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FOOD WASTE AND CARBON FOOTPRINT ASSESSMENT ON SELECTED FOOD SERVICE ESTABLISHMENTS ON THE EAST COAST OF MALAYSIA

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Abstract: The food service sector is expected to keep expanding with the increasing population's demand for food. This study investigates how the daily operations of food services along Malaysia's East Coast affect the environment. Food stalls, steamboats, and casual dining restaurants were among the various food service establishments chosen. During an audit of food waste, three categories were identified: Preparation loss (PREP), serving loss (SERVE), and customer's plate loss (PLATE). The data was acquired by getting a record of water and electricity bills, as well as by weighing the food waste that was generated and recording it in a checklist. The flow process of the generated food waste was analysed and illustrated using Material Flow Analysis (MFA). Food waste was highest over the weekend. The average amount of food wasted per week was highest from PLATE waste at 84.75 kg and lowest from serving loss at 21.68 kg. The steamboat restaurants had the greatest weekly average electricity and water use, with 141.4 kWh and 15.46 $kgCO_2e$ of carbon footprint and 13.05 m^3 and 5.5 $kgCO_2e$, respectively. Reduced excessive amounts of eating and careful assessment during food preparation are the first two ways to decrease food waste.

Keywords: Food services establishment, material flow analysis, carbon footprint.

Introduction

The world's rapid development has increased the demand for various resources, including food, energy, and water. A greater amount of solid waste is produced due to the high supply demand. Retailers must consider the effects of environmental issues such as greenhouse gas emissions, water usage, and water contamination, air and soil systems when making decisions regarding food waste management (Moult *et al*., 2018). The term "food waste" describes food that has been purposefully discarded during the retail or consumption phases, even if it is fit for eating (Food and Agriculture Organisation of the United Nations, 2011). This applies to food that had been ruined before being thrown away and still edible food. Food waste often occurs at the retail and consumer level and is influenced by decisions made by customers and companies that take quality, appearance, and/or safety specifications into consideration. From the beginning of the preparation process, food waste generation is a challenge for the producer to manage. Meanwhile, any edible or inedible portion of food removed from the supply chain and either lost or cannot be retrieved is considered a food loss (Ostergren *et al*., 2014). Food loss occurs when it is inevitably rendered inedible by humans before being consumed. It is particularly common in low-income countries for food to be contaminated or damaged by pests or mould.

In the process of preparing food, waste can be created by chopping and peeling raw ingredients, making a mistake in the kitchen, and leaving food on the plates of customers. As a result, it stands out as the food service sector that provides the most solid waste (Girotto *et al*., 2015). Additionally, important elements that contribute to the development of food waste include serving style and timing (such as a buffet or à la carte), the types of food offered, and the precision of consumer expectations. Food waste is one of the largest contributors to the amount of waste generated daily due to the factors leading to other impacts, such as food security, the environment, and the economy (Eriksson *et al*., 2017; Schanes *et al*., 2018). Massive amounts of waste dumped at the dumping site contribute to air pollution and global warming due to methane gas emissions (Bingham, 2020).

Food waste production in Malaysia has grown during the past ten years. Huge amounts of food waste are produced due to many factors, including holiday celebrations, fruit-growing seasons, population growth, tourism, and lifestyle choices. The study was conducted in Marang, Terengganu, and Tanah Merah, Kelantan, two Peninsular Malaysia's East Coast states. These areas have beaches, waterfalls, and a jetty to Kapas Island, among other tourist attractions. Three food service businesses: Casual dining restaurants, steamboat restaurants, and food stalls, with various s were chosen.

A restaurant that uses table service or full-service, where the waiter serves the customer's order at the table, is known as casual or family-style dining. Typically, casual eating serves various meals, including breakfast, lunch, and dinner. Children are welcome in a family-style restaurant's relaxed ambience, and adults can eat a full meal there (Filimonau *et al*., 2020). In the steamboat restaurant, where all the ingredients and materials are prepared and served, guests are invited to cook their meals.

The exhaust fans, refrigerators, and fridges used the most electricity. Food stalls, in contrast, typically use raw materials that are ready to eat on their menus, meaning less time is needed for cooking and, therefore, less electricity and water are needed. The input and output techniques are used in material flow analysis (MFA) to determine whether the quantity or weight of the raw material used is equivalent to the quantity or weight of the food waste generated. The study aims to determine the food waste generation and carbon footprint production by the electricity and water consumption of the food services.

