Article

Carbon Footprint based on Tourists Consumption toward Sustainable Tourism in Japan

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Abstract: The importance of the contribution from tourism to climate change was pointed out by the International Tourism Organization (UNWTO). By combining process-based Life Cycle Assessment (LCA) and Input-output analysis, several researches have tried to evaluate the impacts of the tourism industry as well as its products and services. Indeed, the tourism sector has a wide range of industries including travel and tour, transportation, accommodation, food and beverage, amusement, souvenirs etc. However, the existing cases did not show a breakdown of the impact on climate change. In this paper, the carbon footprint (CFP) of the Japanese tourism industry was calculated based on tourist consumption, using the Japanese Input-output table and the Japanese tourism industry. It was shown that the total emissions were approximately 136 million t-CO2 per year. The contribution ratio of each stage is as follows: Transport 56.3%, Souvenirs 23.2%, Petrol (direct emissions) 16.9%, Accommodation 9.8%, Food and Beverage 7.5%, Activities 3.0%. Then, in the breakdown, the impact is high in the following order Air transport 24.7%, Petrol (direct emissions) 16.9%,Accommodation 9.8%, Food and Beverage 7.5%, Petrol 6.1%, Textile products 5.3%, Food items 4.9%, Confectionery 4.8%, Rail transport 3.9%, Cosmetics 1.9%, Footwear 1.8%, etc. In addition to transportation, this research also highlighted especially the contribution from souvenirs, accommodation, food and beverages.

Keywords: Life Cycle Assessment (LCA), Carbon Footprint (CFP), Tourism

1. Introduction

According to the United Nations, more than 3 million people travel across the world every day and about 1.2 billion people travel abroad every year. This includes not only personal travel, but also MICE [1] (Meetings, Incentives, Conferences, and Exhibitions,) which are international meetings (Convention) held for example by international organizations, academic societies, etc.

2017 was designated as the "International Year of Sustainable Tourism for Development" to spread the awareness of the role of tourism. One of the messages was, though the contact with the nature, to raise the challenges posed by the effective use of resources and climate change. Another point was to make people aware of global issues [2]. The United Nations World Tourism Organization (UNWTO) is still recognizing the impact of tourism on global warming as an important issue in the 21st century. Defining sustainable tourism as "Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities" [3]. The world tourism industry has also begun to implement the "Tourism for SDGs" aiming to contribute to the SDGs. In the "SDG compass", which shows the approach to the SDGs, "Life Cycle Assessment (LCA)" is introduced as one of the means to map the high impact areas in the value chain in "Step 2 Determine priority issues".

In japan, according to a survey by the Japanese Ministry of Land, Infrastructure, Transport and Tourism [4], environmental efforts are one of the most important issue regardless of the business field. Today, in the field of tourism in Japan, there are a variety of local governments, residents, tourism industries, etc. which are making efforts to protect the environment. Establishing a cooperation system that goes beyond the initiative of a single entity has been strongly recognized as

an option to tackle the issue. In addition, it was shown that environmental conservation efforts are not only indispensable for the sustainable development of tourism, but also greatly related to improving the attractiveness of tourist destinations. According to the Japan Tourism White Paper [5], the GDP of the tourism sector as defined by the UNWTO (2012) is approximately 8.5 trillion yen (about 78.6 billion US dollars), accounting for approximately 1.7% of the country total GDP. Moreover, the growth rate of the tourism sector GDP is about 23%, which is higher than the growth rate of other industries. On the other hand, in a specific tourist area, a significant increase in visitors for example might bring a negative impact on civic life, natural environment, landscapes, etc., which can greatly reduce the level of satisfaction for travelers. Such tourism situation has become a major issue referred as "overtourism". The Japanese government has established the "Tourism Strategy Promotion Task Force" as part of the Japan Tourism Agency (2018). The goal of this entity is to harmonize the increasing needs of tourists and the living condition of residents in the tourist area, a system was developed to comprehensively examine and promote their coexistence. From these social backgrounds, just started considering establish evaluation index for sustainable tourism in japan by the Japan Tourism Agency.

Life-Cycle Assessment (LCA) can be a solution to avoid this situation as it can identify the potential environmental impacts caused by the tourism sector within its different life-cycle stages. From the viewpoint of LCA, there are mainly two methods for calculating the environmental impacts: Process-based LCA (focusing on the different processes constituting the scope of evaluation) and Input-output based LCA (focusing on the monetary interaction between the different industrial sectors). Filimonau et al. (2016) [6] has made a summary of the different LCA studies focusing on tourism (SI-Table1).

The process method, which is a method of examining individual processes that make up the life cycle one by one and collecting and accumulating environmental load data for each process, is often targeted at specific product services such as package tours and lodging. On the other hand, the Input-Output method, which is based on the estimated consumption of energy and resources as well as the environmental impacts of emitted substances by using the input-output table, this later one is often targeted at evaluating industrial sectors such as the local tourism sector and the national tourism industry.

Lenzen et al. (2018) [7] calculated the carbon footprint (CFP) of global tourism using multi-regional input-output (MRIO). The tourism industry is composed of a wide range of industries including travel, lodging, dining, amusement, souvenirs, etc. expected to grow at a global annual rate of 4%. It was noted that the global GHG (Greenhouse Gas) emissions related to tourism until now were not well quantified. In this study, based on tourism-related data from 160 countries, the CFP for tourism was estimated to having grown from 3.9 to 4.5 GtCO2eq between 2009 and 2013. This is about four times the previous estimate and accounts for about 8% of global GHG emissions. The authors pointed out the high contribution of Food and beverage in addition to travel and shopping.

In Japan, the LCA Society of Japan (JLCA) New Tourism Research Group has been studying the GHG emissions related to tourism since 2009 [8] to highlight their importance In 2013, the calculation method for travel tour was examined based on the works from: Ito et al. (2011) [9] focusing on transportation, Tamari et al. (2011) [10] focusing on accommodation and finally Kazama et al. (2011) [11] focusing on Food and beverage. In the same year, the Product Category Rule (PCR) [12] for travel was also examined in the Carbon Footprint Communication Program (CFP Program). The bottom-up evaluation results were used for labeling such as PCR for the CFP program and for the establishment of certification standards for Eco Mark (Type I label) [13,14].

Finally, Shimizu et al. (2015) [15] also examined 27 industrial sectors related to tourism in Japan and Korea using the input-output table approach, tourism statistics related to consumption, and various data on CO2 emission intensity. In the future, while the production value of the tourism industry can be expected to increase, it is pointed out that this is a possibility of increasing emissions of greenhouse gases such as carbon dioxide (CO2). However, for the domestic case, there is no breakdown that clarifies the degree of impact of "travel, lodging, amusement, souvenirs, etc." which are the key elements which compose tourism therefore our study aims at clarifying this point.

So, In this study, we calculate the CFP for the entire Japanese tourism industry and quantitatively show the breakdown by the different items which are composing this industry (Transportation, Accommodation, Food and Beverage, souvenirs, Activities etc.).

2. Materials and Methods

2.1. Input-Output table approach

In this method, the evaluation is conducted retrospectively from the supply chain, so that a comprehensive evaluation is performed from the viewpoint of the life cycle of products and services. Therefore, this study uses the LCA method in order to meet the objective of considering comprehensive evaluation by including the pre-tourism preparation stage and post-tourism as well as the different stages occurring during travelling.

In this research, the Japanese input-output table is used. This method principles are based on the works from W.W. Leontief [17] and is often used in the LCA research field. The formula used in this method is

$$\text{Environmental loads} = d(I - A)^{-1}f \quad (1)$$

d is the direct environmental impact and the environmental impact per production value. (I-A)$^{-1}$ is the Leontief inverse matrix and can consider the direct and indirect economic ripple effect caused by the consumption of one type of goods. f is the amount of activity. This method helps to evaluate the entire supply chain. According to Hondo (2008) [18], it has the following advantages:

-Arbitrariness is not involved in the choice of system boundaries
-Full understanding of indirect environmental impact
-Public statistics with excellent transparency and objectivity
- It can evaluate all goods and services.

To sum up, it is possible to make an objective evaluation, and the existing limit to get the data for each process, is overcome by using the Input-Output table. Therefore, the calculation following this approach was adopted in this study.

