UNIVERSITÀ POLITECNICA DELLE MARCHE
FACOLTÀ DI ECONOMIA "GIORGIO FUÀ"

Corso di Laurea Magistrale in International Economics and Commerce
Curriculum International Economics and Business

THE ECONOMICS OF MICROPLASTICS IN THE SEAS

CAUSES, EFFECTS AND PRACTICAL SOLUTIONS

Relatore: Chiar.mo
Prof. Roberto Esposti

Tesi di Laurea di:
Karolina Aleksandra Korzeniewska

Anno Accademico 2018 – 2019

ABSTRACT

Questa tesi studia a livello globale le principali fonti, il destino e gli effetti delle microplastiche negli oceani e applica un approccio settoriale allo studio della potenziale perdita di valore economico per l'industria e il turismo. Questo approccio include anche un'analisi dei costi economici del degrado dell'ecosistema dovuto ai rifiuti marini, cercando di chiarire quanto sia dannosa la plastica nei mari e in che modo influisce sull'economia globale.

Nel 2018 degli 8,3 miliardi di tonnellate di plastica prodotta, 6,3 miliardi sono diventati rifiuti, e solo il 9 % è stato riciclato. La stragrande maggioranza - il 79 % - si sta accumulando nelle discariche o si sta sgretolando nell'ambiente naturale, il che significa che ad un certo punto gran parte finirà negli oceani. Se le attuali tendenze di produzione e gestione dei rifiuti continueranno, gli oceani conterranno entro il 2050 circa 937 milioni di tonnellate di plastica e 895 milioni di tonnellate di pesce. La plastica negli oceani supererà i pesci.

L'inquinamento da plastica di fiumi e oceani può costare all'economia mondiale fino a 19 miliardi di dollari all'anno. Tra 15 e 51 trilioni di microplastiche negli oceani stanno attualmente andando alla deriva, e si stima pesino tra 93 e 236 mila tonnellate. Le microplastiche sono state rilevate nella birra, nel miele, nell'acqua in bottiglia, nonché in tutti gli animali marini. Gli umani mangiano ogni anno (insieme ad acqua e cibo) l'equivalente in microplastiche del peso di una carta di credito, circa 250 grammi. Esse possono interferire con l'equilibrio ormonale del corpo e interrompere lo sviluppo, oltre a causare obesità e cancro.

L'inquinamento da plastica negli oceani del mondo costa alla società fino a 2,5 trilioni di dollari all'anno. Dopo un breve ciclo di primo utilizzo, il 95% del valore del materiale di imballaggio in plastica, ovvero 80-120 miliardi di dollari all'anno, viene perso. L'economia circolare può essere una soluzione per il mercato delle materie plastiche e ridurre le emissioni di anidride carbonica associate alla loro produzione del 56% entro il 2050.

TABLE OF CONTENTS

INTRODUCTION

The oceans have been treated for years as infinite, and therefore the right place to throw all kinds of garbage. Earlier in the history of mankind, the water ecosystem managed to break down a large part of organic waste, so up to a point their impact on the environment was of little importance. Unfortunately, this is not the case today. Every year, a lot of garbage lands in the seas and oceans. Some lie on the bottom and some float on the surface of the water or are thrown to the brim. Throwing garbage into the oceans not only causes the suffering of marine animals, but also brings serious socio-economic consequences.

The idea of this thesis comes from the fact that plastic contamination has been widely spoken in recent times, but there is little information about its particles called microplastics and its impact on various aspects of human life. The purpose of this work is to attempt to identify globally the main sources, fate and effects of microplastics in the oceans and to apply a sectoral approach to studying the potential loss of economic value for industry and tourism. This approach also includes a possible analysis of the economic costs of degradation of ecosystem goods and services due to marine litter, trying to answer: how harmful is the plastics that we eat and how does it affect the global economy.

The first chapter discusses the production of plastics, starting with its history, time pattern and forecasting for 2050 on the basis of Statista, OECD and UNEP database, analyzing as follows, the amount of plastic waste in the oceans, types and its sources, because the key to solving the problem of plastics in the seas is to understand exactly what it consists of and where it comes from, focusing as follows on microplastics and the size of their contamination.

The second chapter outlines the problem of the impact of microplastics on global ecological, social and economic aspects, focusing on health consequences for wildlife and human life. The consequences for people suffering social and economic losses caused by water pollution with microplastics are also presented. Monetary losses for various industries, fisheries and tourism are thoroughly analyzed based on various sources.

The third chapter focuses on green economics and practical solutions related to plastic pollution, based on selected legal solutions, proposed by the European Union and other international organizations as a basis for changing the activities of industries and consumers. Then, the idea of the Circular Economy is presented and proposals for consumers and manufacturer's activities to reduce plastic production. The chapter also focuses on the idea of cleaning the oceans and the power of recycling as a tool for cleansing the Earth. In addition, this chapter suggests possible ways to solve the problem of high CO_2 emissions and plastic reduction in one, as they are closely related. By implementing the Circular Economy model, it is possible to solve many problems at various levels.

CHAPTER 1

PLASTICS: A WORLD-WIDE PROBLEM

Plastics is essential material commonly found in the economy and in everyday life. Due to many functions, these substances contribute to solving various problems of modern society. Such lightweight and innovative materials for planes and cars reduce fuel consumption and CO2 emissions. They also allow you to pay less energy bills as a result of efficient insulation materials, on the other hand, in the packaging sector plastics ensure food safety and reduce waste and in combination with 3D printing, biocompatible plastics can save lives by increasing innovation in medicine. Nowadays it is so ordinary to be surrounded by plastics (as when driving a car, playing football and even while eating) and without a question, it is difficult to imagine living in a different way. In conclusion, plastics is undoubtfully an amazing thing and it is literally used everywhere.

The amount of mentioned plastics does not end there, since the volume of plastic production is such a big problem, that it is possible that our current era will generate an anthropogenic horizon of plastic markers in the Earth's sedimentary record. It leads to some conclusion that plastics is currently some kind of epidemic. However, while consuming all those products, are we asking ourselves where is all this plastic waste going? The truth is that some of it is send abroad for recycling, some of it goes to landfills, and more than we can imagine - ends up on the loose as plastic pollution, eventually reaching our waterways.

70 % of the Earth's surface is occupied by seas and oceans. Every year, over 10 million tons of plastic waste goes there. These pollutants threaten not only the flora and fauna of the sea, but also the health of people living inland. Only 10 % of total marine pollution are elements of fishing gears thrown into the water (over 600,000 tones per year) or other parts of vessels' equipment. 80% substances that pollute the seas and oceans arise on land, and they do not always come from industrial activities or everyday human activities in coastal areas.

The world has found itself in such point, that it is not able to control anymore the extent to which plastic pollution affects everyday life, thoroughly destroying the natural environment and living organisms. It is obvious that the international problem of environmental pollution by plastics is increasing and difficult to stop. Recently, people finally started to understand the true problem of massive production of these products and the difficulty of recycling it, specially that is also an economic problem for the entire world and as well as generational problem of degrading environment, through the very important fact, that plastics never absolutely disappear from our environment.

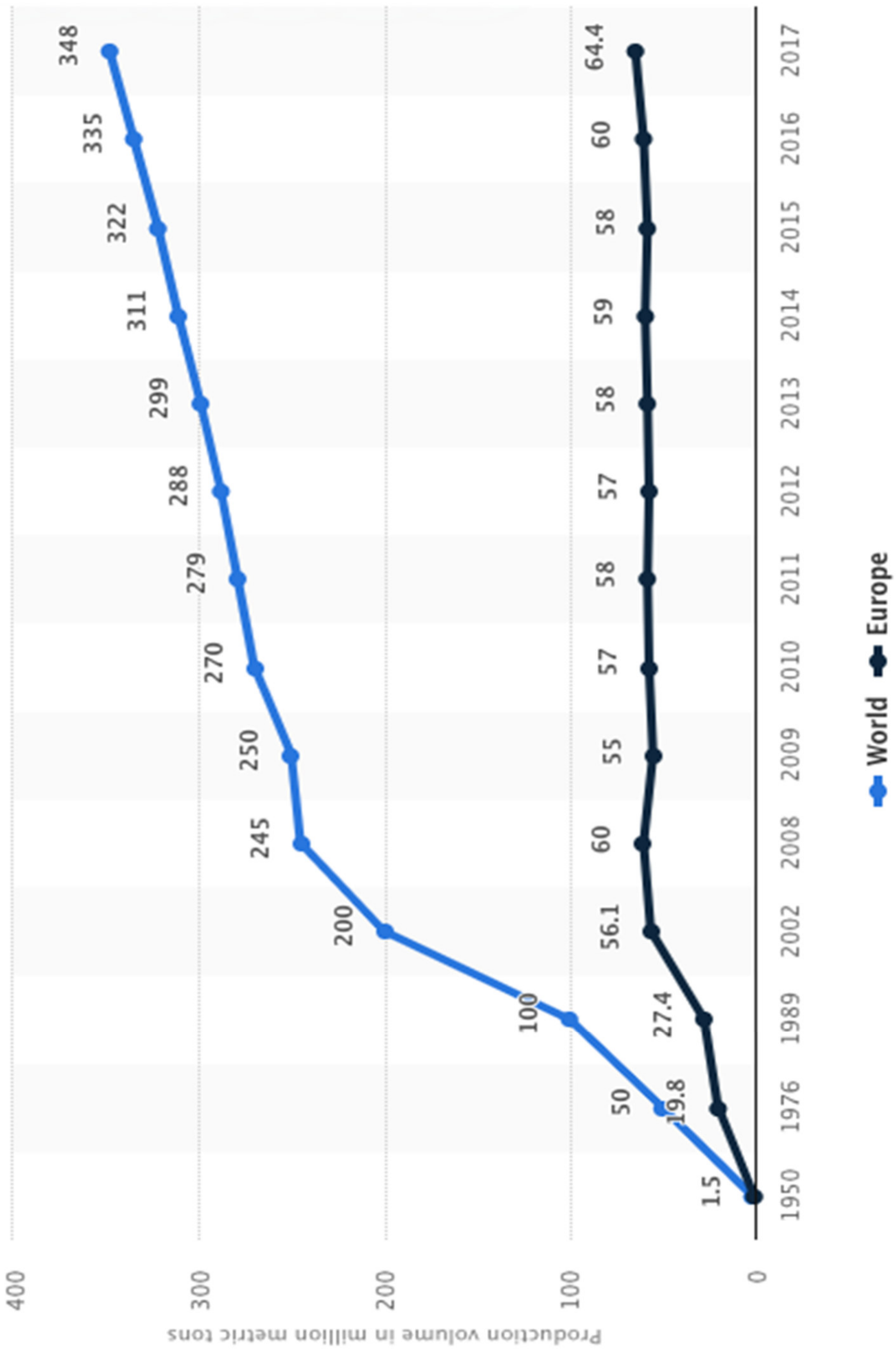
1.1. PLASTICS PRODUCTION AND ITS TIME PATTERN

More than 100 years ago, in 1907, Belgian industrialist and inventor living in the USA, a graduate of the University of Ghent - Leo Baekeland, has invented Bakelite. Before, at high cost and effort, humanity used natural materials for production, for example shellac obtained from insect secretions. Baekeland saw his chance to replace it with a completely synthetic substance that could be produced on a massive scale. Bakelite was light, inexpensive, flexible and safe, but probably its biggest advantage was durability. The discovery was accidental, but the industry reacted euphorically, widely opening to a new era of plastic. Baekeland retired in 1939 and spent the last years of his life on a yacht as an avid sailor [Gregersen, E. (2006)].

Globally produced plastics were brought into the market around the middle of the last century as an excellent material. Since then, plastic expansion has grown incredibly fast, with a purpose to create many opportunities and perspectives to society. This miraculous product turned out to be a real scourge for sea creatures: a one-time commercial. Since then, over a decade, annual plastic production has reached 5 million tons. In recent decades, the production of plastics in the world has accelerated rapidly, exceeding the production scale of other types of man-made materials. However, there was a lack of accurate information about what happens next with mass-produced plastics: what part of them is recycled and which goes to landfills [Association of Plastics Manufacturers in Europe - PlasticsEurope, (2018)].

One of the basic sources which provides the data of the enormous scale of massive production of plastics is Statista. The statistics below shows the global production of plastics in 1950-2017. It says that 348 million metric tons were produced worldwide in 2017, and 64 million metric tons were produced in Europe alone. Over one million plastic bottles are sold every minute, or 20,000 every second. This number can be frightening. Only in 2017, the plastic production has already reached 348 million tons (Figure 1.1.), and 40% of this size was disposable packaging [Garside, M. (2019)]

Figure 1.1. Global plastic production from 1950 to 2017



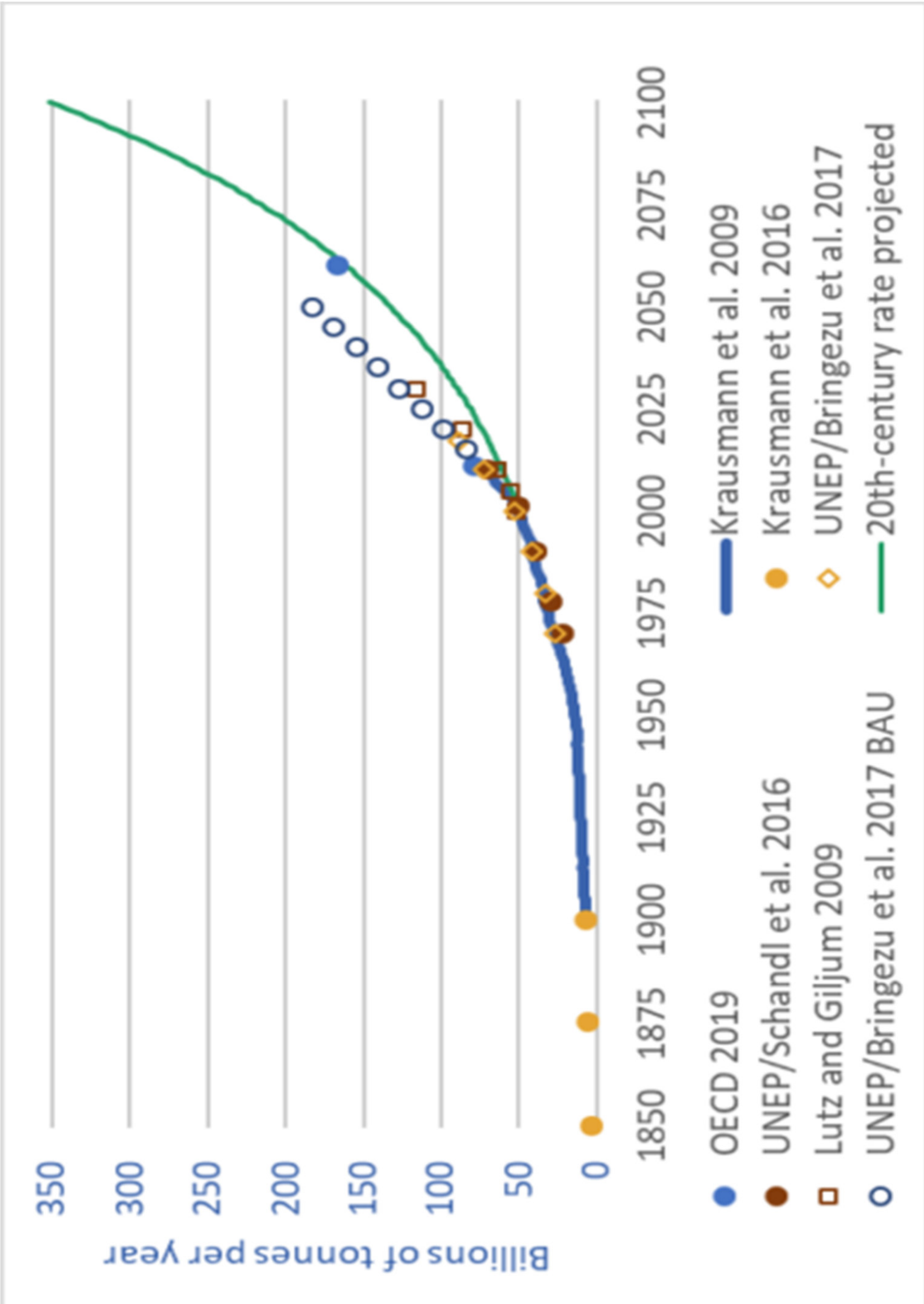
Source: www.statista.com

Exponential growth does not surprise, as it is a hallmark of petro-industrial consumer civilization. Over the past 50 years, the amount of plastics produced has increased 20 times, and it is still growing, although in Europe it has remained fairly stable for 10 years. But first, it should be acknowledged that the production capacities that human race developed are fascinating. Worldwide factories now produce approximately 400 million tons of plastics per year and that is more than a billion kilograms per day [*www.darrinqualman.com/global-plastics-production*] Around the world thousands of machines that can produce plastic soft-drink and water bottles are built at a rate of nearly 20,000 per second. Plastics are used in a wide variety of products and have displaced other materials, such as wood, metal, and glass. It can be formed into polyesters for use in fabrics and textiles, polyvinylidene chloride for food packaging, and polycarbonates for eyeglasses and compact discs, among thousands of other uses [Geyer, R. et al. (2017)].

Production of plastics requires four basic steps: the acquirement of raw material, synthesizing a basic polymer, compounding the polymer into a usable fraction, and lastly, molding or shaping the plastics. This process is quite energy intensive, requiring 62 to 108 mega joules of energy per kilogram based on U.S. efficiency averages. Producing silicon can require up to 235 mega joules per kilogram of material. In 2017, the global production of plastics reached 348 million metric tons, with 64 million metric tons produced in Europe alone [Clements, A. et al. (2010)].

Currently the annual production of plastics is over 300 million tons (more than 8.3 billion metric tons of plastics has been produced so far, as stated Dianna Cohen - CEO of the Plastic Pollution Coalition on the ABC News), when around 50% of them are disposable, used just for a few moments and remaining on earth for at least a few hundred years. On the other hand, the newest report of the Ellen MacArthur Foundation says, that new plastics will consume 20% of all oil production over 35 years, compared with today's estimated 5%. The report states that plastics production has increased 20-fold since 1964, reaching 311 million tones in 2014. It is expected to double again in the next 20 years and almost four times by 2050. Despite growing demand, only 5% of plastics are recycled efficiently, and 40% goes to landfills, and a third in sensitive ecosystems such as the world's oceans. Decades of plastics production have already caused environmental problems [*www.ellenmacarthurfoundation.org*]. Anyway, it is hard to not consider plastics as a product of human ingenuity and innovation, and one of the best civilization's incredible solutions. Those products are light, economical, durable, decay resistant, airtight and can be formed into a wide range of products. But the expected production levels for 2050 are far too good as a growth-dependent economic system has the ability to turn any solution into a problem, any strength into weakness. Figure 1.2. shows the projected four-fold increase in production tonnage by 2050.

Figure 1.2. Projected global plastics production 1850-2050



Source: www.darrinqualman.com

The chart above shows 250 years of actual and forecast material flows through our global economy. The chart combines seven different sources and data sets, and includes a forecast for 2050. The overall shape and outline of the ever-growing uptrend line - exponential growth - is important. “Between 1900 and 2000, global material tonnage increased sevenfold—to approximately 49 billion tons. Tonnage rose to approximately 70 billion tons by 2010, and to approximately 90 billion tons by 2018. At the heart of our petro-industrial consumerist civilization is a network of globe-spanning conveyors that, each second, extract and propel nearly 3,000 tons of materials from Earth’s surface and subsurface to factories, cities, shops, and homes, and eventually on to landfills, rivers and oceans, and the atmosphere. At a rate of a quarter-billion tons per day we’re turning the Earth and biosphere into cities, homes, products, indulgences, and fleeting satisfactions; and emissions, by-products, toxins, and garbage. And these extraction, consumption, and disposal rates are projected to continue rising—to double every 30 to 40 years. Just as we increased material use sevenfold during the 20th century we’re on track to multiply it sevenfold during the 21st. If we maintain the “normal” economic growth rates of the 20th century through the 21st we will almost certainly increase the volume and mass of our extraction, production, and disposal sevenfold by 2100” [*www.darrinqualman.com/category/production-and-manufacturing*].

1.2. PLASTICS WASTE AND ITS SOURCES

Oceanologists are alarming that the world's oceans are beginning to resemble dumpsters. Not only the water is becoming dirty, but there are hundreds of wrecks at the bottom. It is very difficult to calculate the exact amount and weight of plastic pollution in seas and oceans. According to researchers from the Five Gyres Institute in Santa Monica, there are already 269,000 tons of plastics in the oceans. Scientists for six years studied the level of plastic pollution in several places on Earth in the Bay of Bengal, the Mediterranean Sea and the waters surrounding Australia. They were looking for so-called microparticles in these places (they caught them in very dense nets) as well as large pieces of plastics, visible to the eye plastic bags, pieces of old toys and also plastic ropes. These studies also estimated the total number of plastic garbage in marine waters, which was 5.25 trillion [*www.5gyres.org*].

On the other hand, the Ellen MacArthur Foundation estimated that only by 2050 the volume of plastics in the oceans will be larger than that of fish. The report says that every year "at least 8 million tons of plastics leaks into the ocean - which is equivalent to dropping the contents of one garbage truck into the ocean every minute. If no action is taken, it is expected to increase to two per minute by 2030 and four per minute by 2050." [*www.ellenmacarthurfoundation.org*]. Additionally, according to a Greenpeace report, more than 8 million tons of plastics are discharged into our oceans every year. [Greenpeace, (2006)]. In a traditional scenario, the ocean should contain one ton of plastics for every three tons of fish by

2050. Researchers also found that countless tiny fragments drift to the bottom of the oceans, lining the seabed [*www.ellenmacarthurfoundation.org*]. Other forecasts say that by 2020 the amount of plastics in the seas and oceans will increase by 10 times [*www.plasticseurope.org*].

In the research published in 2015 in the journal "Science", a team of scientists from the American University of Georgia under the direction of Dr. Jenny Jambeck, calculated that almost 9 million tons of plastic waste is landed from the oceans and seas each year [Jambeck, J.R. et al. (2015)]. In turn, the American National Center for Ecological Analysis and Synthesis (NCEAS) cautiously estimated in 2010 that it is from 4.8 million to 12.7 million tones [*www.nceas.ucsb.edu/news/new-science-first-estimate-quantifies-plastics-flowing-ocean*].

On a global scale, 82 % plastics in the seas and oceans come from Asia, only 2 % from Europe and the USA, and 16 % from other parts of the world. Only five very densely populated Asian countries are responsible for more than half of all plastic waste that goes into the marine environment: China, the Philippines, Vietnam, Indonesia and Sri Lanka [*www.ourworldindata.org/plastic-pollution*]. As much as 2.4 million tons of new plastic garbage in the sea comes from China alone, which is one of the largest producers of plastics in the world, considered as more, than one quarter of the global production. Imports of plastics from China into the United States are steadily increasing as China's plastic industry grows. Production of plastics in China will continue to develop and include more efficient companies that produce higher quality plastics [Garside, M. (2019)]. In the top twenty, the most littering countries are only one Western country - the USA. However, the United States only releases approximately less than 1 percent annual sum for the whole world. The Member States of the European Union (counted separately) are outside the top twenty. Such calculations were presented by Dr. Jambeck's team after analyzing the garbage circulation in 192 countries around the world [Jambeck, J.R. et al. (2015)].

