

國立臺灣大學管理學院企業管理碩士專班

碩士論文

Global MBA

College of Management

National Taiwan University

Master Thesis



生鮮食品包裝之循環經濟研究- 以臺灣家樂福為例

Research on the Circular Economy of Fresh Produce Packaging:

The Case of Carrefour Taiwan

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中華民國 112 年 7 月

July, 2023



國立臺灣大學碩士學位論文
口試委員會審定書

Master Thesis Certification by Oral Defense Committee
National Taiwan University

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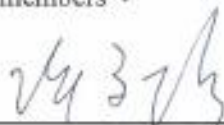
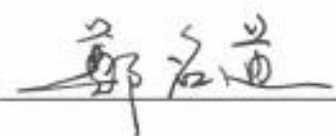
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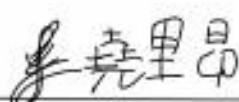
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Acknowledgment

Completing this Case Study could not have been possible without my thesis advisor's invaluable support and patience, Professor Charlie Chen, Ph.D. Thank you so much for teaching me and for your guidance. I also greatly appreciate the Committee members, Professor Audrey Hsu, and Professor Ming Daw Cheng, for their time and useful suggestions.

My sincere gratitude to Carrefour's Management, in particular to Ms. Dream Lin, CSR Manager Carrefour Taiwan; Ms. Joanne Liao, Project Manager of Carrefour Taiwan Cultural & Educational Foundation (財團法人家樂福文教基金會), Carrefour CSR Division (家樂福企業社會責任部), and Carrefour's Impact Store staff for their courteous hospitality and collaboration. I deeply appreciate their willingness to participate in this research, answer all my questions, and clarify doubts.

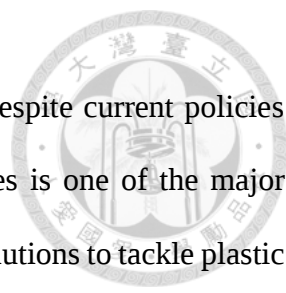
Thanks also to all my friends and individuals that made this research possible. A debt of gratitude to Professor Leon Van Jaarsveldt, Ph.D., Joyce Chu, Ann Chen, and Peter Chang for their invaluable advice and support when decisions were difficult to make.

Finally, yet importantly, to my beloved family, who showed me the value of nature and involvement in common causes with their life examples. Thanks for encouraging me from a distance (12,961 km away from Mexico to Taiwan) to put my heart into this project.

Humans first shaped plastics, but plastics have shaped humans' life.

– Daniela Mendez

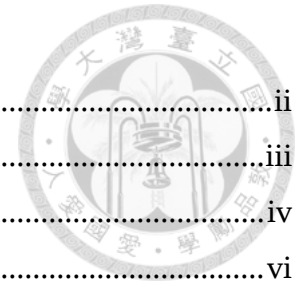
Abstract



Global projections warn that plastic production will double by 2050 despite current policies and the use of alternative materials. Packaging for food and beverages is one of the major demand drivers of the global plastic demand, and experts suggest that solutions to tackle plastic waste generation and pollution must rely on new economic models and policies to prevent and reduce plastic. Taiwan has one of the highest recycling rates in the World; nonetheless, pollution is still a problem. Some environmental organizations point out Supermarkets as responsible for generating a considerable amount of plastic waste. However, there is limited knowledge of the challenges and opportunities that retail companies face to attain plastic packaging use prevention and reduction. This study focuses on the retail sector in Taiwan, taking the case of Carrefour Taiwan to analyze, from the business perspective, the barriers and enablers to reducing and eliminating primary plastic packaging for a specific and limited range of products: fruits and vegetables. The main purpose is to understand which factors prevent and enable the reduction of fresh produce packaging, to what extent those factors can be controlled by the retail company, and detect opportunities to reduce plastic packaging and, consequently, achieve a Circular Economy guided by the Waste Hierarchy Principles. The methodology combines qualitative data and a model adapted from Ma et al. (2019b). The results provide an overview of organizational, operational, technical and technological, stakeholder-related, legal, and commercial considerations.

Keywords: Plastic Packaging, Circular Economy, Waste Hierarchy, Retail Industry, Fresh Produce, Plastic Reduction

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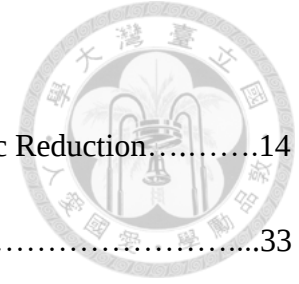


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List of Abbreviations



ABS	Acrylonitrile Butadiene Styrene
AFA	Agriculture and Food Agency
ASA	Acrylonitrile Styrene Acrylate
CAGR	Compound Annual Growth Rate
CE	Circular Economy
CGR	Circularity Gap Report
COA	Council of Agriculture
C2C	Cradle-to-Cradle
DRS	Deposit Return System
EPA	Environmental Protection Administration
EPR	Extended Producer Responsibility
EU	European Union
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FMCG	Fast-Moving Consumer Goods
FSMA	Food Safety Modernization Act
GHG	Greenhouse Gas Emissions
HDPE	High-Density Polyethylene

KPI	Key Performance Indicators
LCA	Life Cycle Assessment
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MAP	Modified Atmosphere Packaging
MDPE	Medium-Density Polyethylene
MOF	Ministry of Finance Taiwan
MSW	Municipal Solid Waste
MT	Million Tonnes
NPEGC	New Plastics Economy Global Commitment
OAPC	Organic Agriculture Promotion Center
OECD	Organization for Economic Cooperation and Development
OMO	Online-Merge-Offline
PE	Polyethylene
PET	Polyethylene Terephthalate
PLA	Polylactic Acid, or Polylactide
PP	Polypropylene
PS	Polystyrene
PS-E	Polystyrene Expandable
PSF	Plastic Soup Foundation



PUR	Polyurethane
PVC	Polyvinyl Chloride
rPET	Recycled PET
SAN	Styrene Acrylonitrile Resin
SDG	Sustainable Development Goals
TAP	Traceable Agricultural Product
TFDA	Taiwan Food and Drug Administration
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
WFD	Waste Framework Directive
WH	Waste Hierarchy
WHO	World Health Organization



1. Chapter 1: Research on the Circular Economy of Fresh Produce Packaging:

The Case of Carrefour Taiwan



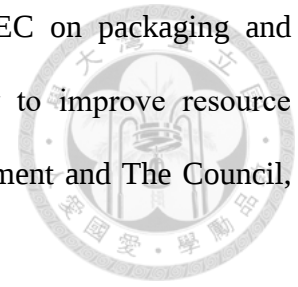
1.1 Background

Plastic has transformed humans' life since the nineteenth century, providing countless benefits that have contributed to the rise of modern societies. According to the OECD (2022b), global plastic production reached 460 million tonnes (MT) in 2019 being packaging the sector that accounts for the largest global demand (about 40%) for this raw material, from which “about 60% is driven for food and beverage products” (Groh et al., 2019; as cited in Wang & Lin, 2022).

On the other hand, global plastic waste more than doubled from 2000 to 2019, with 353 MT in 2019 (OECD, 2022b), fueled by the massive usage of single-use and disposable plastics. Recent research studies have raised awareness of plastics' fate and negative impact on biodiversity and human health. Jung (2023) explained that “more than 8 MT of plastic waste are dumped into oceans annually.” The OECD, in its report “Global Plastics Outlook: Policy Scenarios to 2060,” stated that solutions to tackle environmental problems generated by plastics “should rely on more than one single solution and instead take actions to curb plastic demand, increase product lifespans, improve waste management and recyclability, and implement policies to encourage a circular use of plastics” (OECD, 2022a).

Similarly, Jung (2023) has pointed out that the approach focusing on waste management will not be able to prevent the generation of plastics and their negative environmental impact since their usage generates substantial damage at each stage of the plastics lifecycle, underlying the importance of taking a lifecycle approach and a change from waste management to resource management. In addition, the Directive (EU) 2018/852 of the European Parliament and of The

Council appointed in paragraph number 4 of the Directive 94/62/EC on packaging and packaging waste that “waste prevention is the most efficient way to improve resource efficiency and to reduce its environmental impact,” (European Parliament and The Council, 2018).



1.2 Research Problem

In Taiwan, according to estimations by Wang and Lin (2022), “around 21,846.04 tons of plastic waste were generated by the major supermarkets and convenience store chains solely in Taipei in 2020, from which 65% was recycled in the same year”. Although recycling extends plastics’ lifecycle, it does not prevent the final disposal of a material that does not decompose and accumulates in landfills, open dumps, or ecosystems (Geyer et al., 2017). Models like the Circular Economy (Ellen MacArthur Foundation, n.d.-a) and Waste Hierarchy Principles propose the adoption of an economy based on “closed-loop systems” (Kara et al., 2022) that prioritize in order of environmental contributions, the reduction, reuse, and recycling of materials (Pires, 2019). At the same time, plastic packaging has a broad range of applications for the steadily growing retail industry. It helps to ensure food safety and makes the supply chain more efficient. It also serves marketing purposes such as product display, labeling, communication, brand differentiation, and sales (Francescucci, n.d.). More importantly, plastic packaging extends food shelf life, reducing food loss and waste, which is a serious “social and environmental concern” (UNEP, 2021; World Wildlife Fund, n.d.). Therefore, several challenges to plastic packaging reduction and elimination require a better understanding of factors that constitute barriers and enablers, the level of control retail companies have over those factors, and opportunities to achieve this reduction.

1.3 Research Objective and Questions

There is increasing pressure on the global retail industry for a faster and more significant plastic packaging reduction and to adopt sustainable business models and practices such as the Circular Economy (CE) and Waste Hierarchy Principles. However, there is limited knowledge of the challenges and opportunities that retail companies face to attain plastic packaging use prevention and reduction.

This study focuses on the retail sector in Taiwan, taking the case of Carrefour Taiwan to analyze from the business perspective barriers and enablers to reducing and eliminating primary plastic packaging (referred to only as plastic packaging for the effects of this research) for a specific and limited range of products: fresh produce. According to the Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA), fresh produce “is defined as any fruit or vegetable (or their intact mixes) that includes mushrooms, sprouts, peanuts, tree nuts, and herbs” (Rogers, n.d.). The main purpose of the study is to understand which factors prevent and enable the reduction of fresh produce packaging, to what extent those factors can be controlled by the retail company, and detect opportunities to reduce plastic packaging and, consequently, achieve a Circular Economy guided by the Waste Hierarchy Principles. Therefore, the following research questions are addressed:

- Which factors inhibit and enable fresh produce plastic packaging reduction in Carrefour Taiwan?
- How controllable are those factors by this retail company?
- What are the opportunities to achieve plastic packaging reduction?

1.4 Scope and Limitation of the Study

Citing the analogy by Carter (2020), “I needed a roadmap to navigate to my destination,” this case study follows a roadmap that explores different sections that helped to frame this research. First, from a general perspective, this case study introduces global plastic production and summarizes the most recent and relevant global plastic reduction initiatives. It also provides an overview of Taiwan’s regulations, waste management system, plastic waste generation, and pollution, and the importance of implementing a Circular Economy model guided by the Waste Hierarchy Principles, taking the Waste Hierarchy scheme proposed by the European Waste Framework Directive as a base.

From a particular standpoint, this Case Study analyzes factors that inhibit and enable plastic packaging reduction and elimination by the retail sector for a specific group of products: fruits, and vegetables, and how controllable they are, taking the example of one of the leading supermarkets in Taiwan, being Carrefour, the primary focus. Conversely, this study does not deepen the vast CSR strategies the research participant has implemented for other product categories. It is not the purpose of this research to criticize or judge actions carried out by the participant but instead to take a critical approach to identifying opportunities to reduce plastic packaging.

The study's limitations are the number of retail companies participating. A bigger number of research subjects can help to have a deeper understanding of their challenges, compare differences and similarities, and generate conclusions applicable to the whole industry. Nonetheless, this work can still provide insights into the context and challenges to reducing fresh produce plastic packaging in Taiwan.

1.5 Importance and Significance of the Study

Current literature does not analyze the reasons plastic reduction has not been successfully achieved from a business perspective and how to effectively implement a circular economy of plastics that does not simply focus on recycling but on resource management considering the whole lifecycle of plastics where implementing the waste hierarchy principles is crucial. More importantly, it is essential to understand each stakeholder's roles in the system to contribute and help the retail industry attain its environmental plans and goals since their actions and decisions may affect the overall plastic packaging reduction.

2. Chapter 2: Literature Review

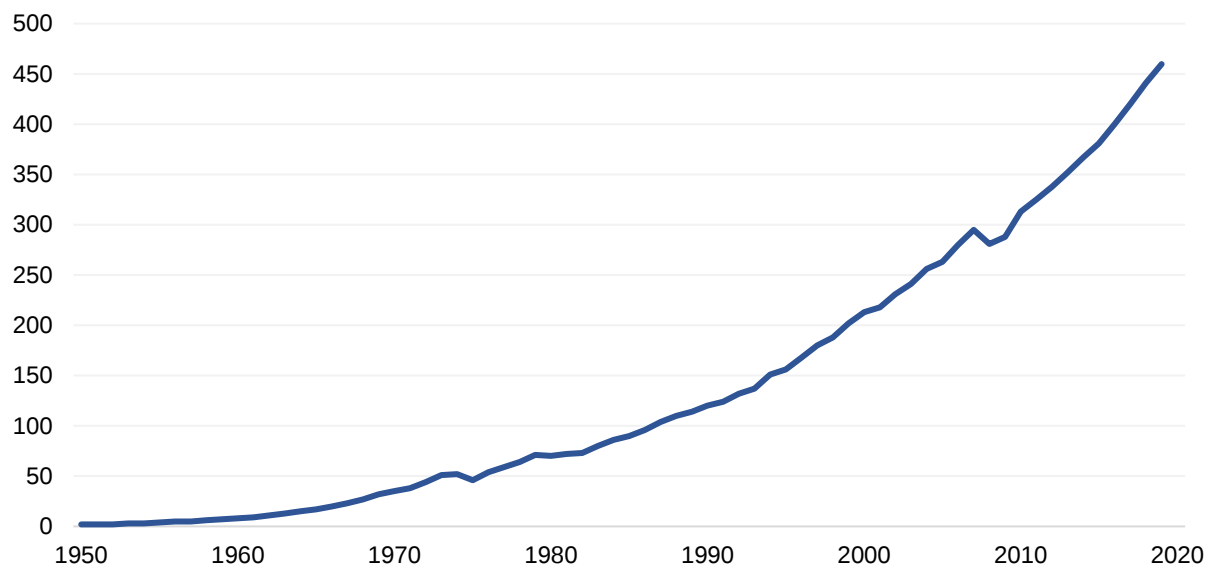


2.1 Plastic Evolution Through Time

Curiosity and the need to find new materials helped humans to start using natural resources with plastic properties, such as chewing gum, horns, tortoiseshell, and shellac, a resinous excretion of the Asian lac insect (Plastics Europe, 2023). Later, humans experimented with the chemical transformation of natural substances like collagen, nitrocellulose, and vulcanized rubber. In 1855, Alexander Parkes invented the “Parkesine,” known these days as celluloid, the first artificial plastic. Polyvinyl chloride (PVC) was polymerized for the first time between 1838 and 1872. However, it was until 1907 that Leo Baekeland, a Belgian chemist created the first synthetic mass-produced plastic called “Bakelite,” a thermosetting phenol formaldehyde resin that was relatively expensive at that time but rapidly adopted for the automobile and radio industries (Plastics Europe, 2023; Science History Institute, 2017). Plastics enabled producers to create and sell new products in local and foreign markets that were thereafter reachable even for consumers of low purchasing power (Freinkel, 2011), leading to a social and economic transformation.

Plastic consumption increased after World War II, around 1950, at a compound annual growth rate (CAGR) of 8.4% (See Figure 1) (Geyer et al., 2017; Our World in Data, 2019). Nowadays, there are hundreds of types of plastics, but just a few constitute the basis of materials we use daily, and even fewer types can be recycled, depending on each country's and municipality's capacity and capabilities (See Figure 2) (Hardin, 2021; Plastic Action Centre, n.d.; Ministry for the Environment, 2023). Although the massive production of plastics has been no more than 100 years, it has changed modern life, providing countless applications and benefits but also drawbacks due to the lack of vision and prevention of future consequences.

Figure 1. Global Production of Polymer Resins and Fibers (1950 – 2019, in MT)



Source. Our World in Data (2019). *Global Plastics Production*. Global Change Data Lab.

(<https://ourworldindata.org/grapher/global-plastics-production>).

Figure 2. Plastic Identification Code and Recyclability

Easier	Easier	Difficult	Possible	Easier	Difficult	Difficult
PET	HDPE	PVC	LDPE	PP	PS	OTHER
Polyethylene Terephthalate	High-Density Polyethylene	Polyvinyl Chloride	Low-Density Polyethylene	Polypropylene	Polystyrene	Other
Common Products						
Often used as a single-use food and drink container such as water & fizzy drink bottle, trays, and prepared frozen food.	A hard plastic, not as transparent PET, that is often used for household cleaners, shampoo bottles, and yogurt containers.	Frequently used for tubing, pipes, trays, cling film, blister packaging, food packaging, paneling, decking, fencing, bottles, and children's toys.	Often used for soft plastic products, food and non-food bags, paper milk cartons, hot-cold beverage cups, squeeze bottles, and plastic film.	Commonly found in temperature-resistant food containers, trays, takeaway containers, straws, furniture, luggage, and caps.	It can be hard or expanded (known as styrofoam). It is usually used for tableware, meat trays, CD cases, foamy packaging, and insulation.	Any plastic not made from the previous types of plastic, such as bioplastics, PLA (Polylactic Acid), meat trays, bottles, and mixed plastics.

Source. Adapted from Hardin, T. (2021, February 23). *Plastic: It's Not All the Same*. Plastic Oceans International. (<https://plasticoceans.org/7-types-of-plastic/>); Plastic Action Centre. (n.d.). *Plastic by the Numbers*. (<https://plasticactioncentre.ca/directory/plastic-by-the->

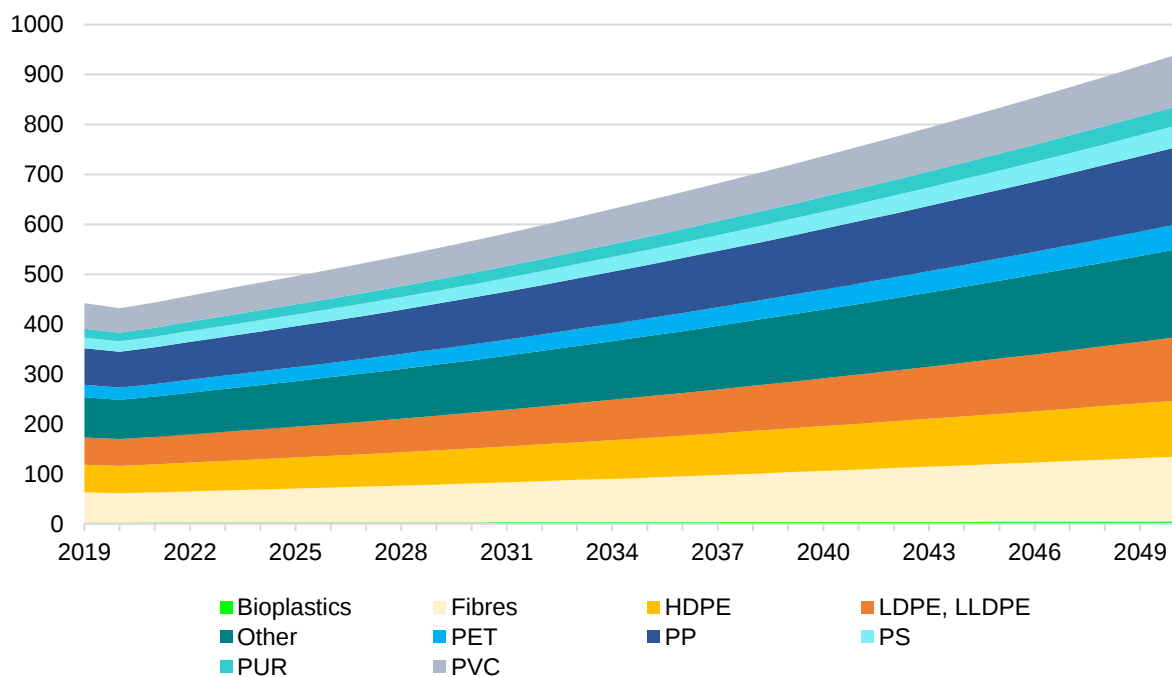
numbers/); Ministry for the Environment. New Zealand. (2023). *Phasing out hard-to-recycle and single-use plastics*. (<https://environment.govt.nz/what-government-is-doing/areas-of-work/waste/plastic-phase-out/>).

