

Product carbon footprint assessment supporting the green supply chain construction in household appliance manufacturers

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Abstract. Supply chain carbon emission is one of the factors considered in the green supply chain management. A method was designed to support the green supply chain measures based on the carbon footprint assessment for products. A research for 3 typical household appliances carbon footprint assessment was conducted to explore using product carbon footprint assessment method to guide the green supply chain management of the manufacturers. The result could reflect the differences directions on green supply chain management of manufacturers of washing machine, air conditioner and microwave, respectively. That is, the washing machine manufacturer should pay attention to the low carbon activities in upstream suppliers in highest priority, and also the promotion of product energy efficiency. The air conditioner manufacturer should pay attention to the product energy efficiency increasing in highest priority, and the improvement of refrigerant to decrease its GWP. And the microwave manufacture could only focus on the energy efficiency increasing because it contributes most of the carbon emission to its carbon footprint. Besides, the representativeness of product and the applicability of the method were also discussed. As the manufacturer could master the technical information on raw material and components of its products to conduct the product carbon footprint assessment, this method could help the manufacturer to identify the effective green supply chain measures in the preliminary stage.

1. Introduction

The international standard on addressing climate change focus on not only the carbon emission from the GHG sources in the organizational boundary, but also the emission related to supply chain [1]. As the international standard generally reflect the global market demands, we could find that the carbon emission related to the enterprise's supply chain are paid more and more attentions [2 - 4]. This trend might influence the supply chain management of an enterprise, although the application of green supply chain management on to the enterprise is not a new issue, which has been discussed and researched for several decades [5 - 7]. There is another kind of international standard in addressing climate change, that is the standards for carbon footprint assessment for products [8]. The carbon footprint assessment is based on the life cycle assessment method, which has relationship with the method of supply chain carbon emission quantification for enterprises [9]. For some manufacturer having long value chain, the product carbon footprint might be a good tool to reflect the carbon emission hot points in the supply chain, with the advantages of result available, easier control and lower cost [10].

A research was conducted to establish a method of guide green supply chain management for enterprises through the carbon footprint assessment for products. Typical household appliances were



selected since they have characteristics of complicated product structure, long supply chain and a number of medium and small suppliers. Through building the model the products' components and material structures, a carbon footprint for representative washing machine, air conditioner and microwave were implemented. Based on these work, the method was designed and the applicability of this method was also discussed.

2. Carbon footprint assessment method for household appliances

According to the purpose of supply chain management, a partial life cycle carbon footprint assessment was conducted, which only including three relevant phases of material phase, manufacturing phase and usage phase in the product's life cycle. The material phase is related to the upstream supply chain. The manufacturing phase is related to the GHG sources contributing to the direct emission and energy indirect emission of the manufacturer. And the usage phase could also influence the upstream supply chain through its impact on product design, because there is a Chinese government's mechanism to encourage the purchase of higher energy efficiency household appliances. The methods for these phases are shown below separately. The carbon footprint of the household appliance is the sum of the carbon emission from three phases.

The data to assess the emission from the material phase was mainly from the product's Bill of Material (BOM), which also help to establish the product structure models. The emission from the manufacturing phase was mainly identified as the electricity consumption, calculated with the data of electricity consumption and emission factor for electricity consumption in China. The calculation of the emission from the usage phase was same with that of the manufacturing phase, but the electricity consumption data is from the using process.

3. Results

3.1. Product carbon footprint

The result of carbon footprint assessment for the representative household appliances were shown in Table 1. For washing machine, the contributions of carbon emission in the material phase, the manufacturing phase and the usage phase were 55.0%, 2.1% and 42.9%, respectively, to the total emission. Based on this result, the washing machine manufacturer should pay more attention to the material phase and usage phase to consider the measures to achieve the low carbon supply chain. The measures could include low carbon-impact materials selection and energy efficiency enhancement. For air conditioner, the contributions of carbon emission in the material phase, the manufacturing phase and the usage phase were 33.0%, 0.1% and 66.9%, respectively, to the total emission. So the air conditioner manufacturer should focus on increasing product energy efficiency with the highest priority. Besides, low carbon-impact material selection could also be the possible way to construct green supply chain. For microwave, the contributions of carbon emission in the material phase, the manufacturing phase and the usage phase were 1.0%, 0.2% and 98.8%, respectively, to the total emission. Thus, the measure relating to increasing product energy efficiency would be the main pathway considered. Some of these measures could be about green supply chain management, for example, the energy efficiency control to the supplier of the compressor.