The part of the problem with plastic waste, which is very well known to us from television and newspapers, is called a marine litter. Such wastes can be seen on the beaches, as well as swimming in our seas and most of them come from land as a result of wind or rainfall. The key to solving the problem of plastics in the seas is to understand exactly what it consists of and where it comes from. According to Greenpeace, it has been estimated that around 80% of marine debris is from land-based sources and the remaining 20% is from ocean-based sources. Greenpeace in its research [Greenpeace, (2006)] distinguishes plastic sources in 4 different categories:

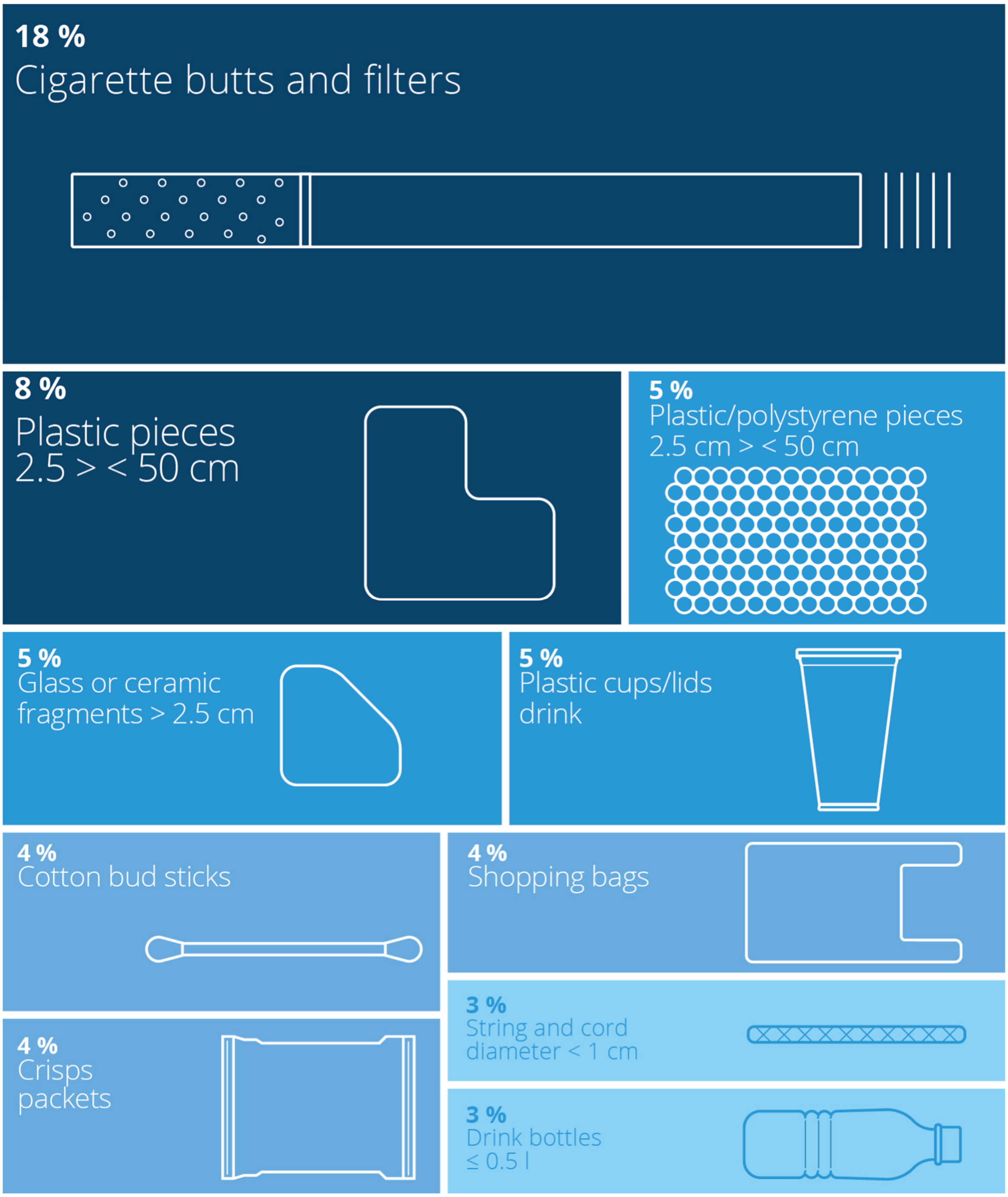
- "Tourism related litter at the coast: this includes litter left by beach goers such as food and beverage packaging, cigarettes and plastic beach toys.
- Sewage-related debris: this includes water from storm drains and combined sewer overflows which discharge waste water directly into

the sea or rivers during heavy rainfall. These waste waters carry with them garbage such as street litter, condoms and syringes.

- Fishing related debris: this includes fishing lines and nets, fishing pots and strapping bands from bait boxes that are lost accidentally by commercial fishing boats or are deliberately dumped into the ocean.
- Wastes from ships and boats: this includes garbage which is accidentally or deliberately dumped overboard. Huge volumes of non-organic wastes, including plastics and synthetics, are produced in more developed, industrialized countries. Conversely, in less developed and more rural economies, generally a much smaller amount of these non-biodegradable persistent wastes is produced. However, in the future, as less developed countries become more industrialized, it is likely that they will also produce more plastic and synthetic wastes and this will increase further the threat of pollution of the marine environment."

On European beaches the most common garbage appears to be plastic caps and cigarette butts, as well as rings made of plastic caps, fragile packaging, packaging for sweets, cords, fragments of plastic objects and cotton swabs. The JRC researchers in the first EU-wide analysis of this type gathered information on the most common types of garbage on European beaches, also analyzing data sets on beach waste collected in 2016 across Europe. These pollutants were identified on the basis of 356,671 objects collected from 276 European beaches in 679 studies [*www.ec.europa.eu*]. Researchers compared the collected items by various national and ecological organizations from different parts of Europe, including the North Sea, the Baltic Sea and the Mediterranean, looked at them and found the similarity of products and their popularity. The ten most commonly collected types of garbage in the analysis, make up about 63% of all garbage found on European beaches [UNEP, (2006)].

Figure 1.3. The most common pieces of litter found on Europe's beaches



Source: Marine LetterWatch data viewer

In Figure 1.3. can be seen the specification of the parts of pollution of Europe's beaches, which volunteer groups found on, used the EEA's Marine LitterWatch mobile app to collect data on litter. Based on nearly 700 000 items found at 1 627 beach clean-up events across Europe's four regional seas, as stated before, the most common pieces of litter were cigarette butts and filters [*www.ec.europa.eu*]. These top-ten most common items correspond to 59% of the total litter found on Europe's beaches.

As mentioned before, another common category of beach waste of fishing activity are abandoned, lost or discarded fishing gears, such as nets, lines and buoy. Researchers say it is unquestionably more difficult to determine if certain items, such as ropes or ropes, come from fishing. Lines, nets and other fishing objects often remain in the sea and can only be identified with special techniques that allow the search of the seabed. That's why scientists estimate that the percentage of garbage related to fishing is between 3% and 15% [*www.microplastics.whoi.edu*]. Plastic residues come from a wide and diverse range of sources. Estimates suggest that much of what pollutes the seas and oceans comes from the mainland. The results that litter the coast are compounded by vectors, such as discharging garbage from inland urban areas through rivers and storm drains [*www.plastic-pollution.org*].

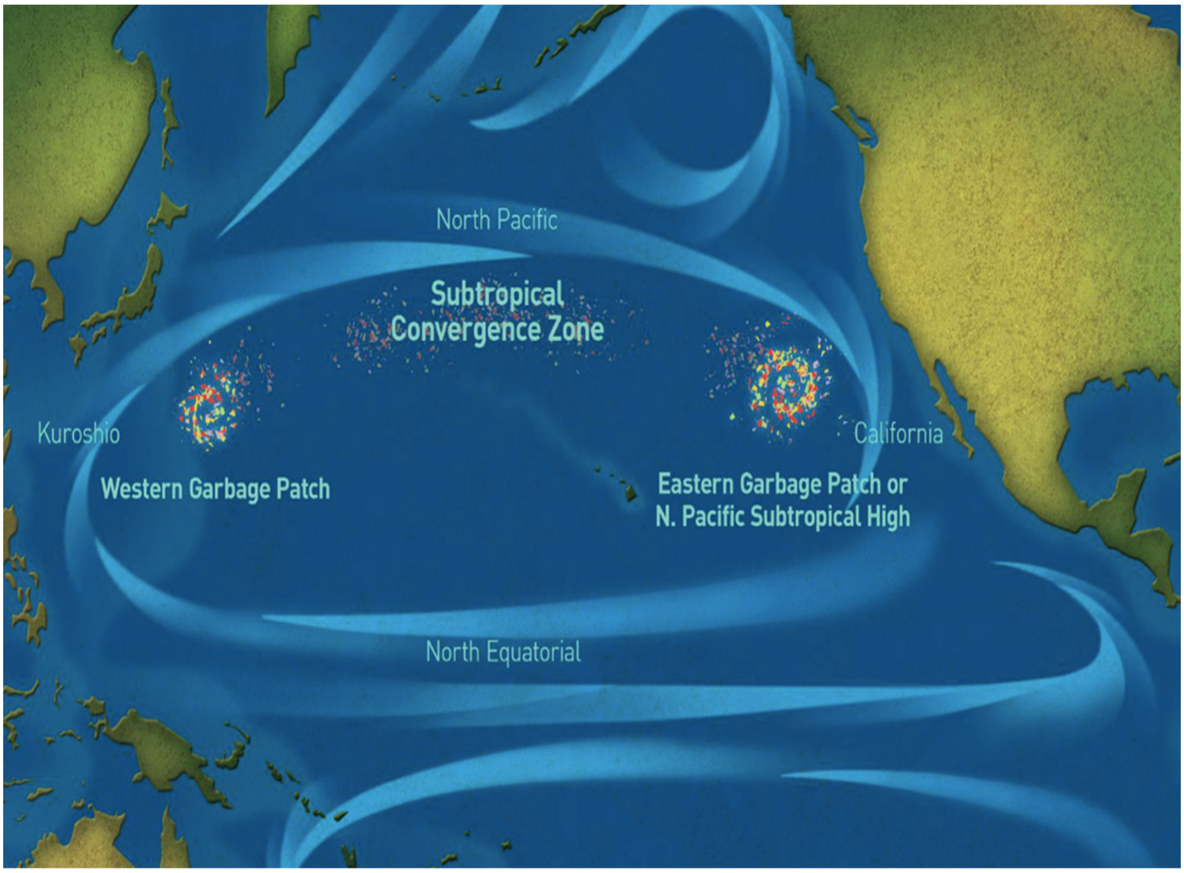
German scientists have proven that up to 95 % of littering plastic oceans come from just 10 large rivers (of which 8 are Asian), and is the result of poor management of plastic waste in their basins. Every year, millions of tons of plastic garbage end up in the seas and oceans, and the overall consequences of plastic water pollution are unpredictable, scientists warn. "One thing is certain: this cannot go on. If we cannot clean the oceans from the plastic waste already in them, so we need to take countermeasures and quickly and effectively reduce the further inflow of plastic," says a hydrogeologist at the German Helmholtz Center for Environmental Research (UFZ) in Leipzig, Dr. Christian Schmidt [*www.ufz.de/index.php?en=36336&webc_pm=34/2017*]. His team of researchers decided to look more closely at how and which kind of plastic waste goes to the oceans. To this end, he analyzed and compared the results of previous research on the amount of plastics in 57 rivers around the world. Scientists have been able to prove that there is a relationship between the amount of plastics in rivers and improper storage (or lack) of plastic garbage in their basins. Of course, the size of the river is also important, as they write in the publication in Environmental Science & Technology [Schmidt, CH. et al (2017)]. "The concentrations of plastics, i.e. the quantity of plastics per cubic meter of water are significantly higher in large rivers than small ones. The plastic loads consequently increase at a disproportionately higher rate than the size of the river.," explains dr Schmidt. Together with his colleagues, he calculated that as much as 88-95 % all the plastics that hits the seas and oceans on Earth comes from just 10 rivers. Eight of these rivers - Yangtze River, Indus, Yellow River (Huang He), Hai He, Ganges, Pearl River, Amur and Mekong - are located in Asia, the other two, Nile and Niger, in Africa.

Another significant type of marine pollution is The Great Pacific Garbage Patch, also described as the Pacific Trash Vortex. It is one of the five largest vortices in the world that attract plastic waste, and on the surface floats almost 3.5 million tons of plastics. These huge vortices can transport plankton, seaweed, and what goes into the sea water through human fault over huge distances. The size of the Pacific Trash Vortex is very difficult to estimate, according to various sources, the densest layer measures about one million square kilometers, while the periphery spans 3 to 5 million km2. There was a debate about the size of the Pacific Trash Vortex estimates compare it to Texas or twice the size of France. Accurate measurement is not possible because the amount of waste visible on the surface changes with the current and wind. According to the UN environmental agency, the size of the stain grows so fast that it can already be seen from space [Lebreton, L. et al. (2018)]. Scientists from around the world began to conduct research, and in 2013 came to the conclusion that there are more than 5 trillion pieces of plastics in the oceans, mostly in the form of micro particles [Eriksen, M. et al (2014)]. Scientists have already called this part of the ecosystem “a plastic sphere”. An aerial survey last year by Dutch foundation The Ocean Cleanup found it is far bigger than previously estimated, while the UN’s environmental programme warns it is growing so fast that it is now even visible from space. Around 54 % of the debris in the Great Pacific Garbage Patch comes from land operations in North America and Asia. The rest of it, 20 % originates from sailors, offshore oil rigs and large cargo ships that drop or lose trash directly into the water. Most of these debris - around 204,000 tons - are fishing nets. More unusual items, such as computer monitors and LEGO bricks, come from dropped shipping containers. Most of the remaining garbage comes from plastic bags, bottle caps, plastic water bottles and Styrofoam cups [*www.theoceancleanup.com/press/press-releases/ocean-plastic-pollution-worse-than-expected*].

The situation in the North Pacific has been very famous in recent years, but that fact does not imply, that there is no problem elsewhere. A lot of plastic waste also floats in sea waters off the coast of South and Southeast Asia. Plastic garbage is also present in the Baltic Sea. Particular pollution of Asia's oceanic areas is not only due to the fact that the coastal areas of this continent are very densely populated and constitute one of the most populated areas in the world. The amount of waste in the Great Pacific Garbage Patch accumulates because much of it is not biodegradable. For instance, many plastics do not wear out; they just break down into smaller and smaller pieces [*www.plastic-pollution.org*]

The areas of rotating debris are connected by the North Pacific Subtropical Convergence Zone, located several hundred kilometers north of Hawaii, which meets warm water from the South Pacific with cooler water from the Arctic. This zone acts like a highway that transfers garbage from one field to another.

Figure 1.4. Areas of rotating debris connected by the North Pacific Subtropical Convergence Zone



Source: www.marinedebris.noaa.gov

The entire Great Pacific Garbage Patch is bounded by the North Pacific Subtropical Gyre. The National Oceanic and Atmospheric Administration (NOAA) defines this phenomenon as a large system of rotating ocean currents [*www.oceanservice.noaa.gov/facts/gyre*]. To an increasing extent, however, also applies to the garbage patch / plastic waste vortex and debris that breaks down into small particles in the ocean. The four currents rotating clockwise over an area of 20 million square kilometers (7.7 million square miles) create The North Pacific Subtropical Gyre: North Pacific, North Equatorial Current, Kuroshio Current and California Current. [*www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/10th-grade*]. Debris gets trapped into this stable center by the circular motion of gyre draws. Possible journey of a plastic bottle thrown off the coast of California may look like this: the bottle takes the California Current south towards Mexico. There it can catch the North Equatorial Current, which crosses the vast Pacific, and near the coast of Japan, the bottle can travel north through the powerful Kuroshiro current. Finally, the bottle travels west on the North Pacific tide. The gently swirling swirls of eastern and western garbage patches gradually pull the bottle in. The seabed under the Great Pacific Garbage Patch can also be an underwater heap of garbage. Oceanographers and environmentalists have recently discovered that about 70% of marine debris are actually sinking at the bottom of the ocean [*www.marinedebris.noaa.gov/info/patch*].

1.3. MICROPLASTICS AND SEAS POLLUTION

"Microplastics" are small pieces of plastics, less than 5 mm in length, which are present in a variety of products, from cosmetics to synthetic clothing to plastic bags and bottles, and of a consequence of category of a plastic pollution, there different types of those can be distinguished. Many of these products readily enter the environment in wastes [*www.oceanservice.noaa.gov/facts/microplastics*].

For the first time the concept of "microplastics" was brought to the scientific world in 1972 in a paper describing the problem of plastics floating on the surface of the Sargasso Sea. Authors observed that among the huge amounts of bulky plastic waste there are also smaller fragments, often with sizes well below 1 mm. Further research conducted by many teams of scientists has shown that this type of pollution is present in all seas and oceans. Particularly high concentrations of small plastic fragments are observed within marine beaches [Carpenter E.J., Smith K.L., (1972)]. There can be distinguished two different types of microplastics depending on their origin: **primary microplastics** – which are directly released in the environment as small particles, they represent between 15-31% of microplastics in the oceans, and they come from laundering of synthetic clothes (35% of primary microplastics); abrasion of tires through driving (28%); intentionally added microplastics in personal care products, for example microbeads in facial scrubs (2%); and **secondary microplastics** - originate from degradation of larger plastic objects, such as plastic bags, bottles or fishing nets, and they account for 69-81% of microplastics found in the oceans. Sources of microplastics, the size of which varies from 5mm to 10 nanometers, are different. This can be the transport of granules of raw plastics for further processing [Hidalgo-Ruz, V. et al (2012)]. Microplastics can also come from the so-called microgranules, i.e. tiny plastic balls used in face scrubs or toothpaste. In some countries, including Great Britain, their sale has been banned. Microgranules, like microfibers, i.e. threads pulled out of synthetic clothes during washing, are too small to be stopped by sewage treatment plants, which means that they reach the seas and oceans [*www.bbc.com/news/science-environment-37161479*].

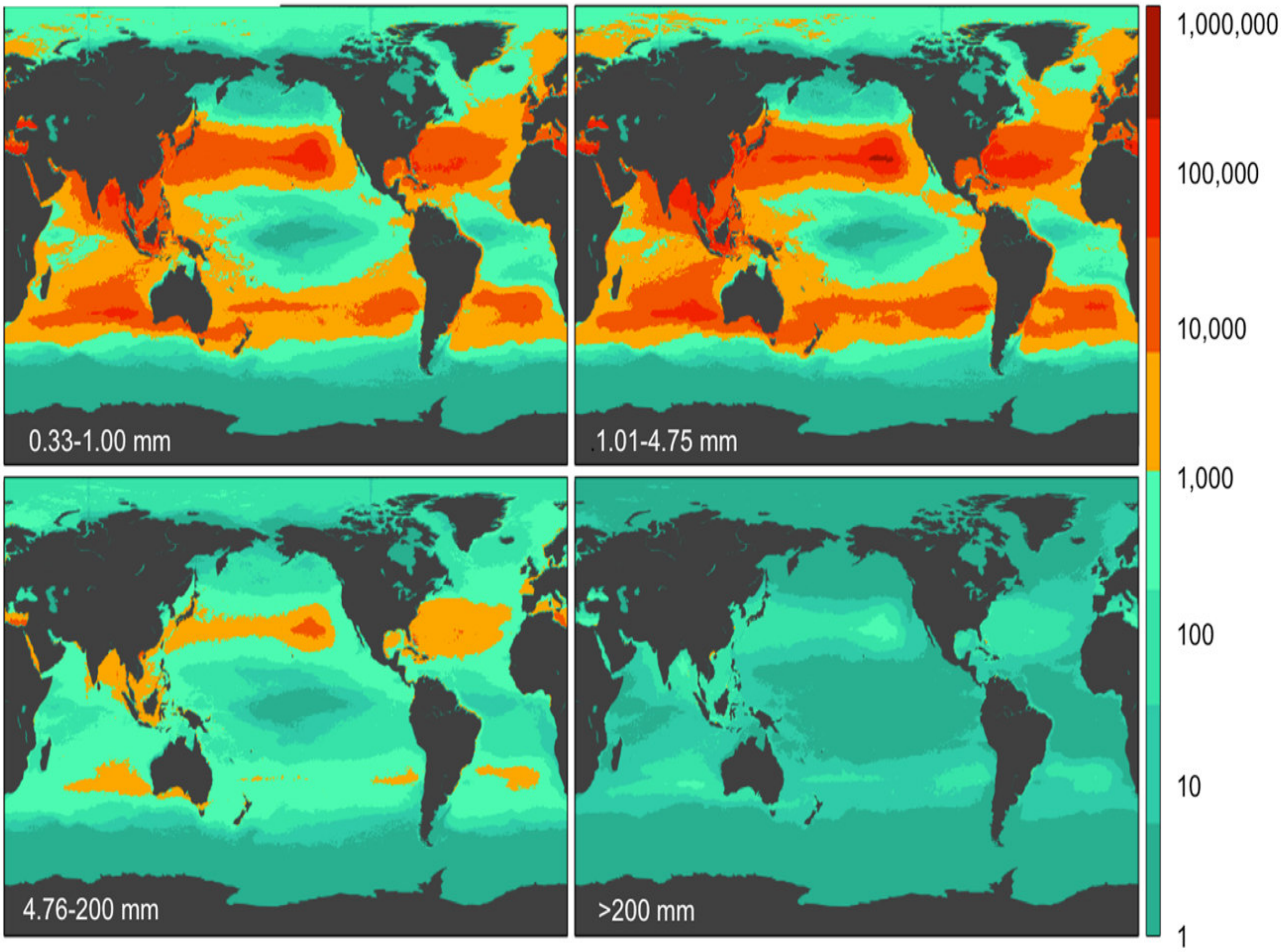
Data collected by scientists from the US, France, Chile, Australia and New Zealand suggest that the oceans contain at least 5.25 tons of plastic particles, most of which are "microplastics" smaller than 5 mm. Researchers were able to calculate the volume of plastic components, mainly from products such as food and drink packaging and clothing [*www.journals.plos.org*]. The study, based on data from 24 expeditions over a six-year period to 2013, was published in the journal PLOS One and is the first study to identify plastics of all sizes in the world's oceans. Another study has estimated that there are 15 to 51 trillion microplastic particles in the world oceans [Van Sebille, E. et al (2015)].

Marcus Eriksen and a group of scientists said that more than 5 trillion plastic elements weigh over 250,000 metric tons at sea already in 2014. Researchers collected small pieces of plastics in the network, while larger pieces were observed from the boat [Eriksen, M. et al (2014)]. The study presented estimates the total number of plastic particles and their mass floating in the world's oceans from 24 expeditions (2007–2013) in all five subtropical gyres in coastal Australia, the Bay of Bengal and the Mediterranean. Researchers compared four size classes, two microplastics - less than 4.75 mm and meso- and microplastics - larger than 4.75 mm, and found massive loss of microplastics from the sea surface compared to expected fragmentation rates, suggesting that removal mechanisms exist plastic particles from the ocean have an area of less than 4.75 mm. Scientists have found that due to their buoyancy and strength properties, and the sorption of toxic substances into plastics when traveling through the environment, plastic contaminants are globally distributed in all oceans [Teuten, E. et al (2007)]. This also prompted some researchers to claim that synthetic polymers in the ocean should be considered hazardous waste [Rochman, C. et al (2013)]. Through photodegradation and other weathering processes, plastics disintegrate and disperse in the ocean, converging in the subtropical gyroscopes. Plastic pollution generation and accumulation also occurs in enclosed bays and seas surrounded by densely populated coastlines and drainage basins [Law, K. et al (2010)].

