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Qualitative analysis of reducing packaging consumption through reusable systems for takeaway containers

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Affidavit

I, **MARIE-ELISABETH VON BOMHARD BSC (HONS)**, hereby declare

1. that I am the sole author of the present Master's Thesis, "QUALITATIVE ANALYSIS OF REDUCING PACKAGING CONSUMPTION THROUGH REUSABLE SYSTEMS FOR TAKEAWAY CONTAINERS", 99 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

This thesis is a qualitative review of reusable takeaway systems and how they may decrease packaging consumption and so negative environmental effects. First, the thesis introduces plastic, the main material used for both disposable and reusable food packaging. Its benefits and disadvantages, as well as its economic implications are explained. The thesis finds plastic to be a complex set of materials and delves into further details on different types of plastic. The thesis also determines that plastic still has heavy environmental impacts and a high potential for environmental improvement, especially through recycling, and new technologies using alternative feedstocks. Thus, while plastic is a necessary and practical material, action is needed for improved lifecycle management. This has been recognised by governments who have taken legislative action, which is examined by this thesis with a focus on the EU. Because of plastic's examined features, this thesis establishes that it is also a practical material for reusable takeaway containers. Hence the thesis examines LCAs, which compare disposable with reusable plastic containers as well as other materials, aluminium, bagasse, and glass. Various LCAs indicate that PP is a sustainable choice for a reusable container system under certain conditions, if the container is reused at least 40 times. The use of local manufacturers, commercial dishwashers and short distribution paths are important factors, too. Overall, findings confirm that indeed a reusable plastic container system is preferable to disposable containers.

Finally, the thesis gives an overview of systems and provides case studies of their application. All examined types of systems, where containers are washed on-site or elsewhere, seem viable from an economic, environmental and social perspective. Surprisingly this thesis observes that deposit fees of up to EUR/CHF 10 had no significant negative effect on the system. System success rather depends on how the rate of loss and efficiency is managed through clear definition of the system's area, accountability and distribution mechanisms, incentives, marketing and pricing. It also depends on expected container lifetime (durability) as well as how and where these are produced, washed, monitored, and discarded. Short reuse times are essential, too. The thesis finds that the main cause for longer reuse times are consumers who keep the container instead of returning it. Keeping and washing the container at home is not optimal from an environmental perspective, also as returned containers may have to be rewashed because of sanitation regulations, wasting valuable resources. Outdated and complicated sanitation regulations are one example of a barrier where local government action could substantially help change the situation. Local governments are central to help modify consumer behaviour and decrease waste and litter. This can be achieved through zero waste strategies or charges on disposable container waste, as examples in Canada and Australia have shown and European ones soon will. The EU has led by example extending producer responsibilities but local governments must follow suit, focussing on public waste. Also, regulations on using recycled granulate for food containers must be adjusted to allow closed loop recycling.

Overall, societal trends will continue pushing for convenience but also increased environmental awareness. The author believes it is only a matter of time before the takeaway industry mainstreams reusable systems. Vienna has strong potential for a reusable system, especially if it is grown through clusters and the right communities are targeted.

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List of Abbreviations

ABS	acrylonitrile butadiene styrene
BPA	Bisphenol A
BYOC	Bring-your-own-container
C	Celsius
CBD	Central Business District
CHF	Swiss francs
CO	Carbon Monoxide
CO2	Carbon Dioxide
CZK	Czech koruna
DDE	Dichlorodiphenyldichloroethylene
EC	European Commission
EPR	Extended Producer Responsibility
EPS	expanded polystyrene
EU	European Union
EUR	Euro
EU28	The EU in its current composition of 28 member states
GBP	British pound sterling
GDP	Gross Domestic Product
GHG	greenhouse gas
GMO	genetically modified organism
HDPE	High-density polyethylene
HF	Hydrofluoric acid
ISF	Institute of Sustainable Futures at the University of Technology Sydney
kg	kilogram
lbs	pounds
LCA	life cycle assessment
LDPE	Low-density polyethylene
MFA	Mass Flow Analysis
mm	millimetre
MSW	Municipal Solid Waste

NP	Nonylphenol
PAH	polycyclic aromatic hydrocarbon
PBT	polybutylene terephthalate
PCB	Polychlorinated biphenyl
PE	polyethylene
PET	polyethylene terephthalate
PHA	polyhydroxyalkanoates
PLA	polylactic acid
PO	polyolefin
POP	Persistent Organic Pollutant
PP	polypropylene
PS	polystyrene
PVC	polyvinyl chloride
SO2	sulphur dioxide
t	tonne
TPE	thermoplastic elastomer
TPU	thermoplastic polyurethane
UNEP	United Nations Environment Programme
UK	United Kingdom
US(A)	United States (of America)
USD	United States dollar
VOC	volatile organic compound
WWF	World Wide Fund for Nature
WtE	Waste to Energy

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1. Introduction

For practical and financial reasons most restaurants serve takeaway food in single-use plastic containers which are thrown away afterwards. The use of plastic, however, has long been criticised for its *harmful effects* on the environment. More recently this problem has entered the limelight through social media with videos of marine pollution showcasing direct effects on ocean life. Public awareness and pressure have increased since, as the FridaysforFuture movement and recent European Elections have shown[1]. The enlarged publicity has resulted in various projects to clean the environment, internalise external costs, and decrease plastic consumption.

Recognising plastic's large and ever-growing environmental impact, *governments* around the world have started to take action. The *European Union* put a clear focus on plastics in its *Circular Economy Package* in 2015 and in January 2018 created the *Plastics Strategy* which examines plastic's life cycle and sets the goal that *all plastic packaging* be *recyclable* and *55% of it recycled* by 2030. As a first of many steps towards fulfilling the Plastics Strategy, EU legislation *restricting the ten most utilised single use plastic items* has just entered into force at the *end of June 2019*.

The plastic *packaging* industry, as producer of 50% of post-consumer plastic waste in Austria[2] (van Eygen 2018, 25) and whose products are often foreseen to only be used once, "thrown away after one brief use, […] rarely recycled and prone to being littered" (European Commission 2018, 4), plays a key role in reducing the environmental footprint of plastic. This is especially the case as the growth of the plastic packaging sector is the main driving factor for the industry's growth as a whole across the European Union (European Commission 2013, 4).

Within plastic packaging waste, *single-use takeaway containers* are an ever-increasing section as the takeaway industry grows faster than plastic packaging waste overall[3]. Mega

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[1] where the Green Party has gained in popularity, notably in Germany and France
[2] and almost 60% of post-consumer waste in the European Union in 2015 (European Commission 2018)
[3] The *online* food delivery industry alone is expected to grow at least 3.5% p.a. versus the plastic packaging waste which is expected to grow 3.3% p.a..Thus, the difference is likely even greater. (McKinsey 2016; BIO Intelligence Service 2011, 122)

trends such as urbanism and individualism as well as changes in societal structures and technological development have *exacerbated disposable container* use. Hence, their usage is especially *high in developed metropoles* such as New York City, London, or Vienna where many young singles, employees and students alike, are concentrated. Takeaway food has become part of their culture. Their pace of life is continuously increasing and time devoted to meals shrinking. This makes *time* and *convenience* in addition to *money* decisive factors. Thus, many of them have resorted to takeaway for their daily meals, making the consumption of takeaway food a *habit*. Takeaway is hence responsible for a rapid *surge in waste*, laying a heavy burden on cities' waste management capabilities. In the city of Vancouver, for example, almost half of all waste from public bins is now from takeaway containers (Chung 2018). Further down the waste treatment chain, the takeaway industry also increasingly contributes to pollution derived from plastic.

The development of smartphone *apps* such as Deliveroo and Foodora has, however, truly made takeaway become *readily* available. These services exponentially increased the market, *optimising* delivery paths and times through their large and *flexible* employee fleet whilst also allowing any restaurant to use their delivery service, thus establishing extensive *networks*. In a society where convenience is key and the user is king this technological advance is thus market changing. Whilst in Vienna, the trend may not be as strong as in London or New York City, it is still non-negligible and growing.

Thus, successful takeaway systems should take the following into consideration and aim to:

1. Increase quality (health)
2. Decrease littering
3. Decrease environmental burdens (especially of supplying new containers)
4. Decrease landfilled or incinerated waste volume (arising e.g. through bad sorting or food contamination)

while keeping convenience, money, and time at least constant.

In Austria in 2010, 33%[4] of plastic post-consumer waste was recycled, similar to the figures within packaging where 34% was mechanically recycled (van Eygen 2018). For single use takeaway containers, however, the figure for recycling is likely still close to zero as sorting is less prevalent on the street where most on-the-go containers are thrown away. An even smaller share of takeaway containers is probably reused. Of the collected packaging waste, half is small films (mainly LDPE) which through the new EU regulation on banning single use plastic bags have received a lot of coverage and hence will undergo change. 1/3 of the collected packaging waste is small hollow bodies (mainly PET and PP) and is likely to see numbers increasing for the afore mentioned reason of increased demand in takeaway and packaging. Austria aims to increase mechanically recycled plastic waste from 34% to 55% in 2030 in line with the EU strategy. To reach this goal, however, the perception, production and consumption of plastic and plastic packaging as well as waste management processes have to be examined and reimagined. While this is an important goal to strive for it should not counteract efforts to also reuse material and so decrease consumption in the first place.

2. Aim and research questions

To achieve the above-mentioned aims for takeaway containers, this thesis will consider the *viability* of product-service systems, which intend to make containers more environmentally friendly through reuse. Hence, this thesis will begin by presenting the plastic takeaway container market and how *changes* in recyclability, biodegradability, and reusability could affect packaging waste. These possible changes will be analysed through examples of existing systems, which have been developed in the New World and more recently in some European cities and could be applied to Vienna making it a beacon for the sustainable takeaway industry.

Thus, the following research questions will be examined.

1. To what extent is plastic recyclable and biodegradable? Can or should plastic be used for (reusable) takeaway containers?
2. To what extent can a (plastic) reuse system decrease waste and environmental impacts from takeaway containers?
3. Which initiatives to decrease takeaway (plastic) packaging consumption exist?

[4] This is a little higher than the European average of 30% (p.9)

a. How were they implemented?
b. How were they accepted?
c. How much plastic packaging could be decreased? How could the environment be affected by these systems?
d. Can the case studies examined be applied to Vienna?

Recyclability and biodegradability research already exists. Hence, this thesis will put a focus on reusability. The implications of reusability are however very complex as they involve strong social components that are not easily quantified.

Further investigation beyond this thesis to investigate the social dimensions of reusable systems still is necessary. This thesis finds a strong case for polypropylene reuse systems if a threshold of 40 uses is surpassed and a professional cleaning system is in place.

3. Methods

To investigate and answer the posed research questions this thesis has done an extensive literature review on various topics, including legislation.

To answer question 1) the author researched the material plastic, its applications, economic and environmental situation, as well as its recyclability and biodegradability.

To answer question 2) scholarly articles including life cycle analyses comparing plastic reuse systems to different types of disposable containers were investigated. Unfortunately, not much data was available here.

To answer question 3) this thesis performed a general worldwide search of systems, finding reports on various case studies as well as conducting own interviews. Here, some own calculations were made to estimate takeaway packaging waste saved.

4. Review of literature and relevant legislation

4.1 Plastic

The first part of this chapter will focus on plastic, its financial and environmental implications, and whether it can be considered a sustainable choice. This section finds that plastic is a very complex material which can only be recycled under the right circumstances. However, following the waste hierarchy where reuse is preferable, finding a way where plastic can be sufficiently often reused would strongly decrease its impact on the environment.

The success of takeaway food is interconnected with omnipresent plastic's qualities as well as its incredible development as an economic sector. Thus, these will be examined in detail.

4.1.1. Properties and Applications

Plastic can be easily shaped, has low weight and low cost, as well as relative innocuousness (Andrady and Neal 2009). These properties which qualify plastic as the main material for food containers have also made it successful in many *other fields*. Its lightness, combined with its durability and high strength to weight ratio, and stiffness, has given plastic a competitive advantage saving large amounts of energy consumption costs. *In transport* vehicles such as cars or airplanes, for example, it is used as an alternative to metal or wood, weighing up to 75% less. Considering the sheer amount of vehicles worldwide, even a small decrease in energy consumption per vehicle means a substantial emission decrease globally (Andrady 2015, 123–26)[5]. In addition to saving fuel, this lighter solution also saves material production costs, which in return may make travelling more affordable. This, however, may also increase demand and hence counteract the emissions-saving effect resulting from decreased fuel consumption per unit.

[5] Andrady gives the example of a new airplane such as the Boeing 787 (Dreamliner), 50% of which is now made of plastic composites. This weight reduction translates into 30% less fuel and resulting emissions. When comparing the 787 to previous models, it saves up to 18 tonnes of weight and 20% in emissions while carrying 45% more cargo.

In *buildings*, plastic is utilised for its insulating properties to reduce energy consumption, whereas in medicine, 3D printed plastic which is compatible with human tissue finds increasing use (Andrady 2015, 132–33; European Commission 2018). Plastics are also used in clothing, cosmetics and electronics.

4.1.1.1 Packaging

In *packaging*, plastic brings even further benefits. Its biological and chemical inertness is key to its use for consumer products, from shampoo to food, where high standards of hygiene and health must be ensured. Its natural barrier hence also helps reduce food waste by preventing food from spoiling fast. Furthermore, as in plastic's other fields of use, it contributes to lower transportation costs through its light weight. All these qualities account for its production growth and have also designated it for takeaway containers. (European Commission 2018; van Eygen 2018; Andrady 2015, 126–31; Ellen MacArthur Foundation 2017).

Thus, plastic's benefits as a material can be summarised as follows: i) it preserves material; ii) it saves energy; iii) it helps "assure consumer health and safety" (Andrady 2015, 121). The last point may however be disputable over the long term as it remains questionable whether plastic is indeed safe for food uses.

The use of plastic for takeaway containers is just one of many examples of the importance which plastic has taken in our daily lives. The plastic industry's development, i.e. its ubiquitous use and fast and steady growth may also be an indicator for plastic's social and economic benefits and importance (Andrady and Neal 2009). Hence, it is described in more detail.

4.1.2 The Economy

4.1.2.1 Plastic

Just as the packaging sector is a major part of the plastic industry, the plastic industry also has a strong effect on the plastic packaging sector. Thus, dissociating takeaway food from the economics of plastic is not easy as plastic is a major economic sector.

The versatility and wide applicability of this low-cost material has led to *exponential growth.* Indeed, the sheer development of the plastic economy, which penetrates almost all sectors of production, has caused a certain inertia within itself, which may not facilitate banishment of plastic from takeaway food.

Since its first industrial production at the beginning of the 20th century, plastic has become one of the *most important and competitive* materials. In the last half century, plastic *production* has *grown* more than any other man-made material and remains *central to economic development.* Production reached 348 million tonnes in 2017 with Asia contributing 50.1% and China leading with 29.4%. *Europe is the second largest producer*, responsible for 18.5%, i.e. 64.4 million tonnes in 2017[6] (Plastics Europe 2018). Worldwide production *is likely to double* before 2040 (European Commission 2018; van Eygen 2018).

Plastic in Europe constitutes an *important* market, ranking 7th in industrial value-added contribution, which places it at the same level as the pharmaceutical industry in Europe, according to Plastics Europe. It is thus a major employer. Within the EU, close to 60,000 mainly SME plastic companies *employ 1.5 million people,* with a turnover of EUR 355 billion[7], contributing over EUR 17 billion to the trade balance in 2017. Furthermore, according to Plastics Europe, the plastic industry has also contributed EUR 32.5 billion to public finance and welfare.

4.1.2.2 Packaging

Plastic packaging is the *largest sector* of plastic production accounting for at least 26% in the world (Ellen MacArthur Foundation 2017, 12) and 40% in the EU (European Commission 2018, 2) of total plastic production measured in tonnes. It has had an output growth of 5% p.a. which has resulted in its share in the global packaging sector growing to 25% (Ellen MacArthur Foundation 2017, 19) and it producing at least *60% of post-consumer plastic waste* (BIO Intelligence Service 2011, 13; European Commission 2018, 7) as well as 62% of litter found on beaches (Ellen MacArthur Foundation 2017, 21 from data from the Ocean Conservancy's International Coastal Cleanup 2014 Report). Indeed,

[6] These figures were also used by the EU in their legal documents
[7] The EU strategy paper quotes a similar figure (340 billion) in 2015 which may have been given by Plastics Europe

at least *80% of marine litter is plastic* and 50% of marine litter is single-use plastic in the EU (European Commission 2018, 3, 10 with data from Eunomia's 2016 study to support the development of measures to combat a range of marine litter sources and the EC's Joint Research Centre's 2017 Report on Top Marine Beach Litter Items in Europe). In the EU, this has resulted in *losses equivalent to 1% of total fishing revenues* (European Commission 2018, 4).

The plastic packaging sector is expected to continue growing at an output growth of *at least 5%* p.a., *doubling by 2030* and quadrupling by 2050 and its waste is expected to grow by at least 3% p.a. (BIO Intelligence Service 2011, 122; European Commission 2013, 4; Ellen MacArthur Foundation 2017, 19, 21; Transparency Market Research 2015).

The plastic packaging sector's continued growth and plastic's wide array of *qualities and applications* as well as its *economic data* show how far-reaching, connected, and integrated the plastic industry is within society. Hence, policy makers have to be careful and aware of plastic's wide societal reach taking demand as well as livelihoods into consideration.

4.1.3 Concerns

Plastic's exponential growth also brings growing concerns on how it may have negative environmental and health effects. These have to be clearly understood to know how they can be avoided or mitigated when considering a sustainable takeaway system for Vienna. Firstly, two major environmental concerns are described, plastic's production sources and its durability.

4.1.3.1 Origin / Feedstock

Plastic - as a carbon-based polymer - still is mainly produced from fossil sources, requiring *at least 4%* of yearly non-renewable resource production for manufacturing. At least a further *4%* are consumed as energy during processing. While the production process is quite efficient[8], this strong and direct reliance on fossil carbon sources should be examined when assessing the overall impact of plastic on the environment (Andrady 2015, 98; Hopewell, Dvorak, and Kosior 2009).

The production of plastic may initially seem to have positive effects on the environment as plastic - given its durability- resembles a carbon sink. However, if plastic waste is treated, the carbon will likely be released to the atmosphere. In the case of fossil sources, this gives a negative balance and effect on the environment.

Attempts have been made to enhance the environmental sustainability of plastics by *moving towards other feedstocks*. As alternative feedstock both recycled plastic and bio-based polymers under certain conditions could substantially decrease CO2 emissions and save energy. Another technology is carbon sequestration where plastic is created from CO2 or methane as is done by Newlight Technologies in California.

Carbon is extracted from methane and CO2 by polymerisation "through isolation with a naturally-occurring microorganism-based biocatalyst" and synthesising it with hydrogen and oxygen into a "naturally-occurring polyhydroxyalkanoates (PHA)-based biopolymer material". As methane is at least 28 times more powerful than CO2 in terms of climate impact, this conversion is especially impactful when sourced from places with high methane emissions, such as agriculture, sewage, and energy plants, allowing them to be carbon neutral. The resulting purified thermoplastic can be made into furniture, cars, electronics[9], clothes, or packaging and is formed through fibre spinning, extrusion, blown film, cast film, thermoforming, or injection molding. This plastic can be used as a substitute for polypropylene, polystyrene, and thermoplastic polyurethane (TPU) among others (Newlight Technologies 2019; Lippman 2014; Rewri 2016). This carbon sequestration technology given its youth, still needs to be scaled to commercial level. It does, however, seem to compete better on a cost basis with fossil based plastic compared to bio- based ones (Lippman 2014).

[8] Especially compared to car engines. 70% of annual petroleum production is used for transportation. The conversion rate of thermal energy produced from burning fuel into mechanical work is no more than 26%, probably even lower due to frictional losses (Andrady 2015, 98).
[9] E.g. for cell phone cases (Virgin Mobile) or laptop packaging sleeves (Dell)

The most commonly used bio-based feedstock is corn starch, but other biological sources such as rice, sugar cane, and potatoes are utilised, too[10]. However, only circa **2%** of worldwide plastic production is from *bio-based* polymers[11]. This proportion is currently growing at a similar rate to the overall growth rate which does not foresee a relative decline of plastic produced from fossil sources (Chinthapalli et al. 2019). This may be because of the oil and chemistry industry's reluctance to change and its strong economic and political influence. Also, the production of biological sources may require crops otherwise used for food production or even cause deforestation. Both may have negative environmental effects countering the positive ones, such as an increase in carbon emissions, an increase in food prices in developing countries, or a decrease in biodiversity. Hence, companies are examining other biological sources such as agricultural waste. Carbon sequestration avoids this food-fuel debate.

More straightforward benefits are offered by *recycled plastic* since it processes existing plastic and so does not require any new resources. Its production instead of fossil-based plastic is favoured because of lower energy costs that should translate into lower financial costs. Plastic recycled from bio-based or green-house-gas-produced plastic gives an even better environmental balance. Whilst for recycled plastic the production figure in Europe of *6%* is higher than for bio-based feedstocks, it is also still fairly low. This is because it is not only dependent on supply but also on recycling capacity. The recent low commodity prices and market uncertainties have discouraged investments in new recycling capacity, research and development (European Commission 2018, 2), as well as waste management. For recycled plastic, however, it may be difficult to keep the same quality as primary plastic, because often its feedstock may contain various *additives***.** These may

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[10] Examples include:

1) *NatureWorks* who convert *corn* into *lactic acid* producing "*Ingeo*"**,** a replacement for *PET and polystyrene* which often become litter through their food packaging uses. Ingeo packages Dannon's Activia yogurt in Germany, Stonyfield Farm's yogurt, and Wal-Mart's deli and vegetables. This plastic is said to be "*60 percent less carbon-intensive than a regular plastic like PET*".
2) *Gevo* produces *isobutanol* from *corn* which are supplied to the US military and Total as fuel. The company intends to convert isobutanol into *paraxylene* from which plastic can be made.
3) Since 2010 *Braskem* uses *ethanol* from *sugar cane* to produce a more environmentally friendly *polyethylene* which becomes juice bottles, shampoo bottles (Pantene), and safety hats for mines. (Lippman 2014)

[11] Compared to 0.5-1% consumption in the EU (European Commission 2018, 14)

be costly to extract and hinder the recycling process, thus decreasing the quality of the end-product.

