Excessive Plastic Litter: The Hidden Green Swan Threat

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Abstract

At first Europeans believed that black swans did not exist. When they sighted a black swan for the first time in Australia, it was seen as an extremely rare but perhaps predictable event. Today, a 'black swan event' is one that whilst being extremely rare and of severe impact, is nevertheless characterised by the widespread insistence they were obvious in hindsight. The Covid-19 pandemic was described as such an event.

Environmental damage is a swan of a different colour: a green one. 'Green swans' are the consequences of the risks we humans create for ourselves by pumping contaminants into our air and water, destroying our ecosystems, and destabilizing our climate. Some causes of an impending green swan event, like global warming are being well studied. However, other causes remain 'hidden'. The looming plastic pollution pandemic can have equally devastating consequences of triggering a green swan event as green-house gas emissions, which in hindsight will be seen as being obvious.

This paper will separate the energy and emissions issues related to plastic production and the air and water pollution issues related to plastic consumption and excessive littering. The paper recommends that we go 'Back to the Future' of the 1950s and ban all plastic single-use consumption products; and if such a drastic move is not politically feasible, then at least impose a cap-and-trade system with 'plastic-credits'; i.e., one similar to a carbon credit system, as a workable solution to curb excessive plastic pollution.

Introduction

The evolution of the plastic bottle - from amazing to scourge of land and sea - has played out inside of a generation.

What sets bottles apart from other plastic products born in the post-World War II rise of consumerism is the sheer speed with which the beverage bottle - now ubiquitous around the world - has shifted from convenience to curse.

Over a million plastic beverage bottles were purchased each minute in 2019. The Covid-19 Pandemic increased this dramatically to almost 2 million bottles by mid- 2021. The plastic bottle's journey from convenience to curse has played out quickly—within the living memory of all of us.

Studies on plastic bottles fall into two categories: (a) those that highlight plastic's 'green credentials' in terms of energy efficiency in manufacturing, distribution and recycling – i.e. that plastic is a greener alternative to most materials (paper, metal, glass) and alternative bio-based materials; and (b) those that show that plastic is an environmental and social disaster in terms of its role in pumping contaminants into our air and water, destroying our ecosystems, and destabilizing our climate.

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Plastic: Hero or Villain?

The moment the modern plastic beverage bottle changed the world's drinking habits is difficult to pinpoint. Since 1862, whilst there have been many iterations of 'plastic', it was in 1973, when engineer *Nathaniel Wyeth* patented *polyethylene terephthalate (PET)* that the world order changed. PET was used in the first plastic bottles that were able to withstand the pressure of carbonated liquids. They were also a much cheaper alternative to glass bottles. *[See Appendix 1 for a quick history that led to the development of the PET Bottle].*

In 1978, *Evian* started selling bottled water in PET bottles. Perhaps the actual day that plastic was given *cult-status* was the day New York supermodels began carrying tall bottles of *Evian* water as an accessory on fashion show catwalks in the late 1980s. This was a signal that if it was acceptable by high society, then it was acceptable by all.

Plastic the Hero

Since then, billions of bottles have been sold on the promise that bottled water is good for hair and skin, healthier than soft drinks, and safer than tap water. It didn't take consumers long to buy into the notion that they needed water within reach virtually everywhere they went.[2]

In most western societies people seemed to think that if they did not have water at hand, terrible things will happen to them. This same mindset was then transplanted into affluent westernised societies in Asia and Africa. One can understand that in some of these countries tap water had to be boiled before drinking; but even in Asian countries like Singapore and Hong Kong, with perfectly drinkable tap water, no one left home without a bottle of water in their hand. It was both a healthy lifestyle statement and a fashion statement.

The rest is history… and we are living through the consequences of this mindset!

PepsiCo finally joined the water business and introduced *Aquafina* in 1994. *Coke* followed with *Dansani* in 1999. Both brands use refiltered tap water. Between 1994 and 2017, water sales in the United States had grown by 284 percent, according to *Beverage Marketing Corp*. data published by the *Wall Street Journal.*[3]

The benefits of plastic are an undisputed fact. They are very resource efficient by having a high strength-to-weight ratio, stiffness and toughness, ductility, corrosion resistance, bio-inertness, high thermal/electrical insulation, non-toxicity and outstanding durability at a relatively low lifetime cost compared with competing materials such as aluminium can and glass-bottles.[4]

Plastic Becomes the Villian

Since the introduction of plastic, our society has taken full advantage of this material and created many purposes for it besides beverage bottles. However, now that the movement toward

[2] Laura Parker (2019), "How the plastic bottle went from miracle container to hated garbage", National Geographic, August 23 https://www.nationalgeographic.com/environment/2019/08/plastic-bottles/

[3] Saabira Chaudhuri (2018), "Plastic Water Bottles, Which Enabled a Drinks Boom, Now Threaten a Crisis", *Wall Street Journal,* December 12. https://www.wsj.com/articles/bottled-water-americas-most-popular-drink-has-a-plastic-problem-11544627923

[4] Balint Simon, Mourad Ben Amor, Rita Fold (2016), "Life cycle impact assessment of beverage packaging systems: focus on the collection of post-consumer bottles", *Journal of Cleaner Production* 112: 238-248.

sustainable living has become a priority, plastic is as the enemy rather than the hero it once was developed to be.

In addition to the issue of pollution, there are studies that show that bottled water requires up to 2,000 times the energy used to produce tap water, affecting global warming.[5]

This resulted in 1983, author Normal Mailer saying:[6]

> *"I sometimes think that there is a malign force loose in the universe that is the social equivalent of cancer, and it's plastic. It infiltrates everything. It's metastasis. It gets into every single pore of productive life…".*

By the first decade and a half of the 21st century, this once celebrated invention had become almost like a disease that has spread to a significant number of commodities sold today, including: forks and spoons[7]; toothbrushes[8]; plastic wraps[9]; plastic clamshell containers[10]; cigarette butts[11]; tampons and pads[12]; shoes[13] and tyres[14]. In fact, hospitals were filled with sterile single-use plastic used to keep healthcare hygienic.[15]

The world has now awakened to the burgeoning crisis of plastic waste. Homeowners are now struggling to rid their lives of this material in an effort to go green. The backlash against the glut of discarded plastic commodities clogging waterways, polluting the oceans, and littering the interior has been swift. Suddenly, carrying plastic bottles of water around is uncool.