Their oceanographic model assumes that the amount of plastics getting into the ocean depends on three main variables: maritime activity, catchment and population density [Eriksen, M. et al (2014)]. Based on the results of the model, scientists estimated that at least 5.25 trillion plastic particles with a mass of 268,940 tones are currently drifting at sea. Observations show that the two ocean regions in the northern hemisphere contain 55.6% of particles and 56.8% of plastic mass compared to the southern hemisphere, with the North Pacific 37.9% and 35.8% respectively by number of particles and mass. In the southern hemisphere, it appears that the Indian Ocean has an exceptionally higher number of particles and weight than the combined oceans of the South Atlantic and the South Pacific.

Of the 680 net tows, 70% brought an estimated density of 1,000–100,000 km-2, and 16% resulted in an even higher number up to 890,000 km2 found in the Mediterranean. The forecast of the scientific model agrees with the pattern saying that ocean edges are areas of migration of plastics, while subtropical veins are areas of accumulation. Data from four size classes (small microplastics, large microplastics, meso and macro plastics) were executed separately by the model, creating four maps for each number and density (Figures 1.5. and 1.6.). combining two classes of microplastic sizes, they account for 92.4% of the global number of particles, and compared to each other the smallest microplastic category (0.33-1.00 mm) had about 40% less particles than larger microplastics (1.01-4.75 mm). Most of the small microplastics were fragments resulting from the decomposition of larger plastic objects [Geyer, R., et al (2017)].

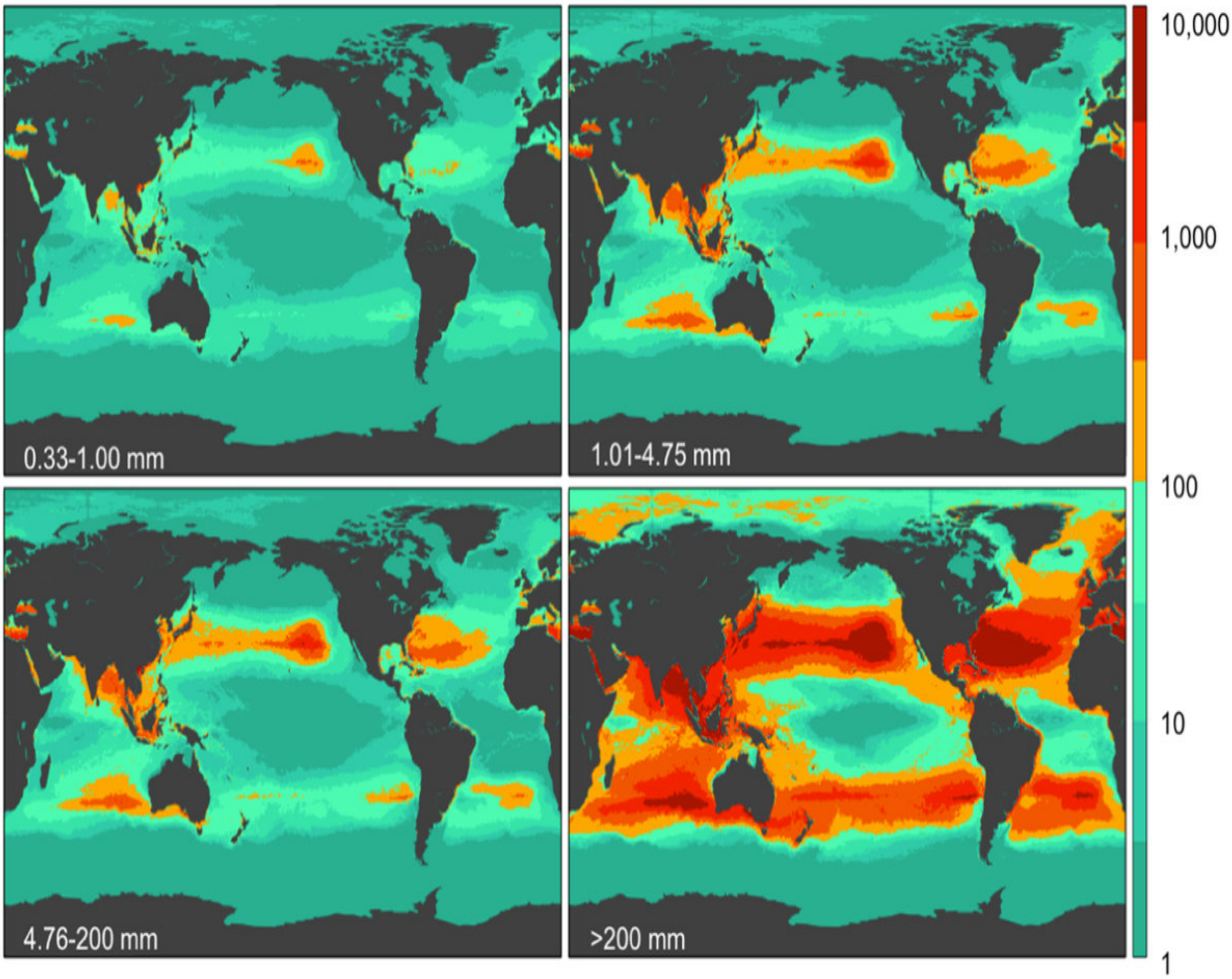
Figure 1.5. Global count density in four size classes



Source: www.journals.plos.org

Model prediction of global count density (pieces km^{-2}) for each of four size classes (0.33–1.00 mm, 1.01–4.75 mm, 4.76–200 mm, and >200 mm).

Figure 1.6. Global weight density in four size classes



Source: www.journals.plos.org

Model prediction of global weight density (g km^{-2}) for each of four size classes (0.33–1.00 mm, 1.01–4.75 mm, 4.76–200 mm, and >200 mm). The majority of global weight is from the largest size class.

Scientists found a similar pattern of material loss from the sea surface by comparing the weight of four size classes. The obtained data proved that the global weight of plastic contamination contains 75.4% macroplastic, 11.4% mesoplastic and 10.6% and 2.6% in two classes of microplastic sizes, respectively. It turned out that at least 233 400 tons of larger plastic objects float in the world's oceans compared to 35 540 tons of microplastics. This is the first study comparing all sizes of floating plastics in the world's oceans, from the largest items to small microplastics. Plastics of all sizes were found in all oceanic regions, converging in the accumulation zones of subtropical gyroscopes, including the southern hemisphere, where there is a lower population density on the coast than in the northern hemisphere [Geyer, R., et al (2017)]. This proves that contamination of these materials has spread to all oceans of the world, a comparison of size classes and mass dependence suggests that during fragmentation plastics lose themselves from the sea surface. The above comparisons between size classes have enabled us to understand possible paths for oceanic debris.

Dominant winds and surface currents carry plastic debris across oceans around the world. This appeared in the northern hemisphere, where accumulating plastic garbage in the center of ocean basins, results in long-term surface transport. Similar patterns confirmed by the results of scientists are observed for all oceans of the southern hemisphere [Law, K. et al (2010)]. It is surprising that for the oceans of the southern hemisphere the total quantities of plastics determined are in the same range as for the oceans of the northern hemisphere (Figure1.7.), which can be very surprising considering that inputs are much higher in the northern hemisphere. This would probably mean that plastic contaminants travel easier between oceanic veins and hemispheres than previously assumed. In addition, there may be important sources of plastic contamination in the southern hemisphere that are not considered, such as currents from the Bay of Bengal that cross the equator south of Indonesia. [Lebreton, L. et al (2012)].

Figure 1.7. Model results for the total particle count and weight of plastics floating in the world's oceans

	Size class	NP	NA	SP	SA	IO	MED	Total
Count	0.33–1.00 mm	68.8	32.4	17.6	10.6	45.5	8.5	183.0
	1.01–4.75 mm	116.0	53.2	26.9	16.7	74.9	14.6	302.0
	4.76–200 mm	13.2	7.3	4.4	2.4	9.2	1.6	38.1
	>200 mm	0.3	0.2	0.1	0.05	0.2	0.04	0.9
	Total	199.0	93.0	49.1	29.7	130.0	24.7	525.0
Weight	0.33–1.00 mm	21.0	10.4	6.5	3.7	14.6	14.1	70.4
	1.01–4.75 mm	100.0	42.1	16.9	11.7	60.1	53.8	285.0
	4.76–200 mm	109.0	45.2	17.8	12.4	64.6	57.6	306.0
	>200 mm	734.0	467.0	169.0	100.0	452.0	106.0	2028.0
	Total	964.0	564.7	210.2	127.8	591.3	231.5	2689.4

Source: Plos One. 2014

Estimated total count (n×1010 pieces) and weight (g×108 g; or g×102 tons) of plastics in the North Pacific (NP), North Atlantic (NA), South Pacific (SP), South Atlantic (SA), Indian Ocean (IO), Mediterranean Sea (MED), and the global ocean (Total). Estimates were calculated after correcting for vertical distribution of microplastics [Collignon, A. et al (2012)].

A recent study on the global distribution of microplastics suggests that the total floating microplastic load varies between 7,000 and 35,000 metric tons, and the study of these scientists is 35,500 metric tons. The study also found a 100-fold discrepancy between the expected microplastic mass and the number and their observations, which indicates a huge loss of microplastics [Law, K. et al (2014)]. The similarities between the results of Dr. Ericksen and the results of mentioned study give further confidence in their estimates and confirm their hypothesis that the final fate of emerging microplastics does not lie on the ocean surface [Cózar, A. et at (2014)].

The observed lower level of microplastics on the sea surface - than might be expected – suggests, that removal processes are underway, such as UV degradation, biodegradation, ingestion by organisms and reduced buoyancy due to fouling organisms. Beach [Barnes, D. et al (2009)]. The speed of grinding already fragile microplastics can be very high, quickly breaking down small microplastics into smaller and smaller particles, which makes them inaccessible to scientists' nets (0.33 mm hole). A lot of recent research also shows that many more organisms consume small plastic particles than previously thought, directly or indirectly, i.e. through their victims' bodies [Goldstein, M.C., Goodwin, D.S. (2013)]. Many species consume microplastics, and thus make them available to higher-level predators, or may otherwise contribute to the differential removal of small particles from the sea surface, e.g. by packaging microplastics in fecal granules, which improves sinking [Cole, M. et al (2013)].

Properties of those materials prove that plastics are very durable and useful, and their stability and resistance to degradation makes them so problematic after their use and further unsuitability. As it is mentioned earlier, these materials do not disappear easily from the environment and are not easily processed by natural biological mechanisms. However, in the aquatic environment, the weathering process occurs when the particles break down mechanically or under the influence of sunlight into smaller and smaller fragments. Ultimately, these small fragments are reduced to small pieces the size of sand grains, or smaller ones, as called before - microplastics. These particles were suspended in seawater as well as on the seabed. Even such small particles can cause harm to the marine environment, because it has been proven that small creatures eat them and can concentrate persistent organic pollutants (POPs) present in the seas [Greenpeace, (2006)]. The next chapter will discuss the impact of plastics and microplastics on ecosystems and various aspects of human life.

CHAPTER 2

GLOBAL ECOLOGICAL, SOCIAL AND ECONOMIC IMPACTS OF MICROPLASTICS

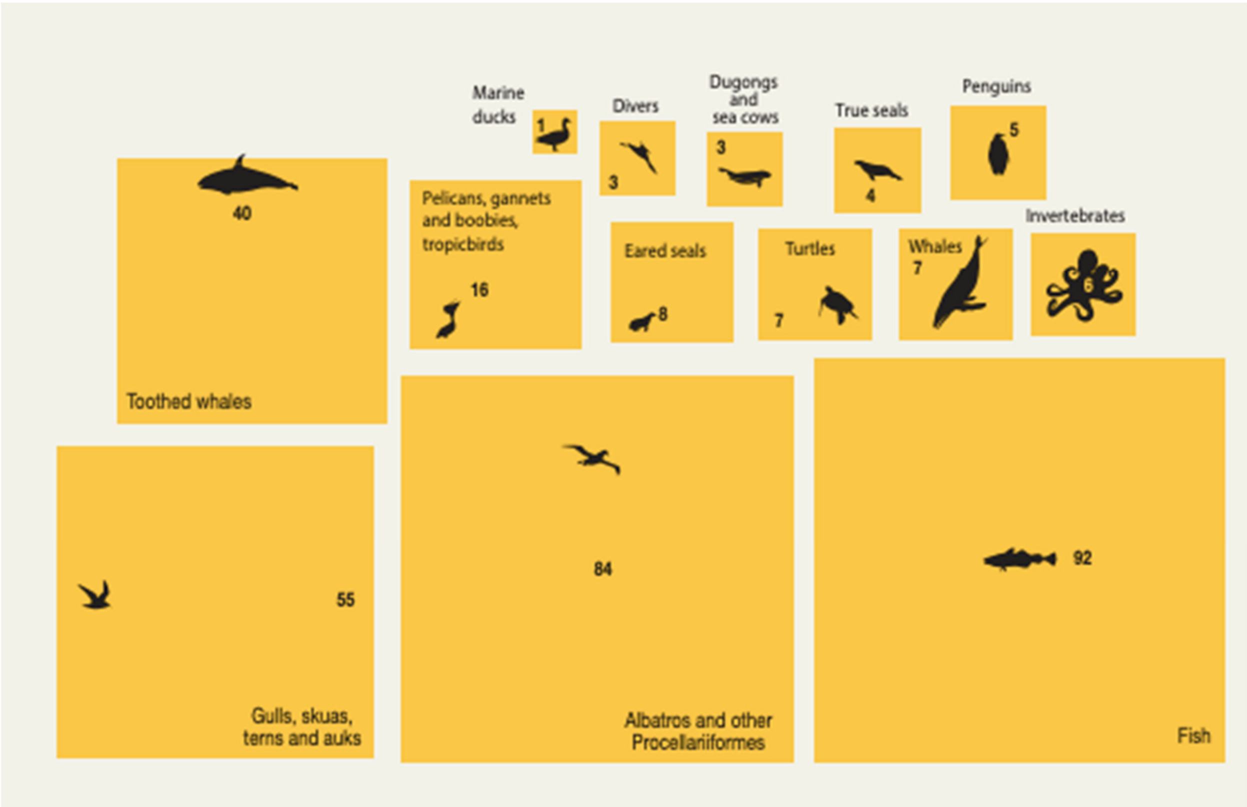
It is estimated that 2 to 5 % all manufactured plastics go to the seas, which not only clutter the coast, but also harm many marine animals that get tangled up in larger waste and get it confuse with food [Boucher, J., Friot, D. (2017)]. Afterwards, they are devoured by marine animals, entering the food chain, and subsequently in the end can being consumed unconsciously by humans. For example, significant amounts of microplastics have been found in various sea food, like tuna, lobster and shrimps [*www.news.mongabay.com/2018/11/research-finds-humans-across-the-globe-have-microplastics-in-their-stool*]. The absorption of plastic particles can cause improper digestion of normal food and attract toxic chemical pollutants to their bodies. It is not very surprising, that people also consume plastics found in the food chain, but unfortunately, it is still not fully known how this affects human health. In addition, it is highly likely that food becomes contaminated with plastics during various stages of processing or as a result of packaging.

Besides, marine waste also causes financial losses in sectors and communities dependent on marine resources, but also among producers. Only 5 percent plastic packaging values remain in circulation (the rest is literally thrown away) indicating the need for a more recycling-oriented approach and reuse of materials [*www.ec.europa.eu/commission/presscorner/detail/en/MEMO_18_6*], which will be discussed in Chapter 3.

2.1 IMPACT OF MICROPLASTICS ON WILDLIFE

Plastics in the oceans is, above all, a huge threat to marine ecosystems and very harmful to its life. It is eaten by the animals living there and, in this way, travels up the food chain. Plastic garbage in the oceans is one of the reasons for the decline in fish or sea birds. The organization based in California "The Turtle Island Restoration Center", which deals with the protection of sea turtles, estimated in its report from 2010, that annually as a result of plastic pollution of oceans and seas, about 100 thousands of marine reptiles and mammals die. Counting together with birds, fish or mollusks, the whole number of animals that die each year as a result of plastics getting into the marine ecosystems is about 1 million [Sea Turtle Restoration Project, (2016)]. Microplastic particles also occur in large quantities on beaches, in sand – at a depth of up to several dozen centimeters [*www.naukawpolsce.pap.pl*]. Most sea turtles are usually confused by plastic bags, considering them as their favorite food - a jellyfish, while albatrosses confuse resin granules with fish eggs and feed them to chicks, which in consequence are dying cruelly of hunger or ruptured organs. The numbers can be very frightening (Figure 2.1.).

Figure 2.1. Number of species with documented records of marine debris ingestion



Source: UNEP, (2016).

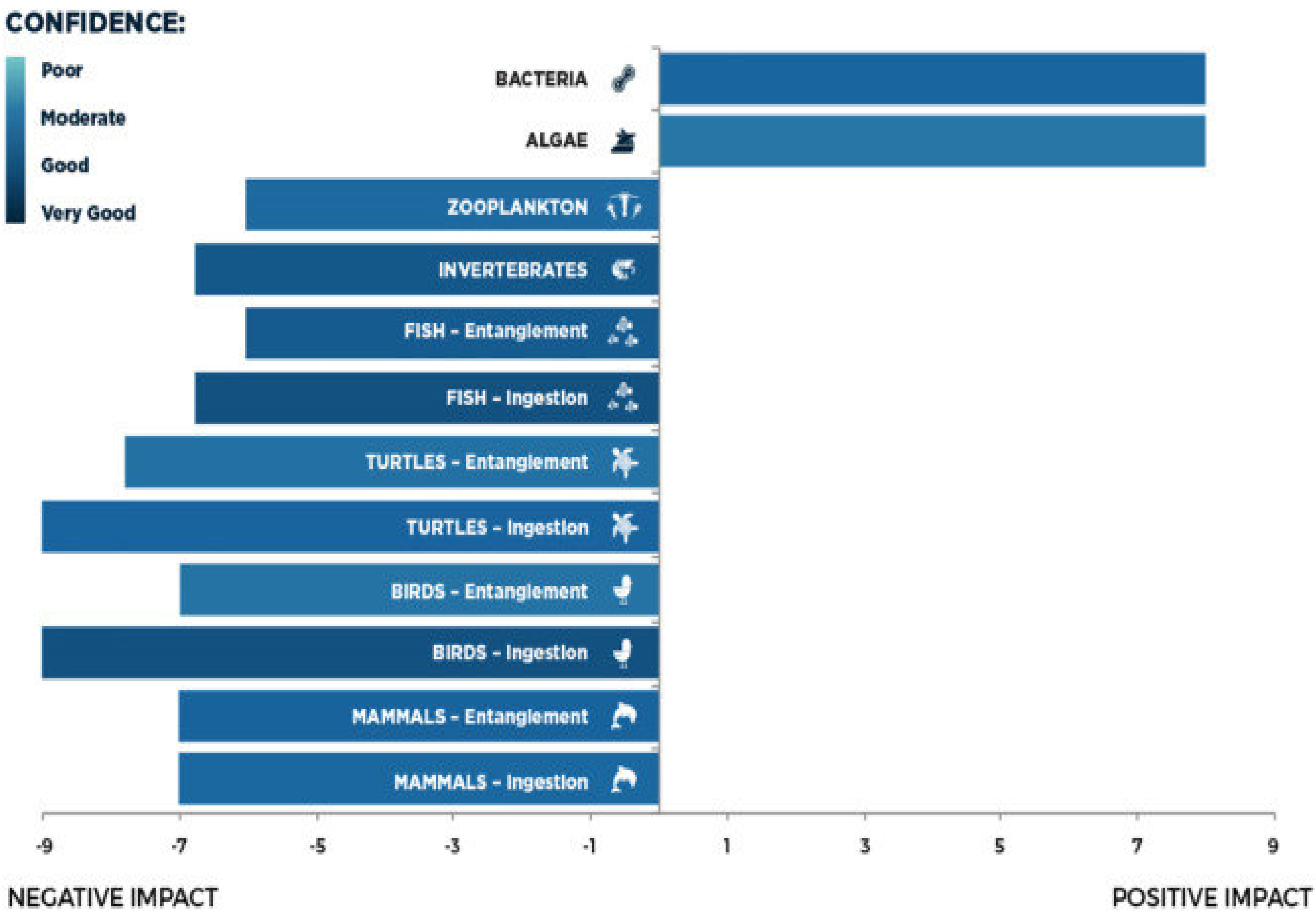
The effects of plastic contamination due to swallowing and entanglement of marine fauna, from zooplankton to cetaceans, seabirds and reptiles, are well documented [Gregory, M.R. (2009)]. Professor Jan Marcin Węsławski, head of the Marine Ecology Department at the Institute of Oceanology of the Polish Academy of Science, confirms this thesis and he points out two threats. The scientist said that the problem for marine wildlife is microplastics (microgranules and threads), which are so small that marine zooplankton is able to swallow them, and this consequently means that it cannot supply itself with food and suddenly it stops growing. The second threat is the direct, mechanical effect of macroplastics - mainly films and tapes, which are eaten by large marine animals, causing mechanical damage to the gastrointestinal tract and a false feeling of filling the stomach. As a result of eating garbage by sea animals, many of them die [*www.iopan.gda.pl*]. It is also estimated that about 300 species are endangered because undigested plastic residues block the digestive system and, in many cases, lead to their death. An equivalent threat also applies to turtles and sea otters, which get tangled in nylon nets [Carson, H.S. et al (2013)]. It has been also discovered that the consumption of microplastics smaller than 1.4 mm by freshwater crustaceans (Daphnia magna) causes an increase in mortality even after 48 hours [Jemec, A., et al (2016)]. Absorption of persistent organic pollutants on plastics and their transfer to tissues and organs through consumption affects the sea megafauna, as well as organisms with a lower trophic level and their predators [Bakir, A. et al (2014)]. These influences further worsen the quality of the floating plastic particles [Setälä, O. et al (2014)].

Not only the brutal mechanical consequences affect marine animals because of this contamination. As mentioned in Chapter 1, toxins are released as plastics breaks down. The results of laboratory tests indicate that the chemicals accompanying microplastics accumulate in the tissues of marine animals, including those popular on our tables. Microplastic particles are found in a large variety of marine organisms, including species we consume as seafood. In 2011, as much as 83% of shrimps from the Dublin Bay had microplastics in the digestive system, as did 63% of shrimps from the southern North Sea. And a group of experts on marine pollution called Gesamp, published the results of their analysis, which says that scientists found particles in ten thousand organisms from over 100 species [*www.gesamp.org*]. Likewise, according to Dr. Andres Cózar of the University of Cadiz - the head of the research, in 2010 together with scientists from the Spanish Malaspina Institute obtained similar data. They found microplastic garbage made of polyethylene and polypropylene, which is present today in about 88 percent of waters on our planet. They penetrate marine organisms, systematically poisoning them, from the smallest plankton or shellfish to large fish and mammals [UNEP, (2016)].