2.2. System boundaries

As shown in Table 1, the system boundaries of this study are following the traditional approach adopted for tourism evaluation. Preparation (Pre-tourism), Inbound Tourism, Domestic Tourism, Outbound Tourism and After (Post-tourism) are the different life stages. It covers consumption related to: movement and accommodation of tourists and MICE events staff and participants. However, it does not include the consumption of foreign tourists before/after travelling but also items purchased by MICE organizers and energy consumption at the venues.

The tourism statistics data "Internal and National tourism consumption, by timing of purchase and products" provided by the Japan Tourism Agency [19] are distinguishing: foreign visitors visiting Japan (referred as Inbound tourism in this study), domestic tourism which includes also the travels within Japan of foreign visitors (ex: flight connection) and finally Japanese nationals/Japan foreign residents overseas travel (referred in this study as outbound tourism). The items evaluated in this study are displayed as "○" in Table 1, and those that are not included are displayed as "Not applicable". This data provided by JPY (1$ = 113 JPY (2017 Ave.)).

Table1. Scope of evaluation data

		Inbound tourism	Domestic tourism overnight stay	Domestic tourism day trip	Domestic tourism for transit	Outbound tourism
Life cycle stage	Travel agencies, tour operators and guide	○	○	○	○	○
	Transport	○	○	○	○	○
	Accommodation	○	○	Not applicable[2]	○	○
	Food and beverage	○	○	○	○	○
	Souvenirs	○	○	○	○	○
	Activities (include others[1])	○	○	○	○	○

[1] It is included not only Cultural services, Recreation and other entertainment services, but also other services.

[2] Day trip are not included for non-staying trips.

2.3. Caluculation method of CFP

As mentioned earlier in Section 2-2, this study calculates the CFP using the input-output approach. The calculation formula is shown below:

$$\sum_{k=1}^{5} CFP_k = d_i(\underbrace{\overbrace{(I - A)^{-1}f_i} + DE_i}_{}) \quad (i=1,\ldots,n) \quad (2)$$

Cradle-to-grave
Cradle-to-gate
Direct emissions from fuel combustion

Where d_i is the direct GHG emission intensity provided for each sector by Inventory Database for Environmental Analysis version 2" (IDEAv.2) developed by National Institute of Advanced Industrial Science and Technology (AIST); A is the direct input coefficient matrix: we used the 2011 waste input output table (WIO) developed by Kondo et al. (2019) [19] to have a broaden overview. I is an identity matrix; $(I-A)^{(-1)}$ is the Leontief inverse matrix and f_i is the amount of activity obtained from the statistics of the Japan Tourism Agency (2017) as detailed previously. It would be better to use data focusing on the same year, however the last waste input output table available is focusing only on 2011. DE_i is the direct emission from fuel combustion added to the calculation in order to cover the full cradle to grave aspects of products and services.

The tourism statistics data "Internal and National tourism consumption, by timing of purchase and products" [20]" regularly surveyed by the Japan Tourism Agency is based on Tourism Satellite Accounts (TSA). Items were aggregated to represent the total amount spent during or for travel. Including those paid for souvenirs for example. Here, travel is defined as "going away from the area of daily life regardless of the content of activities at destination" and is used synonymously with tourism. Business trips are included in the data, but the organizer's consumption / waste amount and direct environmental impact at MICE events are not included. The data is provided for 2017.

As shown in Table 2, it can be seen that spending for "Accommodation services" and "Food and beverage serving services" are important , and also inside "Passenger transport services", the amount of spending is higher for planes (sum of domestic and international flights) and Shinkansen (Japanese bullet train).

The following table describes in detail the spending for each lifecycle stage. During the preparation stage respectively textile products, confectionery, food products and Rubber/Plastic footwear represent the largest spending. For inbound tourism: accommodation expenses, eating and drinking expenses, followed by pharmaceuticals and cosmetics expenses. For domestic tourism:

accommodation expenses, eating and drinking expenses and Shinkansen expenses. Finally, for outbound tourism: accommodation expenses, eating and drinking expenses and finally international flights expenses. In the post-travel stage, it can be confirmed that the consumption amount is the most important for photo development / printing and then cleaning.

In this article, each product / service item is associated with an I / O classification code. Some major items such as "Travel agencies, tour operators and tourist guide services" do not include detailed sub-items but still correspond to I / O classification codes. See SI-Table2 for each inventory items and I / O classification correspondence

Table 2. Amount of consumption for items subject to evaluation. The I / O classification codes corresponding to each TSA inventory items were applied. See SI-Table2 for details.

Category of Products and services	Inbound tourism	Domestic tourism overnight stay	Domestic tourism day trip	Domestic tourism for transit	Outbound tourism	Total (B-JPY)	Rate (%)
Travel agencies, tour operators and guide	22	225	33	159	27	466	1.6%
Transport	748	5,320	2,128	852	1,041	10,090	33.6%
Accommodation	1,077	4,148	0	18	883	6,125	20.4%
Food and beverage	766	2,077	646	26	400	3,914	13.0%
Souvenirs	1,418	3,587	1,583	250	397	7,234	24.1%
Activities	115	1,151	641	128	150	2,185	7.3%
Total (Billion-JPY)	4,146	16,508	5,031	1,432	2,897	30,015	100.0%
Rate (%)	13.8%	55.0%	16.8%	4.8%	9.7%	100%	-

3. Results

3.1. CFP of tourism

The CFP was calculated as shown below (Figure 1), it was found to be 136 million t-CO2eq. The contribution ratio of each stage is as follows: Transport 56.3%, Souvenirs 23.2%, Petrol (direct emissions) 16.9%, Accommodation 9.8%, Food and Beverage 7.5%, Activities 3.0%.

Then, in the breakdown, the impact is high in the following order Air transport 24.7%, Accommodation 9.8%, Food and Beverage 7.5%, Petrol 6.1%, Textile products 5.3%, Food items 4.9%, Confectionery 4.8%, Rail transport 3.9%, Cosmetics 1.9%, Footwear 1.8%, etc.

Table.3 shows summary of each travel type top contributors ranking of items to GHG emissions. The top 5 rankings for Inbound tourism are as follows Air transport, Accommodation, Cosmetics, Food and beverage, Food items; for overnight stay of Domestic tourism are as follow Petrol (direct emissions), Air transport, Accommodation, Food and beverage, Petrol; for day trip of Domestic tourism are as follow Petrol (direct emissions), Petrol, Food items, Food and beverage, Confectionery; for transit overseas of Domestic tourism are as follow Air transport, Textile products, Footwear, Petrol (direct emissions), Confectionery; for Outbound tourism are as follow Air transport, Accommodation, Food and beverage, Textile products, Confectionery.

From these results, it is clear that the impact of Transport is important, not only because of the transportation but also due to the contribution from souvenirs, accommodation, and Food and beverage.
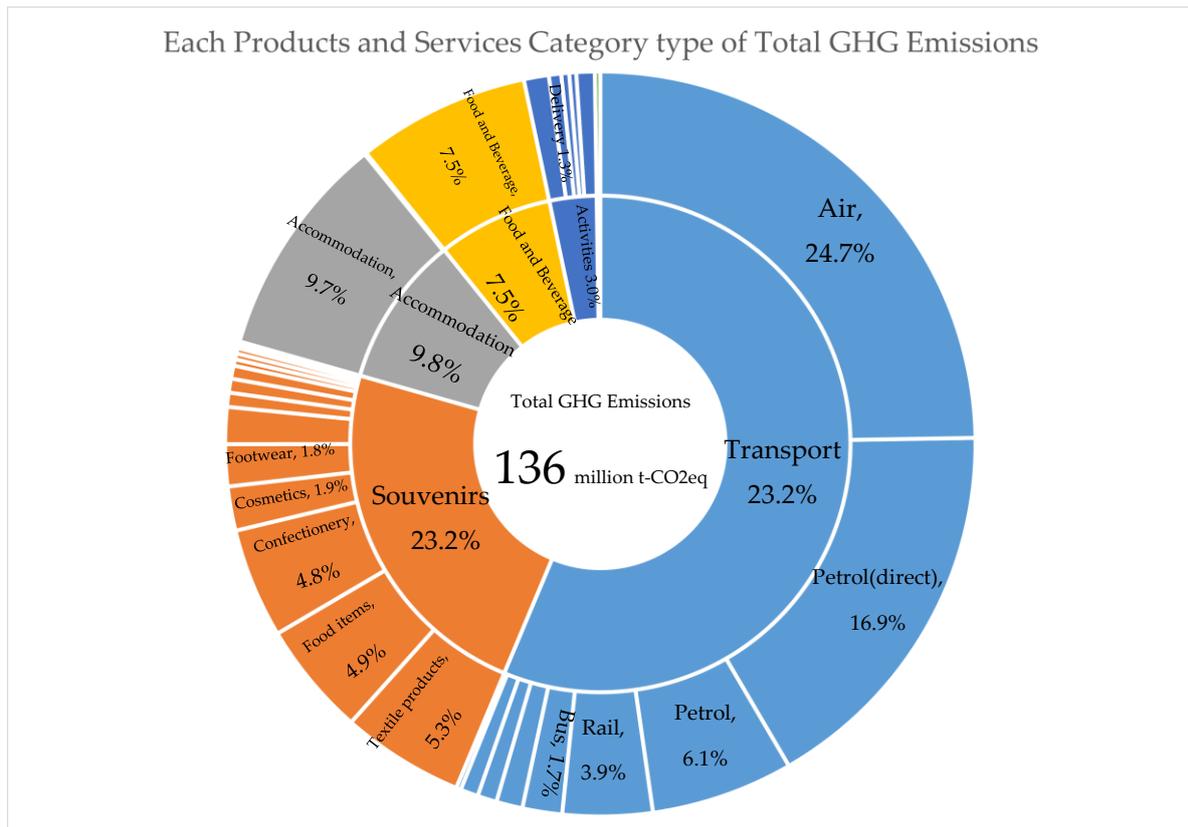
Figure 1. Breakdown of the CFP by each life-cycle stage. The above figure shows "GHG emissions" and shows the contribution of the impact in each life stage.

