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# Greenhouse Gas Emission in Jewelry Industry: A Case Study of Silver Flat Ring

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## Abstract

This paper describes an assessment of the carbon footprint (CF) of a silver ring, together with an attempt to measure material and energy consumption. The boundary of analyzing CF was defined as Business to Business (B2B). All primary data were obtained from a survey of the case study factory. Acquisition of raw material (silver) was the main GHG contribution to the overall CF and was thus considered as a CF hotspot. Acquisition accounted for 0.9740 kg $CO_2$e or 94.44% of total emissions, followed by production processes (0.0573 kg $CO_2$e) and transportation (0.002 kg $CO_2$e). The total CF amounted to 1.03 kg $CO_2$e per silver ring product. To reduce the CF, it is suggested that choosing low GHG production processes could result in significant reduction in total CF. In addition, the study proposes options for recycling waste and using high performance electronic equipment.

**Keywords:** Carbon footprint product; Silver flat ring; Jewelry industry

## Introduction

Thailand's gem and jewelry industry is widely considered one of the greatest potential markets in the world, highly regarded both as a source of a wide variety of gemstones, and for its highly skilled artisans [1]. The gem and jewelry industry is important to the country's economic development; trade in gems and jewelry products was ranked fourth among Thailand's exports in 2011, valued at US$ 32.95 billion, with more than 1.3 million employed in the industry, representing 3.31 percent of the country's total workforce [2]. However, the slowdown in the economies of key trading partners, together with volatility of major currencies have led to adverse impacts on the competitiveness of the sector. In a highly competitive sector, environmental issues have emerged as factors for selecting products, especially the impact of jewelry products on climate change.

Over the past century, the planet's average temperature has risen by 0.6 ºC and is forecast to rise by 1.1 to 6.4 ºC over the next hundred years [3]. Many countries have already felt the impacts; from heat waves and droughts, floods, extreme weather events, melting glaciers and rising sea levels. Anthropogenic causes are recognized as one of the major contributions to climate change [4].

As a result of multilateral agreements such as the Kyoto Protocol and the Copenhagen Protocol, most UN Member States, including Thailand, have agreed to force their industries to take actions to mitigate greenhouse gas (GHG) emissions [5]. Therefore, Thailand's Ministry of Industry has promoted its eco-industry policy to support sustainable economic growth in parallel with environmental conservation [6]. In regard to trade, some additional requirements have been specified to facilitate exports to developed countries, including product carbon footprints, ISO 14000, carbon credits, life cycle assessment, or green label.

Mining for diamonds, gold, silver, and other precious metals can result in water pollution, soil erosion, and greenhouse gas emissions [7]. Glaister and Mudd (2010) reported that the critical sustainability issue concerning raw materials for the jewelry industry (e.g. platinum) was not the size of the resource, but was related to environmental costs including greenhouse gas emissions. In future, environmental footprint and social concerns will carry an increasingly important influence on both demand and the ability of mines to increase their capacity. Consumers can raise awareness of such issues by supporting eco-friendly jewelers, and by selecting only products carrying 'green certification' [8].

The term 'Carbon Footprint Product' (CFP) refers to the mass of $CO_2$ equivalent emitted throughout the life-cycle of a product [9, 10]. It has emerged as a useful indicator for consumers, policy makers, governments and especially investors because CFP can serve as a proxy for investment risk [10]. In addition, the goal of reducing CFP can stimulate innovation and drive progress towards a low carbon society [11]. In the jewelry industry, CPF is used not only as an indicator to determine the amount of GHG emissions throughout the product life cycle, but also as a benchmark for improving production processes. Although there are many studies of carbon footprint of diverse products such as grapes [12], plastic products [13] and beef products [14], there have been few studies to quantify CFPs in the gem and jewelry industry.

To fill this gap in the data, the sliver ring was selected for study. The study objectives were to (1) create an inventory of GHG emissions for the process of producing a sliver ring; (2) estimate GHG emissions from silver ring production; and (3) propose options for reducing GHG emissions from silver ring production.

## Methodology

### 1) Site study and data collection

The survey was conducted in 2015. The silver ring production process, packaging process, and waste treatment facilities at the plant were surveyed. The data obtained included the amount of raw material, energy consumption, and quantity of waste; the data were collated in a spreadsheet.

### 2) Goal and scope

The objective of this study was to calculate the carbon dioxide emission throughout the life cycle of silver ring production, from raw material acquisition, production processes, transportation, and waste treatment.

2.1) Functional unit

The definition of the functional unit for estimating CFP was based on 1 silver band. The data on energy consumption, chemical reagents, pollutant emissions and materials are based on this functional unit.

