
THE PLASTICS
PARADOX
FACTS FOR A BRIGHTER FUTURE
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Contents

PREFACE

I once sat next to a young person on a plane. She took a nap and I glanced at a sticker on her laptop that read: "Rise above plastics". I had to smile at the naïvety. Why? Well, the sticker was made of plastic, and so was the adhesive that held it on her laptop, which was also made of plastic. Her backpack was made of nylon plastic, and so were her shoes. She had a PET plastic water bottle in her hand and was cozied up in a polyester (plastic) blanket. In fact, the only thing I could see that wasn't synthetic plastic was her cotton jacket. Later, she woke up and started editing video clips made on her ABS plastic Go-Pro camera—in the video, she was swimming in the ocean in a rubber suit with plastic flippers on. She had no idea that her life would not be possible without the very plastics she claimed to object to.

That incident made me think—there must be many people who are against plastic but who don't fully understand what it would mean to live without it. I have spent my whole career as a plastic materials scientist, so to me it's obvious, but how are the public supposed to know? In fact, how can the public be sure of anything these days when extreme headlines go viral and misinformation spreads at the speed of light? You would think that eventually the truth would come out and public opinion would correct itself, but scientists have studied that, and it turns out that the sensational lies spread faster and farther than the truth. So, when the truth does finally come out, it never catches up with the lie. Why is that? Well, the truth is often not as exciting as the lie was.

Over the last decade or so, there has been a vocal campaign against plastics and the plastics industry has done almost nothing to counter it. Perhaps they assumed it would go away. However, it didn't go away, so now we are ten years on and the public has made up their minds that plastics are bad. Politicians make policies in response to that public opinion, and companies make policies and even create new product lines to address the public's demands. Progress is being made in the war on plastics, and that must be a good thing, right?

I didn't think too much about it until recently when my two daughters came home from school and told me what they had learned that day. To my horror, they had been taught clear, undeniable lies about plastic. I should not have been so surprised—after all, teachers are just members of the public, and they pick up their information from the same online sources we are all exposed to. However, it's a serious problem when we start teaching our children lies. They will grow up and vote for policies based on those lies, and that is likely to have unforeseen—and unfortunate—consequences.

So, what was the lie that triggered me? My kids were told that plastics take a thousand years to degrade. As someone who has spent my whole career as a plastic materials scientist, I know that's a whopping lie. I had a BSc, a master's, a PhD and 30 years of experience telling me this was just plain wrong. The fact that plastics degrade is as certain as the sun rising or an apple falling. It's not open for debate. There are thousands of scientific articles on it, and a whole journal called Polymer Degradation and Stability devoted to the topic.

Just how stable are the typical plastics we use today? I had just finished a project as an expert witness for a large class-action lawsuit, which led to appearances on CBS's 60 Minutes, Sky News, and the BBC. It was all about the stability of polypropylene mesh used in the body to repair hernias and other abdominal ailments. I had just read hundreds of peer-reviewed articles on the stability of polypropylene and other plastics, so I had the information at my fingertips. Would you like to guess how long polypropylene lasts at room temperature? Please take a guess…

The answer is that polypropylene (PP) is extremely unstable. Scientists found that out almost as soon as they made PP for the first time. If left at room temperature, it will oxidize and degrade, losing its strength in less than one year.

Does that shock you? That's what the peer-reviewed scientific articles tell us. It's a fact proven in the laboratory. That's a big deal, because polypropylene is the second-most common plastic produced today. You use it every day in household items like shampoo bottle caps (especially the ones with the hinge), pot scrubbers, and string. It's the main plastic used in cars due to its attractive properties and low weight. It's not just PP, either. Other common plastics degrade rather rapidly too. My kids had been told a blatant lie.

How can it be that this accepted "fact" that plastics take hundreds or thousands of years to degrade has penetrated our minds, our schools, and our policies? It turns out that a lie begins to sounds like the truth if it is repeated enough. Of course, it's still a lie, but everyone will believe it. This is exactly what the plastics industry has allowed to happen. It made me wonder about the other "facts" we all believe about plastic. If this one was a lie, what about the others? The first thing I did was to check whether plastic bags really are bad for the environment. Can you guess what I found? I found several studies from all around the world and every single one of them showed that plastic bags are far greener than either paper or cotton. Shocking, isn't it?

Now, I was even more suspicious. I started downloading articles on plastic waste, litter, microplastics, and other related topics. I spent a year reading several hundred articles so that I could present them to the teachers at my kid's school. Members of the public often make up their mind and then only read articles that confirm what they already believe, but that's not how a professional scientist works. I had to read every article I could find and only then make up my mind, based on the evidence. It was a preposterous amount of work, but that was the only way to get to the bottom of the matter.

You are about to see the evidence from scientists all around the world, as published in peer-reviewed journals. I will cite their work and quote from the studies word-for-word to avoid any "spin". In this book, you will discover that everything you have been told about plastics and the environment is a lie, and you will be left with a choice. Hopefully, you will take the real facts and start fighting for a brighter future. Or, you can continue believing the lies you have been told online, which means you will be fighting for changes that seriously harm, rather than help, our environment. It's that simple.

"When you see a text box, like this one, you are reading a verbatim quote, usually taken from the abstract or conclusions section of a peer-reviewed scientific study."

When you see some small text like this, it is the citation to the study, so you can go look it up yourself. This is how professionals show that what they have said is backed by evidence.

As a guide to reading the book, when you see a box like the one below, it is a headline from a newspaper or other print article.

SUSTAINABLE BUSINESS NOVEMBER 6, 2019 / 12:21 PM / A MONTH AGO

Coca-Cola chooses plastic bottle collection over aluminum cans to cut carbon footprint

As I mentioned, this book is based on over 400 scientific articles and reports. It would be cumbersome to list every single one here, so I have provided a comprehensive list at plasticsparadox.com. That way the list can grow as new articles are published.

We are told that plastics are our saviour and our nemesis. That is the "Plastics Paradox". How can they be our friend and our enemy at the same time? How do we know whether to promote or persecute plastics? To discover the answer, we need to present the evidence to you, the jury, the public. Only then can we make an informed decision.

INTRODUCTION

THE PLASTICS PARADOX

FACTS FOR A BRIGHTER FUTURE

INTRODUCTION

When making important decisions, responsible people take extra care to do their research. The more important the decision, the more effort we invest. When buying a car, most of us spend time reading online reviews and the opinions of professionals with years of experience. You, the reader, deserve respect for checking to see what's really going on with plastic. It is an important topic, and understanding the facts is the only way to make wise choices for future generations.

Now, let's consider the uproar about plastics and the environment. We can all agree that it's an important topic, but what do we really know about it? I have seen countless articles online, and most have one thing in common: they are not by experts and they contain no proven facts. What do I mean by that? Professional articles list sources and refer back to peer-reviewed science. If an article doesn't do that, then it's worthless.

It's shocking to me that public opinions about plastic are based on articles with neither data nor substance. Our children and our planet's future deserve better than that.

> "Without data you're just a person with an opinion."
> **W. Edwards Deming**

Here's one example to illustrate the point. A story claimed that Americans use 500 million single-use plastic straws per day. That number was repeated by the New York Times, Washington Post, National Geographic, CNN, Fox News, Wall Street Journal, USA Today, environmental groups, and countless other publications. None of them checked the figure or where it had come from. Where did it come from? It was later revealed that the source was Milo Cress, a 9-year-old schoolboy. He had no proof for the data, and when the number was eventually checked, it was found to be wrong. The actual number was far lower.

How a 9-Year-Old Boy's Statistic Shaped a Debate on Straws, New York Times
Niraj Chokshi, July 19th 2018

This is exactly how lies about the environment spread. The more sensational the claim, the more readily it is repeated. When the truth is finally learned, that news does not travel as fast or as wide, so the truth never catches up with the lie.

This book is about exposing the truth so that smart, caring people can act on it. In the case of single-use straws, Marriott, Starbucks, McDonalds and more have banned straws based on a lie. They replaced them with paper straws that cost more, don't work as well, and as you will discover later, are actually far worse for the environment. This example shows why we need facts before we act.

As a professional scientist, it worries me that everyone has made up their mind on this topic in a vacuum of information. Think back to when you formed your opinions. Did you see a YouTube video? Maybe it was a LinkedIn article, or even a newspaper article. That is rumour, not science, and it does not provide a basis upon which to form a sound opinion.

As a leading plastic materials scientist, I could instantly spot that some of what we were being told was totally untrue—and that was enough to make me investigate further. I decided to look for the science and see what I could uncover. A good scientist reads everything they can find before making up their mind, so I went on a mission and reviewed over 400 articles. I was continually waiting for the moment when I would find an article that proved plastics were our enemy. I read and I read, article after article, and that moment never came. What I found was exactly the opposite. In this book, I share what I found with you.

I should probably explain why you should trust what I'm writing. One reason is that I am one of the world's top plastic materials scientists. In terms of qualifications, I am a PhD chemist, Chartered Chemist, and a Fellow of the Royal Society of Chemistry. Companies like HP, P&G, iRobot, Disney, CBS, Sky News, the BBC and many more trust me and turn to me for help. I would not be able to make a living without high integrity because the Fortune 100 would not trust me with their secrets. I do not sell or market plastic—rather, my career has been as a professional scientist. So, when I make a claim, I always back it up with data and links to the peer-reviewed science so you can check it for yourself. You don't even have to believe me because everything can be checked.

As well as listing my sources, I have quoted many of the studies word for word so that there can be no accusation of "spin". After reading this book, you will be one of a handful who knows the truth and can see a clear path to the preservation of our environment. A path that actually works.

In writing this book, I know that I am going against what is politically correct at the moment. The book will not make me popular. However, the facts speak for themselves and we cannot make progress based on the foundation of lies that we have now. Therefore, I feel compelled to proceed regardless. Ideally, the plastics industry would have spoken up in the last decade, as these lies were being repeated over and over. Unfortunately, they chose not to, and now public opinion has already turned against plastics. As you will soon discover, that opinion is completely unfounded.

WHAT ARE PLASTICS ANYWAY?

Commonly occurring molecules we talk about every day include water, acetone, alcohol, and so on. These are all small molecules. Plastics, however, are a type of very large molecule called polymers, where "poly" means many and "mer" means unit. People tend to be wary of anything unfamiliar, but it turns out that some of our favourite things in nature are made of polymers. One example is collagen, which keeps your skin healthy. Another is cellulose, which is what holds trees and plants together. Silk is made of polymers, and so are cotton and wool. We eat polymers all the time. For example, Casein, a protein in the milk we drink. Our very existence depends on polymers. The enzymes that make our bodies function are polymeric molecules, and even DNA, the blueprint for all life on Earth, is a polymer.