Table 3. Summary of each travel type top contributors' items to GHG emissions

From the results in Figure 2-6., the top five highest contributions in each stage are displayed.

	Inbound tourism	Domestic tourism overnight stay	Domestic tourism day trip	Domestic tourism for transit	Outbound tourism
1	Air transport	Petrol (direct emissions)	Petrol (direct emissions)	Air transport	Air transport
2	Accommodation	Air transport	Petrol	Textile products	Accommodation
3	Cosmetics	Accommodation	Food items	Footwear	Food and beverage
4	Food and beverage	Food and beverage	Food and beverage	Petrol (direct emissions)	Textile products
5	Food items	Petrol	Confectionery	Confectionery	Confectionery

The following sub-parts 3-1 to 3-3 show the detailed breakdown by stage.

3.2. Inbound tourism

Figure 2. shows the comparison of travelers' consumption and GHG emissions of the inbound tourism stage. Travelers spend a lot on Accommodation, Food and beverage and cosmetics, and GHG emissions have a similar tendency. It can also be seen that Air transport has a high impact than others.
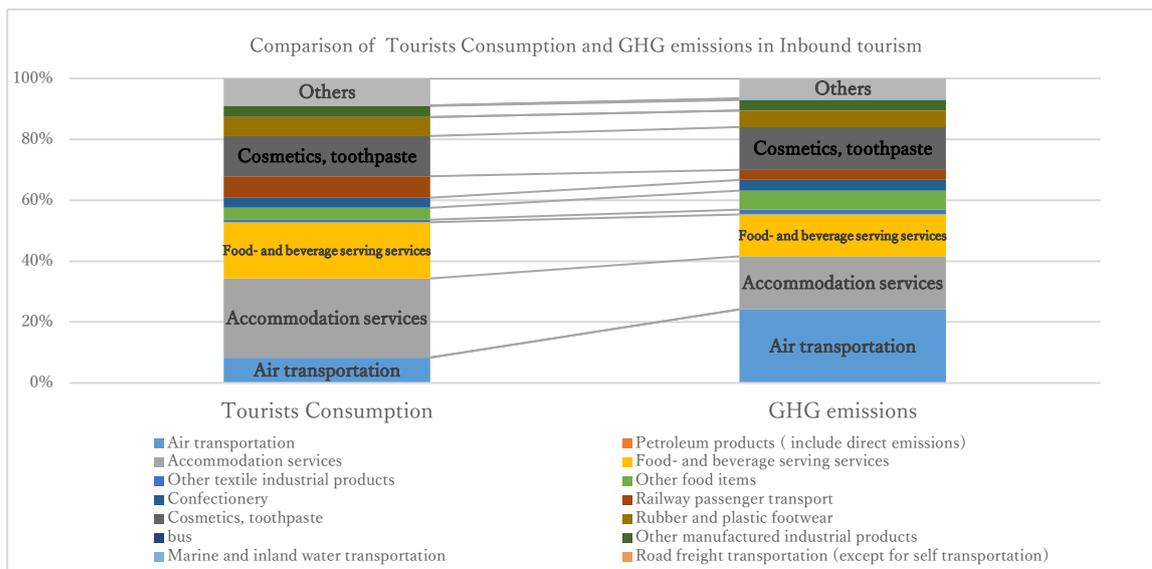
Figure 2. Comparison of traveler's consumption and GHG emissions of Inbound tourism stage

3.3. Domestic tourism

3.3.1 overnigh stay

Figure 3. shows the comparison of travelers' consumption and GHG emissions of the Domestic tourism (overnight stay) stage. Travelers spend a lot on Accommodation, Food and beverage and Railway transport, and GHG emissions have a similar tendency. Certainly, Petroleum products (include direct emissions) has a high impact than others. And Air transportation also have the fourth highest impact in this stage.
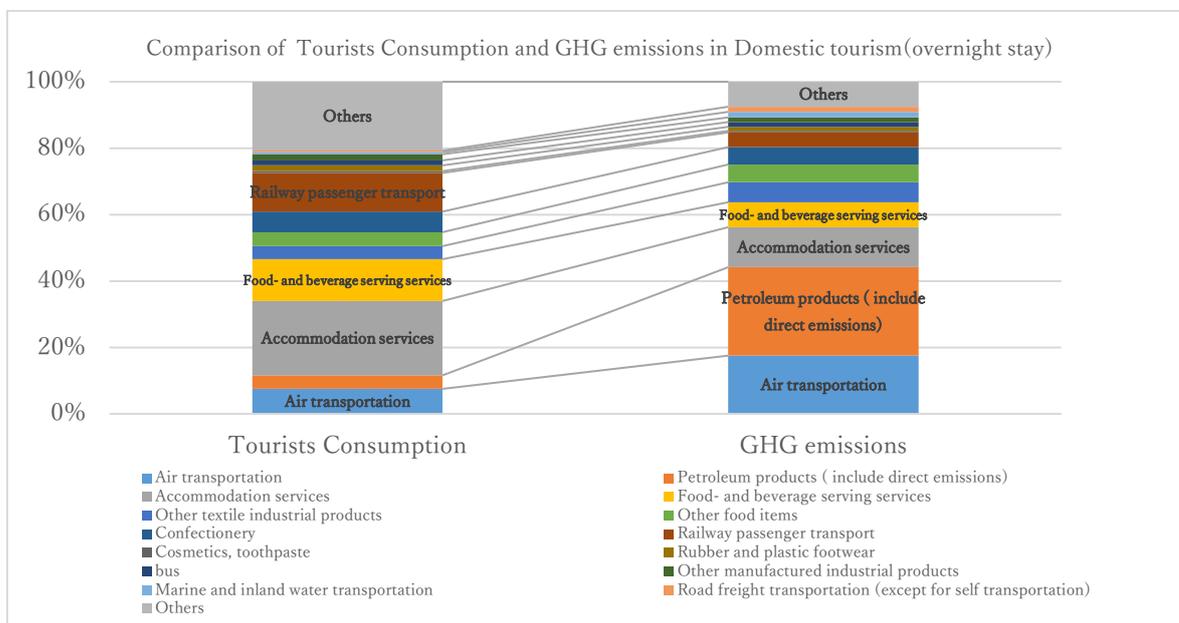

Figure 3. Comparison of traveler's consumption and GHG emissions of Domestic tourism stage (overnight stay)

