What to do about PLASTICS?

South Australia's
State of the Environment Report 2023

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About the Author:
Vaughan Levitzke is an ecologist, graduate from Adelaide University. His early career was spent mapping rangelands and national parks in South Australia and Northern Territory, leading to multidisciplinary remote sensing projects in Australia and internationally. During 10 years at the South Australia EPA he developed policy and regulated waste and recycling industries and expanded beverage container deposits in 2002. He founded statutory authority Zero Waste SA in 2003, and then its successor, Green Industries SA. Here he oversaw four 5-year waste strategies, Australia's first plastic bags ban in 2009, the first Australian state Circular Economy strategy in 2017, provided advice to the UN and developed guidelines for disaster waste management in South Australia, overseeing the clean-up of the 2019-20 bushfires. He has participated in many national and international fora, including with United Nations Centre for Regional Development and has directed substantial investment towards key circular economy initiatives in South Australia. He is a member of Australia's national Ministerial Circular Economy Advisory Group, and is a director of several organisations regarding product stewardship and circular economy. In 2016 Vaughan received the Public Service Medal for outstanding public service in the area of waste management reform and policy.

2023 SA State of the Environment Report: What to do about PLASTICS?

The Global Problem
Prior to 1950, we hardly had any plastics at all, we had Bakelite light switches and phones, and nylon stockings[1]. Over 70 years we have created a huge global industry and that has produced 8,300M metric tonnes, an industry that has been mainly focussed on packaging, and to a lesser degree infrastructure and other products.

Plastics have helped to demarcate the next identifiable geological time sequence- the Anthropocene[2]. Although not yet formally recognised, scientists have been talking about such an epoch since the 1930s. However, now it's closer to a reality, as this can be clearly identified and defined by a number of markers in recent sediments and geology. One such indicator is the presence of plastics, micro-plastics and nano-plastics, among other unique and long-lasting human generated markers.

Plastics are complex and heterogeneous synthetic chemicals being a polymer with a carbon-based backbone, often with additives that ascribe unique properties. They have gained much attention from researchers, media, the public and governments in recent years, and as a result there is a large amount of effort being expended to try and solve the environmental problems plastics now present. There are news articles, new research, new technologies and new issues discovered almost daily. This has resulted in a plethora of information and growing detail and data on a global scale, but it is also showing that the problems are immense, and business as usual won't fix them at the speed and scale required.

Strategies are beginning to emerge on how to deal with these problems, with local, national and international actions being proposed and implemented. The data is improving, and methodologies, definitions and study scopes are becoming more precise, and a consensus is being broadly reached, but it's taking too long.

How much is there?
It is estimated by the OECD that **430million tonnes** of plastic are made worldwide each year, with approximately two thirds of these being short-lived products that soon become waste[3]. Most is made in China (32%) followed by North America (18%) the rest of Asia (17%), and the EU (15%)[4]. Global plastics production is expected to ***triple by 2060***[5]. That equates to a staggering 1,231 Mt per year unless we take steps to arrest and reduce plastics consumption. Globally, fossil-fuel based plastics make up 90% of production, post-consumer 8.31% (i.e. recycled) and bio-based approximately 1.5%[6].

In terms of polymers, there are seven dominant types described in the chart below. Of these, PP comprises 19.3%, LDPE makes up 14.4%, PVC 12.9%, HDPE 12.5%, PET 6.2%, PUR 5.5% and PS, PSE 5.3%, recycled plastics is 8.3%, with other fossil-based thermoplastics 7.1% and thermosets (excluding PUR) 7.1%[7]. Those most used in packaging are PP, LDPE,

[1] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.
[2] https://en.wikipedia.org/wiki/Anthropocene
[3] Global Plastics Outlook policy scenarios to 2060 OECD. https://www.oecd.org/environment/global-plastic-waste-set-to-almost-triple-by-2060.htm
[4] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022
[5] Global Plastics Outlook policy scenarios to 2060 OECD. https://www.oecd.org/environment/global-plastic-waste-set-to-almost-triple-by-2060.htm
[6] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/
[7] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/

HDPE, PET, and PS. Recycling pathways for PP, LDPE, HDPE and PET are relatively well established, but not at a scale necessary to deal with the volume produce and wasted globally. Contamination remains the biggest problem for recyclers.

Each polymer type (broadly speaking) has a unique identifier 1-7. This is a resin marker and does not necessarily mean the polymer is recyclable[8].

Most plastics are used in packaging (44%), followed by building and construction (18%), automotive (8%), electrical and electronics (7%), household leisure and sports (7%) and agriculture, farming and gardening (4%)[9].

Open dumping on land and sea is the principal cause of plastic materials entering the environment, where these are blown or wash into streams and rivers and then into the ocean. However, plastic can also enter the environment as litter, windblown from homes and streets, bins, trucks and landfills.

It has been estimated 8m tonnes per year enter our oceans as a pollutant[10] globally, where they choke wildlife and enter food chains. That figure has been recently re-estimated to be closer to 11m tonnes[11]. On land plastics also contaminate farmland, rivers and streams, choking wildlife and stock. According to recent scientific data, single-use plastics represent half of all marine litter. It has been forecast that by 2050 there will be more plastic than fish in the oceans, by weight[12].