[5] Ken Fullerton (2018), "Welcome to Bundanoon, Australia: the world's first bottled water free town" *Sense & Sustainability (International Development Journal),* January 16. https://www.senseandsustainability.net/2018/01/16/9801/

[6] Elizah Leigh (2011), "The History of Plastic Bottles", *RecycleNatio*n, March 17. https://recyclenation.com/2011/03/history-plastic-bottles-recycle/

[7] Tik Root (2019), "Why carrying your own fork and spoon helps solve the plastic crisis", *National Geographic*, June 28. https://www.nationalgeographic.com/environment/article/carrying-your-own-fork-spoon-help-plastic-crisis

[8] Alejandra Borunda (2019), "How your toothbrush became a part of the plastic crisis", *National Geographic*, June 14. https://www.nationalgeographic.com/environment/article/story-of-plastic-toothbrushes

[9] Sarah Gibbens (2019), 'The sticky problem of plastic wrap', *National Geographic*, June 12. https://www.nationalgeographic.com/environment/article/story-of-plastic-sticky-problem-of-plastic-wrap

[10] Stephen Leahy (2019), "This common plastic packaging is a recycling nightmare", *National Geographic*, June 27. https://www.nationalgeographic.com/environment/article/story-of-plastic-common-clamshell-packaging-recycling-nightmare

[11] Tik Root (2019), "Cigarette butts are toxic plastic pollution. Should they be banned?", *National Geographic*, August 10. https://www.nationalgeographic.com/environment/article/cigarettes-story-of-plastic

[1212] Alejandra Borunda (2019), "How tampons and pads became so unsustainable", *National Geographic*, September 6. https://www.nationalgeographic.com/environment/article/how-tampons-pads-became-unsustainable-story-of-plastic

[13] Alejandra Borunda (2019), "Your shoes are made of plastic. Here's why", October 19. https://www.nationalgeographic.com/science/article/shoes-sneakers-plastic-problem

[14] Tik Root (2019), "Tires: The plastic polluter you never thought about", *National Geographic,* September 21. https://www.nationalgeographic.com/environment/article/tires-unseen-plastic-polluter

[15] Sarah Gibbens (2019), "Can medical care exist without plastic?", *National Geographic*, October 4. https://www.nationalgeographic.com/science/article/can-medical-care-exist-without-plastic

Plastic bottles and bottle caps rank as the third and fourth most collected plastic trash items in the *Ocean Conservancy's* annual September beach clean-ups in more than 100 countries.[16] Activists are zeroing in on the bottle as next in line for banning, after plastic shopping bags.[17]

According to the *United Nations*, the developing world has 2.2 billion people who still do not have access to clean drinking water.[18] However, these people cannot afford to buy sealed plastic bottles of water. Instead, they often fill used unwashed bottles with contaminated water. In such countries it is the tourists who see bottled water as the only safe option. They drink the water and throw away the container as litter. Often, as there is no proper trash collection system in these beautiful remote locations that tourists visit - these pristine sites are now littered with plastic bottles and containers. Sri Lankan heritage sites, Myanmar Temples and beaches in Bali are now littered with plastic. We all have heard of the litter on Mount Everest. We will discuss later in the article how this uncontrolled litter leads to a pollution pandemic that ultimately severely damages our environment.

Some countries in the developing world are recognising the problem of excessive litter. Kenya has announced a ban on single-use plastics at beaches and in national parks, forests, and conservation areas - effective in June 2020.[19] The *South Delhi Municipal Corporation has* banned disposable water bottles in all city offices.[20]

However, in most of the developing world, uncontrolled litter, caused by both tourists and their own affluent local population is rampant, and when coupled with inefficient or non-existent waste management systems ultimately leads to a plastic pollution pandemic that is damaging our environment. Control the litter, or else a hidden 'Green Swan' will emerge.

The Impact of Plastics on the Environment

As one can see, there are two interrelated issues here:

1. *Plastic Production:* The greenhouse gases (GHGs) emitted in creating, recycling, and incinerating the plastic.

2. *Plastic Consumption:* The deadly impact of littering on air and water pollution, wildlife, and the spread of disease.

Let us consider these two issues in turn.

[16] Op. cit. Parker (2019). August 23.

[17] Sarah Gibbens (2019), "See the complicated landscape of plastic bans in the U.S.*", National Geographic*, August 16. https://www.nationalgeographic.com/environment/article/map-shows-the-complicated-landscape-of-plastic-bans

[18] United Nations (2019), "1 in 3 people globally do not have access to safe drinking water", *UNICEF & WHO*, June 18. https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-%e2%80%93-unicef-who

[19] The Star (2019), "Uhuru announces ban on single use plastic in Kenya", June 5. https://www.the-star.co.ke/news/2019-06-05-uhuru-announces-ban-on-single-use-plastic-in-kenya/

[20] Times of India (2019), "No plastic bottles in SDMC offices", July 24, https://timesofindia.indiatimes.com/city/delhi/no-plastic-bottles-in-sdmc-offices/articleshow/70356760.cms

The Plastic Lifecycle and Green House Gas Emissions

There are many studies done on the 'whole-of-life' impact of GHG emissions related to plastic. On balance, most studies show that, on a 'per unit' basis, plastic emits less GHG than a similar product that uses renewable materials. For example, according to the plastics industry, every plastic grocery bag cost about one cent to produce. A paper bag costs 4 or 5 cents per bag to produce. There are plastic bags that are compostable, but the cost rises to between 8 to 10 cents.[21] Cloths bags use more GHG when the cost of washing is computed.[22]