3.3.2 day trip

Figure 4. shows the comparison of travelers' consumption and GHG emissions of the Domestic tourism (day trip) stage. Travelers spend a lot on Railway transport and Food and beverage, and GHG emissions have a similar tendency. Certainly, Petroleum products (include direct emissions) is high impact than others.
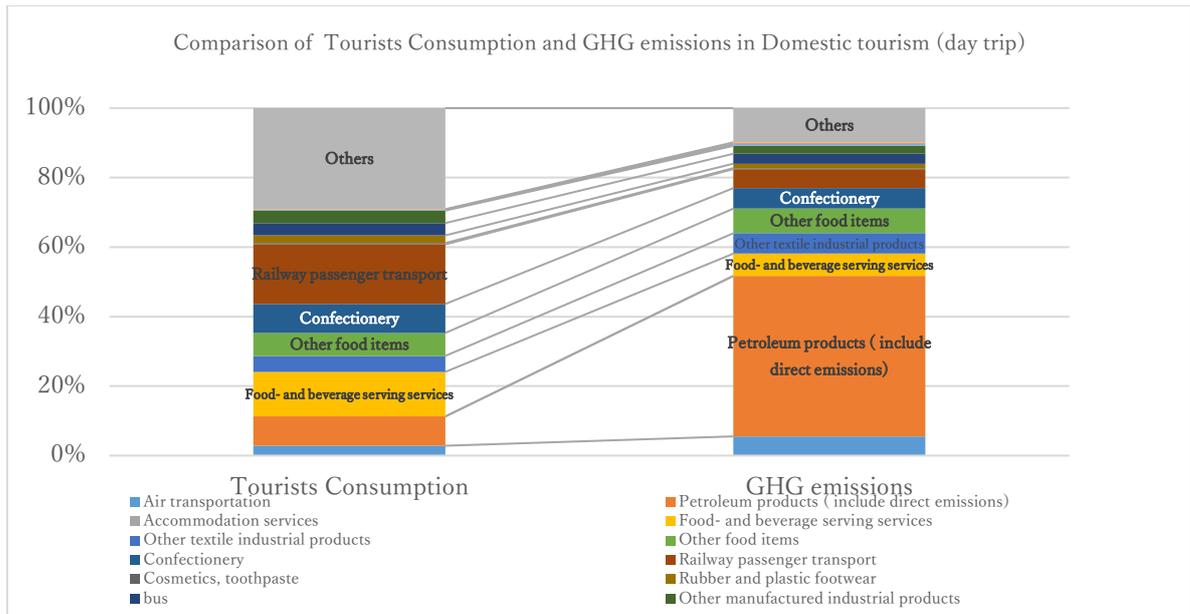
Figure 4. Comparison of traveler's consumption and GHG emissions of Domestic tourism stage (day trip)

3.3.3 for Transit Overseas

Figure 5. shows the comparison of travelers' consumption and GHG emissions of the Domestic tourism (for Transit) stage. Travelers spend a lot on Air transport, and GHG emissions have a similar tendency. Certainly, Air transport a high impact than others. On the other hand, the ratio of Rail transport is lower.

Figure 5. Comparison of traveler's consumption and GHG emissions of Domestic tourism stage (for Transit)

3.4. Outbound tourism

Figure 6. shows the comparison of travelers' consumption and GHG emissions of the Outbound stage. Travelers spend a lot on Air transport, and GHG emissions have a similar

tendency. Certainly, Air transport a high impact than others. On the other hand, the ratio of Rail transport is lower.
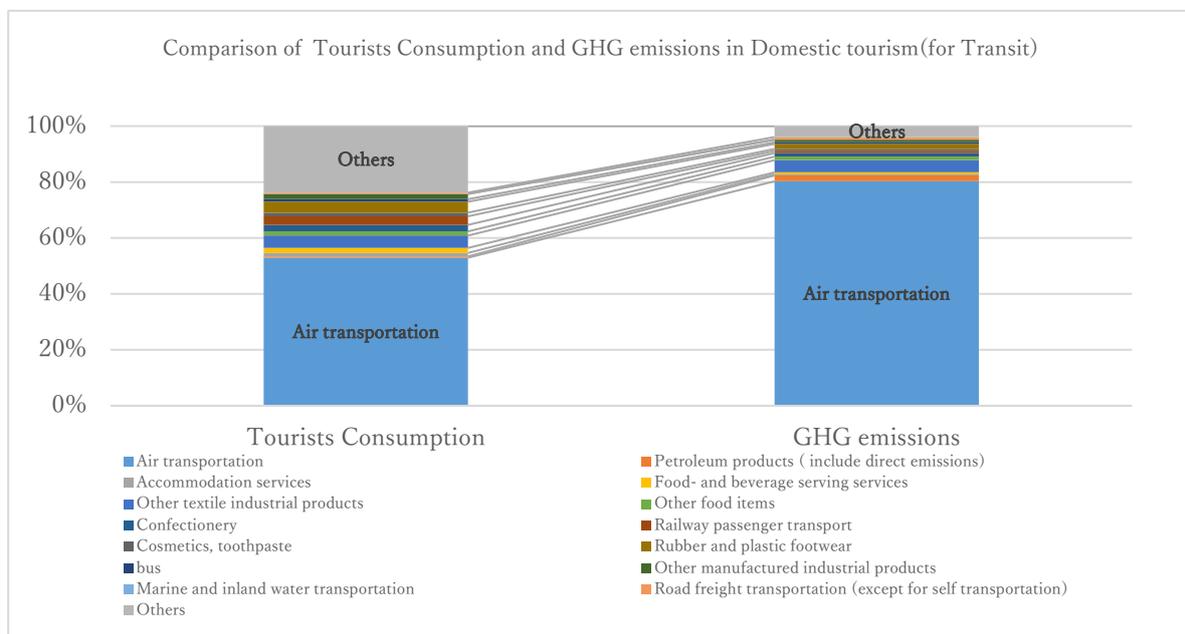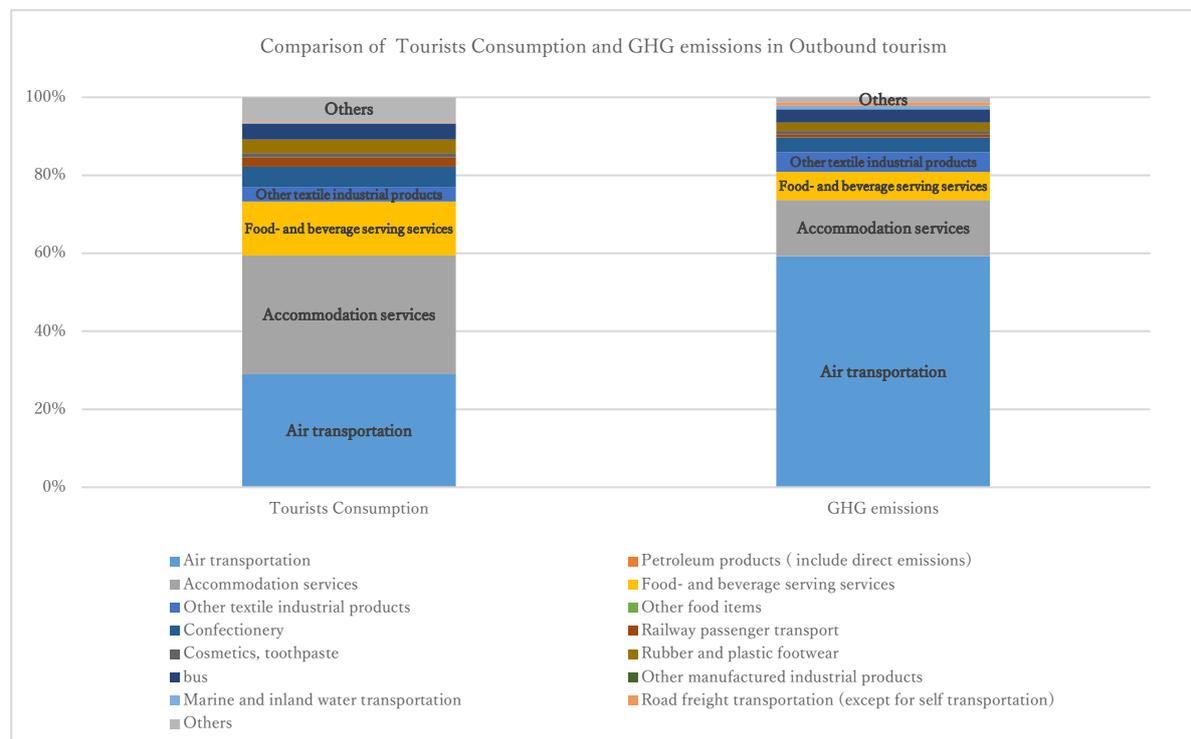

Figure 6. Comparison of traveler's consumption and GHG emissions of Outbound tourism stage

4. Discussions

4.1. Comparison with existing research

GHG emissions of Japan in 2017 announced by the Ministry of the Environment is 1,292 million t-CO2eq [21]. Therefore accoriding to the results developed in this study, tourism in Japan accounts for about 10.5% of the national CFP (Table 4).