Note. Plastic recycling depends on each country and municipality's regulations, capacity and infrastructure.

2.2 Global Plastic Consumption Projections

Global plastic consumption and waste are expected to increase despite efforts on recycling, technological innovation, and sectoral economic shifts “in the absence of bold new policies” OECD (2022a). Projections made by the OECD (2023) show a use increase from 460 MT in 2019 to 976 MT by 2050, where polypropylene (PP), polyethylene (PE), fibers, and PVC are predicted to be some of the most widely used. This trend could be changed by adopting new policies and resolutions towards plastics (See Figure 3).

Figure 3. Plastic Use by Polymer, Global Projection (2019 – 2050, in MT)



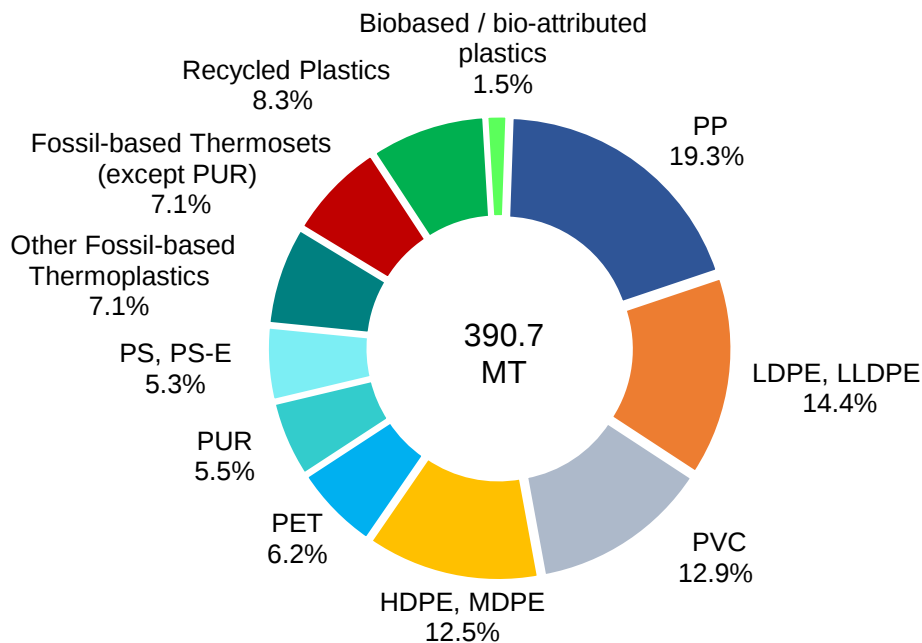
Source: Organization for Economic Cooperation and Development. OECD. (2023). *Global*

Plastics Outlook: Plastics use by Polymer – Projections. OECD Environment Statistics. [Data set]. (<https://doi.org/10.1787/b9bae4d1-en>).

Note. Excluding data about elastomers (tires), marine coatings, road marking coatings, acrylonitrile butadiene styrene (ABS), acrylonitrile styrene acrylate (ASA), styrene-acrylonitrile resin (SAN) for not being relevant for this study.

A report published by Plastics Europe (2022) shows that, in 2021, circular plastics (recycled, biobased and bio-attributed plastics) constituted about 9.8% of the global production of plastics (See Figure 4). Some of the most widely-produced plastics were PP at 19.3%, followed by low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE) at 14.4%, PVC at 12.9%, high-density polyethylene (HDPE) and medium-density polyethylene (MDPE) at 12.5%, polyethylene terephthalate (PET) 6.2%, polyurethane (PUR) at 5.5%, polystyrene (PS) and polystyrene expandable (PS-E) at 5.3%, other fossil-based thermoplastics at 7.1%, and fossil-based thermosets except PUR at 7.1%. As explained, recycled plastics had only an 8.3% and an even lower portion for biobased/ bio-attributed plastics at 1.5%. Brizga et al. (2020) mentioned that “replacing fossil-based plastic packaging with bioplastics is currently not viable since it may lead to a significant increase in land and water use and chemical pollution.”

Figure 4. Global Plastic Production Distribution by Type 2021



Source: Plastics Europe. (2022, October). *Plastics - the Facts 2022*.

(<https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/>). Based on data from Conversio Market & Strategy GMBH and Nova-Institute.

Note. Data are rounded estimations. Polymers not used in converting plastic parts and products are not included.

2.3 Global Plastic Pollution

It is infrequent to find literature talking about plastic pollution that does not acknowledge the multiple advantages and characteristics by which this material became so ubiquitous. Plastics are versatile, lightweight, inexpensive, durable, and resistant to degradation. Nevertheless, as Geyer et al. (2017) pointed out in a study about all plastics ever made globally, these two last-mentioned properties “are the same that make them hard or impossible to assimilate by nature” and, thus, one of the most significant pollutants on earth. The author mentions:

We estimate that 8300 million metric tons (MT) of virgin plastics have been produced to date. As of 2015, approximately 6300 MT of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. If current production and waste management trends continue, roughly 12,000 MT of plastic waste will be in landfills or ecosystems by 2050. Besides, most commonly used plastics do not biodegrade in any meaningful way.

Plastic pollution strongly correlates with rising populations and income per capita (OECD, 2022a). Its production and waste impact terrestrial and aquatic ecosystems such as rivers, groundwater, and oceans. With this regard, Jung (2023) mentioned that “80% of the plastics poured into the ocean come from land-based sources, causing damage to habitats, entanglement, and other risks to species”. One of the most impressive examples is the Great Pacific Garbage Patch, a giant floating mass of marine debris in the North Pacific Ocean that “is estimated to take 67 ships, one year to clean less than 1% of it”, resulting in a highly costly process. Moreover, this contamination may be only the tip of the iceberg when considering that “70% of marine debris sink to the base of the ocean” (National Geographic, n.d.).

Plastics also release toxins and damage the ozone layer when burnt. Animals mistakenly or inadvertently ingest macroplastics, mesoplastics, microplastics, and nanoplastics. The first is defined as fragmented plastic particles and fibers greater than >20 mm, the second in a 5–10 mm range, the third as less than 5 mm in size, and the latter as fragments in the 0.2–2 mm range (UNEP, 2015) which can penetrate human organs and tissue due to its small size (Crook, 2022). Recent studies have found microplastics in placentas, meconium, breast milk, infant feces, and infant formula that enter human bodies via the food chain (Liu et al., 2022); therefore, making

the fight against plastic pollution one of the most substantial challenges in recent years (Beaumont et al., 2019).



2.4 Plastic Reduction International Regulatory Framework

Several international laws, regulations, and treaties have been created to tackle plastic use and pollution and improve sustainability; nonetheless, this study approaches two of the most relevant from recent years: the UN Sustainable Development Goals, and the New Plastics Economy.

2.4.1 The UN Sustainable Development Goals

The UN Sustainable Development Goals (SDG) were born in 2012 at the United Nations Conference on Sustainable Development Rio de Janeiro (Rio+20 Summit) and launched in 2015 to establish universal objectives addressing environmental, political, and economic challenges (UNDP, n.d.). All 17 Goals have been adopted by many governments, enterprises, and organizations across the globe to improve their sustainability by 2030. These interconnected goals incorporate 169 targets measured against 248 indicators (United Nations, n.d., United Nations, 2022). The SDG and the CE model are interrelated since they both seek the sustainable use of resources and the prevention of climate change and loss of biodiversity.

Walker (2021) pointed out that only SGD 14: Life Below Water, has an indicator directly linked to reducing plastic and microplastic impacts. Nonetheless, his research analyzes the implications of twelve of the SGDs on plastic pollution and the Circular Economy. Similarly, the Plastic Soup Foundation (PSF, n.d.) has evaluated the connection of seven SDGs on plastic use reduction and pollution. Table 1 compares both authors' perspectives on seven SDGs in common in their respective works. It is also essential to note that conversely, plastic

packaging can positively contribute to SGD 2: Zero Hunger since it helps to prevent food contamination with external agents, human disease, and food waste, which are other critical problems (UNEP, 2021; World Wildlife Fund, n.d.).



2.4.2 The New Plastics Economy

The New Plastics Economy Global Commitment (NPEGC), proposed by the Ellen Macarthur Foundation and backed by the UN Environmental Programme, encourages governments, companies, and other organizations to “voluntarily commit to tackling plastic waste and pollution at its source” with the goal that plastic “never becomes waste or pollution.” The NPEGC initiated in 2018 has strict definitions that align with the Waste Hierarchy, although there is also a lack of precision in the formulation of targets that may affect the implementation of goals from companies (Rhein & Sträter, 2021). Signatories must commit to implementing CE measures by 2025 aimed at reducing or eliminating all unnecessary plastic and innovate to ensure the reusability, recyclability, and or compostability of plastic items. As of June 2023, thirteen countries from different continents and more than 500 organizations have joined the initiative, including Carrefour Group since 2018 (Our Ocean, 2022; UNEP, 2023; Ellen MacArthur Foundation (n.d.-e).

Table 1. Sustainable Development Goals and their Relation with Plastic Reduction

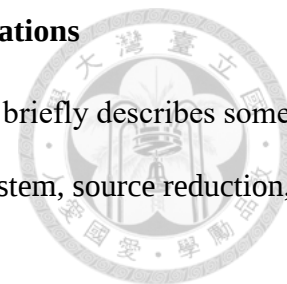
SDG Target		(PSF, n.d.)	(Walker, 2021)
	Good Health and Well-Being	Plastics can enter animals' and humans' bodies via inhalation, ingestion, and dermal exposure.	Some additives used in plastics may disturb hormone balance and other physiological effects.
	Clean Water and Sanitation	Freshwater quality must be improved, and reduce plastic pollution of inland bodies of water.	Pollution caused by plastic particles (microplastics) in drinking water and wastewater must be tackled.
	Sustainable Cities and Communities	Effective waste collection and processing, preventing plastic in the environment through reduction, is needed.	Indiscriminate disposal of plastics is affecting urban infrastructure.
	Responsible Consumption and Production	Plastic reduction is the best way to promote SDG 12 since recycling is not a realistic solution.	Sustainable consumption, production, and plastic waste reduction require extraordinary efforts.
	Climate Action	Production and the use of plastic have a smaller carbon footprint than alternatives like paper and metal.	Plastics and GHG emissions are intricately connected with every step of the plastic life cycle.
	Life Below Water	Cleaning plastic from beaches and the ocean is important, but overall, plastic flow must be reduced.	Extraordinary efforts are required to reduce emissions of plastics to marine and freshwater ecosystems.
	Life on Land	Significant reduction in plastics and microplastics will lead to the recovery of ecosystems and biodiversity.	Terrestrial ecosystems are estimated to receive 4–23 times more plastic waste annually than oceans.

Source. Plastic Soup Foundation. PSF. (n.d.). *Individual Sustainable Goals*.

(<https://www.plasticsoupfoundation.org/en/plastic-problem/sustainable-development/individualsdgs/#:~:text=SDG%2012%3A%20Responsible%20consumption%20and%20production&text=Burning%20all%20the%20plastic%20as,an%20absolute%20reduction%20in%20plastics>); Walker, T. R. (2021). (Micro)plastics and the UN Sustainable Development Goals. *Current Opinion in Green and Sustainable Chemistry*, 30, 100497. (<https://doi.org/10.1016/j.cogsc.2021.100497>).

2.5 Taiwan Environmental Context and Waste Management Regulations

In order to provide an overview of Taiwan's context, this study briefly describes some of the most relevant regulations on waste management, the recycling system, source reduction, environmental policies, and plastic pollution.



2.5.1 *Municipal Solid Waste Management in Taiwan*

The Waste Management System in Taiwan is a worldwide reference and has been praised for its efficiency and high recycling rates. This results from the evolution of almost five decades of waste management policies and programs that started in the 1970s. The industrialization and economic growth attained since the 80s propelled “rapid urbanization, an increase in living standards and consumption, and a decrease in the available land for waste disposal” (Sung et al., 2020). According to the Environmental Protection Administration (EPA), before 1984, only 2.55% of waste was properly discarded (EPA, 2023b). Consequently, and as stated by Houngh et al. (2014):

In 1984, the “Municipal Solid Waste (MSW) Disposal Plan” was framed to create and promote standard sanitary landfills to prevent illegal dumping areas and transform them into recreational and sports facilities. Besides, incineration was set as a long-term policy. Seven years later, the EPA announced the “MSW Disposal Plan,” targeting the improvement of waste recycling and a shift from landfill to incineration by constructing 21 incineration plants.

These incinerators would also function as power generators to supply electricity for incineration operations and the exceeding, to be sold to the Taiwan Power Company and governments for public use (Tsai et al., 2020). By 2020, 24 incinerators were in operation. A report made in 2018 by National Geographic (Sedaghat, 2018) about Neihu's Incineration Plant

in Taipei mentions that single-use plastics made of non-recyclable materials such as melamine (plastic type identified with the recycling number 7 used in some food containers) generate the most waste to be incinerated at the plant. A report by Ching (2022) mentions that waste volume keeps growing around Taiwan. In 2021, for example, residential garbage set a new record at over 10 million tons, while industrial waste output reached around 20 million tons.

2.5.2 Waste Recycling

In 1998, several laws were promulgated to enhance the recycling process, and the “Four-in-One Recycling Network” was established involving four parties: community residents, recycling enterprises, municipalities, and recycling funds (EPA, 2023c; Houngh et al., 2014; Sung et al., 2020). This still ongoing program also works as a way of “Extended Producer Responsibility (EPR),” where manufacturers, importers, and retailers of mandatory recycling items must pay a fee that goes into a recycling fund to subsidize recycling activities. Furthermore, the support provided by the public through waste sorting, community-based voluntary recycling organizations, as well as from governmental institutions for education and promotion of the reuse and recycling of some products has been vital to accomplishing favorable outcomes. Under the framework of these measures, the Taiwan Recycling labeling system was developed to identify and guide consumers on the sorting for recycling of products (EPA, 2012).

As a result of the implementation of these and many subsequent laws, regulations, and programs, by 2020, 96.86% of waste was properly disposed of (EPA, 2023b). The resource recovery rate (equal to the summation of the recyclable regulated articles that includes plastic, paper, metal, glass, batteries, tires, electronic appliances, and IT equipment, among others) was 62.71% in the same year. Nonetheless, percentages of recycled waste and refuse (not recycled

waste) have varied depending on the municipality, city, and county and their particularities, such as lifestyle or the implementation of specific programs like the volume-based waste collection fee system known as “pay-by-bag” applied in Taipei City and New Taipei City (Sung et al., 2020).

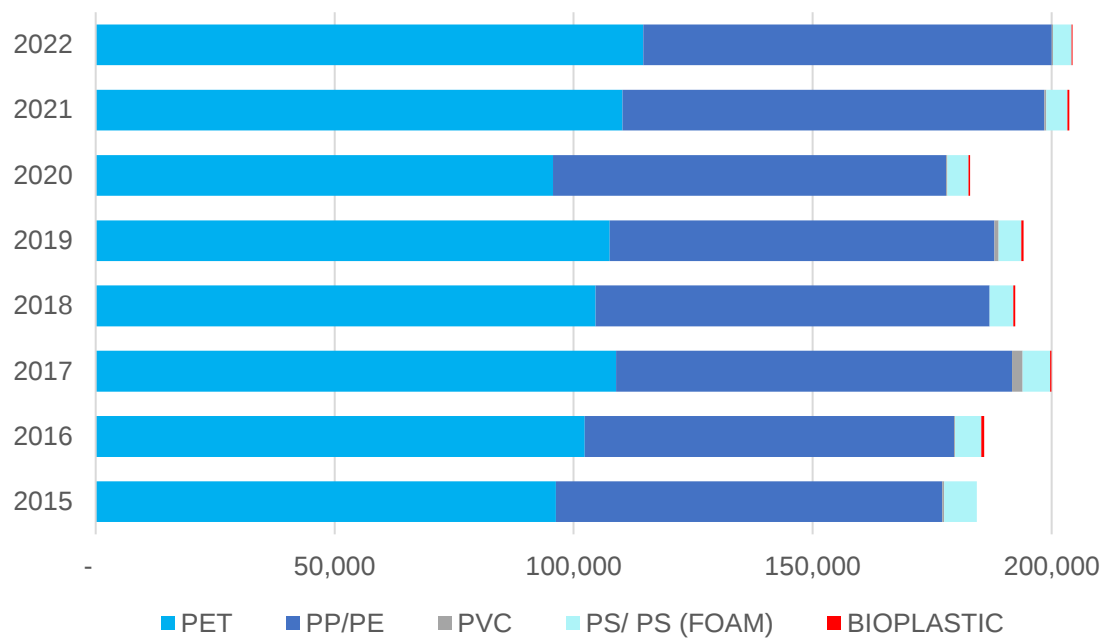


2.5.3 Plastic Source and Recycling

Taiwan primarily relies on imported feedstock to supply its plastic industry. Research published by Lai & Lee (2022) mentioned, for example, that in 2019, “there was a total of 13.05 MT of plastic resources available in Taiwan, from which 12.55 MT were imported, and 0.5 MT domestically recycled. Almost 80% of the existing plastic was used to produce finished goods and high-quality pellets to export to foreign countries.” Recycling is not only good for the environment but also helps Taiwan to relieve reliance on fossil fuel imports, affected by the international petrochemical prices, especially after the Russia and Ukraine conflict, and by the implementation of carbon taxes from important trading countries (Liu 2022; Strong, 2022).

An analysis made using data collected by the EPA on certified recycled plastic volume in Taiwan (2015 – 2022), shows an overall increase in the recycled volume of PET and PE/PP and a decrease in PS, PS (Foam), PVC and Bioplastics. Lai & Lee (2022) pointed out that biobased plastic volume significantly increased between 2017 and 2019 when materials like the polylactic acid (PLA) boomed in the country; however, when analyzing a more recent period, data shows a 64% decrease in volume from 2019 to 2022 (See Figure 5), mainly attributable to a shift on policies to outpace the use of bioplastics due to environmental concerns.

Figure 5. Annual Certified Recycled Plastic Volume in Taiwan (2015 – 2022, in Tons)



Source. Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan). EPA. (2021a). *Yearbook of Environmental Protection Statistics Republic of China* 110. (<https://www.epa.gov.tw/Page/27372777FD92ADDB>); Lai, Y., & Lee, Y. (2022). Management strategy of plastic wastes in Taiwan. *Sustainable Environment Research*, 32 (1). (<https://doi.org/10.1186/s42834-022-00123-0>); Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan). EPA. (2022). *Recycling Volume and Recycling, Disposal and Reuse of Waste Plastic Containers*. Recycling Fund Management Board. (https://recycle.epa.gov.tw/en/recycling_materials_01_01.html).