This sort of reasoning has given rise to some arguments that, plastic is a greener alternative to most materials (paper, metal, glass) and alternative bio-based materials - if it is not released as litter.[23]

Such an argument is a classic '*Straw-man fallacy'*. A straw man is a form of argument that gives the impression of refuting an argument, whereas the real subject of the argument was not addressed or refuted, but instead replaced with a false one. One who engages in this fallacy is said to be *"attacking a strawman".*

Chris De Armitt, the author of the book *'Plastic Paradox'* has built such a 'strawman' by quoting the many arguments that say that plastic is not green (i.e., that its production emits more GHG than alternatives such as aluminium and glass), and then attacks this strawman in many public forums including *BBC, 60-Minutes* and *Sky News*.[24]

However, the GHG emitted in the plastic life cycle is not the big issue. The big issue is that the resultant 'litter' is piling up and causing irreversible damage to the planet's ecosystems. Mr. De Armitt has not addressed the potential green swan impact of the plastic pollution pandemic, but instead attacked the GHG emissions 'strawman' he has created.

Further, even if one accepts the whole of life GHG emissions arguments in favour of plastic on a *unit basis*, when considering the sheer volume of plastic production on a *total basis*, the numbers tell a different story. Production has increased exponentially, from 2.3 million tons in 1950 to over 600 million tons by 2020. This production is expected to double by 2050. A recent report predicted that the plastics industry in the United States is on track to release more greenhouse gas emissions (GHG) than coal-powered electricity generating plants by the end of the decade.[25]

There are also many studies that show that bottled water is a drain on the environment in many other ways. Transporting the bottles and keeping them cold also burns fossil fuels, which give off greenhouse gases. According to some estimates, it takes up to three litres of water to produce one litre of bottled water. Groundwater pumping by bottled-water companies draws heavily on

[21] Ben Davis (2021), "How much energy does it take to produce plastic?", *MV Organising*, June 1. https://www.mvorganizing.org/how-much-energy-does-it-take-to-produce-plastic/

[22] Kate Ng (2021), "Cotton tote bags not environmentally-friendly due to overproduction, says report", *The Independent*, August 26. https://www.independent.co.uk/climate-change/sustainable-living/cotton-tote-bags-sustainable-shopping-b1909035.html

[23] Chris De Armitt (2020), "The Plastics Paradox: Facts for a Brighter Future", *Phantom Plastics LLC*, 30 April. P. 188.

[24] Ibid

[25] Maya Yang (2021), "US plastics to outstrip coal's greenhouse gas emissions by 2030, study finds", *The Guardian*, October 22. https://www.theguardian.com/environment/2021/oct/21/plastics-greenhouse-gas-emissions-climate-crisis

underground aquifers and harms watersheds, and this has caused significant unrest in developing countries where most citizens depend on direct access to the water table via wells and rivers.[26]

The Deadly Impact of Litter

More than a million plastic bottles are sold every single minute globally. Half of all plastics ever manufactured have been made in the last 15 years. Every year, about 8 million tons of plastic waste escapes into the oceans from coastal nations. That is the equivalent of setting five garbage bags full of trash on every foot of coastline around the world.

Plastics often contain additives making them stronger, more flexible, and durable, all excellent qualities. But many of these additives can extend the life of products if they become litter, with some estimates ranging to at least 450 years to break down. Plastics can take anywhere from 20 to 500 years to decompose, depending on the material and structure ***[See Table 1].***

This litter leads mainly to water pollution, and the disaster that can be caused by excessive litter that does not degenerate is no longer a potential threat but a real one.

Water pollution is the release of substances into bodies of water that makes water unsafe for human use and disrupts aquatic ecosystems. Water pollution can be caused by a plethora of different contaminants, including toxic waste, petroleum, disease-causing microorganisms and in more recent times plastic and microplastic litter.

Clearly, excessive litter (and not GHG emissions) is the real issue, and if not tackled, can lead to a green-swan catastrophe.

Table 1: Estimated Decomposition of Litter

Material	**Estimated Decomposition**
Cigarette butts	5 years
Plastic bags	20 years
Plastic-lined coffee cups	30 years
Plastic straws	200 years
Fizzy can rings	400 years
Plastic bottles	450 years
Toothbrushes	500 years
Disposable diapers	500 years
Styrofoam	500 years
Fishing line	600 years
Glass	1 million+

Source: Adapted from Brian Armentrout (2021).

[26] Solvie Karlstrom & Christine Dell'Amore (2010), "Why Tap Water is Better Than Bottled Water", *National Geographic's Green Guide*, March 13. https://www.nationalgeographic.com/science/article/why-tap-water-is-better

As one can see from Table 1, although the estimated decomposition time for glass is estimated to be more than a million years, due to its weight, lack of buoyancy and the ability for washing and recycling, does not cause pollution levels of glass litter.

Excessive Litter Causes Pollution

The word 'litter' originally was used to describe any rubbish that was not household waste, i.e., small things such as cans, bottles, and paper that people leave lying on the streets and in other public places. Litter can come in a variety of different things, but some items are littered more frequently than others. Researchers found that the most common littered items are: cigarette butts; food wrappers; plastic bottles; disposable cups; grocery bags; straws; beverage cans; tires; vehicle debris; personal items (e.g., toothbrushes, tampons). Of these 10 items, there is plastic at least 9 items.

Littering in developed countries is when someone throws things like a cigarette butt or a plastic cup out of a car window. In such countries, researchers say that close to 20% of litter on land comes from lose items in the back of trucks or trash bins but most litter comes from people who discard materials on purpose. Around 76% of litter on roads originates from motorists and pedestrians.[27]

In developing countries where there are no readily available trash cans, however, litter is simply thrown on the street or in a waterway or a beach. These types of litter items became more of an issue when manufacturers started producing disposable products and packaging produced with materials such as plastic.