Some decades ago, scientists discovered how to make their own polymers which we often refer to as plastics. Plastics have ushered in a technological revolution leading to stunning advances in our quality of life. Plastic pipes deliver clean drinking water and plastic-insulated wires deliver electricity. The rapid adoption and sudden prevalence of plastics have created a backlash, and we will look to see whether that is truly justified or more of a knee-jerk reaction.

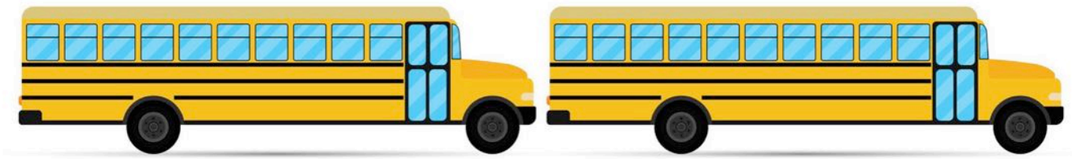
PLASTICS - SHORT FOR THERMOPLASTICS

Thermoplastics are polymers that can be melted and formed into sheets or complex parts. Thermoplastics like polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and nylon (PA6 and PA6,6) get their strength from polymer chain entanglements. If the chains are too short, then molecular entanglements cannot form, so the material has no strength. Imagine very short spaghetti strands. Short spaghetti strands do not hold together, whereas when you try to lift up long strands of cooked spaghetti, the whole bunch comes up in a tangled lump. It's the same with plastic polymers. The long chains get tangled together. We will hear more about chain entanglements later.

On the other hand, thermosetting polymers have a different structure. Instead of entanglements, the molecules are all joined together in one continuous network instead of entangled straight chains. The 3D network is strongly bonded and is effectively one giant molecule, so unlike thermoplastics, thermosets do not flow when heated. A common example of a thermoset is epoxy resin. This type of polymer is not called "plastic" because it does not flow when heated.

WHAT DO POLYMER MOLECULES LOOK LIKE?

A polyethylene chain made from 10,000 monomer units joined together would be about two Ångströms across and 25,000Å long (2.5µm). An Ångström is one ten-billionth of a meter, which is too small to imagine, so let's go back to our spaghetti analogy. If the polymer chain were as thick as a piece of spaghetti, how long would the spaghetti strand have to be in order to have the same proportions as a polymer chain? The answer is about 25 meters (about 25 yards) long. So, visualize a piece of spaghetti as long as two school buses and you have the right relative dimensions.



A polymer chain as wide as a spaghetti strand would be two busses long

It's easy to understand why polymer chains get tangled up so easily. If the polymer chain were a strand of human hair, then the hair would be about three feet long. I think anyone who has had hair that long knows how easily it gets tangled. Polymer chains can be even longer—take for example the ultra-high molecular weight polyethylene (UHMWPE), which is sold under the trade name Dyneema® and is used to make bulletproof vests and cut-resistant gloves. If a UHMWPE chain had the same thickness as a piece of spaghetti, it would be over 20 busses long. In the hair analogy, the UHMWPE chains would be over 30 feet long! Such long polymer chains entangle even more and give exceptional strength—in this case, strong enough to stop a bullet.

HOW SAFE ARE POLYMERS?

As we have seen, polymers are very long and large molecules. What does that mean when it comes to safety? Well, for one thing, polymers don't have any smell. It is fundamentally impossible for them to smell because there's no way for polymer chains to evaporate and reach your nose. They have no taste, and by the same token, they cannot pass through your skin. In fact, polymers are considered so safe that the FDA created a polymer rule whereby polymers are considered safe for the reasons given above. It is known as the FDA polymer exemption.

PLASTICS IN OUR LIVES

It would be unfair and unbalanced to write a book only on the negative perception of plastics without mentioning the good that plastics do.

Plastics such as polyester and nylon are used to make our clothes. Toys, containers, and innumerable other items are made from various types of plastic. Kevlar® and Dyneema® vests stop bullets and save lives, as do the Nomex® outfits that the fire department rely on to protect them from flames. Medical devices rely heavily on plastic. In many instances, it is the only material that works. The list of uses is almost infinite, but there are a couple more items that cannot be overlooked. Plastic pipes bring us clean water, and plastic-insulated wires bring us electricity. Without plastic, we would have no electricity, no cell phones, no laptops or computers of any kind, and no internet to use them on. Many people are not aware of the many uses of plastics and what a plastic-free world would really mean. When considering any topic, we need to carefully weigh the pros and the cons before deciding on the best course of action.

CONCLUSIONS

So, now we have an idea what polymers and plastics are. We know they occur in nature and are just very long molecules, which are considered safe.

Here's what we now believe about plastics:

1. Plastics are bad for the environment, so we must replace them
2. Plastics leads to a waste problem, so we must use less plastic
3. Plastics take 1,000 years to degrade, so we must move to degradable options
4. Plastics cause litter, so we must replace them with paper and degradable materials
5. Microplastics in the ocean are harming marine life, so we must ban disposable plastic items

Plastics have been tried in the court of public opinion and found guilty. Unfortunately, the trial was conducted without any evidence. That's right, plastics have been convicted based purely on gossip. No one bothered to check what the science says about all of this. Why is that? Part of the reason is that it's much more work to check the facts. It takes hundreds of hours of painstaking research. Until now, no one has been prepared to face that daunting task and present the findings for all to see.

You are about to discover that the peer-reviewed science disproves every one of the statements above. This has huge consequences. It means we need to change course if we want to preserve our planet for future generations. If you want to help the environment, I applaud you—and when you have finished this book, you will be a powerful force for good.

CHAPTER ONE
THE MEANING OF GREEN

THE MEANING OF GREEN

These days, everyone wants to be green, or at least look like they are paying attention to the environment. This has led to big businesses creating new products to vie for your dollars. It has become so prevalent that some companies are accused of "greenwashing," whereby they fake being green in order to create a good impression and make a sale. How can a citizen or a corporation be sure what is truly green and what is not? I first learned the answer to that at a party in Stockholm in the mid-1990s.

WHAT IS AN LCA?

Sweden is a leader in environmental responsibility, and even back then they were diligently collecting glass bottles and other items for recycling. It made everyone feel good because they were helping the community. I was chatting with a friend of mine who worked at a large pharmaceutical company. He told me about something called a lifecycle analysis (LCA) as a tool to see what was really "green". He explained that a lifecycle analysis is where you look at everything needed to make a product, including raw materials, energy, waste, by-products, transportation, waste, disposal, and so on. You have to add it all up and see what the total environmental burden of the item is. I told him it sounded fascinating but also like a lot of work. He said it was a lot of work, but it was the only way to be sure of an accurate answer. He told me about an LCA on glass bottles. In Sweden, they collect all the bottles and drive them to Norway where the processing plant melts them to make new bottles. The result of the LCA was that it was not green to collect and recycle glass bottles in Sweden. All the CO_2 created by the trucking meant it was greener to go to the beach, get some sand, and make new bottles from that.

L. L. Gaines and M. M. Mintz, Energy Implications of Glass-Container Recycling, ANL/ESD-18, NREL/TP-430-5703, UC Category: 249, DE94000288 1994

That is when I learned that the obvious answer is not necessarily the right answer when it comes to determining what's green. Going by gut instinct doesn't work. The whole of Sweden was feeling great that they deposited and recycled their bottles, but that well-intentioned action was actually harming the environment instead of helping it. I asked my friend why that was happening, and he said it was probably the government trying to raise awareness about the environment. I thought it was strange to raise awareness by forcing people to do something proven harmful to the environment. Perhaps, because LCA was new back then, the government were unaware that they were doing more harm than good.

Molten glass is processed at ~1100°C (~2200°F), which is very energy intensive

HOW IS LIFECYCLE ANALYSIS OR LCA DEFINED?

"Life-cycle assessment (LCA, also known as life-cycle analysis, ecobalance, and cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling."

Source: Wikipedia's "Life-cycle assessment" page

Thankfully, these days, LCA is a lot more common. You don't have to do it all from scratch because there are databases with most (or all) of the information—computer programs can also make it simpler. There is an ISO standard, so everyone uses the exact same approach, and the results are audited by external experts to make sure that there is no bias. Companies all around the world are using LCA, and environmental groups like Greenpeace use it too. In fact, it is the only accepted way to determine what really is green.

PLASTIC BAGS LCA

We have all heard the outcry about plastic bags. I have read countless articles, and not a single one had any evidence one way or the other about whether plastic bags were green compared to the other options like paper or cotton. As you can imagine, the first thing I did was to Google "LCA plastic bag". I was delighted, and a little surprised, to get hits right away. There were LCA studies available for free as pdf files for anyone to read. What did they say? Well, the first one said that the standard polyethylene bag was the greenest option if all bags are used only once. However, a reusable polypropylene bag was even greener after a few uses. So, plastic came in first and second place. What about paper? Paper bags, even ones from recycled paper, were far worse than plastic. They require more energy, more CO_2 emissions, more water, and more chemicals to make. How about cotton? I've seen plenty of posts online about people proudly taking their cotton totes in order to be green. The LCA showed that cotton was disastrous for the environment, and organic cotton was even worse. You would have to reuse a cotton bag over 100 times for it to break even with the single-use plastic bags we use today.

How do we know which one is actually green?

This came as a surprise to me, but as a scientist, I needed to see more than one study to be sure. So, I did more searches for terms like "LCA grocery bag," "lifecycle analysis plastic bag," and so on. In the end, I found every LCA study from all around the world by scientists in Denmark, US, UK, Canada, Australia, and more. They all agreed that the greenest bags are made from plastic. Let me restate that. There was no cherry-picking. Every single study ever done shows plastic bags are greenest. I even challenged a PhD chemist friend of mine to see if I'd missed any LCA studies. He searched and searched and finally agreed that I had found them all, and they all said plastics are the greenest alternative.

This was conclusive proof that what we have all been told is just plain wrong. Why demonize plastic bags when the evidence says that replacing them does more harm than good? The same lies have been repeated so often that most people accept them without question, but now you know better because you took the time to check the facts. When they ask you "paper or plastic" in the supermarket, you can hold your head high and say, "Plastic please, it's better for the environment". That's what I say. I just wish that the CEO of Kroger had read the studies, because they have announced they are about to ban plastic bags. As I said, if you start with faulty information, then you make decisions that harm the environment instead of helping it.