Note. PE and PP data are presented combined as per the data source. PS and PS (Foam) data were combined for a more straightforward interpretation of the present study.

2.5.4 Source Reduction and Reuse

The “Resource Recycling Act” and the “Zero Waste Action Plan” were formulated in 2002 and 2005, respectively, to reinforce the correct sorting, handling, and reduction of disposable goods, helping companies to design “easy to recycle” products and use alternative

materials (EPA, 2023c; Houngh et al., 2014). Both initiatives focused on the 3Rs: source reduction, reuse, and recycling. In 2002, the first of several consecutive regulations were enacted for the progressive elimination of all single-use plastic bags, straws, and tableware, targeting public institutions and schools. As described by Walther et al. (2021):

One year later, this measure was extended to malls, supermarkets, hypermarkets, convenience stores, and other large food and beverage enterprises to reduce the use of plastic single-use tableware by about 37% (or 16,000 MT) and shopping bags by about 31% (or 20,000 MT) annually. The plastic and packaging industry initially opposed the ban, lobbying and organizing protests, but the EPA remained adamant. The EPA would avoid this divergence by holding advanced consultations with stakeholders and informing the population before enforcing or amending new regulations. At present, the EPA continues communication and collaboration with the plastic, packaging, and retail industry to achieve consensus and get their support.

Other measures introduced by the EPA not directly related to plastic packaging for food products but with a source reduction approach are the “Excessive Packaging Limitation Policy” enforced in 2006 to regulate packaging volume and layers for pastry, cosmetics, alcoholic beverages, processed food, and computer software optical disks (EPA, 2005). The “Own-cup policy” was implemented in 2011 to reduce the utilization of single-use cups by offering a discounted price per drink. Furthermore, the EPA also encourages voluntary packaging reductions for other industries, such as online shopping stores.

2.6 Opportunities to Implement a CE Based on the Waste Hierarchy Principles

Despite the remarkable results of Municipal Solid Waste Management and high recycling rates, plastic leakage and pollution still are ongoing problems. Since 2020, the central

and local governments have maintained coasts under their respective jurisdiction, collecting over 89,000 metric tons of debris (EPA, 2021b). Estimations made by Walther et al. (2018) indicated that:

During 2004 and 2016, an average of 3.7 and 7.9 million items weighing 560 to 1,110 MT polluted Taiwan's coastline. This calculation derives from twelve-year data collected from beach cleanups organized by local NGOs and civilians where more than 131,000 kg. of waste was collected and classified, resulting in about 90% of items made of plastic (64%) or a mix of it (27%). The most common debris collected was divided into six categories, where items related to food, such as plastic food wrappers and disposable tableware, represented 12% of the total.

In addition, there is a problem related to infrastructure capacity. On the one hand, "landfills and facilities for recycling waste are reaching their limits. On the other, many of the country's operating incineration plants are reaching a major service period or even the end-of-life, reducing treatment capacity" (Sung et al., 2020). This situation is not exclusive to Taiwan. As stated by the Ellen MacArthur Foundation (2020), "if plastic waste continues to grow, it will be hard to keep it all in circulation since the infrastructure development limits collection and recycling." The current "Zero Waste" policies in Taiwan mainly focus on recycling activities and using recycled materials. This situation represents a good opportunity to enhance existing schemes that restrict the use of plastics, implementing a Circular Economy based on the Waste Hierarchy Principles to prioritize plastic packaging use prevention as a sustainable long-term solution.

2.6.1 A Shift from Linear to Circular Economy

Plastic packaging waste reduction requires wide-scale system changes and a shift from

a Linear to a Circular Economy (Allison et al., 2022). The transformation of economic models from linear to circular is considered a long-term solution to the plastic packaging waste problem, providing a double-fold benefit: economic and environmental sustainability (Rhein & Sträter, 2021). The Linear Economy, also known as “Cradle-to-Grave,” refers to the model implemented since the Industrial Revolution, based on the “Take-Make-Waste” pattern (Ellen Macarthur Foundation, n.d.-b). Under this scheme, natural resources are massively extracted, transformed, transported, consumed, and disposed of without being used to their full potential, ending most of the time in landfills, incinerated, or dumped in the ecosystem. According to The Global Circularity Report (CGR) 2023 (Circle Economy, 2023), virgin materials constitute about 92.8% of the current global economic model, while circular materials are estimated to be 7.2% in 2023, a decrease from 8.6% in 2020 and 9.1% in 2018.

A Circular Economy is instead the “Cradle-to-Cradle” (C2C) model (McDonough & Braungart, 2002) in which products and materials flow in loops that are as closed as possible to reduce waste. The European Parliament defines it as “a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible, extending product’s life cycle and creating further value” (European Parliament, 2023). The origin of the term “Circular Economy” is imprecise; nonetheless, some sources relate it to similar theories and concepts developed in the 1960s and 1970s, such as “Biomimicry,” “Limits to Growth,” “Industrial Ecology,” “Performance-based Economy,” among others (Circular Taiwan Network, n.d.).

The “Butterfly Diagram” created by the Ellen MacArthur Foundation (See Figure 6) (Ellen MacArthur Foundation, n.d.-c) explains the CE as an ideal continued flow of materials within two major circles, the biological and the technical cycle:

On the left side, in the biological cycle, nutrients from biodegradable materials are returned to the environment. On the right side, corresponding to the technical cycle, products, and materials are kept in loops, prioritizing the smaller inner loops of sharing, maintaining, reusing, and refurbishing since those are the ones that keep most of the products and materials' value. Lastly, recycling is the less preferable option in the outermost loop since it implies losing the embedded value of a product to use its basic materials. In this sense, implementing a CE requires products to be kept in loops for reuse and, when no longer possible, to recycle them.

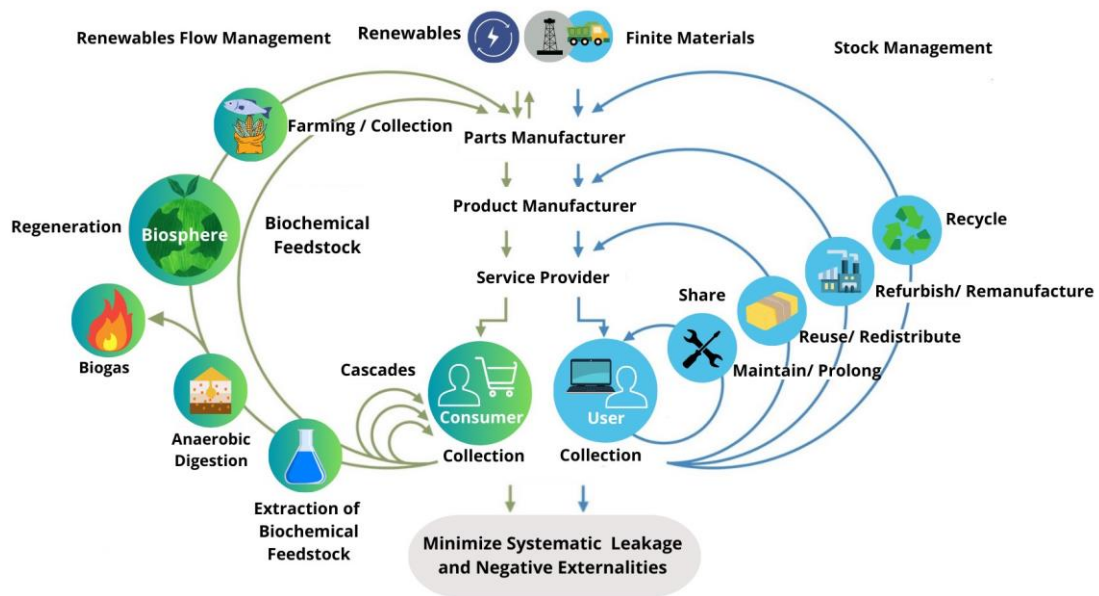
Even for recycling, the CE implies that upcycling should be prioritized over downcycling, but this might depend on the quality and design of products and materials. When the material's quality is low, upcycling is hard to achieve. The CE concept applies to diverse industries, products, and materials. In the case of plastics, the Ellen Macarthur Foundation proposes the implementation of a Circular Economy of Plastics based on three actions (Plastics and the Circular Economy, n.d.-a). First, eliminate all problematic and unnecessary plastic items. Second, innovate to make them reusable, recyclable, or compostable; third, circulate them within the economy and out of the environment.

The previous three actions are divided into six key points:

1. All problematic and unnecessary plastic items are eliminated through redesign, innovation, and new delivery models.
2. Reuse models are applied where relevant to keep the entire packaging in the economy, reducing single-use packaging.
3. All packaging is designed to be 100% reusable, recyclable, or compostable at a scale.

4. All plastic packaging is reused, recycled, or composted in practice through infrastructure, policies, funding, and Extended Producer Responsibility (EPR).
5. The production, transportation, cleaning, and recycling of plastic is completely separated from using finite resources, utilizing renewable resources instead.
6. All plastic packaging is free from hazardous chemicals, respecting the health, safety, and rights of all people involved.

Figure 6. The Butterfly Diagram: The Circular Economy System



Source. Adapted from Ellen MacArthur Foundation. (n.d.-c). The butterfly diagram: visualizing the circular economy. Circular Economy Systems Diagram (2019). (<https://ellenmacarthurfoundation.org/circular-economy-diagram>).

Note. Diagram based on McDonough & Braungart Cradle-to-Cradle (C2C).

2.6.2 The Circular Economy Based on the Waste Hierarchy Principles

As Ghisellini et al. (2016) mentioned, the Circular Economy implementation is still at an early stage worldwide, with companies mainly focused on achieving a recycling economy rather than a Circular Economy. Therefore, introducing the Waste Hierarchy Principles into

the plastic packaging reduction strategy is essential. These Principles were created over forty years ago (Pires, 2019). They were introduced in the US in 1975 by the company 3M Corp with the “Pollution-Prevention-Pays” (3P) employee-based program to prevent pollution at the source. Later, their influence was expanded to the industry's policies (Overcash, 2002).

In Europe, these principles were first proposed to the European Parliament in 1979 by the Dutch politician Ad Lansink, connecting the structure of the Waste Hierarchy with today's key elements of the Circular Economy (Lansink, 2018). In 2008 the Waste Framework Directive (WFD) in Europe adopted the Waste Hierarchy Principles (Art. 4, Directive 2008/98/EC). As a result, they became a part of national law in all of the EU member States (European Parliament and The Council, 2008). They were also included in the 12th Sustainable Development Goal in 2016 to reduce waste generation (Pires, 2019).

The Waste Hierarchy (WH) model is based on the 4Rs framework “Reduction, Reuse, Recycling and Recovery” and indicates which is the most and least preferable behavior, being waste prevention and reduction the most desirable and disposal the least desirable (See Figure 7). Some versions of the WH widened to 9Rs, including Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover. However, this study references the 4Rs established by the European Waste Framework Directive.

At the top level of the Waste Hierarchy is Reduction, where products and their packaging must be designed to consume as few resources as possible so they do not quickly become waste. According to Rhein and Sträter (2021), for some companies, “reduction represents the decrease of virgin plastic volume by introducing recycled plastic, which is far away from the strict definition of reduction made by the Waste Hierarchy that refers to the

promotion of unpacked alternatives per se.”

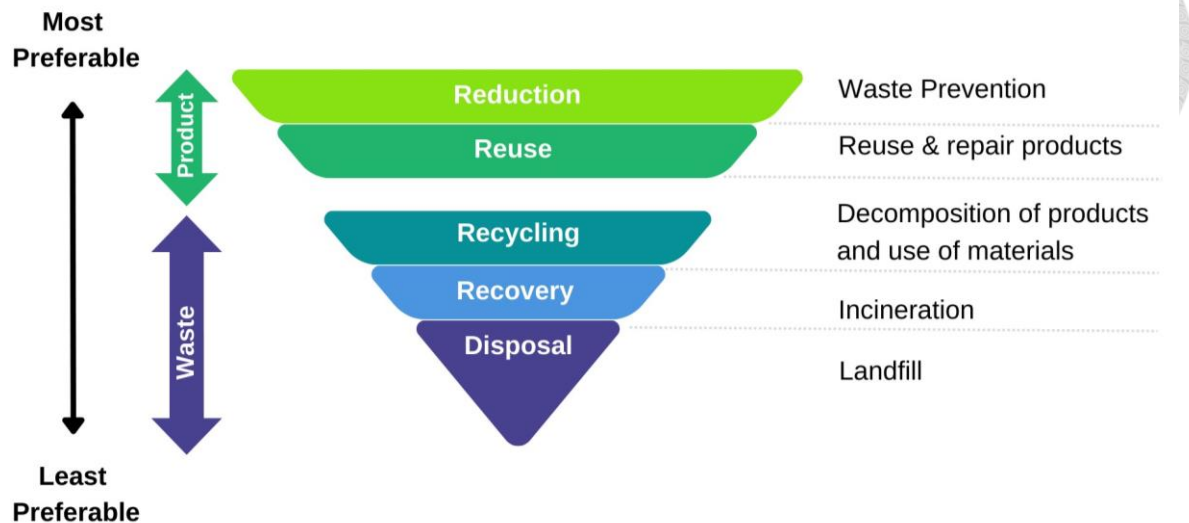


The second level is the Reuse and Repair of discarded "products" and their components to be used again for their original purpose (European Environmental Agency, 2019). According to the Waste Hierarchy Principles, this measure should be more important than recycling. In the third level, "materials" are used repeatedly by recycling products and repurposing their constituent parts for the same or different use. In this sense, the product's value is lost when recycling, but the material's value is preserved (Ellen MacArthur Foundation, n.d.-d). When a plastic container is recycled, for instance, its fiber can be used to make another container or convert it into clothing or any other product. In this regard, Rhein and Sträter (2021) point out:

The term Reuse is often employed to refer to using “materials” obtained from the recycling process, mistakenly interpreting recycling as if it was in the second level in the Waste Hierarchy Model. Thus, a clear understanding and application of the 4Rs concepts are vital to avoid the loopholes created by the various interpretations made by different system actors and ambiguous companies’ goals to obtain the best outcomes proposed by the CE.

The fourth level then has Recovery, which refers to the incineration of waste to generate energy. Lastly, disposal comes in fifth place when waste is deposited into landfills. Overall, the Reduction, Reuse, and Recycling of materials are considered positive contributors to the environment and resource conservation, in contrast to the disposal of products sent to landfill and incineration (Pires, 2019). In this context, the European Parliament and The Council (2008) mentioned: “Waste prevention should be the first priority of waste management, and reuse and material recycling should be preferred to energy recovery, where and insofar as they are the best ecological options.”

Figure 7. Waste Hierarchy Model



Source. Adapted from the European Commission. (2023). *Waste Framework Directive*. Environment. (https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en).

2.7 The Retail Industry in Taiwan and the CE Implementation

This section provides a general overview of the Taiwanese Retail Industry, indicators, key players, trends, and some plastic reduction initiatives to understand the sector's context.

2.7.1 Taiwan's Retail Industry Overview

In Taiwan, the Retail Food sector segmented by distribution channel comprises hypermarkets, supermarkets, and convenience stores with an annual revenue of NT\$885.97 billion in 2022, an increase of 3.8% from 2021 (Department of Statistics Taiwan, 2022). After the Covid-19 outbreak and the implementation of epidemic prevention measures in 2021, supermarket and hypermarket revenue soared 8% and 7%, respectively, resulting from increased demand for food and ingredients to cook at home and daily necessities, while

convenience stores sales stagnated (USDA, 2022). Taiwan has the second highest density of convenience stores in the world, after South Korea, with 11,027 directly-operated chain convenience stores and 4,738 franchise chain convenience stores in 2022 (MOF, 2023; as cited in USDA, 2022). In contrast, based on statistics from the Ministry of Finance Taiwan (MOF), in 2022, there was a total of 2,275 supermarket stores on the island, an annual increase of 0.5% from 2021 to 2022 and a 3.5% with regard to 2018 (See Figure 8) (MOF, 2023).

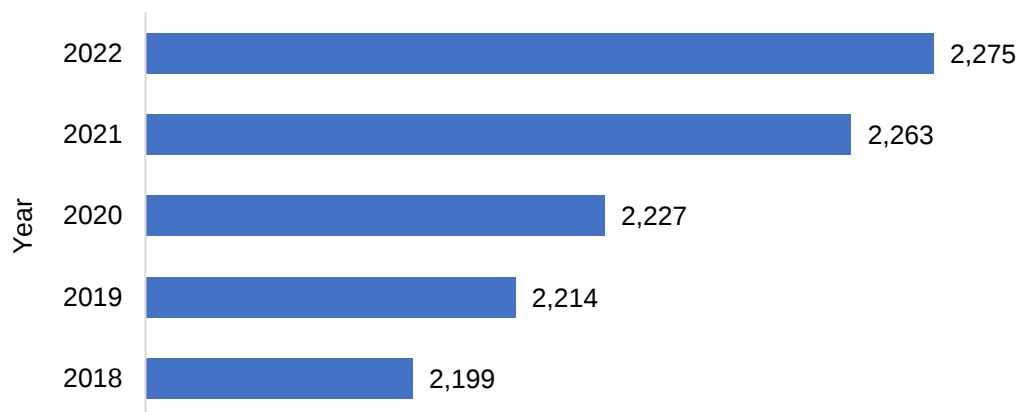
The retail industry grew at a CAGR of 1.8% from 2010 to 2021 (Mirai Business, 2023). Competition is fierce, pushing companies to implement an “Online-merge-Offline (OMO)” strategy helping them to collect data and better understand their customer’s preferences. Online shopping was especially accelerated after Covid-19, leading to the establishment of partnerships of retailers with online delivery food platforms such as FoodPanda and Uber Eats (Rickards, 2023), but now sales in physical stores show a sign of recovery (Kantar, 2022b). Besides, there has been an increasing number of digital payment applications and e-Commerce platforms that adapt to a fast-paced urban lifestyle and high level of digitalization characteristic of Asian countries.

Consumers are generally highly price sensitive but less sensitive when purchasing organic and natural products, showing an increasing interest in food safety and health that has helped these products to achieve growth momentum. Consumers are brand-conscious and prefer fresh products over frozen ones (Kantar, 2022b; USDA, 2022). As explained by Mordor Intelligence, “Taiwan Retail Sector Size & Share Analysis Report 2023 – 2028” (Mordor Intelligence, n.d.):

Demographics have a significant role in determining shopping preferences. Many older Taiwanese consumers prefer buying meat, fish, fruits, and vegetables at specialist

markets. Some supermarkets are trying to attract this consumer segment by recreating the look of a more traditional market within their stores. In addition, Taiwanese consumers shop for food at least twice a week and sometimes daily, while consumers who prefer supermarkets and hypermarkets tend to do one big grocery shopping per week. Top-up food shopping occurs daily, mostly at convenience stores.

Figure 8. Number of Supermarkets in Taiwan per Year (2018 – 2022)



Source. Ministry of Finance Taiwan. MOF. (2023). *Number of Profitable Businesses and Sales*. (Eighth Revision). [Data Set].