In summary, bio-based plastic, carbon sequestration plastic, and recycled plastic are all promising new approaches to the production of plastic. In bio-based plastic, a focus on its source is necessary where waste products should be favoured so as not to use precious land which may have been used for agriculture otherwise. With carbon sequestration plastic, a critical volume needs to be reached for commercialisation which should be achieved through synergies with companies who produce high amounts of CO2 and methane. For recycled plastics, a close link to product designers and plastic producers is key to ensure minimal use of additives[12]. If these difficulties are overcome and with enough investment, all areas may grow and become important plastic feedstocks. Also, a synergy of these areas should also be beneficial where bio-based plastic and carbon sequestrated plastic are recycled.

4.1.3.2 Durability, Microplastics, and Biodegradability

Another environmental concern is plastic's inherent property, durability, which is a constant feature independent of feedstock. Plastic's *durability* - often the reason for its favoured use – is also its problem. Plastic's long polymer chains usually do not degrade at a significant rate instead accruing in the biosphere (American Chemistry Council 2010; n.d.; n.d.). This issue has become such a problem that more plastic is expected to be found in the ocean than *fish by 2050* (Ellen MacArthur Foundation 2017). Indeed, plastic is becoming an indicator for human activity dominating geology[13].

Plastic and its debris are first found in the lithosphere. Here, they are mostly observed where they are produced, frequently used, or discarded, e.g. in agriculture, landfills, roads, and unused piping and cabling infrastructure. However, most debris is then mobilised over time into the hydrosphere by runoff, river, and current flows, ending and accumulating in oceans. Hence, the marine environment is of particular focus when discussing plastic and its durability.

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[12] The use of additives will be described in more detail in the Recycling chapter

[13] the so-called "anthropocene"

In oceans both macro- and microplastics exist and are defined by their size. Macroplastics may tangle, suffocate, or be eaten by marine life. Invasive species may also travel on and disseminate through macroplastics. Microplastics, ranging from 1 to 10 mm, are mainly ingested and accrue in the food chain. Some microplastics, so called primary microplastics, are even intentionally used by the industry in cosmetic products, e.g. for a peeling effect. All the other -secondary - microplastics, result from the breakdown of plastic into ever smaller debris triggered by the sun, wear and tear, and other organisms. One major source of broken-down plastic are garments made by polymers which loose microplastics in each wash cycle (Browne et al. 2011). The breakdown of plastic can cause it to leach its components or absorb other contaminants[14], thus altering chemical compositions and producing possible further damage to the marine environment (Andrady 2015). Microplastics have already spread throughout the environment and have been measured in the air, drinking water, food (fish, salt, honey) (European Commission 2018, 8), as well as recently in human feces (Parker 2018).

Hence, bona fide *waste stream management* is critical to the geosphere's health and resources by ensuring plastic does not pollute the environment. The next section will thus examine plastic waste and what problems its management may encounter. The section starts with a framework which summarises important points to consider when planning an efficient system. Next, general inefficiencies in the current system will be explained which are partially caused by the sheer size and variety of plastic compound consumption. Thus, the most frequently used types are presented in more detail and sorting and recycling techniques as well as their applicability to the different types of plastic are explained. Finally, additives which are often part of the various plastic compounds are highlighted as a major problem for efficient recycling because they decrease plastic purity.

[14] Such as polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene (DDE), and nonylphenols (NPs) (Mato et al. 2001)

4.1.4 Waste

4.1.4.1 Framework

The environmentally sound waste management principles defined by UNEP offer a general framework with practical steps to efficiently manage waste deriving from plastic, with the goal of protecting human health and the environment against adverse effects. *Source reduction* prevents the emission of waste in the first place while better *design* of products ensures cleaner production and higher reusability and recyclability. Promoting an *integrated life cycle* while planning the production process also improves chances of reducing waste. An *integrated production control* and a *standardisation* of waste management ensures better compliance of all actors and higher efficiency in the chain, as well as facilitates the application of the *polluter pays* principle. Moreover, *public participation* is key at all steps of the cycle to ensure that the product will not be simply wasted. This approach can also be described as putting a decreasing emphasis on the "4R's", reduce, reuse, recycle, recover (as energy as a last resort). The instruments at hand to promote this waste hierarchy are regulatory and enforcement mechanisms, technology, market mechanisms and public information. These principles have also inspired the EU Circular Economy Action Plan.

4.1.4.2 Inefficiencies

However, in current waste management practices there still is a lot of room for improvement. Increasing production and consumption of plastic are negatively affecting *waste streams*. Currently, Europeans produce *26 million tonnes* of *plastic waste* every year of which 30%[15] is collected for recycling and 70% is landfilled or incinerated at a high cost. Only *5%* of the *value* of plastic *packaging* material *remains in the economy,* the rest being lost after first use, at an annual cost of between *EUR 70 and 105 billion*. Furthermore, plastic, even after a single use, is often *discarded improperly* (Ellen MacArthur Foundation 2017; European Commission 2018).

The mismanagement of single-use plastic can be a threat to the economy (tourism, agriculture, fishing), the environment (terrestrial and marine pollution, decreased

[15] In Austria 33% is recycled (p.2)

biodiversity) as well as human health (contaminating food and water sources, air sources when burned or worsening natural disasters through drain blockage).

Hence, the first step towards an improved waste management system is an *improved sorting* system with better separation at source from other waste streams or between plastics which may also have different lifetimes. A well working sorting system is also a pre-requisite for recycling to function and requires a more detailed understanding of the different types of plastic. Each plastic has different properties, which imply different uses, recycling needs, and environmental impacts.

4.1.4.3 Typology of plastic

To answer whether and which plastic can and should be used requires *a typology of the various plastics available*. This is quintessential for understanding which plastics are recyclable or reusable and hence most sustainable for use as takeaway containers.

While plastic is often seen as one material, it is in fact a *collective term* for many different materials with various customisable properties. The word plastic derives from the Greek adjective πλαστῐκ-ός, -ή, -όν (Henry George Liddell and Robert Scott 1940) which describes something as "fit for moulding". Thus, originally plastic was a very broad term and meant something was malleable.

In *chemical* terms, plastic is a synthetic or semi-synthetic organic compound formed from very long polymerised monomer chains usually containing carbon and hydrogen. In fact, the original starting material (feedstock) is not what defines plastics, but instead how it is chemically engineered, i.e what its polymer chain looks like (which is often customised for an intended purpose).

Innovative and complex *compositions* of polymers and additives have resulted in almost 85,000 separate compounds or formulations (Andrady 2015). The choice of compound is usually dependent on "cost, production volume and performance". Thus, plastic compounds are subdivided into three categories: commodity (low cost, high quantity), engineering (improved physical properties, more specific uses) or high-performance plastics (focussed on a sole specific application). Takeaway containers are mainly made from the commodity category (van Eygen 2018).

Plastics may also be further classified along their chemical composition or properties, the chemical procedure used in their fusion, their physical or other properties, which may be significant for product design, manufacture, or recycling.

Often, plastics are however categorised into two categories based on how they are processed, as thermosets or thermoplasts. *Thermosets* once heated and melted, can only be moulded once and stay in that permanent shape because of a changed chemical structure where the monomer chains cross-link. Thus, the shape remains fixed, irreversible and unchangeable. Reheating them would cause the material to decompose. So, they cannot be resoftened, reshaped, and reused after being subjected to heat and pressure. This can be a disadvantage for recycling. *Thermoplasts*, on the other hand, when heated and melted can be resoftened, remoulded and reshaped repeatedly allowing for reversible changes as there are no chemical changes to their structure. Here the monomer chains can glide past each other. Thus, thermoplasts are of particular interest when examining recyclability as they allow for easier mechanical recycling (van Eygen 2018; The Columbia Electronic Encyclopedia 2012).

Within thermoplasts, the most used materials for consumer products are polyethylene (PE) (low density (LD) and high density (HD)), polyethylene terephthalate (PET), polypropylene (PP), and polystyrene (PS) or expanded polystyrene (EPS). Attempting to improve their separation and so recyclability, the US Society of the Plastics Industry, created a system in 1988 where each material is assigned a number, thus enabling *quick sorting*. This has now become an international standard, the ASTM International *R*esin *I*dentification *C*oding System (RIC) allowing for uniform and consistent sorting globally.

The table below illustrates the system and gives more details on each of the materials.

Table 1: Typology of plastics

Resin code Name	**Properties & Limitations**	**Applications**	**Recyclability & Reusability**
1 **Poly-ethylene Tere-phthalate (PET / PETE)**	• Clear, glass-like, optically smooth surface letting UV light pass through • aroma tight, excellent gas (oxygen, CO2) & moisture (water) resistance • tough, rigid, high impact capability and shatter resistance • Ovenable and microwavable	**Food:** one of the most commonly used plastics: • <u>bottles</u> for beverages (soft & sports drinks, water, juice, beer), mouthwash, ketchup, salad dressing • injection-molded consumer product containers, e.g. cups <u>Other packaging</u>:	**Recyclability** The plastic is crushed and shredded into small flakes which are then reprocessed to make new bottles or spun into polyester fibre used in textiles. *Secondary products:* • Containers for food, drink

	• Capability for hot filling • Excellent resistance to most solvents **Sensitivity to heat & chemicals**: • Poor burning behaviour • Affected by boiling water • Attacked at temperatures >60°C by ketones, aromatic and chlorinated hydrocarbons, and diluted acids & bases and alkalis	• Food jars for peanut butter, jelly, jam and pickles • films for packaging • viewing windows • deep-draining parts for horti- and agriculture **Non-food:** Fibres for textiles (polyester), carpets, padding, jacket & sleeping bag fillings, sports shoes & bag fillings, fleece, home & medicinal goods monofilament, strapping, thermoformed sheets, furniture, panelling, engineering moldings	(bottles), and non-food items •Film and sheet strapping • spinning fibre for carpet yarns, fleece, fibrefill, comforter fill, tote bags, and geotextiles In the US, about 25% of PET bottles are recycled. **Reusability** intended for single use as repeated use increases risk of leaching and bacterial growth. May leach carcinogens
2 **High-Density Poly-ethylene (HDPE)**	• Excellent chemical resistance to most solvents • Relatively stiff material • very hard-wearing: does not break down under exposure to sun, extreme heating or freezing • Higher tensile strength compared to other forms of polyethylene (harder and stiffer than LDPE) • Withstands higher temperatures than LDPE • considered as one of the safest types of plastic • When unpigmented / translucent: good barrier properties & stiffness • When pigmented: better stress crack resistance	**Bottles** for products with short shelf life (milk, juice), household & industrial chemicals (cosmetics, shampoo, dish & laundry detergents, household cleaners, bleach, fertilisers) cans, buckets, cups and beverage boxes, toys, bags for purchases, cereal box liners, reusable shipping containers, (recycling) bins, canisters, tubs, sheets, injection molding, extruded pipe and conduit, plastic lumber, wire & cable covering, molded plastic cases, car stops, playground amenities, picnic tables, plastic lumber, waste bins, park benches, bed liners for trucks, garden beds	Relatively simple and cost-effective to recycle and therefore most commonly recycled plastic; also reusable *Secondary products*: • Bottles for non-food items (shampoo, conditioner, liquid laundry detergent, household cleaners, motor oil, antifreeze) • Plastic lumber for outdoor decking, fencing, picnic tables • Pipes, floor tiles, buckets, crates, flowerpots, garden edging, films & sheets, recycling bins. 30-35% of HDPE plastic used in the US is recycled each year
3 **Polyvinyl Chloride (PVC)**	• stable physical properties (relatively impervious to sunlight) • High impact strength, • hard and brittle • good chemical resistance (grease, oil), weatherability • flow characteristics • stable electrical properties • brilliant clarity (amorphous) • excellent processing performance soft and malleable for technical use *only* through additives (plasticisers and stabilisers) • dubbed "poison plastic" because it contains numerous toxins which it can leach throughout its entire life cycle • requires virgin material for its production	• **Flexible**: bags for bedding & medical (blood bags, medical tubing), shrink wrap, clear plastic food wrapping, cooking oil bottles, teething rings, children's and pet's toys, tamper resistance, wire & cable insulation, carpet backing, flooring, shower curtains • **Rigid**: blister packs, clamshells, non-food bottles, pipes, flooring, siding, window frames, fencing, decking, railing, lawn chairs, toys, records	Less than 1% is recycled in the US *Secondary products* • Pipe, decking, fencing, panelling, gutters, carpet backing, floor tiles & mats, resilient flooring, mud flaps, cassette trays, electrical boxes, cables, traffic cones, garden hose, mobile home skirting • Packaging, film & sheet, loose-leaf binders
4 **Low Density Poly-ethylene (LDPE)** also Linear Low Density Poly-	• Toughness, flexibility, relative transparency (good combination of properties for packaging needing heat-sealing) • Excellent resistance to acids, bases, vegetable oils • almost no water vapour permeability • odourless & taste-neutral	most used plastic material for **packaging**: Shrink wrap and stretch film, grocery bags, bags for dry cleaning, newspapers, bread, frozen foods, fresh produce, household waste, coatings for milk cartons, hot & cold beverage cups, container lids, flexible lids, clamshell packaging, squeezable, dispensing bottles (e.g. honey, mustard), six-pack rings, toys,	Not commonly recycled but recycling has started to develop Secondary products: • Shipping envelopes, bin liners, bins, floor tiles, panelling, furniture, film & sheet, sacks and foils for construction & agriculture, landscape timber, outdoor lumber, pipes, buckets

ethylene (LLDPE)	Considered as less toxic than other plastics and relatively safe for use	some clothing, injection molding applications, molded laboratory equipment, adhesives and sealants, wire & cable coverings, tubing, outdoor furniture, siding, floor tiles, shower curtains	
5 **Poly-propylene (PP)**	• strong • Excellent optical clarity in biaxially oriented films & stretch blow molded containers • very low permeability for water & oxygen • Inertness toward acids, alkalis & most solvents (good chemical resistance), oil & grease resistant • high melting point (excellent heat-resistance qualities) **hence a favourite material for reusable food containers**	• flexible & rigid packaging Containers (yogurt, margarine, edible oils, mayonnaise, ketchup, mustard, syrup, salad dressings, savoury biscuits, bread, cakes, pastries, takeout, deli, hot-fill liquids) • Medicine bottles, Bottle caps (of PET and HDPE bottles), drinking straws, potato chip bags, straws, packing tape & rope, dishware, disposable diapers • industrial fibres • large molded parts for appliances & consumer products, including durable applications such as automotive parts (e.g. fenders), carpeting, pressure pipe systems	3% of PP is currently recycled in the US, rate is increasing Considered safe for reuse Secondary products: • Automobile applications: battery cases, signal lights, battery cables • brooms & brushes, ice scrapers, oil funnels, flowerpots, landscaping border stripping, battery cases, brooms, bins and trays, hangers, furniture parts, tubs, bicycle racks, garden rakes, storage bins, shipping pallets, sheeting, trays
6 **[Expanded] Poly-styrene ([E]PS)**	• inexpensive, lightweight • Excellent moisture barrier • Significant stiffness • Excellent optical clarity in general purpose form **rigid** general-purpose PS • clear, hard, brittle relatively low melting point **foamed / EPS** • Low density and high stiffness • Low thermal conductivity and excellent insulation properties often combined with rubber to make high impact polystyrene (HIPS) used for packaging and durable applications requiring toughness, but not clarity **favourite material for disposable containers**	• containers (take-out clamshell, for short shelf life products, egg cartons) • other food service items (tableware, disposable cups, coffee cup lids, plates, bowls, cutlery, meat & poultry trays, cafeteria trays) • bottles, medical products (e.g. aspirin bottles) • building insulation, underlay sheeting for laminate flooring • protective foam packaging (e.g. furniture, electronics), loose fill (packing peanuts) • electronic housings, CD, video and cassette cases, video cartridges, desk accessories, coat hangers, toys • agricultural trays, cable spools	not widely **recycled** (technology exists but is not very financially viable) [E]PS accounts for about 35% of US landfill material. Secondary products: • Thermal insulation, light switch plates, vents, desk trays, rulers, license plate frames, Cameras or video cassette casings, plastic mouldings (i.e. wood replacement products), loose fill **Reusability:** Because polystyrene is structurally weak and ultra-lightweight, it breaks up easily and is readily dispersed throughout the environment. Beaches globally have polystyrene lapping at shores, and many marine species have ingested this plastic with negative consequences to their health. Polystyrene may **leach** styrene, a possible human carcinogen, into food products (especially when **heated** in a microwave). Chemicals present in polystyrene have been linked with human health and reproductive system dysfunction
7 **Other poly-carbonates**	made with a resin other than the six listed above or made of more than one resin Primary concern: some #7 plastics have potential for chemical leaching into food or drink products e.g. from Bisphenol A (BPA). BPA is a xenoestrogen, a known endocrine disruptor. Some polycarbonates are marketed as 'non-leaching' minimising	baby bottles, sippy cups, water cooler bottles, Large reusable water bottles, citrus juice and ketchup bottles Oven-baking bags, barrier layers, custom packaging car parts	The #7 category was designed as a catch-all for polycarbonate (PC) and "other" plastics, so reuse and recycling is not standardised in this category. Secondary products: • Bottles, plastic lumber, headlight lenses, safety shields/glass

Polylactic Acid (PLA)	plastic taste or odour, however it is still possible that trace amounts of BPA migrate from these, particularly if used to heat liquids. Compostable plastics, such as PLA, made from renewable sources like corn starch, are being developed. These are also included in category #7, which can be confusing to the consumer.	**PLA favourite "environmentally friendly" option for disposable containers**	#7 plastics are usually not intended for reuse **Compostable plastics should not be recycled and can contaminate this waste stream.**
Poly-butylene Tere-phtalate (PBT) **(similar to PET)**	Mechanically strong, resistant to solvents, shrinks very little during forming, heat-resistant up to **150°C** (or 200°C with glass-fibre reinforcement) Compared to PET, PBT has better moldability, lower strength and rigidity, better impact resistance, and a lower glass transition temperature. Like PET, PBT is sensitive to hot water above 60°C and UV transparent	Chosen by the case study reCIRCLE for its **reusable takeaway containers**. Originally used as an insulator in the electrical and electronics industries, but also in automotive construction and households. As fibres, also used for toothbrushes and eyelashes, or in keyboards. Used as a yarn in sportswear. Due to its chlorine resistance, also used in swimwear.	PBT GF30 (with 30% glass fibres) is used by reCIRCLE, which thanks to the glass, is more resistant to **hydrolysis** and **dries** more **quickly**. According to reCIRCLE its phtalates are innocuous, too. PBT GF30 is **recyclable** (currently open loop because of regulations) but there is no municipal collection (has to be collected by reCIRLCE). PBT GF30 is **reusable** at least 100 times

Sources: American Chemistry Council n.d.; n.d.; Eartheasy 2019; Encyclopaedia Britannica 2019; Ecoplast Kunststoff-Recycling GmbH 2013

4.1.4.4. Sorting

Although the RIC is an international standard, recycling is dealt with locally and so many different programmes exist. Thus, consumers are often confused whether a material is recyclable in their local area. Hence, the RIC which focuses on the type of material and not whether it is recycled in that area, was criticised as not relevant. To alleviate this problem, new codes focussing on the product's wider recyclability have been developed, such as the How2Recycle code by the US Sustainable Packaging Coalition which shows how likely a consumer good is recyclable in the US, with four categories: "widely", "limited", "not yet", and "store drop-off" (Sustainable Packaging Coalition 2019). Also, the *ASTM's D20.95* subcommittee on recycled plastics is *re-examining the existing RIC*. Until a new international system emerges, the American Chemistry Council is encouraging more standardised language through its "*Recycling Terms & Tools*" issue.

Having presented the first step in waste management- sorting by the consumer - as complicated because of the large amounts of plastic waste, its variety, and also consumer confusion, this thesis will introduce the next step in waste management, recycling, its current system, and its weaknesses.

4.1.4.5. Recycling

Recycling is seen as an important part of the solution to managing plastic waste. This part will examine whether and how recycling is contributing to solving the plastic waste problem.

Once the sorted plastic waste reaches the treatment facility, it can be processed through recycling into some form of granulates, feedstock, or energy, which can be used again. There are four types of *recycling*, but they are unequally developed and practiced throughout the world. The first two types are the ones usually meant when using the term "recycling" as they both denote mechanical recycling. Primary recycling is the same as closed loop recycling, i.e. the new product is equivalent in properties to the recycled product. Secondary recycling is equal to open loop recycling, i.e. the new product is of lesser quality than the recycled product. Tertiary recycling is no longer mechanical but instead chemical, breaking the material down into its chemical components and recovering the monomers or other basic forms. The final type of recycling, quaternary recycling, is often not even seen as a form of recycling as the material is completely consumed in the process when it is incinerated. Only its energy content is recovered and can be used for electricity. Each of these four methods needs a lower input quality than the previous one, however also giving lower material recovery yields. If none of these methods are used, then plastic is thrown away in contained landfills or elsewhere where it may end up polluting the environment. *Mechanical recycling*[16] *is the main method* currently used as chemical recycling is not very economical for large amounts (Hopewell, Dvorak, and Kosior 2009).