Likewise, the latest study by Greenpeace [Greenpeace, (2016)], proved that 121 specimens of fish from the central Mediterranean, including commercial species such as swordfish, bluefin tuna and albacore tuna, showed the presence of plastic fragments in 18,2 % of samples which have been analyzed. Studies on 26 species of fish from the Portuguese Atlantic coast revealed the presence of microplastics in 19,8 % of the tests performed: the largest amounts were found in Lanzardo, a species similar to mackerel. A Norwegian lobster study found plastic fragments in the stomach of 83 % of specimens collected along the coast of Great Britain. And these are just one of many cases that occur around the world. Other mussel testing in the laboratory showed that 10 μm microplastics were transferred to the circulatory system [Browne, M.A. et al (2008)], leading to studies that currently show evidence that micro- and nanoplastics can penetrate trophic levels to crustaceans and other secondary consumers [Farrell, P. Nelson, K. (2013)]. Swallowed microplastics loaded with polybrominated diphenyl (PBDEs) can spread to birds [Yamashita, R. et al (2011)] and lugworms [Tanaka, K. et al (2013)]. Increasing evidence indicates an effect on individual animals, including cancer in fish, and lower reproductive success and shorter life span of marine worms [Wright, S.L. et al (2013)]. There are also studies that have shown the effects on laboratory populations: one oyster study states that "evidence that micro-PS (polystyrene) cause feeding modifications and reproductive disruption, with significant impacts on offspring". [Sussarellu, R. et al (2015)].

At a conference organized by IPPR, Legambiente and Enea, one of the best experts in the world in researching the impact of marine waste on biodiversity - Maria Cristina Fossi from the University of Siena, explained that scientists are trying to determine whether the consumption of plastics and microplastics can have a negative impact on species associated with the transport of pollutants whose microplastics are vectors, because they absorb POP (persistent organic pollutants) at concentrations that can be thousands or millions of times higher than those present on the sea surface [*www.ecomondo.com*]. Dr Fossi explained that a whale, for example, filters 700,000 liters of water every time it opens its mouth, taking on a huge amount of plastics and microplastics that have a high concentration of pollutants. So much so that in the whales of the Mediterranean the levels of microplastics or plastic additives such as phthalates are 4/5 times higher than those of whales that live in less contaminated areas of the planet. Not just whales are mostly endangered. More than 80% of the turtles that populate the Mediterranean have plastics in the stomach, furthermore in some specimens it reaches up to 150 plastic pieces. Scientists presenting the results in Marine Pollution Bulletin come to the same conclusions [Beaumont, N.J. et al (2019)]. Impacts on birds, fish, mammals and turtles have been divided into ingestion and entanglement. The results described in the study by Nicola J. Beaumont, Margrethe Aanesen and other scientists can be seen in Figure 2.2. and show that there is global evidence of a medium to high frequency effect on all animals with a medium to high degree of irreversibility.

Figure 2.2. Ecosystem impacts of marine plastic on biota



Source: Marine Pollution Bulletin, 2019

A score of −9 means: lethal or sub-lethal effect which is global, highly irreversible, and occurring at a high frequency; a score of +9 means: positive effect in terms of diversity and/or abundance, which is global, highly irreversible, and occurring at a high frequency.

Most of these effects are negative except for algae and bacteria. In this case, plastic increases the range of habitats available for colonization and allows these species to spread to new areas, thereby increasing their range and abundance [Beaumont, N.J. et al (2019)]. How much of these pollutants can be transported to the muscle of edible species such as tuna, sea bass or sword (and therefore end up on our tables) and what the consequences are for the final consumer, is an aspect still to be investigated. From the data that emerge both from the marine strategy carried out in the Italian field and from the specific research carried out in the laboratories, 15-20% of the edible species examined have microplastics, but in a reduced quantity, of about 1/3 fragments less than 5 millimeters [Giani, D. et al (2019)].

As mentioned before, by their appearance, micro-particles resemble food for many species. In July 2015, a team from the Maritime Laboratory in Plymouth showed a film shot under a microscope, in which zooplankton eats microplastics. [*www.youtube.com/watch?v=FAi1okMUdQ8*]. These tiny organisms play a key role in the food chain; hence the consequences of this phenomenon can be huge. While most of the plastics is in the intestines of fish, and thus does not hit our plate, some studies alert that microplastics, especially the one measured in nanometers, can get into the meat. And there are also fish or crustaceans that people eat whole [Collignon, A. et al (2012)].

Specific knowledge of the indication of effects caused by micro- and nanoplastics in the marine environment is still poor. But one thing is for sure - microplastics can not only affect species at the organism level; they can also be able to modify the population structure with potential impact on ecosystem dynamics, including bacteria and viruses. Negative impact on photosynthesis of major manufacturers and potentially an increase in secondary producers result in reduced productivity of the entire ecosystem and might be the main problem [Wright, S. L. et al (2013)].

2.2. IMPACT OF MICROPLASTICS ON HUMAN HEALTH

Worldwide, marine ecosystems provide a wealth of benefits that people derive from nature, primarily providing food to billions of people, carbon storage, waste detoxification, and cultural benefits, including recreational opportunities. Any threat to these ecosystem services can have a significant impact on the well-being of people around the world due to a loss of food security, livelihoods, income and good health [Naeem, S. et al (2016)].

Researchers from the Robert Koch Institute in Berlin, commissioned by the German Ministry of the Environment, conducted a study in 2014-2017, which proved that plastics, which is every day more common in the environment and whose production is constantly growing, is also deposited in human organisms. The journal “Spiegel” described this study showing that as many as 97 percent of the children surveyed had traces of plastics. It is true that, according to current scientific knowledge, not all substances detected in the study pose a threat to health, but some of them may interfere with the body's hormonal balance and disrupt development, as well as cause obesity and cancer. The presence of perfluorooctanoic acid (PFOA) in children's bodies is particularly alarming. It is used, among others, in the production of pan coatings or waterproof clothes. PFOA can cause fertility problems and damage the liver. “The smaller the size of the plastic particles, the more likely they are to cross biological barriers such as cell membranes. What we know is that nanoparticles in general can interact with proteins, lipids and carbohydrates in the body. Nanoparticles can even cross the blood-brain barrier and it seems probable that they can affect the central nervous system.” [*www.spiegel.de/international/zeitgeist/toxicologist-rosemary-waring-on-the-danger-of-microplastics-a-1249144*]. The study shows that ingestion of microplastics by living organisms can lead to gastrointestinal lesions, tissue inflammation, liver problems, cancer and endocrine disorders. Microplastics can also facilitate in humans the transmission of toxic chemicals and pathogens. There was also quite a surprising result of the research described in the “No Plastic in Nature: Assessing Plastic Ingestion from Nature to People”, commissioned by the WWF at the University of Newcastle, Australia, which says, that humans eat (together with water and food) the equivalent in plastic fragments of the weight of a credit card, which is more or less 250 grams per year [*www.newcastle.edu.au/newsroom/featured/plastic-ingestion-by-people-could-be-equating-to-a-credit-card-a-week*]. Researchers from the University of Vienna and the Austrian environmental agency Umweltbundesamt conducted a study on a group of eight people from different countries (Austria, Finland, the Netherlands, Japan,Poland, Russia, Great Britain and Italy) [*www.umweltbundesamt.at/news_en_181023/*]. It turned out that all participants were exposed to plastics, none of the participants were vegetarian, and six of them consumed sea fish. Nine different materials were found - their fragments were from 50 to 500 microns in diameter. Microplastic was present in each sample - an average of 20 particles per 10 grams of feces. The most common materials were polypropylene (PP) and polyethylene terephthalate (PET). Lead study author Dr Philipp Schwabl said this was the first study of its kind to confirm what has long been suspected, namely that plastics eventually reach the human intestine. This is a very unfounding thesis, especially for patients with gastrointestinal diseases. During animal studies, the highest levels of microplastics were detected in the intestines, however, its smallest particles are able to enter the bloodstream, lymphatic system and even reach the liver. "We have the first evidence of the presence of microplastics in the human body, now we need further research to understand what this means for human health", concluded Dr Schwabl. Likewise, professor of Environmental Science at the University of York - Alistair Boxall noted that previous studies have shown the presence of microplastics in tap water, bottled water, fish and beer. "It is therefore inevitable that at least some of these things will get into our lungs and digestive system." [*www.eppm.com/blogs/editors-blog/hard-to-swallow/*]. The presence of plastics in human bodies can have a certain negative impact on their health. It is also believed that bisphenol A contained in plastics can disrupt hormonal balance [*www.echa.europa.eu/it/-/msc-unanimously-agrees-that-bisphenol-a-is-an-endocrine-disruptor*].

In spite of all, in the "Spiegel" journal, the researchers said that "There is no concrete evidence right now that nanoplastics penetrate brain tissue in humans, let alone affect behavior. But it has been reported that plastic particles cause oxidative stress in human cell lines. This could potentially cause a number of problems including tissue degradation or inflammation, and it flags up the possibility that an individual with a high concentration of plastic contamination in the central nervous system might have an adverse reaction. Depression for instance has been linked to nanoparticle toxicity in the central nervous system. The plastic fragments might even initiate plaque formation and make Alzheimer's more likely. It is never good news having particles in your brain." [*www.spiegel.de/international/zeitgeist/toxicologist-rosemary-waring-on-the-danger-of-microplastics-a-1249144*]. A recent study by scientists from the University of Ghent in Belgium showed that mussels enthusiasts eat 11,000 plastic particles annually. However, the absorption of plastics by the human body is not more than 1%, but it must be noted that the plastics accumulates [Van Cauwenberghe, L., Janssen, C. (2014)]. That is, Belgians are the greatest gourmet mussels in Europe, but the above information applies to all residents of European continent. Recently, research results from the University of Plymouth caused quite a stir when it turned out that plastics are present in 1/3 of fish sold only in England [*www.plymouth.ac.uk*]. Plastics can be found, among others, in cod, haddock, mackerel and crustaceans. Another source of microplastics in the human diet is sea salt, obtained by evaporating salt water. Microplastics were also detected in beer, honey and bottled water [*www.teraz-srodowisko.pl/aktualnosci/plastik-biodegradowalny-ciemne-strony-3072*].

The above sections demonstrate evidence that microplastics are a potential threat to human and animal health, especially with increasing direct exposure to plastics. Although many researches have not yet been done and there are significant gaps in key results, the evidence from various studies already carried out indicates the likely exposure and potential hazards associated with both microplastic particles and related chemicals [Smith, M. et al (2018)]. The specific and detailed impact of microplastics on human health is uncertain, but it cannot be ignored and is one of the motives to reduce the growing influx of plastics into the environment. Governments, industry and civil society have an important role to play at this point, as will be discussed in Chapter 3.

2.3 ECONOMIC IMPACT OF MICROPLASTICS ON GLOBAL ECONOMY AND LOSS OF WELL-BEING

The richness of marine ecosystems contributes to the well-being of people in a complex way, and their pollution carries a threat by limiting the coastal society in particular of the fine fettle. There have been identified several negative economic impacts on three key ecosystem functions, each of which is associated with specific values and has direct and indirect consequences for humans. The first of these functions is to provide fisheries, aquaculture and agricultural materials. Marine plastics has the potential to reduce the efficiency and productivity of commercial fisheries and aquaculture through physical entanglement and damage, but also through a direct threat to fish stocks and cause big losses. And around the world, seafood is the main source of animal protein and accounts for over 20% of food consumption (by weight) for 1.4 billion people (19% of the world's population) [Golden, C. et al (2016)].

As mentioned in the previous paragraphs, plastics is often consumed by a wide range of marine species, including those, that are an essential component of the diet of other marine species, such as crustaceans and fish at all stages of their life cycle [Rochman, C.M. et al (2015)]. Polymers contained in plastics are usually rich in additives (for example plasticizers, biocides, flame retardants), and when in the marine environment, they can easily concentrate microbial pathogens and toxic persistent organic pollutants (POPS); they can accumulate in the tissues of marine animals and bio magnify in higher predators, including humans (Teuten, E.L. et al (2009)]. Plastics and related contaminants contaminate food chains, threatening fish and shellfish resources and their victims that can cause lethal and sub-lethal damage (i.e., reduced reproductive success and growth), which can affect population levels [Galloway, T.S. et al (2017)]. However, it is easy to imagine that the removal of garbage from fishing nets, as well as damage caused to catches, which in themselves can lead to a significant reduction in catches, and also take a lot of time and costs associated with repairing fishing gear damaged by marine litter, such as tangled propellers and clogged cooling systems. This can lead to a direct reduction of catches in its vicinity and an increasing risk of reducing the number of affected fish stocks. At European level, it is estimated that such damage and loss cost reach around EUR 61.7 million (Appendix A), which corresponds to a reduction of almost 1 % of the total revenue generated by the EU fleet in 2010. [Werner, S. et al (2016)]. Other sources measure it at 5 % [Bergmann, M. et al (2015)].

"For both fishing nets and pots, a cycle is set up whereby marine organisms are captured and, in turn, these species may attract predator species which may then also become trapped. Organisms which die and decay in the nets and pots may subsequently attract scavengers such as crustaceans and again these species may then also become trapped. Indeed, ghost nets have been described as perpetual "killing machines" that never stop fishing. Many organisms can be caught and trapped by ghost nets and pots. For example, one 1500-meter long section of net was found that contained 99 seabirds, 2 sharks and 75 salmon. The net was estimated to have been adrift for about a month and to have travelled over 60 miles. Ghost fishing can lead to economic losses for fisheries. For example, an experimental study on ghost fishing of monkfish from lost nets in the Cantabrian Sea, northern Spain, estimated that 18.1 tons of monkfish are captured annually by abandoned nets. This represented 1.46% of the commercial landings of monkfish in the Cantabrian Sea. A study on ghost fishing by lost pots off the coast of Wales, UK, noted that potential losses to the brown crab fishery caused by ghost fishing could be large. In the USA it was estimated that USD 250 millions of marketable lobster is lost annually to ghost fishing." [Greenpeace, (2006)].

Practically, the evidence collected suggests that the productivity, profitability and safety of the fishing industry and tray agriculture are very sensitive to the impact of marine plastics, especially when combined with wider factors, including climate change and overfishing. High dependence on seafood in nutrition means that the well-being of a significant part of the world population is very susceptible to any changes in the quantity, quality and safety of this food source [Golden, C. et al (2016)].

Another key function of the ecosystem, which is negatively affected by pollution by microplastics is cultural heritage. This means that various marine organisms have cultural and / or emotional significance for individuals, which cannot be measured in a monetary way, but which is a measure of well-being. Nowadays, there is a lot of talk about on the global scale of the washed-up whales and sea birds that have their stomachs filled with plastics. These species can generate special value for humans, and there is ample evidence that humans experience prosperity, knowing that marine animals exist and will remain for future generations, even if they never experience them directly [Aanesen, M. et al (2015)]. In research carried out by T. Börger and other scientists [Börger, T., et al (2014)], it has been proven that the problem of water contaminated with plastics causes a complex negative impact on marine species, and thus also a loss of human well-being. Public concern about plastic destruction of iconic marine species suggests that even individual incidents can have a strong and harmful effect on well-being, and that the relationship between impacts on the ecosystem and loss of human well-being is not necessarily linear [Jobstvogt, N. et al (2014)].

There is a third type of economic ecosystem function, which directly and negatively affects the well-being of people and is associated with water recreation. A society that enjoys spending free time on the coast is more often exposed to the effects of plastics and microplastics, which is why it experience many negative effects on well-being [Hartley, B., et al (2013)]. The key motive to reduce the time spent in this environment is the fear of the littering shore and water, what in result generate a number of economic costs for people earning from these activities, and these costs can include cleaning the beaches or wide damage to tourism income

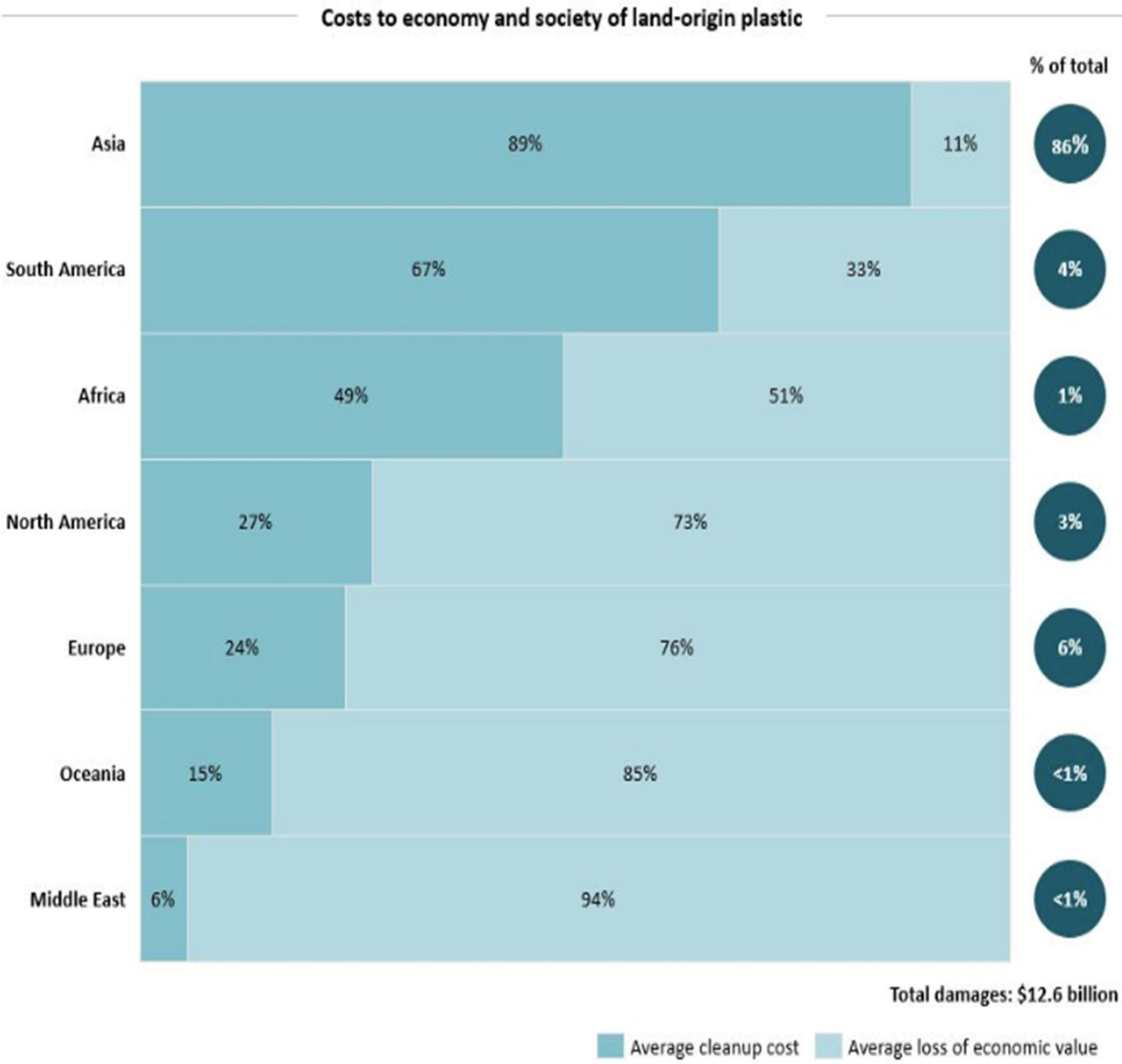
[Ballance, A., et al (2000)]. The European Commission estimates that only in the EU, activities such as cleaning the coast and beaches from objects and plastic particles that waves have washed ashore, costs EUR 630 million [*www.ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm*]. As shown in Appendix B, the costs of purifying waters and oceans vary from country to country. The presence of garbage on beaches not only has a negative impact on the economics of these environments, but also affects the physical and mental health of people. Tourists and maritime workers are particularly vulnerable to various types of threats to health, such as injury from sharp rubbish, getting tangled in the net and being exposed to unsanitary items, which has a negative impact on the mood of sunbathers and in result brings considerable economic losses [Wyles, K.J. et al, (2016)]. At the same time, the limited possibility of staying on cluttered beaches for these reasons, causes an adverse effect on health, preventing the benefits that the coast usually offers, such as promoting physical activity, facilitating important social interactions, such as strengthening family ties and improving physical and mental health, which also can lead to significant economic losses for a particular region. [Papathanasopoulou, E. et al. (2016)]. As previously mentioned, marine wastes generate serious costs on various levels for coastal regions.

According to scientists from Marine Pollution Bulletin, it is not yet possible to accurately estimate the decline in the annual provision of ecosystem services related to marine plastics, based on the basis of available research. However, the evidence collected points to a significant negative impact on almost all ecosystem services on a global scale. “In light of this evidence, it is considered reasonable to postulate a 1–5% reduction in marine ecosystem service delivery as a result of the stock of marine plastics in the oceans in 2011. Such a conjecture is conservative when compared to the reduction in terrestrial ecosystem services due to anthropogenic disturbances available in the literature, e.g. a 11–28% decline of global terrestrial ecosystem services (by value) arising from land use changes between 1997 and 2011, and a reduction of up to 31% (by value) due to urbanization in China.” [Beaumont, N.J. et al, (2019)]. In 2011, annual benefits were estimated at around USD 49.7 trillion from the services of marine ecosystems to society only. These results and values were obtained by means of maximum sustainable use (actual or hypothetical) of natural (or semi-natural) systems, reflecting functioning characteristic extensive areas with minimal changes in the environment due to human activities. Despite the limitations on the accuracy of these approximations, it is considered that the number is sufficiently precise to carry out a global analysis, and the estimation of the decrease in its value due to the presence of marine plastics can be considered as a first order approximation of an economic cost. [Constanza, R. et al. (2014)]. Mentioned 1–5% decline in the supply of marine ecosystem services is equivalent to an annual loss of USD 500–2,500 billion in the value of the benefits of these global services. Given that the resources of these marine ecosystem services in 2011 in the marine environment were estimated at 75-150 million tons. As a result, the economic costs of marine plastics associated with marine natural capital are cautiously projected at USD 3300 to 33000 per tons of marine plastics per year, based on the value of 2011 ecosystem services. These economic cost results relate solely to the interaction of marine plastics on marine natural capital and as such is the lower limit of the full economic cost of marine plastics [Jang, Y.C. et al. (2015)].

At the same time, Deloitte economists have calculated that plastic waste in rivers and oceans led to costs in key economic sectors of USD 6-19 billion in 2018. The study [Viool, V. et al, Deloitte, (2019)] covered 87 coastal countries, and the results were included in the report on "The price tag of plastic pollution". The calculations were based on a model developed by The Ocean Cleanup (a Dutch non-profit organization aimed at cleaning oceans from plastics). It is estimated that due to plastic pollution of waters, losses for the Asian economy are from 0.2 to 2.3 billion USD per year. In Europe it is USD 0.1-1 billion, and in North America it is 44-465 million USD. [*www.theoceancleanup.com*].

Figure 2.3. presents the cost to economy and society of land-origin plastics and its dependencies with average clean-up cost and average loss of economic value in 2019 for different parts of the world [Delotitte, Ocean Cleanup, (2019)].