Materials and Methods

The summary of the strategy for this research is shown in Figure 1. The preparatory process involved creating a checklist and choosing food service businesses based on the predetermined criteria. The checklist consisted of information on water and electrical consumption, information on the food service process and establishment, food production, waste generation information and the weight of the food waste for calculating the carbon footprint. Phase two involved the observation sampling and tracking of the production of food waste, waste disposal

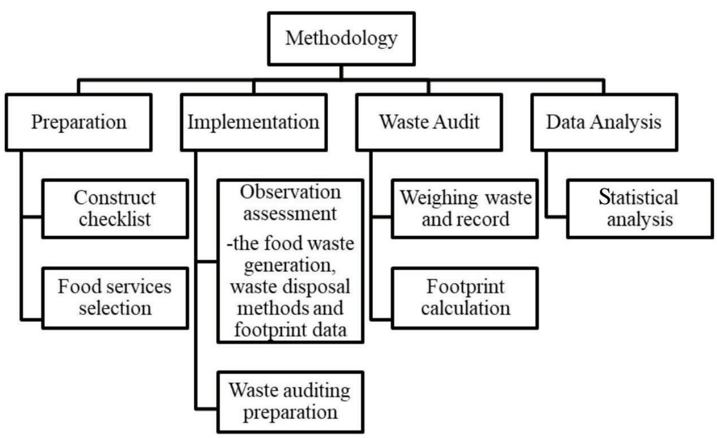

Figure 1: Phases in carrying out this study

techniques, and footprint information, which have been recorded in the checklist. After that, during the garbage collection phase, the gathered food waste was weighed using a calibrated laboratory analytical balance. Meanwhile, electricity and water consumption data were collected using readings from the meters taken before and after operating hours. The acquired data were then evaluated and interpreted for carbon footprint calculation.

Determination of Food Waste

The source and weight of food waste were obtained every day for a week for three categories: Preparation loss (PREP), serving loss (SERVE), and customer's plate loss (PLATE). Plastic bins and bags of different colours were given to each processing group. The checklist contained all the information that was collected. The weight of the garbage was determined using an in-situ calibrated measuring scale. In addition, electricity and water consumption data were collected based on the meter readings taken before and after operating hours. Data analysis was performed after all data required were obtained from the food services. The MFA and descriptive analysis were used to analyse the data.

Five food services were selected in Marang, Terengganu and Tanah Merah, Kelantan comprising similar criteria such as customer visits per day and food being served. Sunday till Thursday is assumed to be weekday one (WD 1) until weekday five (WD 5). Since the weekend in Kelantan and Terengganu fell on Friday and Saturday, some restaurants may close their operation on Friday, while others close on Saturday. So, Friday and Saturday were assumed to be weekends (WE 1). In order to complete the data collection for seven days, one weekday is repeated and assumed as weekday six (WD 6). Classifications of days were done to identify significant differences between food waste loss during weekdays and weekends.

Quantification of Carbon Footprint

The total amount of Greenhouse Gases (GHGs) emitted into the atmosphere caused by human activity daily, either directly or indirectly, and are typically expressed as carbon dioxide equivalents are known as a person's carbon footprint (CO_2e). These gases are known as greenhouse gases because they can trap heat in the atmosphere and emit radiant energy in the thermal infrared spectrum. The release of greenhouse gases causes climate change and global warming (MacCarthy *et al*., 2018). Two key variables must be considered when determining carbon footprint emission. The first variable is Activity Data (AD), which represents the quantification of processes. An organisation's activity data is used to determine the measurement unit.

This study uses electricity (kilowatt-hour, kWh) and water (m^3) consumption to determine carbon footprint emissions released into the atmosphere. The emission factor is the following variable for calculating carbon footprint (EF). The emission factor shows the CO_2 emission amount for each unit of the activity data. The value of emission factors was determined from direct measurement or publicly available data, according to a study done by Malek and Kumaresan (2019). Information was consistently collected over one week to determine the average electricity use. Equation 1 can be used to calculate the carbon footprint (Malek & Kumarasan, 2019).