4.1.4.5.1 Recycling Today

In Europe in 2016, of the 60 million annual plastic production, *25.8 million* is *waste* and 8.4 million recycled (European Commission 2018; Plastics Europe 2018). This shows

[16] Excluding quaternary recycling (incineration)

that ca. 14% of annual production is recycled and gives a recycling rate of around 30%[17] compared to the 18% global average (Geyer, Jambeck, and Law 2017)[18]. Europe's global production share is falling. Meanwhile, its recycling levels are still low and unexploited[19] compared to other materials such as paper and metals which have much higher recycling rates as high as 58% and 90% respectively (Ellen MacArthur Foundation 2017, 12). Also, the post-consumer plastic recycling rate within Europe varies strongly between countries some of which unfortunately still have landfill rates as high as 80% (e.g. Greece) (Plastics Europe 2018, 35) and are thus far away from fulfilling the ambitious EU targets of a 55% recycling rate by 2030. Furthermore, a significant amount of "recycled" plastic has been sent abroad where lower environmental standards may exist. China was a major recipient of European recyclables but has now stopped accepting these which means Europe will have to deal with them itself putting further pressure on improving the recycling economy.

While landfill rates are indeed decreasing, incineration rates rather than recycling rates are currently increasing. This is not the best solution as while incineration creates energy it also creates emissions which can harm the environment, especially if unfiltered. The production and incineration of plastic alone have caused circa *400 million tonnes of annual CO2 emissions* globally[20]. As mentioned in the section on feedstocks, using recycled plastic would significantly decrease emissions and potentially *save energy equivalent to 3.5 billion barrels annually of oil,* which is the same as 9.6 million daily, just under Russia's daily production and over 1/10 of global daily production**.** (European Commission 2018, 3; US Energy Information Association 2019).

In packaging, the situation is even more worrisome. Globally there is a high leakage into the environment of 32% and still 40% is landfilled which may also cause leakage. Only 14% are incinerated and 14% collected for recycling, with however 4% being lost in the process and so only 10% mechanically recycled, of which only 2% are closed loop. In Europe, still up to 95% of the value of the material, i.e. EUR 70 to EUR 105 billion annually, is lost to the economy after a "very short first-use cycle" although more

[17] In Austria, 33% is currently recycled
[18] Non-fibre waste plastic
[19] PET bottle-to-bottle recycling is at 7% which is best within plastic packaging which is best within plastic (Ellen MacArthur Foundation 2017, 12)
[20] Assuming 1 tonne of plastic saves 2 tonnes of CO2 (Fédération des Entreprises du Recyclage and Agence de l'Environnement et de la Maîtrise de l'Energie 2017)

optimistic estimates assess the proportion of secondary plastic in total production at 5% in the EU (European Commission 2018, 2; Ellen MacArthur Foundation 2017, 21; European Commission 2015, 11). Beverage bottles account for 16% of plastic by weight: although 50 to 60% of beverage bottles (PET) are collected, only 7% are recycled into PET bottles in the EU (32% in Germany) (Ellen MacArthur Foundation 2017, 46).

Hence, recycling packaging has become an important focus of the EU plastics strategy and is key to sustainable development. Recycling, however, encounters a big problem when additives are part of the plastic.

4.1.4.5.2 Recycling Problem: Additives

As mentioned in the section on feedstocks, various *additives* are used to enhance plastics: fillers, plasticisers to change mechanical properties (e.g. to make them more moldable), antioxidants to change chemical properties (e.g. to make them flame resistant), antistatics to improve their surface properties, or colourants to tinge them. When they are *pure, all thermoplasts* can be *recycled*. When they include additives, however, recycling may be hampered or hindered.

While food polyethylene films usually contain no additives, polyolefins (POs) contain 10% by volume, styrenics 5%, and other polymers on average 12%. Especially PVC has a high rate (73%) of additives which may prevent closed loop recycling (van Eygen 2018). Currently, businesses mainly recycle PET. There are also companies in Austria which recycle LDPE (Ecoplast) and HDPE (Ecoplast and mtm plastics) as well as PP (mtm plastics).

Additives can often only be separated at high energetic and financial costs. Hence, a main priority in improving recyclability of products, is to minimise the use of additives in plastics. This has been addressed by the European Union when demanding improved product designs and extended producer responsibility which take the entire life cycle of the product into consideration, but for now still remains problematic.

One approach to solve the recycling problem is to produce plastic which does not have to be recycled, because it degrades organically at a meaningful rate. The next section introduces these plastics, which are referred to as biodegradable or compostable and are gaining in notoriety and popularity. Their biodegradability also suggests that they are less of a hazard when encountered in the environment. This will be questioned in the next section.

4.1.4.6 Biodegradability

To counteract plastic's durability and waste management problems, biodegradable plastic is now being marketed and produced. Consumers are led to believe that biodegradable plastic degrades relatively quickly and completely into something organic thus not negatively affecting the environment. Thus, biodegradability has received a lot of media coverage as a possible solution to plastic's harmful effects on the environment. The term "biodegradable" also suggests that the plastic is compostable. In reality, however, the widely used word "biodegradable" is misleading as it only means a product can be degraded by bacteria or living organisms but does not consider the time or circumstances necessary for this degradation to take place. Hence, products are often greenwashed as biodegradable when in fact it is not clear whether they may degrade in the open environment at all.

Recent research by the International Marine Litter Research Unit of Plymouth University shows that grocery bags labelled as (oxo)biodegradable did indeed not degrade at a meaningful rate. These bags which were submerged in the ocean or buried in soil could still hold groceries after 3 years. Only the bags exposed to air had become brittle after 9 months and so had somewhat degraded. Interestingly, it was the compostable bag which tested best, disappearing from the marine environment after 3 months and unable to hold groceries after 27 months of soil exposure (Napper and Thompson 2019). This study shows that although the bags were labelled "biodegradable" they did not degrade at a meaningful rate under circumstances which resemble likely final resting places of littered bags. Only the compostable bag, which does not advertise itself as biodegradable but instead as "plastic which should be composted at an industrial facility", did in fact degrade in the natural environment. An industrial composting facility ensures specific conditions of constant high humidity and temperatures, as well as constant pH and oxygen values, which are advertised as necessary for the plastic to degrade properly. Even under the best circumstances, plastic will take years to decay completely.

Furthermore, all these conditions are not easily met in nature or landfills. Actually, landfills should especially be avoided as compostable plastic often has added stabilisers and catalysts which together with the intensive decomposition process at work in landfills could compound leaching effects and contaminate water.

Thus, biodegradable products are not a solution to littering as they need to be disposed of correctly, too (European Bioplastics e.V. 2019). Given the added stabilisers and catalysts for the purpose of extending lifetime and ensuring compostability, biodegradable plastic is also not suitable for recycling and would negatively affect the quality and purity of other plastic when recycled together. Hence it should not be mixed with other plastic and needs to be collected separately which requires an improved infrastructure as the current one is not equipped for this separation. Especially consumers need to be informed how and why to separate this type of plastic from the others. Here, once again, clear labelling is essential.

The market for biodegradable plastic remains small and major concerns persist on biodegradable plastic's true usefulness. Another important aspect is that biodegradable plastic is often produced from renewable sources and as such would bring the same advantages and problems connected to land-use and the environment as bio-based plastic.

It remains to be seen whether biodegradable plastic is indeed beneficial throughout its entire life cycle. Its sustainability depends on a functioning disposal system, which includes sorting and separation as needed for conventional plastics. Thus, currently it is not yet a better alternative to conventional plastic as it encounters similar waste management problems of proper sorting and separation.

This chapter has presented the main takeaway container material, plastic, shown its practicality as well as economic, environmental, and social importance and implications. Results are not straight forward but suggest that plastic is indeed useful for takeaway container use as it is *lightweight, leak proof, microwaveable*, and *does not break* when dropped. Choosing the right type of plastic will directly affect its environmental footprint.

Pure recyclable plastic preferably from renewable waste sources would be a good material for reusable containers. [21]

The next chapter gives an overview of what institutions and legal bodies have done to help their territories become more sustainable. Here, a special focus is put on the European Union (EU), which has recently taken significant steps to create a more sustainable and efficient economy. Its directives are transposed into national law and so should have a strong effect on national approaches to sustainability, too.

4.2. Governmental strategies and legislative measures

According to the United Nations Environment Programme (UNEP)[22], the proliferation of plastic waste in the environment is one of the greatest environmental challenges of our times. A society without plastic is not possible. So, it is key *how* we deal with this product. The previous chapters have examined possible problems that are encountered when managing the plastic life cycle, including its waste management. UNEP's previously described waste management framework is a first step towards formulating a solution towards an improved system and has been included by the EU in its own strategic plans.

Another important approach, the precautionary principle which has been used for other chemicals and Bisphenol A in baby products is increasingly popular. Reports like the World Wide Fund for Nature's (WWF) "Solving plastic pollution through accountability" suggest the plastics crisis will improve only if all stakeholders across all sectors and not just consumers and waste managers take responsibility. In response to reports and increased media coverage, civil society, local authorities and governments have started to take action.

Drawing inspiration from circular economy theory (which increasingly regards waste as a resource and where the value of products and their resources remain in the economy for as long as possible creating an intentional continual, restorative, and regenerative cycle (Ellen MacArthur Foundation 2012; Ghisellini, Cialani, and Ulgiati 2016; Geissdoerfer

[21] However recycled plastic is not always allowed for use in food products

[22] A Roadmap for Sustainability Report on single use plastics in 2018

et al. 2017)), the Chinese government was one of the first to introduce a circular economy model already in 2007 through a top down approach. After several warning signs China eventually banned the import of certain plastic waste. This process had put further pressure on the European Union to adopt its own solution in *December 2015*, a bottom up circular economy as defined in their *Circular Economy Action Plan*. The EU thus created a stricter framework for the whole plastic life cycle as part of their Circular Economy Action Plan where plastic was made one of five priority areas. Other priority areas were food waste as well as biomass and bio-based products which for this thesis' topic are also relevant and connect with plastic takeaway containers (European Commission 2015). With this document, the EC provides a first step to a model which should help protect the environment while fostering innovation, increasing competitiveness, creating growth and jobs, and improving supply security (European Parliamentary Research Service 2018).

The Action Plan follows the "four Rs" principle: "Reduce (prevention), Reuse, Recycle, Recover (energy)" which is part of the waste hierarchy that as a final step before proper disposal also includes energy recovery. While the Action Plan mentions the importance of preventing waste in the first place, this first step was unfortunately not focussed on and no clear guidelines were given to avoid waste and decrease consumption. Instead, the EC concentrated on the status quo and gave (among other things) stricter rules for *calculating recycling rates and new rules on separate collection*. The Action Plan aims *to reduce landfilling* to *10% or less* of the total amount of municipal solid waste (MSW) generated and to establish *mandatory extended producer responsibility* schemes *for all packaging by 2024*. It also intends to improve the reparability, upgradeability, durability, recyclability, and reusability of products through increasing the scope of the *Ecodesign* Directive. Progress in the *implementation of the Circular Economy Action Plan* is assessed through a *monitoring framework* composed of a set of *ten key indicators*.

As part of this action plan, a *European Plastics Strategy* was adopted in *January 2018,* which foresees that *all plastic packaging* on the EU market will be *recyclable by 2030, consumption of single-use plastics* will be *reduced* and intentional use of microplastics will be *restricted*. Also, *more than half* of plastic waste must be *recycled* by *2030*. The Plastics Strategy should also contribute to meeting the *2030 Sustainable Development*

Goals and the *Paris Agreement* objectives on climate change and reducing CO2 emissions.

The first piece of *legislation* deriving from this action plan and concerning plastic was the *plastic bag directive of 2014,* which had to be implemented by member states by *November 2016*. It calls countries to restrict access to single use plastic bags by banning them or establishing a *charge* for them. These actions have shown spectacular success. According to studies in the UK, a levy caused consumption of paid plastic bags to immediately plummet by 80% - 95% and the share of plastic bags in the total visible litter items was reduced by 90% in the first year after its implementation (Ellen MacArthur Foundation 2017, 46; Green Budget Europe 2016; Zero Waste Scotland 2015).

Encouraged by this success, the European Commission proposed in *May 2018* a *directive on single-use plastic* aimed amongst other at *reducing marine litter.* This directive concentrates on the *ten plastic products constituting 70% of litter* found on EU beaches, as well as abandoned fishing gear[23]. According to the current version of the text, where alternatives are readily available and affordable, *single-use plastic products* will be *banned by 2021 from the market,* such as *plastic cotton buds, cutlery, plates, straws, drink stirrers, balloon sticks, products made of oxo-degradable plastic, and food and beverage containers made of expanded polystyrene (EPS),* while *single-use drink containers made with plastic will only be allowed if their caps and lids remain attached*. For other products, the focus is on *limiting their use* through a national *reduction in consumption* (through the setting of national reduction targets, making *alternative products available* at the point of sale, or ensuring that single-use plastic products cannot be provided free of charge); on *design and labelling requirements* (on how waste should be disposed and the negative environmental impact of the products, such as sanitary towels, BC at wipes and balloons); on measures *raising awareness* of consumers; on *collection targets* for member states (*90% of single-use plastic drinks bottles by 2029*, for example through deposit schemes, and plastic bottles will have to contain at least 25% of recycled content by 2025, 30% by 2030); and on *waste management/clean-up obligations for producers* (like states sharing in the costs of waste management and clean-up, and giving incentives to develop

[23] across the world, plastics accounts for 85% of beach litter

less polluting alternatives). This directive was adopted in a weaker version[24] by the Council of the EU on *21st May 2019* and entered into force in *the summer of 2019*. Upon publication in the journal member states will have two years to implement the directive (European Union 2019; European Commission 2019b; 2019a).

According to the European Commission, replacing the most common *single-use* plastic items with innovative alternatives can lead to the creation of *60,000 jobs* whereas the *overall plastic strategy* can bring up to *200,000 jobs by 2030* in the sorting and recycling industries. The *Horizon 2020* programme devotes *EUR 250 million to R&D* financing in areas pertinent to the EU *Plastics Strategy. Until 2020, another EUR 100 million* will be used for *priority actions*, including the *development of better materials and better recycling processes* which among other things enable the removal of hazardous substances.

On 30 May 2018, the EU has adopted *Directive (EU) 2018/852* Amending Directive 94/62/EC on *Packaging and Packaging Waste*. Concentrating on reusable and reuse of packaging, the new text requires Member States to take appropriate measures "to encourage an increase in the share of reusable packaging placed on the market and the reuse of packaging." In particular, its Article 5 which focusses on reuse gives examples pertinent to this thesis, suggesting the "use of deposit-return schemes", "qualitative or quantitative targets", and "economic incentives".

The EU Commission also announced it would issue *guidelines on separate collection and sorting* of waste *in 2019*.

In *December 2018*, the European Commission also launched the *Circular Plastics Alliance*, which brings together *key industry players along the whole plastic value chain*. The Alliance is aiming at *improving plastics recycling* in Europe, amongst other by improving *the match between supply and demand* for recycled plastics.

These new legislations and schemes, which are created at EU level could also be *adopted* at *municipal level* by an innovative city like Vienna, thus speeding up the implementation

[24]Among other things, the directive now only recommends restricting the use of EPS food and drink containers (European Union 2019, recital 15)

process and allowing a *faster path to success*. Vienna, home of the Vienna International Centre (VIC) a business district where offices of the United Nations (UN) are located and 7th largest city in the EU, could take the lead and already independently implement EU strategies at city level becoming an environmental city beacon in the EU. A *bottom-up-approach* with a smaller implementation basis and more tangible goals give quicker results where successes can be copied as *best-practices*.

To make Vienna an exemplary city managing takeaway container waste, however, requires an analysis of materials and usage as well as already existing systems and schemes. Having presented the main takeaway container material, plastic, its benefits and problems, as well as government's recent attempts to deal with these and create a more sustainable economy, this thesis will now examine widely used materials for takeaway containers and whether these offer a sustainable solution.

4.3. Materials

A takeaway container should allow food to be well packaged, distributed, kept at its filling temperature, and reheated. Single-use containers usually account for packaging for short distance transport and not much more. Often containers are not microwave-safe, leak, and are not very durable. They are cheaply produced which also raises the question how healthy the used material is for human consumption.

A reusable container allows to cater more for consumer needs. The ultimate reusable container should be heat resistant, durable, leak-proof, microwaveable and dishwasher safe. It also should be made of material not detrimental to human health (e.g. BPA free) and if possible light weight, not too expensive, and easily stored (e.g. through stacking). It should also not influence taste and have a design that allows *easy and quick cleaning*. Consisting only of *one part* may also help *increase its life span* as parts are then less easily lost. Lastly, it should be reused for as long as possible and be recyclable when it reaches its end. Overall, it should have the lowest financial, environmental, and social cost possible.

One of the *most widely* and *longest* utilised containers for reusable systems in North America are the EcoTakeout Series from G.E.T. Enterprises[25], whose *EcoClamshells* are closest to the original prototype and still the most prominent choice (Downes et al. 2018). EcoClamshells are reusable, recyclable food containers, which consist of one piece of durable BPA-free PP plastic with a hinged lid and a texturised interior to avoid food slippage. They are advertised as microwave and dishwasher safe up to 180° Fahrenheit (82°C) and at least 1000 cycles. They are also stackable. The original version was not leak proof, but G.E.T has since further developed the containers to be leak resistant (G.E.T. Enterprises 2019; Ormsby and Copeland 2009).

Various life cycle analyses exist for the EcoClamshells comparing them to extended polystyrene (EPS), polypropylene (PP), and biodegradable containers. The first life cycle analysis (LCA) was part of a report made for the Environmental Research and Education Foundation in 2009 ("*the 2009 report*"), which included the development of the EcoClamshell prototype first used at Eckerd College (FL) in April 2008. This first pilot programme was evaluated at the end of the 2008 spring semester as well as in the autumn of 2009, further improving design. Between 2008 and 2012, over 1,200 Eco-Clamshell were utilised at Eckerd College (Ormsby and Copeland 2009; Copeland, Ormsby, and Willingham 2013).

The report conducted a simple *gate-to-grave* life cycle analysis with quite narrow boundaries to measure the effectiveness of the EcoClamshell *EC-01* compared to a single-use *EPS* takeaway container. The analysis was meant to reflect the environmental impacts, which were *only* associated with the containers. Thus, packaging and machinery maintenance was excluded. Also, raw material extraction because of no access to reliable data was excluded. Since the manufacturing process of the EcoClamshells is molding and hence simple, the authors assumed it to be equal to the manufacturing of the single-use EPS container. Also, transport was assumed to be equal, only adjusted by weight as the EPS container at 0.025 lbs (*11.3 grams*) was much lighter than the EcoClamshell which weighed 0.58 lbs (*263 grams*). For its LCA the report considered *4 criteria*, greenhouse

[25] based in Houston, Texas. Leading producer of break-resistant melamine and alternative materials "tabletop solutions" for commercial food service with 30 years of experience

gas emissions in kg, energy consumption in kWh, waste production in pounds and water consumption in gallons.

Based on initial results from the pilot programme at Eckerd College, it was assumed the EcoClamshells have an average lifetime of *360 uses*[26]. The analysis shows that if an EC-01 EcoClamshell is used 360 times instead of 360 disposable EPS containers it saves 50% in energy, 88% in GHG emissions, and 89% in solid waste, however consuming 18 gallons (68 litres) of water. Even though water consumption theoretically increases for each reuse, the report writes that in reality the commercial dishwasher which functions like a conveyor belt during mealtimes is likely to be running anyway (and not always at full capacity) and hence the increased water consumption on paper is negligible in actuality. In fact, the largest impact on greenhouse gas (GHG) came from cleaning the container in a commercial dishwasher (59%), followed by its landfilling (17%) and transportation (15%) cost. While the dishwashing phase increased GHG and energy consumption per reuse, they were however offset by other larger savings over time when compared to the EPS containers' consumption.

Although *production costs* for the EcoClamshell are *higher* than for single-use plastic containers, the *marginal cost decreases* for each reuse hence decreasing total cost over time. Thus, the report finds EcoClamshells to be *better* for the environment and effective for their intended purpose. The report is limited by excluding raw materials, but this should be an obvious reduction as 360 containers are replaced by one. Lastly, the paper assumed that also the reusable containers are landfilled at their end of life. If they were recycled, the LCA should show even better results.

The main question which arose for the reader is whether indeed EcoClamshells are used at least 360 times in their lifetime and at which *minimum* they are better for the environment.

A *cradle-to-grave* LCA conducted by G.E.T. enterprises in 2011 ("*the G.E.T. report*") on the *EC-12* [27] tries to answer this question by examining GHG emissions (kg) and

[26] Based on producer and consumer data, which estimated containers are used for two school years (2*9months) for 5 days a week.
[27] Which only weighs 0.50 lbs (225 grams) compared to the EC-01, which weighs 0.58 lbs (263 grams)

embodied energy (kWh). It finds that an EcoClamshell produces the same GHG as *24* and the same embodied energy as *32* single-use EPS containers. This study also postulates the EcoClamshell is used at least 360 times and so finds that it reduces GHG emissions by 93% and embodied energy by 91% (Downes et al. 2018, 4). This dataset compared to the 2009 report calculates similar GHG emissions of 2kg for one EcoClamshell, however higher GHG emissions for 360 EPS containers and substantially higher energy for both types of containers, likely because of the inclusion of raw material production. For this study, however, very little and only secondary data exists.

In 2013, Ms Copeland and Ms Ormsby, the founders and authors of the first 2009 report, together with Ms Willingham, published an LCA ("*the 2013 report*") also on GHG emissions and embodied energy in "Sustainability: the Journal of Record". This publication is largely based on the original 2009 report with two main differences. Here, the LCA additionally includes raw materials and thus is *cradle-to-grave* and less efficient assumptions are made for the dishwasher[28]. Furthermore, this LCA, very similar to the G.E.T study, aims to find the *breakeven point* rather than examine the differences at a fixed point of 360 uses. The journal article finds in a first step that the EcoClamshells produce 12 and 21 times more GHG and energy. When reusing the EcoClamshells, the break-even points are at *15* and *29* uses respectively, thus suggesting that the EcoClamshell must be used at least 30 times to be environmentally preferable for the criteria examined (Copeland, Ormsby, and Willingham 2013).