(<https://web02.mof.gov.tw/njswww/webMain.aspx?sys=220&ym=10700&ym%20t=10900&kind=21&type=1&funid=i0514&cycle=4&outmode=0&compm%20ode=00&outkind=3&fld0=1&codspc0=973,2,981,1,&rdm=R49087>)

2.7.2 Leading Retail Companies

The leading supermarkets are PX Mart, Carrefour, Simple Mart, Taiwan Fresh Supermarket, and Mia C'bon, formerly Jasons. Carrefour offers specialty foods and is recognized for its “Food Transition for Everyone” with a unique social responsibility approach. PX Mart offers a wide variety of products, accounting for more than 1,072 stores and 64% of the market share by 2021 (Statista, 2023b). Both retailers own super and hypermarket stores

and compete strongly to dominate the market. Simple Mart, in contrast, has implemented a different strategy, opening stores in residential areas and targeting local communities (USDA, 2022).



Carrefour and Costco are the key players retaining more than 50% of the market share in the hypermarket segment thanks to their American and European product selections. Other competitors are Far Eastern A-Mart (遠東愛買) and RT-Mart (大潤發), the latter acquired in 2021 by PX Mart. A report by Chen (2021) described the biggest challenges for hypermarkets in 2021 as “price competition, low gross profit, and rising labor costs.”

Finally, major convenience stores are 7-Eleven with 46.5% of the market share by 2021, Family Mart with 22.5%, Hi-Life 6.5%, OK Mart with 2.5%, and 22.5% for other companies in the same period, according to data from Statista (2023a). Convenience Stores provide a wide range of services and extended opening hours in strategic locations for commuters. Nonetheless, fresh produce usually is not one of their star products, which is the main focus of this study. Distribution of food product sales in Retail in Taiwan is mostly done in supermarkets and hypermarkets (Statista, 2023c).

According to the KANTAR Consumer Index of the first half of 2022, Carrefour occupies one of the first positions in the Fast-Moving Consumer Goods (FMCG) ranking in Taiwan, based on Consumer Reach Points (See Figure 9) (Kantar, 2022a).

Figure 9. KANTAR Consumer Index 2022H1 Taiwan FMCG Retail Channel Consumption

Ranking

Ranking	Overall FMCG Market	Number of Consumer Touch Points (Ten Thousand Times)
1		17,092
2		6,859
3		5,472
4		4,333
5		4,205
6		2,170
7		2,153
8		1,095
9		1,083
10		1,075

Source. Adapted from Kantar. (2022a). 凱度 2022 最新民生零售通路排行 電商來勢洶洶 消費觸及成長 50%. [*Kantar's latest retail channel ranking for people's livelihood E-commerce is on the rise and consumption hits a growth rate of 50%*].

(<https://www.kantarworldpanel.com/tw/news/2022-H1-retailer-crp-ranking>).

Note. Consumer Reach Points (CRP) are the number of consumers (households in the country), the channels' penetration rate, and consumption times. Worldpanel Taiwan Household Index (4000 households).

2.7.3 Carrefour: Company Brief Overview

Carrefour Taiwan was created in 1987 thanks to the joint venture of the French Carrefour Group with Uni-President Enterprises, Corp., a Taiwanese food and beverages conglomerate that also operates 7-Eleven and Starbucks franchises in Taiwan. Carrefour acquired 60% of the equity in the company and opened its first store in 1989. In 2021, the Net Revenue generated was equivalent to €2.5bn. Nowadays, Carrefour Taiwan accounts for more

than 68 hypermarkets, 272 supermarkets and premium stores, and 129 shopping malls, hiring nearly 15,000 employees (Carrefour Group, 2022a). In 2022, the equity of the French company was sold back to Uni-President for €2.0bn and is expected to be completed after receiving the approval of the Taiwanese Competition Authorities (TFTC). The transaction gives Uni-President the license to continue using Carrefour's brand.

Carrefour's competitive strategy is based on a strong focus on outlet expansion at a rate of twenty stores per year. It acquired Wellcome and Jasons stores in 2020, changing their names to Carrefour and Mia C'bon, respectively. The company bets on high-quality products focusing on organic and sustainable food, endorsing a Food Transformation Plan since 2018 with the philosophy that "everyone deserves the best." In July 2019, the Carrefour Impact Store was opened in Taipei in response to the creation of the UN SDG, promoting food waste reduction, healthy living, people-oriented policies, care for the environment and biodiversity. In 2022, Carrefour Group launched the "Act for Food Program," which aims to achieve food sustainability in their own brand products that includes production, consumption and food donation to prevent food waste (Lim, 2021).

Carrefour Group set a global KPI to reduce a cumulative 20,000 tonnes of packaging, including 15,000 tonnes of plastic, from 2017 to 2025, achievable by the contribution of each of its stores in the world that, includes: Argentina, Belgium, Brazil, France, Italy, Poland, Romania, and Taiwan. The company has joined the New Plastics Economy initiative, the Global Commitment, the European Plastic Pact, Plastic Pact Poland, and the "Pacte National sur les Emballages Plastiques." It aims to reach 100% reusable, recyclable, or compostable packaging for its own brand by 2025 (Carrefour Group, 2022b).

Carrefour's business model aims to contribute to the UN SDG by implementing a series of KPIs and plans. The company primarily targets goals related to Good Health and Well-Being, Responsible Consumption and Production, Climate Action, Life Below Water and Life on Land related to plastic, as discussed in the International Regulatory Framework in this chapter, well as goals towards Zero Hunger, Gender Equality, Decent Work and Economic Growth.

2.8 Barriers and Enablers for Implementing a CE of Plastics, Group Classification

Implementing a CE Model that prioritizes the Waste Hierarchy Principles is necessary and perhaps unavoidable, given the worsening environmental conditions and the ensuing enforcement of international treaties and policies. Governments, environmental organizations, and consumers are increasing pressure on retailers to progressively eliminate unnecessary plastic packaging in their business practices and receive criticism if an insufficient response. However, “there is a lack of proven methods to help them tackle this issue more quickly and easily” (Ma et al., 2019b). Therefore, analyzing factors that represent barriers and potential enablers to the primary plastic packaging on fresh produce for the retail sector is crucial.

The following section classifies and analyzes factors from the literature review related to the Reduction, Reuse, and Recycling of plastic packaging. It does not include factors related to the Recovery & Disposal since those procedures “are considered detrimental to the environment and resource conservation” (Pires, 2019). These factors are grouped thematically into six categories based on a similar classification made by Dieckmann et al. (2020):

1. Organizational Context
2. Operational
3. Technical and Technological
4. Stakeholders

5. Legal
6. Commercial



Ma et al. (2019b) mentioned that it is fundamental to consider the company's size since some barriers in one company can be enablers in others.

2.8.1 Organizational Context

These are factors related to the internal culture, values, goals, and commitments influencing sustainability initiatives set by companies. According to Ma et al. (2019b), employees and collaborators must believe in sustainability, and all departments must have good communication and support, including financial provision from the upper levels of the organization. Companies must set self-commitments to guide their efforts toward a CE, not only for political or marketing reasons but for an authentic interest in tackling current and future environmental problems (Lyon & Maxwell, 1999). Furthermore, establishing clear goals and definitions to reduce plastic packaging is fundamental, as well as metrics to track and measure results and, if necessary, set corrective actions. Rhein and Sträter (2021) mentioned that ambiguous goals and commitments and imprecise terminology used in companies' CSR statements may lead to an imprecise implementation of the Waste Hierarchy Principles. Sustainability as a core business strategy is essential to ensure that it is adopted by the senior level and spread from top to bottom in the organization.

Table 2. Organizational Context Factors

Factors	
Organizational Context	Corporate Values & Culture
	Internal Communication and Collaboration
	Financial Capability
	Lack of a Transition Plan Toward Circular Economy
	Internal Goals and Metrics

2.8.2 Operational

Operational factors are related to the activities needed for reducing, reusing, and recycling plastic packaging based on the company's nature. For example, lack of collection and storage infrastructure are some of the biggest challenges for recycling, specifically increasing recycling rates (Rhein & Sträter, 2021). Implementing a Deposit-Refund System (DRS) at the source (retail store) requires the evaluation of environmental cost-benefits, including impacts derived from transportation like energy consumption, materials, and added value from the processing of reusable or recyclable products. Dieterle et al. (2018) proposed a Life Cycle Gap Analysis (LCG-A) to assess "all environmental efforts versus environmental benefits from giving a product a second life." The author mentioned that C2C is not always favorable from a Life Cycle Assessment perspective, especially when using non-renewal energy.

Similarly, contracting Pooling Services "require more economic and management resources with the introduction of a third party in charge of returning and washing reusable containers affecting the whole cycle from the economic, environmental perspectives, adding complexity to the supply chain" (Battini et al., 2015).

Transportation, handling, and storage are other variables. Some packaging alternatives increase carbon emissions related to plastic, especially those with a long supply chain (White & Lockyer, 2020). The supply chain may also affect fresh produce shelf life, packaging design, and quantity needed. Ma et al. (2019a) described:

The supply chain will affect a product's shelf life and packaging design. Alternative materials for primary packaging should comply with the requirements for secondary packaging, where speed and efficiency are critical. If the time from production to

consumption can be reduced, then the need for plastic packaging decreases since the core function of packaging is to extend the product's life.



Table 3. Operational Factors

Factors	
Operational	Facilities and Infrastructure
	Recycling at a Source (Deposit-Refund System)
	Proper Sorting and Handling (of Waste)
	Pooling Services (Reuse of Plastic Packaging)
	Supply Chain (Transportation, Handling, and Storage)

2.8.3 Technical and Technological

Dieckmann et al. (2020) cited, “the availability of appropriate processing technology is often a key barrier to transitioning to a CE.” However, under certain circumstances, it could be an enabler. Chauhan et al. (2022) explained:

Technology and Innovation can act in favor of the environment and CE implementation, taking advantage of emerging technologies like Big Data, the Internet of Things (IoT), Blockchain, Machine Learning, and Artificial Intelligence (AI) for the generation, transfer, and processing of data for decision making and the enactment of new policies at the international, national, local or organization level. In addition, digitalization enables process automation and optimization, as well as new ways of connectivity and communication.

Moreover, new business models and ways of delivering goods can help to shift to environmentally friendly materials. E-commerce can enable greater choice on behalf of consumers to specify the packaging they want (Ma et al., 2019b).

Innovation for the development of alternative materials to plastic is essential. They should be able to provide higher functionality to compete with the characteristics and benefits of plastics. Advocates of alternative materials state that biobased resources can prevent environmental damage (Friedrich, 2020). Nonetheless, there is a lack of evidence proving they are environmentally friendlier than plastics. Some studies indicate that companies keep dubious about their current environmental and functional properties (Ma et al., 2019b). Moreover, if the production of substitute materials consumes more energy, it will be hard to justify their adoption. Much more research on alternative, biodegradable, and non-toxic products to replace plastics is needed (Walther et al., 2021).

Table 4. Technical and Technological Factors

Factors	
Technical and Technological	Technology
	Innovation
	Digitalization
	Substitute Materials' Functionality
	Design and Harmonization

2.8.4 Stakeholders

Rhein and Sträter (2021) described that “stakeholder cooperation is vital to attain a CE and develop innovative technologies and solutions for plastic packaging reduction. Efforts would be meaningless without cooperation between all parties involved.” Consequently, connecting Suppliers, Consumers, Environmental Organizations, Investors, Competitors, and News & Media is vital.

Similarly, Allison et al. (2022) stated that eliminating plastic waste and implementing a CE “relies in part on changing the behavior of all actors in different levels of the plastic

system. People need to interact appropriately with technology and infrastructure innovation in order for them to provide the intended benefits.” In addition, Gutowski (2018) explained that “social sciences must be integrated into the environmental Life Cycle Assessment (LCA) of a product, considering real human behaviors since they may alter LCA outcomes. Frequently, LCA is made based on optimistic or scaled-up scenarios, not easily achieved in real life.” This is of relevant importance when assessing technological and alternative material innovations.

For this study, Governments were included in the Legal factors group represented by Laws and Regulations (See Tables 5 and 6).

Table 5. Stakeholder Factors

Factors	
Stakeholders	Investors
	Suppliers
	Competitors
	Customers (Behavior)
	News & Media
	Non-governmental organizations (NGOs)

2.8.5 Legal

According to Friedrich (2020), “factors such as government regulatory instruments can influence the retail industry’s strategic behavior toward plastic avoidance.” Norms, laws, and regulations are mainly aimed at protecting consumers and the environment. They comprise mechanisms such as labeling to guarantee food safety and traceability throughout the food chain. Whereas communicating trustworthy information about content, ingredients, nutritional values, brand identification, product code, origin, expiration date, pricing, use directions, and warnings helps enterprises control their products’ quality and assist consumers in making informed purchasing decisions.

Another legal mechanism is taxation. Governments are pushing producers and retailers to reduce or eliminate “avoidable” plastic and especially “single-use plastic” in their business practices (Ma et al., 2019b). Pigovian Taxes (also Pigouvian Tax) are one method. They are defined as “an emission fee paid by individuals or organizations and set to activities that generate negative externalities to be exactly equal to the aggregate marginal damage caused by the pollution level” (Kolstad, 2000; as cited by Walls, 2013). Fiscal measures have shown a strong effect on reducing single-use plastic consumption (Allison et al., 2022).

Table 6. Legal Factors

Factors	
Laws and Regulations	Regulations
	Food Safety
	Labeling
	Pigovian Taxes

2.8.6 Commercial

Food Shelf Life is directly linked with food waste prevention, which is of environmental, social, and economic concern. As mentioned by White and Lockyer (2020), “there is an important trade-off to consider when removing plastic packaging from fruit and vegetables, which is the resultant reduction in shelf life and therefore a potential increase in food waste.” Plastic packaging helps to prevent food damage and keep the product features intact, visible, and appealing for consumers to generate sales. In the end, retail companies have sales goals to consider. Ma et al. (2019a) pointed out that “one of the most important functions of packaging is to promote the goods inside and ensure the product is attractive.” In addition, their research found that some companies believe that when packages are big, they have more visibility and, thus, generate more revenue which can be another obstacle.

Another reason is plastic's lower cost than most of the alternatives to plastics. This factor has been identified as one of the major barriers for companies to adopt alternative materials that generally are more expensive and require investments in new technology. Friedrich (2020) suggests that since some of the substitute materials are more expensive, an increase in the cost of plastics is needed to make alternative materials more competitive; however, the cost of switching may be transferred, whether in the form of a price increase to the market or a decrease in the quality of products.

Table 7. Commercial Factors

Factors	
Commercial	Cost
	Sales
	Marketing Strategy
	Brand Differentiation
	Food Shelf Life

3. Chapter 3: Methodology

The following section describes the design, participants, data collection, analysis method, validity, and reliability of this research.



3.1 Research Design

Priya (2021) explained that research design is decisive for the final outcome's efficacy, validity, and reliability. As cited by Creswell & Creswell (2018), "a case study is a qualitative research design in which the researcher explores in-depth an activity, event, program, process, or one or more individuals." It is one of social research's most commonly used methods. It expands to anthropology, psychology, sociology, business and management, medicine, and political science. Therefore, this research uses a single case study focusing on the retail sector, taking the case of Carrefour Taiwan to analyze from the business perspective which factors prevent and enable fresh produce packaging reduction, how controllable these factors are, and detect opportunities to reduce plastic packaging.

Baxter and Jack (2008) mentioned that there are two fundamental approaches to case studies: one proposed by Stake (1995) based on the constructivism paradigm, where "participants describe their views of reality, enabling the researcher to understand their actions" and the second based on a positivistic paradigm introduced by Yin (2003) that focuses on facts maximizing four conditions: construct validity, internal validity, external validity, and reliability. A case study can be: descriptive, explanatory, and exploratory (Yin, 2014; as cited by Priya, 2021). The first describes a phenomenon in detail in its natural setting. The second explains the "why" and "how" of factors to explain a specific phenomenon. The third investigates a phenomenon that has yet to be studied in depth, which is the base used for the present work.

Priya (2021) pointed out that “single case studies are justifiable if they are revelatory, test a hypothesis or if the case is the representative example of a specific phenomenon.” They can use any data collection method that fits the research purpose as long as it is “feasible and ethical,” such as interviews, surveys, questionnaires, observation, and study of documents, among others.

3.2 Participants

De Vaus (2001) stated that “the unit of analysis of a case study can be an individual, family, household, community, organization, event, and even a decision.” The selection criteria for participating in this research were:

- a) Being a supermarket leader in Taiwan
- b) Offering an ample variety of fruits and vegetables to consumers
- c) Having experience implementing plastic packaging reduction strategies, and, most importantly, d) Willingness to share their experience.

Carrefour’s CSR Team was first contacted at an in-campus fair at the National Taiwan University. The CSR Manager was invited to join this research via email. Carrefour Group (Carrefour, n.d.) stated that the company “is committed to responding to all questionnaires from NGOs, investors, and rating agencies to assess the global and local utility of its policies and action plans as a way to engage in a transparent dialogue.”

3.3 Data Collection Method

3.3.1 Research Instruments

First, a systematic literature review was performed to identify relevant studies on plastic packaging use and benefits for the retail sector, plastic reduction initiatives, barriers, plastic

pollution, waste management, and global and local environmental policies. It included academic papers, grey literature, government statistics, laws, regulations, NGOs' websites, CSR reports, industry reports, news, and media.

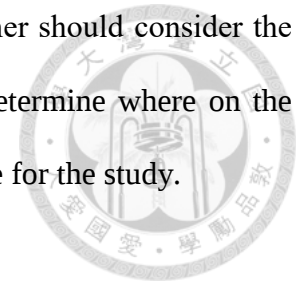


Second, the “Action Research” method (Näslund et al., 2010) was implemented limited to problem identification, consisting of information collected through onsite observation on a small non-probability sample of three Carrefour stores located in Taipei City, Taiwan, for a defined and comparable group of products: fruits and vegetables. The main objective was to understand what type of packaging Carrefour uses. Field notes were used to record observations and integrated into the Discussion Section to add to the findings. According to Näslund et al. (2010), “field notes are an ongoing commentary on what is happening in research, capturing ideas whenever they occur, without attempting to judge the importance of events at the time of recording.” A more comprehensive sample using Simple Random Sampling (SRS) is recommendable to be done for future research.

Third, a semi-structured interview was performed with the CSR Manager of Carrefour Taiwan to learn from their own experience which factors inhibit and enable plastic packaging reduction in fresh produce. Insights from the interview are presented in the Discussion Chapter to summarize the participant’s perspective and experience. Naturalized/intelligent verbatim interview transcripts are provided in the appendix of this paper (See Appendix C). In this regard, McMullin (2021) mentioned:

Qualitative research can help us understand some important issues from the third sector in ways that quantitative methods fall short of explaining, such as how individuals and organizations make sense of public policy and societal challenges and how and why their services and activities are designed in particular ways. Also, there is no one best

or “most accurate” style of transcription, but rather, a researcher should consider the particular theoretical background and research questions to determine where on the scale of full verbatim to intelligent verbatim is most appropriate for the study.



For the interview session, a methodology was adapted from Ma et al. (2019b) to measure the level of control the interviewed company perceived over those factors and identify which can act as barriers or enablers of plastic packaging reduction on fresh produce. The session was divided into two sections:

Section 1: Following Ma et al. (2019b) method, the interviewee was required to share general information, including:

- a. The interviewee’s job responsibilities.
- b. Relevant projects, initiatives, or partnerships the company has implemented for plastic packaging reduction in fresh produce.

Section 2: Based on the participant’s experience:

- c. Brainstorm factors acting as barriers and enablers to reduce plastic packaging in fresh produce and measure the control level the company perceived over them. The information generated during the discussion was recorded using notes and an audio recorder (previous consent from the interviewee).
- d. For measuring factors, a printed grid was adapted from Ma et al. (2019b) (See Figure 10). The interviewee was provided with a set of cards containing factors compiled during the literature review for this case study.