Table 4. Comparison between the results of this study and the annual total CO2eq emissions in Japan
This article is based on the Japan Tourism Agency statistical data [19]] compiled from January to December, and the Ministry of the Environment's published values [21] are compiled from April to March. A comparison was made for confirming the contribution from the tourism sector

Case	GHG emission of Japan (fixed report) in FY 2017	This case result (Data of 2017)
Object	The whole of Japan	Tourism consumption of Japan
Amount of emission million t-CO2eq	1,292	136
Ratio (%)	100	10.5

According to the estimation from the Japan Tourism Agency [20], tourism GDP in 2017 was 10.7 trillion yen which is about2.0% of Japan's nominal GDP (545.1 trillion yen) (**Table 5.**).

Table 5. Comparison between Japan's GDP and tourism GDP (UNWTO standard)

Case	GDP	Japan Tourism Agency
Object	The whole of Japan (2017)	Tourism consumption of Japan (2017)
Amount of GDP	545.1	10.7

trillion-JPY		
Ratio (%)	100	2.0

The tourism policy of the Japanese government is aimed at stimulating both inbound demand and domestic consumption, it can be estimated that the economic effects will increase further in the future [22].

Shimizu et.al (2014) [15] stated that in the future the tourism industry should actively consider measures to reduce greenhouse gases as one of the leading industry in the world. However, there are only a few certfications rgistrations in the CFP program [9] and Eco Mark [13,14], which are labeling systems for businesses in Japan.Lenzen et al. (2018) [7] pointed out that the majority of CFP is emitted by travelers from high-income countries inside or outside their countries. In addition, the surge in tourism demand is becoming an urgent issue that it far exceeings the decarbonization systems of tourism-related technologies.

Figure 7. shows the relationship between GHG emissions and tourism consumption. The larger the vertical value is, the higher the GHG emissions and therefore the higher the environmental impacts are. The larger the horizontal value is, the greater the tourism consumption is and the higher the economic effect are. Therefore, products and services with low GHG emissions and largely consumed by the tourism sector can be said to be products and services that contribute to both environment and economy. For example, it could be confirmed that accommodation and eating and drinking services have lower environmental impact and better economic effects than air transportation. If focusing on transportation only, the economic effects of air transportation and railway passenger transport are similar, but it can be seen that air transportation is superior in terms of environmental burden. In addition, it can be seen that sweets related to souvenirs, other foodstuffs, and other textile industry products have certainly a small environmental impact but also a small economic effect.

The following SI-Figures 1 to 6 show Figure 7 in detail. In each figure, the items for each product category are displayed in text. For example, **SI-Figure 5.** shows text in figure indicates are only Souvenires items. Most items are above linear approximation. Also, **SI-Figure 6.** shows text in figure indicates are only Activites items. Many items are below the linear approximation. So, activities have less environmental impact than souvenirs and contribute to economic impact. But, the Accordation in Figure 3 is only Accomodation services and Vacation home ownership (imputed). No difference is shown here from the type of accommodation or set plan. Furthermore, the Food and bevarege in Figure 4 has only one item and cannot show different types of meals.

In this reason, in Japan, it is necessary to consider measures to reduce GHG emissions for each product and service that compose tourism, such as accommodation, Food and bevaregeouvenirs, etc. In addition, it is necessary to educate the relevant operators to identify the environmental issues and actively work on reducing GHG emissions. Finally, we believe that it is an urgent to develop products and services that can be selected by travelers based on environmental labeling and other labeling systems. In recent years, the tourism trend has shifted from consumption of goods to experience. The study found that it is also good to increase experiential consumption for a sustainable tourism style. After this, we need to assess the environmental and economic impact of individual travel as a case study. And hope to see if it is sustainable tourism.

Filimonau et al. (2016) [6] expects that many of the LCA evaluation examples for tourism shown in the book, can lead to educate the tourists to choose sustainable tourism. In Japan, there are only a few applications based on LCA methods (particularly Process-based LCA) to evaluate the different components of tourism. In other countries, for example, the Input-output LCA approach is used to evaluate the hotel industry by focusing not only on climate change but also on other environmental impacts (SI-Table1: Rosenblum et al. ((2000))
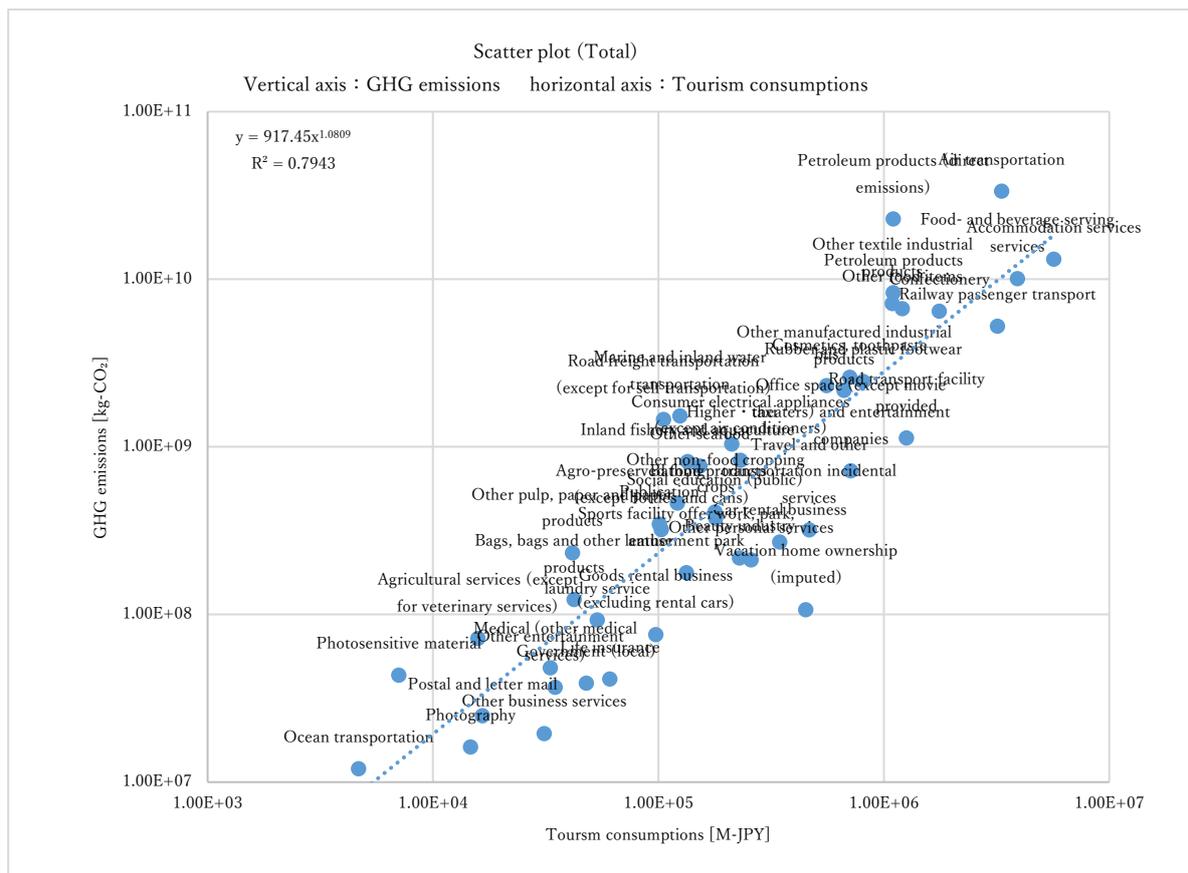
Figure7. Scatter plot of Total GHG emissions and Tourism consumptions.

4.2 Limitations

As an issue related to these results, it is necessary to expand the products and services that constitute tourism, from the viewpoint of evaluation with higher extensibility and comprehensiveness. In particular, this article does not include procurement, direct energy, waste, etc. of MICE organizers. In addition, since the results differ depending on the setting of the boundary range (ex: inbound tourism/ domestic tourism, local consumption, etc.), it is also necessary to examine how to use the results.