Table 1. Carbon footprint assessment result for washing machine, air conditioner and microwave

Life cycle phase	Carbon emission contribution (%)		
	Washing machine	Air conditioner	Microwave
Material phase	55.0	33.0	1.0
Manufacturing phase	2.1	0.1	0.2
Usage phase	42.9	66.9	98.8

3.2. Further analysis for carbon emission contributions relating to supply chain

The carbon footprint results showed that it is necessary to further analyze the contributions of components of washing machine and air conditioner to identify the relationship between the upstream supply chain management measure and the product carbon footprint.

In order to further analyze the carbon emission contributions relating to supply chain, fifteen components contributing higher than 1% of the total carbon footprint were identified from the 101 components of washing machine, Figure 1. The supply chain of these components would be paid attention to by the manufacturer to apply the green supply chain measures. If the selection criteria was set as higher than 5% of the total carbon footprint, only 6 components were identified, which could facilitate the manufacturer to consider green supply chain measures and identify relevant suppliers more effectively.

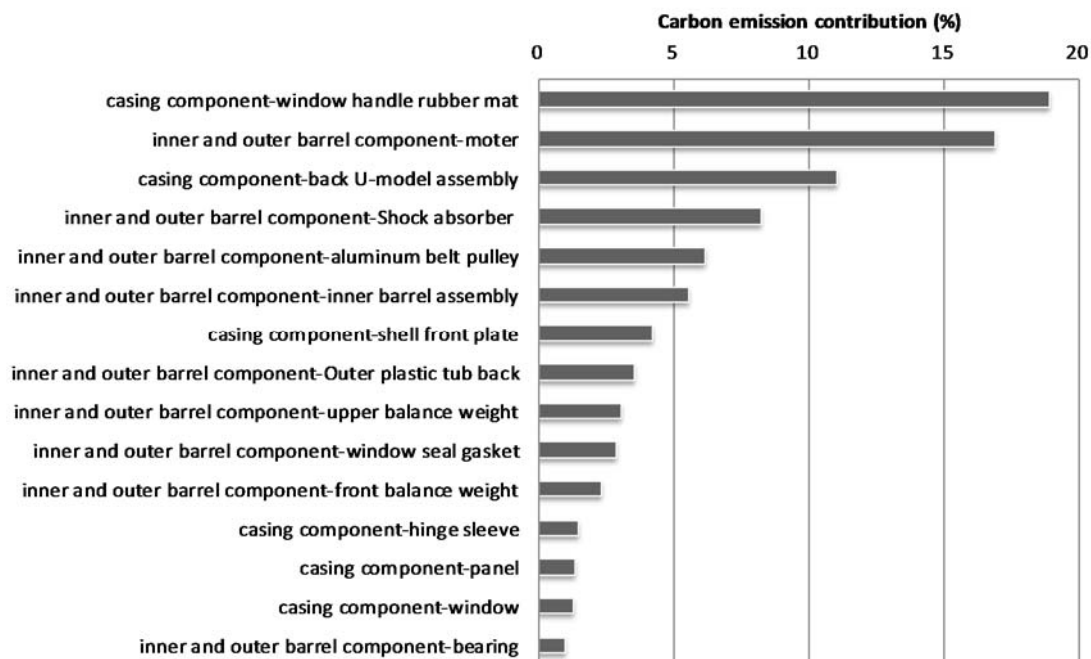


Figure 1. Carbon emission contributions of main components in washing machine

For air conditioner, the refrigerant contributed much more carbon emission among the components. The refrigerant of the representative air conditioner was R410a¹, which carbon emission was 30.9% to the whole product carbon footprint. Thus, the improvement and the replacement of refrigerant should be as the green supply chain measures with the highest priority. Besides, the leakage of the refrigerant contributed 18.5% of the total product carbon footprint, under the assumption of 10% leakage each year in the life of 6 years. In this case, improving the anti-leakage technique by the compressor manufacturer could be another effective green supply chain management measure.

Furthermore, as refrigerants without greenhouse effect have been developed, it is necessary to consider the measures related with not only the refrigerant but also the components. Twelve components contributing higher than 1% of the total carbon footprint were identified from the 85 components of air conditioner, Figure 2. The supply chain of these components would also be paid attention to by the manufacturer to apply the green supply chain measures. If higher than 5% of the total carbon footprint, only 6 components were identified, which could facilitate the manufacturer to consider green supply chain measures and identify relevant suppliers more effectively.