Plastic in the environment is cumulative, since it does not easily break down and is ingested by marine mammals, birds, and reptiles. Around the world, nearly half of all seabird species

[8] https://polychem-usa.com/plastic-coding-system/
[9] https://www.plasticsoupfoundation.org/en/plastic-facts-and-figures/
[10] EMF (Ellen MacArthur Foundation 2016) Rethinking the Future of Plastics 2016, online at https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics
[11]https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop
[12] https://ec.europa.eu/commission/presscorner/detail/sv/MEMO_18_6

are likely to ingest debris, with balloons considered to be the biggest plastic killer of seabirds. A third of marine turtles also ingest debris, most of which is plastic, and whales, dolphins, dugongs, fish and crabs, etc, are killed and maimed through entanglement with it.[13]

When it does break down through sunlight, abrasion and oxidation, it is most often into smaller particles - micro-plastics (<5mm) and nano-plastics (<0.1mm), and as this material becomes smaller and smaller it is ingested by plankton and enters the food chain. These small plastic particles also attract long chain molecules. Once in the food, water and air, they enter blood streams, livers and lungs[14].

Micro-plastics and nano-plastics in the marine environment also attract other long chain molecules such as insecticides and persistent organic pollutants (POPs), which are known carcinogens. These typically start out as insecticides, pharmaceuticals, solvents and industrial chemicals,[15] and are 'forever' chemicals, accumulating in food chains.

Professor Hideshige Takada of Tokyo University of Agriculture and Technology has been working on plastic 'nurdles' for many years. Nurdles are plastic pellets used in the manufacture of plastics and can easily escape manufacturing processes. They spill from plastics manufacturers and recyclers, can be easily blown or washed into stormwater systems, and end up in sediments in the marine ecosystem. Prof. Takada collected these as he analysed sediments in Tokyo Bay (sedimentology was his main interest) and found them to have attracted other long chain molecules which latch onto the nurdles' surface, including Poly Chlorinated Biphenols (PCBs), DDT, DDE, and DDD, along with Hexachlorohexane, an insecticide. In addition, the additives (see below) used in plastics are also present, and these are known endocrine disruptors and antioxidants. Professor Takada started the International Pellet Watch, and has encouraged people from all over the world to look at their local beaches and mud flats to find pellets and send these to his lab for analysis. There's now a map of where these pellets have come from, along with their attached POPs[16].

Probably the biggest source of micro-plastics entering the environment is motor vehicle tyres. As tyres wear, they emit tiny fragments (as small as 23 nanometres) which can be inhaled directly or washed into runoff from roads and into the environment, and can contain various toxic compounds. Wear rates for tyres vary depending on manufacture, weight of the vehicle and how abrasive road surfaces are and driving behaviour. A chemical 6PPD is used as a preservative in tyre manufacture and has been found to be toxic to salmon in North America.[17] There is a growing field of research in relation to this issue, including in Australia and its expected that there will be increased concern and interest in limiting additives and reducing wear through design.

Another of the biggest sources of micro-plastics is from washing clothes. Plastic fibres break off and enter the waste water stream and are eventually discharged into the oceans. Micro plastics in the form of micro-beads in exfoliators and body washes, etc, also contribute to this pollution stream.

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[13] https://www.csiro.au/en/research/natural-environment/oceans/Marine-debris

[14] Impact of Microplastics and Nanoplastics on Human Health. (2021) Maxine Swee-Li Yee, Ling-Wei Hii, Chin King Looi, Wei-Meng Lim, Shew-Fung Wong, Yih-Yih Kok, Boon-Keat Tan, Chiew-Yen Wong, and Chee-Onn Leong, Nanomaterials(Basel), 2021 Feb; 11(2): 496.

[15] Karlsson, T., Brosché, S., Alidoust, M., & Takada, H. (2021). Plastic pellets found on beaches all over the world contain toxic chemicals. International Pollutants Elimination Network (IPEN), 25.

[16] http://pelletwatch.org/pollutants

[17] Markus Brinkmann, David Montgomery, Summer Selinger, Justin G. P. Miller, Eric Stock (2022-03-02), "Acute Toxicity of the Tire Rubber-Derived Chemical 6PPD-quinone to Four Fishes of Commercial, Cultural, and Ecological Importance", Environmental Science & Technology Letters, vol. 9, no. 4, pp. 333–338.

New plastic materials are, however, still beginning their lives in the market. Poly Lactic Acid or Polylactides are a relatively new form of plastic based on renewable sugar, corn starch or cassava or sugar beet, and are manufactured through an industrial scale fermentation process. Such products are industrially compostable, have a lower carbon footprint (being not fossil-fuel based) and can be recycled if collected separately, or can be separated through a sorting process. However, we need recyclers to be able to detect and sort these to a high degree of accuracy using new technology, and there needs to be a market established for this material.

A recent report (2020), *Breaking the Plastic Wave* (Pew & SystemIQ, 2020)[18] covers the issue of global plastics consumption, end-of-life flows, and losses to the environment. The report has a particular focus on losses of plastics to the oceans. High-level findings from the report, in terms of 2016 plastics flows, and projected 2040 flows modelled under today's business-as-usual scenario, are as follows:

- 11 million tonnes of plastics per year went into the oceans in 2016;
- 29 million tonnes of plastics per year will go into the oceans by 2040;
- 80% of 2016 leakage to the environment was from flexible and multilayer plastics (mostly packaging);
- 11% of 2016 leakage to the environment was made up of micro-plastics;
- Without considerable action to address plastic pollution, by 2040, 50kg of plastic will enter the ocean for every metre of shoreline;
- By 2040, waste plastics generation will double, and plastics leakage into the oceans will triple, with the stock of plastics in the oceans quadrupling.