Figure 2.3. The cost to economy and society of land-origin plastics



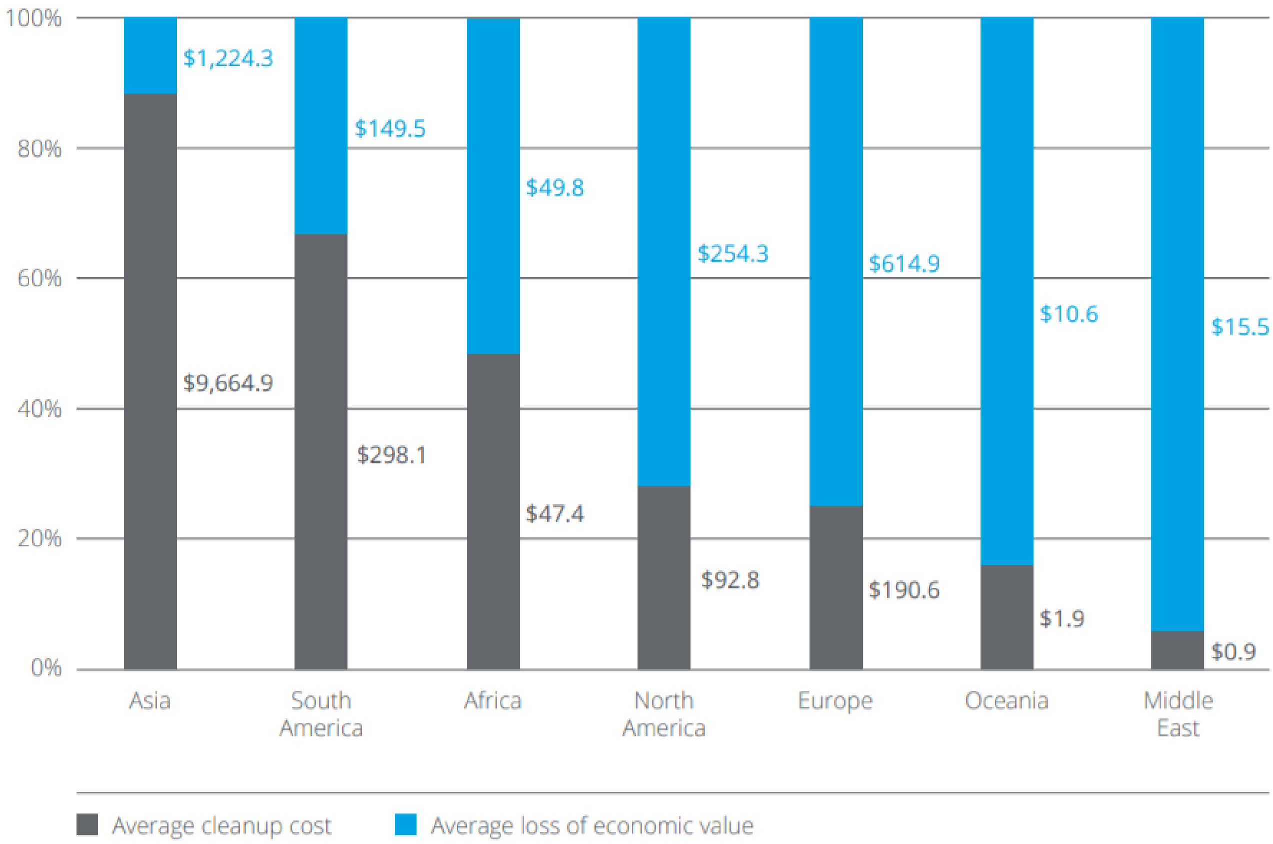
Source: Delotitte, Ocean Cleanup, (2019).

The biggest wrongdoer is of course the growing economy - Asia. By contributing the largest disposal of pollutants and various substances to waterways and oceans, it contributes 86 % of the global costs associated with plastic pollution. Meanwhile, Europe also significantly contributes 24 % when the Middle East represents the lowest part of the cleaning costs associated with pollution originating from land, but thanks to that it lost the highest level of economic value [Delotitte, (2019)].

Deloitte points out that the consequences of waste in the seas are mainly felt by local coastal governments, and that the sectors most affected are fisheries, aquaculture, tourism and commercial shipping. Experts divide the impact of plastic water pollution into two groups. The first is indirect impact (i.e. impact on biodiversity and ecosystems) that combines financial costs with long-term environmental changes. The destruction of nature has a huge impact on the environment, which is ultimately difficult to convert into money. First of all, this is associated with the deterioration of the health of the population and the degradation of the marine environment - which by no means cannot be converted into money. As previously mentioned, it is estimated that as a result of the disintegration into millions of fragments of plastic microparticles, more than 100,000 fish, birds, whales and turtles die each year due to ingestion or asphyxiation with plastic residues. The second group is the direct quantitative effects (i.e. measures related to purification and potential loss of economic value) that financially and short-term burden the economy. Here it stands out a decrease in revenues from tourism and other industries, as well as charging local authorities with costs of water purification.

Deloitte specialists emphasize that the biggest cost associated with water pollution is treatment. Removing plastic from maritime areas, ports and beaches can cost USD 5.6 billion to USD 15 billion globally (Figure 2.4.).

Figure 2.4. An overview of the cost components in 2018 by region (in USD mln)



Source: Deloitte, The price tag of plastic pollution (2019)

Asia is the continent that may incur the highest purification costs, where such activities can consume between USD 5.3 billion and 14 billion. It is not surprising that such high purification costs in Asia, because based on the density of pollutants in the rivers, we can see that 19 countries surveyed from this continent account for as much as 82 % global emissions of plastic garbage flowing into the oceans. In North America, purification may involve expenses in the range of USD 47-139 million, while in Europe from 73 to 308 million USD. Despite the negative impact of pollution on the economy, it is worth remembering that damage to the environment is much more difficult to reverse and will affect the functioning of future generations.

Report “The new plastics economy, Rethinking the future of plastics” of Ellen MacArthur Foundation postulates, that the current plastics economy has disadvantages that are becoming more apparent day by day. “After a short first-use cycle, 95% of plastic packaging material value, or USD 80–120 billion annually, is lost to the economy. A staggering 32% of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as the ocean and clogging urban infrastructure. The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, is conservatively estimated at USD 40 billion annually - exceeding the plastic packaging industry’s profit pool. In future, these costs will have to be covered.” [Ellen MacArthur Foundation, (2014)]. And since the majority of marine plastics take decades, if not centuries, to fully degrade [Andrady, A.L. et al (2015)], and given annual increases in plastic production and losses to the environment (between the 2011 and 2017, an additional 28–71 million tons of plastics are predicted to have been added to the marine environment from land-based sources, it is likely that the negative ecological, social and economic impacts of plastic pollution will continue to increase into the future.

The evidence presented here demonstrates that by acting to reduce marine plastic pollution society would be an investing in both the current and future provision of marine ecosystem services and the human benefits they provide [Jambeck, J.R. et al. (2015)].

CHAPTER 3

PRACTICAL SOLUTIONS TO PLASTIC POLLUTION

As mentioned in previous Chapters, 90% of plastic waste found in oceans goes through only 10 large rivers, and as estimated by scientists, reducing the plastic content only in these rivers by half, would reduce the total "inflow" of plastics to the oceans by 45 percent. Dr Schmidt confirmed that it would be a great success to halve the amount of plastics from river basins, however, locally better waste management and public awareness are needed [Schmidt, CH. et al (2017)]. It has also been proven that geographical location also plays a significant role. People living in the same country but closer to the coast have been noticed more awareness of sea problems and people's sensitivity to this problem [Buckley, P. et al (2011)].

However, the problem of plastics is a perfect illustration of the importance of individual human choices without organized, top-down activities on a large scale. Even if we want to completely abandon the production of plastic waste, it will be extremely difficult for us. Plastics is part of the entire food industry. Trays, bags and boxes made of plastics mean that food on store shelves can be stored longer. As a result, it is extremely difficult to do shopping so that the basket does not contain a lot of plastic packaging. In the fight against plastics, system solutions are needed.

As a result of publicizing this problem lately and thanks to many studies proving the negative aspects of microplastic contamination, we have a better understanding of the scale of the problem associated with their presence and the connection between larger plastic components (macroplastics) and the generation of "secondary" microplastics. It can be said with greater conviction that plastics and microplastics are a huge global problem for marine ecosystems, human health and the global economy. Although there is a lot of research confirming this thesis, there are still significant areas of uncertainty that will require further research. Policy makers and other decision makers in the public (e.g. municipalities) and private (e.g. production, retail, tourism, fisheries) sectors now need guidance on how to best address the problem of microplastics. For too long, various decisions were delayed for many years before sufficient evidence of the harmfulness of plastics was collected.

3.1. LEGAL SOLUTIONS FOR THE PROBLEM OF CONTAMINATION WITH PLASTICS

Based on new knowledge, it becomes clear that we should think of plastics as a type of pollution from the perspective of their production and to prevent the release of plastic products and waste into the environment. In practice, there are no specific provisions for microplastics as such contaminants, and various types of directives / regulations (cosmetics Regulation and REACH) are determined on a case-by-case basis. To help solve the problem of plastic waste, the European Union, in 2017 adopted an important Directive number 2015/720 by the European Parliament and the Council, in order to prevent or reduce the impact of packaging waste on the environment [*www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015L0720*]. Although plastic shopping bags are packaging within the meaning of this Directive, it does not contain specific measures regarding the consumption of such bags. The directive imposes on the Commission to study the environmental impact of using oxidative plastic shopping bags.

The European Commission has targeted 10 single-use items as well as lost and abandoned fishing nets. It was a consequence of the alarming increase in the amount of harmful plastic waste in seas and oceans. The new regulations will prohibit the use of plastics in some products. Where there are easily available and affordable substitutes for them, single-use plastic products will be banned from placing on the market. The ban will cover plastic sticks, cutlery, plates, straws, agitators and cups for drinks as well as food containers made of foamed polystyrene or products made of oxidizable plastic (so-called oxidizing plastics). As for other products, the emphasis was on limiting their use by setting national consumption reduction targets. For example, from 2025, EU member states will be required to recycle at least 25 % plastic bottles (PET). In 2030, a minimum of 30 % of all plastic bottles are to be recycled [European Commission, (2018)]. Appropriate design and labeling requirements are also expected to help reduce plastic waste. On the packaging of wet wipes for personal hygiene will have to be markings that will inform consumers about the presence of plastics in the product and the environmental harm if it is thrown elsewhere other than in the bin. Manufacturers of plastics containing tobacco filters will have to cover the costs of public cigarette butt collection systems, as well as the maintenance of adequate infrastructure, for example waste containers in popular places for smokers. Plastic-containing tobacco filters are the second most littering disposable plastic product in the EU [*www.ec.europa.eu/commission/presscorner/detail/en/IP_18_3927*].

New regulations have already been introduced in various countries to combat pollution. The United Nations Convention on the Law of the Sea (UNCLOS), adopted in the early 1980s, assumed global efforts to protect the marine environment. Back in 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development, which aims to “prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution” by 2025 [*www.sustainabledevelopment.un.org/post2015/transformingourworld*]. On December 28, 2015 President Obama signed the Microbead-Free Waters Act of 2015, banning plastic microbeads in cosmetics and personal care products [*www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs*].

In Norway, however, it was introduced the bail system for plastic bottles and also city initiatives to promote drinking tap water [*www.thelocal.no/20200213/norway-offsets-fondness-for-plastic-bottles-with-high-recycling*], reusable coffee mugs used by the Freiburg café association in Germany [*www.zerowasteeurope.eu/wp-content/uploads/2018/09/FreiburgCupfinal*], a ban on the use of disposable plastics at cultural events in Munich [*www.dw.com/en/earth-lovers-in-lederhosen-oktoberfest-goes-green/a-18722603*] and a ban on the use of disposable tableware in France [*www.france24.com/en/20191231-france-begins-phasing-out-single-use-plastics*]. The new regulations will reduce environmental pollution by plastics and they will improve the European recycling system. From 2021, disposable cutlery, plates and straws await the end, and Styrofoam cups and food packaging will be withdrawn from the market [*www.europarl.europa.eu/news/en/press-room/20190321IPR32111/parliament-seals-ban-on-throwaway-plastics-by-2021*]. The trouble with them is that, even if they can be collected selectively, they most often end up in incineration plants because they are a serious challenge for recyclers and entities recovering raw materials. The ban will also cover the so-called oxo-degradable plastics, once promoted, which also just fall apart instead of composting. A universal bail system for plastic bottles will also be implemented soon. Selective plastic bottle collection of 77% cannot be achieved without it. in 2025 and 90% in 2029, and that was what was agreed during the negotiations on the content of the directive [*www.ec.europa.eu/commission/presscorner/detail/en/ MEMO_19_1481*].

Therefore, the Proposal for the Circular Economy Package announced in December 2015 is the European Commission's response to these challenges, which aims to reconcile environmental and business interests. The proposals provided a clear signal to economic operators that one of the European Union's priorities is to use all available tools to fully implement the new principles of ecological and raw material policy [*www.ec.europa.eu/environment/circular-economy*]. The first version of the Circular Economy Package was presented in July 2014, at the end of the second term of office of the President of the European Commission José Manuel Barroso. After completion of the legislative procedure, the final acts were signed on 30 May 2018. Member States are required to transpose the directives into national law by 5 July 2020.[*www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI(2018)625108*]. The package contains a proposal to significantly increase the mandatory levels of waste recycling, which met with criticism of both business and governments of member states. As a result, in December 2014, the Commission, in its new composition and under the chairmanship of Jean-Claude Juncker, withdrew from the previous proposal, justifying the desire to prepare a "more ambitious package of measures", covering the entire circular economy, and not only waste [GS1, (2019)]. The new EU

Circular Economy Action Plan was officially adopted in 2018 [*www.ec.europa.eu/commission/presscorner/detail/en/IP_18_3846*].

According to the justification of the Commission, the plan takes into account a very wide range of legislative proposals that are aimed at reducing food waste, developing quality standards for secondary raw materials, developing eco-design, i.e. design ensuring products durability, reparability as well as recycling or recovery. The package also includes a strategy on plastics related to issues related to their recycling, biodegradation, as well as the presence of hazardous substances in plastics and a significant reduction of marine waste. It also proposes new provisions on fertilizers to encourage the recycling of nutrients, while ensuring protection of human health and the environment. The plan provides for a series of actions for the reuse of water, as well as a review of legislation on eco-labeling (Ecolabel) and the eco-management and audit system (EMAS) [*www.eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN*].

The Circular Economy Package also includes proposals to set new waste management targets to be achieved by 2030, aiming to significantly increase levels of recovery and recycling of waste (municipal to 65%, packaging to 75%), and also a significant reduction in municipal waste storage. The Package includes four legislative proposals amending the following legal acts:

- Framework Directive 2008/98 / EC on waste;

- Directive 1999/31 / EC on the landfill of waste;
- Directive 94/62 / EC on packaging and packaging waste;
- Directive 2000/53 / EC on end-of-life vehicles;
- Directive 2006/66 / EC on batteries and accumulators and waste batteries and accumulators;
- Directive 2012/19 / EU on waste electrical and electronic equipment (WEEE).

According to the European Commission, some sectors face particular challenges in the context of the circular economy, due to the characteristics of their products and value chains, their environmental footprint, and often dependence on non-European materials. As a result, five priority areas requiring a special approach are listed in the Circular Economy Package: plastics, food waste, critical raw materials, construction and demolition waste, biomass and bioproducts.

The interests of individual 28 EU countries are also particularly important in developing a common position. Looking at the level of involvement in preparations for the transition to the Circular Economy model, divergent approaches to the new concept can be seen. Certainly, the pioneers include the Netherlands, which already in 2013 prepared a report entitled "Opportunities for a circular economy for the Netherlands" [*www.government.nl/documents/reports/2013/10/04/opportunities-for-a-circular-economy-in-the-netherlands*], and in September 2016 adopted a strategy for the Circular Economy with a perspective up to 2050 [*www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050*]. Finland followed the leader and, at the end of 2016, adopted a 'road map' For the Circular Economy [*www.circulareconomy.europa.eu/platform/en/strategies/leading-cycle-finnish-road-map-circular-economy-2016-2025*].

Ecological organizations like to see in circular economy a return to nature, to a closed cycle in nature, where there is no uselessness and every waste is "managed" in one way or another. And although similar comparisons often occur, the natural world can only be an inspiration for a Circular Economy. It is not without reason that we are talking about "circular economy" and not about "circular environment" [*www.ephemerajournal.org/contribution/against-wasted-politics-critique-circular-economy*].

Because at first glance it may seem that Circular Economy is an expression of ecological concern for the depletion of resources, stopping excessive exploitation of our planet, as well as reducing the volume of waste overwhelming the planet. That is right, but ambitious rules - to really apply - must be realistic. That is, designed not to stifle the competitiveness of EU enterprises. In other words, circular economy aims to become a double eco - ecologically and economically.

The European Commission’s Circular Economy Action Plan sets out 54 ways to "close the loop" of product lifecycles. It puts a major emphasis on finding new, innovative means to move away from a 'take-make-dispose' culture, for instance by recycling and re-using products for longer. This approach helps to drive forward not just environmental, but also economic progress. To sum up, a circular economy can offer major benefits:

- 450 million fewer tons of EU carbon emissions by 2030
- Savings of €600 billion for EU businesses (8% of their annual turnover)
- 580,000 new jobs

The Action Plan is accompanied by over €10 billion in funding, confirmed by the Commission for 2016-2020" [*www.ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en*].

According to a study of the Ellen MacArthur foundation and McKinsey for the European Commission, the transition to a Circular Economy model is expected to provide annual savings of 4%. European Union GDP. This is a tempting promise for European economies tired of successive crises and a painful tightening policy. The European Commission also hopes that the implementation of the Circular Economy Strategy will contribute to increased investment, wider use of regulatory incentives and the development of eco-innovation [*www.ellenmacarthurfoundation.org/circular-economy/concept*].

This economic model is based on the idea of recovering more and more waste so that it can be recycled or reused. It is estimated that increasing plastics use after life to 55% and decreasing landfill to 10% in North America and Europe alone can reduce environmental costs by USD 7.9 billion. For the packaging sector, for example, manufacturing companies could find agreements with plastics recycling companies to optimize the process, such as standardizing packaging formats to facilitate handling during recycling [Lord, R. (2016)]. Of course, the transition from a linear economy to a circular economy is a solution that should be policy driven and encouraged, also because real environmental and social benefits are expected. In addition, policy should aim to tackle the real problem of plastic or disposable. It seems that the consumer himself cannot and will not be able to solve the problem of plastics, but he will always need careful and decisive political guidelines.

Italy as a recent example of an economy implementing "green" solutions, is particularly trying to fight plastic pollution and to introduce changes in the form of plastic taxation. The majority of Italians believe that the manufacturing companies are mainly responsible for the use of plastic as a component of packaging, and that the state should oblige them to reduce its use. And citizens are also willing to spend more on environmentally friendly packaging. According to a Nielsen survey, 54% of Italians are in favor of introducing a tax for companies that produce disposable plastic packaging. And 64% expect a reduction in the use of non-recyclable plastic in packaging [*www.repubblica.it/economia/rapporti/osserva-italia/stili-di-vita/2020/01/16/news/italiani_ambientalisti_il_54_e_favorevole_alla_plastic_tax-245879094/*].

The tax on plastics will enter into force on 1 July 2020 and will be worth 45 cents per kilo; expected revenues correspond to EUR 140.6 million, compared to the initial forecast of EUR 1 billion [*www.money.it/plastic-tax-2020-come-funziona-chi-paga-nuova-tassa-legge-bilancio*]. The Conte II Cabinet with article 79, contained in the bill "State budget for the financial year 2020", provides for a tax on the consumption of plastic products with single use (the so-called MACSI) which have a function of containment, protection, handling or delivery of goods or food products. The illustrative report of the bill [*www.senato.it/service/PDF/PDFServer/BGT/01125659.pdf*] specifies that the MACSI that fall within it are made also in the form of sheets, films or strips, with the use, even partial, of plastic materials, consisting of organic polymers of synthetic origin and are designed or placed on the market to make multiple transfers during their life cycle or to be reused for the same purpose for which they were designed. The report clarifies that, by way of example, among the products subject to the tax, there are "polyethylene bottles, bags and trays for food, tetrapak containers used for various liquid food products (milk, soft drinks, wines, etc.) as well as containers for detergents made of plastic materials. Among the items used for the protection or delivery of goods such as household appliances, IT equipment, etc., however, include, among other things, expanded polystyrene packaging, plastic bubble wrap rolls and stretch plastic films". Paragraph 2 of article 79 also establishes that semi-finished products - with plastic materials - used in the production of the same MACSI as well as those devices that allow closure (e.g. caps), marketing or presentation (labels) are also considered MACSI or manufactured products made entirely of different materials (e.g. glass) from those of which MACSI is made. The tanks and buckets with long-lasting use and the containers used for the storage of various objects do not fall into the category of disposable products. Compostable products and syringes are also excluded from the tax.

The amount of the tax was set at 1 euro per kilogram of plastic contained in the MACSI. According to a provisional estimate of the political report, the effect on a 1.5-liter plastic bottle will be a price increase in a range of between 2.5 and 6 euro cents (an increase between 5.5% and 27%), depending on the quality of the water. The State recognizes a tax credit of 10% of the expenses incurred, from January 1 to December 31, 2020, to those companies active in the plastics sector involved in the provision for the technological adjustment aimed at the production of biodegradable and compostable products. This relief will have a maximum amount of 20 thousand euros for each beneficiary, with an overall spending limit for the state of 30 million euros. The tax obligation will start with the production or import of these products and will be payable upon release for consumption in the national territory. However, it will not be applied to exported products. The tax will be paid by the manufacturer or the importer of the product [*www.valigiablu.it/plastica-rifiuti-tassa/*]. According to this report, the aim of the provision is "a reversal of the trend in the common use of plastic products, while promoting the progressive reduction of the production and therefore of the consumption of disposable plastic products".

Anyway, reducing the impact of plastic on the environment is done by better collection, and above all by a higher rate of plastic recycling. The path to zero waste must combine "hard" measures (such as the management of organic waste, the separate collection of different types of waste, decentralized and low-tech models, economic incentives, bans on certain materials and policies and practices for reducing waste) and "soft" (such as involving residents and businesses in all phases of policy development). All of this helps to create new business models and generate savings that are reinvested for the community. In this sense, therefore, the objective of the plastic tax cannot be limited to earning cash, but to significantly reduce the environmental impact of plastic consumption. It is also necessary to adopt long-term policies that also give citizens important alternatives, both in terms of materials and solutions that avoid packaging production according to the principle: in the case of returnable containers fully recyclable or reusable, and finally, tax receipts which should at least partly focus on more sustainable consumption policies and promote a better collection and recycling of post-consumer plastic waste [*www.altroconsumo.it/casa-energia/pulizie/consigli/come-ridurre-la-plastica*].

3.2. CLEANING THE OCEANS

As the report of Greenpeace states, “Many different measures have been adopted to try to prevent garbage from entering the marine environment or to clean up existing marine debris. These measures can be categorized into global, international and national initiatives, clean-up operations of beaches and the ocean waters and education programs. For example, an important international initiative that was taken many years ago to help prevent ships from discarding their garbage at sea was the International Convention for the Prevention of Pollution from Ships (MARPOL)” [Greenpeace, (2006)].

The targeted treatment of floating marine waste or waste deposited on the seabed is limited to distributed initiatives and programs. In most cases these are voluntary or financed by private entities, local authorities [*www.kimointernational.org/fishing-for-litter/*] or the EU. A number of projects have already been undertaken around the world to reduce the amount of marine litter and the EU is also very active in this field. For example, the current European Maritime and Fisheries Fund foresees investments of EUR 22 million to support fishing for waste operations in the period 2014-2020. Compared to the previous funding period, the number of Member States planning "fishing operations" has doubled compared to operations carried out under the European Fisheries Fund. The number of planned operations increased by 130% and planned EU funding by 320% [European Commission, (2018)]. Likewise, in those seas and oceans in the European neighborhood that are affected by the problem of littering, the European Commission has committed to 2020 to ensure the so-called Good Enviromental Status (GES), which was included in the Marine Strategy Framework Directive 2008/56 / EC, MSFD, adopted in June 2008.