2.2) System boundary

In this study, the boundary for analyzing the carbon footprint of the product was defined as B2B, as shown in Figure 1. The B2B life cycle considers greenhouse gas emission from raw material extraction throughout the production process until the point where the product was delivered to a third party. It excludes final product distribution, consumer use, and disposal [15].

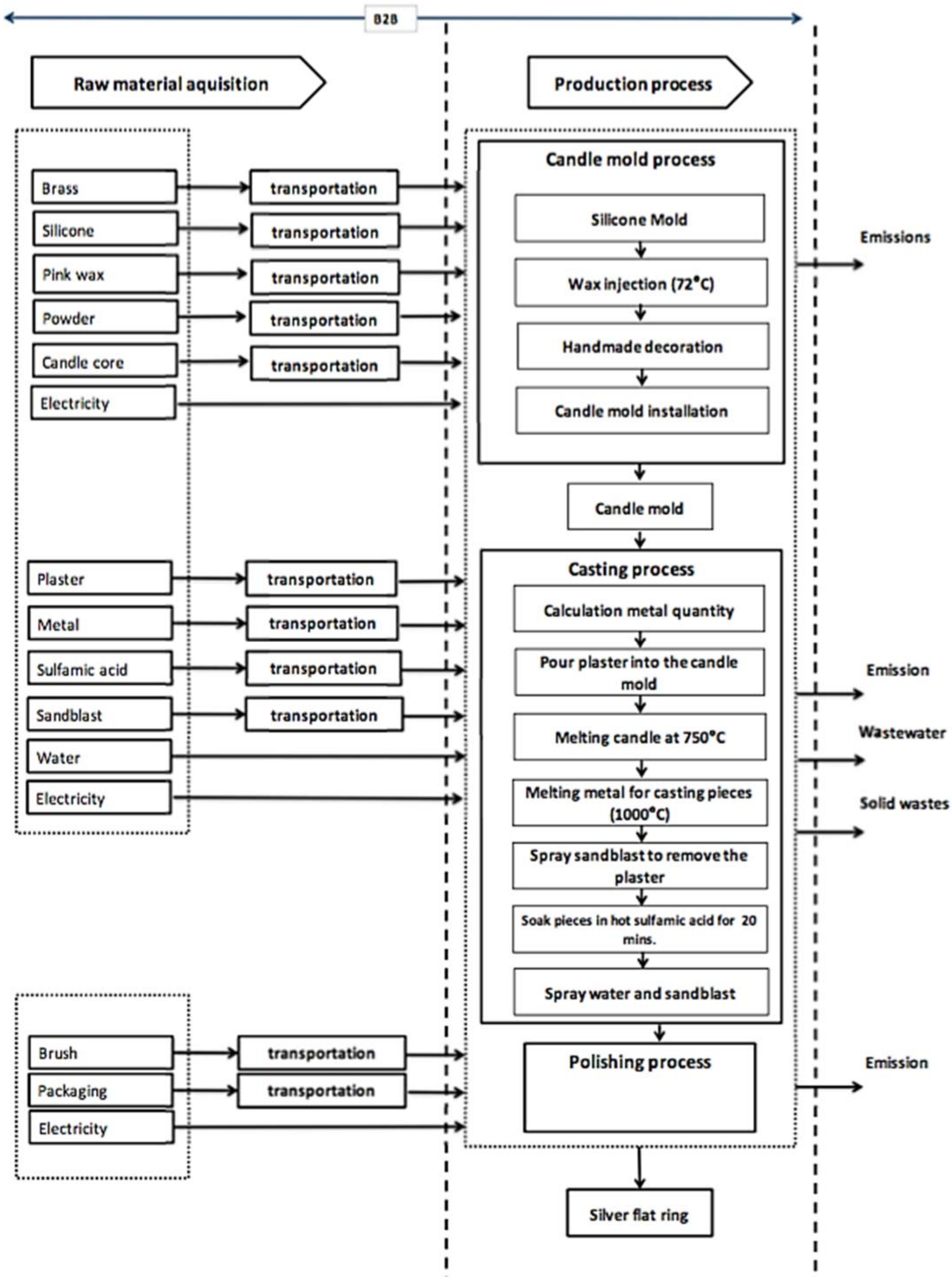


**Figure 1** Boundary system for estimating GHG emissions in this study

**3) GHG Life cycle inventory analysis**

All raw material used in the production process was collected at the factory. Data from the Thai database e.g. TGO guidelines and Thai National LCI database were used as first priority when available. In case data were not available in the Thai database, Ecoinvent v2.0 was used instead [16]. Inventory data for estimating greenhouse gas emission of a single silver band are shown in Table 1.