The recommendations from this report are highlighted later in this document.

The Additives

The story doesn't end here, since plastics aren't limited to the materials associated with their name, but have also had chemicals added to them to give them different properties, depending on their application. Some of these are toxic, hazardous and also long-lived[19]. According to the above report, these can include the following:

- Flame retardants- long chain paraffins, boric acid, brominated retardants with the metal tin;
- Stabilisers, UV antioxidants, Bisphenol A etc - a huge list;
- Heat stabilisers such as lead, cadmium and zinc compounds;
- Plasticisers - a long list - from long chain chlorinated paraffins to phthalates and adipates;
- Lubricants;
- Slip agents – e.g. fatty acid, amides and esters;
- Foaming agents e.g. pentane, CO_2;
- Biocides such as arsenic, Triclosan, and organic tin compounds;
- Colorants and pigments - organic as well as inorganic pigments;
- Fillers such as talc, zinc, clay, kaolin, barium sulphate, metals, and wood powder;
- Glass fibres and carbon fibres;

[18] https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings

[19] Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. *Journal of hazardous materials*, 344, 179-199.

- Pro-oxidants - usually metal salts and oxides added to plastic to allow quicker oxidation and breakdown into smaller fragments, such as Fe_2O_3, Cu_XO and ZnO.

In the environment, these potentially toxic substances can leach and migrate into air, water, saliva, food, and so-on. Releases are, however, very, very low in quantity compared to what would be considered to be toxic, and are well below upper limits. However, many of these chemicals can be endocrine disruptors, potentially having impacts on a variety of functions in many organisms, including humans. The other issue is that we don't yet know the impact of being exposed to low-level mixtures of these chemicals.

A large study of this migration of chemicals was undertaken by Buhinia et al [20]. This work covered a large number of chemicals but of note were styrene from PS cups, and pthalates, where migration into water was clearly evident, but increased significantly if the package contained fats or oils, and this was further increased if it had been exposed to higher temperatures. The potential health effects of these range from cancer/ leukemia, organ damage, nervous system effects, skin and eye irritation.

These chemicals additives can also add to the complexity of recycling, and any burning of plastics for energy recovery.

Additives that hasten the oxidising of plastics are problematic in recycling, as the plastic will degrade faster, and its properties will be compromised. PVC or halogen containing plastics, Teflon or brominated plastics entering a waste to energy plant, and combusted in an uncontrolled way, will give rise to hazardous persistent organic pollutants (POPs) such as dioxins, and acid gases (e.g. Hydrochloric acid) which can corrode the incinerator or kiln. Waste to energy facilities must have state of the art pollution control equipment, to as-far-as-is possible, eliminate the risks of POPs being emitted. These are the most expensive parts to any waste to energy facility. Of course waste to energy also releases CO_2 from the plastic, adding to greenhouse gas (GHG) emissions.

Plastics and Greenhouse gases

The UN's latest report 'Turning off the Tap: How the world can end plastic pollution and create a circular economy' (2023) suggests that cutting plastics pollution by 80% would prevent $3tn worth of negative environmental and other impacts[21]. Such a reduction would achieve a reduction of 500m metric tonnes of carbon emissions. According to the OECD[22], in 2019 plastics production globally contributed 1.8bn tonnes of GHG emissions or 3.4% of all global emissions, 90% of those coming from the conversion of fossil fuels.

By 2050 greenhouse gas emissions associated with plastic production, use and disposal would account for 15% of allowed emissions, under the goal of limiting global warming to 1.5°C (34.7°F)[23].

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[20] Bhunia, K., Sablani, S. S., Tang, J., & Rasco, B. (2013). Migration of chemical compounds from packaging polymers during microwave, conventional heat treatment, and storage. *Comprehensive Reviews in food Science and food Safety*, 12(5), 523-545.

[21] Fletcher, S., March, A. L. A., Roberts, K., Shirian, Y., i Canals, L. M., Cairns, A., ... & Bass, A. (2023). Turning off the Tap: How the world can end plastic pollution and create a circular economy.

[22] https://www.oecd.org/environment/plastics/increased-plastic-leakage-and-greenhouse-gas-emissions.htm#:~:text=In%202019%2C%20plastics%20generated%201.8,and%20conversion%20from%20fossil%20fuels.

[23] UN- https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop

Where does plastic come from? Why is it so cheap?
In the main, plastic comes from a by-product of the petroleum industry i.e. ethane gas or naphtha, which is used to fabricate various plastics through polymerisation and polycondensation. They can also be made from cellulose, coal, natural gas, and practically any long chain hydrocarbon.

However, not all plastics are created or disposed of equally. Designers, producers and consumers, governments and investors, all need to better understand their chemical structures and physical properties, how they're made and what they're used for. New synthetic materials (plastics) are being invented every year. We have little or no information on how these behave in the environment, or how to sort them in materials recovery and recycling facilities. Pre-sorting in homes and businesses is largely not done to any great degree, as it's too difficult and time consuming to identify separate streams, and so is left to Materials Recovery Facilities (MRF) to do.