Since not specified by Ma et al. (2019b), the number of cards was determined at the sole discretion of the researcher of the present study, resulting in thirty cards with factors collected from the literature review and ten additional empty cards to include any missing

factor previously identified by the participant (See Appendix B). During the interview, at least ten and a maximum of forty cards could be selected and placed on the grid by the interviewee to measure from 0 to 100% the level of control the company believes to have over the selected factors (Y-axis) while assessing from 0 to 100% the potential for those factors to act as barriers and enablers of plastic packaging reduction (X-axis). Notes and a photograph of the final grid were taken for documentation and evidence (See Appendix D). In addition, stickers were added to each card to prevent displacement on the grid and any possible error on records. As Ma et al. (2019b) described, “this graphical approach to data collection provided a structured means of engaging with the topic.”

3.4 Data Analysis

For the data analysis, a visual method was developed. In the first step, factors placed on the grid by the participant were divided into four quadrants and highlighted with different colors to distinguish them as enablers and barriers by control level (See Figure 11).

For the next step, factors were listed and categorized in a table, following the Group classification in Chapter 2: “Barriers and Enablers for Implementing a CE of Plastic Packaging” adapted from Dieckmann et al. (2020). The table included four columns. The first one, “Group,” shows each factor’s category: Organizational Context, Operational, Technical and Technological, Stakeholders, Legal, and Commercial. The second, “Group Size,” reflects which group has more factors, while “Percentage” rates the previous column. Lastly, “Factors” lists Barriers and Enablers. This classification was made regardless of the control level and Plastic Packaging Reduction Opportunity, only showing enablers and barriers and their rates per group type.

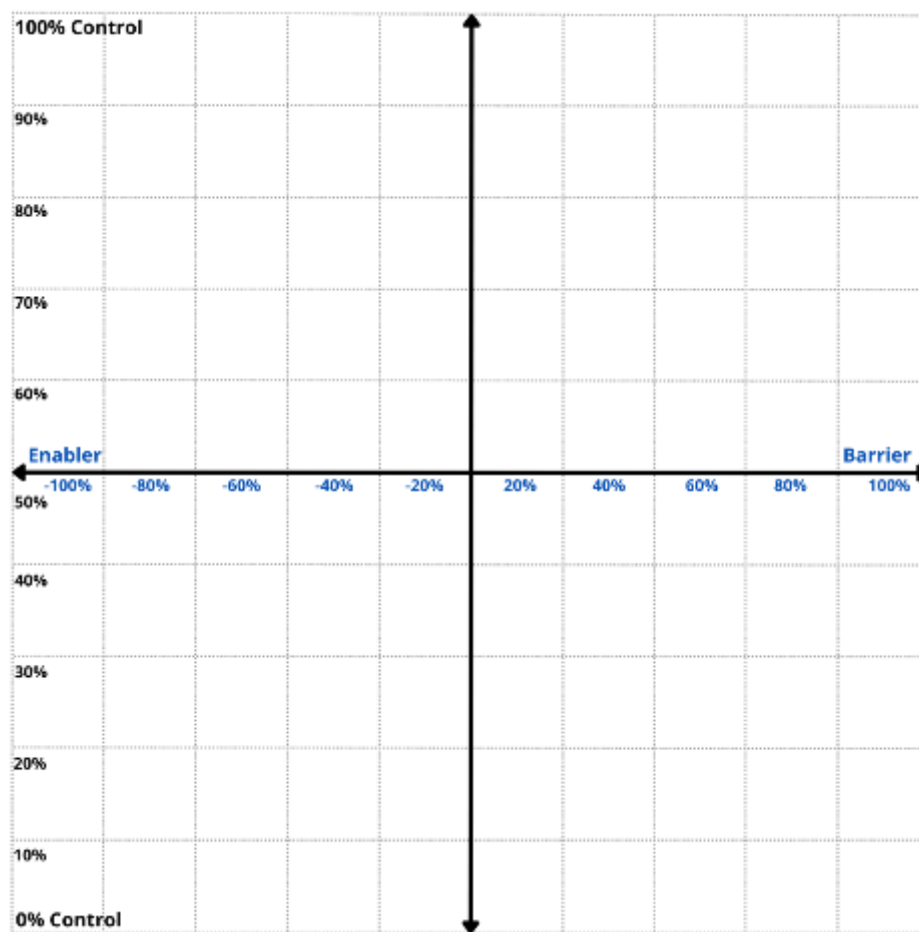
Finally, results were quantified by multiplying the control level (Y-axis) by the inhibiting and enabling intensity (X-axis) representing the “Plastic Packaging Reduction Opportunity.” Factors on the left side of the X-axis (enablers) were randomly given negative values just for differentiation, with factors on the right side of the X-axis (barriers) assigned positive values (percentages). Factors placed over the axis (X or Y) were considered neutral since the product equals zero. The product of the control level (Y-axis) and intensity (X-axis) was then plotted in a horizontal bar chart. The outcome is a visual instrument showing barriers, enablers, and opportunities for plastic packaging reduction.

3.5 Validity and Reliability

Priya (2021) referred to Guba and Lincoln (1994), who used the term quality to denote validity and reliability in qualitative research. This study was designed to ensure quality and eradicate data collection and analysis bias derived from “the researcher’s theory, values, and preconceptions” (Maxwell, 2009) by listening to the interviewee’s insights, collecting, and recording information accurately.

Furthermore, since a case study entails uniqueness, it may not be representative of a sample of cases nor become the basis for statistical generalizations (Yin, 2014). However, a case study allows for analytic generalizations in which a previously developed theory is used to compare the empirical results of the case under study.

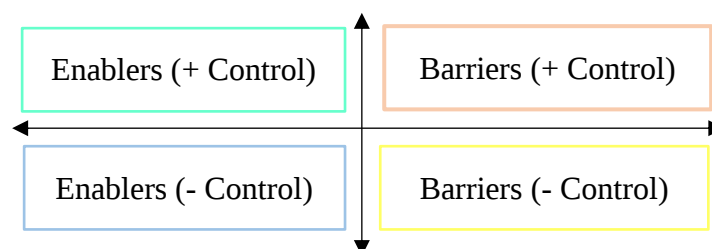
Figure 10. Barriers and Enablers Measuring Grid



Source. Adapted from Ma, X., Park, C., Moultrie, J., & Hua, M. (2019b). An Exploratory Study to Identify the Barriers and Enablers for Plastic Reduction in Packaging. *Sustainable Design and Manufacturing 2019. KES-SDM 2019. Smart Innovation, Systems and Technologies, vol 155*. Springer, Singapore. (https://doi.org/10.1007/978-981-13-9271-9_1).

Note. Enablers were given negative values, while barriers were assigned positive values.

Figure 11. Factors Classification per Control Level, by Quadrant

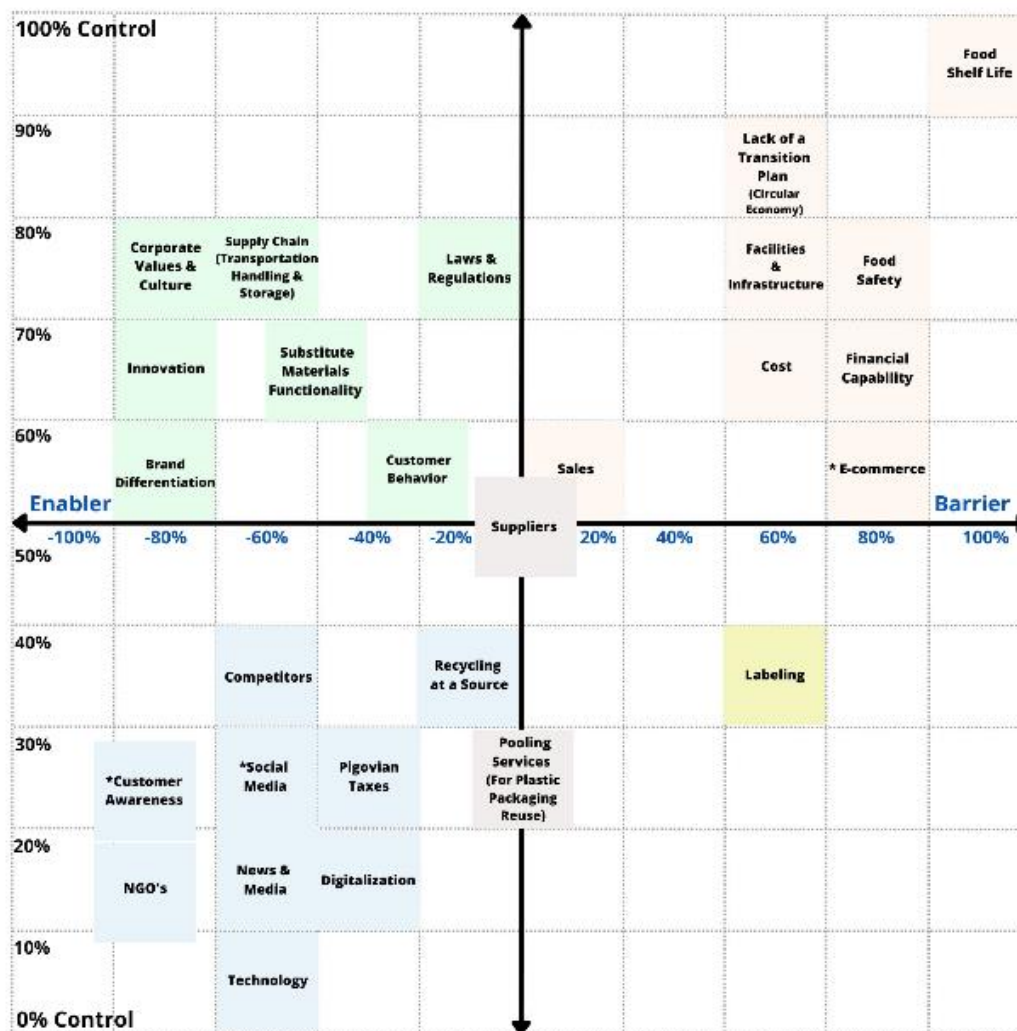


Source: The author

4. Chapter 4: Results

This Chapter presents the case study results intending to provide a better understanding, from the business perspective, of factors preventing and enabling fresh produce packaging reduction, how controllable these factors are according to the participant's point of view, and detect opportunities to reduce plastic packaging. Results are presented in a digital version of the printed Grid used during the interview with Carrefour (See Figure 12).

Figure 12. Carrefour's Results - Factors Classification per Control Level, by Quadrant



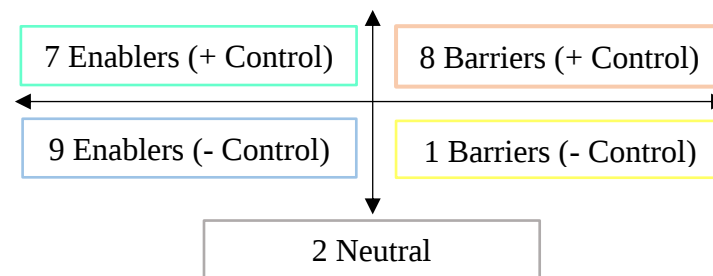
Note 1. Factors marked with an asterisk (*) were added by the interviewee.

Note 2. Factors placed over the axis were considered neutral since the product value is zero.

4.1 Which Factors Inhibit and Enable Fresh Produce Plastic Packaging Reduction in Carrefour Taiwan?

From a set of 30 cards or “factors” collected from the literature review, 24 were selected, and the interviewee added three new factors: Customer Awareness, Social Media, and E-Commerce. A total of 16 enablers, nine barriers, and two neutral factors showed a more significant number of enablers than barriers (See Figure 13).

Figure 13. Factors Classification Result per Control Level, by Quadrant



To answer which factors enable and inhibit fresh produce plastic packaging reduction, the appointed variables were listed and grouped by type according to the classification made in Chapter 2. This classification does not reflect the control level, plastic packaging reduction opportunity, or individual contribution to plastic packaging reduction. It provides an overview by category to weigh and better understand the nature of all selected enablers and barriers.

In the first place, two groups of factors account for 50% of the total enablers. The first is the Technical and Technological Group at 25%, comprising Innovation, Substitute Materials Functionality, Digitalization, and Technology. The second one, Stakeholders, is represented by Competitors, Customer Behavior, NGOs, and News & Media at 25% (See Table 8).

The Operational, Legal, and “New Factors” Groups account for 12.5% each, summing 37.5%. The enabling Operational factors are Supply Chain and Recycling at a Source. Next, Laws and Regulations and Pigovian Taxes comprise the Legal enablers, while the participant added Customer Awareness and Social Media that were grouped in the “New Factors” classification. Finally, Corporate Values & Culture represent 6.3% for the Organizational Context Group, and Brand Differentiation 6.3% for the Commercial.

Table 8. Enablers of Fresh Produce Plastic Packaging Reduction

Enabling Group	Group Size	Percentage	Factors
Technical and Technological	4	25.0%	Innovation Substitute Materials Functionality Digitalization Technology
Stakeholders	4	25.0%	Competitors Customer Behavior NGOs News & Media
Operational	2	12.5%	Supply Chain (T., H., and S.) Recycling at a Source (Store)
Legal	2	12.5%	Laws and Regulations Pigovian Taxes
New	2	12.5%	Customer Awareness Social Media
Organizational Context	1	6.3%	Corporate Values & Culture
Commercial	1	6.3%	Brand Differentiation

Note. T., H., and S., meaning Transportation, Handling, and Storage

In the same way, barriers were listed and classified. Commercial factors were the biggest group by number at 33.3%, encompassing Food Shelf Life, Cost, and Sales. Next, the Organizational Context group at 22.2% is represented by Financial Capability and Lack of a Transition Plan (towards a CE). It is followed by the Legal Group comprising Food Safety and Labeling at 22.2%. The Operational Group represented by the Facilities and Infrastructure accounts for 11.1%. Lastly, the interviewee included E-Commerce as a barrier and was grouped

in the “New Factors” classification at 11.1%. Interestingly, no Technical and Technological, or Stakeholders' related factors were appointed as barriers (See Table 9).



Table 9. Barriers to Fresh Produce Plastic Packaging Reduction

Enabling Group	Group Size	Percentage	Factors
Commercial	3	33.3%	Food Shelf Life Cost Sales
Organizational Context	2	22.2%	Financial Capability Lack of a Transition Plan (CE)
Legal	2	22.2%	Food Safety Labeling
Operational	1	11.1%	Facilities and Infrastructure
New	1	11.1%	E-Commerce
Technical and Technological	0	0%	Not Selected
Stakeholders	0	0%	Not Selected

A couple of neutral factors resulted from being placed over the Y-axis. These variables are Suppliers and Pooling Services from the Stakeholders and Operational Group.

4.2 How Controllable are Selected Barriers and Enablers?

The measurement of factors is presented in a ranking of Barriers and Enablers obtained from the control level product (Y-axis) by the intensity (X-axis) and sorted in ascending order (See Table 10). The resulting variables with lower control levels are Technology at 10%, NGOs at 15%, Digitalization at 20%, News & Media at 20%, and Customer Awareness at 25%. Despite having a low perceived control level, they all act as Plastic Packaging Reduction Enablers.

On the other hand, factors with the highest perceived control level are the Barriers: Food Shelf Life at 100%, Lack of a Transition Plan (towards a CE) at 90%, Facilities and

Infrastructure, and Food Safety at 80% each. These are followed by the Enablers: Corporate Values & Culture, Supply Chain, and Laws and Regulations, all at 80% each. It is noticeable that variables with higher control levels are located at the extremes of Table 10 and the bar chart (See Figure 14). In contrast, factors with the lowest control level are mainly scattered at the bottom.

4.3 What are the Opportunities to Reduce Fresh Produce Plastic Packaging?

The resulting product of the control level (Y-axis) and intensity (X-axis) provides an overview of the Plastic Packaging Reduction Opportunity, also plotted in the bar chart (See Figure 14). It shows at the top and bottom, Enablers and Barriers to tackle since those are perceived as the most controllable. It should be noted that Enablers located at the center of the graph, while being important, are considered less controllable, as previously mentioned.

The Top five Enablers representing Plastic Packaging Reduction Opportunities are Corporate Values & Culture (-6,400), Innovation (-5,600), Supply Chain (-4,800), Brand Differentiation (-4,800), and Substitute Materials Functionality (-3,500). On the other hand, the Top five Barriers are Food Shelf Life in first place (+10,000), Food Safety (+6,400), Financial Capability (+5,600), followed by Lack of a Transition Plan towards a CE (+5,400), and Facilities and Infrastructure and E-Commerce in a tie (+4,800).

Table 10. Grid Results Quantification Carrefour by Control Level

Factors Acting as an Enabler	Control %	Enabler %	Plastic Packaging Reduction Opportunity
Corporate Values & Culture	80	-80	-6,400
Innovation	70	-80	-5,600
Supply Chain (Transportation, Handling & Storage)	80	-60	-4,800
Brand Differentiation	60	-80	-4,800
Substitute Materials Functionality	70	-50	-3,500
Competitors	40	-60	-2,400
Customer Awareness	25	-85	-2,125
Customer Behavior	60	-30	-1,800
Social Media	30	-60	-1,800
Laws & Regulations	80	-20	-1,600
NGOs	15	-85	-1,275
Pigovian Taxes	30	-40	-1,200
News & Media	20	-60	-1,200
Recycling at a Source (Store)	40	-20	-800
Digitalization	20	-40	-800
Technology	10	-60	-600
Suppliers	55	0	0
Pooling Services (For Plastic Packaging Reuse)	30	0	0
Sales	60	20	1,200
Labeling	40	60	2,400
Cost	70	60	4,200
E-Commerce	60	80	4,800
Facilities & Infrastructure	80	60	4,800
Lack of a Transition Plan (Circular Economy)	90	60	5,400
Financial Capability	70	80	5,600
Food Safety	80	80	6,400
Food Shelf Life	100	100	10,000
Factors Acting as a Barrier	Control %	Barrier %	