In the future, it is necessary to study the close link between the economic expansion and the several environmental impacts (climate change, land use, water use for example) of the different products and services which are consumed in the tourism industry, not only air transportation but also other services including for example accommodation and souvenirs. Moreover, not only a mid-range view is profitable but also a long-term assessment to track the possible evolution compared with the past-evolution

5. Conclusion

We have established a procedure to quantitatively view the Japanese tourism industry as CFP. In this study, we calculated CFP it was found to be 136 million t-CO2eq (Figur1.). The contribution ratio of each stage is as follows: Transport 56.3%, Souvenirs 23.2%, Accommodation 9.8%, Food and Beverage 7.5%, Activities 3.0%. Then, in the breakdown, the impact is high in the following order Air transport 24.7%, Petrol (direct emissions) 16.9%,Accommodation 9.8%, Food and Beverage 7.5%, Petrol 6.1%, Textile products 5.3%, Food items 4.9%, Confectionery 4.8%, Rail transport 3.9%, Cosmetics 1.9%, Footwear 1.8%,

From the results of this study, it was shown that GHG emissions that contribute to climate change are contributing to the environmental burden can be generated by tourism (travel, lodging,

Food and beverage, souvenirs, etc.). In addition, it showed a tendency to express the characteristics of tourism and tourist consumption. The breakdown is not only the use of air transportation and accommodation services, which are indispensable for transportation and stay, but also the contribution of food service and souvenir confectionery. By considering different types of movements (domestic and global), we were able to confirm the high contribution from the purchase and consumption of pharmaceuticals, cosmetics, shoes and bags.

In addition, if the tourism industry is prosperous, it can be shown that despite a great economic effect advantage, there is drawback as the environmental burden increases. It is then necessary for travelers to be able to select products and services with a lower environmental impact.

Appendix A

SI-Table 1: Existing case study and paper

The following table was added by the author based on V. Filimonau et.al 2016 [7]

Study	Object of analysis	Primary environmental impacts assessed	Geographical scope
Process-based LCA			
Castellani and Sala (2012)【23】	Holiday travel, Including accommodation	A range of impacts	Italy
Filimonau et al. (2011a)【24】		Climate change	UK
Filimonau et al. (2014) 【25】			UK and France
El Hanandeh (2013) 【26】	Religious travel, Including accommodation		Saudi Arabia
Pereira et al. (2015) 【27】	Holiday travel, Excluding accommodation		Brazil
Filimonau et al. (2013) 【28】	Holiday package		UK and Portugal
Kuo et al. (2005) 【29】	Tourist catering	A range of impacts	Taiwan
Michailidou et al. (2015) 【30】	Tourist accommodation		Greece
König et al. (2007) 【31】			Portugal
Sára et al. (2004) 【32】			Italy

De Camillis et al. (2008) 【33】			
Cerutti et al. (2014) 【34】			
Filimonau et al. (2011b) 【35】		Climate change	UK
Rosselló-Batle et al. (2010) 【36】			Spain
Li et al. (2010) 【37】			China
Input-output LCA			
Scheepens et al. (2015) 【38】	Sector of regional tourism	Climate change	The Netherlands
Berners-Lee et al. (2011) 【39】	Large tourism business		UK
Patterson and McDonald (2004) 【40】	National tourism industry		New Zealand
Cadarso et al. (2015) 【41】			Spain
Zhong et al. (2015) 【42】			China
Qin et al. (2015) 【43】	Tourist destination		
Manfred Lenzen (2018) 【7】	Global tourism		160 countries
Rosenblum et al. (2000) 【44】	National hotel industry	A range of impacts	USA

SI-Table: 2, Internal and National tourism consumption, by timing of purchase and products (CY2017, Unit: Billion JPY)

Products	Inbound	Domestic			Outbound	Total
		overnight stay	day trip	for Transit		
Travel agencies, operators and guide						
Travel agencies, tour operators and tourist guide services	22	225	33	159	27	466
transport						
Airplane (domestic, local)	19	1,244	143	32	127	1,565
Airplane (international flight)	326	0	0	726	713	1,765
Bullet train	292	1,443	595	22	0	2,353
Railways (excluding bullet train)	0	453	255	22	72	802
Bus	0	248	178	13	118	558
Higher・taxi	61	112	33	5	0	212
Ships (inner service, local)	6	97	10	0	11	125
Ships (outbound)	1	0	0	4	0	5
Car rental fee	43	256	45	0	0	345
Gasoline cost	0	672	424	7	0	1,103
Parking lot, toll road charge (except for highway charge)	0	175	104	13	0	291

Highway charge	0	618	341	8	0	967
Accommodation						
Accommodation services	1,077	3,697	0	18	883	5,674
Vacation home ownership (imputed)	0	451	0	0	0	451
Food and beverage						
Food and beverage serving services	766	2,077	646	26	400	3,914
Souvenirs						
Agricultural products	0	97	82	0	0	179
Agricultural processed products	0	65	38	0	0	103
Marine products	0	93	42	0	0	135
Fisheries processed products	0	105	48	0	0	153
Confectionery	137	1,022	419	33	150	1,762
Other food items	163	691	333	21	0	1,208
Fiber products	35	652	232	63	109	1,091
Shoes, bags	257	285	111	56	101	810
Ceramics and glass products	0	33	9	0	0	42
Publication	18	50	24	9	0	101
Wood products and paper products	0	23	18	0	0	42
Medical supplies and Cosmetics	549	89	20	19	29	705
Film	0	5	1	1	0	7
Electrical equipment and related products	107	71	25	21	8	231
Camera, glasses, watch	80	101	25	22	0	229
Sports equipment · CD · stationery	0	124	109	5	0	238
Other manufactured products	72	80	48	0	0	199
Activities						
A day spa · warm-bathing facility · beauty salon	0	83	39	0	0	121
Museums, museums, zoos and gardens, aquariums	26	105	47	0	0	178
Watching sports and Art appreciation	9	82	93	0	44	228
Amusement parks and expositions	47	232	151	0	55	486
Sports Facilities	0	53	80	0	0	132
Ski lift fee	0	27	13	0	0	40
Camp site	0	0	1	0	0	1
Exhibition and convention participation fee	0	16	16	0	0	31
Tourist farm	0	7	8	0	0	16
Fishing boat	0	20	14	0	0	33
Guide fee	0	20	12	0	0	32
Rental charge	10	64	12	13	0	97
Massage	0	32	3	0	0	35
Photo shoot fee	0	10	4	0	0	15
Mail and communication charges	0	11	2	1	2	17
Home delivery	0	80	10	6	9	105
Travel insurance · Credit card admission fee	0	27	3	32	0	61
Passport application fee	0	0	0	41	0	41
Visa application fee	0	0	0	0	7	7
Hairdresser / Barber	0	155	64	11	0	229
Develop and print photos	0	31	14	5	0	49
Laundry service	0	38	13	3	0	53
Other	22	61	43	17	33	176
Total	**4,146**	**16,508**	**5,031**	**1,432**	**2,897**	**30,015**

SI-Table: 3, Sector row code table of Input-output table items sector applied in this study

| Products	Input-output table items	
	Row code	sector
Travel agencies, operators and guide		
Travel agencies, tour operators and tourist guide services	5789090	Travel and other transportation incidental services
transport		
Airplane (domestic, local)	5751010	Air transportation
Airplane (international flight)	5751010	Air transportation
Bullet train	5711010	Railway passenger transport
Railways (excluding bullet train)	5711010	Railway passenger transport
Bus	5721010	bus
Higher · taxi	5721020	Higher · taxi
Ships (inner service, local)	5742010	Marine and inland water transportation