What are they used for?
Plastics are used for a huge variety or products and packaging, and the various forms of plastic have properties, which are best suited to particular applications.

- Clothing and footwear (PVC; PP; PU; PET; Nylon)
- Vehicle components (HDPE; LDPE; PVC)
- Tyres comprise 24% - 50% plastic polymers
- Furniture (PVC; PP;)
- Foams (PUR)
- Plumbing (PVC; HDPE)
- Packaging (PVC; PVDC; PP; PET; LDPE; PETc; PS; EPS)
- Sealants (Silicon rubber)
- Paints, coatings and varnishes
- Pharmaceuticals, cosmetics, medicines
- Adhesives
- Tools, Utensils and Containers (PVC; PP)
- Electronics, capacitors, IT equipment- computers, printers, phones, etc
- Photo Voltaic panels, Wind farms (blades), (Waste from this category growing at an alarming rate)
- Roads (All, often mixed)
- Fishing (PVC Nylon)
- Special applications in packaging (PETc; PETg etc)
- Buildings - components for windows and framing, additions to concrete (PVC; PE, HDPE etc.)

Plastics are used to protect food, beverages and goods from being wasted or contaminated, saving resources through their use in packaging. They're light-weight and hence can decrease emissions during transportation (e.g. glass). They're used in tanks, pipes, including to provide clean water, and act as replacements for metals, ceramics, and wood in vehicles and aircraft, in this way reducing weight and reducing fuel requirements. Plastic in clothing and safety equipment is common (airbags, helmets, etc) and can even be made fireproof to prevent injuries. In the medical industry they've become indispensable, as they're used in blood bags, tubing, syringes, masks, protective clothing and prostheses, to name a few. They form hoses, gaskets and seals, across all industries.

These diverse applications lead to a diverse and complex waste stream. This complicates collection, sorting, cleaning, shredding and pelletising, and ultimately what the next use might be, IF they're recycled. This is why most plastics have ended up in landfill or the environment as waste.

What's happening internationally and in other countries?
Significant research has been and continues to be undertaken to develop new technologies to help better sort plastics, clean sorted material, find new applications for waste plastic (e.g. turning it into oils), chemically denaturing it to recover plastics' building block molecules, pyrolysis to do the same, and waste to energy. The latter has been a long-established technology in the EU and Japan, and ironically is now greatly dependent upon plastics for the fuel needed to reach the necessary calorific value. Waste to energy is also problematic as it also releases CO_2 and other pollutants into the atmosphere, as noted above.

The Global Plastics Treaty
In a ground-breaking achievement, 193 of the world's nations (at time of writing) have agreed to begin negotiations to end plastic pollution.[24] Australia is one of them. They have agreed to develop an internationally binding agreement by 2025 (originally 2024). An International Negotiating Committee began its work in 2022. While we await the outcome, it is likely that there will be a broad agreement around actions, scope and outcomes. Importantly, this initiative has correctly recognised that there needs to be coordination and collaboration internationally on this problem.

Beach litter, comprising predominantly plastic which is left stranded on shorelines is unfortunately becoming commonplace. Photo courtesy Green Industries SA.

Foundations, Not for Profits, NGOs, For Profits and related entities
Many international funds such as WWF, Ellen McArthur Foundation, have been working on the plastics problems for years. The World Economic Forum's Global Plastic Action Partnership (GPAP), with the Ellen MacArthur Foundation's Plastics Initiative and

[24] UN https://www.un.org/en/climatechange/nations-agree-end-plastic-pollution

international climate action NGO WRAP– organisations leading work to reduce the impacts of plastics – have joined forces to drive forward global action on plastics through greater knowledge exchange.

There are currently thirteen 'Plastics Pacts' around the world – ANZPAC (Australia, New Zealand and Pacific Islands), Canada, Chile, Europe, France, India, Kenya, the Netherlands, Poland, Portugal, South Africa, the UK and the US - and a new Pact in development in Colombia. In addition, there are National Plastic Action Partnerships, developed by the World Economic Forum under the GPAP project, in Indonesia, Vietnam, Pakistan, Maharashtra (India), Nigeria, Ghana, Ecuador, South Africa and Mexico City (Mexico).

Plastics Free July began in 2011 and has grown rapidly from humble beginnings to the Plastic Free Foundation, supported by the Minderoo Foundation, and other philanthropic supporters, into be a global phenomenon. In 2022, Plastic Free July was marked worldwide by a record 140 million participants making conscious changes and reducing their waste by 2.6 million tonnes[25].

There are many other foundations globally and operating in single jurisdictions with not for profits operating in research, community awareness, concerns over plastics in oceans, and so-on. It seems that globally most citizens are probably aware of the problem but feel relatively powerless to solve it.