PLASTIC BAGS ARE GREENEST – PROOF, PROOF & MORE PROOF

For years, we have been told that plastic bags are bad. The vast majority of the general public have fallen for that narrative, and it is hard to change people's minds once they are already made up. Studies have shown that people will believe lies if they hear them enough, and even people with high IQ are not immune.

> M. Warren, Higher Intelligence And An Analytical Thinking Style Offer No Protection Against "The Illusory Truth Effect" – Our Tendency To Believe Repeated Claims Are True, Research Digest, June 26th 2019

So how can we get people to change their mind? I am a realist, so I know that for some people, no amount of evidence will help. Their opinions are based on emotion and are set in stone. However, wiser, more open-minded people can be persuaded if the case is strong enough, and this book is for those people. Here are three reasons to discard the falsehoods and embrace the truth:

1. What we have been told is not credible because it comes from non-experts such as hack journalists with click-bait headlines vying for views
2. The assertion that "plastics are bad" has zero support from scientific studies; it is pure fiction (more on that later)
3. It is vital to align ourselves with the facts because that is the only way to make wise decisions that help, rather than harm, our environment

Having spent months looking for LCA studies on grocery bags, every study shows that plastic is the best choice. Bear in mind that these studies were performed in different countries by independent organizations spanning two decades. Let me show you the conclusions from each study. If you are already convinced, then feel free to skim through the rest of this section. Extraordinary proof is needed when fighting the prevailing view, so I will take up that challenge and present several LCA studies I have found.

STUDY 1 – CLEMSON UNIVERSITY

"A compilation of all of the statistically-based, scientific studies of litter in the U.S. and Canada over an 18 year period shows consistently that 'plastic bags' (which includes trash bags, grocery bags, retail bags and dry cleaning bags) make up a very small portion of litter, usually less than 1%."

"Our results also show that Paper bags, even with 100% recycle content, have significantly higher average impacts on the environment than either of the reusable bags or single-use plastic retail bags."

"Our results in this study show that these regulations and policies may result in negative impact on the environment rather than positive. Even though Paper bags come from a renewable resource and are easily recycled, it is likely that they are not the best environmental choice."

R. M. Kimmel, Life Cycle Assessment of Grocery Bags in Common Use in the United States, Environmental Studies, Clemson University Digital Press 2014

In summary, they found that paper bags are much worse for the environment and that the best two choices were reusable polypropylene bags or single-use polyethylene bags. They also note that plastic bags are not really a significant problem in the first place.

STUDY 2 – FRANKLIN ASSOCIATES

"The study results support the conclusion that any decision to ban traditional polyethylene plastic grocery bags in favor of bags made from alternative materials (compostable plastic or recycled paper) will be counterproductive and result in a significant increase in environmental impacts across a number of categories from global warming effects to the use of precious potable water resources."

"This study supports the conclusion that the standard polyethylene grocery bag has significantly lower environmental impacts than a 30% recycled content paper bag and a compostable plastic bag."

Resource and Environmental Profile Analysis of Polyethylene and Unbleached Paper Grocery Sacks, Franklin Associates Ltd for the Council for Solid Waste Solutions 1990

Plastic bags were found to be even greener than recycled paper bags.

STUDY 3 – DANISH EPA

"In general, LDPE carrier bags, which are the bags that are always available for purchase in Danish supermarkets, are the carriers providing the overall lowest environmental impacts when not considering reuse. In particular, between the types of available carrier bags, LDPE carrier bags with rigid handle are the most preferable. Effects of littering for this type of bag were considered negligible for Denmark."

Life Cycle Assessment of grocery carrier bags, Environmental Project no. 1985, The Danish Environmental Protection Agency 2018

The study found that polyethylene bags were best. They also noted that litter was not an issue, presumably because Denmark handles their waste effectively.

STUDY 4 – UK

"The conventional HDPE bag had the lowest environmental impacts of the lightweight bags in eight of the nine impact categories."

"The paper bag has to be used four or more times to reduce its global warming potential to below that of the conventional HDPE bag, but was significantly worse than the conventional HDPE bag for human toxicity and terrestrial ecotoxicity due to the effect of paper production. However, it is unlikely the paper bag can be regularly reused the required number of times due to its low durability."

"The cotton bag has a greater impact than the conventional HDPE bag in seven of the nine impact categories even when used 173 times (i.e. the number of uses required to reduce the GWP of the cotton bag to that of the conventional HDPE bag with average secondary reuse). The impact was considerably larger in categories such as acidification and aquatic & terrestrial ecotoxicity due to the energy used to produce cotton yarn and the fertilisers used during the growth of the cotton."

C. Edwards & J. M. Fry, Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006, Report: SC030148, Environment Agency 2011

Standard polyethylene bags were greener in almost every possible way. Paper was worse for the environment and reusable cotton bags were disastrous.

The next study is from the Reason Foundation. They are described as an American libertarian think-tank. Some may say that their study should be excluded for fear of possible political bias. I have no political views, and as their conclusions are the same as all the other studies, I see no evidence of bias and therefore no sound reason to exclude their conclusions. The message is the same, whether or not you choose to give more or less credence to any one of them.

STUDY 5 – REASON FOUNDATION

"Proponents claim that banning plastic shopping bags will benefit the environment. Yet, as this study has shown, there is very little empirical support for such claims. Indeed, the evidence seems to point in the other direction for most environmental effects. Some of the alleged benefits are simply false, such as the claim that eliminating plastic bags will reduce oil consumption."

"Unfortunately, policymakers have been cajoled into passing ordinances that ban plastic bags. That is bad news for consumers. It is also bad news for the environment, since the public has been misled into believing that by restricting the use of plastic bags, the problems for which those bags are allegedly responsible will be dramatically reduced."

J. Morris & B. Seasholes, How Green Is that Grocery Bag Ban? An Assessment of the Environmental and Economic Effects of Grocery Bag Bans and Taxes, Reason Foundation 2014

They found that plastic bags are the best option and that replacing them would not reduce oil consumption. They also point out that the public and policymakers have been misled into making decisions that actually harm the environment.

STUDY 6 – SOUTH AFRICA

"As a first order assessment, it can be reliably concluded that plastic bags have a smaller environmental footprint for use ratios of up to 2.5 plastic bags to one paper bag. Above this ratio, the uncertainty of data accuracy is too high to form reliable conclusions. Only for very high ratios of 7:1 and above does the paper bag begin to compete with the plastic bag."

J. Sevitz, A. C. Brent and A.B. Fourie, An environmental comparison of plastic and paper consumer bags in South Africa: Implications for the Local Manufacturing Industry, SA Journal of Industrial Engineering,14(1): 67-82 2003

Once again, plastic bags are found to be far greener than paper.

STUDY 7 – AUSTRALIA

- "Reusable bags have lower environmental impacts than all of the bags with only 1–3 typical uses.
- A substantial shift to more durable bags would deliver environmental gains through reductions in greenhouse gases, energy and water use, resource depletion and litter.
- The reusable PET bag with 100% post-consumer recycled content was found to achieve the greatest environmental benefits, closely followed by the non-woven plastic (polypropylene) 'Green Bag'.
- The shift from one single use bag to another single use bag may improve one environmental outcome, but be offset by another environmental impact. As a result, no single-use bag produced an overall benefit.
- Recycled content in bags generally led to lowering the overall environmental impact of bags.
- From a climate change perspective the paper bags performed most poorly, due in large part to their relatively high weight."

LCA of shopping bag alternatives - Final Report, Hyder Consulting Pty Ltd for Zero Waste South Australia 2009

Plastic bags were found to be greenest, with reusable PP and PET bags best of all. Paper bags performed badly due to their high weight (~10x more than PE).

WHAT TYPE OF PLASTIC BAG IS GREENEST?

So, after looking at all the studies, which type of plastic bag wins? The consensus is that the standard disposable PE bag is greenest and even better if it's reused at least once (as a trash can liner, for instance). The reusable PP bag wins if it's reused several times, but studies have highlighted some downsides to reusable bags. If reusable bags aren't sanitized properly after each use, they can harbour dangerous bacteria.

C. Gerba, Assessment of the Potential for Cross Contamination of Food Products by Reusable Shopping Bags, University of Arizona, June 9th 2010

Mould, yeast, and bacteria were found in reusable plastic bags. Conclusions of the study included:

"The test findings clearly support concerns that reusable grocery bags can become an active microbial habitat and a breeding ground for bacteria, yeast, mold, and coliforms."

and

"This study provides strong evidence that reusable bags could pose a significant risk to the safety of the food supply if used to transport food from store to home."

Grocery Carry Bag Sanitation - A Microbiological Study of Reusable Bags and `First or single-use' Plastic Bags, Environment and Plastics Industry Council 2009

Another publication looked for any health effects recorded due to single-use plastic bag bans. Here is an excerpt from their conclusions:

> "We examine deaths and emergency room admissions related to these bacteria in the wake of the San Francisco ban. We find that both deaths and ER visits spiked as soon as the ban went into effect. Relative to other counties, deaths in San Francisco increase by almost 50 percent, and ER visits increase by a comparable amount. Subsequent bans by other cities in California appear to be associated with similar effects. Conservative estimates of the costs and benefits of the San Francisco plastic bag ban suggest the health risks they impose are not likely offset by environmental benefits."

J. Klick, J. D. Wright, Grocery Bag Bans and Foodborne Illness, U of Penn, Inst for Law & Econ Research Paper No. 13-2, November 2nd, 2012

I was only able to find this one study on the topic, so more research should be done to be certain. Nevertheless, the findings are alarming. It would appear that banning disposable plastic bags caused a serious health crisis.

The consequences of bag bans can be frightening

Thus, although re-useable bags appear to be the greenest solution by LCA, we need to factor in the safety aspect as well. Such bags would need to be washed after each use, and it is not clear whether they would still be the greener than single-use PE bags when the water and detergent used for washing them is taken into account.

PLASTIC BANKNOTES

Lifecycle analysis is specific to each application of the material. We know that plastics like PE and PP are far superior to paper or cotton when it comes to grocery bags, but we cannot assume that plastic will come out ahead in other applications. Perhaps grocery bags are an exception. The only way to be sure is to look for other applications where paper and plastic compete, so I searched for LCA reports comparing paper and plastic. This revealed two reports on paper banknotes versus plastic notes. It may surprise some people to hear that plastic banknotes have been used widely for decades in several countries. The reports I found online were from the Bank of Canada and the Bank of England.