Also in 2013, the Institute of Sustainable Futures (ISF) at the University of Technology Sydney issued a report ("*the Sydney report*") examining whether a reusable container system would be viable for the Sydney Central Business District (CBD). Hereby they analysed the first two mentioned studies and used the 2009 report to instead compare the *EC-04*[29] EcoClamshell with *single-use* polypropylene (*PP*) containers, which are most widely used as disposable containers in Sydney. Having compared the differences in material and weight the authors argue that the 2009 data can be utilised as a *conservative* estimate for their comparison. The Tool for the Reduction and Assessment of Chemical

[28] In the 2009 report it is assumed the dishwasher can handle 2340 racks per day (running for 10 (!) hours) whereas in the 2013 report only 400 are calculated per day. For energy the 2009 report assumes 43,346 kWh annually compared to 29,792 kWh in the 2013 report. Thus, the dishwasher in the 2009 report is more efficient. (18,52 kWh per rack vs 74,48kWh per rack).
[29] Which only weighs 0.42 lbs compared to the EC-01, which weighs 0.58 lbs

and Other Environmental Impacts (TRACI) from the US Environmental Protection Agency (EPA), which compares the environmental impacts of different materials only gives a small difference between EPS (11 micropoints/lbs) and PP (13 micropoints/lbs). Since the value for PP is greater than EPS this data suggests reducing single-use PP containers would hence also have a higher positive impact on the environment. Thus, given the lack of detailed data and the small difference in favour of PP (reductions would increase by 13/11), the study decided to not change the EPS data. With regards to weight, the 2009 report established a single-use EPS container to weigh 11.3 grams whereas the Australian study finds the average Australian PP disposable container to weigh *68 grams*. As the 2009 report is based on number of uses, 360 EPS containers weigh much less than 360 PP containers. Hence, the PP containers, which have a much heavier burden on the environment, would again result in higher savings if avoided. An adjustment here would not necessarily be linear and hence was not made, once again making the resulting estimates conservative. These results are then applied to 4 different scenarios, which differ as to how and where the reusable containers are washed. As the 2009 report has shown that the washing step is relevant for environmental impacts over time, it is important to consider in detail how the containers are washed. These different systems will be discussed in the next chapter (Downes et al. 2018, 3–4, 43–45).

A third study conducted in 2013 by Ms Harnoto at the University of California, Berkeley, compared the *EC-01* EcoClamshell with a disposable *compostable* bagasse[30] container through a *cradle-to-grave* LCA ("*the Harnoto report*"). It calculated the breakeven point as well as two scenarios. The first assumes the EcoClamshell is reused 360 times (based on manufacturer data and previous reports) and afterwards is *recycled* (and the compostable container is composted). The second scenario is based on own observations made at the university dining hall where EcoClamshells were tested for 4 months. Here, *43* cycles are assumed with *21% recycling* (and 25% composting for the compostable container) and the rest landfilled. For the LCA, the same *four criteria* as for the 2009 report were examined, however water was measured in litres, energy in megajoule (MJ) and waste in volume (m³) instead of weight. The study calculated a break-even point at *14* uses for GHG emissions, energy, and material waste, however not water consumption as water consumption was always higher for the reusable option (Harnoto 2013).

[30] Waste product from sugar cane production (ca. 30% of plant)

The most extensive and detailed analysis comparing reusable to disposable options was presented recently in the Journal of Cleaner Production ("*the Gallego report*"). It compared three most commonly used single-use containers with two reusable options and how these would fare in different scenarios, including one where the new European Union circular economy strategy is followed (Gallego-Schmid, Azapagic, and Mendoza 2019; Burnside 2019).

As single-use containers, a foldable extended polystyrene (*EPS*) clamshell, a polypropylene (*PP*) container with PP lid, and an *aluminium* container with a polyethylene (PE) coated cardboard lid were examined. All three had the same filling size of 670ml. Comparing only the single-use items with each other, the study finds that the *EPS* container has the *best* environmental footprint as it requires the lowest material and electricity input during manufacturing. The PP container has the *worst* impact in *7 out of 12* categories, also in global warming potential. This is mainly because of *higher production costs* and its *landfilling*. Intriguingly, *aluminium*, which only has the highest negative impacts for 5 categories, has however an especially strong impact *intensity*, of *up to 23 times* the level for PP and *28 times* for EPS, thus being *especially bad for certain impacts.* This also means that the *PP* container although being worst in most categories is *overall closer to the EPS results* than aluminium, as the *worst* impact for PP is *only 6 times* higher than the one for EPS *compared to* the worst impact for *aluminium*, which is *28 times higher* than the one for EPS.

Thus, the results change when the PP container is assumed to be kept by the consumer and reused, or the consumer brings his own *tupperware*, which is made of PP with a silicone border around the lid to make it leak-proof. Then, the *PP* container becomes *most environmentally friendly*, if it is used at least 9 times for 10 impacts and *32 times* for all but one impact to be improved[31]. Interestingly, the *reused single-use PP* container is *more environmentally friendly than the tupperware*, which needs to be reused at least 16 times for it to be viable compared to aluminium and even more, *39* times for 10 criteria to be

[31] Terrestrial ecotoxicity potential is least for EPS compared to the reusable containers independent of the number of uses; EPS is also much better compared to aluminium. The difference between the PP and EPS impact compared to the EPS and aluminium is however much smaller.

better compared to EPS. Again, to improve all but one criteria[32], the tupperware has to be reused *208* times, thus substantially more often. The underlying reason for the tupperware's bad performance with the remaining two criteria, abiotic depletion potential (ADP) and terrestrial ecotoxicity potential (TETP) is given as the *electricity* which is needed to *heat* the *water* to wash the reusable containers. These two criteria were also highest for the PP reusable container, abiotic depletion potential, however, was much lower at 32 compared to 208. Also, freshwater toxicity potential, the third highest impact, is likely influenced by the washing of reusable containers, but here too the tupperware value at 39 is higher than the PP value at 9. Given that the *size* of both containers are *equal* and both have separate lids, it is surprising to find a difference between the two when both should have the same consumption of electricity during washing. Hence, the relatively high numbers for the *tupperware* are likely more linked to its *higher weight* and so its *higher raw material, production, and transport costs*.

Establishing that waste management is a key factor influencing environmental impacts, the study also examines in its third part three different *recycling* scenarios against the status quo of the single-use options, where one scenario is the *EU proposal* of recycling *55% of plastics* and 75% of aluminium. The other two scenarios are best and worst cases based on available figures of the best and worst current waste management of EU countries[33], which do not necessarily include recycling. Examining the main contributions to each impact and how *scenario changes* affect these impacts, the following was discovered.

Main contributors to 11 out of 12 impacts for *aluminium* are *extraction and refining* (>48%) through electricity use as well as gas (CO, HF), polycyclic aromatic hydrocarbon (PAH), and heavy metals emissions. Hence, using more *recycled* aluminium would substantially decrease impacts on the environment. The baseline assumed that already 54% of the container is recycled. While this has a positive impact, increasing recycling would give further benefits: a 10% increase in recycling reduces impacts by 6-*19%*, especially reducing toxicities. However, PE coated cardboard used as a lid for the

[32] See footnote above

[33] *Best*: aluminium 89% recycled, EPS 100% incinerated; PP: 30% recycled, 69% incinerated; *worst*: aluminium: 22% recycled; EPS 100% landfilled; PP: 2% recycled, 8% incinerated; all missing percentages landfilled; all incineration with energy recovery

aluminium containers would remain the main contributor to ozone depletion (through halon 1301).

Raw material production of *EPS* is responsible for *over 50%* of each of 5 impacts including GWP. Raw material production also has a significant impact (>20%) on 4 further criteria (through electricity, fuel oil, CO_2, SO_2, VOCs,). Further *production* (extrusion and thermoforming) is the main contributor to 6 categories (*>33%*) (mainly through electricity). This, too, suggests that *recycling* EPS would be *beneficial* as the EU case shows, where 10 criteria are reduced by over *18%*. This case scenario decreases the most impacts the furthest, avoiding organic carbon leachates, CO_2 and heavy metal emissions. While steering clear of landfilling may increase *energy costs* and so *global warming* potential, this can be counteracted over time by using renewable energy. Since EPS is very light weight, its transport has no significant influence (<9%).

For PP both raw materials and manufacturing also contribute significantly (*>42%*) to seven criteria, again through electricity, fuel oil, and CO_2 and VOC emissions. *Transport***,** too, is a significant factor for one criterion. For the end of life only landfilling is a major contributor to four criteria, whereas the *recycling* and waste to incineration parts improve seven criteria up to *21%*. Once again, this data suggests that recycling indeed would be beneficial.

Comparing the four different case studies, the study finds that the EU strategy, where *recycling* plays a key role and landfilling is avoided, decreases all impacts by between 2% to *60%*, with global warming potential being reduced by 33%.

Recycling was estimated using the net scrap approach where already recycled material in the product is subtracted from the amount recycled at end-of-use. The rate of recycling for aluminium is 54%. The container in this study is assumed to contain 32% recycled aluminium, whereas for EPS and PP no recycled content is first considered. Thus, if *recycling rates increase,* the *positive effect* on the LCA is likely *stronger for PP* and EPS further supporting their use, especially if no recycled content is used for production as it is not yet common for products who come into contact with food. However, using recycled material in containers would be beneficial as it would reduce raw material and production costs. Since *EPS* is *not very recyclable* on a practical level due to *low cost-*

effectiveness, where the light-weight material must be made denser before it is recycled, an *increase in recycling* rates would mainly *benefit PP*[34] as it has the highest untapped potential for recycling. Also, *EPS* is easily *littered* due to its lightness and may be blown away[35]. Hence, EPS is only a sustainable option if its end-of-life situation were made more cost effective.

In general, the study also assumes for its *status quo high landfilling rates,* of *45%* for *PP*, 46% for aluminium, 50% for EPS, and 100% for silicone. In *Vienna*, landfilling rates are much lower and would thus substantially decrease impacts[36]. Hence, the best-case scenarios may be more applicable to Austria. Compared to the EU strategy scenario, the best case reduces seven impacts up to *18%*, however the other five are worsened across all containers. This is mainly because the *best-case scenario* does not assume any recycling for EPS, a *low recycling rate of 30% for PP*, and 11% of aluminium to still be landfilled. As mentioned above, recycling however, would bring more benefits.

The study conservatively estimates that *2556 million* takeaway containers (2025 of the three examined) will be used *annually* in the *EU in 2025* based on research, which gives 1638 million for the top five EU countries in 2014. This figure could easily be extrapolated to more than 2556 assuming larger growth rates (>1.5%)[37] or larger country markets, especially if the country has large cities. In fact, other research gives already *6949 million* takeaway transactions for the same top five EU countries in *2009* and forecasts *7426 million in 2014* (Moneo, Sirgado, and Lamas 2011). The disparity between these projected figures reveals how difficult it is to monitor this fragmented market and its expectedly dynamic growth.

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[34] For PP an initial recycling rate of 11% was assumed.

[35] 92% of collected microplastic on beaches in Hong Kong was EPS (Fok and Cheung 2015)

[36] In Austria, 2/3 of plastic is incinerated with energy recovery and the rest mechanically recycled, thus less than 1% residual waste is landfilled (van Eygen 2018)

[37] Other data suggests at least 3% p.a., e.g. McKinsey gives a rate of at least 3.5%p.a. for online delivery fast food.

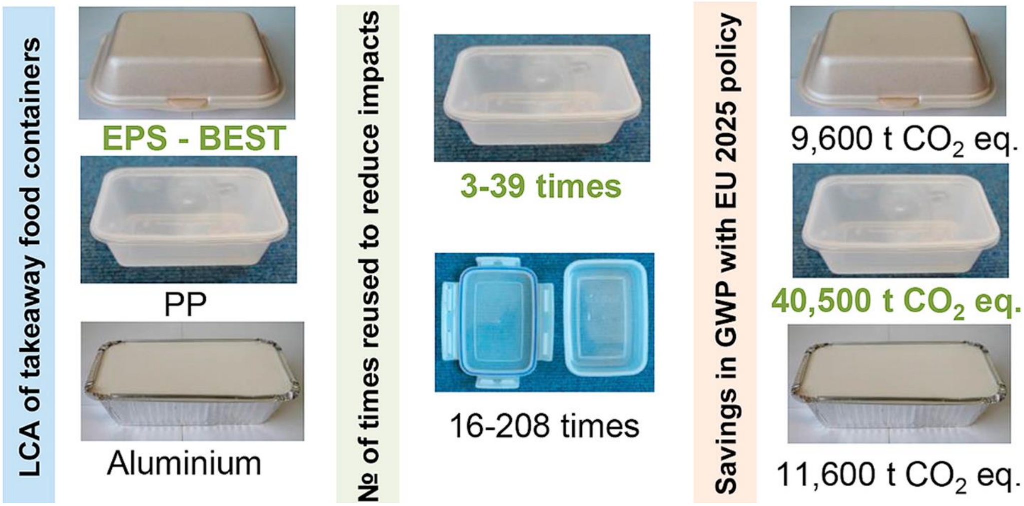

Figure 1: Graphical summary of the Gallego report

In summary, the Gallego report gives an in-depth analysis of common single-use takeaway containers and finds that *EPS is best for single use*. Its main advantages come from needing *less material* for production than PP (EPS is mostly air) and *less electricity* than aluminium. PP while worse in most categories is *only up to 6 times worse* in a single category compared to aluminium at 28 times. Especially when examining PP as a material that is *reused*, it becomes a more environmentally friendly option. Furthermore, the study finds that *recycling is key* to improving all materials' impacts but may be difficult to implement for EPS, thus further making the case for PP.

Noteworthy additional decreases to impacts may be generated through using the *dishwasher* instead of manual washing as cleaning the containers is the main impact over time for reusable containers. This would substantially save water and soap. The other previously discussed studies also support the notion that the choice of dishwasher / washing method affects results. Dishwashers, however, require *electricity* which would worsen certain impacts. But using electricity from a *more renewable energy mix* throughout the life cycle would improve many impacts, though elements and ozone depletion potential may be increased through a higher use of photovoltaic panels and natural gas (Gallego-Schmid, Mendoza, and Azapagic 2018). Also, impacts could be diminished through making *production processes more efficient* or requiring *less raw materials* as these two are main influences on impacts. Weight as an important factor is also emphasised by Harnoto and the 2013 report. According to the Gallego report these suggestions, however, seem to have already reached their developmental and technical limitations.

In contrast, however, the *variation* of PP weights *between reports* suggests there may still be *potential* to *reduce weight*. But if weight is decreased, it poses the question *how many reuses* would still be possible. Would durability decrease linearly? How decreasing weight affects maximum number of reuses (before breakage) and thus the environmental balance should further be investigated by academia. *Less material* would also *improve transport* impacts, which are another important factor for the presented reusable options also because they are produced far away in *China*. Furthermore, China has a *less favourable energy mix* for environmental impact categories. If *PP* were produced in *Europe*, its impacts from transport and electricity would thus likely improve further.

Lastly, the study extrapolated the distribution of containers characteristic of the *UK* to the EU. While overall the types of containers are the same, this *distribution* may, however, *not apply to Austria*, where EPS, for example, is not often utilised. Rather, *PP* is the *most widely used* material for single-use takeaway in Austria, like in Australia. Hence, the Sydney report which finds that disposable EPS data from the 2009 report can be applied to disposable PP as a conservative estimate, suggests Austria could also follow this logic. This makes *all* previously discussed *reports relevant for Austria*, too, as it can use data on disposable EPS as a conservative estimate for impacts from disposable PP.

Below is a collection of tables to help compare the different studies and their results.

Table 3: images of containers compared in the different studies

Container	Study	Image
EC-01 (PP)	2009	
	2013	
	Harnoto	
EC-04 (PP)	Sydney	

EC-12 (PP)	G.E.T.	
EPS	Gallego (similar ones for 2009 and 2013 studies)	
PP	Gallego	
tupperware	Gallego	
compostable	Harnoto	

Sources: G.E.T. Enterprises 2019; Gallego-Schmid, Azapagic, and Mendoza 2019; Harnoto 2013

Table 4: Comparing GHG and energy production of EcoClamshells when used 360 times

Report	2009	2013	Harnoto	2009	2013	Harnoto
Container	EC-01			360 EPS		360 compostable
Weight (g)	263			4,096.8		15,624
GHG (kg)	2	n/a	1.27	16	36	85.5
Energy (kWh)	4	n/a	9.2	4	129.6	235

Report	G.E.T	Sydney	G.E.T	Sydney
Container	EC-12	EC-04	360 EPS	360 PP

Weight (g)	227	189		24,480
GHG (kg)	2.4	<2	35.6	>16
Energy (kWh)	12.02	<4	131.4	>4

Table 5: Comparison of LCAs and their breakeven points[38]

Report	G.E.T	2013	Harnoto	Gallego	Gallego
Container	EC-12	EC-01	EC-01	PP	tupperware
Weight (g)	227	263	263	31.5	141.3
Breakeven point GHG	24	15	5.5	4	18
Breakeven point Energy	32	29	14	5	19
Breakeven point overall	32	29	14	9 (excl. ADP and TETP)	39 (excl. ADP and TETP)

Sources: Ormsby and Copeland 2009; Copeland, Ormsby, and Willingham 2013; Downes et al. 2018; Gallego-Schmid, Azapagic, and Mendoza 2019

All studies find that initially *raw materials and manufacturing* have a *large share* of the *environmental impacts* and their share can be *decreased over time*. All studies also assume PP manufacturing in China. The Gallego report though assumes EPS is produced in Europe which makes EPS relatively more competitive. However, this report also based their calculations on lighter EPS and especially PP containers, with their PP containers weighing only 11.7% and 52% of the EC-01 EcoClamshell. Thus, it would be interesting to see how Gallego's LCA would fare with heavier containers and EPS also produced in China. Unfortunately, impacts would likely increase as the lighter EPS' further transport impact is probably less significant than the heavier PP's impact.

[38] PED (primary energy demand) is compared with embodied energy, and global warming potential (GWP) with GHG emissions.
The difference in weight between EPS containers (11.3g for Clamshell ones and 7.8g for the Gallego report) has been assumed as negligible for this comparison.
Furthermore, the break-even points in Gallego for aluminium and glass are far before EPS for both types of PP containers and are omitted from the table.

One should not forget that the other studies were conducted for the *US* and so closer distances were calculated for China as well as the final destination. The geographical difference between studies also affects the *energy mix* assumption and *end of life* management. In the US, still most PP is landfilled, whereas in Austria already 33% of plastics are recycled. The US studies (except Hamoto) assumed landfilling. Hamoto and especially Gallego show alternative end of life management, especially recycling, can significantly improve the balance.

Furthermore, it would be worth investigating how *the manufacturing of PP in Europe* would affect LCAs if *consumption* was also intended for Europe. One case study (REBOWL), which will be discussed in Chapter 5.2, uses a European manufacturer in the Netherlands. Lastly the examination of the studies indicate that they were conducted at different accuracy levels dependent on the scope of the report and data availability. The 2009 report was the only known report to not use the professional LCA software called GaBi but instead gave important first sources of information stemming from its pilot project. It is not known whether the G.E.T report used LCA software. It however has a lot of resemblance to the 2013 report and was likely based on an earlier version of it. Gallego's LCA is the most detailed one, including 12 criteria and also -as the only one- estimates for packaging.

On a practical level all studies support the idea of implementing a reusable PP container system as it is beneficial for most environmental criteria. Especially GHG and energy production seem to be important indicators for the consumer and give a clear positive sign with *breakeven* points not higher than *32* and a median of 16.5. In fact, the GHG break-even point was easier to reach at a maximum of 24. Both highest values, 32 and 24, are from the same study however, which may suggest a certain numerical bias. Overall, across studies the breakeven point is at *39* uses, if abiotic depletion potential (ADP) and terrestrial ecotoxicity (TETP) are excluded. If indeed the high ADP and TETP values result from electricity use, then this may be partially mitigated through renewable energy use. If the high values of ADP and TETP result from production and transport, better alternatives can be searched for, too. More importantly their high values should be compared on the grand scale of things, where their impact is likely small and elsewhere significant reductions may be possible. Hence, excluding only these two criteria is an acceptable trade-off. The increased use of water is also seen as acceptable in all reports. Further investigation though should be made for different scopes, as well. The American studies were based on campus case studies, whereas the Sydney one was intended for an entire business district and the most recent Gallego report for all of the EU.

Finally, *40 uses* is a *realistically achievable* number, even if some containers may break after 43 uses (Harnoto 2013) instead of 360 (Ormsby and Copeland 2009). To ensure high numbers of reuse and low *rates of loss*, a working *system* and *accountability* mechanism are necessary. Different types of systems and accountability mechanisms will be examined in more detail in the next chapter.

The above reports indicate that PP is indeed a front runner material for takeaway containers not just because of its affordability, durability, lightness, and insulation. It has also been a favourite choice of material for reusable cups. Its insulation may however also pose a risk to scalding. In the Burns Journal this was examined comparing ceramic cups, single-use paper cups (with or without lid), and reusable thermoplastic cups (with or without lid). The cups were analysed under two scenarios, one with black coffee and the other with a café latte. As expected, across both scenarios the study finds that lidded cups generally take longer to cool down and unlidded thermoplastic cups took longest to cool the liquid compared to the other two cup types. They, however, establish that this is not in itself an increased scald risk. Rather they find that the general to-go trend, which necessitates the use of lids may add to scald risk (Naik, Lewis, and Allison 2019). For takeaway containers, this means that a PP container with a lid will help keep food warm and scald risk is highest for liquid food, but otherwise with proper attention negligible.

Having delved deep into plastics, this paper should make short mention of other alternatives for reusable containers, such as glass and stainless steel. Glass has been found to need 3.5 times more uses than a PP tupperware to match its environmental footprint and also is more impractical as it is much heavier and may break (Gallego-Schmid, Mendoza, and Azapagic 2018). Furthermore, the 2013 report finds that using a different manufacturing technique causes a larger variation of impact criteria.

Stainless steel is a more viable option and one that is being considered by some case studies. It is however likely heavier and not microwavable as well as more expensive. An academic comparison between stainless steel and PP or EPS for takeaway containers, however, does not yet exist. Indeed, *no LCA exists* which compares different types of reusable containers, only.