European Union: Directives, Action Plans and Strategies

Europe has realised that plastics' loss to the environment is a loss to its economy, as it prevents attaining circularity. The cost has been estimated to be between EU80bn and EU105bn annually.[26] The plastics sector is huge in Europe, employing 1.5m people with a turn-over of EU405bn.[27] Much of Europe's plastic destined for recycling has historically travelled to poorer countries abroad. However, by 2030, Europe plans to ensure all plastic packaging is recyclable or re-useable. The rest of plastics waste has been sent for waste to energy (the majority), or landfill. In 2020, 35% or 29.5m tonnes of post-consumer plastics were sent for recycling, 23% to landfill and 42% for energy recovery. Interestingly, there are only four EU countries with plastics recycling rates above 40%, The Netherlands, Germany, Norway and Spain. Plastics recycling is growing at the fastest rate of all across most countries, with waste to energy decreasing, as is sending plastics to landfill. [28]

The EU's Packaging and Packaging Waste Directive aims to harmonise the management of packaging waste and prevent or reduce the impact of packaging and packaging waste, including by setting recovery and recycling targets. The EU's Waste Framework Directive sets out definitions for waste, recycling, and recovery along with end of waste criteria, including the polluter pays principle, the waste hierarchy and Extended Producer Responsibility.

In 2015 the EU adopted an Action Plan for a Circular Economy, and in 2018 it adopted a Plastics Strategy, setting out a circular economy plan for plastics, including an aim of making recycling profitable for businesses. In 2020 it confirmed a new Circular Economy Action Plan, including binding targets for 2030 to reduce material and consumption footprints, and proposed binding product-specific and sector-specific targets for recycled content. As a

[25] https://www.plasticfreejuly.org/wp-content/uploads/2022/11/Plastic-Free-Foundation-Impact-Report-2022.pdf
[26] https://ec.europa.eu/commission/presscorner/detail/sv/MEMO_18_6
[27] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/
[28] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/

result, since 2021, it has been illegal to sell certain single use plastics in EU states,[29] with the EU at the forefront of such bans.

Trials have shown that emissions from tyres could be reduced by 35%[30]. According to a press release dated 2022[31], The European Commission plans to place limits on tyre wear from 2025.

Jurisdictions within the EU are also doing what they can to reduce plastic use and recycle more. Two of note are Portugal and Italy, both having introduced what's termed eco-modulation, that is, penalising the use of materials that are less environmentally friendly, and rewarding the use of those which are better. Portugal introduced Sociedade Pontoverde in 2019, with penalty fees for three types of packaging that disrupt 'the recycling process', such as PET bottles with a metal cap, glass bottles with non-removable stoppers, and PET bottles with PVC labels.[32]

Italy has the CONAI scheme,[33] which has four bands for plastic packaging: packaging with an effective recycling process (industrial), packaging with an effective recycling process (household), packaging with a developing recycling process (industrial), and packaging with a developing recycling process (household). Fees are then set for materials contained in the different bands, with lower fees for those which can be easily recycled.

Micro-plastics phase-out

In line with the EU Plastics Strategy (2018), the European Chemicals Agency (ECHA) was asked to make a proposal for restricting the use of intentionally added microplastics under the Regulation on the EU's Registration, Evaluation and Authorisation of Chemicals (REACH). In 2021, the proposed actions were handed over to the European Commission, allowing some sectors 8 years to comply, and untested 'bio-degradable' plastics to replace those currently used. At present, around 42,000 tonnes[34] of micro-plastics are released into the environment each year in the EU.[35] In April 2023, the EU voted to adopt the European Commission's proposal on the restriction of intentionally added micro-plastics. This has still not been adopted as there's now a 3 month 'scrutiny period'.

United States of America

The Microbead-Free Waters Act of 2015[36] is a United States law that prohibits the addition of plastic microbeads in the manufacturing of certain personal care products, such as toothpaste. Manufacture was prohibited since January 2018 and sale since July 2018. Currently there are no other federal laws in the USA which deal with single use plastics or other related initiatives, with a third of US jurisdictions now having laws to actually prevent interventions of this nature. One exception is the proposed Plastic Pellet Free Waters Act being considered by the House and the Senate as part of a wider environmental bill and proposes to assist EPA regulators to achieve compliance.

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[29] https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics_en#:~:text=From%203%20July%202021%2C%20single,made%20of%20oxo%2Ddegradable%20plastic.

[30] https://www.theguardian.com/environment/2023/feb/23/health-impact-tyre-particles-increasing-concern-air-pollution

[31] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6495

[32] https://www.pontoverde.pt

[33] https://www.conai.org

[34] https://rethinkplasticalliance.eu/news/rethink-plastic-alliance-welcomes-the-eu-restriction-of-intentionally-added-microplastics-urges-faster-implementation/

[35] https://rethinkplasticalliance.eu/news/microplastics-restriction/

[36] https://www.govinfo.gov/content/pkg/COMPS-11806/pdf/COMPS-11806.pdf

Some US jurisdictions however have led the charge - California has had single use plastic bags bans since 2014, and a 2022 bill[37], the Plastic Pollution Reduction and Packaging Producer Responsibility Act, is being implemented by CalRecycle, ensuring that 65% of single-use products are recycled by 2032, among other interventions to be implemented between now and 2032. This represents a significant expansion from the current level of about 10%, which would transform how companies package and ship their products. California has also been working with the EU on tyre wear emissions[38].

Vermont has a single use plastic bag and straws ban and food service providers cannot use EPS. Since May 2022, New Jersey has banned single use plastic and paper bags and food services cannot use EPS. Maine has banned single use plastic bags since 2019, with a 5c fee on paper bags. Colorado plans for a ban to take effect from 2024. Washington DC has imposed a tax on plastic bags and many other cities try their hand at curtailing single use plastic bags with taxes and bans, but some have repealed their legislation (Chicago).[39]

There are 10 states in the USA (beginning with Oregon in 1971) that have container deposit legislation which also assists in the effective removal of plastic beverage containers from the waste and litter streams.