The Canadian report concluded:

> "For all indicators under study (Primary Energy Demand, Global Warming Potential, Eutrophication Potential, Acidification Potential, Smog Potential, human and ecosystem toxicity), most of the impacts are associated with the distribution and use phase. The polymer substrate shows benefits over cotton for all main phases of the life cycle: for the manufacturing phase, since it has to be produced 2.5 fewer times than the cotton paper bank note for the distribution, since it has to be distributed 2.5 less times and its weight is lighter for end-of-life, since the contained carbon in cotton paper bank notes is released as GHG in the landfill."

Life Cycle Assessment of Canada's Polymer Bank Notes and Cotton-Paper Bank Notes - Final Report, C. Marincovic et al., Bank of Canada, Ottawa, ON K1A 0G9 2011

We can see that the polymer (polypropylene) banknotes are clearly superior to cotton because they last much longer.

The Bank of England study concluded:

> "When comparing substrates, it is seen that for a given mass of bank notes the paper substrate generally has slightly lower environmental impacts than the polymer substrate. However, because polymer bank notes are assumed to last 2.5 times longer than paper bank notes (the default assumption in this study) a significantly lower mass of polymer bank notes are required to satisfy the functional unit. Hence, overall polymer bank notes have lower environmental impacts than paper bank notes for all impact categories assessed except for photochemical ozone creation potential."

LCA of Paper and Polymer Bank Notes - Final Study Report, P. Shonfield, Bank of England 2013

So, polymer banknotes last 7.5 years in circulation, far longer than a paper banknote, which lasts only three years, and the plastic are far better for the environment. We know with certainty that polymer notes last much longer because they have been in circulation since the 1980s.

THE BEST CHOICE IS THE ONE THAT DOES THE LEAST HARM

Unfortunately, the ideal material doesn't exist. For example, if we start with a natural material like trees, we need to grind them up to make pulp, use nasty chemicals to bleach the pulp, then use a vast amount of water to process the pulp, and so on. In the end, we have paper, but the process to get there places a huge burden on the environment, so it turns out not to be green after all.

Once we realize that there is no perfect material, we see that we need to choose those that do the least harm. Winston Churchill once said:

> "Indeed, it has been said that democracy is the worst form of Government except for all those other forms that have been tried from time to time…"
>
> **Sir Winston Churchill**

The same can be said for plastics. They are not perfect, but they are the best alternative we have. According to scientific studies, some of the best options include PE, PP, and PET. That's rather fortuitous because they are the most common plastics, and they are among the least expensive as well.

We have all heard the calls to replace plastics. Scientists have looked into the implications of doing just that. They calculated the effects of substituting other materials for plastics packaging and made a report. Here are some of their conclusions:

> "Plastic packaging has many properties that are vitally important for packaging applications, including light weight, flexibility, durability, cushioning, and barrier properties, to name a few. This substitution analysis demonstrates that plastic packaging is also an efficient choice in terms of environmental impacts."
>
> "For the six packaging categories analyzed – caps and closures, beverage containers, stretch and shrink film, carrier bags, other rigid packaging, and other flexible packaging –14.4 million metric tonnes of plastic packaging were used in the US in 2010. If other types of packaging were used to substitute US plastic packaging, more than 64 million metric tonnes of packaging would be required. The substitute packaging would result in significantly higher impacts for all results categories evaluated: total energy demand, expended energy, water consumption, solid waste by weight and by volume, global warming potential, acidification, eutrophication, smog formation, and ozone depletion, as shown previously…"

Lifecyle Impacts of Plastic Packaging Compared to Substitutes in the United States and Canada, Franklin Associates, A Division of Eastern Research Group (ERG) 2018

We can see that plastic packaging is by far the best solution. It would take 64 million tons of alternative material to replace 14 million tons of plastic. Another study showed that plastic packaging also leads to enormous reductions in CO_2 emissions because it helps food stay fresh longer. Food production is a major contributor to CO_2 emissions and plastic packaging greatly reduces CO_2, even after accounting for the carbon dioxide from plastics production.

The report also considered electronics, toys, and many other applications for plastics. In every case, switching away from plastics would mean more environmental damage and more end-of-life disposal problems.

Other studies have come to the same conclusions. For example, an Australian study stated:

> "If plastic packaging would be substituted by other materials, the respective packaging mass would on average increase by a factor 3.6 life-cycle energy demand would increase by a factor 2.2 or by 1,240 million GJ per year, which is equivalent 27 Mt of crude oil in106 VLCC tankers or comparable to 20 million heated homes GHG emissions would increase by a factor 2.7 or by 61 million tonnes of CO_2-equivalents per year, comparable to 21 million cars on the road or equivalent to the CO_2-emissions of Denmark."

The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe, denkstatt GmbH, July 2011

These researchers conclude that replacing plastic packaging would require vastly more alternative materials, use far more energy, and lead to far more carbon dioxide emissions. The other consequence is that moving away from plastics would generate several-fold more waste. People are quick to point out how much plastic we use and how much waste is generated, but they fail to consider that replacing it creates a problem that is several times worse. Perspective is needed if we are to make sound choices.

SOFT DRINK CONTAINERS

This is a topic that comes up again and again. I see posts online claiming that we need to replace PET with aluminium or glass to save the environment. As always, there was no evidence given, so I decided to look for the evidence.

Franklin Associates did a cradle-to-grave analysis and found that PET was significantly greener in all three categories because it created the least greenhouse gas, used the least energy, and created less waste than either aluminium or glass. The report shows that moving from PET to aluminium would mean double the CO_2, double the waste, and use about 50% more energy usage. Does that sound like a good idea now?

Plastic PET bottle design which uses far too much material

Of course, some products are over-designed and we need to avoid using more material than needed to get the job done.

Container Type	Energy (million BTU)	Solid Waste		Greenhouse Gas (CO_2 equivalents)
		Weight (lb)	Volume (yrd^3)	
Aluminium Can	16.0	767	0.95	2,766
Glass Bottle	26.6	4,457	2.14	4,848
PET Bottle	11	302	0.67	1,125

Lifecycle inventory of three single-serving soft drink containers, Franklin Associates, August 2009 (figures are per 100,000 ounces of soft drink)

It seems that Coca-Cola has checked their facts, seen the studies, and moved to PET over aluminium cans in order to reduce CO_2 emissions.

SUSTAINABLE BUSINESS NOVEMBER 6, 2019 / 12:21 PM / A MONTH AGO

Coca-Cola chooses plastic bottle collection over aluminum cans to cut carbon footprint

A review of several such studies conducted by Owen and Boyd highlighted the pros and cons of each material and the variations between each study.

T. H. Owen & K. Boyd, Beverage Container Review – Final Report, Thompson Rivers University, Office of Environment & Sustainability 2013

In general, PET comes out as having the lowest impact compared to glass and aluminium, especially when it is recycled and when larger containers are used.

CONCLUSIONS

In general, it turns out that plastic is a much better choice than cotton, metal, glass and usually paper. The main factor is weight—that is, for a given application, far less plastic is needed than wood, paper, glass, or metal to do the same job.

As a rule of thumb, to know which solution makes sense, just weigh the items and compare. A plastic straw weighs 1g whereas a paper straw weighs 2g. Plus, a plastic straw can be used many times and a paper straw barely works once. A plastic Kroger grocery bag weighs less than 6g but a paper Kroger bag weighs 60g. The paper bag is far less green according to LCA and generates 10x more waste. In the next chapter, we will take a closer look at waste.

Lie #1 – Paper, cotton, glass, and metal are greener than plastics.

Truth – Common plastics like PE, PP and PET are the best choices according to multiple independent lifecycle analyses from all around the world. Replacing plastic leads to far more material used, more energy consumed, more waste, and more CO_2.

CHAPTER TWO
WASTE

WASTE – PAST, PRESENT, FUTURE

When presented with the facts and the many lifecycle analyses on materials, people usually see that plastics are actually the preferred solution. They then ask, "What about all the waste and the litter?" We hear a lot about these topics, and rightly so. Let us once again look at the best available data to see what we can learn about waste. What lessons can we learn from the past? How much waste is there today and what is it made up of? What can be done to reduce waste?

HISTORICAL PERSPECTIVE

In 1880, there were over one-hundred-and-fifty-thousand horses living in New York, each creating over twenty pounds of manure a day. That translates to forty-five thousand tons a month of horse excrement. The streets were covered, and the smell was horrific. This was not isolated to New York. In London, it was estimated that fifty years into the future the whole city would be buried under nine feet of manure. Back in New York, this inspired architects to create the Brownstone buildings whereby the front door is elevated far above street level to avoid unpleasant odours.

Hosed - Is there a quick fix for the climate?, Elizabeth Kolbert,
The New Yorker, November 8th, 2009

This is only one instance of a major environmental crisis. Regulatory solutions were discussed but, in the end, electrification of public transportation and the adoption of the automobile quickly solved the problem. The point is that the developed world has had huge environmental problems in the past. Some were solved by technology, as with the horse example above. Others were solved by aggressive regulation; for example, the infamous Great Smog of London that killed thousands of people in the early 1950s.

The Great Smog of London Wikipedia entry

Is it so surprising that developing countries have similar issues now to the ones we had just a few decades ago? I would say not. They have major problems with litter because they do not yet have regulations in place, nor do they have the collection and disposal infrastructure. It appears to be human nature to act only when the conditions become unbearable, and that is starting to happen in many parts of the world.

THE PRESENT

Let us look at how waste has grown over the years and how the introduction of plastic has influenced it.

The EPA (US Environmental Protection Agency) records the amount of household waste produced per year, so accurate records exist and are available to the public. There is so much data that I had an independent data expert put it in a manageable form. We found a steady growth of US waste over the last several decades. There was virtually no plastic to begin with because it was a new type of material, but then it became more prevalent as time went on. Plastic is a relatively small fraction of overall waste, which is surprising given that virtually every newspaper article and online post talks about plastic as if it were the number one cause of waste. Instead, the data shows that plastic became the 4th most common type of waste and has remained in that position for decades. We can conclude that plastic is not the most pressing problem and that it is not taking over as the environmentalists tell us.

What else can we see from the EPA data? The amount of trash (the EPA call it municipal solid waste, or MSW for short) increases as the population increases. That comes as no surprise. A closer look at the data, however, shows that the rate at which waste increased has actually declined. That means that something has happened to help us reduce waste generation per person over recent years.