**Table 1** Inventory data for producing 1 silver band

| Process | Quantity | Unit |
|---|---|---|
| **Candle mold** | | |
| Material/Energy consumption | | |
| Silicone | 3.75E-05 | kg |
| Electricity | 1.25E-04 | kWh |
| Brass | 9.00E-03 | kg |
| Pink wax | 3.93E-07 | kg |
| Candle core | 3.67E-04 | kg |
| Electricity | 3.94E-02 | kWh |
| **Casting process** | | |
| Material/Energy consumption | | |
| Plaster | 3.33E-02 | kg |
| Silver | 9.34E-03 | kg |
| Alloy | 4.92E-04 | kg |
| Additional | 9.40E-04 | kg |
| Stopper | 1.18E-05 | kg |
| Seal | 1.25E-03 | kg |
| Sulfamic acid | 8.33E-04 | kg |
| Electricity | 3.50E-02 | kWh |
| Sandblast | 6.88E-05 | kg |
| **Polishing process** | | |
| Material/Energy consumption | | |
| Brush | 1.04E-05 | kg |
| Packaging | 1.82E-02 | kg |
| Electricity | 1.47E-03 | kWh |

**4) Calculation of GHG emissions for silver ring**

GHG emissions will be expressed in terms of the mass of carbon dioxide equivalent ($CO_2e$). The Global Warming Potential (GWP 100) for six greenhouse gases (i.e., $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, and $SF_6$) are in accordance with the latest document available from the Intergovernmental Panel on Climate Change or the IPCC [17].

The methodology of estimating GHG emissions through the product's life cycle is based on Equation (1).

$$\text{Total GHG emissions} = GHG_{\text{Raw material extraction}} + GHG_{\text{Transportation}} + GHG_{\text{Production}} \quad \text{........(1)}$$

$GHG_{\text{Raw material extraction}}$ refers to GHG emissions from raw material extraction, normally calculated by multiplying the amount of raw material (kg) by the emission factor (kg$CO_2$/kg raw material)

$GHG_{\text{Transportation}}$ refers to GHG emissions generated during transportation of raw materials from site to factory. In this study, however, these data could not be collected. Therefore, the default values were used instead in accordance with the suggestion from [18].

$GHG_{\text{Production}}$ refers to GHG emissions generated from the production process; mainly from combustion processes or chemical reactions. In addition, it includes energy usage during the process, e.g., electricity and steam.

**5) Interpretation**

The result of calculating GHG emission entire life cycle product was evaluated and analyzed. The hotspot of GHG emissions was identified during this step, and options proposed for reducing GHG emissions.

**Result and discussion**

**1) GHG emissions of 1 silver band**

The result of calculating the carbon footprint of production of a silver band can be divided into 3 parts: raw material acquisition; transportation; and production process, as shown in Table 2.
The CF calculation shows that the raw mate- rial acquisition stage makes the highest GHG contribution (0.9740 kg $CO_2e$ or 94.44%) followed by production (0.0573 kg $CO_2e$) and transporttation (0.002 kg $CO_2e$). In conclusion, the total CD of silver rind product is 1.03 kg $CO_2e$ per silver band.

The hotspot of CF in this study was identified as shown in Figure 2. It can be identified that the process of silver production was the hotspot of GHG emissions for producing a silver ring .GHG emissions from this phase was 0.93 kg $CO_2$e per silver band, or 90.19 % of the total CF. Electricity in process production makes the second highest contribution, with 0.0565 kg $CO_2$e per silver band, or 5.45% of the total CF.

**2) Proposed options for reducing CFP**

**2.1) Selecting low GHG emission of silver**

The results indicate that raw material extraction (silver) makes the most important contribution to the CF of production of a silver ring. Therefore, alternative low-emission sources of raw materials should be sought. Silver is normally produced as a by-product of the smelting of other metals such as gold, lead and Copper. Emissions vary for each process, as shown in Table 3.

Choosing low GHG emission sources of silver can reduce the total CF for production of a silver ring. This will raise awareness of climate change issues among both silver producers and ring manufacturers. Manufacturers of silver rings may face pressure from consumers who need low carbon products; manufacturers can respond by using low-emission processes as suggested herein.