Carbon footprint ($kgCO_2e$)
= Activity Data (AD) x Emission Factor (EF) (1)

An emission factor is required in calculating the carbon footprint generated by the restaurant. The emission components in this study were focused on electricity and water usage in producing food. According to Malek and Kumarasan's (2019) methodology, the emission factor value for Malaysia's commercial electricity rate is 0.10919 $kgCO_2e/kWh$, while the emission factor value for water use is 0.344 $kgCO_2e/m^3$.

Results and Discussion

The Food Waste Generation by Different Loss Categories

Following three distinct categories of food services: Preparation loss (PREP), serving loss (SERVE), and customer's plate loss (PLATE), Table 1 displays the overall amount of food lost for a week. The highest total weight of food loss recorded was at the steamboat restaurants with 452.68 kg, followed by casual dining and food stalls with a total weight of 211.20 kg and 29.81 kg, respectively. Food stalls, on the other hand, used ala carte and self-service, thus serving loss was irrelevant.

The daily average of the various food loss categories in the food services is shown in Table 2. The number of customers per day influenced food waste generation in restaurants. Comparing weekends to weekdays, the anticipated consumer volume may rise to over 50%. Most food waste is produced on weekends (Friday or Saturday). This is consistent with the general practice where people spend time with their families and dining on the weekends (Aamir *et al*., 2018). In addition, it causes consumers to order more food than is required. Whereas on weekdays, customers prefer to order delivery or take out, which results in less waste being produced at the food facilities. The business operation

Table 1: Total food losses generated at each type of food service

Types of Restaurants	Food Loss Categories			Total Weight (kg/week)
	Preparation Loss	Serving Loss	Plate Loss	
Food stall	17.63 kg	Not applicable	11.68 kg	29.81 kg
Casual dining	81.0 kg	48.4 kg	81.80 kg	211.20 kg
Steamboat	56.81 kg	70.20 kg	326.17 kg	452.68 kg

*Serving loss is not applicable for food stall restaurant

Table 2: Daily average of food loss categories at restaurants

PREP Loss	kg/day							Total weight (kg/week)
	WD 1 (Sun)	WD 2 (Mon)	WD 3 (Tue)	WD 4 (Wed)	WD 5 (Thu)	WD 6 (Sun)	WE 1 (Fri/Sat)	
Food stall	0.49	0.37	0.49	0.55	0.44	0.47	0.72	3.53
Casual dining	1.92	2.12	2.56	2.24	2.08	2.20	3.08	16.20
Steamboat	1.24	1.30	1.57	2.04	2.96	-	2.55	11.66
							Total:	**31.39**

SERV Loss	kg/day							Total weight (kg/ week)
	WD 1 (Sun)	WD 2 (Mon)	WD 3 (Tue)	WD 4 (Wed)	WD 5 (Thu)	WD 6 (Sun)	WE 1 (Fri/Sat)	
Food stall	*Serving loss does not apply to food stalls							
Casual dining	0.68	0.84	1.12	1.32	0.88	1.24	1.64	7.72
Steamboat	1.37	1.94	2.13	2.67	3.05	-	2.88	13.96
							Total:	**21.68**

PLATE	kg/day							Total weight (kg/week)
	WD 1 (Sun)	WD 2 (Mon)	WD 3 (Tue)	WD 4 (Wed)	WD 5 (Thu)	WD 6 (Sun)	WE 1 (Fri/Sat)	
Food stall	0.29	0.22	0.36	0.36	0.29	0.35	0.49	2.36
Casual dining	2.08	2.68	3.00	2.28	1.84	2.08	3.20	17.16
Steamboat	7.03	7.38	8.97	11.54	16.74	-	13.57	65.23
							Total:	**84.75**

(*Note: WD - Weekday, WE - Weekend)

hours were shorter than typical during the data collection period because of the COVID-19 pandemic.

Material Flow Analysis (MFA)

The business operation hours were shorter than typical during the data collection period because of the COVID-19 pandemic. An ecological tool called Material Flow Analysis (MFA) is used to quantify the intake and output of materials to comprehend each material's flux and flow across the entire system. MFA improves resource usage by reducing waste emissions and flattening resource consumption and intensity (Thushari *et al*., 2020). The MFA technique was used to identify the categories of food loss that contributed to the total amount of food waste at the food service operation, as shown in Figure 2. Thus, the MFA technique was created to generate a detailed understanding of the waste generation flow from the preparation stage to the plate. The Sankey diagram represents three types of food services and loss categories. A framework for the food consumption lifecycle is beneficial to comprehend and create the interactions between people and their food (Ng *et al*., 2015). The highest food waste was generated by PLATE with 51.21% and, followed by PREP with 37.40%. Steamboat restaurants had the highest PLATE with 71.80%, while food stalls had the most PREP with 59.93%. However, neither a steamboat restaurant nor a casual eating establishment has significantly increased SERVE.