This was investigated by scientists in a peer-reviewed article. They found that plastics are responsible for the reduction in our creation of waste:

> "A comparison of waste generation rates for each material category found in MSW reveals that plastics increased by nearly 84 times from 1960 to 2013 while total MSW increased only 2.9 times. The increase in plastic waste generation coincides with a decrease in glass and metal found in the MSW stream. In addition, calculating the material substitution rates for glass, metal and other materials with plastics in packaging and containers demonstrates an overall reduction by weight and by volume in MSW generation of approximately 58% over the same time period."

D. A. Tsiamis, M. Torres, M. J. Castaldi, Role of plastics in decoupling municipal solid waste and economic growth in the U.S., Waste Management, 77, 147-155 2018

They conclude that plastic dramatically reduced the amount of municipal solid waste (MSW). This is in line with the other studies that found replacing plastics would lead to far more material usage, waste, and environmental burden. I have seen endless posts where people ask us to replace plastic with some other material such as paper, metal, or glass, but the science clearly shows that we need 3-4 pounds of material to replace just one pound of plastic. Who in their right mind would propose generating 3-4x more waste?

This is the kind of insanity that results from taking action before checking the facts. It is exactly the sort of nonsensical knee-jerk reaction that I hope we can avoid after people have read this book.

This data may also explain why the public believe that plastic waste is a problem when in reality, it is not. The public has seen the amount of plastic waste increase 84x over the last several decades. It must look as though it is mushrooming out of control. And yet, what the public does not realize is that the increased use of plastic has dramatically lowered the amount of paper, cardboard, and other materials. It's ironic that the more plastic we see, the worse it appears but the better it actually is for the environment. Appearances can deceive us, which is why we need hard data to be sure of the facts.

An in-depth analysis has been performed to estimate the impact of replacing plastic. Here is an excerpt from that report:

> "For the six packaging categories analyzed – caps and closures, beverage containers, stretch and shrink film, carrier bags, other rigid packaging, and other flexible packaging – 14.4 million metric tonnes of plastic packaging were used in the US in 2010. If other types of packaging were used to substitute US plastic packaging, more than 64 million metric tonnes of packaging would be required.
> The substitute packaging would require 80 percent more cumulative energy demand and result in 130 percent more global warming potential impacts, expressed as CO_2 equivalents, compared to the equivalent plastic packaging."

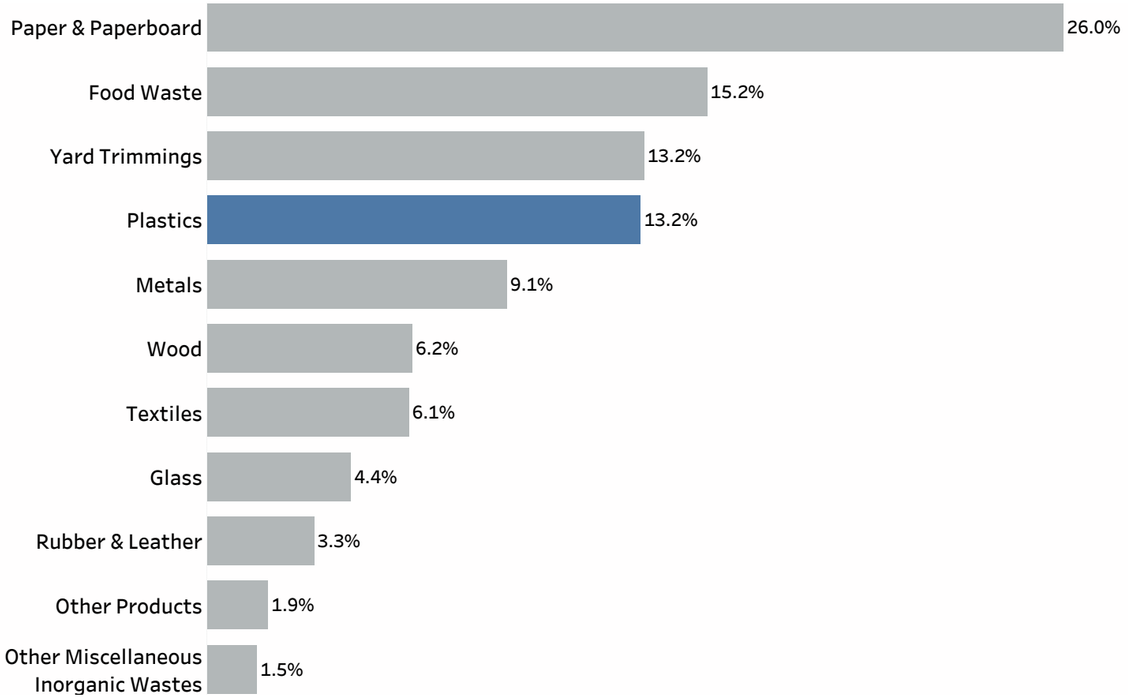
Impact of Plastics Packaging on Life Cycle Energy Consumption & Greenhouse Gas Emissions in the United States and Canada – Substitution Analysis, Franklin Associates, A Division of Eastern Research Group (ERG), January 2014

The study showed that replacing plastic packaging in the US would mean adding 50 million tons more material, leading to 50 million tons more waste every year. Does that sound green to you? It would be a spectacularly stupid thing to do, and yet, yielding to pressure from us, the customers, companies like the supermarkets Iceland and Waitrose and other companies like Nestlé, IHG, and Etihad Airlines are doing just that. Companies are listening to the demands of the public, but those demands are based on misinformation. Be careful what you wish for is a saying that applies well here. Right now, we are wishing for 50 million tons more waste, 80% higher energy usage, and double the CO_2.

J. Zheng, S. Suh, Strategies to reduce the global carbon footprint of plastics, Nature Climate Change, 9, p 374–378 2019

We noted earlier that waste grows with population. When I was at school, we were taught that the world's population was exploding, and a crisis was coming as the population spiralled out of control. However, as we know now, that has not happened. We reached the maximum rate of population growth many years ago and it has been slowing ever since. It turns out that poor countries have more children, but as they climb out of poverty there is no need for large families and effective birth control brings the population growth down dramatically. This is important because as each country gets out of poverty, the waste problem will decline as their ability to manage their waste improves. There has been tremendous progress in reducing global poverty; you can see compelling data in books such as Factfulness by Hans Rosling and Enlightenment Now by Steven Pinker. We can safely expect that the global waste problem will be mitigated by more moderate population growth.

Now that we have seen that plastics are not the primary contributor to waste and that waste is not growing out of control, it seems like a good idea to see which materials are causing waste.



Source: www.epa.gov

The first thing that leapt out to me was that paper and cardboard are by far the largest culprits when it comes to waste. Why then is all the media attention, all the attention from green groups, and all the public scrutiny focused on plastics, which are tied for third place? Surely, if we want to make the biggest impact, we should be looking at the major source of waste. We could ask ourselves how it came to be that the truth is so very different than the narrative we are fed. We will address that topic later in the book. You may be thinking that we need not be concerned with paper, cardboard, food waste, and yard trimmings because they are degradable and plastics are not. Actually, that turns out to be a fallacy as well, and we will cover it later on.

SINGLE-USE PRODUCTS

Single-use products are under intense scrutiny, and rightly so. Although we probably don't want to be reusing plastic syringes in hospitals, there are plenty of products where single-use is not a wise approach.

How did single-use come into existence? It is made possible only when materials become so inexpensive that we can afford to discard them without a second thought—or a second use. Think of the lollipop sticks, newspapers, candy wrappers, and water bottles we have become accustomed to discarding. I would argue that some of these items do not have to be single-use. What do I mean by that? Well, for example, one of my daughters likes to drink her water through a straw at night. We all know that the single-use plastic straw is notorious. However, it turns out that a plastic straw does not have to be thrown away after one use. After all, who is forcing us to use these products only once? She reused the same (rinsed) plastic water straw for three months and it was still in pristine condition. Reusing it 100x drastically lowers the environmental impact of the straw. Of course, we now know that a paper straw is less green, generates more waste, and barely survives one use, let alone a hundred. The best option, though, is to take no straw at all.

Single-use sounds like the ultimate example of wastage, doesn't it? After all, what could be worse than single-use? I'll tell you what! Zero-use! I get over a pound a day of zero-use paper shoved in my letterbox and thrown on my driveway! I get fliers, brochures, magazines I never ordered, catalogues, and even a hefty newspaper I didn't ask for. It is all zero-use because it goes directly into the trash can. We just saw from the EPA data that paper is the number one cause of waste, and it's obvious that zero-use is worse than single-use. It therefore boggles my mind that no one is talking about all the paper junk we have delivered to our doorsteps every day. The problem is far worse than it is for plastics, and yet we hear not one word about it. It's shocking, and there is no way to stop it. It's relentless. To put it in perspective, a plastic straw weighs 0.5g, yet I received 600g of spam paper today alone. That paper weighs as much as 1,000 plastic straws or 100 plastic bags. Why is it that people are obsessed with plastic straws when 1,000x more paper is delivered every day to our houses?

Please note that this is not an attempt to defend the use of plastic. All waste is undesirable. Rather, the point is that if we are to attack the waste problem, why overlook the major problem and devote all of our attention and effort to a lesser issue? There should be a way to report this senseless destruction of trees and our environment. There should be fines and jail time for repeat offenders. I hope we can pass laws against automated delivery of litter to our driveways and junk to our mailboxes. The impact would be instantaneous and huge.

The book Rubbish! The Archaeology of Garbage points out that removal of plastics from landfills would not solve anything, as plastic occupies just 16% of landfill space by volume. It turns out that humans are not good at estimating where the real problems lie. For example, there is a lot of talk about disposable diapers as a huge problem when, in actuality, they account for less than 2% of the space in a landfill. Similarly, plastic bottles take up less than 1% of landfill space. Instead, they point to paper and construction debris as the main culprits, which combine to account for well over half of US refuse. They say that these are the two big ticket items we should be focussing on.