United Kingdom (UK)[40]
The UK is no longer a member state of the EU, and it isn't required to adopt the more recent directives. However, it has developed some unique approaches of its own. These efforts are further complicated by jurisdictions in England, Scotland, Wales, and Northern Ireland either doing their own or adopting, or not adopting, or delaying, national policy directions.

Carrier bags have had minimum charges for a number of years, however the rates vary across the UK from 5p Wales to 25p (Northern Ireland).

In England, the distribution and sale of single-use plastic drinking straws, plastic-stemmed cotton-buds and plastic drink stirrers was banned from 1 October 2020. The government confirmed in January 2023 that it will go further and ban the supply of single-use plastic plates, trays, bowls, cutlery, balloon sticks, expanded and extruded polystyrene food and drink containers in England from October 2023, to align more closely with the ban that applies in Scotland and in the EU. Scottish regulations go further still to capture oxo-degradable plastic products. The Welsh Government is in the process of introducing similar regulations.

In relation to micro-beads, a ban was imposed on the manufacture and sale of microbeads in personal care products in England in 2018. Similar provisions apply in Wales, Northern Ireland and Scotland.

A plastic packaging tax (PPT) was introduced in April 2022 to incentivise business to use recycled plastic in plastic packaging. Companies manufacturing in the UK or importing into the UK at least 10 tonnes of plastic packaging in any rolling 12-month period need to register to pay PPT with HM Revenue and Customs (HMRC). The PPT is then payable on finished plastic packaging components which contain less than 30% recycled plastic. When introduced, the tax was charged at a rate of £200 per tonne but on 1 April 2023 this increased to a rate of

[37] https://www.earthday.org/end-plastic-pollution-leading-anti-plastic-legislation-in-the-us/#:~:text=Currently%2C%20in%20the%20United%20States,has%20laws%20preventing%20plastic%20bans.
[38] https://ww2.arb.ca.gov/resources/documents/brake-tire-wear-emissions
[39] https://en.wikipedia.org/wiki/Plastic_bag_bans_in_the_United_States
[40] https://cms.law/en/int/expert-guides/plastics-and-packaging-laws/united-kingdom

£210.82 per tonne. Figure released in August 2023 by HMRC showed receipts of £276m. 39% of packaging was declared as taxable, 40% claimed to have 30% or more recycled content, and 21% was exported or intended for export. 52% of declared packaging was manufactured in the UK and 48% imported[41].

The Environment Bill also confers powers on the relevant national authorities for England, Wales and Northern Ireland to establish charges for single use plastic items. The Scottish Government has confirmed that they will introduce provisions in the Circular Economy Bill, which will enable charges to be applied to items that cause environmental harm such as single-use drinks cups. The Welsh Government is exploring the possibility of a Welsh tax on single-use plastic cups to drive down demand.

England plans to ban wet wipes containing plastics from 2024, after many years of debate and is currently consulting on a ban's introduction. Around 93% of sewer blockages across the UK (that's 300,000 a year) are attributable to wet wipes, costing around £100m per year[42]. Wales and Scotland have already consulted on such a ban however are yet to announce the introduction of any.

The UK's Packaging Waste Regulations 2007 require packaging producers (defined widely to include, in some cases, importers and sellers), except those with a turnover of less than £5m, to meet annual recycling targets, known as business packaging waste recycling targets. Total UK packaging waste recycling rates are reported to the government on an annual basis. These requirements take effect from Jan 2023, with a waste management fee coming into effect in 2024.

New recycling targets for the following packaging materials apply for 2023, including:

- All packaging waste – 77%
- Glass – 82%
- Plastic – 61%
- Aluminium – 69%
- Steel – 87%
- Paper/board – 83%
- Wood – 35%

Deposit return systems are to be adopted in Scotland in 2024 (originally 2022, but postponed), with the rest of the UK adopting such systems sometime in 2025, however with the English and Northern Ireland schemes leaving out glass bottles.

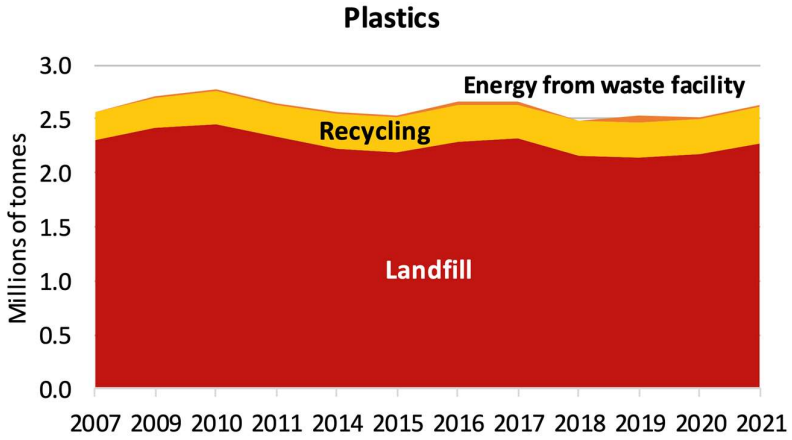
[41] https://www.gov.uk/government/statistics/plastic-packaging-tax-ppt-statistics/plastic-packaging-tax-ppt-statistics-commentary

[42] https://www.water.org.uk/news-views-publications/news/new-proof-flushing-wipes-major-cause-sewer-blockages

Australia

Australia recycles about 14% of its plastics, while South Australia recycles 28%.[43] 60% of plastics are imported to Australia and 130,000 tonnes are leaked into the environment every year.[44] The CSIRO[45] states that in Australia, plastic is responsible for three quarters of our marine debris, of which 2% was from fishing.