¹ R410a is combined of 50% R32 (difluoromethane) and 50% R125 (pentafluoroethane). The GWP of R32 is 675 [11], and the GWP of R125 is 3500 [11]

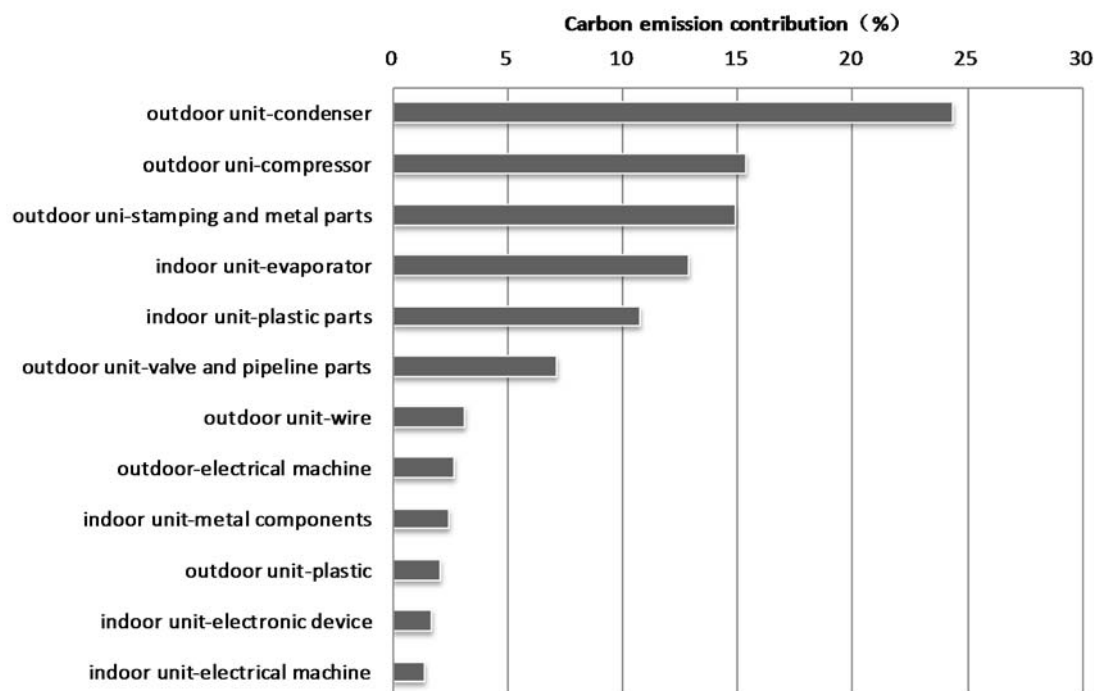


Figure 2. Carbon emission contributions of main components in air conditioner

4. Discussion

4.1. The applicability of the method

The relationship between product carbon footprint assessment and enterprise supply chain carbon emission assessment is shown in Figure 3. To household appliance manufacturer, the supply chain carbon emissions are mainly from the upstream suppliers for raw material acquisition and components production, which are in the category of scope 3 emission of GHG Protocol standard [9] or the category of other indirect emissions in international standard of ISO 14064-1 (2006 version) [12]. To household appliance, the product carbon footprint involves the carbon emission relating to raw material and component. It could be found that these two kind of quantification methods both involve the upstream supply chain in, but in different perspectives. The information on carbon emission of upstream suppliers is often out of manufacturer's control, so there would be quit big difficulties for the manufacturer to implement the carbon emission accounting related to its suppliers. Meanwhile, the manufacturer could master the technical information on raw material and components of its products, which could be used in the product carbon footprint assessment, supported by some LCA database. The results could supply the information about the carbon emission from the upstream suppliers of raw material and components in some extent.