ReCIRCLE, a case study, which will be discussed in the next chapter gives good practical reasoning on why they chose plastic. They find the following: Glass breaks to easily and if it is hardened is not recyclable. Also, it is hard to stack. Heat can create a vacuum and makes glass too hot to touch. Aluminium and steel are not microwaveable and hard to make leak-proof without clips or silicone, which are a physical barrier to quick and good cleaning. They, too, can be too hot to touch unless they are double-walled, which would substantially increase costs. Wood takes too long to dry and may also cause hygiene problems as it is porous. Biodegradable plastic often contains additives which certainly don't make it healthier than other "normal" plastics. It is also often separated incorrectly polluting other waste streams (ReCIRCLE 2019b).

This chapter finds that PP is an acceptable material for a reusable container system even if it is landfilled. Recycling and incineration at end of life, however, improve results. Containers should be reused at least 40 times to fulfil most environmental criteria, which also depend on how they are washed and transported as well as where they are produced. The next chapter will introduce different systems which can be used to operate a reusable container scheme. In addition to their environmental implication, they have to be considered under financial and social aspects.

5. Results and Discussion

5.1 Systems

Having presented the economics of plastic, the EU legal framework for preventing and managing plastic waste, and an analysis of PP as a material for reusable containers, this paper will now give a *theoretical framework* of different types of reusable container *systems* developed around the world. The next chapter will then present *case studies* derived from these systems and whether they can be applied to Vienna. In general, reusable container systems can be distinguished along two main criteria: by who *owns* the containers and who is *responsible* for their collection, cleaning, and redistribution.

5.1.1 Decentralised First Generation: Individualised - Bring Your Own Container (BYOC)

A first approach was *initiated by customers*, who had their own tupperwares filled at takeaway restaurants. Through buying a container themselves, customers could choose their favourite materials and design and be sure their container fit their expectations and was leak and microwave proof. Thus, a market for good quality reusable containers started to develop. From this, so called *"Bring-your-own-container (BYOC)"* schemes evolved where customers were further encouraged through discounts to bring their own containers. Most modern day *first generation BYOC* schemes aiming at replacing single use takeaway containers with reusable ones refer to the Tiffin project, which was operated by Hunter J. Moyes between 2012 and 2015 in Vancouver, a *city where takeout containers and disposable cups represent half of all waste* collected from public waste bins (Chung 2018). His inspiration was drawn from India where "tiffin" means light meal. Since the 1880s, systems of food delivery in tin containers have been in operation in India to supply workers with ready-made meals at their place of work. The delivery companies take back dirty containers every day to clean and reuse them the next day. The Tiffin Project in Vancouver, however, allowed individuals to purchase a tin container (for CAD 25) and use it in participating restaurants around the city for takeaway food, whilst receiving a small discount. Thus, the Tiffin project encouraged customers to acquire Canadian-made reusable Tiffins and restaurants to offer a fixed or percentage discount to customers who brought their own containers, bringing the number of reusable containers in circulation to a total of 5,000 at the height of the system. Customers though had to take the dirty container home and wash it themselves (Stainsby 2012; Moyes 2014).

The Tiffin project was halted in 2015 because of the *city's health and safety concerns.* The authorities required that all reusable containers be washed in a *commercial dishwasher* before being refilled. Many small vendors could not fulfil this criterion (Chung 2018). However, the same scheme survives to this day in Brussels (Tiffin 2019). Also, many other similar BYOC projects have since developed. However, this first-generation scheme leaves the *responsibility for sustainability fully with the customer.* First, they must do their own research on which container is most suitable. Second, they must carry the extra weight of a container with them all day, also when it is dirty. Lastly, it requires them to be organised and build a habit remembering to always have a clean container at hand when ordering takeout. Unfortunately, as the example of Vancouver shows, local health authorities who fear that unproperly washed containers could contaminate food can put these schemes under pressure hampering their development and use. Furthermore, this system lacks *standardisation* which is important for food retailers handling containers. Most importantly, as the previous chapter has established, how the containers are *washed* has a large *impact* on their *LCA* and hence sustainability. In this described system, containers are likely *washed by hand* or in a *household dishwasher*, thus not reaching full environmental potential even though transport distances may be shortest here.

5.1.2 Decentralised Second Generation: Return your container to restaurants

The *second generation of reusable containers systems* involves *professional sanitising* of containers. A *first version* relied on a *decentralised cleaning system* where customers would take back their dirty reusable container to the *same restaurant* where it was offered and filled. This implies however that takeaway restaurants joining the scheme need appropriate cleaning facilities which resemble more those of dine-in restaurants. Many take-away restaurants may, however, be too small to have the necessary equipment. Hence, this version of the scheme has been unequally successful across various cities because it puts high *pressure on* participating *restaurants*. It also does not profit from *economies of scale* for container *cleaning* as the scheme expands across the city. Furthermore, it is not easily applied to online delivery systems as returning the food container to the same restaurant is a lot of *hassle* for the *consumer* or delivery person. Hence, it may also lack *standardisation* for the *consumer* as restaurants may each be utilising different types of containers.

In a *second version*, many restaurant *chains* have launched their own scheme of reusable containers like Starbucks and Tim Hortons for reusable coffee cups (Tim Hortons 2019; Starbucks 2019a), or Just Salad for a reusable bowl (Just Salad 2019b; 2019a).

5.1.3 Centralised: return your container at the closest collection point

A *centralised scheme* of reusable container sanitising implies collecting dirty containers, either in restaurants, collection points (e.g. *reverse vending machines* at universities) or even on the customer's doorstep (as is common practice in India and South Korea), to have them *industrially cleaned* by a special company. This function could also be performed by larger restaurants taking part in the scheme, who would sanitise the containers for other smaller participants. This would, however, require placing collection points throughout the city as for logistical reasons one single large restaurant should not be the sole collection point for all other restaurants[39]. Hence, another player, a company specialised in collection would have to be part of this type of system. While this system is likely the most *efficient* in *cleaning* the containers, it may worsen the LCA through *increased transport costs* when collecting and redistributing containers. This can though be easily mitigated through *bicycle couriers*, as case studies in the next chapter will exemplify.

5.1.4 Can one system be converted into the other?

One could consider starting a reusable container scheme in the *decentralised* mode and then *convert* it into a more *centralised* system once it reaches *sufficient scale*. The transition from one scheme to the other is however not straightforward. When transferring to a centralised scheme, any *investments* in *cleaning facilities* may be *sunk costs*. Vice versa when transferring from a *centralised* scheme *to a decentralised* scheme, the *infrastructure of collection points* may be *sunk costs* and a sufficiently dense infrastructure of participating restaurants is needed to ensure a seamless change. Either way a *switch* from one system to the other would *confuse* customers and hence is not practical. Thus, centralisation or decentralisation are options, which should be chosen early on. Decentralised cleaning should rely on efficient parameters from the start so as to remain viable in the long term whereas centralised cleaning needs careful initial planning of infrastructure and a reliable partner.

5.1.5 Incentives

Various *incentives* have been developed for customers to move towards reusable containers. The most common schemes usually include at least one of the following points:

[39] This paper has not yet identified an example of a centralised system, which is centred around one large restaurant only.

- a *discount* for bringing one's container or reusing a container provided by the restaurant;
- symmetrically, a *surcharge* for taking one's food in a single-use container. It may seem equivalent to a discount, but has a stronger psychological effect
- *non-financial incentives* like a free topping, or skipping the queue
- encouraging a different approach to eating takeaway food, e.g. by making it a *social* experience (*curry mobile* in Ottawa encourages customers to order at least five meals at a time, which also makes pick-up of dirty containers easier (Chung 2018))
- a combination of these approaches

Starbucks, which has been giving discounts to *BYOC* customers since 1985, recently tested the effects of a 0.05 GBP *surcharge* for disposable cups while offering a 0.25 GBP discount for using reusable cups in all its London stores for *3 months*. It found that the use of reusable cups *increased* from 2.2 to 5.8% (Starbucks 2018).

5.1.6 Area of the system

Parallel to defining the economic model of a reusable container system, one has to decide whether the scheme should be operated in a *restricted area* like a campus, business district, or at the scale of a city. A smaller or confined area, where consumption of take away food is high, has the advantage of *reducing possibilities of containers exiting the scheme* and so *the rate of loss*. A larger area, however, offers better *economies of scale*.

5.1.7 Accountability and return mechanisms

To decrease the rate of loss and increase the container's lifespan, customers should be held *accountable* for their containers. This is usually done through a *deposit fee* or some form of *token*, which is handed out when the container is returned in good shape. According to the 2013 report, especially financial consequences of some form are important for individuals to *associate a cost* with how they treat their containers. Containers can be tagged and monitored through *QR* or *bar codes, chips*, or near-field-communication (*NFC*) systems and registered by a restaurant *employee, cell phone,* or *machine*. Often *apps* are a helpful tool for this.

5.1.8. Social acceptance

A final factor important for a system's success is its social acceptance. The earlier mentioned studies emphasise the importance of marketing the system and ensuring clear understanding of how it operates. The 2009 report even includes a handbook for successful implementation along 5 steps.

Dorn and Stöckli researched whether a higher penetration rate of a reusable system can be achieved through social influence by testing two scenarios, one based on social norms, the other on *social modelling*. The first saw a normative message[40] included at the counter of takeaway restaurants whereas the second examined whether reusable packaging was *chosen while other* customers were *visibly using* it. The first showed no clear effect whereas the second scenario did indeed *increase* the *probability* of a reusable container being chosen if its use was already *witnessed*. This confirms the importance of *role models* for new ideas and products. For their research the authors used the ReCIRCLE system, which will be presented in more detail in the next chapter.

5.1.9 A comparison of systems: the semi-centralised hybrid

In the already mentioned Sydney report, the Institute of Sustainable Futures (ISF) whose aim is "to develop sustainable futures through research and consultancy" with an interdisciplinary approach, studied the feasibility of various systems in Sydney's CBD in 2013 and again in *2018*. Even though Sydney has strong recycling programmes, high figures of takeaway container *waste* and international *pressures* such as China's ban on importing foreign mixed plastic waste, were strong reasons for the ISF's re-examination and re-publication of their report.

In Sydney, single-use food containers cause *6 tonnes of PP waste daily* (2013). The Australian Greens specifically suggest in their Recycling Reboot policy to ban disposable takeaway containers and the city of Sydney's 2030 strategy aims to "produce less waste, maximize resource recovery and provide cleaner streets".

[40] "Our customers demand a reduction of packaging waster. Many of them already use reBoX [a reusable container]"

By comparing costs and performing a market search for *active* reusable container systems the Sydney study found that in all analysed programmes throughout North America one type of container called EcoClamshell was utilised. As already presented in the previous chapter, the *EcoClamshell, is a plastic (100% BPA-free PP)* reusable takeaway container that according to various life cycle analyses has a lower environmental impact than an average single-use EPS or compostable container when used at least *32* times. The founders and manufacturer, however, expect that the EcoClamshell is used much more often, on average 360 times.

The EcoClamshell's various applications led to the University of Sydney's identification of *four possible systems* with varying customer and restaurant responsibilities, which the study examined against the baseline model of continued usage of disposable packaging. The four systems were analysed through *8 criteria*, spanning *environmental* costs (resource and energy savings vs. costs of cleaning and transporting), *economic* costs (operation and implementation), and *social* costs (ease of implementation, customer and food outlet acceptance, health & safety compliance, and likely uptake). *Social costs* are *less quantifiable* and closely linked to *convenience*. Each criterion was rated on a 5-level scale from very good, good, average, poor, to very poor -if applicable- giving an overall feasibility of high, low, or not at all.

The first system, like the Tiffin project, is an *individualised* system and assumes customers *bring their own containers (BYOC)* and clean them afterwards. It is likely somewhat familiar to Australians through reusable coffee cup systems like KeepCup (KeepCup 2019). Other systems -more similar to the original Indian one- where the *customer* is *not responsible for cleaning* the containers, were also analysed and are likely new concepts for the Australian market. Here, a *centralised, decentralised* and *semi-centralised* system were considered[41]. In the decentralised system, the same restaurant where the food was bought, takes back containers. The centralised system allows for a return at any collection point within the city. The *semi-centralised system* considers a *confined area* where containers can be returned, e.g. at any restaurant within a shopping mall.

[41] With reference to the place where the container will be cleaned

According to the study, all systems were *overall more environmentally friendly* for an *equal or lower operational cost* than the current system of businesses purchasing single-use packaging for containers at an average price of USD 0.15 per container. *Implementation costs,* which were evaluated qualitatively, were also equal or lower than the status quo except for the centralised system where implementation cost performance was marked as poor. This was likely the case because a *centralised* system would need more *sophisticated infrastructure*. This assumption is supported by the rating of very poor in "ease of implementation" under social costs.

Overall, however, *only two systems were rated feasible*, the individualised and semi-centralised ones, whereas the *semi-centralised* one had *higher benefits*. The *decentralised* system was not seen as feasible because it was rated *poor* in 4 out of 5 *social criteria*. It was assumed that the ease of implementation and acceptance of the scheme as well as uptake would be difficult and hence the system inconvenient. This is because of a lack of economies of scale where *each separate restaurant* carries the *responsibility* to choose, source, brand, store, and clean their own containers as well as figure out a suitable accountability mechanism. A high variability of containers in *microsystems* would increase barriers for customers to return their container.

Similarly, the *individualised* system was rated *very poor* for *customer acceptance*. Here, the *customers* would have to *do all the work* of choosing, sourcing, and cleaning their own containers. The individualised system was also graded average for food outlet acceptance as the *outlets would have to accept a variety* of containers from customers. These two stakeholders, of course, are key to ensuring implementation and thus success of the schemes.

The *centralised* system would certainly be accepted by *customers* as they *carry the least burden* here. However, as already mentioned, this system likely requires the highest amount of initial *funding* and (regulatory) *incentives* to work. Surprisingly, the centralised system was marked as *poor for health and safety* compliance. One should have expected that having *only one responsible party for cleaning* would ensure *professional high quality* and thus a good rating. The ISF, however, argues that *dirty containers* may *remain at collection points* for some time before being collected and also may be *affected by other waste.*

Thus, the *semi-centralised system*, where customers can enjoy *convenience* whilst any *logistical issues* are *manageable* given the confined area, was best for Sydney CBD. On the basis of these results, the University of Sydney was contemplating a pilot programme at a shopping centre or university campus and looking for relevant partners from the local public and private sector (Downes et al. 2018).

Interestingly, the Sydney study made *no mention of franchises or chains* when analysing the decentralised system, nor did it contemplate *large office spaces* as system centres. The latter are, however, often also part of a retail complex and thus may have been implicitly included when speaking of shopping centres.

This chapter finds that systems can be divided into two major categories, decentralised and centralised, which depend on whether containers are collected and brought to a central cleaning point. Within the decentralised system, the first generation, individualised system specifies that customers individually buy and take care of their reusable containers whereas the second-generation decentralised system puts this responsibility on individual restaurants or chains. A *semi-centralised* system which is a centralised system in a confined smaller area, is expected to be most feasible and will be examined through case studies of North American universities in the next chapter. This system can benefit from professional sanitisation while takeaway demand density is high and container pathways are short. In a city like Vienna, however, where universities are an integral part of the city, a semi-centralised system only has limited applicability for universities. It may be more applicable to office complexes outside the city centre, like the VIC.

While the Sydney report finds the decentralised and centralised systems unfeasible, they should not be dismissed so easily. The *decentralised* system was not expected to pass *social criteria* of implementation ease, acceptance, and uptake because of each individual restaurant being responsible for their own microsystem. As own research has shown, restaurant chains have proven that a wider system can be managed decentrally as long as *all use the same container*. The next chapter will give examples where decentral systems have even been successful across cities.

With regards to *centralised* systems, the Sydney study considered them to be too difficult and expensive to implement as well as responsible for health concerns. Here, too, case studies will show that *sanitation is unproblematic* and implementation with the right partners financially viable and possible.

Whichever system is chosen, this chapter identified that its incentives, accountability, area, marketing, and social implications have to be carefully considered and defined.

The next section will elaborate on case studies giving examples of different types of systems, incentives, and accountability mechanisms. The chapter starts with examples in North America, which have been running for much longer than the European ones. Most European examples are very recent only having been founded in the last years. Many have not yet started proper business operations but are in their respective test phases.

5.2 Examples

5.2.1. Just salad (US - decentralised)

Recognised by the EPA Waste Wise award, Just Salad, which sells healthy affordable food[42], advertises to have the “world’s largest restaurant reusable programme”, selling customers dishwasher-safe reusable BPA-free PP blue containers for only *USD 1*. For every reuse, customers receive a *free topping*. The company claims to have saved *75,000 lbs* (34,019 kg) of plastic in 2018 and plans to increase this to 100,000 lbs in 2019. To further market its reusable containers, the company launched in 2019 a VIP black version, with which customers can *skip the queue* and receive up to *three* free toppings per use. To own a VIP bowl, customers have to enter a competition (Just Salad 2019b; 2019a).

5.2.2 EcoClamshells and the Ozzi machine at North American universities (semi-centralised)

As mentioned in the Sydney report, the EcoClamshells were used across the US on *university campus in semi-centralised systems.* The EcoClamshells originated and were first tested at Eckerd College which thus produced the 2009 report on their pilot. In

[42] 10 items under USD 10

addition to the already discussed LCA, the report gave information on how the system was *marketed* and *implemented*. It also included a *calculator*, so potential participants could calculate their savings and a *handbook* giving a 5-step implementation guide.

160 North American universities[43] participated with many creating their own customised campus programme. Hundreds more were testing it. 40 healthcare and corporate locations (e.g. Google, Disney Studios, and Nestle in California) took part, too. Participation was expected to quadruple to ca. 800 by 2010. A major partner is Aramark (large food service operator) who has accounts with over 500 universities throughout North America, of which 80 in 2009 were using EcoClamshells. Aramark also services many corporate and retirement home accounts, which were further potential customers (up to 1000 more). It was estimated that throughout all programmes EcoClamshells were saving up to *32 million* disposable containers from landfills annually[44]. To date this initiative has been the largest implemented semi-centralised system and hence offers best data availability.

The University of Florida, which has over 50,000 students and an account with Aramark estimates to have saved 1.2 million disposable containers or 24,000 lbs (10,886 kg) of EPS alone. Also, the Universities of Texas and Maryland participated in the programme and have deemed it successful having seen sustained growth throughout the first year. They have observed positive reception in the community with some especially keen students taking the initiative to promote the programme through informational facebook events and raffles where the prizes included participation in the reusable system. The universities did, however, note that *marketing* overall was somewhat lacking since customers showed limited knowledge and sometimes confusion. They attribute the programme's success to *word of mouth* advertisement and *social influence* by already participating users (Downes et al. 2018).

The University of Maryland reports savings of 52,000 containers whereas the University of Texas has had 1,411 members in two years using 30,000 reusable containers. Both universities used a token-based system to distribute containers and charged a membership

[43] Such as Johns Hopkins University, Massachusetts Institute of Technology (MIT), Duke University, University of Virginia (UVA), and University of Toronto)

[44] 179,640 reusable containers sold*180 disposable units saved/reusable container= 32,335,200 (180 disposable containers saved assumes their use 5 days a week for 9 months (one university year))

fee of USD 5, which was one dollar above acquisition costs. The University of Maryland, however, also charged USD 0.25 for disposable containers cross-financing the reusable programme. It also used a reverse vending machine by OZZI to collect the returned EcoClamshells. Both universities implemented the programme in dining halls, the University of Texas also allowing nearby cafes to participate. After initially hand washing dishes the cafes discovered it was much easier, quicker, and cleaner to send their dirty containers to the cafeteria to have them washed with a commercial conveyor belt dishwasher.

Both institutions state to be breaking even, but they found the token system difficult. While it is easy and quick to implement it is complicated to explain and students may easily loose them. Both would prefer using a digital system such as utilising the student's ID card to manage usage. This would also allow them to monitor lending times and frequency but is difficult to implement. The University of Texas is worried about cross contamination as students would receive their container when entering the dining hall rather than when being served. The University of Maryland could not use its Ozzi machine which only works with tokens. The university criticises that the machine only fits 75 containers and thus has to be emptied every 45 minutes during peak mealtimes.

In Canada, McGill University has also utilised the Ozzi system since 2014. While compostable single-use containers remain available at a cost of CAD 0.60, students can return their reusable plastic clamshells to Ozzi machines. In 2017, the system had processed 100,000 clamshells, three quarters through Ozzi machines and one quarter directly in restaurants, saving as many single-use containers from the trash. The Ozzi system was used for summer camps as well (McGill University 2019).

Overall, the universities agree that a campus with *regular high demand* and *commercial facilities* perfectly accommodates this reusable system, but a *larger space* may encounter logistical as well as practical *challenges* when getting everyone to agree on the same conditions. Both universities recognise convenience as key to success.

These case studies are examples of *efficient* systems benefitting from *commercial dishwashers* and *high takeaway density* in an *involved community* where takeaway is ordered regularly in groups or alone. Thus, it is *surprising* to see that the universities are *only breaking even*. This may however be the case because their intent was never to make profit in the first place.

An interesting factor, which should be further examined to determine its influence on the system, is the Ozzi machine. It has since developed and now can accommodate at least 125 containers and integrate a digital system, too (OZZI 2019). Financially, it is a substantial investment of at least *USD 14,000* to acquire a machine, two carts where the containers are collected, plastic liners for the carts, and suitable tokens. Currently, the Ozzi machines are marketing their own reusable containers with the system, too. They do, however, seem to be customised EcoClamshells with their own logo and colour for Ozzi. Ozzi claims it can save institutions 7-10% if they switch from disposables to the Ozzi system. (OZZI 2019).