William L. Rathje, Cullen Murphy, Rubbish!: The Archaeology of Garbage, HarperCollins 1992

The cardboard & paper industry creates most waste but is hiding from scrutiny

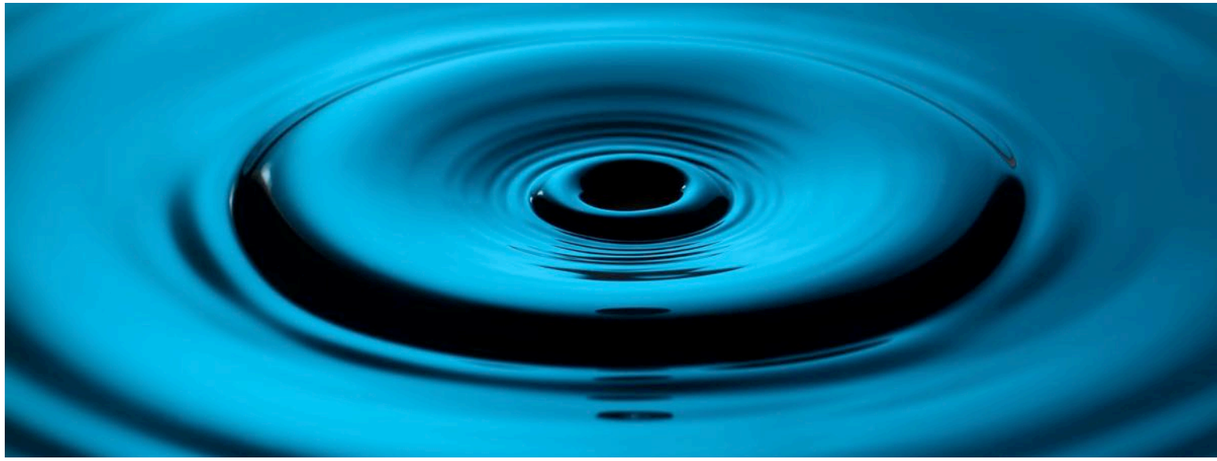
I recently discovered that the single-use problem is not new. In fact, it has been around for several thousand years. It is always presented a modern-day invention, but the evidence says otherwise:

3,600-year-old disposable cup shows even our ancestors hated doing dishes

3,600-year-old disposable cup shows even our ancestors hated doing dishes, Amy Woodyatt, CNN December 16th 2019

> "People may be very surprised to know that disposable, single-use cups are not the invention of our modern consumerist society, but in fact can be traced back thousands of years. Three-and-a-half-thousand years ago, the Minoans were using them for a very similar reason to us today: to serve drinks at parties. The only difference is the material."

The difference was that in those days, they cast aside clay drinking cups which have clearly survived for thousands of years because they are being discovered today. In contrast, a cup disposed of today is made of paper or plastic and will degrade in just a few years of exposure outdoors. More about that later.

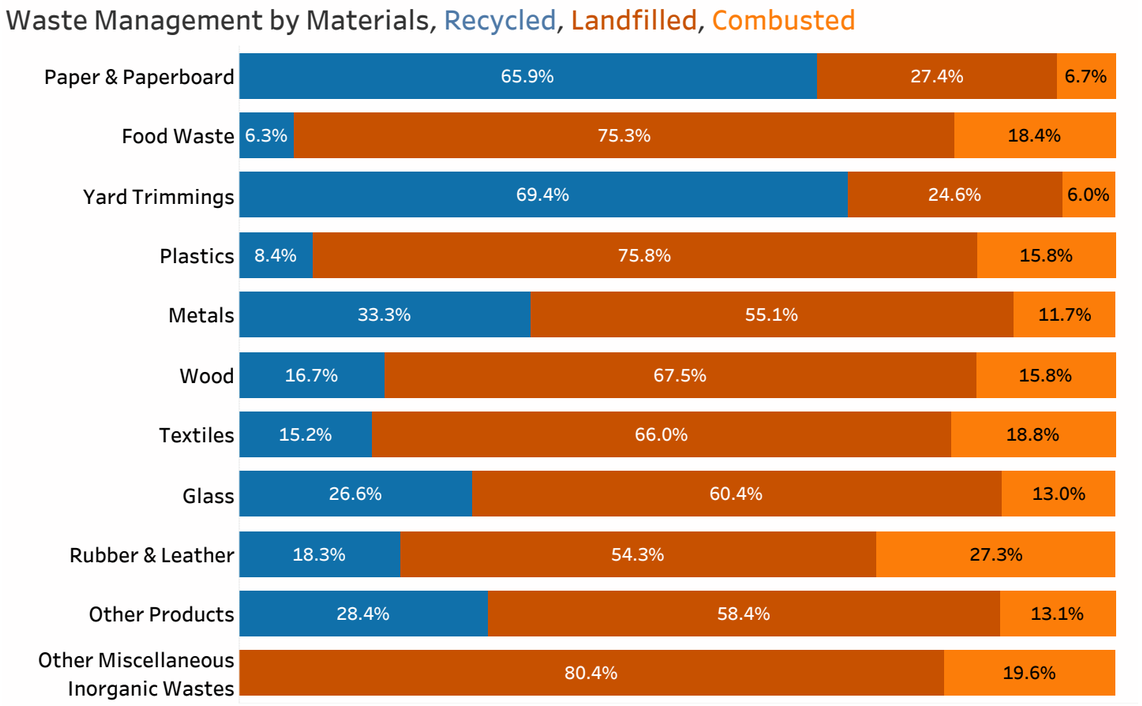


MINIMIZING WASTE

All living things create waste. Every breath we take leads to an outward breath of waste gases. Other bodily functions create waste too. There is no avoiding waste entirely, as anyone who has attempted to hold their breath will know. Civilization has simply created new kinds of waste, and we need to adapt in order to minimize it, just as we did in the past for horse manure and smog. One way to reduce waste is to reuse materials so they have a longer useful life. Another way is to recycle materials so they can become new products, thereby extending their life.

RECYCLING

One frequent criticism of plastics is that they are not recycled enough. Lifecycle analysis tells us that recycling plastics is good for the environment, so why isn't it done more? Once again, it is time to check the data to see what it reveals.



Source: www.epa.gov

In the USA, only 9% of plastic is recycled at present. It is a low percentage, but that's also the case with several other popular materials. Looking at plastics, though, there is no denying that the number should be higher. What prevents more recycling of plastics?

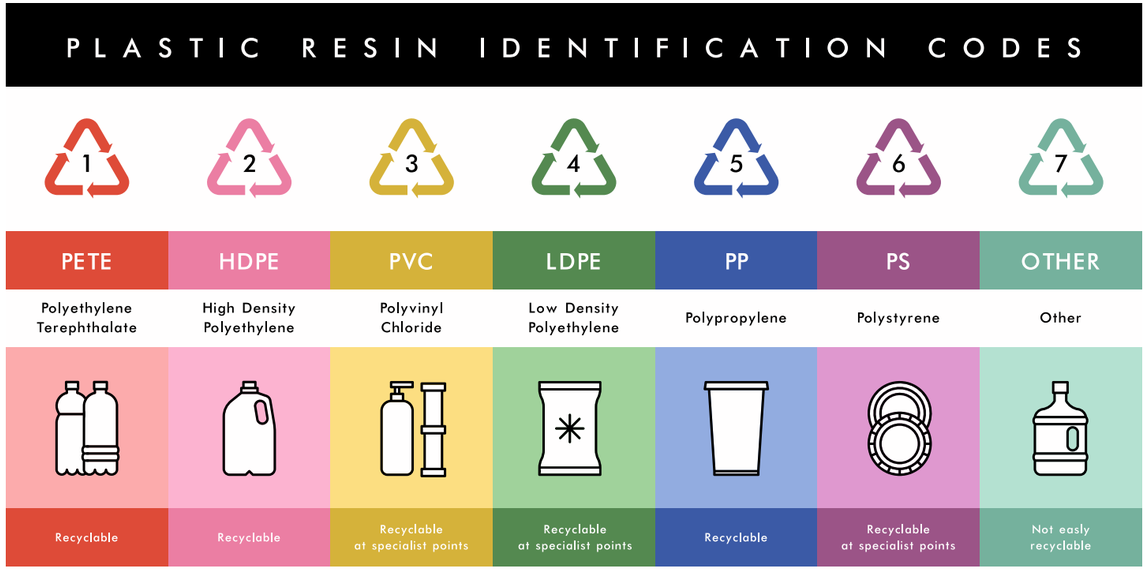
A lot of misinformation has been spread on this topic. As one example, we are told to avoid black plastics because they cannot be recycled. But is that true? As a plastic materials expert, I can explain. Black plastics are actually easy to recycle. You simply melt them and make a new part. Where's the problem, then? The issue is with sorting. To recycle plastics, you first need to sort them, so that you recycle PE waste together with only PE waste, PP waste with PP waste, and so on. It is harder to sort conventional black plastics automatically because the machines that check the type of plastic work based on light, so they don't work properly on black parts which absorb all the light. So, instead of telling us that, we are told the lie that they cannot be recycled. What it really comes down to is that the recycler doesn't want to go to the extra effort to recycle black plastic. This kind of lie confuses and misleads the public. Even more worrying is that the solution to the problem of sorting black plastic has been on the market for several years. By using a different kind of black colourant, the machines are able to sort the parts without difficulty. Nowadays, there really is no reason not to recycle black plastic, and yet this misinformation persists.

You may think that is an isolated case, but it is not. In Ohio, school children are taught that containers whose opening is wider than their base cannot be recycled. I was really surprised when my kids came home and told me that because I know it's not true. Plastic can be ground up, remelted, and recycled no matter what shape it is. So, I searched on Google, and sure enough, only in Ohio do they tell people that such containers cannot be recycled. Here is what we are told online:

> The following items are not currently accepted through this recycling program.
>
> Plastic: Containers that DO NOT have a bottle neck or a base larger than the top. For example, yogurt cups, butter tubs, drinking cups, disposable storage containers, toys, plastic bags, plastic films and bubble wrap, and plastic utensils.

https://www.swaco.org

The rest of the country has no problem with such containers but in Ohio, the children are taught these items are “unrecyclable”.



Most plastics can be recycled if the right facilities are present

In general, most plastics are rather easy to recycle. You need to sort them by type, grind them up, and then remelt them into new shapes. This takes very little energy and recycling can be done many times with little or no loss in properties. Why doesn’t the public know this? This is what we should teach children in school because it’s true. The plastic types one through six can all be recycled by melting, and together they account for 87% of plastics (see the diagram Market share of commodity plastics in Chapter 4).

So, from a technical perspective, there is no reason not to recycle far more than we do now in the US. We know it’s the green choice, and we know it’s possible because several other countries have been doing it for years. If we look at the data for Europe, for example, we see that every country is far ahead of the US. In Europe, the average recycling rate is ~45% and is as high as 75% in Lithuania. This is a clear indication that the USA has chosen to fall behind by not making the appropriate investments in recycling infrastructure.