As for more practical solutions to the problem, several important projects have been organized. The name Boyan Slat says little, but this young Dutchman came up with an idea how to eliminate the Great Pacific Garbage Patch. In 2013, he founded the Ocean Cleanup foundation, which managed to raise over $ 30 million to free the Earth from plastic in the ocean. Ocean Cleanup organized a series of expeditions, during which he examined the mass and distribution of plastics in the oceans. All this to determine what technology is best for collecting garbage, also in economic terms [*www.theoceancleanup.com*]. On September 8, 2018, a large collection campaign began. A large buoy floating on the water surface, over half a kilometer long, was launched, into which (thanks to sea currents) five tons of garbage are to be sent monthly. Within a year and a half there will be sixty such devices. Within five years, half of the floating waste is expected to disappear, and by 2040 – 90 % [*www.theoceancleanup.com/milestones/interceptor-2-point-0/*].

But the cleaning project of the Great Pacific Garbage Patch is facing also some criticism. Some say it's just sliding on the surface or that is threatening a marine life [*www.theguardian.com/environment/2018/dec/20/great-pacific-garbage-patch-20m-cleanup-fails-to-collect-plastic*]. Another problem appearing is that there is a lot more of such collective pollution. Four other (though slightly smaller) garbage patches float on Earth's oceans: one in the South Pacific, two in the Atlantic and one in the Indian Ocean.

One of the first non-profit organizations taking action to clean beaches was the Ocean Conservancy in Texas in 1986. Later, the organization has since evolved into International Coastal Cleanup (ICC), in which 127 countries are involved. Each of them combines one day a year in the idea of cleaning their local beaches [*www.oceanconservancy.org/trash-free-seas/international-coastal-cleanup/*]. Another important global cleaning program, also organized by UNEP, is the well-known "Clean Up the World" program, involving over 40 million people from 120 different countries in cleaning operations and has a special marine waste initiative [UNEP (2005)].

However, special boats are already working in the coastal waters and bays and ports in the USA to collect garbage from the water surface (so-called skimmer boats). Experts from the Institut Superieur de Design in the French Valenciennes have developed a design for special drone called "automatic sea dumpsters" that will collect plastic bags or containers from the surface of the water (and up to 20 meters deep into the ocean) [*www.hometowndumpsterrental.com/blog/ocean-drone-captures-sea-garbage-like-a-butterfly-net*]. When they fill up, they will wait for the garbage truck on special floating docks. Americans, Hong Kongs and Japanese involved in the Project Kaisei have a different idea, who, thanks to a specially rebuilt sailing ship, are trying to convert the plastics immediately collected from water into diesel oil [*www.projectkaisei.org*]. The whole thing has an additional Polish accent. The ship "Kaisei" was built in the shipyards in Elbląg and Gdańsk (Poland). Unfortunately, this ship can process only 2 thousand tons of sea plastic per year. For now, everything is rather a scientific experiment and a social campaign at the same time.

In Greece, NGOs are also involved in this matter. HELMEPA organized local people to voluntarily clean the beaches and offered them a lot of educational materials as well as for schools (UNEP 2005). The Thai authorities also carried out a large operation to remove the island of garbage, which stretched over an area of one square kilometer. Four ships, working continuously for 10 days, however, removed only 300 tons of waste that went to the Gulf of Siamese as a result of the floods that hit the south of the country. Such a pace of cleaning the seas and oceans is not enough. It is also known for a long time that it is much better (and cheaper) to prevent problems than to deal with them later. Above all, collecting plastic does not solve the basic problem - that new waste goes to the oceans every day, and this must be resolved through the support of state representatives and sustainable development. In addition to clean-up programs of marine debris, it is essential that sufficient waste recycling or disposal facilities are provided (UNEP 2005).

3.3. TOWARDS A CIRCULAR ECONOMY

Circular economy is a concept that has hit the European business dictionary by storm, increasingly displacing the well-known, but somewhat commonplace "sustainable development". One of the main promoters of the concept has been the Ellen MacArthur Foundation. Gaining popularity of circular economy is to be a response to the challenges of the modern world, both economic and environmental, as well as social. Some will say it is utopia, others that here people have a new paradigm in economics and a chance for sustainable development to finally enter the mainstream shaping the EU economy for the next decades. A circular economy cannot be denied the potential to focus business, administration, but also ecological organizations. This can be seen at conferences from industry to general economy, from the Economic Forum to the European Forum for New Ideas. Circular economy has recently been a "hot" topic and nowhere to be missed.

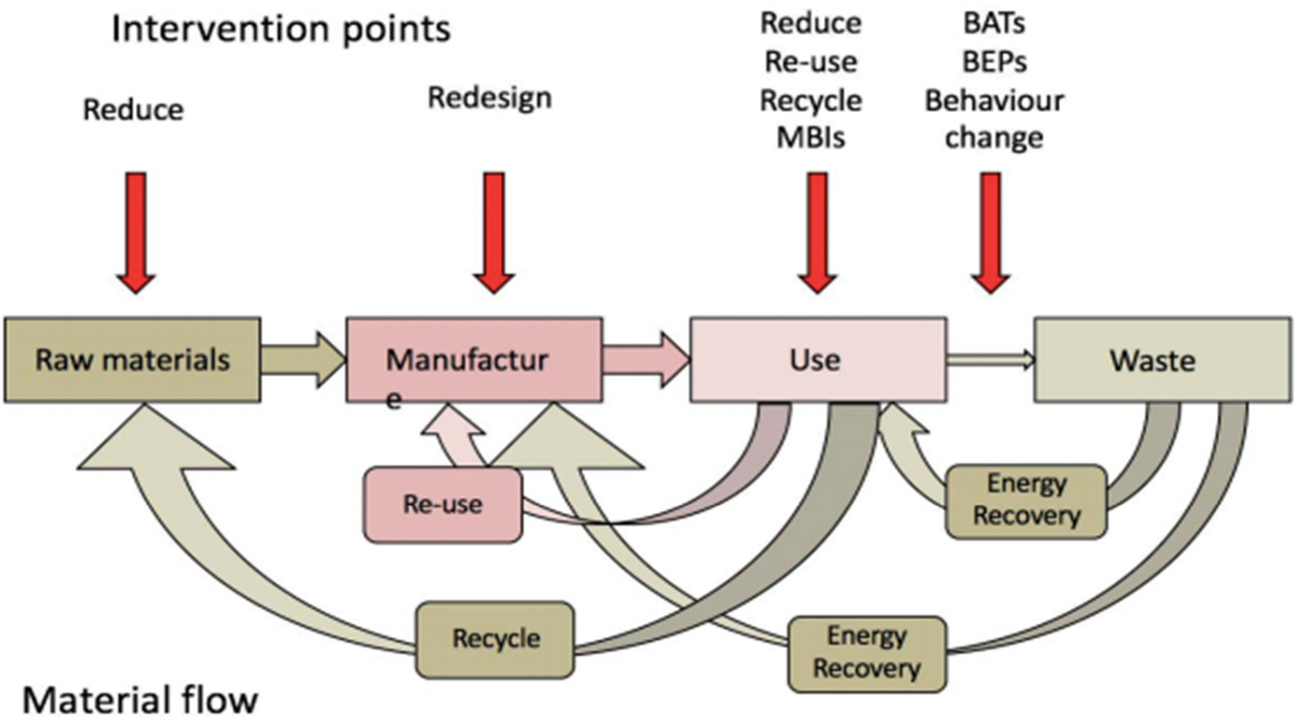
This new economic model is based on the assumption, that the value of products, materials and resources is to be maintained in the economy as long as possible, in order to reduce waste generation to a minimum (Figure 3.1.). In this concept, raw materials are repeatedly recycled, often moving from one industry to another. In other words, it is about closing the product life cycle and moving from a **linear economy model** (raw material acquisition - production - utilization - waste utilization) to a **circulation model** (production - utilization - utilization of waste as raw material in the next production cycle) [European Environment Agency, (2017)].

Figure 3.1. Cycle of a Circular Economy.

Source: UNIDO

“Creating a ‘circular economy’ which works effectively, and is accepted by business and the public, requires a great many intermediate stages, including introducing appropriate infrastructure and investment, and facilitating behavioral change throughout the supply chain. Without these changes the concept is likely to remain for many as an aspirational target rather than become an everyday reality. The goal of a circular economy is to severely restrict both the use of new raw materials and the production of residual waste. A fundamental requirement is to reduce overall consumption, recognizing that the present per capita use of energy and other resources is extremely unequal." [UNEP, (2006)]. Figure 3.2. presents a simple circular economy model using plastics for closed loop production, showing potential intervention points and the flow of materials and energy.

Figure 3.2. Conceptual representation of the circular economy.



Source: UNEP, (2006)

Energy recovery in this model was used to close the loop, however, if possible, waste generation should be designed outside the plastic cycle, which will encourage the development of improved collection infrastructure. The design of materials and products can be improved to increase the end of life value and hence provide an incentive to prevent leakage, especially for those working in the informal waste sector [World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company (2016)].

As already mentioned in the previous paragraphs, packaging constitutes a huge amount of waste thrown away, and striving to reduce the amount of packaging waste stored is also an important assumption of the circular economy and, at the same time, one of the legislative assumptions of the European Union. The packaging is to be sorted after use, and the largest percentage should be subject to the recovery of raw materials that will be used in the production process of subsequent packaging. The very choice of packaging type for a given food product is extremely important. First of all, it is important to focus on environmentally friendly materials that are easily recyclable. Secondly, the form of packaging should be thought out so that it can prevent food waste by the consumer. For example, a ketchup bottle with a long, narrow neck contributes to food waste more than bottles with short, wide necks or jars. It is similar with plastic tubes, from which it is difficult to empty the ending product [*www.veolia.pl/gospodarka-o-obiegu-zamknietym-ekonomiczne-rozwiazania-dla-przemyslu-spozywczego*].

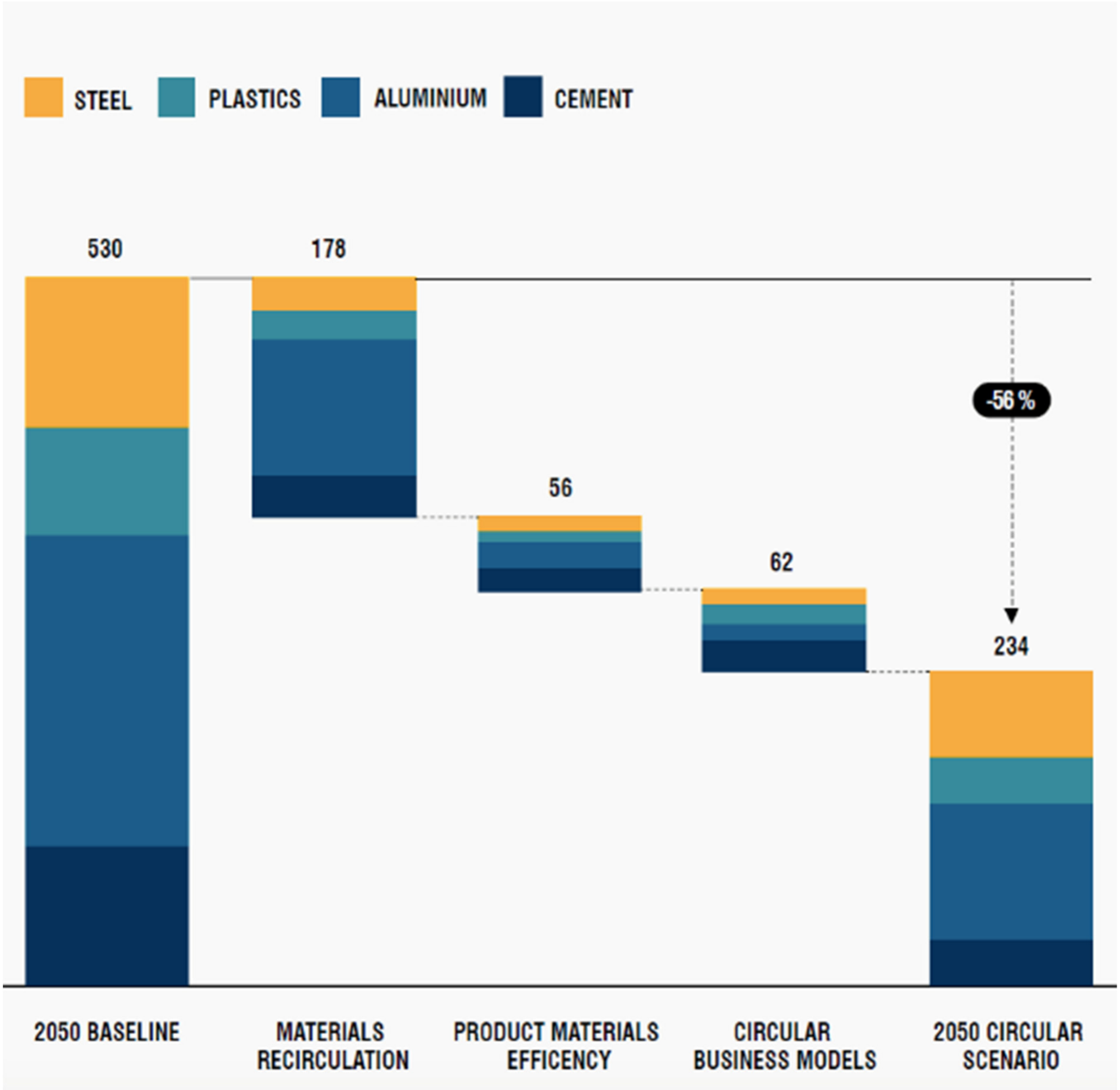
At the same time, educating consumers about circular economy and recyclable materials is an important issue. It happens that the consumer rejects the product for purely aesthetic reasons. On the same principle, as many customers will not choose recycled paper, they will not reach for a PET bottle that has been used several times, which will lose its aesthetic value or an opaque glass bottle made of recycled glass [*www.hbr.org/1993/11/recycling-for-profit-the-new-green-business-frontier*].

The L'ObSoCo study conducted in July this year at the request of DS Smith (Appendix C) shows that the vast majority of respondents (86%) say that environmental problems are currently the main challenge facing society, and the type of product packaging is a concern of consumers all over Europe. Germany is most concerned about the environmental impact of packaging (83%), followed by the British (78%), Belgians (73%) and Poles (71%). Therefore, it is not surprising that Europeans declare their willingness to buy products in packaging containing less plastic. As many as 62% of European consumers say they would be willing to pay more for food products in packaging with less plastic. A similar number (59%) admits that they sort and recycle more waste than five years ago. In addition, with two packaging options for the same quality product, more than 90% of Europeans say they choose a packaging that contains 85% less plastic. When asked if they would pay 12.5% more for such a product, 62% of respondents said they were willing to do so [*www.hbrp.pl/b/jesli-opakowania-to-tylko-zrownowazone/PRQIQpEpU*].

According to the latest analysis by the Finnish organization Sitra and the European Climate Foundation, the circular economy can significantly help achieve the objectives of the Paris Agreement. The report focuses on four industry sectors, such as steel, cement, aluminum and plastic, which account for around 66% of total CO2 emissions from European industry. If we do not do much to reduce emissions in these sectors (e.g. by modernizing technologies, increasing the energy efficiency of processes or increasing the share of green energy), in 2050 emissions will be 530 Mt CO2 (Figure 3.3.). Now it is 564 Mt CO2, so the reduction would not be very significant. The situation is different when the idea of the circular economy is used on a large scale. Now it is 564 Mt CO2, so the reduction would not be very significant. The situation is different when the idea of the circular economy is used on a large scale [*www.sitra.fi/en/publications/the-role-of-the-eu-ets-in-increasing-eu-climate-ambition]*.

Figure 3.3. EU emissions reductions potential from a more circular economy, 2050.

Mt of carbon dioxide per year



Source: www.sitra.fi/en

The conclusions from the implementation of such a scenario look promising. According to them, the implementation of circular economy principles in these sectors can reduce emissions associated with their production by 56% by 2050 [*www.sitra.fi/en/publications/the-role-of-the-eu-ets-in-increasing-eu-climate-ambition*].

Harvard Business Review found that companies, which became successful in implementing the circular economy focused on three things: "(1) They all implemented modular product architectures; (2) they leased, instead of sold, at least some of their products; and (3) they expanded their refurbishing operations. Together, they create the scale needed to make CEs profitable." [*www.hbr.org/2018/07/rethinking-sustainability-in-light-of-the-eus-new-circular-economy-policy?autocomplete=true*]. The model enterprises that have successfully implemented the circular economy include the Dutch Douwe Egberts Master Blenders plant or the Bonduelle factory in Hungary. In both of these plants, Veolia was responsible for implementing closed-loop solutions.

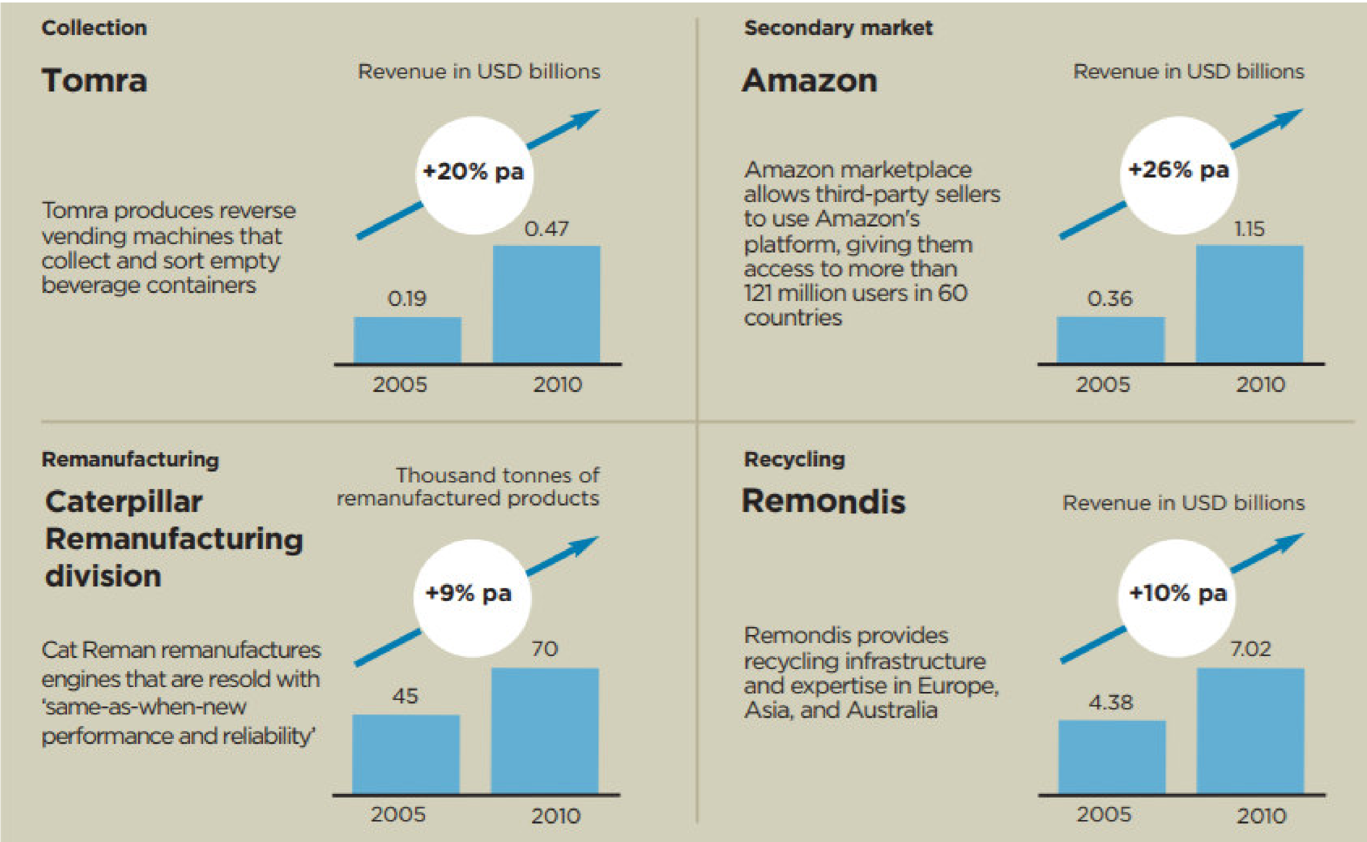
Douwe Egberts Master Blenders in the Netherlands is a coffee production plant, and the main by-products include coffee grounds, which are currently used to generate steam in a biomass boiler designed, built and operated by Veolia. As a result of cooperation, Veolia also took over the management of plant installations supplying drinking water and compressed air, as well as the operation of sewage treatment plants. As a result, Douwe Egberts reduced CO2 emissions by 14,000.

tons per year, and reduced operating costs by 10% due to lower consumption of gas used for steam production and reducing the costs of coffee grounds utilization. In addition, the plant does not transfer any waste to the landfill, it meets legal and environmental requirements. By transferring responsibility for the supply of industrial media to a trusted partner, the client could focus on core business, which allowed him to increase production [*www.jacobsdouweegberts.com/globalassets/corporate-responsibility/jde-cr-report_2106192.pdf*]

The Bonduelle plant in Hungary, which due to new legal regulations had to build an on-site sewage treatment plant, implemented the solution proposed by Veolia - using the biogas plant as a by-product as a fuel for a small reserve boiler, supplying steam to the production process. This allowed to improve the plant's energy efficiency while reducing energy production costs by 17%. The factory saves 350 thousand Nm3 of natural gas per year and avoids 650 tons of CO_2 per year [*www.planet.veolia.com/en/bonduelle-food-beverage-industry-wastewater-recovery*].

Other companies that provide reverse cycle solutions and services are TOMRA, Amazon.com, Inc., Caterpillar Remanufacturing ltd and Remondis SE & Co. KG (Figure 3.4.) These companies moving in the direction of a circular economy will enjoy attractive development opportunities.

Figure 3.4. The new 'reverse' sector created by the circular economy



Source: Ellen MacArthur Foundation, (2013).

It would be best to implement a circular economy as soon as possible, which not only limits the generation of waste (because waste is also a raw material), but also has a positive impact on the climate by reducing CO2 emissions. In the following paragraphs other practical solutions for the circular economy will be discussed.

3.4. THE POWER OF RECYCLING

After what has been said so far, the engineering value of plastics should be out of the question, however the problem of waste remains. Fortunately, this is a topic that is deeply felt by public opinion and the scientific community and is therefore highly studied. From an economic point of view, there is a huge problem in Europe of wasting materials, money and energy [*www.eea.europa.eu/themes/waste/intro*]. Meanwhile, using recycling, the production of secondary raw materials is burdened with much lower specific emissions than the use of primary raw materials. Of course, this option requires a well-functioning system of collecting raw materials, avoiding impurities and using the right composition of the raw material mixture to maintain quality. Over time, various alternatives or solutions have been developed that can be implemented, and as many in the development phase.

