, it is apparent that in 2018, the phase of manufacture has greenhouse gas emission of 72.30% (792.99 kg CO_2e per product ton); and the phase of raw material acquisition has greenhouse gas emission of 27.70% (303.83 kg CO_2e per product ton).

Concerning the rate of greenhouse gas emission, it is apparent that in 2019, the phase of manufacture has greenhouse gas emission of 72.37% (698.15 kg CO_2e per product ton); and the phase of raw material acquisition has greenhouse gas emission of 27.63% (266.56 kg CO_2e per product ton).

Concerning the rate of greenhouse gas emission, it is apparent that in 2020, the phase of manufacture has greenhouse gas emission of 64.82% (661.21 kg CO_2e per product ton); and the phase of raw material acquisition has greenhouse gas emission of 35.18% (358.82 kg CO_2e per product ton).

Therefore, the decrease of carbon footprint should be done by considering decreasing the carbon footprint in the phase of manufacture first. Meanwhile, as the phase of raw material acquisition, the carbon footprint from the raw material transportation should be decreased.

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