Mass production of plastics, which began just six decades ago, has accelerated so rapidly that it has created 8.3 billion metric tons—most of it in disposable products that end up as excessive litter, i.e. pollution. Even the scientists who set out to conduct the world's first tally of how much plastic has been produced, discarded, burned, or put in landfills, were horrified by the sheer size of the numbers.[28]

Most of the litter that finds its way into the oceans every year continues to be done on purpose.

Most of the plastic litter in the oceans flows from land. Litter is also carried to sea by major rivers, which act as conveyor belts, picking up more and more trash as they move downstream. Once at sea, much of the plastic trash remains in coastal waters. But once caught up in ocean currents, it can be transported around the world. For example, on *Henderson Island*, an uninhabited atoll in the *Pitcairn Group* isolated halfway between Chile and New Zealand, scientists found plastic items from Russia, the United States, Europe, South America, Japan, and China. They were carried to the South Pacific by the South Pacific gyre, a circular ocean current.[29]

Unfortunately, what each individual considers as a minor littering misdeed, when considered collectively has a deadly impact on the environment. In our oceans, which provide the largest natural carbon sink for greenhouse gases, plastic leaves a deadly legacy. It directly chokes and smothers a host of marine animals and habitats and can take hundreds of years to break down. As it does, sunlight and heat cause the plastic to release powerful greenhouse gases, leading to an

[27] Sagay Galindo (2021), "Breakdown: Why littering can lead to pollution", *Action News 5*, https://www.actionnews5.com/2021/06/30/breakdown-why-littering-can-lead-pollution/

[28] Laura Parker (2018), "A whopping 91% of plastic isn't recycled", *National Geographic*, December 21. https://www.nationalgeographic.com/science/article/plastic-produced-recycling-waste-ocean-trash-debris-environment

[29] Laura Parker (2019), "The world's plastic pollution crisis explained', *National Geographic,* June 7. https://www.nationalgeographic.com/environment/article/plastic-pollution

alarming feedback loop. As our climate changes, the planet gets hotter, the plastic breaks down into more methane and ethylene, increasing the rate of climate change, and so perpetuating the cycle.[30]

In addition to water and soil pollution, plastic litter can also pollute the air. Researchers estimate that more than 40% of the world's litter is burned in the open air, which can release toxic emissions.[31] These emissions can cause respiratory issues, other health problems, and even be a starting base for acid rain.

The Impact of Microplastics

Other than just being unsightly, excessive litter can cause serious consequences for the environment. As litter degrades, chemicals and microparticles are released. These chemicals are not natural to the environment and can, therefore, cause a number of problems. For example, cigarette butts can contain chemicals such as arsenic and formaldehyde. These poisons can make their way into the soil and freshwater sources, impacting both humans and animals. In fact, 60% of water pollution is attributed to litter.[32]

Broken bits of takeaway containers and straws, tiny fibres from activewear, plastic shed by synthetic products that get into our waterways. Rather than breakdown, they just get smaller until they are invisible to the naked eye. These end up in our waterways, blown as wisps in the wind.

Once at sea, sunlight, wind, and wave action break down plastic waste into small particles – pieces less than 5mm across. These are called microplastics and have spread throughout the water column and have been found in every corner of the globe, from *Mount Everest*, the highest peak, to the *Mariana Trench*, the deepest trough. Plastic microfibers have been found in municipal drinking water systems and drifting through the air.

Once in the ocean, it is difficult—if not impossible—to retrieve plastic waste. Mechanical systems, to intercept litter can be effective at picking up large pieces of plastic, such as foam cups and food containers, from inland waters. But once plastics break down into microplastics and drift throughout the water column in the open ocean, they are virtually impossible to recover.[33]

Litter Kills Wildlife

Animals are innocent victims affected by litter every day. Researchers estimate that over one million animals die each year after ingesting, or becoming entrapped in, improperly discarded trash. Plastic litter is the most common killer of animals, and marine animals are the most notably affected. Each year over 100,000 dolphins, fish, whales, turtles, and more drown after becoming entangled in or digesting plastic and microplastic litter.[34]

[30] Kerri Major (2021), "Plastic waste and climate change - what's the connection?", *World Wildlife Fund*, June 30. https://www.wwf.org.au/news/blogs/plastic-waste-and-climate-change-whats-the-connection#gs.ebm9ff

[31] Andrea Thompson (2014), "For Air Pollution, Trash Is a Burning Problem", *Climate Central*, September 2, https://www.climatecentral.org/news/where-trash-is-a-burning-problem-17973

[32] Op. cit. Galindo (2021).

[33] Op. cit. Parker (2019), June 7.

[34] United Nations (2009), "Facts and figures on marine pollution", *UNESCO*, http://www.unesco.org/new/en/natural-sciences/ioc-oceans/focus-areas/rio-20-ocean/blueprint-for-the-future-we-want/marine-pollution/facts-and-figures-on-marine-pollution/

Most of the deaths to animals are caused by entanglement or starvation. Seals, whales, turtles, and other animals are strangled by abandoned fishing gear or discarded six-pack rings. Microplastics have been found in more than 100 aquatic species, including fish, shrimp, and mussels destined for our dinner plates. In many cases, these tiny bits pass through the digestive system and are expelled without consequence. But plastics have also been found to have blocked digestive tracts or pierced organs, causing death. Stomachs so packed with plastics reduce the urge to eat, causing starvation.

Plastics have been consumed by land-based animals, including elephants, hyenas, zebras, tigers, camels, cattle, and other large mammals, in some cases causing death.

Tests have also confirmed liver and cell damage and disruptions to reproductive systems, prompting some species, such as oysters, to produce fewer eggs. New research shows that larval fish are eating nanofibers in the first days of life, raising new questions about the effects of plastics on fish populations.[35]

Litter Facilitates the Spread of Disease

Improperly discarded trash is a breeding ground for bacteria and diseases. Litter can spread diseases, viruses, and parasites through two methods, direct and indirect contact.