5.2.3 GO Box and GreenToGo (US - centralised) turnkey solution

GO Box in Portland (OR) and San Francisco and *GreenToGo* in Durham (NC) have taken up the challenge of applying a centralised system to an *entire city*. GO Box, founded in 2011, was the first public reusable system and claims to still be the largest in the US. GreenToGo, likely inspired by GO Box, as well as the college programmes followed in 2013 as first public reusable system on the East Coast.

Their schemes both use EcoClamshells, which are recycled at end of life. Each scheme is based on an *app*[45] with membership through email addresses. The app allows users to locate restaurants where reusable containers are available, like in *bicycle sharing programmes*. Members can then check out a container through inputting the vendor's ID number into the app. Containers can be returned at collection points through scanning the point's QR code with the app. Each point is emptied regularly by GO Box/ GreenToGo staff on cargo bicycles who *wash* the containers *industrially*. As a non-profit GreenToGo works with another non-profit, TROSA, which helps addicts, and uses their commercial dishwashers for *free*. GreenToGo mainly has its collection points in the participating restaurants whereas GO Box also has them in many other places, such as office buildings, throughout the city. GO Box's collection points are made of bamboo and contain a *nylon*

[45] GO Box first operated with tokens but switched to a digital system after 5 years.

liner which is also replaced and *washed* when containers are picked up. If containers are lost, customers are charged USD 5 the first (GO Box) or second time (GreenToGo).

Both companies charge a similar membership fee to customers of *USD 21-25 per year*, which allows customer to check out a maximum of one container at any time. This means customers have to have returned their container before they can check out a new one. If, however they feel they need more than one container, they can choose a two-container membership at USD 30 per year which allows them to check out up to two containers as often as they would like[46].

GO Box also *charges vendors USD 0.25* for each container stocked, which is the amount they claim a disposable container would have cost the vendor anyway, thus making participation for the vendor cost neutral. GO Box does not seem to charge vendors for a collection point.

They do, however, charge *companies USD 95* per month (*USD 1140* per year) for setting up a collection point in their office. For this fee, companies also receive collection statistics and can use this information and programme participation for positive publicity. Soon, participation will even allow corporate buildings to collect LEED points, a global standard for sustainable building design.

GreenToGo charges vendors *USD 500* per year which includes a collection point, unlimited containers as needed, and for the first year free 1-container memberships for the vendor's employees. To ensure a smooth start with sufficient turnover, GreenToGo conducted a funding campaign in 2016 on kickstarter collecting over *USD 26,000* from 464 supporters. Perks included business and individual memberships to the scheme (Don't Waste Durham 2016).

[46] USD 35/year for 3 and USD40/year for 4 containers

Figure 2: Collection point GreenToGo

Figure 3: Collection point GO Box

GO Box also is offering a franchise package to companies interested in setting up a similar system elsewhere. The package includes ”materials, tools and blueprints that support licensees in building a reuse system in their own local community”, including their software. Recently, GO Box helped restaurant chain Dig create their own reusable decentralised system, which relies on the GO Box app and checkout system to track and manage containers. Containers only can be returned to Dig restaurants, where they are also washed and reoffered to customers who are part of the USD 3 per month programme.

While GO Box is for *profit*, GreenToGo is *not*. GreentoGo even stated it plans to share its experiences as an *open source* for others to utilise and its intention to find a partner for closed loop recycling of the containers.

As of October 2019, GO Box could boast 140 vendors and almost 4,000 subscribers, resulting in over *226,000* containers saved across both locations. GreenToGo has 27 participating vendors and over 550 subscribers (GO Box 2019; GreenToGo 2019). Both companies had to choose a centralised system, where containers are professionally sanitised and returned directly to restaurants because health authorities did not allow consumers to bring their own containers for risk of cross-contamination. Also, both agree their largest obstacle was ensuring potential customers were well informed about the scheme and understood its potential convenience.

European Schemes

More recently, based on American examples, companies are starting their own city-wide schemes in Europe. The American and European schemes, however, also reveal an important difference of approach. The *urge* to replace single-use takeaway food containers with more sustainable alternatives has appeared much later in Europe. The most likely reason is that eating habits have a *deeper social* connotation in Europe than in the US. The act of eating is more intimately *linked to a certain place*, the home as the centre of family life or the restaurant as a meeting place. Taking food away is thus not as developed as in the US, where eating is more seen as an unavoidable but short-kept moment of everyday life, at least during working week. If *centralised* schemes have appeared on the American continent, it is mainly on *university campuses,* which offer one of the strongest *senses of community* which Western society can offer, especially in the US. So far, they had not appeared in Europe because takeaway food had not yet penetrated food habits to the extent that it would be viable to create a *centralised* cleaning system of reusable takeaway containers at community level or within a neighbourhood.

Indeed, as the development of takeaway food can be a *reflection of interpersonal relations* in a society, the possibility to limit the use of single-use containers depends on the size of basic communities. In America, they can be structured at the size of a campus, i.e. up to several tens of thousands. In Europe, the pertinent scale for community life is that of the *neighbourhood*, which has *a lower penetration* rate of takeaway food. Centralisation seems to make sense on a relatively small geographical scale where takeaway food is strongly prevalent, like that of a campus in America or possibly a business district in Europe like the City of London, Canary Wharfs, la Defense in Paris, or the Vienna International Centre, among others.

Within Europe the longest operating reusable system, reCIRCLE, stands out with a thought through strategy covering a large area across countries. It has also developed an elaborate rationale to justify its choice of material, plastic.

5.2.4 ReCIRCLE (mainly Switzerland - decentralised)

ReCIRCLE presents itself as the first and biggest scheme of its kind *in the world*, offering reusable food containers (reBOXes) over a *large geographical scale*. Founded in Bern in *2016*, it is constituted of a network of *over 1000 partners* with *70,000 containers* in circulation. 456 partners are restaurants *throughout Switzerland* and in *Stuttgart*. In addition to further German cities close to the Swiss border, reCIRCLE has recently expanded into France (Montpellier), Belgium (Brussels), Ireland (University College

Cork), and the Czech Republic (mainly Prague). It helps restaurants and companies offer a more sustainable solution for ordering takeaway food within the reCIRCLE scheme or within their own separate scheme.

The reCIRCLE scheme is a *decentralised* system. Partner restaurants charge *customers a CHF 10*[47] *deposit fee* when ordering takeaway food in reBOX containers. Customers can return their dirty containers to any of the partner restaurants, where they are washed. In exchange, customers are offered the deposit fee or another clean container with their order. Instead of a cash deposit fee a branded prepaid card can be used, too.

Restaurants buy the containers from reCIRLCE at the deposit price and also pay a *participation and turnover fee* to reCIRCLE for the know-how, set-up, development, and marketing of the scheme, the re-distribution of containers between restaurants, and partially the replacement of worn out containers with new ones[48]. They can be sent back to the company for replacement thanks to a *partnership with the Swiss post*. ReCIRCLE also guarantees to buy back any surplus containers resulting from imbalanced distribution over time.

In order to join the reCIRCLE scheme, restaurants must participate in a *three-month trial period* which costs *CHF 150* and *includes 20* reusable containers as well as *marketing material*. At the end of the trial period, restaurants can decide to exit or join the scheme. Should they exit, they must *return* all containers and marketing material to reCIRCLE and *pay* the normal deposit fee *for any missing containers*. The *CHF 150* from the trial remain valid for a year and are equivalent to the yearly *participation fee*, which allows restaurants to be advertised as *supporters* who *refill* reBOXes but do not necessarily collect or hand out any. This lets small restaurants without washing facilities also partake in the scheme.

If restaurants wish to *offer reBOXes* to their customers, they are also charged a *turnover fee* by reCIRCLE based on their takeaway turnover and expected reBOX use. This is calculated to be below the cost of utilising disposable containers which averaged *CHF*

[47] In the other countries EUR 10 and CZK 10
[48] This is limited to a certain amount per year depending on the turnover fee per year

0.20 per disposable container in the scheme. Turnover fees start with a “basic” fee of *CHF 60* per year where vendors are charged delivery costs (CHF 18.50) and CHF 5 for the exchange of worn out products. With this basic fee, reCIRCLE claims restaurants realise savings from 5 reBOX uses per day for 260 business days in a year[49]. Higher reBOX use rates are charged a “flat rate” starting at *CHF 180* per year and can go up to *CHF 1500* per year. The CHF 180 flat rate includes free delivery, 10% off reBOX purchases and surplus returns; 10% off if billed yearly rather than quarterly, and free exchange of *25* worn out reBOXes. Any further exchanges cost CHF 5 per container. Savings are claimed to be realised from **7** reBOXes used per day[50]. The CHF 1500 flat rate includes all the same perks but allows for up to *300* containers to be exchanged for free. Even though restaurants are paying a yearly participation and quarterly adjustable turnover fee, they are expected to realise savings from decreasing the use of disposable containers. ReCIRCLE *recommends charging customers for disposable containers*. Most restaurants, however, continue to offer disposable containers in parallel to reBOXes and are reluctant to impose an extra charge fearing they could lose customers.

Participating restaurants in the reCIRCLE scheme *must* also *accept all products*. There are 5 different types of stackable reBOXes varying in size, form, and divisions, from 400ml to 1200ml. Various materials[51] such as glass, aluminium, steel, bio-based and degradable plastic, and wood, as well as all stakeholders[52] and their needs had been carefully considered. ReCIRLCE decided to use for all its products polybutylene terephthalate (*PBT*) with *30% glass fibres* to make them more resistant to hydrolysis and dry faster. The material contains no phthalates and is BPA-free. It can withstand temperatures up to *121°C* and so is microwaveable and dishwasher safe. It can also be placed in the freezer as it can be subjected to temperatures until *-20°C*. The material is produced in Switzerland from granulate “preferably” sourced from Europe. It is expected to have a lifetime of at least *100* uses and is completely recyclable. It however is not collected publicly and so *has to be returned to reCIRCLE for it to be recycled*. ReCIRCLE is currently still collecting enough material for its first recycling load of one tonne.

[49] 5*260*0.2=260 vs. 150+60=210
[50] 7*260*0.2=364 vs. 150+180=330
These calculations, however, do not include other costs such as labour or washing costs.

[51] See chapter 4.3 (Materials) for more detailed information for their exclusion
[52] These include restaurants, consumers, health, logistical, and environmental representatives, municipalities and governments

Unfortunately, due to legislative health restrictions closed looped recycling is not yet possible. All *lids* are made of *PP* which is also recyclable and BPA free.

Figure 4: reBOXes

Parallel to the reCIRCLE scheme, reCIRCLE lets companies *buy branded reBOXes* and *help* them *implement* their own *inhouse* scheme. For example, more than half of the Swiss restaurant partners (*230* in 2018) are part of the *Migros* supermarket chain, which uses its own, separate reusable container scheme, where containers[53] can only be returned at Migros stores. They also charge a lower deposit fee of CHF 5. Interestingly, reCIRCLE has found *no significant difference in demand* for both schemes, even though the reCIRCLE one charges double the deposit fee. This speaks for a certain inelasticity of demand.

In the *other countries* to which the scheme has started to expand, the same reCIRCLE idea is applied by local companies. Some, like the Irish and German versions contain non-profit aspects. VOICE Ireland, for example, a partner of the Irish programme, is an environmental charity. In Germany, the programme is administered by volunteers. Germany, the first programme to be started outside of Switzerland, can boast 56 restaurants of which 25 are in Stuttgart, saving a total of 4648 containers to date. All the other programmes started in 2019, some under different names such as LoopYourBox (Belgium and France), others (Czech Republic) are still in the test phase[54]. While the 3-month trial fees and the deposit fees are numerically equal to the Swiss scheme but in the respective country's currency, turnover rates seem to have been somewhat simplified by only offering flat rates. These are set at different price levels to the Swiss scheme and include different benefits, e.g. four free deliveries for all German reBOXes ordered in one year. About the Irish implementation little is known, only that it will be used at University College Cork.

[53] while the usual boxes are of an aubergine colour, the Migros boxes are bright green
[54] with 17 restaurants

From the beginning, reCIRCLE has seen substantial government support. In fact, the business idea itself was triggered by the city of Bern, who had started a programme to decrease public waste and littering resulting from disposable takeaway container waste. A part of the programme, the city imposed a tax on disposable containers. The tax intended to promote the use of reusable takeaway containers, however, was declared illegal by the judge. While the judge recognised that imposing an *extra charge* for dealing with the *cost of littering* was *admissible*, he ruled it was beyond the municipality's competence and rather *the canton's competence*.

Thus, currently no tax or charge on disposable containers exist. Nevertheless, reCIRCLE benefits from the *support of municipalities and cantons* in Switzerland, many of which even provide their employees with reCIRCLE containers or use them at their own events. Furthermore, their endorsement helps reCIRCLE gain new members. Also, several cantons, like the canton of Bern, are still investigating imposing *taxes on single-use containers* so as to establish a financially level playing-field between both types of containers and change consumer habits. Indeed, according to the study conducted by Zero Waste Europe in 2018, "Although the social perception of disposables is already changing, making reusables truly go *mainstream* requires a coordinated action of public authorities, restaurants and customers" (Zero Waste Europe 2018; ReCIRCLE 2019a; 2019b; ReCIRCLE Belgium 2019; LoopEat 2019; VOICE Ireland 2019; Otoč kelímek 2019).

5.2.5 Fehmarn island (Germany- semi-decentralised)

Following a consultation with reCIRCLE, NABU, the oldest German environmental protection association, has launched a scheme on the island of Fehmarn. Set in a geographically closed space and targeting a specific community (holidaymakers), this scheme in which *two dozen* restaurants partake resembles those of American campuses. It is however based on the direct return to participating restaurants. It would be interesting to examine in which scheme the rate of return of food containers is higher and whether a system of collection points should not be considered for the island of Fehmarn. It would be equally interesting to determine whether the closed space offered by an island ensures even higher rates of return than that of a campus (Naturschutzbund Deutschland e.V. n.d.).

In 2017, NABU published a first comprehensive study focussing on single-use waste. It found that in Germany in *2017* over *163,000t* of waste was created by *disposable food containers*, of which almost *53,000t* were *plastic*. Since 1994, single-use container waste has thus increased by *173%* (Naturschutzbund Deutschland e.V. 2018). The next case study, RECUP, has taken up the challenge to decrease German numbers.

5.2.6 RECUP and REBOWL (Germany – decentralised)

RECUP operates a well-known reusable coffee cup system in an extensive network of restaurants throughout Germany. RECUP started in November 2016 in Rosenheim with a pilot project and after an early merger with another German startup JustSwapIt entered the reusable cup market in May 2017 in Munich. It has since spread across all of Germany. In slightly more than two years, RECUP has been able to gather *more than 300 partners* (RECUP 2019).

In 2019, the company decided to expand into takeaway food containers through its subsidiary, REBOWL. REBOWL tested a similar approach to the reCIRCLE scheme in Munich and was accepting expressions of interest from other restaurants for after the pilot programme. *REBOWL* and *all participants* were contacted for *interviews* which were granted by all but one restaurant. Information from the interviews is included in the below text.

REBOWL launched its *pilot programme* on 15th May 2019, which lasted *3 months* and involved *5 participating restaurants* in two different central areas in Munich. One area, Schwabing has a large student population, as the main university, the Ludwig-Maximilans-Universität is located there. There are also various offices in the area, such as law practices and consultants. Here, all along Türkenstr. many small cafes offer quick lunches with a takeaway option, as do *Aloha Poke, OrangeBox*, and *Mutter Erde*, all participants of the pilot programme (REBOWL 2019).

Aloha Poke, who receives most food orders in a day, has a simple mix and match concept for creating one's own Hawaii inspired bowl where one starts with a base (different rice, zucchini noodles, or salad), adds a protein (different raw fish, turkey, or tofu), adds up to three sides (mango, cucumber, tomato, nuts, etc), adds some seasoning (algae, sesame, chili, etc), and a sauce (peanut-cilantro, peach-wasabi, etc.) all for EUR 9.40 (regular) or EUR 12.40 (large).

The company also advertises itself as sustainable, sourcing its fish from sustainably caught or farmed fisheries[55] and ensuring that all its products are fresh, high quality, and without additives or preservatives. All its partners are certified and audited offering fair working conditions. The company's *interest in environmental protection* is shown in its takeaway options (bio-based plastic from regenerative sources, bio-carton from a certified sustainable bamboo forestry, or bagasse pots which are a by-product of sugar production) and its promise to invest 5% of profits into environmental protection projects (Aloha Poke 2019). The company has been very successful with its concept since its inception in 2017 and now has *7 locations* throughout Germany. However, it is questionable whether offering ingredients like tuna, salmon, or mango are indeed sustainable choices.

Another company which has made *sustainability* part of its business model is *Orange Box*. It mainly offers *vegetarian, vegan and gluten free meals* (its speciality is roasted oyster mushrooms) from a menu of Asian and Oriental inspired food among others, but also sandwiches, salad, and cake. The urban street café has a reduced, puristic and modest interior where *everything* used in the restaurant, including the takeaway packaging, *can be recycled*. This is advertised by an inscription in their window saying: "to go - not at nature's cost; since our 2014 opening we've only used recyclable packaging, even without EU regulations". The café sources its fruits and vegetables daily fresh from the region and its chicken for the curry comes from a local family-run farm. The café serves its food at no more than EUR 9.60 per meal on wooden recyclable boards. The food can be combined with fresh juices, homemade iced tea, or coffee. No alcohol is served (Latz 2018).

[55] conserving the fish population and using low impact catching methods

Figure 5: Orange Box window inscription

The third restaurant in Schwabing, *Mutter Erde*, however, is the *most sustainable*, even *charging customers 0.5 EUR* when using *single-use takeaway packaging*. In addition to having a 30-year tradition as a sustainable restaurant, they are one of the oldest independent health food stores in Munich. Their independence allows them not only to cater to individual customer requests but also choose their distributors themselves. Like this, they can closely follow their credo and support small regional business as well as ensure payment of fair prices, which is of particular importance to them.

Following their philosophy to not waste food and support a sustainable cycle, the lunch meals are prepared from products which were not sold in the health food store because of flaws or disfigurements. Also, seasonal fruit and vegetables are used as much as possible to strengthen regional agriculture and guarantee short delivery paths. (Mutter Erde 2019; München Fair 2019).

Mutter Erde has the least food orders. This is likely because it is located in a courtyard and not visible from the street, hence somewhat off the beaten track and hard to find whereas both Aloha Poke and Orange Box have top locations.

The other two restaurants, *Siggis* and *Ida's Milchladen* are directly in the city centre, one at Isartor and the other at Sendlinger Tor, both densely populated areas with lots of offices and so also high takeaway demand.

Siggis is a vegan restaurant which offers customers fair-trade, high-quality products and information about a vegan lifestyle. While Siggis most explicitly calls for change to create a world where the environment is respected (Siggis 2019), it was not very forthcoming. Unfortunately, it was unavailable for a short interview the three times it was visited because the owner was too busy. The requested contact by email remains unanswered to date. Thus, its data has been estimated in line with own observations and information from REBOWL.

Ida's Milchladen is a favourite lunch place for locals where blue and white collar alike stop by for a quick home-cooked meal. Since 1979 it has been owned by the same family, first mother, now son. Ida's has an especially *high turnover* with *most* people taking *food to go*, also because there's little space to sit and eat. While his down-to-earth store does not advertise sustainability like the others do, the owner, who is a trained cook, showed strong interest in innovative ideas in favour of customer convenience and decreasing environmental impacts. He immediately commented on the pilot programme as well as enthusiastically gave some of his own ideas (Eppinger 2019; Gottschall 2008).

The pilot programme offered a *total* of *500 reusable containers* to customers for a *deposit fee of EUR 5*. The containers were sourced from a Dutch company called Mepal which also sells them directly to consumers at *EUR 10.99* (Mepal 2019). The REBOWL company, however, managed to purchase them at a wholesale price of just over EUR 5 and have them branded, too.

The *containers* are made of "unbreakable" PP, can carry up to *1250ml* and weigh *267 grams*. PP was chosen because of environmental studies which suggest that PP has the least environmental footprint and hence is most sustainable. Also, the company's reusable coffee cups are made of PP with which they had had a positive experience.

The container lid is made of TPE, has a smooth feel, and is *100% leak proof* as well as air and aroma tight. The lid is also *transparent* so the contents can always be seen allowing food to stay fresh longer. The containers are ideal for storing or transporting liquid or solid foods, such as large soup portions, meat dishes or salads. The container series named Cirqula was specifically developed for a complete "circle of use", from storing meals in the fridge or freezer, warming them up in the microwave (without the lid), and serving them directly at the table. Afterwards, containers can be put into the *dishwasher* and generally can withstand temperatures of up to *110° C*. Of course, the containers are also approved and safe for food use as well as BPA-free. Lastly, the containers can be *easily stored* as they can be *stacked* without lids or placed on top of each other with lids.

All five companies received *40- 80 bowls* to start the programme with. Interest and demand were high and *initial stocks* were *depleted within 4-8 weeks*. All companies reordered, one even the same amount it had started with. At the end of the programme almost *no containers* were *left* except for some at Siggis and Ida's Milchladen who had only just reordered more.

Overall REBOWL deemed the pilot programme successful because of *high customer demand*. Furthermore, already over 150 *restaurants* have expressed *interest* in participating in the planned system when it starts. While the high demand suggests that the environmental footprint would be reduced, it has to be lasting for a significant effect. As this thesis has found earlier, at least 40 reuses are necessary for similar containers. Thus, this is a sign in the right direction but not yet sufficient as containers are unlikely to have already been reused more than 40 times.

Also, REBOWL, plans to reconsider and improve the *material* before starting the scheme. Many bowls showed knife scratch marks. This should not happen so easily and quickly. Thus, REBOWL is considering other plastics or also glass or stainless steel. In their opinion, a durable material is more important than whether it is microwaveable. In their opinion, having the right material is essential for the system to work. Changing the material now, however, would mean that the bowls used in the pilot programme may go to waste and so have a negative effect on the environment. The choice of material is something that should have been better examined before the pilot programme.