|		
Ships (outbound)	5741010	Ocean transportation
Car rental fee	6612010	Car rental business
Gasoline cost	2111010	Petroleum products
Parking lot, toll road charge (except for highway charge)	5789010	Road transport facility provided
Highway charge	5789010	Road transport facility provided
Accommodation		
Accommodation services	6711010	Accommodation services
Vacation home ownership (imputed)	5531010	Vacation home ownership (imputed)
Food and beverage		
Food and beverage serving services	6721010	Food- and beverage serving services
Souvenirs		
Agricultural products	116090	Other non-food cropping crops
Agricultural processed products	1116020	Agro-preserved food products (except bottles and cans)
Marine products	172001	Inland fishery and aquaculture
Fisheries processed products	1113090	Other seafood
Confectionery	1115-030	Confectionery
Other food items	1119090	Other food items
Fiber products	1519090	Other textile industrial products
Shoes, bags	2229-010	Rubber and plastic footwear
Ceramics and glass products	2312020	Bags, bags and other leather products
Publication	5951030	Publication
Wood products and paper products	1649090	Other pulp, paper and paper products
Medical supplies and Cosmetics	2081020	Cosmetics, toothpaste
Film	2083010	Photosensitive material
Electrical equipment and related products	3321020	Consumer electrical appliances (except air conditioners)
Camera, glasses, watch	3919090	Other manufactured industrial products
Sports equipment · CD · stationery	3919090	Other manufactured industrial products
Other manufactured products	3919090	Other manufactured industrial products
Activities		
A day spa · warm-bathing facility · beauty salon	6731040	Bathing
Museums, museums, zoos and gardens, aquariums	6312010	Social education (public)
Watching sports and Art appreciation	6741020	Office space (except movie theaters) and entertainment companies
Amusement parks and expositions	6741020	Office space (except movie theaters) and entertainment companies
Sports Facilities	6741040	Sports facility offer work, park, amusement park
Ski lift fee	5711010	Railway passenger transport
Camp site	6741040	Sports facility offer work, park, amusement park
Exhibition and convention participation fee	6699090	Other business services
Tourist farm	131020	Agricultural services (except for veterinary services)
Fishing boat	6741090	Other entertainment
Guide fee	6799090	Other personal services
Rental charge	6611010	Goods rental business (excluding rental cars)
Massage	6411050	Medical (other medical services)
Photo shoot fee	6799010	Photography
Mail and communication charges	5791010	Postal and letter mail
Home delivery	5722010	Road freight transportation (except for self-transportation)
Travel insurance · Credit card admission fee	5312010	Life insurance
Passport application fee	6112010	Government (local)
Visa application fee	6112010	Government (local)
Hairdresser / Barber	6731030	Beauty industry
Develop and print photos	6799090	Other personal services
Laundry service	6731010	laundry service
Other	6799090	Other personal services
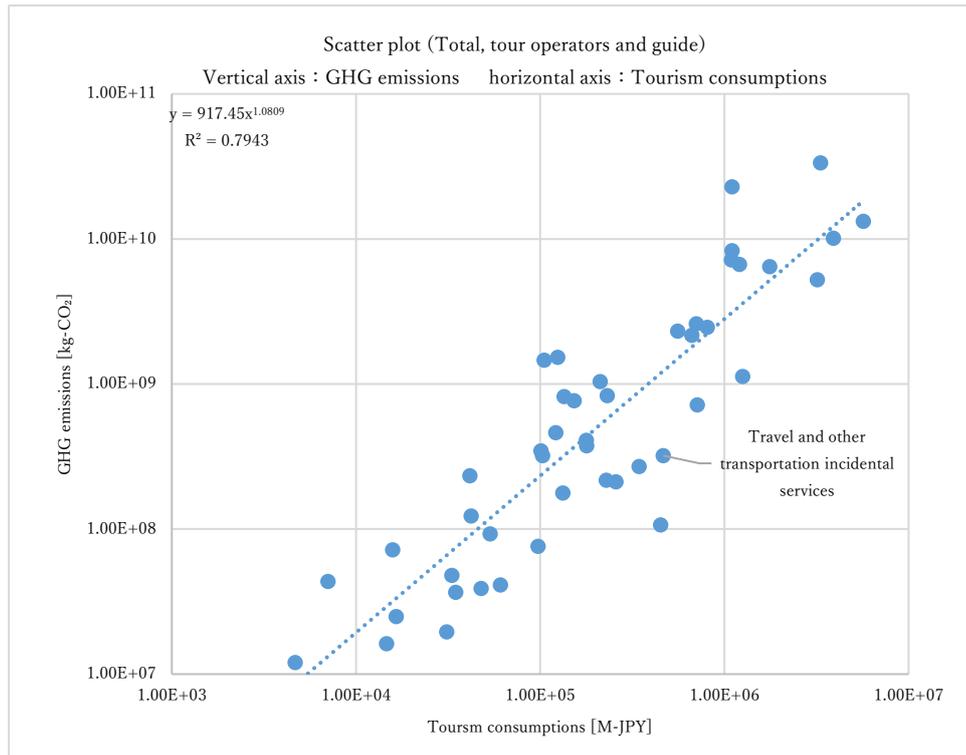
SI-Figure 1., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Tour operators and guide item.
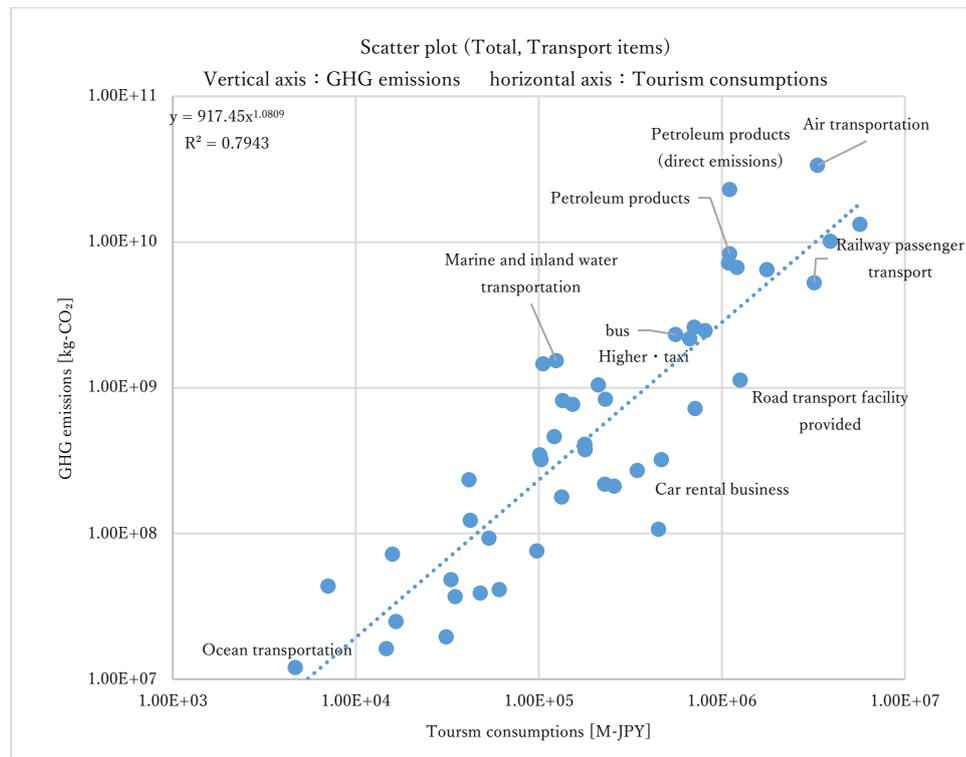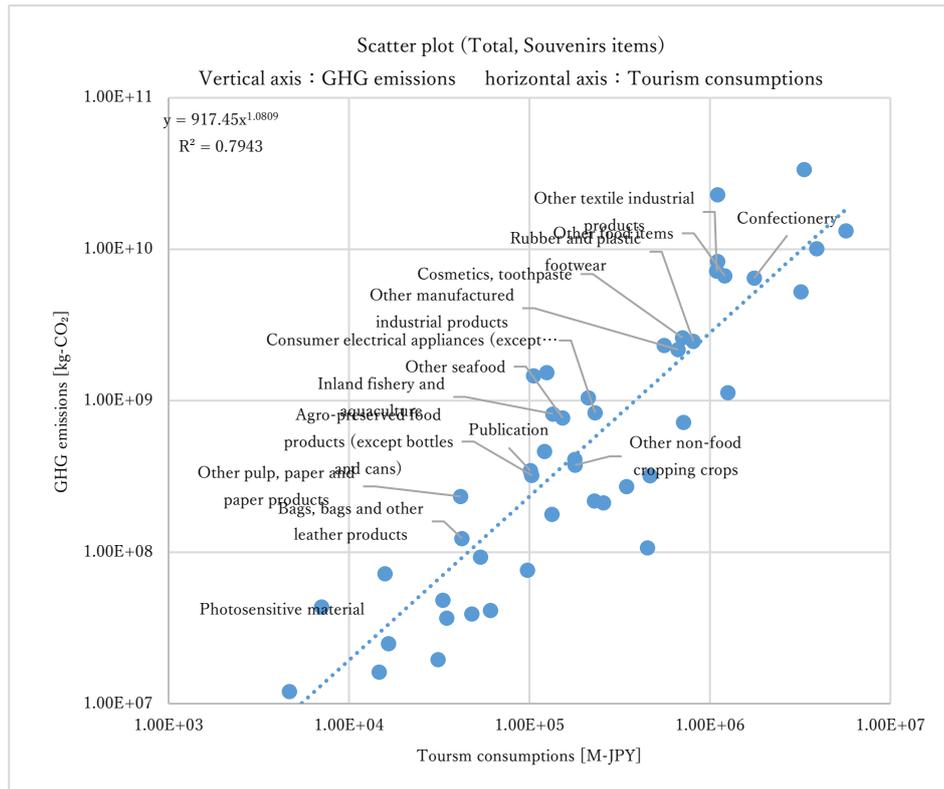