Germs can be transmitted directly by physically coming into contact with litter. This can happen by picking up, touching, or by accidentally injuring themselves on improperly disposed of trash.

Bacteria and parasites can also be transmitted to humans indirectly through an affected vector. Vectors are animals or insects that come in contact with contaminated litter and then transmit those contaminates to humans. This could well have been the origins of Covid-19.

Plastic Recycling – The Big Con

The Plastics and the Chemical Industry realised in the 1970s that if governments made them responsible for bearing the cost of recycling, it would make their product uneconomical.

As a result, they put the onus of responsibility for plastic pollution on the consumer.

They financed expensive advertising campaigns on how we must all be 'good citizens' and recycle. They lobbied influencers to instil in us a *3R (Reduce, Reuse and Recycle)* mindset They introduced the *"Re-cycle" Logo*, even though they well knew that much of the plastic we 'recycle' will end up either in landfill sites or be incinerated.

The fact is, not even10% of plastic waste can actually be commercially recycled. A whopping 91% of plastic is not recycled globally. Country wise the picture is a little different. In the U.S., only 30% of these bottles are recycled whilst Norway recycles 97%.[36]

According to the *World Economic Forum*, just 14% of plastic packaging is collected for recycling globally. And because of complexities in the recycling process, huge amounts of single-use plastic (as well as glass and cardboard) that consumers try to recycle ultimately end up getting burned or tossed into landfills anyway. If recyclable materials are contaminated by food waste, or if consumers

[35] Op. cit. Parker (2019), June 7.

[36] Op. cit. Parker (2018), December 21.

misunderstand what can be recycled and where—to cite two common examples—their garbage may not end up being repurposed at all.[37]

A 2017 study in *Science Advances* estimated that, of all the plastic waste generated globally up to 2015, just 9% had been recycled, while 12% was incinerated and the rest ended up in landfills or scattered around the natural environment. Some plastic waste is burned to create fuel or energy, but this process is itself energy-intensive and in most cases emits carbon dioxide into the atmosphere.[38]

The onus of recycling being placed on the shoulders of consumers was severely tested and found wanting during the COVID-19 pandemic. Since the coronavirus took hold, the consumption of single-use plastic grew by 250-300% (according to the *International Solid Waste Association (ISWA),* which represents recycling bodies in 102 countries).[39]

Much of that increase was due to the demand for products designed to keep COVID-19 at bay, including masks, visors and gloves. The global disposable-mask market grew from an estimated $800m in 2019 to $166bn in 2020. The throw-away containers for all the takeaway food increased five-fold.

Lockdowns also led to a boom in e-commerce. Much of what is bought online are often packaged in plastic comprising several layers. Whilst this keeps the contents safe in aeroplane holds and on delivery lorries, it also makes it nearly impossible to recycle the plastic.

In addition to the public's increasing appetite for single-use plastic, there also appears a diminishing inclination to recycle even materials that can be reused. An unwillingness to recycle might be explained by people's nervousness about venturing out to put waste in recycling bins during a pandemic. Or it might just be that lockdowns have put more pressing matters into their minds, prompting a slip in their diligence.

COVID-19 has led to a glut in plastic waste in other ways. As the pandemic caused initially a crash in the oil price, and because petroleum is a major constituent of most plastics, they have become cheaper to produce. That in turn give firms less incentive to use the recycled stuff. Another reason for the growth of plastic rubbish has been caused by the fact that municipalities around the world curtailed their recycling schemes over fears about spreading the contagion (the virus can survive for about 72 hours in plastic). All of which means that much of the plastic produced during the pandemic ended up either in landfill sites or was incinerated.[40]

Landfills, especially in poor countries, are often little more than open dumps. They are responsible for some of the biggest leakages of plastics into oceans, because the material is light, it is easily swept by rain or wind into waterways.

[37] Jamie Ducharme (2021), "Reusable packaging is the latest eco-friendly trend - but does it actually make a difference?, *Time Magazine*, Sept 28. https://time.com/6101846/is-reusable-packaging-sustainable/

[38] Roland Geyer, Jenna R. Jambeck and Kara Lavender Law (2017), "Production, use, and fate of all plastics ever made", *Science Advances*, July 19, 3(7).

[39] The Economist (2020), "Sea of troubles-Covid-19 has led to a pandemic of plastic pollution", *Economist Magazine*, June 22. https://www.economist.com/international/2020/06/22/covid-19-has-led-to-a-pandemic-of-plastic-pollution?

[40] Ibid.

Economic Solutions to Excessive Litter

As getting the consumers to 'recycle' for ethical reasons was not working out, governments, corporations and scientific establishments need to turn to economic solutions.

The good news is that as the public's focus on the plastic waste crisis narrows, the world is awash with solutions for bottles. Generally, they fall into two categories: (1) efforts to reduce the use of plastic bottles and (2) efforts to find new ways to deal with bottles once they're thrown away.

Reducing the Use of Plastic Bottles

Efforts to reduce the use of plastic bottles abound. Constructing freshwater fountains for refillable bottles; shops and other places where you can bring your own packaging; shopping-centres banning plastic beverage bottles, clamshell container and plastic straws from their food courts in favour of glass bottles, aluminium cans, and refilling stations.

The quantity of new bottles produced can also be dramatically reduced with recycling. Beverage companies have pledged to use more recycled bottles in manufacturing - a goal that aims to reduce the production of new resin and boost recycling numbers - by adding value to bottle recovery.

PepsiCo pledged to increase recycled content in all its plastic packaging 25 percent by 2025. *Nestle Waters* vowed to make all of its packaging recyclable by 2025 and increase recycled content in bottles to 35 percent by 2025 globally. Coca-Cola pledged to recycle a used bottle or can for every one the company sells by 2030 and increase recycled material in plastic bottles to 50 percent by 2030.