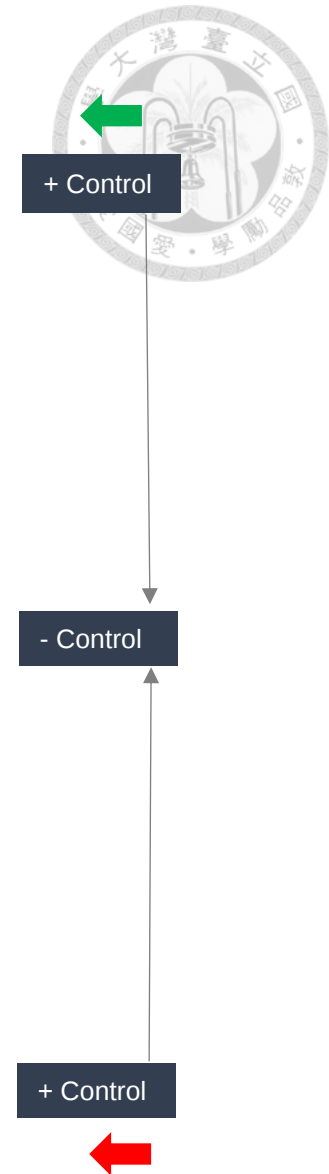
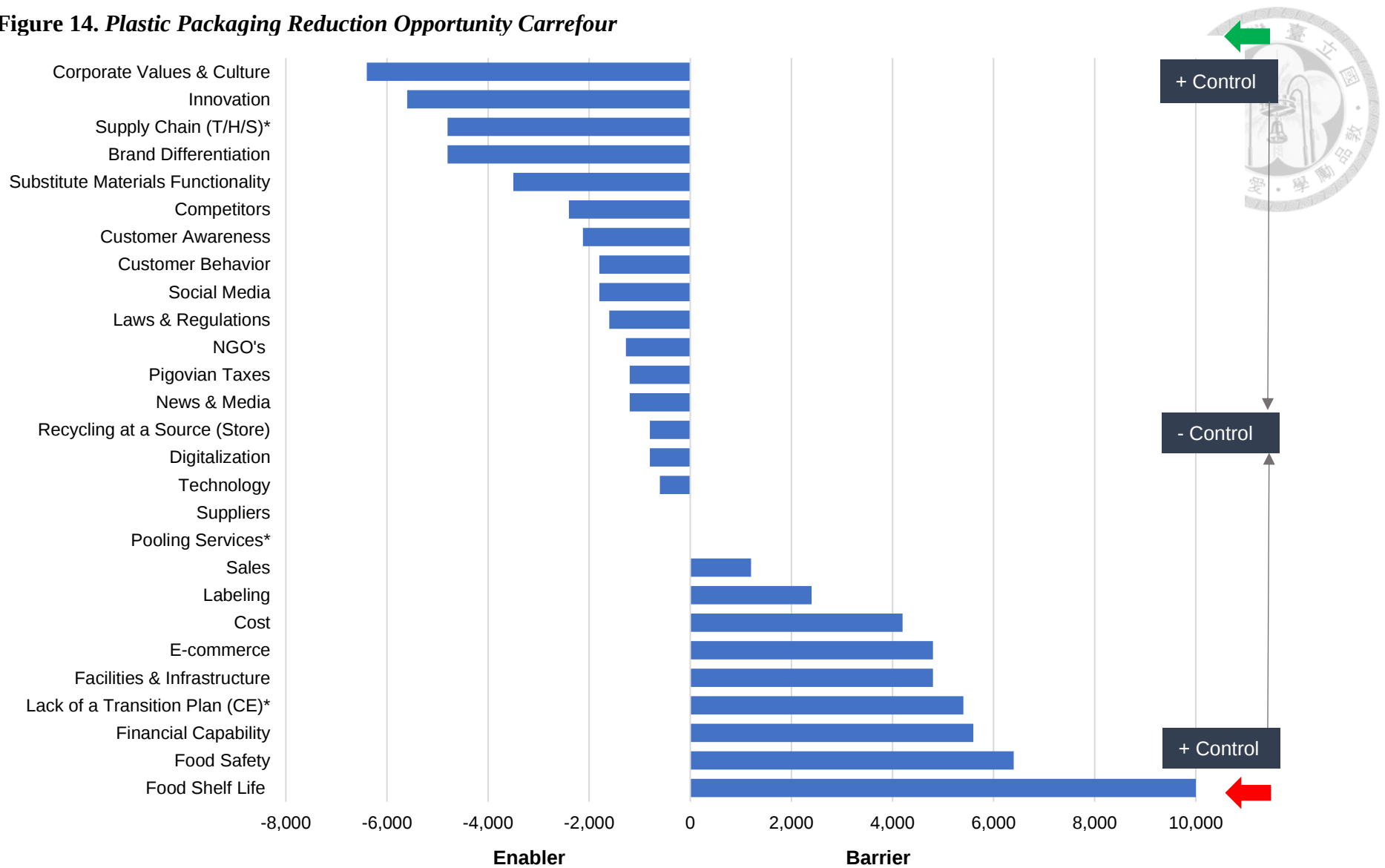


Figure 14. Plastic Packaging Reduction Opportunity Carrefour



5. Chapter 5: Discussion

This Chapter elaborates on barriers and enablers based on the information collected from the interview with Carrefour's Taiwan CSR Manager. It is complemented by the on-site observations and secondary data. It aims to provide a better and deeper understanding of the scope and implications of fresh produce plastic packaging reduction from the business perspective.

5.1 Top Five Barriers Ranking:

5.1.1 Food Shelf Life

During the interview, Food Shelf Life was appointed as the biggest challenge for Carrefour to reduce plastic packaging. This factor has different vertices. It is related to customer behavior, customer awareness, sales, and even weather. The participant explained:

In the past, our company used to sell naked vegetables; however, the breakage rate became considerably high. Consequently, plastic packaging increased to reduce food waste. In addition, the weather in Taiwan is different from other countries. If vegetables are not well packaged, they might cause much breakage. One of the most difficult problems for us is balancing food waste and plastic packaging usage.

It was also mentioned that supermarkets have extended business hours, and rotation is lower compared to traditional markets where fruits and vegetables are displayed naked at room temperature for a reduced period. There, vendors can store a portion of the commodities in their refrigerators and rotate them according to sales. In contrast, if product rotation in supermarkets is not quick enough, some unpacked products must be discarded on the same day they are stored on the shelves. For example, the quality and freshness of leafy products, popular in Taiwanese cuisine, will diminish if displayed unpacked after a couple of hours, even if

exhibited inside the fridges. Thus, goods rotation should be fast. At the same time, rotation is directly related to Customer Behavior. The interviewee pointed out that, especially in urban areas of Taiwan, both heads of family usually work. Therefore, Sales at the supermarket are primarily made in the morning, during lunchtime, or in the evening. Notwithstanding, shelf life can be extended by one or even two days if products are packaged, depending on the product type.

Unpacked produce is also more prone to get damaged and become food loss since bruising and imperfections on the product's skin make it unappealing for customers, even though dark spots do not necessarily mean a product has gone bad. The interviewee cited, "This kind of product is very likely that if it has minimal damage, people will not buy it." In this regard, an article by Michigan State University mentioned that bruising does not necessarily mean a health risk and that a fruit or vegetable must be no longer eaten, "It is simply a reaction that occurs as cells break down and are exposed to oxygen that causes the browning and softening of the tissue" (Hart & Levin, 2016). However, the main challenge may lie in how to persuade customers. Carrefour has launched a campaign to create Customer Awareness regarding some food cosmetic imperfections, expecting to reduce food waste (See Figure 15).

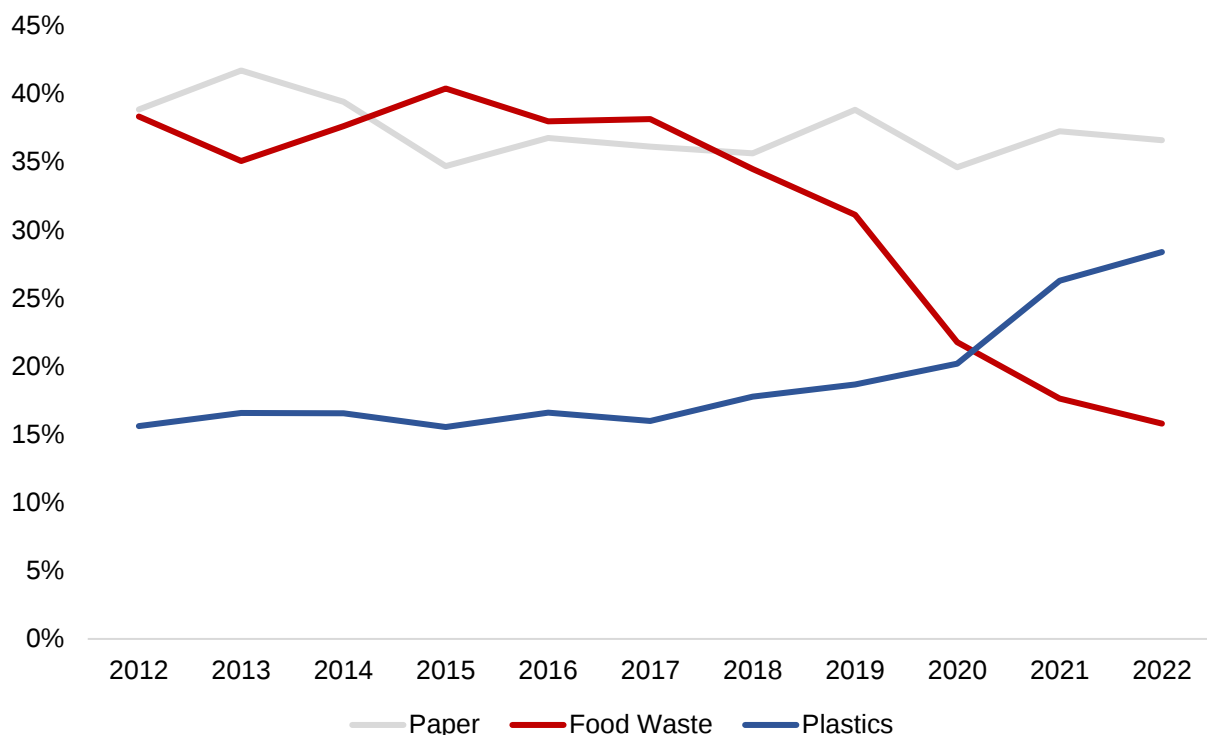
Figure 15. Carrefour's Campaign Food Waste Reduction



Source: Carrefour's Stand, Fair at NTU Campus

An analysis made using data of the Municipal Solid Waste by Physical Composition in Taiwan (EPA, 2023a) shows a correlation between the increase in plastic waste with a decrease in food waste accelerated since 2017, possibly pointing out the benefits of the use of plastic to preserve food products; however, more research is needed (See Figure 16).

Figure 16. Comparison of Municipal Solid Waste by Physical Composition in Taiwan



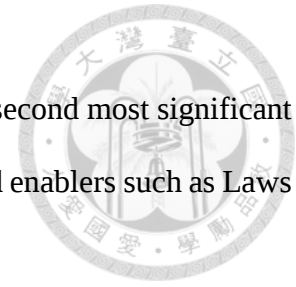
Source. Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) and Local Environmental Protection Bureaus. EPA. (2023a). *Composition of Municipal Solid Waste*.

(<https://www.epa.gov.tw/DisplayFile.aspx?FileID=BD2C75424B541074&P=dc87da4b-5041-4d4c-a2f8-61c963c80aed>).

Note: Excluding data on textiles, garden trimmings, leather & rubber, others, iron, and other metals.

5.1.2 Food Safety

Results from the grid assessment pointed to Food Safety as the second most significant barrier to plastic packaging reduction. It is linked with other barriers and enablers such as Laws and Regulations, Labeling, and Customer Behavior.

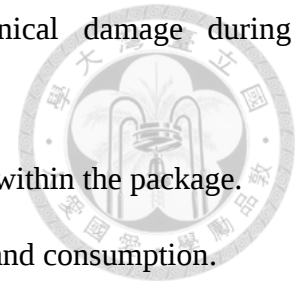


As the World Health Organization (WHO, 2019) described, Food Safety is associated with external contaminants causing the proliferation of harmful bacteria, viruses, parasites, chemical substances, or particles causing more than 200 diseases, ranging from diarrhea to cancers. Almost one in ten people worldwide develop illnesses each year after eating contaminated food, resulting in 420,000 deaths. Therefore, food packaging must be designed and produced to comply with specific functions and regulations.

First, according to the Food and Agriculture Organization of the United Nations, Regional Office for Asia and Pacific (FAO, 2011), fresh produce packaging must provide:

- Protection against external agents.
- Resistance to low-temperature storage.
- Waterproof when water results from fresh produce cooling or external conditions.
- Protection against moisture to minimize weight loss and shrinkage and, simultaneously, allow ventilation to dissipate heat from produce respiration.
- Allow gas permeability (oxygen) to prevent anaerobiosis, except for Modified Atmosphere Packaging (MAP), which requires a degree of gas barrier to extend produce's shelf life.
- Be made of biologically and chemically safe materials (food grade).
- Be compatible with handling and transportation equipment.

- Strength and durability to protect produce from mechanical damage during transportation, distribution, and exhibition.
- Hold produce in place to prevent abrasion, impact, or collision within the package.
- Provide convenience for marketing (product display, labeling) and consumption.



During the interview, it was mentioned that, especially after the Covid-19 outbreak, Food Safety became of particular concern for consumers, to the point that some of them requested the store to add additional plastic layers to products and even provide plastic gloves in case customers want to tamper produce before buying it. Nevertheless, there is one advantage for vegetables: the skin. The interviewee cited:

At that time, we stopped unpackaging ready-to-eat and bakery products, but for the vegetables, I think it is more acceptable for them because you can peel off the skin. However, there are a few people that really care about this kind of exposure.

Food Safety could bring some challenges to plastic packaging reuse. Nahar et al. (2022) explained that “while reusing packaging can be 85% less environmentally damaging than single-use packaging, in the food sector, the risk of cross-contamination between uses presents the hazard of microbial growth and transferrable viruses, adding complexity to tracking and recalling contaminated products.”

The use of recycled plastic has another implication for Food Safety. The interviewee mentioned that before, using recycled plastic for food contact packaging was prohibited due to safety concerns. In May 2022, the Taiwan Food and Drug Administration (TFDA) announced a new application to use recycled PET (rPET) to promote circular food packaging based on the American and European safety assessment of remanufactured PET pellets principles

(Parkinson, 2022b). However, the implementation may be slow since rPET factories must undergo a certification process of their supply chain to produce this material. The participant explained:

In the past, even though we wanted to use recycled plastic, we couldn't because it was not allowed. Currently, only PET is qualified. The regulation was passed last year [in 2022], but the suppliers' supply chain is not ready yet. Only one factory passed all the supply chain checks in Taiwan. Therefore, there is not enough recycled plastic for packaging.

Additionally, in 2022, the EPA announced a ban starting July 2023, applicable to food packaging made of or containing any PVC due to recent research findings that indicate the risk of food contamination with harmful chemicals such as vinyl chloride, classified as a Group A human carcinogen (Parkinson, 2022a; Sheldon, 2022; US EPA, 2000).

Food Safety is also related to regulations on using fertilizers and pesticides and mechanisms to control and trace their usage. Plastic reduction or reuse could be challenging since packaging for organic produce is required to reduce pollution risk by mixing organic with non-organic products or by contact with prohibited substances. In this regard, the "Certification Standard for Organic Agricultural Products and In-conversion Agricultural Products and Allowable Substances in their Production, Processing, Packaging, Distribution, and Sale" (AFA, 2019) mentioned:

When organic and non-organic products are stored, transported, or delivered together, the products shall be distinctively marked, labeled, and appropriately packaged to avoid commingling. Packaging methods shall be based on a principle of simplicity to avoid over-packaging, and packaging materials shall be biodegradable, recyclable, or

reusable; yet, ordinary packaging materials can be used in case the first-mentioned are not available or not applicable.



Besides, norms like Article 18 of the Organic Agriculture Promotion Act 2018 (Ministry of Justice, n.d.) require products to display information on the labels of each unit sold to trace their origin, quality, and safeness, including but not limited to a logo or mark identifier, name of the product, traceability code, QR code, country of origin (if imported), and name of the accredited certifying agent. Labels must be placed on the package, container, or product itself. From this perspective, the interviewee stated:

Another factor is the label. This is a very important one. We can have traceability with the Organic and TAP label, but products must be packaged. The regulation requires it, and in Carrefour Taiwan, we want to ensure that customers buy safe products. About 70 – 80% of fruits and vegetables in Carrefour have the TAP or Organic certification. It means that 70% of products must be packaged. In addition, organic products are more expensive, and suppliers tend to protect the product.

Some examples of fresh produce labeling are Taiwan Organic, USDA Organic for American products imported to Taiwan, and Traceable Agricultural Product (TAP) (Taiwan Agriculture and Food Traceability System, 2022; USDA, n.d.).

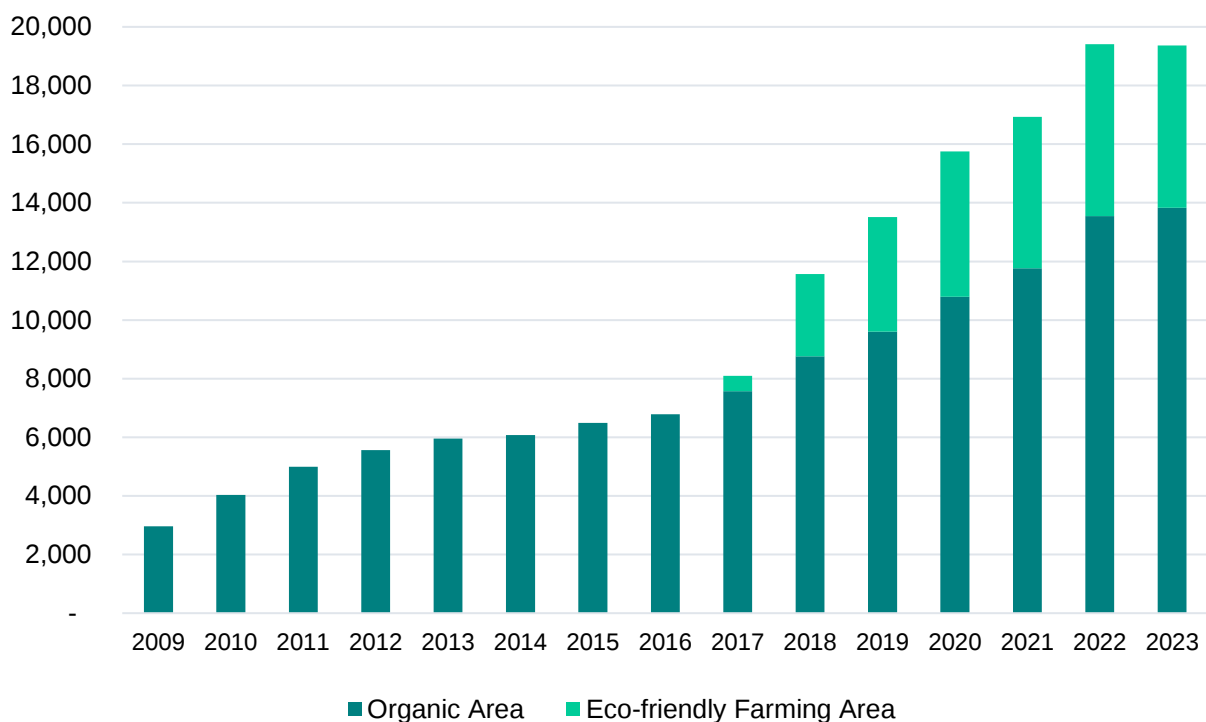
Demand and production of organic food in Taiwan have exponentially increased due to a series of policies, subsidies, and promotions set by the government that started at the end of the 1980s (See Figure 17) (Antonie, 2020; AFA, 2023). After the post-war period in 1945, pesticides and fertilizers helped the agricultural development needed to support the country's industrialization (Mao & Schive, 1995; as cited in Antoine et al., 2018). However, the

awareness of environmental and health risks related to these substances led to the introduction of experimental organic farms and the consecutive development of regulations and standards applicable not only to production methods on farms but to the whole value chain, including packaging and labeling.