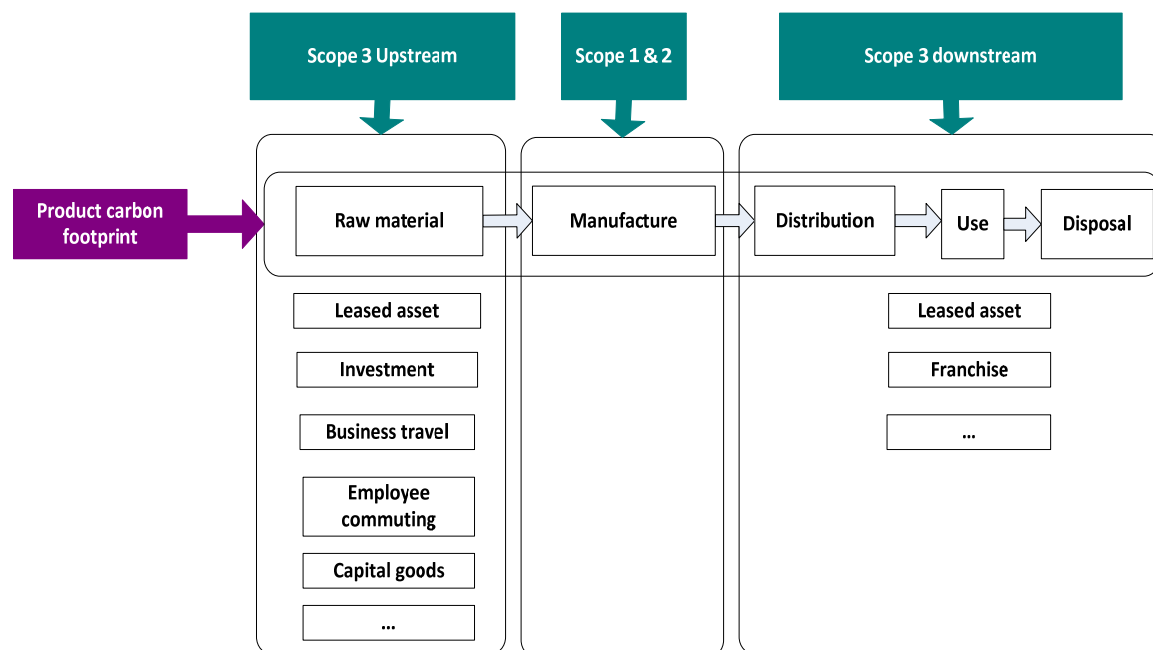


Figure 3. The relationship between product carbon footprint assessment and enterprise supply chain carbon emission assessment

In this case, the representativeness of product should be considered to evaluate the relevance between the product and the enterprise.

In this work, because the product carbon footprint is based on the life cycle assessment methodology, the product structure would be the foundation to build the calculating model. A previous work was conducted, that is, the top 10 sold products from the pilot enterprises were identified and compared their energy efficiency grades, rated powers and component structure. It was found that they have similar energy efficiency grades and rated powers, and the similarity of on product component structures was 65%. This result supported the similar models for carbon footprint assessment of product, and the representative product's carbon footprint could possibly be expanded as the result of the whole enterprise. Furthermore, as there was relationship between the components with the suppliers, the association between the product and the supply chain could be reflected by the model. Thus, the result of household appliances carbon footprint could be used to identify the hot spot of green supply chain management, and evaluate the performance of green supply chain initiatives.

4.2. Recommendations on the green supply chain measures for household appliance manufacturers

Recommendations on the green supply chain measures for the pilot household appliance manufacturers was shown as following:

(1) To decrease the carbon emission, the manufacturer of washing machine should focus on the upstream suppliers related with 6 components with high priority, including motor, back U-model assembly, shock absorber, aluminum belt pulley, and inner barrel assembly, to consider the green supply chain measures. Increasing the energy efficiency should also be considered.

(2) To decrease the carbon emission, the manufacturer of air conditioner should pay attention to increasing the energy efficiency of product first. For the upstream suppliers, considerable measures could be especially decreasing the GWP of refrigerant, and avoiding the leakage of refrigerant in the using process. The suppliers for condenser, compressor, stamping and metal parts, evaporator, plastic parts, and valve and pipeline parts should also be considered.

(3) To decrease the carbon emission, the manufacturer of microwave could simply focus on increasing the energy efficiency of product.

5. Conclusion

For different kinds of household appliances, there were different priorities of green supply chain management measures. The manufacturer of washing machine should focus on the upstream suppliers with high priority, and increasing the energy efficiency should also be considered. The manufacturer of air conditioner should pay attention to increasing the energy efficiency of product first. Besides of that, decreasing the GWP of refrigerant and the anti-leakage technique for refrigerant in the using process could also be considerable measures. The manufacturer of microwave could simply focus on increasing the energy efficiency of product.

The method of carbon footprint assessment for products could help to identify the green supply chain management measures for the household appliance manufacturer. The manufacturer could master the technical information on raw material and components of its products, which could be used in the product carbon footprint assessment, supported by some LCA database. Thus, the results could supply the information about the carbon emission from the upstream suppliers of raw material and components in some extent. Meanwhile, this method has limitation. As the product structure would be the foundation to build the calculating model, this method is not applicable to the enterprise with a diverse product categories.

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