Conversely, proponents of what is known as a 'circular economy' argue that, instead of feeding into the convoluted recycling process, companies should replace single-use containers with those that can be used over and over again—often a durable metal or glass vessel that can be refilled either in a store, by the manufacturer or in a consumer's own home.

The idea of reusing containers is hardly new. If you've ever bought a vat of hand soap and used it to refill various dispensers around your house; or brought your own refillable coffee cup to your favourite café - you have taken part in this system.

However, there is a "payback" period associated with any reusable item, i.e., the number of times it must be reused before it is actually better for the environment than the single-use alternative.[41] Something like reusable sandwich wrap may never break even because the energy and resources required to make and wash it far exceed what goes into making flimsy disposable bags or cotton tote bags.[42] However, most of the comparative 'whole-of-life' cost studies ignore the long-term littering effect of plastics and microplastics.

New Ways to Deal with Discarded Bottles

Once bottles have become trash, entrepreneurs around the world are turning them into printer ink cartridges, fence posts, roofing tiles, carpets, flooring, and boats, to name only a few items. Even houses have been constructed from bottles. A three-story modern house has been built on the

[41] Hannah Fetner & Shelie A. Miller (2021), "Environmental payback periods of reusable alternatives to single-use plastic kitchenware products", *The International Journal of Life Cycle Assessment*, Vol. 26, pages1521–1537.

[42] Op. Cit. Ng (2021).

banks of the Meteghan River in Nova Scotia is being promoted as able to withstand a Category 5 hurricane. It only took 612,000 bottles.[43]

There are other solutions, including smart design and smart packaging being considered such that waste generation is significantly reduced. Here, design solutions of pre-plastic days are being actively reconsidered. In laboratories, new versions of bottles claiming to be biodegradable or compostable appear regularly, and plastic industry chemists are experimenting with "chemical recycling" that returns the polymers to their constituent monomers, enabling them to be remade multiple times into new plastic bottles. *[See Appendix 2 for a discussion of such innovative solutions].*

Controlled Incineration – The Singapore Solution

Interestingly, Singaporeans appear to have realised that advertising campaigns to encourage a 3R (reduce, reuse and recycle) mindset is just a waste of time, as 90% of material sorted for recycling goes to landfills anyway. In contrast, the government appears to be encouraging Singaporeans to *create* plastic waste so that it can be collected and incinerated in a controlled process.[44] Singapore is one of the cleanest cities in the world.

Singapore's process of trash management involves burning the trash and filtering the smoke. First, all the trash is accumulated from all the garbage cans and trash bags. The only drawbacks are the harmful gases and the ash that is left over. However, Singapore was able to overcome these problems. The harmful gases are filtered out so the air that is emitted from the incineration plants is very 'clean'. In fact, it is claimed that it is cleaner than the air into which it is pumped. Additionally, the ash is mixed with sea water to obtain a slurry – so that the ash does not blow with the wind to the sea – and then dumped in the water of a man-made island. As such, the plastic residue ash does not touch ocean waters, and therefore has no harmful impact on marine eco-systems. Surprisingly, this solution offers an additional benefit - the heat from the burned trash is harnessed to power thousands of homes with electricity.[45] According to the *National Environment Agency (NEA),* incineration reduces waste by up to 90 per cent, saving landfill space, and the heat recovered produces steam used to generate electricity [46]

However, a word of caution: *'Clean'* does not mean *'Green'*; often the two are confused.

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide.[47] Whilst these pollutants are obviously not 'clean', they are nevertheless 'green' in that they do not directly trap the Sun's heat in Earth's atmosphere and make the Earth much warmer than it would be.

[43] Tina Comeau (2019), "The Ultimate recycling project in Nova Scotia: Meteghan River house built with around 612,000 recycled plastic bottles", *The Chronicle Herald*, Dec 18. https://www.saltwire.com/halifax/business/indepth-the-ultimate-recycling-project-in-nova-scotia-meteghan-river-house-built-with-around-612000-recycled-plastic-bottles-326276/

[44] Trang Chu Minh (2021), "Five facts about unsustainable waste management in Singapore", *Eco-Business,* Jan. 11. https://www.eco-business.com/opinion/five-facts-about-unsustainable-waste-management-in-singapore/

[45] Vrishak Vemuri (2021), "How Singapore Deals with Trash: And why other countries should take inspiration from this method", Medium, August 20. https://medium.com/techtalkers/how-singapore-deals-with-trash-d12e236f81fe

[46] Op. Cit. Minh (2021).

[47] WHO (2021) "Air pollution", *World Health Organisation Health Topics*, https://www.who.int/health-topics/air-pollution#tab=tab_1

In contrast, climate change is caused by *'greenhouse gases'* which are mainly CO_2 (carbon di oxide) and CH_4 (methane). These gases are transparent to incoming (short-wave) radiation from the Sun but block infrared (long-wave) radiation from penetrating the Earth's atmosphere. However, CO_2 and CH_4 are nevertheless 'clean' as they do not cause the outdoor and indoor air pollution that results in respiratory and other diseases, especially in humans.

Clearly, the Singapore solution whilst being 'clean' is by no means 'green'; i.e. whilst it is not releasing harmful pollutants to the atmosphere; it is nevertheless releasing 'greenhouse gases'. Given the significant damage done to our oceans due to excessive plastic litter, this appears to be the best solution to date on a 'cost-benefit' basis.

A Plastic Recovery Price?

Many of the above solutions are still not scalable to a level that would make a noticeable difference, in countries bigger than the city state of Singapore. Also, most of them—including biodegradables—still require that the most elemental and least functional part of the bottle's lifespan be performed: i.e., *someone needs to pick up the discarded bottle.*

The recovery of plastic waste will not improve much until this 'recovery' is given a greater value, achieved through charging an additional price for the product. This is where management accounting and 'life-cycle costing' comes in.