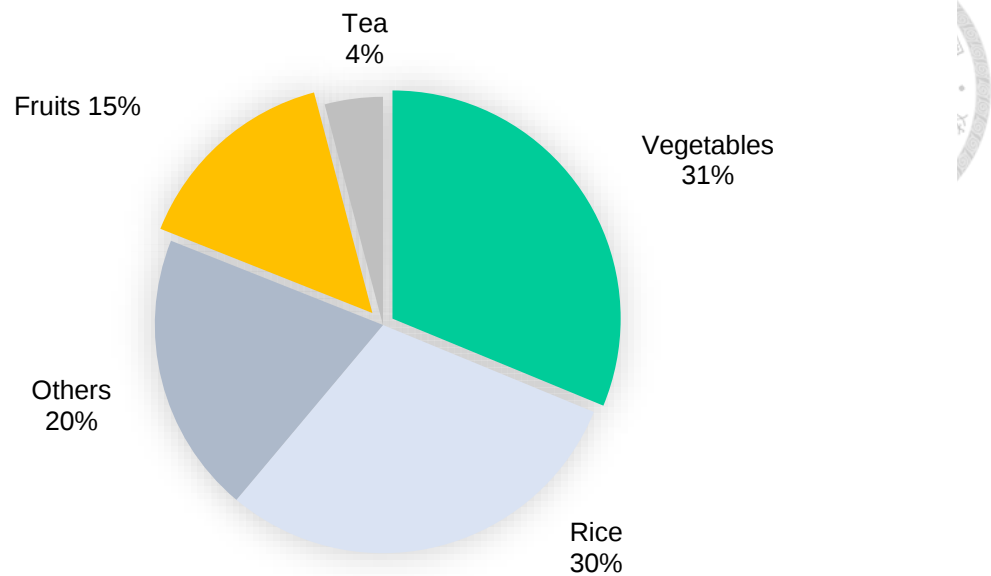
By 2021, the Taiwan COA has certified 11,468 hectares of organic farmlands from which vegetables represent 31% of the organic planting area, followed by rice at 30%, fruits at 15%, tea at 4%, and 20% for other products (See Figure 18) (OAPC, n.d.-a).

Figure 17. Organic and Eco-friendly Farming Area in Taiwan (2009 – April 2023, in Hectares)



Source: Agriculture and Food Agency. AFA. Council of Agriculture. Executive Yuan, R.O.C. (TAIWAN). (2023). *Organic and Eco-friendly Farming Area in Taiwan*. (<https://www.afa.gov.tw/cht/>).

Figure 18. Planting Area of Organic Crops in Taiwan (2021)



Source. Organic Agriculture Promotion Center (OAPC). (n.d.-a). *The Current Situation and Prospect of Organic Agriculture Development*. (<https://www.oapc.org.tw/en/current-status/>).

5.1.3 Financial Capability

Regarding Financial Capability, the interviewee mentioned that it is a barrier since there is a limited amount of money to invest, such as purchasing equipment for cooling unpacked fresh produce or upgrading facilities and infrastructure. Conversely, according to an analysis by Deloitte (2023), 73% of 250 top global retailers have increased investments in sustainability in 2022 or before, as “climate change is among the top three issues affecting consumer-facing companies. Adopting new materials, upgrading supply chains, using energy-efficient equipment and technologies, and even training employees on climate change actions requires significant investment.”

5.1.4 Lack of a Transition Plan Towards a Circular Economy

An unclear Transition Plan toward a CE and difficulty measuring environmental impacts can hinder plastic packaging reduction. However, Carrefour Group has set clear global

targets and three main Key Performance Indicators (KPI) to achieve its Sustainability Plan. The KPI “Tonnes of Packaging Avoided” aims to achieve a Circular Economy, avoiding placing a cumulative 20,000 tonnes of packaging on the market from 2017 to 2025, including 15,000 tonnes of plastic for fresh produce, groceries, and other non-food products. An external verifier audits these KPIs annually (Carrefour, 2022). During the interview, the CSR Manager mentioned that Carrefour Taiwan has a clear target to decrease a cumulative 500 tonnes of packaging by 2025, taking 2017 as a baseline. The interviewee cited:

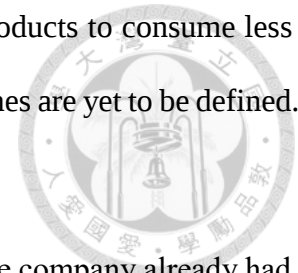
Carrefour Group set global goals and KPIs. Carrefour in different countries has different targets; it depends on your ability. They asked us to do things we did not believe we could, but we reached the target.

The interviewee mentioned that, especially for Carrefour’s brand products, it is easier to set a plan and specify targets for plastic reduction since the company can control the packaging and the content. In this sense, Suppliers were considered essential stakeholders in reaching Carrefour’s KPIs. The interviewee cited:

Some suppliers have a more positive attitude. They are very engaged in tackling environmental issues and are very good partners, but others just cannot understand what we are doing and are more hesitant. We do not have a KPI or penalization for them, but we work with those who have the passion and want to change, those who can support us to reach a KPI.

According to Carrefour’s policies, products are inspected before entering the store, and only those that comply with the specifications are accepted; therefore, suppliers tend to protect their products with packaging. However, Carrefour plans to gradually remove or use trays with

recycled plastic content when needed, shift to plastic bags for some products to consume less plastic, and unpack products in the long term. Nonetheless, exact deadlines are yet to be defined.



Despite challenges, Carrefour's CSR Manager explained that the company already had progress on plastic packaging reduction for some product categories:

For instance, for oranges, we encouraged the supplier to unpack them. For papayas, we have already removed the plastic tray and plastic film used to cover it, but it is very difficult to remove the foam net because it is so easily damaged. We changed to a plastic net for ginger, while for potatoes, the plastic net hole became bigger to use less plastic. We asked the suppliers to try their best. We do not ask them to stop immediately because it is hard and they can refuse to do business, but we ask them to decrease it yearly, step-by-step, then we can reach our target together.

E-Commerce and Customer Behavior can also influence the transition plan toward a CE. On the one hand, online shopping was appointed to be a barrier since it is difficult to ship naked products. Bags are necessary to protect them from being damaged, and certain kinds of fresh produce, like potatoes packed on a plastic mesh, must use a plastic bag to prevent contaminating other products purchased by customers. On the other hand, the interviewee mentioned that Customers frequently request packaging "For many people, if they do not have very good packaging, they will not buy it." This coincides with what Heidbreder et al. (2020) found, "Some consumers consider it difficult to buy products without plastic packaging."

5.1.5 Facilities and Infrastructure

This factor refers to the economic viability of investing in facilities and infrastructure to reduce plastic packaging. The interviewee explained that it can be a barrier if the company

has to upgrade its facilities and acquire new equipment. For example, to purchase mist system refrigerators to preserve moisture on naked fruits and vegetables. Implementing this system also has a side effect: an increase in energy consumption that would affect Carrefours' KPI 1.A, called "Group Greenhouse Gas Emissions Reduction," seeking to reduce energy consumption and CO2 emissions from refrigerants (Carrefour, 2022).

5.2 Top Five Enablers Ranking:

5.2.1 Corporate Values & Culture

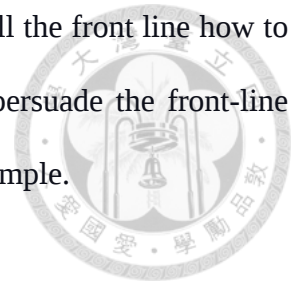
Corporate Culture and Values can influence governance, sustainability strategies, KPIs, and how they are implemented. With this regard, the participant mentioned

In Carrefour, our culture is environmentally friendly. It is more careful of our actions, careful and positive because other retailers do not have this kind of policy or culture, and it is more difficult to reduce the use of plastic. It is helpful because it will push our employees to go and try everything.

Ma et al. (2019b) found that in contrast to the upper and lower levels of the organization, employees at the middle levels are not always willing to make changes to alternatives to plastic because they are the ones who will be challenged to implement those new solutions. However, the participant said that, especially in Taiwan, middle managers are usually the first to think of environmental problems, develop strategies and make proposals to the top levels. Once approved and supported by the top management, middle managers must persuade the front-line employees to implement those changes and actions.

Middle managers are usually the first to think and solve this kind of problem: packaging, sales, or promotion; they normally raise them. They have to persuade their boss, and

after they get support from the top, middle managers have to tell the front line how to do it. The most difficult part for the middle ones is how to persuade the front-line employees. If the top and front line agrees, it will be easy and simple.



5.2.2 Innovation

This factor is set to be a crucial enabler yet hard to control. It is linked to technology and creativity. Carrefour mentioned that their company has developed and experimented with some packaging innovations, for example, using recycled paper nets instead of the plastic foam net to protect papayas.

We tried not to use the plastic net and use recycled paper to make the net, but the result was not good; still an innovation. We may have a good result someday. Innovation is very important. I think it is uncontrollable. If we have some special material, we can make some changes, like smart packaging.

5.2.3 Supply Chain (Including Transportation, Handling, and Storage)

Interestingly, Supply Chain was said to be an enabler and easy to control. The CSR Manager mentioned:

It is not a big problem. Before, we used plastic bars or plastic boxes to transport the product, but now we use recycled ones for delivery [reusable secondary plastic packaging] and reuse them. The supply chain has already changed a lot. It is an enabler and very easy to control.

5.2.4 Brand Differentiation

Whereas fruits and vegetables could be seen as just identical commodities sold by

different vendors, brand differentiation is possible and it was appointed as an enabler of plastic packaging reduction by the interviewee. Brand Differentiation is defined as “a strategy that makes a product stand out from others to gain a competitive advantage and consolidate a position in the market” (Gupta et al., 2020). Supermarkets may choose to compete by quality, price, a stable supply of products, assortment, nutritional benefits, or any other characteristic that adds value for customers (Nelson, 2019). Carrefour envisioned to build brand recognition through the establishment of sustainable business practices, CSR and the Food Transition Index. The company is committed to improving the quality of its own brand products and suppliers to provide healthy and environmentally sustainable food chain, identifying products with labeling, for example, for the “Act for Food Programme” (Carrefour, 2019). It can become a virtuous cycle since customers perceive the company as Socially Responsible, to support their products and initiatives, including plastic packaging reduction. On that account, Houngh et al. (2014) stated, “If more people choose green purchasing, it will encourage more companies to join in on green products, further attracting green consumption.”

While brand differentiation is essential to generate sales, the actions taken by one supermarket may incentivize competitors to make similar changes toward plastic reduction and thus, influence the rest of the industry. The interviewee mentioned:

Competitors are important for us because if a competitor can do that, all the retailers will think: “I can also do that; I have to do that.” It will push us to change. We are retailers and will influence all the suppliers and the industry. If Carrefour does this, competitors will keep a watch and try. Competition is good for enabling these kinds of actions.

5.2.5 *Substitute Materials Functionality*

Alternatives materials were determined to be an enabler if they comply with regulations and effectively reduce environmental impacts. Even so, using substitute materials for food packaging has faced some challenges in Taiwan. In 2007, the EPA enacted a ban by which supermarkets should reduce the use of disposable plastic egg boxes, trays, and other packaging boxes by 15% and 25% in the first and second year, respectively (EPA, 2009; as cited by Walther et al., 2021). Reduction methods included selling naked products, making containers thinner, or utilizing alternative materials to fossil-based plastics. In 2008, it was stipulated that manufacturers of biodegradable materials were exempt from paying recycling fees. Therefore, the industry shifted from using PE to materials like PLA due to its transparency and waterproof benefits, reaching an estimated production of 1,500 metric tons in 2008. Nonetheless, later on, it was found that the use of biodegradable plastic did not resolve the plastic pollution problem, conversely generating health and environmental problems.

Greenpeace (2023) stated that “PLA must be degraded by microorganisms at a specific temperature and humidity, usually in industrial composting facilities currently unavailable in Taiwan. Otherwise, it can release microplastics to the environment.” Another issue is waste sorting since it can be hard for the population to distinguish PLA (compostable) from other recyclable materials like PET due to their similarity. If mixed these two materials, the recycling rates and quality can be affected, compelling PLA waste treatment to incineration.

In 2023, the EPA announced an initial ban on disposable PLA tableware starting in August 2023, applicable to the retail sector and the plastic industry (Focus Taiwan, 2023). During the interview, Carrefour’s CSR Manager explained:

It became an issue for retailers and the [plastic] industry because many factories tried to transfer their production from traditional plastic to compostable in the past years. It was a very big impact. However, I was told that there is still one benefit of this compostable product: lower carbon emissions. But if we compare the price, it is very costly. Additionally, based on our policy, we should not use packaging made from people's food because it is another carbon emission problem. Many people and animals need to eat corn, and we destroy the forest to produce corn. We should not produce plastic from corn or other food. Thus, we changed to traditional plastic again and tried to make it thinner.

Carrefour explored the possibility of manufacturers producing plastic bags for vegetables with recycled content. Still, they were told it is not feasible at the moment since the recycling process will affect the quality of plastic, making it harder and easier to be broken, also affecting transparency. In the same way, producing plastic trays with recycled content also has some challenges since it is easier to brake and will become sharp and risky for people. Thus, more research and development must be done to create better substitute material options.

6. Conclusion

This study focuses on the retail sector, taking the case of Carrefour Taiwan to analyze, from the business perspective, the barriers and enablers to reducing and eliminating plastic packaging for a specific and limited range of products: fruits and vegetables. The Objective is to understand which factors prevent and enable the reduction of fresh produce packaging, to what extent those factors can be controlled by the retail company, and detect opportunities to reduce plastic packaging and, consequently, achieve a Circular Economy guided by the Waste Hierarchy Principles.

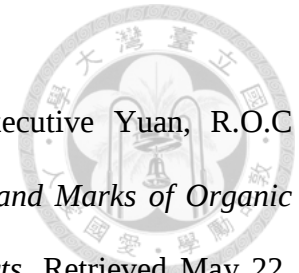
Plastic packaging solves a broad range of needs for the retail industry. At the time that it reduces food waste and safety, it helps companies' operations be more efficient, making the transportation, identification, and storage process easier and faster. Results provide an overview of organizational, operational, technical and technological, stakeholder-related, legal, and commercial considerations, being the top barriers: Food Shelf Life, Food Safety, Financial Capability, Lack of a Transition Plan, and Facilities and Infrastructure. The analysis shows that the opportunity relies on the fact that most of the top barriers are internal factors and are perceived to have a high control level. On the other hand, enablers have a combination of organizational, technical, technological, and commercial factors that may rely on external factors to the organization. The top five enablers are Corporate Values & Culture, Innovation, Supply Chain, Brand Differentiation, and Substitute Materials Functionality.

Factors with lower levels of control can still be important plastic packaging reduction enablers, such as Technology, Digitalization, Recycling at a Source, News & Media, Pigovian Taxes, NGOs, Laws & Regulations, Social Media, Customer Awareness, and Competitors. Overall, stakeholders can contribute to plastic packaging reduction; consumers and NGOs

pushing for plastic reduction, traditional News & Media and Social Media educating and creating environmental awareness among the population, Governments enabling change through clear guidelines and regulations, competitors generating a knock-effect in the retail industry, and Academia boosting research, innovation, and progress.



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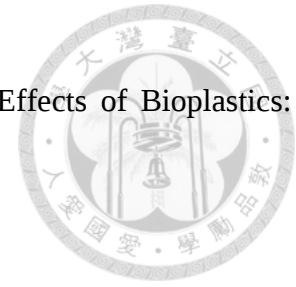
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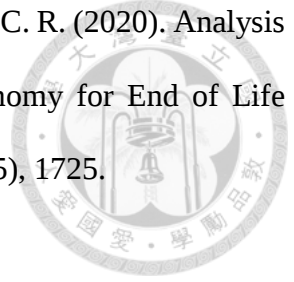
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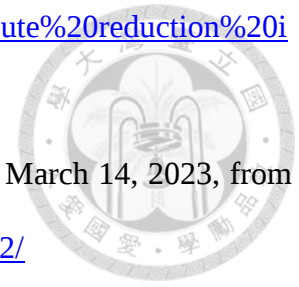
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Appendix A

Interview Outline

Case Study About the Barriers and Opportunities to Implement a Circular Economy Model on Fresh Produce Plastic Packaging by Major Supermarkets in Taiwan



Research Introduction:

There is increasing pressure on the global retail industry for a faster and more significant plastic packaging reduction and to adopt sustainable business models and practices such as the circular economy and waste hierarchy principles. However, limited research exists to understand the challenges and opportunities related to plastic packaging reduction and elimination.

Objective:

This research aims to identify factors that influence the use of primary plastic packaging on a specific and limited range of products: fruits and vegetables. It also analyzes barriers and opportunities associated with implementing a circular economic model for plastic packaging reduction, leading to reflection on how to overcome those barriers and who must be involved in these efforts.

Research Participants:

- Key employees working for retail industry leaders in Taiwan
- Interview in English (45 - 60 minutes)

Interview Outline:

2. Share general information, including:
 - a. The interviewee's job responsibilities.
 - b. Experiences with plastic or packaging issues for fresh produce (fruits and vegetables).
 - c. Relevant projects, initiatives, or partnerships your company has implemented for plastic packaging reduction in fresh produce.
3. Brainstorm the barriers and opportunities encountered to reduce plastics in fresh produce packaging. Listing at least 5 barriers and 5 opportunities will help for discussion and assessment during the interview session.

Questions:

Plastic Packaging Reduction Initiatives

- a. What are your company's main projects and initiatives implemented in Taiwan to reduce primary plastic packaging in fresh produce, and how do you measure their results?
- b. What are the reasons for implementing those projects and initiatives?
- c. What are the potential or current issues faced for their implementation?
- d. What can public and private institutions do to help the Retail sector in Taiwan to implement a circular economy or any other sustainable model for plastic packaging reduction and elimination in fresh produce?

Plastic Packaging Barriers and Opportunities

- e. From the company's perspective, what are the benefits and disadvantages of primary plastic packaging reduction/ elimination of fruits and vegetables?
- f. In your opinion, which barriers can be transformed into opportunities for plastic packaging reduction?
- g. What criteria or factors determine the quantity and type of plastic packaging used for fruits and vegetables?
- h. What are the most valuable properties or benefits of plastic packaging that substitute materials or the current technology cannot easily match for fresh produce packaging?

Notes:

Participation in this interview is entirely voluntary. Participants have the right to refuse questions, and disclosing confidential/sensitive information is unnecessary.

The collection, processing, and use of personal information are with the only purpose of academic research, and in accordance with the law, "carried out in a way that respects the data subject's rights and interest, in an honest and good-faith manner, shall not exceed the necessary scope of specific purposes, and shall have legitimate and reasonable connections with the purposes of collection" Art. 5 Personal Data Protection Administration Act (PDPA).

Interviewees' Consent:

For additional questions or details, please contact:

Daniela Mendez

Email: r09749054@ntu.edu.tw

Master's student at GMBA, National Taiwan University

Thank you!

Appendix B

Set of Cards with Factors (Barriers and Enablers) for Plastic Packaging Reduction



Pigovian Taxes	Labeling	Substitute Materials Functionality	Lack of a Transition Plan (Circular Economy)	Internal Goals & Metrics
Competitors	Brand Differentiation	Digitalization	Corporate Values & Culture	Internal Communication & Collaboration
Technology	Marketing Strategy	Supply Chain (Transportation/ Handling/ Storage)	Laws & Regulations	Innovation
Recycling at a Source	Food Safety	Sales	News/Media	Food Shelf Life
Sorting & Handling (Plastic Packaging Waste)	Packaging Design & Harmonization	Facilities & Infrastructure	Customer Behavior	Suppliers
Pooling Services (For Plastic Packaging Reuse)	Cost	Financial Capability	Investors	NGO's
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Appendix C

Intelligent Verbatim Transcripts of the Semi-structured Interview



Interviewee: CSR Manager, Carrefour Taiwan

Interview Site: Carrefour Impact Store

In Carrefour Group, we have many plastic reduction plans and programs in fresh produce and grocery or other non-food products. Carrefour Taiwan has a clear target to decrease 500 tonnes of packaging from 2017 to 2025; nonetheless, there are some reasons why it is hard to achieve, especially for the fresh product in Taiwan is very difficult for consumers to accept unpacked products. Also, for other reasons, such as food waste prevention, since the weather in Taiwan is different from other countries. If vegetables are not well packaged, they might cause much breakage. I think breakage is one of the most difficult problems for us to balance: food waste and plastic usage reduction.