SI-Figure 2., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Transport items.
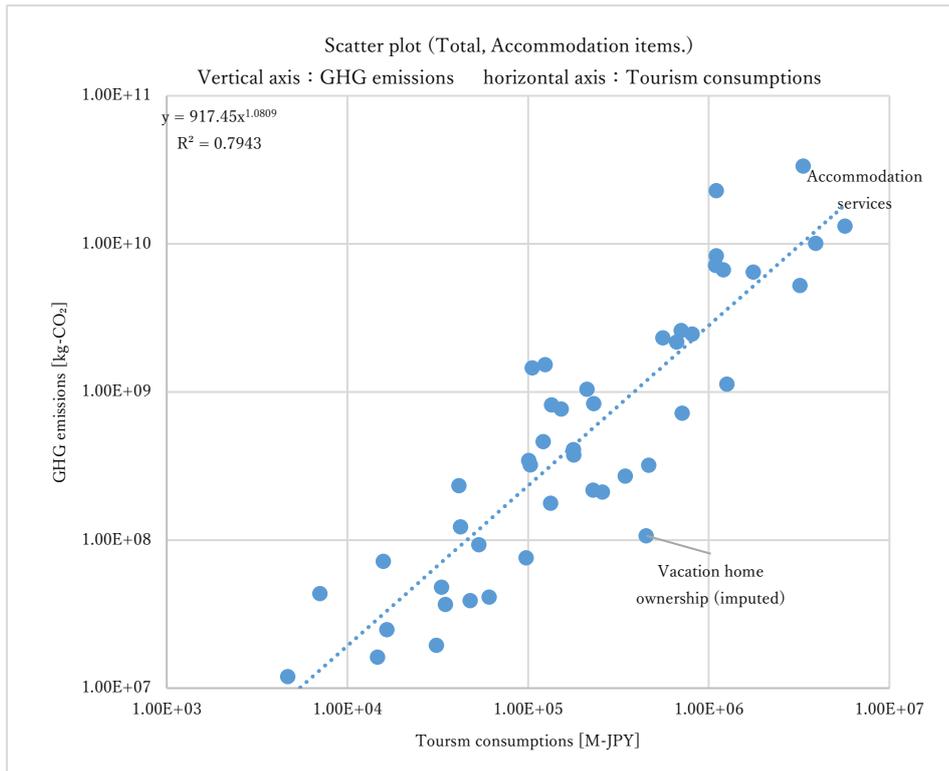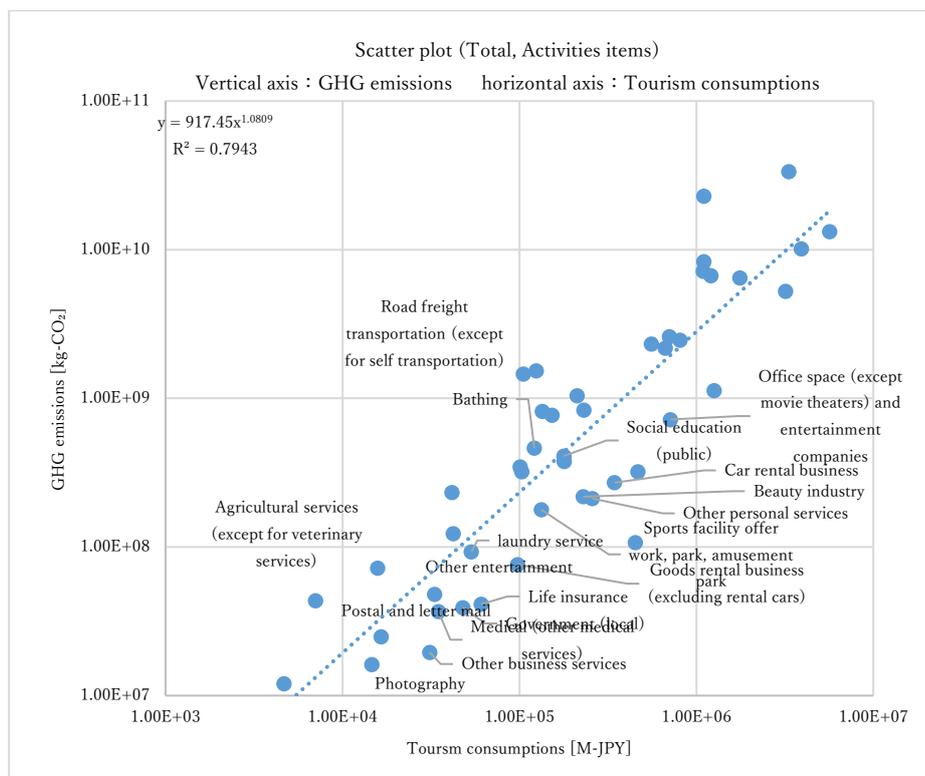
SI-Figure 3., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Accommodation items.
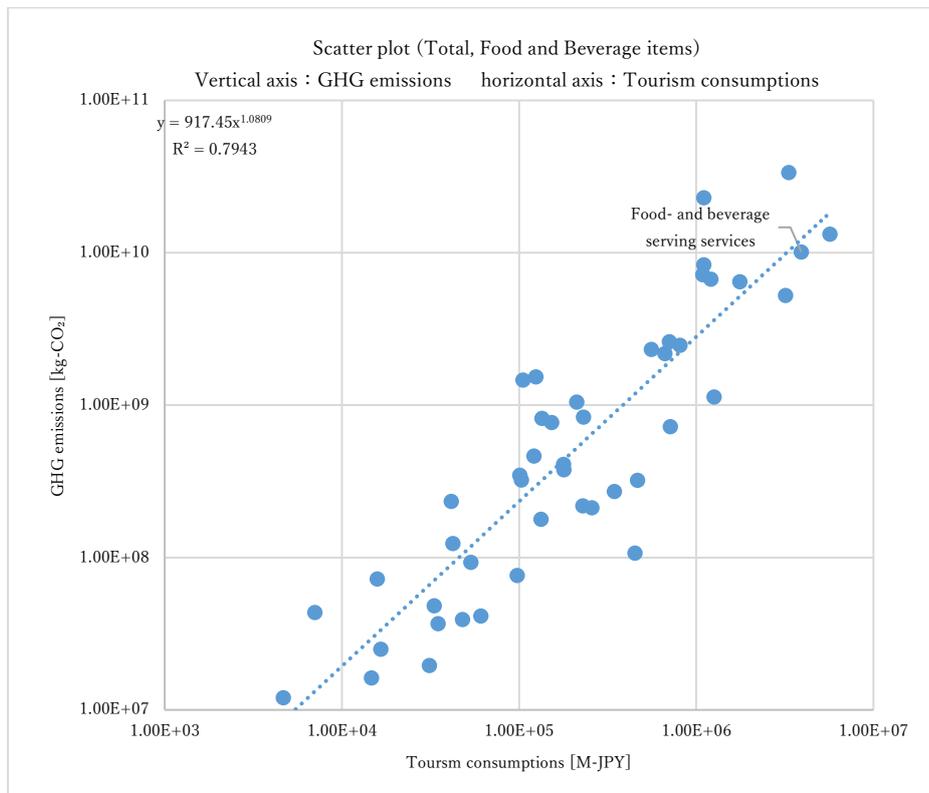
SI-Figure 4., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Food and Beverage items.

SI-Figure 5., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Souvenirs items.

SI-Figure 6., Scatter plot by product category (details in Figure 7 Scatter plot of Total GHG emissions and Tourism consumptions). Text in figure indicates are only Activities items.

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