Plastic waste and the recycling myth, Katharina Wecker, DW 12th October 2018

Plastics are very sensitive to contamination, which is an impediment to recycling. It means that they must be washed properly and then sorted with great accuracy. PE must be recycled only together with other PE of the same type, PP must be mixed only with PP, and so on. The reason is that plastics are immiscible with each other, so when you melt a mixture of two or more plastics, you get droplets of one plastic inside the other one. It’s like the emulsion you get when you shake oil and water together. Those droplets of plastic can dramatically lower the mechanical properties of the material, especially the impact resistance. Thankfully, there are compounds called compatibilizers that act like surfactants to can help improve the properties of immiscible plastics.

You may be wondering why the government or companies don’t simply install more sorting and recycling facilities. Surely, that would make great business sense. Unfortunately, this not the case. If there was money to be made, you can be sure that it would be more popular. It turns out that recycled plastic is often more expensive than new, virgin material. In such cases, recycled plastic is hard to sell. Often the recycled material is discoloured, so you can’t make vibrant, attractive colours out of it. Imagine you start with grey water. No matter how much pigment you put in it, you can’t make the water an intense colour. Companies ask for recycled material only to find it’s more expensive and often looks unappealing. It may be that in the future, customers must become accustomed to less vibrant packaging.

DESIGN FOR RECYCLING

There are three main actions that we can take to improve recyclability:

1. Try to make each product from one material because mixtures of plastics do not recycle as easily
2. Make everything possible from just three plastics (PE, PP or PET) in order to simplify sorting and recycling
3. Make the plastic materials more durable so they can be recycled more times before losing too much strength

I have spent my career working for and with major corporations. I know that competition is intense and that the difference between profit and loss can be a penny here or there in your production and materials costs. At present, products are designed to be as cheap as possible. You may not be aware that over the last few decades, plastic packaging has become thinner and thinner. We use 30% less now than we used to, and it's still decreasing year over year. Every conference I attend focusses on downgauging (making plastic films thinner) and lightweighting (where we make automotive parts lighter for better fuel efficiency). These are industry megatrends which help reduce material use and, in that way, help the environment.

The drive for the lowest possible cost can also have negative effects, however. Designing to be cheap means not maximizing durability. Sometimes parts are made so thin that they are too weak and fail. What is more common is a failure to add enough stabilizers to protect the plastic for the long term. There is a false narrative that plastics last forever, but nothing could be further from the truth. The main plastics in use today are PE and PP. Although they are the greenest choices, these plastics are chemically unstable and can only be used because we add stabilizers that protect them when they are molten during processing and then later on in use. Without stabilizers, they simply degrade and become useless. Polypropylene is the worst example, as it loses strength in just one year at room temperature unless protective additives are used.

At present, companies select the cheapest stabilizers and use as little as possible to protect the product for its intended lifespan. Why are they so frugal? It all comes down to cost. Fierce competition means there is no scope to add more cost than is absolutely necessary. This means that products don't last as long as they could. More importantly, it means that when it comes time to recycle the plastic, the stabilizer is all used up, so that reheating the plastic causes unacceptable degradation, leading to discolouration and loss of physical strength. There is much more about additives later on in the book.

If we are to design for recyclability, then we need to select better stabilizers and use more of them. If we do that, then plastics like PE and PP can be recycled many times without loss in properties. That has already been demonstrated, so it is not mere speculation. This is the way forward.

REUSE

Reusing items is a green alternative to simply throwing them away. Reuse also means generating less waste, as each product remains deployed for longer, thereby delaying disposal. Many of the items we use today don't need to be thrown away. I already gave the example of plastic straws, which can be rinsed or put in the dishwasher and used a hundred times or more. Another example is the PET bottles that sport drinks come in. These are sturdy and can be reused countless times for water or other drinks. The term "single-use" is misleading because it makes it sound as though the item can and should be used only one time. The reality is that we, the customer, can choose whether we want to discard perfectly serviceable items, or do the responsible thing and reuse them until they can no longer function.

REDUCE

Speaking of straws, in most cases, there's no need to give one and no need to accept one. Simply drink out of a cup, unless you have special needs. The same goes for other items. We live in a world where a huge marketing engine makes us crave the latest phone, even though we know our existing phone is just fine. We are told to buy new clothes in the colours and fabrics that are deemed "in" for that season. This way of thinking needs to be adjusted with the environment in mind.

The public doesn't realize it, but plastic packaging has become thinner and thinner over the years, substantially reducing the amount used per item.

"Initial thicknesses of plastic packaging material averaged approximately one-third of the weight of the combined glass and metal replacement until the year 2000. Starting in 2000, the plastic packaging continuously decreased by about 3% per year, further reducing the weight exchanged until the ratio reached one quarter of the combined replacement weight (Franklin Associates, 2014)."

The use of plastics over time has been monitored, so we can tell how much progress has been made over the decades.

"…according to the British Plastics Federation's database, between 1970 and 1990 the weight of the average plastic yoghurt pot decreased from 12 g to 5 g, and the corresponding decrease in weight of a typical plastics detergent bottle was from 300 g to 100 g. Similarly, typical general purpose and industrial plastic films, bags and sacks have decreased in average thickness by up to 400% over the same time interval. As a consequence of these improvements in functional weight characteristics, plastics transportation costs and associated emissions have been reduced dramatically."

T.J. O'Neill, Life Cycle Assessment and Environmental Impact of Polymeric Products, RAPRA Reviews 2003

The same RAPRA report noted that as the use of plastics in cars dramatically increased, the gasoline consumption of those cars decreased by 14%. Plastics are, of course, considerably lighter than the materials they replace.

Although plastic can be used in extremely low amounts, it is up to designers to optimize the design. I have held PET water bottles so thin that you could barely touch them without crushing them. That is efficient design. On the other hand, we are all familiar with the PET sport drink bottles that are so thick you wonder if they are meant to be used on the battlefield. The two designs perform the same function, but the over-designed bottle is made to impress and conveys a certain high-quality brand image. It probably does impress certain customers, but we need to retrain ourselves to respect and admire the minimalist approach. It leads to far more efficient use of our resources and far less waste. We need to retrain ourselves not to demand fancy packaging.

CONCLUSIONS

The public believes that plastics are the main cause of waste and that the problem is spiralling out of control. However, looking at the facts tells a very different story.

We know that plastics are nowhere near the main cause of waste and that our use of plastics has substantially reduced overall waste creation. Furthermore, studies show that replacing plastic would mean creating 3-4x more waste on average, and that would be a supremely unwise decision. The data shows that the number one problem is paper and cardboard, which utterly dominate our waste problem and yet almost no attention is given to that topic. It must be the world's best-kept secret. Worse still, much of the paper waste is zero-use in the form of fliers, newspapers, and catalogues that go directly into the trash can.

If we want to address waste, then first we need to recognize that plastics are helping us reduce waste. Then we need to focus on the materials that dominate the waste stream, including paper, cardboard, and lawn trimmings. We need public pressure for strict laws against delivery of zero-use products, with harsh fines for violators.

Waste is an unavoidable consequence of the industrialization that has dramatically improved our quality of life, but there is still much we can do to reduce it. Inevitably, some waste will be mismanaged and become litter or pollution. These are topics we will cover next.

Lie #2 – Plastics are the cause of our waste problem.

Truth – Plastics account for 13% of waste, they reduce overall waste, and replacing them would lead to three or four times more waste.

CHAPTER THREE LITTER

LITTER – SOURCES AND SOLUTIONS

This section considers litter, including what it is, what causes it, and what we can do to prevent it. As with any topic, checking the facts first allows us to identify the true problem, which is vital for crafting an effective solution.

PERCEPTION

In 1880, there were over one-hundred-and-fifty-thousand horses living in New York, each creating over twenty pounds of manure a day. That translates to forty-five thousand tons a month of horse excrement. The streets were covered, and the smell was horrific. This was not isolated to New York. In London, it was estimated that fifty years into the future the whole city would be buried under nine feet of manure. Back in New York, this inspired architects to create the Brownstone buildings whereby the front door is elevated far above street level to avoid unpleasant odours.

Hosed - Is there a quick fix for the climate?, Elizabeth Kolbert,
The New Yorker, November 8th, 2009

Before we proceed, I have a confession to make. To me, one of the ugliest things I know of is a plastic grocery bag. Just one bag on the kitchen counter and the whole kitchen is an eyesore. And this from a plastics expert! I can't even work out why it's so ugly, but there seems to be a keen response. Interestingly, I once read a book that pointed out that, technically speaking, a felled sequoia is litter.

They had a picture of a huge sequoia on the forest floor, and they even noted that such dead trees have remained intact for at least 500 years with hardly any degradation (Scott, 1999). That's tons and tons of material that doesn't readily degrade, and yet it evokes no negative response when I see that image. In fact, it looks natural and even majestic. My eye accepts that image without issue, and yet, one tiny plastic bag and I'm on edge.

Gerald Scott, Polymers and the Environment, RSC Paperbacks Page 97 1999

I looked into this and found that people favour natural-looking images over man-made ones (Kardan, 2015). Perhaps we're programmed to spot objects that don't belong, as a survival mechanism. That's not my area of expertise, but it may be part of our response to certain objects like plastic straws and bags. In contrast, plastic timber has not caused any outcry with the public. It looks natural like wood, so no one has a problem with it.

O. Kardan et al., Is the preference of natural versus man-made scenes driven by bottom–up processing of the visual features of nature? Front. Psychol. 6:471 2015

Another issue facing plastic litter is how much visual space it occupies. For example, a standard US grocery bag weighs 5.5g but it looks huge to the human eye. What we perceive is a large amount of litter, when the actual weight of that litter is the same a one US quarter coin, a wine cork, a gaming die, or one blackberry. This optical illusion is a large part of the reason for the unjustified attacks on plastic. We think the problem is a lot worse than it really is. It is estimated that 2% of all plastic produced is littered, and there is much room for improvement as certain regions catch up with the best-in-class countries.

J. R. Jambeck, Plastic waste inputs from land into the ocean, Science 347 (6223), 768-771, 2015

The perceived amount of litter is huge, but the actual amount of litter is much less. This is represented by the weight of a plastic bag compared to a plastic gaming die, which is just 18mm, or 0.7 inches, across.

Another material that suffers from this effect is expanded polystyrene. One expanded PS packing noodle weighs just 0.07g, so 80 of them take up a lot of volume but weigh only as much as one bag or gaming die.