**Table 2** CF calculation of silver ring product

| Life cycle phase | GHG emission of raw material acquisition from raw maerial and energy (kg $CO_2$ eq) | GHG emission of transportation (Includes raw material and energy; kg $CO_2$ eq) | Total (kg $CO_2$ eq) | Percentage |
|---|---|---|---|---|
| Raw material acquisition | 0.9740 | 0.0023 | 0.9763 | 94.44 |
| Production process | 0.0573 | 0.0001 | 0.0574 | 5.56 |
| **Total** | **1.03** | **0.002** | **1.03** | **100** |

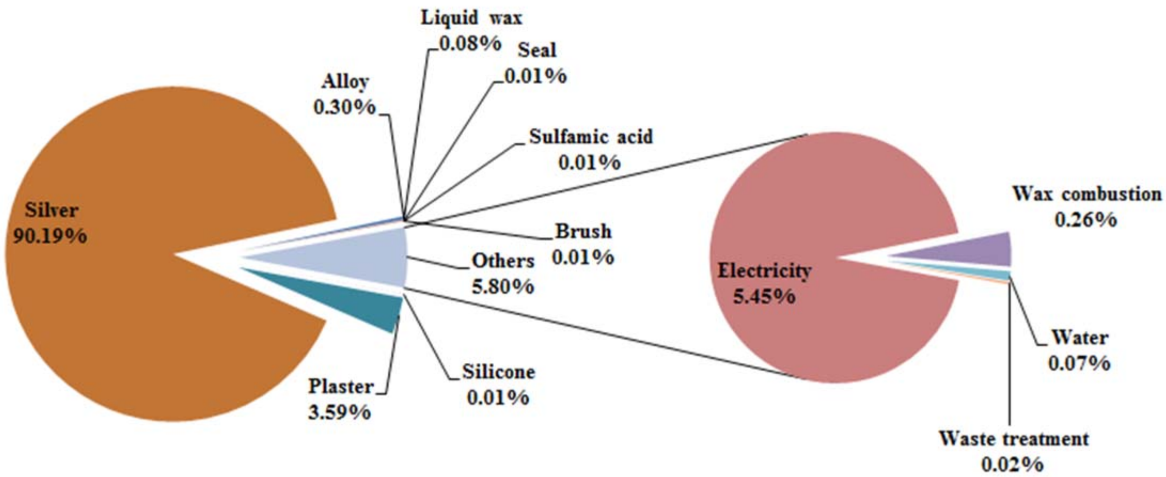


**Figure 2** Contribution to GHG emissions from production of one silver band

**Table 3** GHG emissions for extraction of silver via different processes

| Process | GHG emission factor (kg $CO_2$/kg) |
|---|---|
| Silver, from combined gold-silver production, at refinery/PE S | 110.57 |
| Silver, from combined metal production, at beneficiation/SE S | 61.74 |
| Silver, from copper production, at refinery/GLO S | 20.06 |
| Silver, from lead production, at refinery/GLO S | 55.19 |
| Silver, secondary, at precious metal refinery/SE S | 14.50 |

Source: [19]

**2.2) Recycling process materials (plaster and candle molds)**

Recycling of material using in the production process is another important option for reducing GHG emission. This approach will reduce emissions and also reduce production costs. Used plaster from the casting process can be reused; however, only about 20% can be reused due to damage and deterioration of the material's properties.

Candle molds can be melted and reused to produce new molds. However, only about 40% of candle molds can be recycled due to damage.

**2.3) Using high performance energy-saving electrical equipment**

Electricity consumption is the second most important contributor to the total CF of silver ring production. The survey found that the factory still uses low-efficiency magnetic ballasts for lighting, rather than modern electronic ballasts .Electronic ballasts can reduce energy loss by approximately 10-12 watts per bulb compared to magnetic ballasts [20]. This option can reduce both GHG emissions and reduce production costs for the factory.

**Conclusions**

This study the carbon footprint of silver flat ring was evaluated. Based on the study's defined system boundaries, GHG emission generated from raw material acquisition, production process, transportation, and waste treatment were calculated successively. One silver band was used as the functional unit (FU). The results indicate that the raw material acquisition can be regarded as a hotspot of GHG emissions over the production life cycle. Total emissions from this stage are estimated at 0.9763 kg$CO_2$e, representing 94.44% of total CFP. The emissions generated from the production process itself amounted to only 0.0573 kg$CO_2$e, representing just 5.56% of total CFP.

The study's results indicate that selection of silver produced from low-emission sources should be prioritized. This can considerably reduce the total CFP because of its high share of total emissions over the life cycle. Other options for reducing waste and energy consumption should also be explored, including: (1) recycling plaster and candle molds as raw materials for the productoin process; and (2) using high performance, energy-efficient electrical equipment. These options can reduce emissions and generate significant cost reductions for the jewelry industry.

Although the majority of data used in this study were gathered from on-site factory, some were also gathered from secondary data from previous studies, and using standard assumptions for parameters such as distance of transportation between producers and customers. These assumptions can affect the accuracy of the CFP assessment. Future investigation should investigate and corroborate such assumptions using empirical data. Nevertheless, the results presented in the current study can serve as a guideline for scientists, consultants and engineering managers to understand the concept of assessing CFP for the jewelry industry. Finally, some data presented here could help policy makers develop strategies for reducing GHG emissions from the jewelry industry an emerging issue in Thailand.

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