Another factor, which remains questionable, is whether the *system* will *work as originally intended*. In the pilot programme, container *stocks* in restaurants depleted fast and did *not automatically refill* since most customers ended up *keeping* their containers rather than returning them regularly. While the programme was designed as an exchange system where containers can be returned dirty to all participating restaurants and immediately exchanged for a clean one, in reality customers who did bring in containers, almost always brought them in clean having washed them themselves at home or work. For *hygienic* reasons, restaurants would quickly have to reclean them before filling them with food. Hence, the originally planned system did not work, instead resulting in a *BYOC*-system with good quality containers that could be "bought" on the spot as well as higher washing costs to the environment. This should decrease the expected environmental benefits from the programme.

The fact that people reuse their "bought" bowl is not so problematic in itself as it still saves single-use packaging costs. However, as seen in the pilot programme, this likely requires a higher level of *supply* since a container is only reused when the person remembers and decides to bring it to a restaurant rather than almost immediately being available for any customer. This decreases the system's sustainability and may mean extra costs for REBOWL, which needs to supply more containers. To counteract this problem, most restaurants suggested a *higher deposit fee* of up to *EUR 15*. Like this, people are less likely to keep the containers but instead return them for their money. A too high deposit fee may however completely deter potential customers from participating. Here, a certain proportionality between the deposit fee and the amount spent on food was emphasised as an important factor. Most *meals cost no more* than *EUR 10* and this also seems to be the *invisible line* which most restaurants as well as REBOWL see as a realistic upper limit for the *deposit*.

A further point which remains open is whether restaurants will participate in such a system if they need to pay a *participation fee*. The pilot programme was for free, but REBOWL plans to charge for their container system. They plan to use this money for advertisement and management of the system. Two pilot restaurants said REBOWL was planning a fee of EUR 90 per month. REBOWL themselves, however, would not yet comment only saying it would be at least EUR 30 per month[56]. At a fee of EUR 90 per month, Orange Box is willing to participate. Ida's Milchladen however who had calculated their savings at only EUR 20 per month would hence only consider participating if they find the advertisement and social media effect to be substantial. Mutter Erde who charges customers for single-use packaging has no incentive to participate. Aloha Poke was inspired by the pilot programme to create their own branded system across their 7 locations and thus will also not participate.

Hence out of the 5 pilot restaurants, 4 of which have a strong sustainability orientation, only one plans to participate for sure begging the question whether restaurants which have a lower focus on sustainability may be interested at all. If, however, their costs for single-use packaging are high, they may be potential system participants. Lastly, as mentioned by Ida's Milchladen, the advertisement effect is of high importance to especially boutique restaurants, too.

[56] This is the amount currently charged by the RECUP system

Below is an overview of the restaurants and their responses to interview questions.

Table 6: Interviews on the REBOWL pilot programme

Restaurants	Aloha Poke	Orange Box	Mutter Erde	Siggis[57]	Ida's Milchladen
How many REBOWLs did you start with?	80	80	40	40	60
How many did you reorder?	40	80	10-15	15-20	40
When?	After 1 month	After 2 months	After 6 weeks (date offered by REBOWL)		After 1 month
When was your stock first depleted?	After 1- 2 months	After 2 weeks	After 1-2 months		After 1 month
Is it still?	Yes (0-1 left)	Yes (0 left)	Yes (1-2 left)		No (10 left)
How many food orders do you get per day?	300-350	200-250	40-100	100-150	150
How much of this is takeaway?	Depends on the weather; ca. 50% (if it rains less)	50- 60%	50%	60%	80% (120)
How much of the takeaway was picked up in a REBOWL?	<10% (10-15 regulars)	10-15% (< 20)	10-20% (4-5 regulars)	10-15% (6-9)	8.3- 16.6% (10-20)
How much of the takeaway was picked up in a customer's tupperware excluding REBOWL?	Hardly any	30-35%	80-90%		8.3- 16.6% (10-20)

[57] All data for Siggis was estimated by the author based on the interviews with the other restaurants and REBOWL as well as own observations

How much of the takeaway was picked up in single-use packaging?		55%	<5% (<2; very low as customers are charged for packaging)		66.6%-83.3% (80-100)
How much does your single-use packaging cost?	At least 0.2 EUR (topservice)	0.3 -0.5 EUR (greenbox)	0.5 EUR		0.2 EUR (Bunzl plastic)
Do you charge customers?	No	No	Yes, 0.5 EUR	No	No but they get 0.1 EUR off if they bring their own takeaway
Was the REBOWL size good?	Yes, even a little too large for the regular portion	No, the salads need a bigger container.	Yes		Yes
Should the REBOWL system be continued? Why?	Yes, but the deposit of 5EUR is too low; it should at least be the purchase price	Yes, but at a deposit fee of 5EUR people have kept the containers rather than returning them. If the fee is increased, however, it is questionable whether customers will still participate.	Yes it can be continued. However, the system still needs adjustments as people keep the boxes. The food price has to also be relative to the deposit fee.		Yes as it is a good idea. However, the deposit fee should be 15 EUR. Also people seem to buy and keep their bowls rather than exchanging them. So portions cannot already be prepared in advance in a REBOWL.
Will you participate?	No. Instead Aloha Poke will have its own branded reusable takeaway system with the same type of container	Yes	No. Participation fee too high for Mutter Erde as there are no worthwhile savings since most customers bring their own		Maybe. Depends on the price and advertisement /social media reach. Theoretically using the REBOWL system would currently only imply 20 EUR of savings (10 customer who

	from Mepal. Aloha Poke will start with 4000-5000 containers for 7 stores.		tupperware or eat in and customers are charged for using single-use packaging		come 10 days a month). The RECUP system does not work so well as not many customers use it and the shop is not allowed to sell soup in them. Also, the extra costs of energy and time needed to wash and fill the bowls have to be taken into account.
How much will it cost?		90 EUR/ month	300 EUR/ month		40-90 EUR/ month

In order to estimate how many disposable containers were saved through this pilot scheme, REBOWL usage for each restaurant was estimated. For this the interview data as well as the following assumptions were utilised.

The programme lasted from 15.05-15.08, which is 78 days including Saturdays and excluding holidays, of these 66 days were weekdays and 12 Saturdays. It is assumed less takeaway (ca. one third) is ordered on Saturdays (12 days) as all restaurants cater a lot of offices and students. Of the 66 days, 16 days are assumed to have lower takeaway numbers (ca. half) because of implementation and adjustment time, weather, or no stock towards to the end.

Given the estimates provided, minima and maxima are calculated. Their numbers are averaged at the end to give an estimate of total disposable containers saved throughout the programme.

Table 7: REBOWL container usage throughout the pilot programme

	Number of days	Saved take-away containers per day									
		Aloha Poke		**Orange Box**		**Mutter Erde**		**Siggis**		**Idas Milchladen**	
		min	max	min	max	min	max	min	max	min	max
Working days	50	10	15	15	20	4	5	6	9	10	20
Working days with lower customer frequency	16	5	8	8	10	2	3	3	4	5	10
Saturdays	12	3	5	5	7	closed		2	3	closed	
Total days	78										
Total saved containers (min, max)		616	938	938	1244	232	298	372	550	548	1160
Total saved containers (average)		777		1091		265		461		854	

This gives a grand total of *3,448 containers saved.* All restaurants used different types of disposable packaging from different suppliers. Most used some form of cardboard. A sample was taken from each restaurant and weighed. Please see the figure and table below for more information.

Aloha Poke	**Orange Box 1**	**Orange Box 2**	**Mutter Erde**	**Siggis**	**Idas Milchladen**
					

Figure 6: REBOWL pilot programme's different types of disposable containers

Table 8: Waste saved in the REBOWL pilot programme

	Aloha Poke	Orange Box 1	Orange Box 2	Mutter Erde	Siggis	Idas Milchladen
disposable container	bamboo cardboard with PET lid	cardboard	cardboard with PLA lid	moulded fibre	moulded fibre[58]	PP
usage		20%	80%			
weight (g)	36	42	34	40	43	10
container size (ml)	1300	1500	1200	n/a	850	500
disposable containers saved	777	218.2	872.8	265	461	854
		1091				
total waste saved (kg)	27.97	9.16	29.68	10.6	19.82	8.54

Thus, a total of *105.77 kg* of waste was saved (Na:Pac 2019; Topservice 2019a; 2019b; Bunzl 2019a; 2019b). Likely even more was saved as the packaging of the disposable containers was excluded from calculations because only one supplier gave weight details on their website[59]. This result however assumes that REBOWL was always an alternative to using a disposable option and never an alternative to eating in.

An interesting point to consider, however, is that most containers in this pilot were not made of plastic. This should however not be exemplary for Munich or German containers in general because of the small sample size and their strong focus on sustainability. The thesis' author has observed that most restaurants still utilise plastic, especially PP, for their disposable containers, in Germany and Austria alike.

All the European schemes so far - reCIRCLE and REBOWL – are decentralised and rely on the delivery of a container against a deposit of *EUR 5 (REBOWL)* or *EUR/CHF 10 (reCIRCLE).* When the customer returns the container, he can receive his deposit back or get another container full or empty. ReCIRCLE has even imagined a *plastic*

[58] non-wood fibres, such as bamboo and bagasse that are renewable and sustainable
[59] Orange Box's supplier gives a weight of 52.78g per cardboard box and 46.3g per cardboard bowl and lid (Greenbox 2019a; 2019b; 2019c)

voucher in form of a credit card for CHF 10 which customers can carry in their wallet so as to always have the value of CHF 10 when they need it for a new container and they have already given away all their 10-Franc notes. It is also a way to help customers to overcome their reluctance to give away CHF 10 each time they want to buy takeaway food. Given reCIRCLE's experience with similar demand for both containers with the CHF 5 Migros and CHF 10 normal deposit fee, however, the deposit fee, at 5 or 10, does not seem to be a barrier to customer participation. Thus, this thesis finds that increasing the deposit fee to EUR 10 should be beneficial for the REBOWL programme.

Now, in Europe the first centralised programme is being developed in Vienna.

5.2.7 Skoonu (Vienna- centralised)

The following case study is based on an interview with one of the founders of the company as little public information is available to date.

Skoonu which comes from the Afrikaans words "skoon"- clean and "nu" now, was founded in 2018 with the aim to reduce single-use takeaway packaging in Vienna by giving restaurants the possibility to offer customers a reusable takeaway container which after food consumption can be left at various collection points and is cleaned commercially before it is returned for reuse to restaurants. The company has calculated that in *Vienna* alone *1,700t* of takeaway waste is generated *annually*, producing 6,800t CO2-equivalent. To help understand the sheer volume of these numbers Skoonu compares them to familiar sizes: 1,700t could fill 22 Olympic pools and 6,800 t CO2-equivalent would allow you to drive around earth by train 3,300 times. Assuming Vienna has a population of 1.9 million, this gives an estimate of ca. *900grams* of takeaway waste per person annually.

Currently, the company is preparing its test phase which will start on *15th November 2019* and last until mid to late *January 2020*. In this test phase *3,000* containers equally divided into three different sizes (1l, 1.4l and 4.5l) will be distributed to *20* restaurants, which serve two business areas, one the VGN Digital GmbH headquarters in the 2nd district who produce a weekly tabloid magazine called News and the other at the Kronen Zeitung headquarters in the 19th district (Muthgasse), a Eurosceptic tabloid newspaper read by at least one third of all Austrians. *Both* companies have a total of *ca. 1,200 employees* who can partake in the pilot programme by ordering takeaway from participating restaurants. Skoonu is developing an *app* where each user has an account and a corresponding account number to monitor their container usage. When the user orders from a delivery company like mjam or lieferdienst they add their account number in the comments field and the restaurants will know to send their food in a reusable container. After consuming their meal, the user can return the container conveniently in their office at collection points, which in the future will be *Skoonu-designed reverse vending machines*. These machines collect the containers which are equipped with near-field-communication (*NFC*) wires. This technology allows Skoonu to monitor container use and collection as well as credit the user's account for returning the container. Skoonu will continue to simplify and automate processes after the test phase.

The most distinct feature of Skoonu is that it is a *centralised* system, which *will not require a deposit* but instead offers users advantages or small rewards like a free dessert for proper use of the system. This allows restaurants to also market themselves to especially loyal customers.

The containers which are made of stainless steel and have a transparent silicone lid are leak proof. In 2019, Skoonu won the "Umweltpreis der Stadt Wien"- the city of Vienna's environmental award which is awarded by the "MA22", the environmental protection department, as part of their "Ökobusiness", a service of the agency to support companies to implement environmentally friendly measures (Oekobusiness 2019; m22stb 2019; n.d.; Stadt Wien Presse-Service 2019). Skoonu also received funding from the „Verpackungskoordinierungsstelle (VKS)" – the packaging coordination office for waste prevention in 2019 (Skoonu 2019).

The following gives a summary of different case studies examined. Since limited data is available, some assumptions were made if other case studies were comparable.

Table 9: System case studies North America

Example	Tiffin	Just Salad	Eco-Clamshell	GO Box	GreenToGo
where	Canada / Belgium	US	US	US	US
scheme start	2015	2018	2008	2011	2013
system	individualised	decentralised	semi-centralised	centralised	centralised
for profit?	yes	probably not	only to save costs	yes	yes
container type	stainless steel	PP bowl	PP EcoClamshell	PP EcoClamshell	PP EcoClamshell
min reuse environment			40	40	40
min reuse material			1000	1000	1000
system size	city	franchise	campus	city	city
incentives	discount	free toppings	some charged for disposables		
accountability	customer carries responsibility		token	app	app
container acquisition costs	CAD 25 / EUR 20-25		USD 4	USD 4	USD 4
deposit fee	-	USD 1	USD 5	USD 5	USD 5
disposable container charge			some: USD 0.25 / CAD 0.60		
are customers charged a system fee?	no	no	no	yes, USD 21/year	yes, USD 25/year
are restaurants charged a system fee?	no	no	no	yes, USD 0.25 per reusable container	yes, USD 500/year
Are companies charged a fee?	no	no	no	USD 1140/ year	Yes
is container usage monitored?	no	probably	Some through OZZI machines	yes through app	yes through app
reusables used	5,000				
disposable containers saved			32 million	226,000	

waste saved		100,000 lbs in 2019			
# users			few million	4,000	550
# restaurants	13	30+	160 universities	140	27
# corporates			40		
# partners			200		

Table 10: EcoClamshell case studies

Example	Eckerd College	University of Texas	University of Maryland	University of Florida	McGill
where	US	US	US	US	Canada
incentives			disposables charge		disposables charge
accounta-bility	token	token	token	token	token
container acquisition costs	USD 4	USD 4	USD 4	USD 4	USD 4
deposit fee		USD 5	USD 5	USD 5	
disposable container charge			USD 0.25		CAD 0.60
is container usage monitored?	no	no	yes through OZZI machines	no	yes through OZZI machines
reusables used	1,200	30,000			
disposable containers saved			52,000	1.2 million	100,000
waste saved				24,000 lbs	
# users		1,411			

Table 11: System Case Studies Europe

Example	reCIRCLE	Fehmarn	REBOWL	SKOONU
where	Switzerland	Germany	Germany	Austria
scheme start	2016	2016	2019	2020
system	decentralised	semi-decentralised	decentralised	centralised

for profit?	yes (except Stuttgart & Ireland)	no	yes	yes
container type	PBT	PBT	PP	stainless steel
min reuse env	7	7	40[60]	
min reuse material	100	100		
system size	country	island	country	city
incentives			some offer discounts	rewards
accountability	deposit fee	deposit fee	deposit fee	rewards / app
container acquisition costs	unknown	unknown	just over EUR 5	
deposit fee	CHF/ EUR 10		EUR 5	no
disposables charge			Mutter Erde EUR 0.5	
are customers charged a system fee?	no	no	no	no
are restaurants charged a system fee?	yes, CHF 150+ at least CHF 60/ year		yes, probably EUR 90/ year	
is container usage monitored?	no	no	no	Yes: app & reverse vending machines
reusables used	4,648 in Stuttgart; 70,000 overall		500	3,000
disposable containers saved	7.8 million		ca. 3,500	>10,000 expected for pilot
waste saved			ca. 100 kg	
# users			>500 (pilot)	1,000 expected for pilot
# restaurants	456 CH and Stuttgart	20	100 expected	20 expected for pilot
# partners	1000			

[60] can assume this as the REBOWL has almost the same weight as the EcoClamshell, both are made of pure PP, and the REBOWL has smaller transport distances

While this extensive table helps gain some overview of the schemes, their sizes and success to date, it remains questionable if they all indeed are viable. What the table was unable to capture, are the difficulties programmes may encounter towards their success. These include, marketing and the explanation of the programme to new-comers, inaccuracies in tracking containers, and increasing convenience by reducing distances and the number of steps necessary for checking out or giving back a container.

Especially the recently founded ones have yet to gather sufficient data and prove their concepts work on such large scales. So far, however, all schemes seem to have environmental, economic, and social viability. With regards to the environment, it is important for new schemes to stick to the container they chose and encourage customers to return their containers dirty, so they are not washed twice but only in a commercial dishwasher. System growth has shown that starting and focussing on clusters, such as business districts, within a larger area has been a positive path to success. Socially, marketing through influencers where others see the system in use, is key. Generally, there is consumer demand for more sustainable choices. So, if convenience is ensured, costumers will use the system. Here, the app has shown to be very practical also because it allows monitoring and so effective adjustments. Interestingly, the logistics and redistribution of containers between restaurants has been unproblematic.

Economically, understand demand elasticity is key. Deposit fees, for example, seem to be accepted by consumers. Participation charges to consumers are more unusual. Usually, restaurants are charged a fee, which however has to be smaller than the amount they had been spending on disposable containers.

Studying these case studies, one underlying factor has become clear. Many schemes, like reCIRCLE, Fehmarn, or the university programmes, have received local governmental or non-profit support. Since authorities are responsible for managing container waste, they should be interested in also helping prevent its production. Even if a restaurant offering both single-use and reusables containers provides an incentive in favour of the reusable option (e.g. by *cross-subsidising* the two activities), it is still be exposed to cheaper competition from restaurants who do not offer the reusable option, which could be less profitable in the short run. This therefore calls for public authorities to re-establish a level playing-field of price competitiveness through the application of the *polluter-pays principle*.

5.3 Public authority involvement

Since public authorities are eventually responsible for processing the waste they can legitimately intervene at the beginning of the chain. Here, local authorities in the English-speaking countries have already led by example.

One decisive factor are city strategies towards zero waste. In Australia, the city of *Hobart* was one of the first to adopt a *relevant strategy towards takeaway waste*. In August 2017 it announced that it would ban disposable, fossil fuel-based plastic containers by 2020, along with obliging food vendors to use compostable items for which it would construct an industrial composting facility as part of its “Zero Waste to Landfill” strategy. An NGO, *Sustainable Living Tasmania*, then launched a "*Carrot Mob Project*", to push food outlets away from single-use containers towards compostable alternatives and encourage consumers to use reusable containers. As of September 2018, one third of Hobart's retailers had already moved to compostable items (Sustainable Living Tasmania 2017; Edmunds 2018).

In Canada, reusable container systems have been widely developed as reducing single-use containers has been declared a *priority* in many important Canadian cities. Besides municipalities, restaurants, institutions like universities, and even customers have launched initiatives of their own. The variety of behaviours and patterns shows that fighting against the proliferation of single-use container waste is considered a socially responsible attitude which a growing number of customers is willing to adopt and municipalities like *Calgary* and *Toronto* are keen to encourage (e.g. Toronto's Long Term Waste Management Strategy adopted in July 2016 aims at reducing the amount of waste sent to landfill and has prompted a public consultation which took place in autumn 2018 and spring 2019). In Vancouver, however, where the first of these schemes, the Tiffin project, emerged and later was forbidden for health reasons, bringing one's own containers to the restaurant remains forbidden unless the restaurant has a documented procedure approved by its local health authority. This issue is something with which reCIRCLE was also concerned. They prepared a document explaining the procedure that restaurants could adapt and hand in to authorities for approval.

A reusable container system will have to fit into the legal framework developed by public authorities, at European, national and local level. Adapting such legal frameworks to today's world could help shape these systems and also present an opportunity to inform the public about these schemes. Establishing a dialogue with local authorities seems certainly necessary before starting any scheme.

6. Conclusion

This thesis has found plastic to currently be a problematic material for the environment, especially if it is littered and used only shortly. It is best recycled when pure and well separated. Unfortunately, many plastic products contain a variety of materials as well as additives, which hinder recycling. The EU has hence called for better designs with pure materials and extended producer responsibility. Also, biodegradable options have been researched, which however encounter similar problems as plastic as they are also littered or sorted incorrectly and thus do not currently offer a better solution.

Nevertheless, a plastic reuse system was found to be the best option to decrease waste and environmental impacts from takeaway containers. Various LCAs have shown plastic, specifically PP, to be best when compared to disposable containers as well as other reusable options, such as glass. LCA data suggests a minimum lifetime of 40 uses to offset negative environmental impacts from raw material extraction and production. Unfortunately, however, still little academic data exists.

Furthermore, several systems and case studies were presented, many of which use PP for their reusable containers. This thesis found all concepts to be viable so far, especially if schemes use a professional cleaning system and are not restricted by local regulations. Ensuring customer convenience and savings for restaurants were key to growth. Interviews with participants of the recent REBOWL pilot programme in Munich gave overall positive feedback on social criteria, such as uptake and acceptance of the scheme. This scheme, however, still needs to substantially increase container circulation which was low since many customers bought and kept the containers instead of returning them as intended. This was also an issue for other programmes, such as reCIRCLE, causing restaurants to have to rewash already washed containers for regulatory sanitation reasons.

Also, while this thesis has discovered that health food restaurants who advertise their sustainability are the first to move towards reusable systems, this tendency is likely to have less impact than fast food restaurants' decision to change. This is because most health food restaurants are already using disposable containers made of renewable sources whereas most fast food restaurants still use disposable plastic. Societal trends of convenience and environmental consideration are however likely to push fast food restaurants towards reusable systems, too.