If a company chooses to sell water in a single-serving container, the consumer should have to pay the full cost of delivering that water in a single-serving container, which includes recovering that container after use.

Beverage companies would be wise to take a lesson from their own history. In the days before plastic, bottle deposit programs were established around the world. These can be re-introduced to collect single-use plastic bottles. Such a program now runs in Coke's Mexico City operations; and the company claims that it recycles virtually 100 percent of PET.[48]

As discussed earlier, the voluntary efforts using the 3R campaign and the recycling logo are just not working. The onus for recovery must be put on the plastic's industry and not on the consumers' ethics. The pricing-mechanism should include the recovery cost of the manufactured plastic. Management accountants have the tools and techniques of getting this pricing right.

Concluding Comments: Planet or Plastic?

In recent years the surge in production has been driven largely by the expanded use of disposable plastic packaging in the growing economies of Asia—where garbage collection systems may be underdeveloped or non-existent. In 2010, it was estimated that half the world's mismanaged plastic waste was generated by just five Asian countries: *China, Indonesia, the Philippines, Vietnam, and Sri Lanka.*[49]

As individuals, there are three things we can do to be part of the solution: (1) carry a reusable bottle; (2) choose aluminium cans over plastic when possible, and (3) recycle all plastic bottles. Unfortunately, these ethical 'end-of-pipe' solutions at an individual level are just not working.

[48] Op. cit. Parker (2019).

[49] Laura Parker (2018), "We Made Plastic. We Depend on It. Now We're Drowning in It", *National Geographic*, June. https://www.nationalgeographic.com/magazine/2018/06/plastic-planet-waste-pollution-trash-crisis/

It is possible that high-tech 'end-of-pipe' solutions such as Singapore's controlled incineration can be scaled up in larger countries; as the cost-benefit of releasing 'greenhouse gases' significantly outweigh the looming ecological disaster of excessive plastic pollution. The reality today is however, that we need to *just collect the trash*. This is an issue for all countries, but more so for developing countries. In most countries, trash is piling up in streets, laneways, riverbanks and beaches. This issue needs a global solution such what we had with the *Paris Accord* for Climate Change. Just like greenhouse gas emissions reach all corners of the globe, so does plastic pollution.

Ideally, the United Nations must *Ban single-use plastics* worldwide. At present, 170 nations have pledged to "significantly reduce" use of plastics by 2030.[50] Most of the pledges focus on banning six items that are often found in the environment, are often not recycled and that have readily available alternatives. These are plastic grocery bags, straws, stir sticks, six-pack rings, cutlery and food take-out containers that are hard to recycle. The timelines for these bans range from 2017 to 2030. However, such unilateral bans, whilst helpful, are of little value if excessive plastic litter continues to enter our waterways and are then taken globally via the ocean currents.

If such an across-the-board ban is not politically feasible in some countries (the plastics industry lobby is very strong) then at least institutionalise *controlled waste management* in all countries. Trash needs to be collected on a regular basis and landfilled, recycled, or burned in a controlled way so that it does not end up on top of mountains or the bottom of oceans. Every country needs to be provided with enough garbage trucks and other waste management equipment.

How can this be financed? One way is to tax the consumer through higher prices, and use the extra funds generated to finance cost of collecting of used bottles centrally. This will be as ineffective as a carbon tax was; as the companies will pay the tax and keep on polluting, as they can pass the tax to the customer. Also, it will be difficult to police back-yard small-scale manufacturing companies to pay the tax, with plastic items being so easy to manufacture.

A better way is the impose a tax at the at the source of the problem, the plastics industry. A worldwide tax of two US cent for every kilo of plastic resin manufactured has been estimated to raise roughly six billion US dollars a year into a global fund that could be used to finance garbage collection systems in developing nations.[51]

However, the best way is to impose a *cap-and-trade system* with 'plastic-credits'; i.e., one similar to a carbon credit system. A 'Plastic-credit' can be defined as (say) one kilo of plastic resin that is either recycled or saved from being manufactured (by using alternative materials). Companies can be given a cap, and if they reach it, they can trade with a company that has excess plastic credits.

There are other 'end-of-pipe' solutions that are being developed once the plastic rubbish has been collected and brought to a processing station. Ultimately, however, it is the 'start-of pipe' solutions such as *Smart Design* and *Smart Packaging* - essentially low-tech solutions that takes design 'back to the future' of pre-plastic days - that holds the best hope in preventing the hidden 'Green Swan' event from eventuating.

[50] Victoria Masterson, (2020), "As Canada bans bags and more, this is what's happening with single-use plastics around the world", *World Economic Forum*, October 26. https://www.weforum.org/agenda/2020/10/canada-bans-single-use-plastics/

[51] Op. cit. Parker (2018).

APPENDIX ONE: A Quick History of Plastic

Alexander Parkes invented the first manmade plastic in 1862, which was derived from cellulose and named *Parkesine*. The goal was to replace common materials such as ivory, rubber and shellac. Although Parkesine could be manipulated into various shapes, investors lost interest since the raw materials to produce the plastic were so expensive.

Later in the 19th century, *John Wesley Hyatt* developed *thermoplastic*, which was used in photographic film. The next milestone in resins came in 1907, when New York chemist *Leo Baekeland* created *Bakelight*. The military found this material helpful in the production of weapons, and it was also used for electrical insulators, radios, cups, buttons, false gums and silverware handles. These early applications saved wildlife. In the mid-1800s, piano keys, billiard balls, combs, and all manner of trinkets were made of a scarce natural material: elephant ivory. With the elephant population at risk and ivory expensive and scarce, a billiards company in New York City offered a $10,000 reward to anyone who could come up with an alternative.