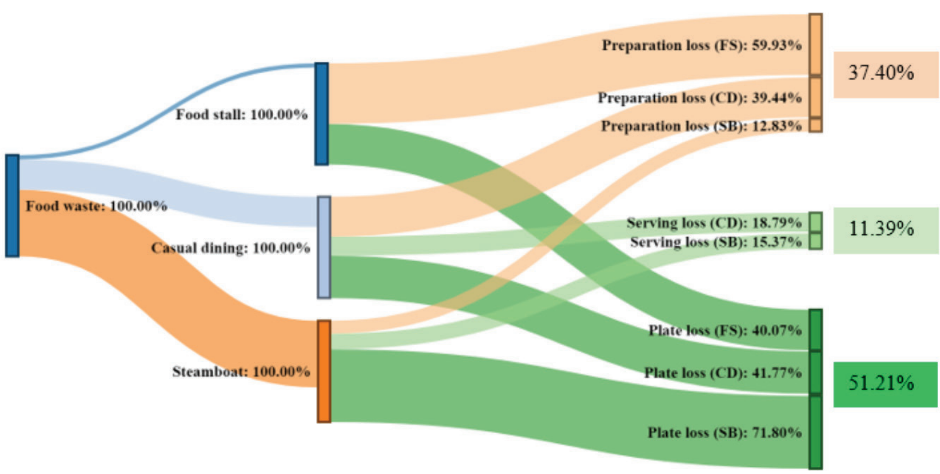

Figure 2: Sankey diagram of material flow analysis for different food loss categories
(*Note: FS-Food stall, CD-Casual dining, SB-Steamboat)

The quantity of food waste produced by Steamboat was 65.92%, followed by casual dining with 29.81%. Based on food loss categories, most food was generated from plate loss. Plate loss commonly occurs because customers tend to take or order too much food but leave the food on the table. For instance, individuals enjoy dining out with their families, especially on the weekends. However, the quantity of food ordered could be greater than what is devoured, leaving food on the table. Besides, large portions of food served may also contribute to plate loss. The provision of unlimited quantities of food at buffets and steamboat restaurants contributed to the accumulation of food waste (Papargyropoulou *et al*., 2019). The size and shape of the plate can also affect how much food is consumed. This is because the large plate size triggered more food to be consumed by customers (Bharucha, 2018). According to many studies, restaurant waste cans overflow with food waste instead of other types of waste, such as glass, paper, plastic-wrapped items, and other materials (Tatano *et al*., 2017).

Since families can spend time together without distraction from everyday activities or technology, steamboat establishments are most popular on weekends (Ng *et al*., 2015). Steamboat restaurants have high PLATE because all the raw materials are served unlimitedly without being fully processed and the consumers acquire to cook by their selves. Thus, the food waste was generated by the ingredients used in the steamboat process, such as the shell, vegetable peels, bones, and non-edible parts. A study found that unavoidable food waste was largely in the cafeteria where the food was dined (Daud *et al*., 2022).

Amount of Carbon Footprint Emission from Daily Electricity Consumption

The food service establishment's daily average electricity consumption is shown in Figure 3. It was discovered that the Steamboat restaurant used the most electricity. This kind of restaurant requires additional ventilation systems in both the cooking area and the dining room, where kitchen extractor fans were installed to eliminate food aroma, bad odours, smoke, steam, and airborne grease while cooking. Refrigerators and fridges were also required to maintain the freshness of the food ingredients. The value of WD6 for the Steamboat restaurant was not mentioned as the Malaysian Movement Order (MCO) was announced and the data collection needed to be stopped immediately.