Having presented the benefits and disadvantages of using plastic for takeaway containers, examined various reuse systems, and studied relevant and recent cases, this thesis finds that a plastic takeaway container reuse system is indeed a viable and sustainable option for Vienna or any other large city with a high and concentrated student population as well as business districts to reduce plastic consumption and waste.

There is a clear trend towards logistically and technically more complex systems to increase the convenience for the consumer and help enforce good environmental behaviour. Even big companies like Starbucks, who has a long standing BYOC scheme, are looking into more sophisticated reusable systems[61].

It will be interesting to monitor Skoonu's progress and whether its unusual approach of not requesting a deposit fee will work in the long term.

[61] Starbucks recently tested a semi-centralised reusable system at Gatwick South airport terminal for one month. It had 5 drop off locations where containers were collected for sanitisation by airport waste management staff. It also charged 0.05 GBP for disposable containers (Starbucks 2019b)

Bibliography

Aloha Poke. 2019. “Aloha POKE.” Aloha POKE. 2019. https://www.aloha-poke.com.

American Chemistry Council. 2010. “Plastics Division: Life Cycle of a Plastic Product.” March 17, 2010. https://web.archive.org/web/20100317004747/http://www.americanchemistry.com/s_plastics/doc.asp?CID=1571&DID=5972.

———. n.d. “How Plastics Are Made.” Accessed May 14, 2019a. https://plastics.americanchemistry.com/How-Plastics-Are-Made/.

———. n.d. “Plastic Packaging Resin Identification Codes.” Accessed May 16, 2019b. https://plastics.americanchemistry.com/Plastic-Packaging-Resin-Identification-Codes/.

———. n.d. “Plastic Packaging Resins.” Accessed May 16, 2019c. https://plastics.americanchemistry.com/Plastic-Resin-Codes-PDF/.

———. n.d. “The Basics: Polymer Definition and Properties.” Accessed May 14, 2019d. https://plastics.americanchemistry.com/plastics/The-Basics/.

Andrady, Anthony L. 2015. *Plastics and Environmental Sustainability*. Hoboken, NJ: John Wiley & Sons, Inc. https://doi.org/10.1002/9781119009405.

Andrady, Anthony L., and Mike A. Neal. 2009. “Applications and Societal Benefits of Plastics.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1526): 1977–84. https://doi.org/10.1098/rstb.2008.0304.

BIO Intelligence Service. 2011. “Plastic Waste in the Environment.” European Commission. https://ec.europa.eu/environment/waste/studies/pdf/plastics.pdf.

Browne, Mark Anthony, Phillip Crump, Stewart J. Niven, Emma Teuten, Andrew Tonkin, Tamara Galloway, and Richard Thompson. 2011. “Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks.” *Environmental Science & Technology* 45 (21): 9175–79. https://doi.org/10.1021/es201811s.

Bunzl. 2019a. “V-Becher PP Rund 101 Mm Höhe 103 Mm 500 Ml Transparent - Verpackungsbecher & Haushaltsboxen.” 2019. https://webshop.bunzl.de/de/product/46226/V-Becher-PP-rund-101-mm-Hoehe-103-mm-500-ml-transparent/.

———. 2019b. “V-Becher-Deckel PP Rund 101 Mm Transparent - Verpackungsbecher & Haushaltsboxen.” 2019. https://webshop.bunzl.de/de/product/46227/V-Becher-Deckel-PP-rund-101-mm-transparent/.

Burnside, William. 2019. “Take-Away Container Impacts.” *Nature Sustainability* 2 (1): 11–11. https://doi.org/10.1038/s41893-018-0216-8.

Chinthapalli, Raj, Pia Skoczinski, Michael Carus, Wolfgang Baltus, Doris de Guzman, Harald Käb, Achim Raschka, and Jan Ravenstijn. 2019. “Bio-Based Building Blocks and Polymers- Global Capacities, Production and Trends 2018-2023. Short Version of the Full Report.” Hürth, Germany: nova-Institute.

Chung, Emily. 2018. “6 Ways to Make Takeout ‘zero Waste’ | CBC News.” CBC News. October 18, 2018. https://www.cbc.ca/news/technology/zero-waste-takeout-1.4867042.

Copeland, Audrey M., Alison A. Ormsby, and Andrea M. Willingham. 2013. “Assessment and Comparative Analysis of a Reusable Versus Disposable To-Go System.” *Sustainability: The Journal of Record* 6 (6): 353–58. https://doi.org/10.1089/SUS.2013.9832.

Don’t Waste Durham. 2016. “GreenToGo Reusable Takeout Container Service — Kickstarter.” 2016.

https://www.kickstarter.com/projects/1095433189/greentogo-durhams-reusable-takeout-container-progr/description.
Dorn, Michael, and Sabrina Stöckli. 2018. “Social Influence Fosters the Use of a Reusable Takeaway Box.” *Waste Management* 79 (September): 296–301. https://doi.org/10.1016/j.wasman.2018.07.027.
Downes, Jenni, Johannes Behrisch, Tim Brennan, Damien Giurco, and Candice Moy. 2018. “Feasibility of Reusable Food Containers for Takeaway Food in the Sydney CBD [Revised].” Australia: Institute for Sustainable Futures, University of Technology, Sydney. https://www.uts.edu.au/sites/default/files/2019-09/ISF_Food%20container%20final%20report%202018.pdf.
Eartheasy. 2019. “Plastics by the Numbers.” Eartheasy Guides & Articles. 2019. https://learn.eartheasy.com/articles/plastics-by-the-numbers/.
Ecoplast Kunststoff-Recycling GmbH. 2013. “Ratgeber & Recycling-Lexikon.” 2013. https://www.ecoplast.com/recycling/ratgeber/.
Edmunds, Sandra. 2018. “In Fast Food Consumption and a Takeaway Lifestyle, What Are We Doing about All Those Single-Use Plastic Containers?” *1 Million Women* (blog). 2018. http://www.1millionwomen.com.au/blog/what-are-we-doing-about-all-those-single-use-plastic-containers/.
Ellen MacArthur Foundation. 2012. “Circular Economy Report - Towards the Circular Economy Vol. 1.” https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition.
———. 2017. “The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action.” https://www.ellenmacarthurfoundation.org/assets/downloads/publications/NPEC-Hybrid_English_22-11-17_Digital.pdf.
Encyclopaedia Britannica. 2019. “Polybutylene Terephthalate | Chemical Compound.” In *Encyclopedia Britannica*. https://www.britannica.com/science/polybutylene-terephthalate.
Eppinger, Michael. 2019. “Ida’s Milchladen.” 2019. https://www.idasmilchladen.de/.
European Bioplastics e.V. 2019. “University of Plymouth Study Misleads on Value of Biodegradable and Compostable Plastics.” *European Bioplastics e.V.* (blog). April 30, 2019. https://www.european-bioplastics.org/university-of-plymouth-study-misleads-on-value-of-biodegradable-and-compostable-plastics/.
European Commission. 2013. “Green Paper on a European Strategy on Plastic Waste in the Environment.” https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52013DC0123.
———. 2015. “Closing the Loop - An EU Action Plan for the Circular Economy.” https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614.
———. 2018. “A European Strategy for Plastics in a Circular Economy.” https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN.
———. 2019a. “Press Release - Circular Economy: Commission Welcomes European Parliament Adoption of New Rules on Single–Use Plastics to Reduce Marine Litter.” March 2019. https://europa.eu/rapid/press-release_STATEMENT-19-1873_en.htm.
———. 2019b. “Press Release - Circular Economy: Commission Welcomes Council Final Adoption of New Rules on Single-Use Plastics to Reduce Marine Plastic Litter.” May 21, 2019. http://europa.eu/rapid/press-release_IP-19-2631_en.htm.

European Parliamentary Research Service. 2018. “Circular Economy Package: Four Legislative Proposals on Waste.” http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/625108/EPRS_BRI(2018)625108_EN.pdf.

European Union. 2019. *Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the Reduction of the Impact of Certain Plastic Products on the Environment*. *155*. Vol. OJ L. http://data.europa.eu/eli/dir/2019/904/oj/eng.

Eygen, Emile van. 2018. “Management of Plastic Wastes in Austria: Analysis of the Status Quo and Environmental Improvement Potentials.” Vienna University of Technology.

Fédération des Entreprises du Recyclage, and Agence de l’Environnement et de la Maîtrise de l’Energie. 2017. “Évaluation environnementale du recyclage en France selon la méthodologie de l’analyse de cycle de vie,” April, 177.

Fok, Lincoln, and P. K. Cheung. 2015. “Hong Kong at the Pearl River Estuary: A Hotspot of Microplastic Pollution.” *Marine Pollution Bulletin* 99 (1–2): 112–18. https://doi.org/10.1016/j.marpolbul.2015.07.050.

Gallego-Schmid, Alejandro, Adisa Azapagic, and Joan Manuel F. Mendoza. 2019. “Environmental Impacts of Takeaway Food Containers.” *Journal of Cleaner Production* 211 (February): 417–27. https://doi.org/10.1016/j.jclepro.2018.11.220.

Gallego-Schmid, Alejandro, Joan Manuel F. Mendoza, and Adisa Azapagic. 2018. “Improving the Environmental Sustainability of Reusable Food Containers in Europe.” *Science of The Total Environment* 628–629 (July): 979–89. https://doi.org/10.1016/j.scitotenv.2018.02.128.

Geissdoerfer, Martin, Paulo Savaget, Nancy M. P. Bocken, and Erik Jan Hultink. 2017. “The Circular Economy – A New Sustainability Paradigm?” *Journal of Cleaner Production* 143 (February): 757–68. https://doi.org/10.1016/j.jclepro.2016.12.048.

G.E.T. Enterprises. 2019. “GET.” 2019. https://get-melamine.com/content/about-get.

Geyer, Roland, Jenna R. Jambeck, and Kara Lavender Law. 2017. “Production, Use, and Fate of All Plastics Ever Made.” *Science Advances* 3 (7). https://doi.org/10.1126/sciadv.1700782.

Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. “A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems.” *Journal of Cleaner Production*, Towards Post Fossil Carbon Societies: Regenerative and Preventative Eco-Industrial Development, 114 (February): 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

GO Box. 2019. “Mission.” GO Box. 2019. https://www.goboxpdx.com/mission/.

Gottschall, Juri. 2008. “Besuch der alten Dame.” *Süddeutsche Zeitung Magazin*, October 2, 2008. https://sz-magazin.sueddeutsche.de/fotografie/besuch-der-alten-dame-75752.

Green Budget Europe. 2016. “Plastic Bag Levy in Ireland.” Institute for European Environmental Policy. https://ieep.eu/uploads/articles/attachments/0817a609-f2ed-4db0-8ae0-05f1d75fbaa4/IE%20Plastic%20Bag%20Levy%20final.pdf?v=63680923242.

Greenbox. 2019a. “Brown Cardboard Takeaway Boxes, 1500 Ml.” Greenbox Bionatic - Ecofriendly Bio Packaging. 2019. https://www.biologischverpacken.de/en/4278-brown-cardboard-takeaway-boxes-1500-ml.

———. 2019b. “Cardboard-Bowls 1000 Ml, Ø 185 Mm, Brown, Round.” Greenbox Bionatic - Ecofriendly Bio Packaging. 2019. https://www.biologischverpacken.de/en/3105-cardboard-bowls-1000-ml-oe-185-mm-brown-round.

———. 2019c. “PLA-Lids Ø 185 Mm, Clear.” Greenbox Bionatic - Ecofriendly Bio Packaging. 2019. https://www.biologischverpacken.de/en/3988-pla-lids-oe-185-mm-clear.

GreenToGo. 2019. “How It Works.” Durham GreenToGo. 2019. https://durhamgreentogo.com/using-greentogo/.

Harnoto, Monica F. 2013. “A Comparative Life Cycle Assessment of Compostable and Reusable Takeout Clamshells at the University of California, Berkeley.” https://nature.berkeley.edu/classes/es196/projects/2013final/HarnotoM_2013.pdf.

Henry George Liddell, and Robert Scott. 1940. “A Greek-English Lexicon.” In . Oxford: Clarendon Press. http://perseus.uchicago.edu/cgi-bin/philologic/getobject.pl?c.58:8:67.LSJ.

Hopewell, Jefferson, Robert Dvorak, and Edward Kosior. 2009. “Plastics Recycling: Challenges and Opportunities.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1526): 2115–26. https://doi.org/10.1098/rstb.2008.0311.

Just Salad. 2019a. “Press Kit.” 2019. https://media.justsalad.com/assets/Just_Salad_2019_Press_Kit.pdf.

———. 2019b. “Sustainability.” 2019. https://justsalad.com/sustainability.

KeepCup. 2019. “Reusable Coffee Cups.” 2019. https://eu.keepcup.com/?countryNameChange=eu&countryChangeType=auto.

Latz, Magdalena. 2018. “Orange Box in der Maxvorstadt: Minimalistischer Imbiss.” *Süddeutsche.de*, September 20, 2018. https://www.sueddeutsche.de/muenchen/restaurant-imbiss-orange-box-maxvorstadt-1.4138067.

Lippman, Daniel. 2014. “Can Plastic Be Made Environmentally Friendly?” *Scientific American*, January. https://www.scientificamerican.com/article/can-plastic-be-made-environmentally-friendly/.

LoopEat. 2019. “Restaurateurs.” *LoopEat* (blog). 2019. https://loopeat.fr.

Mato, Yukie, Tomohiko Isobe, Hideshige Takada, Haruyuki Kanehiro, Chiyoko Ohtake, and Tsuguchika Kaminuma. 2001. “Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment.” *Environmental Science & Technology* 35 (2): 318–24. https://doi.org/10.1021/es0010498.

McGill University. 2019. “The Ozzi System & Reusable Containers.” 2019. https://www.mcgill.ca/foodservices/sustainability/ozzi-system-reusable-containers.

McKinsey. 2016. “The Changing Market for Food Delivery.” https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-changing-market-for-food-delivery.

Mepal. 2019. “Multischüssel Cirqula 1250 ml - Nordic Green.” 2019. https://www.mepal.com/de/multischussel-cirqula-1250-ml-nordic-green-106212092400.

Moneo, Juan Aitor Lago, Mariola Rodríguez Sirgado, and Ángel Lamas. 2011. “El Consumo de Comida Rápida: Situación en el mundo y acercamiento autonómico.” EAE Business School: Strategic Research Centre. http://www.abc.es/gestordocumental/uploads/Sociedad/comida-rapida.pdf.

Moyes, Hunter J. 2014. “The Tiffin Project Reusable To-Go Containers.” We Hate To Waste. February 19, 2014. http://www.wehatetowaste.com/tiffin-reusable-to-go-containers/.

München Fair. 2019. “Shops.” muenchen-fair.de. 2019. http://www.muenchen-fair.de/shops/.

Mutter Erde. 2019. “Über uns.” Mutter Erde, Bioladen und Bioimbiss. 2019. http://www.muttererde-bio.de/über-uns/.

Naik, A., C. J. Lewis, and K. P. Allison. 2019. “Temperature Dissociation of Liquids in Reusable Thermoplastic Containers—An Eco-Friendly Scald Risk?” *Burns* 45 (7): 1621–24. https://doi.org/10.1016/j.burns.2019.07.013.

Na:Pac. 2019. “P r o d u c t _ R a n g e.” 2019. http://napac-paperware.com/product/p_range/index.htm.

Napper, I. E., and R. C. Thompson. 2019. “Environmental Deterioration of Biodegradable, Oxo-Biodegradable, Compostable, and Conventional Plastic Carrier Bags in the Sea, Soil, and Open-Air Over a 3-Year Period.” *Environmental Science & Technology* 53 (9): 4775–83. https://doi.org/10.1021/acs.est.8b06984.

Naturschutzbund Deutschland e.V. 2018. “NABU-Studie: 350.000 Tonnen Abfall durch Einwegprodukte.” https://www.nabu.de/news/2018/10/25298.html.

———. n.d. “Mehrweg fürs Meer.” NABU - Naturschutzbund Deutschland e.V. Accessed October 15, 2019. https://www.nabu.de/natur-und-landschaft/aktionen-und-projekte/meere-ohne-plastik/21122.html.

Newlight Technologies. 2019a. “AirCarbon.” 2019. https://www.newlight.com/aircarbon/.

———. 2019b. “Technology.” 2019. https://www.newlight.com/technology/.

Ormsby, Alison, and Audrey Copeland. 2009. “Beyond Disposables: Eco-Clamshell Reusable To-Go Program.” Alexandria, VA: Environmental Research and Education Foundation. https://erefdn.org/beyond-disposables-eco-clamshell-reusable-to-go-program/.

Otoč kelímek. 2019. “Misky na jídlo.” *Otoč kelímek* (blog). 2019. https://otockelimek.cz/vratne-misky/.

OZZI. 2019. “Changing the World from Disposable to Reusable.” 2019. https://www.planetozzi.com/.

Parker, Laura. 2018. “In a First, Microplastics Found in Human Poop.” *National Geographic*, October 22, 2018. https://www.nationalgeographic.com/environment/2018/10/news-plastics-microplastics-human-feces/.

Plastics Europe. 2018. “Plastics - the Facts 2018: An Analysis of European Plastics Production, Demand and Waste Data.” https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf.

REBOWL. 2019. “Pilot München.” REBOWL. 2019. https://rebowl.de/rebowl-muenchen.

ReCIRCLE. 2019a. “So geht’s.” reCIRCLE. 2019. http://www.recircle.ch/what.

———. 2019b. “Mehrwegsystem Konzept.” https://www.recircle.ch/upload/pdf/RC_Mehrwegsystem-Konzept_20190905.pdf.

ReCIRCLE Belgium. 2019. “Accueil.” ReCIRCLE Belgium. 2019. https://www.recirclebelgium.be.

RECUP. 2019. “SO GEHT’s.” RECUP. 2019. https://recup.de/sogehts.

Rewri, Radhika. 2016. “Aircarbon: Sustainable Plastic Made up of Methane.” Packaging Connections. 2016. https://www.packagingconnections.com/news/aircarbon-sustainable-plastic-made-methane.htm.
Siggis. 2019. “Vision.” SIGGIS - vegan and fresh food. 2019. https://siggis.jetzt/vision/.
Skoonu. 2019. “Home.” 2019. https://skoonu.com/.
Stainsby, Mia. 2012. “The Tiffin Project Launched in Vancouver.” *Vancouver Sun*, August 31, 2012. https://vancouversun.com/news/staff-blogs/vancouvers-ultra-cool-tiffin-project.
Starbucks. 2018. “Starbucks UK Tests First-Ever Paper Cup Charge.” 2018. https://stories.starbucks.com/emea/stories/2018/london-stores-cup/.
———. 2019a. “Greener Cups and Packaging.” Starbucks Coffee Company. 2019. https://www.starbucks.com/responsibility/environment/recycling.
———. 2019b. “Starbucks Launches First Ever Airport Reusable Cup Trial at Gatwick Airport in London.” 2019. https://stories.starbucks.com/emea/stories/2019/starbucks-launch-reusable-cup-trial-at-gatwick-airport/.
Sustainable Living Tasmania. 2017. “Carrotmob.” Sustainable Living Tasmania. 2017. https://d3n8a8pro7vhmx.cloudfront.net/slt/pages/3926/attachments/original/1485744141/Carrotmob_Hobart_final_report.pdf?1485744141.
Sustainable Packaging Coalition. 2019. “How2Recycle - How2Recycle.” 2019. https://www.how2recycle.info/.
The Columbia Electronic Encyclopedia. 2012. “Plastic: Composition and Types of Plastic.” In , 6th ed. Columbia University Press. https://www.infoplease.com/encyclopedia/science/chemistry/organic/plastic/composition-and-types-of-plastic.
Tiffin. 2019. “Tiffin, une lunchbox réutilisable pour vos plats à emporter !” Tiffin. 2019. https://tiffin.be.
Tim Hortons. 2019. “Tims® at Home Merchandise & Gifts.” 2019. https://www.timhortons.com/ca/en/tims-at-home/gifts-and-merchandise.php.
Topservice. 2019a. “Bambus Verpackungen : Deckel PET Zu Salatschale 1300 Ml.” 2019. https://topservicegmbh.de/1-p-0-0-10024-7-101354/Deckel+PET+zu+Salatschale+1300+ml_product.html.
———. 2019b. “Bambus Verpackungen : Salatschale Bambus, 1300 Ml, D: 18,4 Cm H: 6,0 Cm.” 2019. https://topservicegmbh.de/1-p-0-0-10024-7-101353/Salatschale+Bambus%2C+1300+ml%2C+D%3A+18%2C4+cm+H%3A+6%2C0+cm_product.html.
Transparency Market Research. 2015. “Plastic Packaging Market Scenario, SWOT Analysis, Business Overview & Forecast 2020.” https://www.transparencymarketresearch.com/plastic-packaging.html.
United Nations Environment Programme. 2018. *Single-Use Plastics, a Roadmap for Sustainability.*
US Energy Information Association. 2019. “International Energy Statistics.” November 9, 2019. https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000000000000000002&c=ruvvvvvfvtvnvv1vrvvvvfvvvvvvfvvvou20evvvvvvvvvvvvuvo&ct=0&tl_id=5-A&vs=INTL.57-1-AFG-TBPD.A&vo=0&v=H&end=2018.
VOICE Ireland. 2019. “Recircle Ireland.” 2019. http://voiceireland.org/project-work/recircle-ireland.php.

World Wide Fund for Nature. n.d. “Solving Plastic Pollution Through Accountability.” Accessed August 23, 2019. https://www.worldwildlife.org/publications/solving-plastic-pollution-through-accountability.
Zero Waste Europe. 2018. “Food to Go? Bye Bye to Single-Use Containers! - New Case Study.” https://zerowasteeurope.eu/2018/06/food-to-go-bye-bye-to-single-use-containers-new-case-study/.
Zero Waste Scotland. 2015. “Carrier Bag Charge ‘One Year On.’” https://www.zerowastescotland.org.uk/sites/default/files/SUCB%20Charge%20One%20Year%20On%20Report.pdf.

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