LIFE CYCLE INVENTORY FOR PET PACKAGES IN THE INTERGRATION WITH IO TABLE OF VIET NAM

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ABSTRACT

Waste recycle have been strongly focusing in Vietnam. However secondary environmental effects of the recycling activities have been debatable. This study produces a life cycle inventory (LCI) data set of polyethylene terephthalate (PET) packages in the country with further analysis for biggest PET users such as electronic sectors and/or food processing sectors. Loop recycling allocations are approached to calculate GHGs emission and solid waste in the life cycle of 1 ton of PET packages. Input-output (IO) tables are integrated into the study in order to identify indirect environmental burdens from the plastics sector contributed to other sectors in the Vietnamese economy. Based on the 2016 updated IO table, the PET packages occupied 37.43% of GDP of the plastics sector. In term of PET packages demanding, two biggest groups were food processing sectors and electronic sectors, accounted for 5.87% and 10.75% of total PET packages used in 2016, respectively. In term of indirect environmental burdens, these two groups were also the biggest GHGs and waste generators. Among three materials options, GHGs emission from option 1 (100% PET) was biggest and waste from option 3 (100% PETr) was biggest. Beside the LCI results, this study aims to contribute to the existing literature on GHGs as well as PET waste balances by considering the remaining effects in PET production, distribution and recycling in Vietnam.

Keywords: LCI, IO table, solid waste, GHG emission, PET.

1. INTRODUCTION

Input-output (IO) table is a mathematical economic model that reflects cross-sectoral relationships in the production and use of products of the economy. A number of researchers has used IO models to analyze the relationships between energy–environment and economic activities [1, 2, 8].

In Vietnam, products of plastics industry include four main areas: packaging plastic, technology plastic, construction plastic and civil engineering plastic, of which packaging plastic occupied 37.43% in terms of GDP in 2016 [9]. The plastics demand has been increasing rapidly, from 33 kg plastics used per capita in 2010 to 41 kg plastics used per capita in 2015 [9]. The country needs importing raw materials for domestic plastic production and China is one of the
major virgin PET (PET_v) suppliers. Recycled PET (PET_r) from craft villages also can supply about 20-30% of materials demand [9].

In this study, solid waste generation and GHG emission in the life cycle of PET packages production is investigated. Three material supplying options are considered including: 1) 100% PET_v; 2) 80% PET_v and 20% PET_r; 3) 100% PET_r. In order to analyze indirect environmental burdens from using plastic products, the 2016 updated IO table is integrated in the study. As shown in all IO tables, the plastics sector has been contributing to most other sectors.

2. MATERIALS AND RESEARCH METHODS

The research method is shown in Figure 1. The life cycle inventory (LCI) frame is used to determine GHGs emission (through CO_2 equivalent) and solid waste in a life cycle of one ton of PET packages. The IO frame is used to determine plastic demand and PET demand for 164 product and service sectors of the Vietnamese economy. Then, amount of GHGs as well as waste generated directly from the plastics sector and indirectly from using PET packages in other sectors in 2016 are identified.

![Figure 1. Research method diagram.](image)

2.1. Define life cycle emission factors in the PET packages production

The study uses loops recycling analysis to determine GHGs emission (\(EF_{CO2e}\)) and waste (\(WF_{PET}\)) in a life cycle of one ton of PET packages (Figure 1 and 2a) [7]. Electricity and DO are used as energy sources for production processes and transportation activities, respectively. 2.5 ton-trucks are used for transporting materials.

GHGs emission factor of Chinese PET_v is 2.240 kg CO_2/ton of PET_v [1]. GHGs emission factor of Vietnamese grid-electricity is 0.8154 kg CO_2/kWh [4]. GHGs emission factors of the vehicles are: 10.21 kg CO_2/gallon of DO; 0.41 g CH_4/gallon of DO; 0.08 g N_2O/gallon of DO,
these are calculated based on the EPA guidelines [4]. GHG emission and waste factor of PET are inventoried in Minh Khai craft village using open-loop recycling analysis (Figure 2b).

![Figure 2. Illustration of recycling loops for PET.](image)

2.2. Integrating with the IO table

An IO table presents relations between economic sectors (Table 1). Interrelationships of the providing and demanding sectors are balanced, as seen in equations (1) and (2).