I have been working at Carrefour Taiwan for more than fifteen years, and we used to sell a lot of unpacked vegetables, but later on, we found that the breakage percentage would be very high, so we tried to lower it. First, the problem is that, for example, leafy products that are on display -because we eat a lot of leafy vegetables- if they did not have the package, and are just displayed in the normal fridge, in the morning they are very fresh, but after one hour or two, the freshness will become worst, so we have to sell the product by the afternoon and if not, change it around 2 pm. That means that we have to change the product twice a day.

Normally in Taiwan, people go to the supermarket in the morning, during lunchtime, or in the evening because, especially in the city areas, most families have to work both the husband and wife, and they can only go to the supermarket during lunchtime or in the evening. If rotation is not quick enough, vegetables must go to the garbage in the afternoon or the evening; that is why we use the packaging. In contrast, if the product is packed, we can sell it until tomorrow morning; shelf life can be extended by one day or even two days, depending on the type of leafy produce. I think this is the most important issue for the supermarkets because the rotation is lower than in the traditional market where products are sold from six or seven am to eleven am, so it is like only four hours so that they can change the products very quickly; they can put some products in the fridge and some other outside. However, in the supermarket, it is more difficult to do this.

Another reason is the label. This is a very important one because, in Taiwan, we have had many food scandals; we see vegetables as a very risky product in the retail market because it is very easy to find chemicals and pesticides. Around ten years ago, almost every month, it would be found some product that is not qualified by the government. So, we tried to change in our store because, in Carrefour, we asked our farmers to have traceability; when we grow the seeds, how many days it takes to grow them up, if pesticides are used, and how many days you can collect the product. Hence, we have a very clear history of every product. At that time, when the government set up this regulation, they were worried that products grown-up with the traditional method would be polluted because this one maybe has many pesticides, but this one does not, and if put together, there will be contamination.

We can have traceability with the Organic and TAP label, but products must be packaged. The regulation requires it. That is why in Carrefour Taiwan, we want to ensure that customers can buy safe products. About 70 – 80% of fruits and vegetables in Carrefour have the TAP or Organic certification. This means that 70% of products must be packaged. Thus, for TAP products, we cannot decrease plastic, but we tried to change it [packaging]. Before, most of the products we had used a tray, but now we decreased the use of the container [tray], so we have fewer and fewer products using the plastic tray. In the future, most products will be only packaged in a plastic bag because it uses less plastic in weight compared with the packaging that uses the tray, which is much better. We have already changed a lot. For the luffa, for example, before, it used to have a tray, but we already removed it.

In addition, organic products are also more expensive, which is another reason for using more packaging; they [suppliers] tend to protect the product.

Different brands have different packaging. In our policies, only under special conditions the plastic tray can be used, but in our new policies, we will stop using it. If the supplier has to use the tray or the box, maybe in the future, we will encourage the supplier to change to using recyclable PET plastic. This is material that we can use for bottled drinks in Taiwan. We do very good recycling in Taiwan, so we encourage that in the future, they can use recycled plastic [PET] on the box or trays, but this policy started last year, 2022, because, in Taiwan, the regulation just passed. In the past, recyclable plastic was prohibited from being used for food products, so even though we wanted to use recycled plastic, we couldn't because it was not allowed.

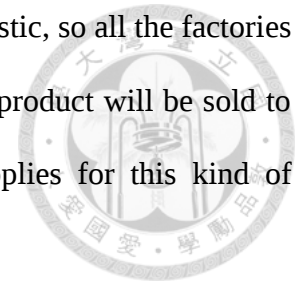
Perhaps we will have more recycled plastic to use on packages in the future. Currently, only PET is qualified by governmental regulation to be used for fresh produce products. We asked if they could have a recycled plastic bag for vegetables, but we were told it was almost impossible because the recycled plastic material is harder and easier to break. After recycling, the material quality would change and be easy to break, affecting the transparency so you cannot see the product. Also, it has some risk for the tray. Some people tried it, and it is easy to be broken, and broken will become very sharp and risky for the customer or other people. We still have to do some research. In the future, our effort is not to use the tray, and if you want to use it, we will encourage the supplier to use the recycled one. This is the current policy, and for the long-term, the naked product is what we are trying now.

The regulation was passed last year, in 2022. However, the suppliers' supply chain is not ready because, in Taiwan, only one factory passed all the supply chain checks by the government, so we do not have enough recycled plastic now for the packaging. If you want the recycled plastic certification, you have to pass some auditing from the government first; then, you can get the certification and produce this kind of recycled material.

Farmers buy the package because only one factory passed the certification. Or two in this year. There is a high demand for plastic packaging; only two factories are not enough, so the price of recycled plastic is higher than normal [virgin] plastic.

Passing the audit and getting certification takes time, and the need for recycled plastic is not only from Taiwan; it is global. Because, in most countries, for example, Carrefour

France asked all their packaging to contain 30% of recycled plastic, so all the factories that passed and got the certification from the government, the product will be sold to other countries. Hence, they need time to have enough supplies for this kind of packaging production.



Regarding KPIs, we already have the review to eliminate the trays. I think that maybe before the end of this year [2023], we will have some progress. For recycled plastic [content integration in packaging], I cannot give you a specific date. The bag may be the last one, but the policy is that it will become as thin as possible.

You can see for this one [naked cucumber] that the skin is getting dry. Suppliers tend to protect the product, so they are unwilling to remove the tray, but it is in our new plan. This will be changed in the future.

When the product comes to our store, we check the product; the responsibility is on the farmer or supplier. Thus the supplier will ensure that their product is in very good condition and acceptable; that is why some suppliers are a bit hesitant about this kind of policy [plastic reduction]. Because this kind of product is very likely that if it has very small damage, the customer will not buy it. In Taiwan, people will check all the products.

We tried in our store; for example, for the eggs, most eggs have cardboard packaging. We change it. At first, it was all in plastic packaging, but then we changed them to recycled paper packaging [cardboard egg trays]. In this Carrefour store, we tried to sell the product [eggs] without packaging; people have to bring their own container or buy

it [reusable plastic container for eggs], but many people do not want to buy another one; therefore, we tell them you can recycle this paper packaging. We just cut the cardboard tray for them so they can put the egg here, but I think it is not a very good measure since we want people to bring their container; nonetheless, we provide the recycled one, and it is very difficult for us because it takes much time to cut the paper tray and the employees can hurt themselves cutting it, that is why we encourage customers to bring their own.

This store, Carrefour Impact, is special because the main customers come from the community, and it is already difficult for some of them to bring their own container; you can imagine how it can be for customers that buy in a normal store. People drive to the store and buy this kind of product, and it is very difficult for them to bring their container because some people just go shopping without planning.

I think that, especially after Covid-19, people are more hesitant to buy unpackaged products. For example, for the bakery, we used to sell it unpacked. We can also provide a small bag to buy a lot of bread, but after Covid-19, people complained and said that they do not dare to buy it unpacked since it may have some contamination. They were afraid even if we had the shelf. They still asked us to pack the product individually. You can see that we now sell it packaged individually. Some people even said that they did not want anyone touching the product. Some asked us to provide gloves if people want to touch the product, but the Covid-19 situation is getting better. At that time, we stopped unpackaging ready-to-eat and bakery products. However, for the vegetables, I think it is more acceptable for them because you can take off the skin, but still, there

are some people that really care about this kind of exposure, but not all people but just a few.



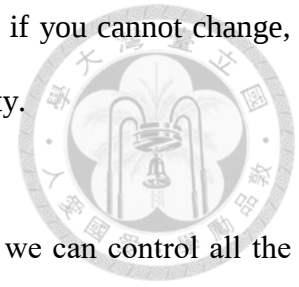
If you want to stop all the use of plastic, regulation is the most efficient way; for example, straws, before we used many straws for drinks; two or three years ago, the government set the regulation to stop the usage of plastic straws, and then it disappeared in one or two years.

I think we will have more products; for example, for oranges that are not so easy to get damaged, we encourage the supplier to unpack them. For the papaya, we have already changed and tried to use less plastic. Before, it had a tray and two–three layers of plastic film covering the fruit, and we took off the tray and film, but the foam is very difficult to remove because it gets easily damaged.

For ginger, we changed to using a plastic net. The plastic mesh hole became bigger to use less plastic. We asked the supplier to try to use less and less plastic. We do not ask them to stop immediately because it is hard and they can refuse to do business with us, but we ask them to decrease it year by year, step-by-step, then we can reach our target together.

For vegetables, we have a policy for suppliers. We do not have a KPI or penalization for them. We work with suppliers who have the passion and who want to change. We want to encourage this kind of supplier. Because we have KPIs to reach, the supplier we work with will be the one that can support us to reach our KPIs. We do not have to

have any punishment for them; we just tell them we need this; if you cannot change, we have to decrease [share of] your product, buying less quantity.



Especially for Carrefour's brand products, it is easier because we can control all the packaging and all the content. This is the product [shampoo] launched last year. It already uses all recycled plastic. I believe in the future, most of the newly launched products in Carrefour will use this kind of plastic packaging. We will try as much as we can.

Before, we were guided by the European company Carrefour. Carrefour Group set all the KPIs. They asked us to do things we did not believe we could, but we reached the target. For example, we did not sell cage-free eggs for animal welfare. In Taiwan, we never mentioned animal welfare until 2018, but the Europeans already had the regulation to stop the battery cage in 2020. So, we are already later than Europe by twenty years. In 2020 they stopped selling the battery cage egg, but we only knew about this issue in Taiwan in 2018. Carrefour Taiwan tried to catch up, and we launched the cage-free for animal welfare commitment to stop selling the battery cage in 2025. However, it is also very challenging in Taiwan because many farms have big issues due to the shortage of eggs. We have already had this policy for five years, and now more and more retailers are aware of this. They provide customers with this kind of choice.

Transcripts for Factor's Measurement on the Grid Discussion

The transcripts below correspond to the second section of the interview, where the participant discussed and assessed on the grid (adapted from Ma et al., 2019b) factors that

determine the quantity of plastic packaging used in fresh produce to identify the level of control the company has over those factors and which of them act as barrier and enablers.



Customer Awareness. They ask us to change.

NGOs. They push us to reduce plastic packaging.

Competitors. They are important for us because if the competitor can do that, all the retailers will think: I can also do that; I have to do that. It will push us to change. We are retailers and will influence all the suppliers and the industry. If Carrefour does this, competitors will keep a watch and try. If Carrefour can do this, we can do it. I think that competition is good to enable these kinds of actions.

Food Shelf Life. I think the most difficult barrier is food shelf life.

Laws and Regulations. If laws and regulations are clear, they will enable change. They can even stop all packaging. For example, in France, they prohibited it in apples and carrots and could not use any packaging, so they stopped.

E-Commerce. For example, online shopping is a barrier since the product must be delivered, and it is almost impossible to ship it naked. We need to add a plastic bag on products packed in a plastic mesh since the skin is dirty; for example, potatoes will otherwise contaminate other products. Also, bags are needed to protect the product and prevent it from being damaged.

Digitalization. It is positive since it can create customer awareness.

Social Media. It can create customer awareness. It encourages customers to try and helps customer education, which is very important. We cannot control what they say, but still, it can be an enabler.

Facilities and Infrastructure. If we have to remove all the packaging, we have to change all the fridges because there are some special ones. For example, in European

countries or Australia, they have fridges that spray water or fog to keep and extend shelf life. We need a lot of new fridges because we cannot put some products at normal [room] temperature, we need to put them all in the fridge, which is another energy problem. For me, it can be both. Sometimes it can be an enabler, and sometimes it can be a barrier. It can be a barrier if we have to upgrade the facilities. Perhaps, some new culture will cause some change.

Pigovian Taxes. It would be helpful. It is like regulations. But I am not sure. I think it depends on the amount of the tax. If it is too high, people will change, but if it is just, for example, five percent, people compare it with the price they will say it is still cheap. I believe it is not easy to control, but it is useful.

Cost. If we want to change it to recycled [instead of virgin plastic], of course, it is costly, and if we want to upgrade all the facilities, the product price will increase.

Substitute Materials Functionality. Compostable is another problem because in Taiwan, in the past, we tried to change the packaging from PE, the traditional PE, to the compostable one. However, then we were told that it would cause some environmental issues. It is very difficult to build up the factory to do compostable work, so even if we provide the compostable bag, it will not be recycled. Only bags that can be compostable are collected. The compostable bag should go to the land because they do not have the factory to do that, so this waste is put into the normal waste and sent to incineration. Greenpeace asked us to stop using it. It became an issue for retailers and the industry because, in the past year, many factories tried to transfer their products from traditional plastic to compostable plastic. However, we were told it is not a good material for the earth. It is a very big impact on the plastic industry.

I was told that there is still one benefit for this compostable product: low carbon emission, and when you burn, it is easier. But if we compare the price, it is very costly.

There are still many people worried about the compostable one. They are worried that if it is not completely compostable, it will become tiny particles [microplastics], go to the ocean, and cause other problems. In addition, all compostable plastic bags are made from food products like corn [starch]. Before we changed the vegetable packaging to compostable one, the material comes from the food. In Carrefour's policy, we should not pack from people's food because it is another carbon emission problem. We already have a lot of people and animals who need to eat corn, and we destroy the forest to produce corn. So, you should not produce plastic from corn or other food. This is Carrefour's policy. Also, a change for environmental protection. We change again to the traditional one, not the compostable one because we cannot recycle it and the material comes from food. It is too many problems, so I think we now just use traditional plastic and try to make it thinner.

I think that in Taiwan, we only have one factory that can produce compostable bags. However, they have now tried to recycle it to produce new plastic containers, for example, flower vases or stationery products.

One problem is that if the compostable bag and PE bag are mixed together, they cannot be recycled. The government tried to stop the compostable PLA material because people cannot know which is PLA, PE, or PP. They look very similar. People disposed of it together for recycling. A lot of PE was destroyed but very few PLA. Sorting was a problem. Now they are trying to make this simpler. They have announced that in the future, the government will not recycle compostable ones, like the PLA. Therefore, there is no reason to use it.

Brand Differentiation. It is important for us, but it is not very controllable. For me, it is an enabler but not very controllable.

Sorting and Handling (Plastic Packaging Waste). It is a barrier if people do not do it

correctly. It can be a problem for the circular economy. But in Taiwan, this is not a big problem; in general, most people do it very well unless they really do not know how to separate it.

Sales. This factor is a barrier because many customers if the product does not have very good packaging, will not buy it.

Supply Chain (Including Transportation, Handling & Storage). It is not a big problem. Before, we used bars or plastic boxes to transport the product, but now we use the recycled ones for delivery [reusable secondary plastic packaging] and reuse them. The supply chain already changed a lot. It is an enabler and very easy to control.

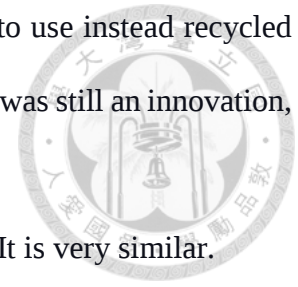
Recycling at a Source. I know one supermarket tried recycling vegetable bags at the store, and on Mother's Day, you will get a flower vase. The container will be made of recycled bags as an incentive for them [customers] to recycle, approximately 10% [recycled plastic], which I think is high. For Carrefour, at this time, the percentage is about one percent.

Perhaps we cannot use 100% recycled plastic. Maybe we must start from 30% and increase it. But the good news is that we have more and more materials.

I cannot say that this is a barrier. In Carrefour France, they tried to do this, you can leave your packaging in the store before you go home, and they will recycle it for you. However, I think it is easier for customers to recycle it in their community. For example, if you remove the bag, once you go home, you have to package it again to keep the vegetable fresh for one week. Maybe you can use a box or something. Maybe it is positive, but not easy to do.

Innovation. It is very important. I think it is uncontrollable, but if we can have some special material, we can make some changes, like smart packaging. For example, the papaya has to be packed, but how to do it without plastic? It needs some innovation.

For example, we tried before not to use the plastic [foam net] to use instead recycled paper to make the net to protect it, but the result was not good. It was still an innovation, but maybe we can have good results someday.



News & Media. I think it is like Social Media; it is an enabler. It is very similar.

Corporate Values & Culture. It is helpful because it will push our employees to go and try everything.

Internal Communication and Collaboration. If the top and bottom agree [to implement some initiative], and both sides agree, I think there is no problem for the middle managers because middle managers, especially in Taiwan, most of them follow the boss; if your boss supports it, then everything will not have any problem. The most difficult part for the middle ones is how to persuade the front-line employees. If people at the bottom and the boss think it is important, there is no problem with it. The normal situation is that middle managers think it is important, have to solve this kind of problem: packaging, sales, or promotion, normally raised by them. They are normally the first people to think about this kind of question. They have to persuade their boss, and after they get support from the top, managers have to tell them how to do it to the front line. If the top and front line agrees to do it, it will be easy and simple.

Food Safety. It is a problem for people to change; it is more like shelf life.

Suppliers. It is sometimes also in between because some suppliers have a more positive attitude toward doing this, but some of them are more hesitant. Some suppliers are very engaged to do this environmental issue, so they are very good partners, but some others just cannot understand what you are doing.

Customer Behavior. I think it is very difficult to say since some behavior is positive, but some behavior can be very difficult. If the customer tells us, "I do not like this kind of plastic," we will have more awareness, people can help us with this. Nevertheless, it

is the customer who asks us to add the plastic bag. We cannot stop the plastic bag because customers ask for it. For example, for this kind of papaya [naked], they will ask to provide a plastic bag to package it and bring it home. They do not bring their own bag. I am not sure, sometimes, it is a barrier, and sometimes it is an enabler.

Financial Capability. It is a barrier because you can always invest a very limited quantity of money, for example, on fridges.

Technology. This factor is very important and should be an enabler in the future, but it is very difficult to control because we do not know when we will have the new technology.

Pooling Services (For Plastic Packaging Reuse). We have this kind of company; one provides reuse services. In France, we tried it, but not in fresh products. We tried shampoos and detergents. They use reusable bottles, and after you finish the product, you return the bottle to the store; they have a special machine that will return some money. The technology and services are not a problem; the problem is the cost. Who is going to pay for the cleaning, transportation, and all? In France, I think Carrefour paid around 70%, which is really high, it is a terrible amount, and I am not sure if the project is still going or not. The name of the company is Loop. They tried to see if the supplier was willing to pay for it. I think it should be shared by the supplier, Carrefour, and customers.

Recycling and reusable bottles are very costly. The bottle is not expensive; the service is expensive. Just clean it; it is not easy. The cost is to collect all the bottles, the transportation to the factory, the cleaning and washing, take them to the factory to refill, and go to the store. Transportation is very costly, and the refill is done by humans. It is a manual process because we still do not have enough quantity to buy or redesign the machines. There is still not enough quantity to buy a machine or redesign the machine.

In Taiwan, some people are now trying to implement this system [Deposit Return System], but the biggest problem with reusing the packaging is the cost. It is very expensive.

Packaging Design and Harmonization. In Taiwan, we have many suppliers that told me they would like to try, but we must have enough quantity so they can buy the machine. It is difficult because if you want to change the bottle, you have to do a lot of testing; every bottle must be filled at a different speed due to the bottle shape. It is better if you want to launch a new product; the price will be attractive if you use the standard bottle because it is very easy. If you have a special design, it will be costly since they have to modify the machine to fill it up. However, I think it is not a big problem.

Internal Goals and Metrics. Carrefour Group has global goals and KPIs. Carrefour Taiwan has specific targets. Different countries have different targets. It depends on your ability. In Carrefour, our culture is environmentally friendly. I think it is more careful of our actions, careful and positive because other retailers do not have this kind of policy or culture, and it is more difficult for people to reduce the use of plastic.

Appendix D

Grid Results Carrefour