One of the most important approaches is to better manage the disposal phase, i.e. the end of life of plastics. "The Plastic Pollution" study has analyzed plastic disposal methods throughout history. In 1980, 100% of the plastics was thrown into landfill, i.e. the worst possible method was used, if we also consider the fact that the landfills were probably not completely compliant, and therefore the risk of dispersion in the environment was quite concrete, the damage is even greater. In the following decade a fraction was incinerated, but only from 2000 onwards there was a significant percentage of recycling which today stands at around 20% plastics can be challenging to recycle, particularly if they contain additives and different plastic blends [Dalberg Advisors, et al (2019)].

There is still a high level of landfilling (31%) and the incineration of plastic waste (39%), the level of landfilling has been somewhat reduced in the last decade, but incineration, on the other hand, has increased. According to estimates by the Ellen MacArthur Foundation, 95% of the value of plastic packaging material, i.e. between EUR 70 and EUR 105 billion per year, is lost to the economy after a very short cycle of first use. So much global economy would be able to save on more sustainable development [Ellen MacArthur Foundation, (2014)].

Greenpeace in report "Bottling It" [*www.storage.googleapis.com/gpuk-static/legacy/Bottling-It_FINAL.pdf*] states that six of the world's largest beverage companies use only 6.6 % in their production recycled material. One-third of these companies do not intend to increase the reuse of material. And plastic bottles could be made from this recovered material almost 100 percent, additionally, using less energy in production. However, aesthetic considerations are an obstacle. A bottle made from recovery is no longer as smooth, transparent and shiny and it is difficult for companies to impose a policy of increasing production from recycling from above, because it is known that they will defend against it.

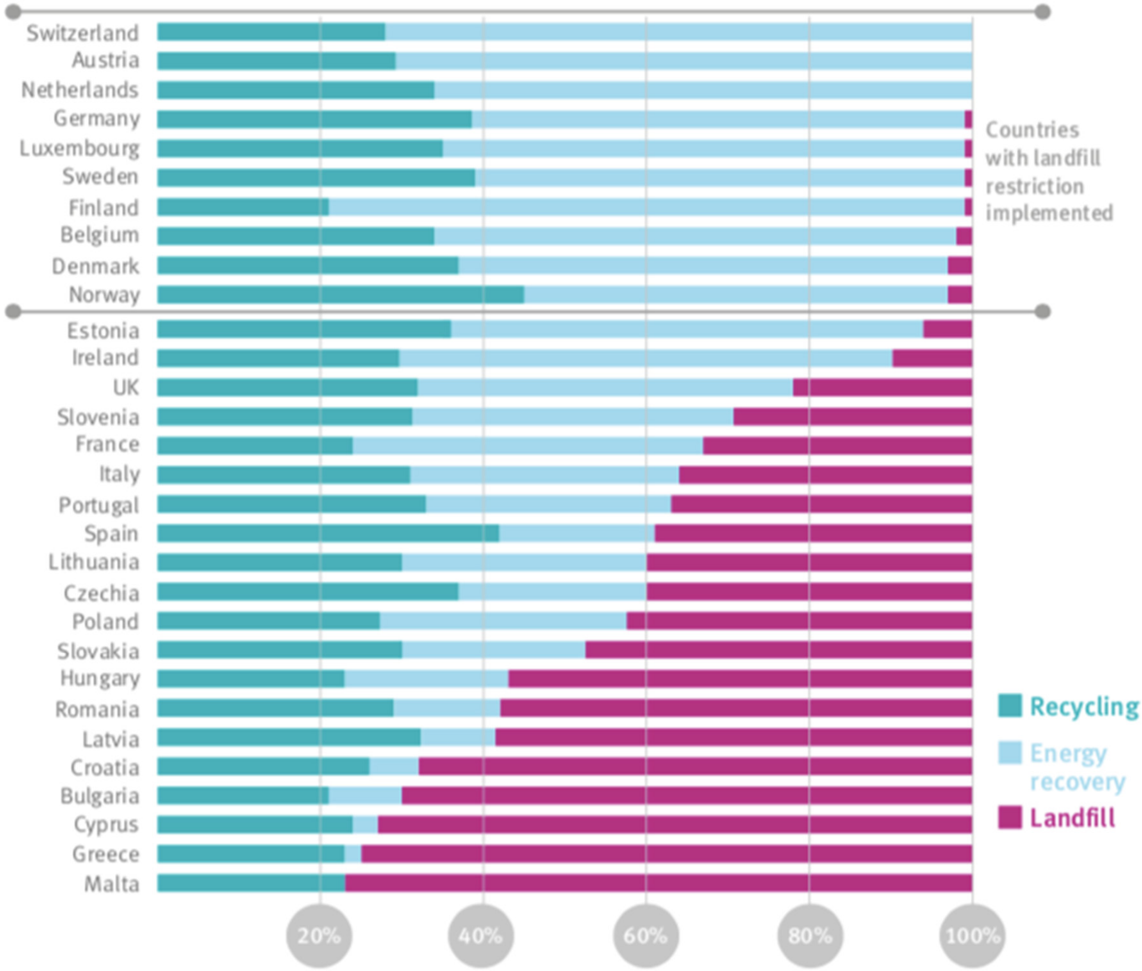
The results of the study (Appendix C) were commented by Krzysztof Sadowski, managing director at DS Smith Poland & Baltics, saying that the excess of packaging and too much plastic content in them, are the biggest concern among

European consumers - to the extent that they are ready to pay more for less content plastic. Europeans have changed their attitude towards definitely more environmentally friendly. They sort and recycle more waste than five years ago. People understand that carton packaging is a much smaller environmental problem: they are sustainable, alternative packaging to plastic and recyclable. For the sake of our planet, we need to create a circular economy in which packaging is reduced to the necessary minimum and consumer goods packaging is increasingly made of recyclable materials, such as cardboard. [*www.dssmith.com/pl/packaging/o-nas/media/aktualnosci/2019/11/europejczycy-s-skonni-paci-wicej-za-opakowania-zwierajce-mniej-plastiku*].

The study (Appendix C) says that Europeans' habits for waste segregation have improved significantly in recent years. On average, six out of ten (59%) respondents from the four markets surveyed say they currently sort and process more waste than five years ago. They represent the majority of respondents in all countries: 62% in Belgium, 64% in Great Britain and 65% in Poland. In Germany, where sorting and recycling habits are already well-established in society, 55% of respondents say they have not changed their behavior in five years, 44% say they sort and recycle more waste. The study shows that in Europe, the main factors that increase consumer awareness of packaging problems are information provided in the media (30% of respondents) and the withdrawal of free plastic bags from stores (26%) [*www.hbrp.pl/b/jesli-opakowania-to-tylko-zrownowazone/PRQIQpEpU*].

However, the attitude and expectations of customers can be changed, and this may be followed by a change in thinking in concerns that will know that they can afford less aesthetic packaging and will not lose customers. Zero landfilling is needed to achieve the circular economy of plastics. Countries with landfill restrictions of recyclable and recoverable waste have, on average, higher recycling rates of plastic post-consumer waste, what can be seen in Figure 3.5. [Association of Plastics Manufacturers in Europe - PlasticsEurope, (2019)].

Figure 3.5. Plastics post-consumer waste rates of recycling, energy recovery and landfill per country in 2018.

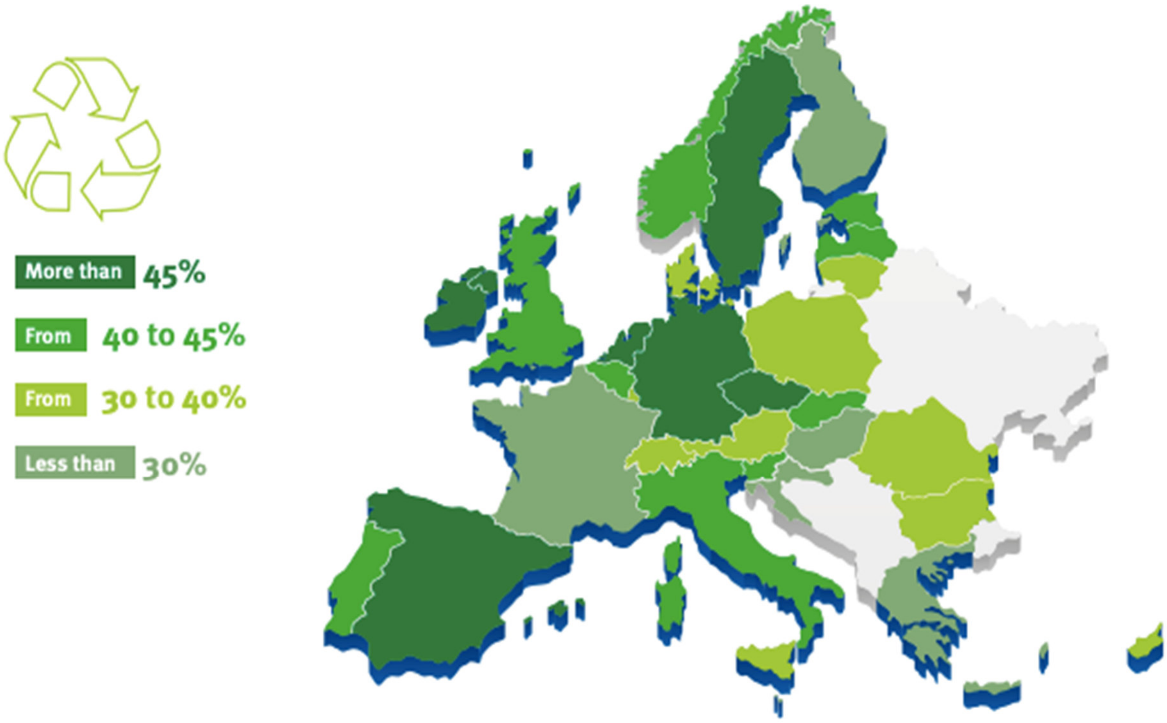


Source: Association of Plastics Manufacturers in Europe - PlasticsEurope, (2019).

The selective collection system in most EU countries is highly unsatisfactory. According to the Ellen MacArthur Foundation, we only process 10 % plastics. In a number of countries, the system itself is still in its infancy, as in the eastern Union.

It was Poland, Hungary, the Czech Republic, Slovakia and Bulgaria as well as small countries, Malta and Cyprus, which were the brake on negotiations. In the case of environmental protection, we have a traditional distribution in the Union. Benelux, Spain and France pressed for bolder changes. This division of roles unfortunately results from the level of ecological awareness of societies. [Ellen MacArthur Foundation, (2014)]. A government representing conscious citizens sets itself more ambitious goals. The attitude of Eastern Europe is also the result of a very strong lobbying of the industry, especially producers of plastics and beverages. Anyway, most countries have plastic packaging recycling rates above 35% (Figure 3.6.). In 2016, 19 countries had plastic packaging recycling rates higher than 35%, when only two countries achieved a recycling rate of 50% or more (Germany and Czechia) [Association of Plastics Manufacturers in Europe - PlasticsEurope, (2019)]. “In the EU, the potential for recycling plastic waste remains largely unexploited. Reuse and recycling of end-of-life plastics remains very low, particularly in comparison with other materials such as paper, glass or metals.”

Figure 3.6. Plastic packaging recycling rates across Europe.



Source: Association of Plastics Manufacturers in Europe - PlasticsEurope, (2019).

On the other hand, plastic processors, especially recyclers in Eastern Europe, will gain access to clean, high-quality raw material from which they produce so-called "recyclate". Its quality should increase, producers will be able to count on a higher price. This is one way how new solutions can create jobs, which should offset any costs of change [European Commission, (2018)]. It will be possible to produce 100% PET bottles from recycled materials, only the problem of the lack of specific technology enabling high-quality recycling is revealed. What is certain is that the selective collection of plastic bottles will help meet this requirement [*www.ec.europa.eu/commission/presscorner/detail/en/MEMO_19_1481*].

It was also estimated that the production of plastics and plastic waste is incinerated around 400 million tons worldwide CO2 annually [*www.europarl.europa.eu/news/pl/headlines/society/20181212STO21610/odpady-z-tworzyw-sztucznych-i-recykling-w-ue-fakty-i-liczby*]. Using more recycled plastics reduce dependence on the extraction of fossil fuels to produce plastics and reduce CO2 emissions. According to estimates, the potential annual energy saving that could be achieved by recycling all of the world's plastic waste corresponds to 3.5 billion barrels of oil per year [European Commission, (2018)]. This is a significant result that can really improve the quality of the global economy and save the environment.

3.5. MANUFACTURERS' EFFORTS TO FIGHT PLASTIC POLLUTION

The plastics industry is also trying to counteract the problem of the presence of plastics in the oceans. To this end, a special declaration on the issue of marine litter was adopted in Honolulu, Hawaii in 2011 ("The Declaration of the Global Plastics Associations for Solutions on Marine Litter"), also commonly known as the "Joint Declaration". To this day 69 organizations representing 35 countries of the world have joined it [*www.consilium.europa.eu/pl/press/press-releases/2018/07/10/eu-nato-joint-declaration/*]. "None of us wants our products, or any other trash, to end up in the oceans," declared the signatories of the document. They also made six commitments: First, engage in public-private partnerships to prevent marine litter. Secondly, work with the scientific community and researchers to better understand and assess the sources, scale and environmental impact of the problem, including possible solutions. Thirdly, promote a coherent, large-scale and science-based legislative policy, along with strengthening compliance with existing laws on the prevention of littering of the marine environment. Fourth, help spread knowledge on eco-efficient waste management and good practices, in particular in countries that lie on the shores of the oceans and seas. Fifth, strengthen the commitment to increase the recovery of plastic waste through recycling and energy recovery. And finally, sixthly, ensure proper supervision over the transport and distribution of plastic industry products - both granules and semi-finished products among their customers and promote such activities among other participants in the supply chain [*www.marinelittersolutions.com/about-us/joint-declaration*].

The signatories of the Honolulu declaration have also created a special website - www.marinelittersolutions.com - on which they document all initiatives and events that are aimed at reducing the current sea litter or preventing the emergence of new ones. Since 2011, over 260 different types of projects have already been implemented (or is ongoing). One of these projects is the involvement of the plastics industry in full control over plastic granules (in this form, plastics are usually produced, transported and processed). As part of the global Operation Clean Sweep program, starting with plastic manufacturers, companies declare to introduce internal procedures to prevent unwanted and accidental leaks of the granulate into the environment [*www.opcleansweep.org/*].

Another path that is being sought is to make the plastic manufacturing sector more environmentally friendly. The 43% of the total environmental cost related to plastics derives from the manufacturing industry, so companies try to move towards low carbon energy sources. It is estimated that by doubling the current share of low-emission energy, there would be a 5% reduction in environmental costs relating to the entire plastic sector, and would become 25% using 100% of low-emission resources [Gielen, D. et al (2019)]. In addition, design strategies for recycling are being tested, such as WRAP in England, trying to minimize the use of plastics, also considering the fact that the higher costs for plastics derive from production and transport, and therefore design packaging more efficient in this respect, it could significantly reduce the environmental cost [*www.wrap.org.uk/sites/files/wrap/MF %20Sampling%20Guidance%20April%202014.pdf*].

WWF calls on all companies and industries involved introducing, promoting and selling plastic goods to:

- “Reduce excessive and unnecessary plastic to prevent it from becoming mismanaged waste or plastic pollution.
- Commit to sourcing recycled plastics or sustainable plastic alternatives for product packaging.
- Innovate and seek out sustainable alternatives to plastics that promote circular economy models and do not have severe negative social or environmental impacts.
- Leverage individual and collective influence to shift industries away from harmful economic models that endanger wildlife, pollute natural systems, and create long-term social and environmental problems.
- Invest in ecologically sound waste management systems in end-use markets and countries where plastic waste is imported for disposal.
- Support the development of legislation and best practices to ensure a sector-wide shift and the effective implementation of government policies.” [Dalberg Advisors, et al (2019)].

Greenpeace speaks a lot on this matter. “To seriously reduce their plastic footprint soft drinks companies need to dramatically cut the number of throwaway plastic bottles they produce. However, given the need for urgent action to reduce ocean plastic pollution, an interim step they can take is to make their bottles from 100% recycled plastic. This will help close the loop on bottle production, reduce wasted materials and energy and help stop them ending up in the ocean" [*www.storage.googleapis.com/gpuk-static/legacy/Bottling-It_FINAL.pdf*]

For the packaging sector, for example, manufacturing companies could find agreements with plastics recycling companies to optimize the process, such as standardizing packaging formats to facilitate handling during recycling. Of course, the transition from a linear economy to a circular economy is a solution that should be policy driven and encouraged, also because real environmental and social benefits are expected [*www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/*].

The very idea of producing plastic items, such as shopping bags, which we use for an average of 12 minutes, but which can remain in the environment for half a millennium, is an abuse of technology that we cannot afford. In conclusion, it seems that the consumer himself cannot and will not be able to solve the problem of plastic, but he will always need careful and decisive political guidelines.

CONCLUSIONS

Plastics in the last ten years have become known to the public, not only for its omnipresence in the modern world, but also, and above all, for the damage it is creating to the environment in different ways. For this reason, plastic materials are facing a strong denigration campaign, which probably, however, does not pay the right attention to what the real problem is, and the result of which is the only demonization of the product. The idea that emerges from the study of history and from the impact that the discovery of new materials has on it, is that plastics are a very important assets and engineering resources, and for this reason they must be protected, studied, certainly improved, but above all it must be managed better. The clear result, supported by the conclusions of scientific studies, is that the problem of plastics is not the material itself, but how it is managed. Furthermore, it seems quite evident that even in the circumstance in which all the solutions that are proposed every day to solve the problem of plastic waste are implemented, the situation would change little if a consumer did not have to go through an awareness and culture process regarding how to manage plastic waste.

Millions of tons of plastic in water burden the economy as 80% of the pollutants that are found in the marine environment have their source on land. Annually, 0.8 to 2.7 million tons of plastics gets into waters, rivers and oceans. For the economies of 87 coastal countries, this phenomenon alone in 2018 generated losses of USD 6 to 19 billion, and it is estimated that the total cost of removing floating garbage around the world can range between USD 5.6 billion and USD 15 billion. Plastic waste reaching water reservoirs blocks the outflow of rivers, canals or waterworks, which can cost the world economy up to USD 19 billion a year, but its replacement is not simple and energy-efficient. To minimize the amount of plastic packaging that accumulates huge pollutants that are being launched on the global market every day, more and more countries are choosing legal restrictions on their distribution. That is why effective measures must be taken before the waste enters the water.

Looking at the overall summary of financial losses, it should be remembered that in this situation specific industries and people lose. Pollution of waters with plastics causes the turnover of the tourism industry to decrease from 0.2 to 2.4 billion dollars. Also, due to plastic pollution of waters, losses for the Asian economy amount to USD 0.2 to 2.3 billion a year, in North America the scale is USD 44-465 million, and in Europe USD 0.1-1 billion. The European Commission estimates that only in the EU, activities such as cleaning the coast and beaches from objects and plastic particles that waves have washed ashore, costs EUR 630 million.

Despite the negative impact of pollution on the economy, it is worth remembering that environmental damage is much more difficult to reverse and will affect the functioning of future generations. The recycling potential of plastics is not fully utilized. After a short first-use cycle, 95% of plastic packaging material value, or USD 80–120 billion annually, is lost to the economy. A staggering 32% of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as the ocean and clogging urban infrastructure. The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, is conservatively estimated at USD 40 billion annually - exceeding the plastic packaging industry's profit pool.

The approaches discussed in the Chapter 3 are outline solutions that only serve to buffer the problem. The "umbrella solution" to the problem of plastics in seas and oceans, taking into account all of the above recommended and implemented expert recommendations, is the circular economy, in which the value of products, materials and resources is to be maintained in the economy as long as possible as a result, waste generation is kept to a minimum. The circular economy is a kind of new, and basically re-named and identified, model for the functioning of the world economy. The circular economy can be a solution for the plastics market and reduce carbon dioxide emissions by 56% by 2050.

The European Union has started implementing regulations aimed at minimizing the negative effects of plastic waste on the environment. Some new requirements will become effective as early as 2021. Not only companies producing disposable plastic cutlery and packaging will feel them, but also producers of beverages, wet wipes or cigarettes.

Rethinking and improving the functioning of such a complex value chain requires efforts and greater cooperation by all its key players, from plastics producers to recyclers, retailers and consumers. It also calls for innovation and a shared vision to drive investment in the right direction. The plastic industry is very important to the European economy, and increasing its sustainability can bring new opportunities for innovation, competitiveness and job creation, in line with the objectives pursued by the renewed EU Industrial Policy Strategy.

The paths chosen are therefore diverse, but no final solution to the plastic waste problem has yet been found, also because all these ideas are still problems to be solved. There is hope, however, that the world will realize that plastics is a basic resource and not an obstacle to overcome, but above all that science will make progress in proposing alternative solutions to satisfy the laziness of the average consumer.

APPENDIX

APPENDIX A

Estimated cost of marine litter for the EU fishery sector.

(based on UNEP, (2006). *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change*, United Nations Environment Programme)

Type of cost	Cost per vessel (€)	Estimated cost for the EU (M€)	Calculation method
Reduced catch revenues (contamination forces fishermen to use more time for the selection of their catches and to discard part of them)	2,340	28.64	The cost estimated by Mouat et al. (2010) for Scottish vessels (€2,200 per vessel per year), actualised in 2013 prices, was multiplied by the number of EU trawlers (EU vessels that use seafloor fishing gear), i.e. 12,238.
Removing litter from fishing gear	959	11.74	The time needed to remove litter from fishing gear, as estimated by Mouat et al (2010) for Scottish vessels (41 hours per vessel per year), was multiplied by the average EU27 labour cost (€23.4 per hour) and then by the number of EU trawlers (EU vessels that use seafloor fishing gear), i.e. 12,238.
Broken gear, fouled propellers	191	16.79	The cost related to broken fear and fouled propellers, as estimated by Mouat et al. (2010) for Scottish vessels (€180 per vessel per year), actualised in 2013 prices was multiplied by the total number of fishing vessels in the EU (87,667 according to Eurostat).
Cost of rescue services	52	4.54	The average cost of incidents around the British Isles attended by the Royal National Lifeboat Institution (RNLI) in 1998 (£4,000 per vessel) was multiplied by the number of incidents (200), and divided by the number of UK fishing boats (7,800), as indicated by Fanshawe (2002). The estimated yearly cost per boat resulting by this calculation was then multiplied by 31.1%, i.e. the share of rescue operation dedicated to fishing vessels, as indicated for the UK by Mouat et al (2010) (year 2008). The result (£32 per vessel) was then actualised in 2013 prices and converted to € and multiplied by the total number of fishing vessels in the EU (87,667 according to Eurostat).
Total		61.71	

APPENDIX B

Estimated clean-up and management costs of marine litter - some examples (based on UNEP, (2006). *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change*, United Nations Environment Programme)

Country / Region	Estimated cost at national and municipality level	Source
Belgium and The Netherlands	USD 13.8 million (EUR 10.4 million) for all municipalities in Belgium and The Netherlands (ave. USD 264 885/municipality/year (EUR 200 000/ municipality/ year; EUR 629 – 97 346 per km)) Costs are higher for areas with high visitor numbers; for example the Den Haag Municipality spends USD 1.43 million/year (EUR 1.27 million/ year) with costs for processing litter (including transport) about USD 229/tonne (EUR 165/tonne).	Mouat et al, 2010 OSPAR 2009
Peru	USD 2.5 million in labour costs (ave. USD 400 000/year in municipality of Ventanillas)	Alfaro, 2006 cited in UNEP, 2009
UK	USD 24 million (EUR 18 million) (ave. USD 193 365/municipality/year (EUR 146,000/municipality/ year) (per km cleaning costs range from USD 226-108 600/km/year (EUR 171-82 000/km/year)). Specific municipality costs: • Suffolk: approx. USD 93 500/year (GBP 60 000/year) on 40km of beaches • Carrick District Council (Devon): approx. USD 56 000/year (GBP 32 000/year) on 5km of beaches. • Studland (Dorset): USD 54 000/year (GBP 36,000/year) to collect 12-13 tonnes of litter each week in the summer along 6km of beaches. • Kent coastline: direct and indirect cost of litter estimated at over USD 17 million/year (GBP 11 million/year). • Annual expenditure on beach cleaning in 56 local authorities ranged from USD 23/km (GBP 15/km) in West Dunbartonshire to USD 78,000/km (GBP 50 000/km) in Wyre.	Mouat et al, 2010 Fanshawe and Everard, 2002 OSPAR 2009
Bay of Biscay and Iberian coast	A Spanish council with 30 beaches (5 Blue Flags) spends around USD 111 000/year (EUR 80 000/year) on beach cleaning A French council with 30 beaches (5 Blue Flags) spends around USD 556 000/year (EUR 400 000/year) on 'beach caring' (including beach clearing, monitoring of buoys, coastguards etc.), of which around 20% (USD 111 000 (EUR 80 000)) relates to beach clearing. In Landes, the cost of cleaning up 108km of sandy beaches was USD 11 million (EUR 8 million) between 1998 and 2005 Cost of beach cleaning between USD 6 250-69 460/year/council (EUR 4 500-50 000/year/council) corresponding to average cost of USD 9 000/km (EUR 6 500/km) of cleaned beach/year.	OSPAR, 2009
Poland	Beach cleaning and removing litter from harbour waters cost USD 792 000 (EUR 570 000) in 2006 (same amount also spent in five com-munes and two ports)	(UNEP, 2009)
Oregon, California, Washington (USA)	Annual combined expenditure of USD 520 million (USD 13/resident/ year) to combat litter and curtail potential marine litter	Stickel et al., 2012
APEC region	USD 1 500/tonne of marine litter in 2007 terms	(McIlgorm, 2009)

APPENDIX C

ABOUT THE STUDY

The study, the results of which are quoted, was conducted by L'ObSoCo in the Respondi panel in July 2019 on behalf of DS Smith. 1000 people aged 18-70 in Germany, 999 people aged 18-70 in Great Britain, 996 people aged 18-70 in Poland and 400 people aged 18-70 in Belgium were examined. This study aimed to understand consumer attitudes and habits regarding the environmental impact of various forms of packaging, recycling and waste management.