<table>
<thead>
<tr>
<th>Table 1. Structure of IO table [8].</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product/service sectors</strong></td>
</tr>
<tr>
<td><strong>Intermediate demand</strong></td>
</tr>
<tr>
<td><strong>Final demand</strong></td>
</tr>
<tr>
<td><strong>Total output (X)</strong></td>
</tr>
<tr>
<td>Goods sectors</td>
</tr>
<tr>
<td>Intermediate providing</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Value added</td>
</tr>
<tr>
<td>Total input (X)</td>
</tr>
</tbody>
</table>

Balance by rows and columns:

\[ X_i = \sum_{j=1}^{n} z_{ij} + Y_i \quad (i = 1, n) \quad (1) \]

\[ X_j = \sum_{i=1}^{n} z_{ij} + V_j \quad (j = 1, n) \quad (2) \]

In the study, the original 2012 IO table is updated for 2016 using standard RAS method [3]. All sectors of the updated IO table are numbered from 1 to 164 according to the General Statistics Office [6]. The IO tables have been compiled in currency unit and based on the producer’s price. In order to get \(PD_i\) and \(P_{PET}D_i\), the updated IO table is then converted into the table of hybrid units in which the plastics sector is compiled in its physical unit.

Then, environmental burdens from using PET packages of each sector (\(E_{CO2e}\) and \(W_{PET}\)) are calculated, as seen in equations (3) and (4). The plastics industry is not participated in this
calculation process in order to avoid double counting – this sector uses PET materials to produce PET packages for other sectors.

\[ E_{CO2e_i} = P_{PETi}D_i \times EF_{CO2e} \]  
\[ W_{PETi} = P_{PETi}D_i \times WF_{PET} \]  

3. RESULTS AND DISCUSSION

3.1. GHG emission and waste factors in the life cycle of PET packages

The life cycle inventory (LCI) of option 2 (80% PET, and 20% PET,) is shown in Figure 3. According to the survey in some plastic producers, the main PET, supplying source in 2016 was Minh Khai plastic recycling village. PET, from other locals or import sources were negligible. Therefore, PET, from Minh Khai recycling village is taken into account in this study [11]. GHGs emission from the life cycle of 1 tons of PET packages (EF\(_{CO2e}\)) is 9,153 tons CO\(_2\)/ton of PET packages. Waste from the life cycle of 1 tons of PET packages (WF\(_{PET}\)) is 0.068 tons PET/ton of PET packages.

![Figure 3. LCI for option 2 (80% PET, and 20% PET,).](image)

Similar LCIs are done for option 1 (100% PET,) and option 2 (100% PET,). As the results, EF\(_{CO2e}\) of option 1 and 2 are 9,783 tons CO\(_2\)/ton of PET packages and 6,632 tons CO\(_2\)/ton of PET packages, respectively. WF\(_{PET}\) of option 3 is 0.41 tons PET/ton of PET packages. Option 1 does not generate PET waste.

3.2. PET packages demand of the economic sectors in 2016

The PET packages demand (P\(_{PETi}D_i\)) of 164 sectors in 2016 is shown in Figure 4. The PET packages occupied 37.43% of GDP of the plastics sector. Total PET packages demand of the economy in 2016 was 147,688 tons, in which three biggest PET packages user groups included: food processing (sectors 35-49); electrical and electronic equipment (sectors 77-86); and
Life cycle inventory for PET packages in the integration with IO table of Viet Nam

transportation services (sectors 92-94). Sectors 1-34 and 115-164 had negligible demands on PET packages therefore the study focuses on sectors 35-114 for further analysis.

In 2016, the population of Viet Nam was 92.7 million people, therefore the amount of PET consumption per capita is 3.7 kg. Compared to other countries such as China, India and Thailand [12], this indicates that the demand for PET in Viet Nam has been relatively high.

3.3. Environmental burdens from PET production and using

Direct GHGs emission and waste from three PET production options in 2016 are identified in Figure 5a and 5b. As seen, direct GHGs emission from option 1 (100 % PETv) was biggest while waste from option 3 (100 % PETr) was biggest. Option 1 did not generate PET waste.

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Indirect GHGs emission and waste from 80 sectors in 2016 based on three PET production options are identified Figures 6 and 7. As seen in every sectors, indirect GHGs emission from option 1 (100% PET_v) was biggest and indirect waste from option 3 (100% PET_r) was biggest. Three biggest contributors always were electrical and electronic equipment (sectors 77-86), food processing (sectors 35-49), and transportation services (sectors 92-94).

These results can be based for developing further analyses on direct and indirect environmental burdens from plastics production and recycling.

4. CONCLUSION

This study provides a LCI data set of PET packages in Vietnam with the integration of IO tables for further analysis in direct and indirect environmental burdens from every PET demander in the economy in 2016. As the results, GHGs emission will be biggest when 100% PET_v is used for PET packages production and PET waste will be biggest when 100% PET_r is used for PET packages production. It should be noted that the results will be changed when the ratio of PET_v/PET_r changes or the raw materials supplying source varies, due to the influence of fuel consumption for transportation of PET_r.

Beside the LCI results, this study aims to contribute to the existing literature on GHGs as well as PET waste balances by considering the remaining effects in PET production, distribution and recycling in the country.

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