Plastic packaging represents approximately one million tonnes of Australia's annual plastic consumption. In 2018-19 about 85% of plastics used were disposed to landfill. This has resulted in at least 50 mega tonnes of plastic accumulating in Australian landfills.[46] About 2.63 Mt or 102 kg per capita of plastic waste was generated in 2020–21, down from 2.66 Mt in 2016–17. Approximately half was from the commercial and industrial waste stream and most of the remainder was from Municipal Solid Waste (i.e. households).



Australia's plastics effort according to Australian Waste Data Base

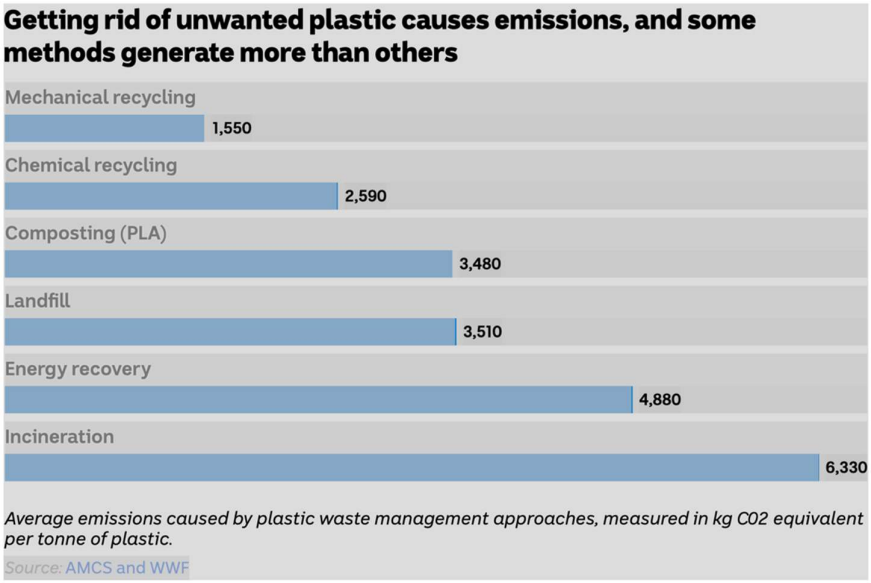
The 2020–21 recovery rate for plastics was about 14%.[47] This was nearly all recycling – less than 1% is recorded as used for its energy value, but this may be an underestimate as some data was unavailable due to commercial confidentiality. Landfills received an estimated 87% of plastics waste. The resource recovery rate for plastics was about 10% in 2006–07 and 13% in 2016–17. Up until 2020, progress has been slow.

This percentage figure for recycled plastics will inevitably improve as beverage container deposit systems are brought into operation across all states in Australia. Kerbside recycling collections can also be improved, with better education and the reintroduction of soft plastics collection. However Australia still lacks the infrastructure to sort and process the various plastics to appropriate levels for high value recycling.

According to a recently released report[48] by the Australian Marine Conservation Society and WWF, Australia's plastics use produced more than 16 million metric tonnes of greenhouse gas emissions (GHG) in 2020, taking into account emissions from production and waste management such as recycling or landfill. Recycling (mechanical) had the least emissions,

[43] https://www.dcceew.gov.au/sites/default/files/documents/apff-national-report-2020-21.pdf
[44] https://www.agriculture.gov.au/sites/default/files/documents/national-plastics-plan-2021.pdf
[45] Hardesty, B. D., Lawson, T. J., van der Velde, T., Lansdell, M., & Wilcox, C. (2017). Estimating quantities and sources of marine debris at a continental scale. Frontiers in Ecology and the Environment, 15(1), 18-25.
[46] DCCEEW https://www.dcceew.gov.au/environment/protection/waste/plastics-and-packaging/national-plastics-plan/prevention#phase-out-problematic-and-unnecessary-plastics.
[47] https://www.dcceew.gov.au/sites/default/files/documents/apff-national-report-2020-21.pdf
[48] https://www.marineconservation.org.au/plasticemissions/

with waste to energy and incineration emitting the most. Fossil fuel derived plastics had 2.7 times the emissions of plant-based plastic and 2.2 times that of recycled plastic. See below.



Note: Depending on the plastic type and disposal/recycling method, different gases can be emitted and some of these have greater GHG potential compared to CO_2. In some instances, the emissions can be higher in kg CO_2 equivalents than the tonnage of plastic concerned.