Plastic grocery bag and gaming die drawn to scale (same weight of plastic)

THE TRUE CAUSE OF LITTER

The Meriam Webster Dictionary defines litter as a noun and a verb…

Litter as a noun: “trash, wastepaper, or garbage lying scattered about”

Litter as a verb: “to strew with scattered articles”

Litterer or litterbug: “one who litters a public area”

From this, we understand what litter is and how it got there. Clearly, litter is defined as objects scattered around and/or created by the action of a litterer. Litter is certainly not made up of objects that spring to life and scatter themselves. When I take a walk outside and see a candy wrapper or a soda can, I know immediately that it was left there by an irresponsible person, namely a litterer, and I conjure up vivid imaginings of punishments for the culprit. Somehow, in recent years, it has become commonplace to discuss litter as though the material itself were somehow to blame. We are presented with a picture of litter on a beach along with a headline telling us to be “tough on plastics”. No one seems to question it, and yet, when you stop to think about it, we all know that the cola can, newspaper, or grocery bag cannot be blamed. It is both naïve and counterproductive to blame objects or materials for the actions of irresponsible human beings. Only by correct placement of the blame can we take appropriate and effective action. Once we realize that people are the problem, then we recognize that altering human behaviour must be the solution. Fortunately, we all know how to encourage proper behaviour. We educate our children, and for adults, we give encouragements for good behaviour and punishments for bad. If it were up to me, there would be heavy, escalating fines and community service for litterers.

People are the cause and litter is the effect

PROOF THAT HUMAN BEHAVIOUR CAUSES LITTER

I know that some people will probably refute the claim that litter is a people problem. So, I created a couple of examples that I would like to share.

Let us imagine you are driving your car. It has 300,000 miles on it, and it finally stops working in the middle of the road. You get out and leave the car there to rust away. It is now a huge piece of worthless litter creating an unsightly mess in the environment. Who created that situation? Is the litter (i.e., the car) to blame? Most people would readily admit that the car cannot take the blame. I contend that it is exactly the same situation with every piece of litter, whether it's a car, a cigarette butt or a candy wrapper. Every piece was left there by a human being. Blaming plastics for litter is equivalent to driving your car into a tree and blaming the car. It's human nature to shift the blame, but that doesn't make it right. Until we face that harsh reality, there will be no progress with our litter problem. This leads me to a related topic. I always see people blaming Coca-Cola or Unilever for litter. How unjust! In the example above, would you blame Ford or Volvo for abandoning your car? Would you demand that they pick it up and recycle it? No! Why then do people demand that Nestlé come to pick up candy wrappers?

An abandoned car – who would expect the manufacturer to pick it up?

Here is an even more powerful example to show that people cause litter. It's estimated that 162 billion new banknotes go into circulation every year. Ninety-five per cent of those are paper and the rest are made of plastic. That means about eight billion new plastic notes are issued per year, which means about one plastic banknote per year for each person on Earth. It's a truly gargantuan number, but how many of those "make their way" into the oceans or wash up on beaches? How many of those eight billion banknotes do we see on the street or pavement when we go for a walk? That's right. None! They have been around since 1996, so we should be drowning in plastic banknote "litter" by now. If using materials like paper or plastic was the real cause of litter, we would see banknotes everywhere. In reality, we see none because people choose to take care of their banknotes, whether they be paper or plastic.

Explainer: what's all the fuss about polymer banknotes?
Mark Harding Chemistry World Magazine, RSC, 13th September 2016

Eight billion PP banknotes printed per year – how many have you seen as litter?

The same argument can be applied to credit cards. They are small, easily misplaced pieces of plastic. According to the latest figures, each American adult carries more than two credit cards on average. That translates to over 300 million plastic cards all around the country. When was the last time you saw one on the sidewalk? When is the last time one washed up on the beach when you were on holiday? Do we see them clogging our rivers and sewers? We do not. These ubiquitous pieces of small plastic do not sprout legs or flippers and "make their way" into the environment. People act responsibly with these small pieces of plastic. The message could not be clearer: people cause litter.

These examples also lead us to an effective and proven way to solve the litter crisis. As long as plastic is cheap, people drop it, but when it is a banknote worth just $1, then they never drop it. Even if a note is dropped on occasion, it is immediately picked up. We see that plastic articles with value are "self-tidying". This explains why the PET bottle return system in Norway works so well. They have a PET bottle return rate of 97% because each bottle has a small deposit associated with it. In Norway, each bottle is recycled twelve times on average, making the whole system very friendly indeed because recycling bottles is greener than making new ones. It uses less material, less energy, and creates less carbon dioxide. Norway has led the way, and other countries are now considering a similar system having seen the success of the Norwegians. We should always be on the lookout for new approaches in other countries so that we can copy them once they are proven to work.

Science & Environment

UK 'could adopt' Norway bottle recycling system

By Roger Harrabin
BBC environment analyst

UK 'could adopt' Norway bottle recycling system, Roger Harrabin, BBC News 7th February 2018

OCEAN LITTER

It is well documented that marine wildlife is affected by plastic objects. For example, animals can become entangled in nets. Some animals eat plastic, and although the material is non-toxic, they may suffer other effects. For example, eating inert material can take up space in the stomach, giving the sensation of being full but without any calorific value (although an animal would have to eat a lot of plastic for that to happen). Another effect is when animals ingest plastic and it gets stuck in their throats, stomachs, or gastrointestinal tract, leading to injury or death.

J. G.B. Derraik, The pollution of the marine environment by plastic debris: a review, Marine Pollution Bulletin, 44(9), 842-852 2002

These effects are real, they are significant in magnitude, and they do need to be addressed. However, we need to recognize that all of this damage happens because plastic and other articles are in places where they should not be. There would be no problem at all if people were not intentionally dumping plastic and other waste into the oceans. The problem is clearly not with plastic itself, but with the unconscionable behaviour of some humans who are littering up our oceans. We will look at that in more detail next.

Marine Anthropogenic Litter, M. Bergmann, L. Gutow, M. Klages (Eds.) Springer, Berlin, 2015

THE GREAT PACIFIC GARBAGE PATCH

The ocean currents can form a vortex that traps any litter floating on the water. This has been the subject of much attention because the patches are so large. One such patch is estimated to hold 80,000 tons of mixed plastic.

Great Pacific Garbage Patch

The Great Pacific Garbage Patch is a collection of marine debris in the North Pacific Ocean. Marine debris is litter that ends up in the ocean, seas, and other large bodies of water.

National Geographic – Resource Library Encyclopedic Entry

The gyres are often described as floating islands of plastic, which conjures up a powerful image. But the image is a false one:

> "Despite the common public perception of the patch existing as giant islands of floating garbage, its low density (four particles per cubic meter) prevents detection by satellite imagery, or even by casual boaters or divers in the area. This is because the patch is a widely dispersed area consisting primarily of suspended 'fingernail-sized or smaller bits of plastic,' often microscopic, particles in the upper water column."

What is the Great Pacific Garbage Patch? National Ocean Service
Great Pacific garbage patch – Wikipedia

You read that correctly, the so-called plastic islands are invisible from space and you can't tell they are there, even if you are swimming in one. Once again, we have been misled into picturing a catastrophic image when the truth is very different.

Another aspect worth considering is the density of plastics. Plastics tend to be light materials, for example PE and PP both float on water. That is why we see mainly plastics floating whereas other materials like metal, glass, ceramics and even some types of wood, sink. The plastic is visible, so it draws our attention. In contrast, the other materials all sink, so we don't give them a second thought — out of sight, out of mind.

WHAT'S IN THE PATCH?

Almost half of it is discarded fishing nets and most of the rest is other fishing industry gear, such as ropes, oyster spacers, eel traps, crates, and baskets. This was a surprise to the scientists who went out to study it.

The Great Pacific Garbage Patch Isn't What You Think it Is

It's not all bottles and straws—the patch is mostly abandoned fishing gear.

The Great Pacific Garbage Patch Isn't What You Think it Is - It's not all bottles and straws—the patch is mostly abandoned fishing gear, Laura Parker, National Geographic, March 22nd 2018

So, if it is mostly fishing gear, how did it get there?

WHO'S AT FAULT?

It is amazing to me that somehow plastics take the blame for the gyres when they are clearly the fault of the fishing industry. I bet if there was a $50,000 dollar fine for returning to harbour without your net, this problem would vanish pretty quickly. Perhaps governments should order fishing boats to go out and get these nets, because fishing boats put them there. Perhaps there needs to be a redesign of the nets so that they are not so easily lost.

40 Tons of Fishing Nets Pulled From Great Pacific Garbage Patch

40 Tons of Fishing Nets Pulled from Great Pacific Garbage Patch, Olga R. Rodriguez, Associated Press June 28th, 2019

This Time Magazine article about a boat that had recovered 40 tons of nets was supposed to be uplifting news, but then I checked to see how much was dumped per year. It was reported that in 1975 alone, the world's fishing fleet dumped approximately 135,400 tons of plastic fishing gear and 23,600 tons of synthetic packaging material into the sea.

J. G. B. Derraik, The pollution of the marine environment by plastic debris: a review, Marine Pollution Bulletin 44, 842–852 2002

Clearly, removing 40 tons is not really going to make a dent, not as long as the fishing industry is not held accountable and not as long as they continue to behave in an irresponsible, reprehensible manner.

M. Cawthorn, Impacts of marine debris on wildlife in New Zealand coastal waters, Proceedings of Marine Debris in New Zealand's Coastal Waters Workshop, 9th March 1989, Wellington, New Zealand. Department of Conservation, Wellington, New Zealand, pp. 5–6 1989

We have been led to believe that the problem of plastics in the ocean is ever increasing. However, that is not the case. A very detailed study over 60 years showed that the entanglement of animals in plastic nets did increase from the 1950s onward and peaked in the 2000s, but has since begun to decrease.

C. Ostle & R. C. Thompson et al., Rate of added microplastic decreased over time: The rise in ocean plastics evidenced from a 60-year time series, Nature Communications, 10:1622 2019

The press always tells us about all the plastic that "makes its way to the sea". None of that plastic grew legs or flippers. All of the litter in our waters is preventable and is not a necessary consequence of using plastic. It is important to recognize that these nets do cause real, measurable damage to wildlife that becomes entangled. Nets are designed to trap things, and I am sure that the pre-plastic rope nets did the same thing. These days, nets happen to be made of plastic and somehow plastic is assigned the blame, but it is the fishermen who should be taking the flak for this disaster. If you are angry at the harm done to wildlife, then I suggest you campaign for heavy fines and jail time for the offenders.