Steamboat restaurants had the greatest daily average electricity consumption among the three food service establishments. The size of the restaurant and the total number of customers it served over the week were considered. The

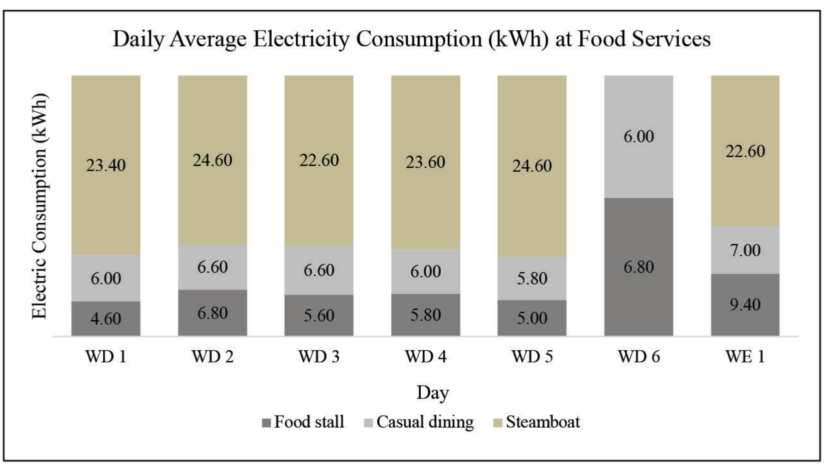

Figure 3: Daily average of electricity consumption (kWh) at food services establishment
(*Note: WD: Weekday, WE: Weekend)

daily average carbon footprint ($kgCO_2e$) for electricity use at three distinct types of food services is shown in Figure 4. The steamboat restaurant had the greatest average carbon footprint emissions, especially on WD 2 and WD 5, with 2.69 $kgCO_2e$, and 2.58 $kgCO_2e$ on WD 4. Electric kitchen appliances such as refrigerators, chest freezers, and food processors, which are frequently used, were the main sources of the carbon footprint. A study by Mudie *et al.* (2016) discovered that refrigerators in commercial kitchens consume the most electricity on average each day, at 70 kWh, or 41% of the total electrical consumption of all kitchen appliances. Many studies have proven strong relationships between energy usage and CO_2 emissions (Oluseyi *et al*., 2016; Sanches-Pereira *et al*., 2016). Energy production is a major source of greenhouse gases (GHG) released into the environment (Uyigue, 2009).

Amount of Carbon Footprint Emission from Daily Water Consumption

The carbon footprint is also influenced by water consumption. Water is required for dishwashing, hand washing, washing raw ingredients, and cleaning the kitchen and dining areas. The average amount of water consumed daily by three different types of food service operations is shown in Figure 5. The energy consumption related to water can be reduced by using less. Water efficiency may offer energy savings and

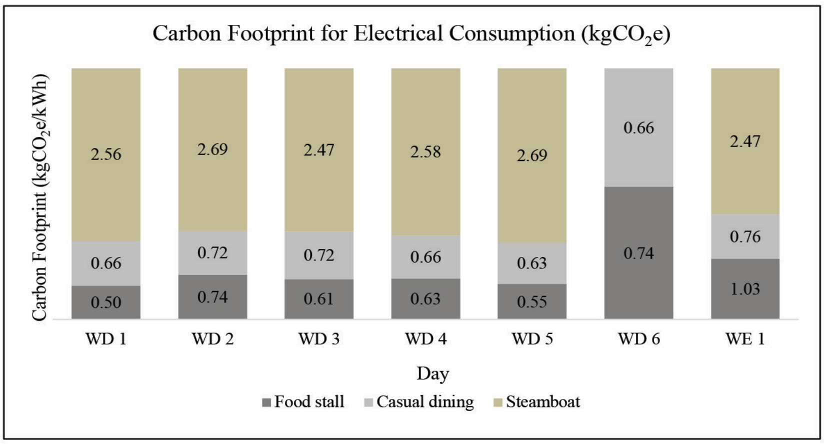

Figure 4: Daily average of carbon footprint for electricity consumption ($kgCO_2e$) at food services
(*Note: WD: Weekday, WE: Weekend)