Source: www.hbrp.pl/b/jesli-opakowania-to-tylko-zrownowazone/PRQIQpEpU

BIBLIOGRAPHY

Aanesen, M. Armstrong, C., Czajkowski, M., Falk-Petersen, J., Hanley, N. Navrud, S. (2015). *Willingness to pay for unfamiliar public goods: preserving cold-water coral in Norway*, Ecological Economics, 112, pp. 53-67.

Andrady, A.L., Bergmann, M., Gutow, L., Klages, M. (2015). *Marine Anthropogenic Litter*, Springer, pp. 57-72.

Association of Plastics Manufacturers in Europe - PlasticsEurope, (2018). *Plastics – the Facts 2018, An analysis of European plastics production, demand and waste data*.

Association of Plastics Manufacturers in Europe - PlasticsEurope, (2019). *Plastics – the Facts 2018, An analysis of European plastics production, demand and waste data*.

Bakir, A., Rowland, S., Thompson, R. (2014). *Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions*, Environmental Pollution, 185:16–23.

Ballance, A., Ryan, P.G., Turpie, J.K. (2000). *How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa,* South African Journal of Science 96, pp. 210-230.

Barnes, D., Galgani, F., Thompson, R., Barlaz, M. (2009). *Accumulation and fragmentation of plastic debris in global environments*, Philosophical transactions of the Royal Society of London. Series B, Biological sciences 364:1985–1998.

Beaumont, N.J. Aanesen, M. Austen, M.C., Börger, T., Clark, J.R., Cole, M., Hooper, T., Lindeque, P.K., Pascoe, C., Wyles, K.J. (2019). *Global ecological, social and economic impacts of marine plastic,* Marine Pollution Bulletin 142:189-195.

Beaumont, N.J., Aanesen, M., Austen, M.C., Börger, T., Clark, J.R., Cole, M., Hooper, T., Lindeque, P.K., Pascoe, Ch., Wyles, K.J.(2019). *Global ecological, social and economic impacts of marine plastic,* Marine Pollution Bulletin, Volume 142, May 2019, Pages 189-195.

Browne, M.A. Dissanayak, E, A., Galloway, T.S., Lowe, D.M., Thompson, R.C. (2008). *Ingested microscopic plastic translocates to the circulatory system of the mussel Mytilus edulis (L.),* Environmental Science & Technology 42, 13, 5026-5031.

Buckley, P., Pinnegar, J., Terry, G., Chilvers, J., Lorenzoni, I., Gelcich, S., Dudek, A., Arquati, A. (2011). *Report on European public awareness and perception of marine climate change risks and impacts*, CLAMER: Climate Change and European Marine Ecosystem Research. Centre for Environment, Fisheries & Aquaculture Science (Cefas), Lowestoft, Suffolk.

Carpenter E.J., Smith K.L., (1972). *Plastics on the Sargasso Sea surface*, Science, 175, 1240.

Carson, H.S., Nerheim, M.S., Carroll, K.A., Eriksen, M., (2013). *The plastic associated microorganism of the North Pacific Gyre,* Marine Pollution Bulletin 75(1-2), 126-132.

Clements, A., Dunn, M., Firth, V., Hubbard, L., Lazonby, J., Waddington, D. (2010). *The essential chemical industry,* CIEC Promoting Science, University of York.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., Galloway, T.S. (2013). *Microplastic ingestion by zooplankton*, Environmental Science & Technology 47:6646–6655.

Collignon, A., Hecq, J., Galgani, F., Voisin, P., Collard, F. (2012). *Neustonic microplastic and zooplankton in the North Western Mediterranean Sea*, Marine Pollution Bulletin 64:861–864.

Collignon, A., Hecq, J., Galgani, F., Voisin, P., Collard, F., Goffart, A. (2012). *Neustonic microplastic and zooplankton in the North Western Mediterranean Sea*, Marine Pollution Bulletin 64:861–864.

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K. (2014). *Changes in the global value of ecosystem services,* Global Environmental Change, Volume 26, May 2014, Pages 152-158.

Cózar, A., Echevarría, F., González-Gordillo, JI., Irigoien, X., Ubeda, B., Hernández-León, S,, Palma, A,, Navarro, S, García-de-Lomas, J,, Ruiz, A., Fernández-de-Puelles, ML., Duarte, CM. (2014). *Plastic debris in the open ocean*, Proc Natl Acad Sci USA doi:10.1073/pnas.1314705111.

Dalberg Advisors, de Wit, W., Hamilton, A., Scheer, R., Stakes, T., Allan, S. (2019). *Solving Plastic pollution through accountability*, WWF Report.

Ellen MacArthur Foundation, (2013). *Towards the circular economy. Economic and business rationale for an accelerated transition*.

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, CH.J., Borerro, J.C. Galgani, F., Ryan, P.G., Reisser, J. (2014). *Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea*, PLoS One. 2014; 9(12): e111913.

European Commission, (2018). *A European strategy for plastics in a circular economy.*

European Commission, (2018). *Reducing Marine Litter: action on single use plastics and fishing gear,* SWD(2018) 254.

European Environment Agency, (2017). *Circular by design. Products in the circular economy*, Report No 6/2017.

Farrell, P. Nelson, K. (2013). *Trophic level transfer of microplastic: Mytilus edulis to Carcinus maenas,* Environmental Pollution, 177:1–3.

Galloway, T.S. Cole, M. Lewis, C. (2017). *Interactions of microplastic debris throughout the marine ecosystem*, Nature Ecology & Evolution.

Geyer, R., Jambeck, J.R., Law, K.L., (2017). *Production, use, and fate of all plastics ever made, Science Advances*, 19 Jul 2017: Vol. 3, no. 7, e1700782.

Giani, D., Baini, M., Galli, M., Casini, S., Fossi, M.C. (2019). *Microplastics occurrence in edible fish species (Mullus barbatus and Merluccius merluccius) collected in three different geographical sub-areas of the Mediterranean Sea*, Volume 140, Pages 129-137.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N., Gorini, R. (2019). *The role of renewable energy in the global energy transformation,* Energy Strategy Reviews Volume 24, Pages 38-50.

Golden, C., Allison, E.H., Cheung, W.W., Dey, M.M., Halpern, B.S., McCauley, D.J., Smith, M., Vaitla, B., Zeller, D., Myers, S.S. (2016). *Fall in fish catch threatens human health*, Nature, 534 (2016), pp. 317-320.

Goldstein, M.C., Goodwin, D.S. (2013). *Gooseneck barnacles (Lepas spp.) ingest microplastic debris in the North Pacific Subtropical Gyre,* Peer J 184:2–17.

Greenpeace, (2006). *Plastic Debris in the World's Oceans*.

Greenpeace, (2016). *Plastics in seafood*, Greenpeace Research Laboratories.

Gregory, M.R. (2009). *Environmental implications of plastic debris in marine settings-entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions*, Philos Trans R Soc Lond B Biol Sci 364:2013–2025.

GS1, (2019). *EU Circular Economy Package.*

Hartley, B., Pahl, S., Thompson, R.C. (2013). *Baseline Evaluation of Stakeholder Perceptions and Attitudes Towards Issues Surrounding Marine Litter*, Marlisco.

Hidalgo-Ruz ,V., Gutow, L., Thompson, R., Thiel,. M (2012). *Microplastics in the marine environment: a review of the methods used for identification and quantification*, Environ Sci Technol 46:3060–3075.

Jambeck, J.R. Geyer, R., Wilcox, CH., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L. (2015). *Plastic waste inputs from land into the ocean*, Science, 13 Feb 2015: Vol. 347, Issue 6223, pp. 768-771.

Jang, Y.C., Lee, J., Hong, S., Choi, H.W., Shim, W.J., Hong, S.Y. (2015). *Estimating the Global Inflow and Stock of Plastic Marine Debris Using Material Flow Analysis*, Journal of the Korean Societyfor Marine Environment and Energy, 18 (2015), pp. 263-273.

Jemec, A., Horvat, P., Kunej, U., Bele, M., Krzan, A., (2016). *Uptake and effects of microplastic fibers on freshwater crustacean Daphnia magna*, Environmental Pollution, 219, 201-209.

Jobstvogt, N., Hanley, N., Hynes, S. Kenter, J.,Witte, U. (2014). *Twenty thousand sterling under the sea: estimating the value of protecting deep-sea biodiversity,* Ecological Economics, 97, pp. 10-19.

Law, K., Moret-Ferguson, S., Goodwin, D., Zettler, E., DeForce, E., Kukulka, T., Proskurowski, G. (2014). *Distribution of surface plastic debris in the eastern Pacific Ocean from an 11-year dataset,* Environ Sci Technol: doi:10.1021/es4053076.

Law, K., Moret-Ferguson, S., Maximenko, N., Proskurowski, G., Peacock, E. (2010). *Plastic accumulation in the North Atlantic Subtropical Gyre*, Science 329:1185–1188.

Law, K., Moret-Ferguson, S., Maximenko, N., Proskurowski, G., Peacock, E.E., Hafner, J., Reddy, C.M. (2010). *Plastic accumulation in the North Atlantic Subtropical Gyre*, Science 329:1185–1188.

Lebreton, L., Greer, S., Borrero, J. (2012). *Numerical modeling of floating debris in the world's oceans*, Marine Pollution Bulletin 64:653–661.

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier,A., Noble, K., Debeljak, A., Maral, H., Schoeneich-Argent, R., Brambini, R., Reisser, J. (2018). *Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic*, Scientific Reports volume 8, Article number: 4666.

Lord, R. (2016). *Plastics and Sustainability: A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement*, American Chemistry Council.

Naeem, S., Chazdon, R., Duffy, J.E., Prager, C., Worm, B. (2016). *Biodiversity and human well-being: an essential link for sustainable development.*

Papathanasopoulou, E., White M.P., Hattam, C., Lannin, A., Harveya, A., Spencer, A. (2016). *Valuing the health benefits of physical activities in the marine* *environment and their importance for marine spatial planning*, Mar. Policy, 63 (2016), pp. 144-152.

Rochman, C., Browne, M., Halpern, B., Hentschel, B., Hoh, E. (2013). *Classify plastic waste as hazardous*, Nature 494:169–171.

Rochman, C.M. Tahir, A., Williams, S.L., Baxa, D.V., Lam, R., Miller, J.T., Teh, F.C., Werorilangi, S., The, S.J. (2015) *Anthropogenic debris in seafood: plastic debris and fibers from textiles in fish and bivalves sold for human consumption*, Scientific Reports 5, 14340.

Schmidt, CH., Krauth, T., Wagner, S. (2017). *Export of Plastic Debris by Rivers into the Sea,* Environmental Science & Technology, 51, 21, 12246-12253.

Sea Turtle Restoration Project, (2016). *A ban on plastic bags will save the lives of California's endangered Leatherback Sea Turtles.*

Setälä, O., Fleming-Lehtinen, V., Lehtiniemi, M. (2014). *Ingestion and transfer of microplastics in the planktonic food web*, Environmental Pollution, 185:77–83.

Smith, M., Love, D.C., Rochman, CH.M., Neff, R.A. (2018). *Microplastics in Seafood and the Implications for Human Health,* Current environmental health reports, 5(3): 375–386.

Steensgaard, I.M., Syberg, K., Rist, S., Hartmann, N.B., Boldrin, A., Hansen, S.F. (2017). *From macro- to microplastics – Analysis of EU regulation along the life cycle of plastic bags*, Environmental Pollution, 224, 289.

Sussarellu, R., Suquet, M., Thomas, Y., Lambert, CH., Fabioux, C., Pernet, M.E.J., Goïc, N.L., Quillien, V., Mingant, CH., Epelboin, Y., Corporeau, CH., Guyomarch, J., Robbens, J., Paul-Pont, I., Soudant, P., Huvet, A. (2016). *Oyster reproduction is affected by exposure to polystyrene microplastics*, PNAS USA, 113:2430–2435.

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M.A., Watanuki, Y. (2013). *Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics,* Marine Pollution Bulletin, 69:219–222.

Teuten, E., Rowland, S., Galloway, T., Thompson, R. (2007). *Potential for plastics to transport hydrophobic contaminants*, Environ Sci Technol 41: pp. 7759–7764.

Teuten, E.L., Saquing, J.M., Knappe, D.R., Barlaz, M.A., Jonsson, S., Björn, A., Rowland, S.J., Thompson, R.C., Galloway, T.S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P.H., Tana, T.S., Prudente, M., Boonyatumanond, R., Zakaria, M.P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., Takada, H. (2009). *Transport and release of chemicals from plastics to the environment and to wildlife,* The Royal Society Publishing.

UNEP (2005). Marine Litter. An analytical overview.

UNEP, (2006). *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change*, United Nations Environment Programme.

United Nations Industrial Development Organization (UNIDO), (2019). *Addressing the challenge of Marine Plastic Litter using Circular Economy methods, Relevant considerations.*

Van Cauwenberghe, L., Janssen, C., (2014). *Microplastics in bivalves cultured for human consumption*, Environmental Pollution, 193, pp. 65-70.

Van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B.D., Van Franeker, J.A., Eriksen, M., Siegel, D., Galgani, F., Law, K.L. (2015). *A global inventory of small floating plastic debris*, Environmental Research Letters.

Viool, V., Gupta. A., Petten, L., Schalekamp, J., (2019). *The price tag of plastic pollution*, Deloitte.

Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T.; (2016). *Harm caused by Marine Litter. MSFD GES TG Marine Litter - Thematic Report*; JRC Technical report; EUR 28317 EN; doi:10.2788/690366.

World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company (2016). *The New Plastics Economy — Rethinking the future of plastics*.

Wright, S. L., Thompson, R.C., Galloway, T. S. (2013). *The physical impacts of microplastics on marine organisms: A review,* Environmental Pollution, 178 (0). pp. 483-492.

Wright, S.L., Thompson, R.C., Galloway, T. S., Rowe, D. (2013). *Microplastic ingestion decreases energy reserves in marine worms,* Current Biology, 23:1031–1033.

Wyles, K.J., Pahl, S., Thomas, K., Thompson, R.C. (2016). *Factors that can undermine the psychological benefits of coastal environments: exploring the effect of tidal state, presence, and type of litter*, Environ. Behav., pp. 1095-1126.

Yamashita, R., Takada, H., Fukuwaka, M.A., Watanuki, Y. (2011). *Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, Puffinus tenuirostris, in the North Pacific Ocean,* Marine Pollution Bulletin, 62:2845–2849.

SITOGRAPHY

www.plasticseurope.org/pl/about-plastics/what-are-plastics/history
www.britannica.com/biography/Leo-Baekeland
www.ourworldindata.org/plastic-pollution
www.statista.com
www.darrinqualman.com/global-plastics-production
www.ellenmacarthurfoundation.org
www.nceas.ucsb.edu/news/new-science-first-estimate-quantifies-plastics-flowing-ocean
www.5gyres.org
www.ec.europa.eu
www.microplastics.whoi.edu
www.plastic-pollution.org
www.ufz.de/index.php?en=36336&webc_pm=34/2017
www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/12th-grade/
www.theoceancleanup.com/press/press-releases/ocean-plastic-pollution-worse-than-expected/

www.oceanservice.noaa.gov/facts/gyre
www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/10th-grade
www.marinedebris.noaa.gov/info/patch.html
www.bbc.com/news/science-environment-37161479
www.journals.plos.org
www.plasticseurope.org/pl
www.darrinqualman.com
www.darrinqualman.com/category/production-and-manufacturing
www.ellenmacarthurfoundation.org
www.naukawpolsce.pap.pl
www.teraz-srodowisko.pl/aktualnosci/plastik-biodegradowalny-ciemne-strony-3072
www.ec.europa.eu/commission/presscorner/detail/en/MEMO_18_6
www.news.mongabay.com/2018/11/research-finds-humans-across-the-globe-have-microplastics-in-their-stool
www.iopan.gda.pl
www.gesamp.org
www.ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm
www.plymouth.ac.uk
www.spiegel.de/international/zeitgeist/toxicologist-rosemary-waring-on-the-danger-of-microplastics-a-1249144
www.echa.europa.eu/it/-/msc-unanimously-agrees-that-bisphenol-a-is-an-endocrine-disruptor
www.eppm.com/blogs/editors-blog/hard-to-swallow/
www.umweltbundesamt.at/news_en_181023/

www.newcastle.edu.au/newsroom/featured/plastic-ingestion-by-people-could-be-equating-to-a-credit-card-a-week
www.ecomondo.com/
www.youtube.com/watch?v=FAi1okMUdQ8
www.kimointernational.org/fishing-for-litter/
www.ec.europa.eu/commission/presscorner/detail/en/IP_18_5
www.ec.europa.eu/commission/news/single-use-plastics-2018-may-28_en
www.audycje.tokfm.pl/gosc/5271,prof-Jan-Marcin-Weslawski
www.hometowndumpsterrental.com/blog/ocean-drone-captures-sea-garbage-like-a-butterfly-net
www.projectkaisei.org
www.euractiv.pl/content_providers/euractiv-pl
www.marinelittersolutions.com/about-us/joint-declaration
www.opcleansweep.org/
www.reuters.com/article/us-usa-climatechange-macron-idUSKBN18S6M2
www.un.org/development/desa/en/news/population/world-population-prospects-2017
www.ec.europa.eu/environment/circular-economy
www.ellenmacarthurfoundation.org/circular-economy/concept
www.ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en
www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015L0720
www.ec.europa.eu/commission/presscorner/detail/en/IP_18_3927
www.europarl.europa.eu/doceo/document/A-8-2018-0317_EN
www.thelocal.no/20200213/norway-offsets-fondness-for-plastic-bottles-with-high-recycling
www.zerowasteeurope.eu/wp-content/uploads/2018/09/FreiburgCupfinal

www.dw.com/en/earth-lovers-in-lederhosen-oktoberfest-goes-green/a-18722603
www.france24.com/en/20191231-france-begins-phasing-out-single-use-plastics
www.europarl.europa.eu/news/en/press-room/20190321IPR32111/parliament-seals-ban-on-throwaway-plastics-by-2021
www.ec.europa.eu/commission/presscorner/detail/en/MEMO_19_1481
www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs
www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI(2018)625108
www.sustainabledevelopment.un.org/post2015/transformingourworld
www.eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN
www.government.nl/documents/reports/2013/10/04/opportunities-for-a-circular-economy-in-the-netherlands
www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050
www.circulareconomy.europa.eu/platform/en/strategies/leading-cycle-finnish-road-map-circular-economy-2016-2025
www.ephemerajournal.org/contribution/against-wasted-politics-critique-circular-economy
www.theoceancleanup.com
www.theoceancleanup.com/milestones/interceptor-2-point-0/
www.theguardian.com/environment/2018/dec/20/great-pacific-garbage-patch-20m-cleanup-fails-to-collect-plastic
www.sitra.fi/en

www.zeme.com.pl/blog-aktualnosci-z-rynku-odpadow-przemyslowych/ceny-odpadow-sytuacja-na-rynku-odpadow-przemyslowych/recykling-odpadow-przemyslowych/
www.eea.europa.eu/themes/waste/intro
www.oceanconservancy.org/trash-free-seas/international-coastal-cleanup/
www.storage.googleapis.com/gpuk-static/legacy/Bottling-It_FINAL.pdf
www.europarl.europa.eu/news/pl/headlines/society/20181212STO21610/odpady-z-tworzyw-sztucznych-i-recykling-w-ue-fakty-i-liczby
www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/
www.consilium.europa.eu/pl/press/press-releases/2018/07/10/eu-nato-joint-declaration/
www.wrap.org.uk/sites/files/wrap/MF%20Sampling%20Guidance%20April%202014.pdf
www.veolia.pl/gospodarka-o-obiegu-zamknietym-ekonomiczne-rozwiazania-dla-przemyslu-spozywczego
www.jacobsdouweegberts.com/globalassets/corporate-responsibility/jde-cr-report_2106192.pdf
www.planet.veolia.com/en/bonduelle-food-beverage-industry-wastewater-recovery
www.hbr.org/1993/11/recycling-for-profit-the-new-green-business-frontier
www.hbr.org/2018/07/rethinking-sustainability-in-light-of-the-eus-new-circular-economy-policy?autocomplete=true
www.hbrp.pl/b/jesli-opakowania-to-tylko-zrownowazone/PRQIQpEpU
www.dssmith.com/pl/packaging/o-nas/media/aktualnosci/2019/11/europejczycy-s-skonni-paci-wicej-za-opakowania-zwierajce-mniej-plastiku
www.valigiablu.it/plastica-rifiuti-tassa/

www.repubblica.it/economia/rapporti/osserva-italia/stili-di-vita/2020/01/16/news/italiani_ambientalisti_il_54_e_favorevole_alla_plastic_tax-245879094/

www.senato.it/service/PDF/PDFServer/BGT/01125659.pdf

www.money.it/plastic-tax-2020-come-funziona-chi-paga-nuova-tassa-legge-bilancio