In 1891, *Louis Marie Hilaire Bernigaut* developed *Rayon* - a modified cellulose. About 10 years later, *Dr. Jacques Edwin Brandenberger* discovered *Cellophane.* By the 1940s*, nylon, acrylic, neoprene, styrene-butadiene rubber (SBR), and polyethylene* were becoming widespread. Between 1940 and 1945, the demand for plastic in America grew immensely and tripled in production due to the war, public funding, and the material's versatility.

All of these inventions and discoveries gave way to further different types of plastic, including: *polyvinyl chloride (PVC) or vinyl, polyvinylidence chloride (Saran), Teflon, high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP) and polystyrene (PS).*

PVC is found in vegetable oil bottles and food wraps; HDPE is used in the making of milk and detergent bottles; LDPE helps to create plastic bags and shrink wrap; PP is found in margarine and yogurt containers; and PS makes egg cartons and disposable utensils.

In 1973, *Engineer Nathaniel Wyeth* patented *polyethylene terephthalate (PET)*; which was used in the first plastic bottles that were able to withstand the pressure of carbonated liquids. They were also a much cheaper alternative to glass bottles.

This was the start of the ubiquitous plastic bottle we encounter daily.

APPEDIX TWO: Innovations in Plastic Recycling

End-of-pipe Solutions

These are solutions suggested *after* the plastic is discarded as waste. Such solutions go hand in hand with efficient waste management systems to collect and transport the trash to a processing station.[52]

AI Sorting: Artificial Intelligence (AI) is the perfect solution for garbage recycling due to the highly irregular and unpredictable nature of garbage. A sensor may only be able to identify a material's composition, but AI can identify its composition and configuration in varying circumstances using deep-learning algorithms that go far beyond simple if > then logic.

[52] Mario Honrubia (2020), "25 Innovations In Plastic Recycling That You May Not Already Know About", *Ennomotive*, March 9. https://www.ennomotive.com/innovations-plastic-recycling/

Plastic-munching Bacterial Species:

Believe it or not, there are several different bacterial species that have been observed to eat non-degradable plastic and turn it into polyhydroxyalkanoate (or PHA). PHA is a polyester that is biodegradable. Unfortunately, the bacteria are limited in how much it can produce PHA up to a certain percentage of its cell weight. Scientists are working on developing genetically engineered bacteria strains that offer no compromises.

Depolymerization:

As plastic comes from petroleum, what is to stop the process from being put in reverse? It turns out it's already happening. A company aptly named "Recycling Technologies" is utilizing a chemical process called thermal cracking to do so. It is still under testing, but if successful it could potentially be used to power vehicles like heavy tankers. With one Recycling Technologies machine capable of processing 7000 tons of plastics per year, the potential to catch up with the world's enormous production of plastic waste is no longer completely out of sight.

Microemulsion:

Mixed materials present a notoriously difficult problem for recyclers. They are composed of multiple types of materials (e.g. cardboard and aluminium foil) that can't be recycled unless they are separated. A company named Saperatec is attempting to use a technology for recycling materials like lithium-ion batteries, LCD panels, plastics composites and more. Using microemulsion substances to separate materials at the molecular level can make otherwise landfill-bound materials recyclable.

Start-of-pipe Solutions

These are solutions suggested *before* the plastic is manufactured as a product.

Smart Design: A price on the recovery of single-use plastic will force manufacturers to first consider the design of their products. Engineers and industrial designers must redesign their products. Many of the daily throwaway products we use, such as toothbrushes, sanitary pads, baby nappies, cigarette butts, tyres, and footwear, can easily go back to pre-plastic designs without any loss of utility. There are edible forks and spoons that have been developed in India. They will probably cost more to manufacture than with plastic, but the consumer needs to pay this to save the planet. Hospital equipment needs to be redesigned not only to keep healthcare hygienic, but also to safely recycle the equipment if plastic must be used.

Smart Packaging: Manufacturers should consider if their products require any packaging at all, and if they do, if plastic can be avoided. The use of glass and paper should be re-introduced. Even with paper, knowing the impact it is having on our climate due to deforestation, bamboo (which is a form of grass) should be considered instead of cutting down trees. Packaging should not have styrofoam or plastic inserts between the cardboard. Even if a company decides to stick with plastic containers and packaging, it should be designed without the peel-out plastic coverings that become trash immediately the container is peeled open. Cling-wrap and single-use plastic clamshell containers must be banned., and consumers forced to use recyclable containers to store food.

Bio-degradable Plastic: Biodegradable plastics are one set of materials that are becoming a popular replacement as consumers demand green alternatives. Rather than remaining stable for hundreds of years – the quality for which we prized plastic when we first began using it – biodegradable plastics can be broken down by microbes, chewed up and turned into biomass, water and carbon dioxide (or in the absence of oxygen, methane rather than CO2). A subset of them are compostable, which

means that not only are they broken down by microbes, but they can be turned – alongside food and other organic waste – into compost. However, only a minority of these plastics are home compostable, so, the label "compostable" most often means industrially compostable; and this requires a well-managed waste system to ensure that this actually happens. If products made from these plastics are discarded into conventional waste streams such as landfill or find their way into the open environment such as rivers and oceans, potential environmental benefits are not realised and evidence indicates that this can actually worsen, rather than reduce, the problem of plastic pollution.[53]

Triggerable Smart Polymer Material Systems: Much like microemulsion, one of the purposes of "smart polymers" is to make materials and textiles with plastic coatings or elements more effectively recyclable. However, this method approaches the problem from an even more fundamental standpoint – by enhancing the material itself from the outset in such a way as to make it triggerable by a designated means instead of adapting the processing mechanism to an existing material type. The type of trigger can come in the form of various means, including chemical, heat, microwave, the intensity of light or even humidity.[54]

[53] Kelly Oakes (2019), "Why biodegradables won't solve the plastic crisis", BBC Futures, 5th November. https://www.bbc.com/future/article/20191030-why-biodegradables-wont-solve-the-plastic-crisis

[54] Op. cit. Honrubia (2020).