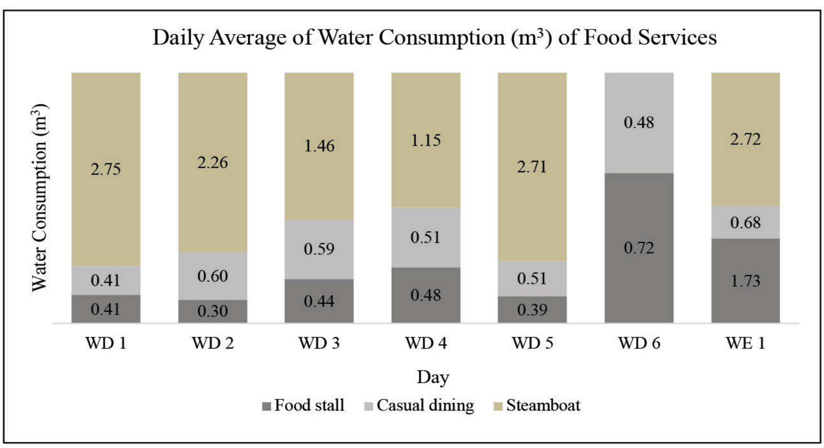

Figure 5: Daily average of water consumption (m^3) of three types of food services
(*Note: WD: Weekday, WE: Weekend)

chances for capturing the relationship between water and energy in terms of maximising energy and carbon reductions (Chen *et al*., 2021).

Figure 6 represents the carbon footprint generated from the water consumption from all three types of food services. The highest carbon footprint was recorded on WD 1 with a value of 0.95 kgCO_2e from steamboat restaurants. Meanwhile, the lowest carbon footprint was on WD 2 from food stalls, valued at 0.10 kgCO_2e.

All the data acquired reveals various findings depending on the kinds of food service establishments. A few variables, such as the size of the food service establishment, the number of customers, and the power and water usage, impacted the output results. Food waste being disposed of in landfills raises serious concerns because, as it decomposes, methane is produced, a greenhouse gas 25 times more potent than carbon dioxide (Jereme *et al*., 2016). Certain countries, including Malaysia, lack a comprehensive food waste management system despite some strategies being in the planning and research processes (Thi *et al*., 2015). In an effort to address the issue of food waste generation, Malaysia may be able to adopt successful food waste management strategies from nations like Japan, Taiwan, Thailand, and South Korea (Lim *et al*., 2016). Malaysia produces a significant amount of food waste, which could become a serious future challenge. The relevant institution or authorities should concentrate more on developing a programme for reducing and recycling food waste because it is recyclable and biodegradable.

Conclusion

The consumers' leftover food generates the greatest amount of food waste. Among other types of service, steamboat restaurants had high average total electricity and water consumption, which resulted in a high overall carbon footprint. The study provides a baseline and depicts the trends in food waste generation and carbon footprints at regular restaurants throughout Malaysia's East Coast. Food waste was produced more frequently on the weekends than on other days. Reducing food waste affects the national economy and the sustainability of the environment by reducing greenhouse gas emissions, water consumption, and land use internationally. A Material Flow Analysis (MFA) approach was discovered to create a full understanding of the waste generation flow from the preparation stage to the plate. A Material Flow Analysis (MFA) approach was shown to be helpful in generating the waste generation flow, which can be used to fully understand the waste generation flow from the preparation stage to the plate.

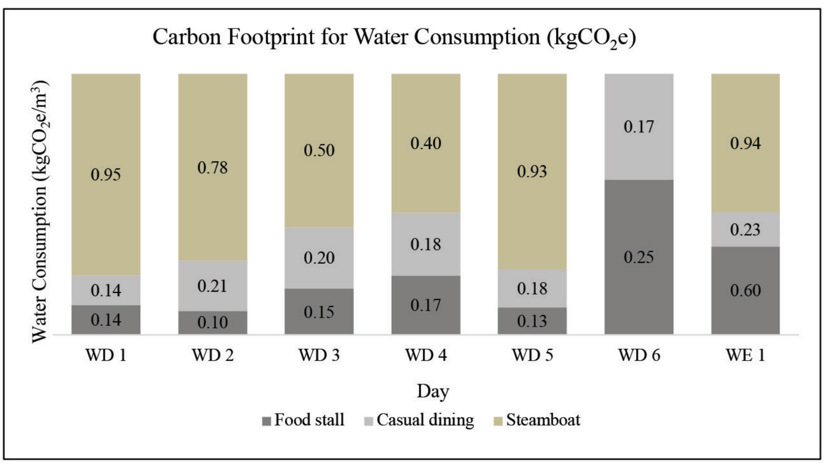

Figure 6: Daily average of carbon footprint for water consumption (kgCO_2e)
(*Note: WD: Weekday, WE: Weekend)

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