National Packaging Covenant and NEPM

The Covenant and associated National Environment Protection Measure was developed to address problems with packaging and lack of recycling and improve diversion from landfill. The instrument is what's known as a co-regulatory arrangement for product stewardship. The Australian Packaging Covenant Organisation (APCO) was established by industry as a not-for-profit to coordinate these efforts. It has for the past 20 years attempted to change the design, approach and systems for packaging in Australia. The NEPM is a regulatory instrument and is designed to catch companies and brand owners not signed up to the voluntary Covenant. Administered by state governments, and with no additional funding or resources, Environment Protection Authorities have the burden to follow up non-signatories. Fines are a possibility, but in reality, few if any have been issued. A 2021 review found no compliance actions by any state over the previous 4 years.

The APCO developed new targets for industry, agreed among its members. However, in 2023 a review by APCO found these wouldn't be achieved. A target to increase the amount of recycled content being used in packaging to 50% would be met for glass and PET plastic used for drink bottles, but would be missed for other plastics used in packaging, APCO stated. The fundamental problem with voluntary arrangements and no compliance actions is that free riders gain access to kerbside recycling by councils but bear no cost, and, further, do not have to change packaging or improve practices. This puts the more positive companies making the changes at a cost disadvantage. Level playing fields are really important to encourage business to invest to make changes, with the certainty that those not pulling their weight will be investigated and penalised.

One positive development has been the Packaging Recycling Evaluation Portal (PREP)[49] design tool (developed in Australia) that can assist in designing better packaging, closures

[49] https://prep.org.au/main/content/home

etc (and potentially other plastic product forms) for kerbside collection and recycling, and this comes with the Australian Recycling Label (ARL), developed with Planet Ark. However use of PREP is not mandatory in Australia, nor is use of the ARL.

Recently, on 9th June 2023, at the Environment Ministers Meeting, they all agreed a more highly regulated approach was required.[50]

'Ministers agreed that:

- *the Australian Government will lead development of a national framework to direct Australia's transition to a circular economy, informed by the work of the Circular Economy Advisory Group.*
- *for the first time, Australia will mandate obligations for packaging design as part of a new packaging regulatory scheme based on international best practice and make industry responsible for the packaging they place on the market. This scheme will also regulate out harmful chemicals and other contaminants in packaging. To support food waste recycling Ministers agreed that a timeline will be set to remove contaminants from compostable food packaging.*
- *a national roadmap will be developed for staged improvements to the harmonisation of kerbside collections, taking into account circumstances of metropolitan, regional and remote communities for Ministers to consider in 2024'.*

This is a very important commitment and many non-government organisations believe it is long overdue.

The National Plastics Plan[51]
Following The National Plastics Summit in 2020, the Commonwealth Government in 2021 committed to work with industry to fast-track the phase out of identified polymer types in certain applications and consider regulatory action should industry phase-outs not be achieved. At the 2020 summit, various pledges were made by large corporations and various alliances formed between companies to address the plastics problem.[52] It is difficult to ascertain how these pledges are going, and while some have been the focus of much interest, others are perhaps more obscure. This demonstrates the need for better and more frequent reporting.

Another summit was planned for 2021, and was subsequently delayed to February 2022, likely due to Covid. It was to be for product designers and manufacturers to showcase their sustainable product design.

The National Plastics Plan has proposed the following:

- Phase out plastic packaging products with additive fragmentable technology that do not meet relevant compostable standards (AS4736-2006, AS5810-2010 and EN13432) (July 2022)
- Phase out expanded polystyrene (EPS) from loose packaging fill and moulded packaging in consumer packaging (July 2022), and EPS food and beverage containers (December 2022)
- Phase out PVC packaging labels (December 2022)

[50] https://www.dcceew.gov.au/sites/default/files/documents/emm-communique-09-june-2023.pdf
[51] DCCEEW https://www.dcceew.gov.au/environment/protection/waste/plastics-and-packaging/national-plastics-plan/prevention#phase-out-problematic-and-unnecessary-plastics.
[52] https://www.dcceew.gov.au/sites/default/files/documents/pledge-slides-national-plastics-summit-2020.pdf

- Work with Boomerang Alliance to eliminate single-use plastics from Australia's favourite beaches and support local businesses to switch to alternative products
- Industry to transition towards higher-value, easily recyclable plastics such as PET, HDPE, LDPE and PP, and encourage the design of easier to recycle products.
- Industry to deliver 4 National Packaging Targets by 2025 of which 2 concern prevention:100% of packaging being reusable, recyclable or compostable, and phase out of problematic and unnecessary single-use plastic.

It is already acknowledged that the industry 2025 targets mentioned above won't be achieved,[53] with APCO stating the latest figures showed that only 18% of plastics packaging was recycled in Australia. A target of 50% for PET would likely be achieved, but all others would fall short.

Export bans
Exports of scrap plastics to Asia (most notably China) grew from 2005 and by 2016–17 had become the dominant market for recovered material. Much of this material was in poorly sorted bales that were finished at lower cost overseas, resulting in poor environmental outcomes, such as conversion to cheap poor-quality fuel or disposal into the environment. Restrictions imposed by the receiving countries, starting with China in 2018, were matched by Australian export regulation later. Exports are now much reduced and regulated to sorted and processed product requiring no further preparation.[54]

'Phase out' of micro-beads
Australia has largely followed the EU 'lead', and requested companies to phase out micro beads added to various products, most notably in the cosmetics /skin-care industry. Australia has an agreement among retailers not to sell products containing micro-beads or micro-plastics,[55] however there are no sanctions in place for those who aren't signatories including on-line suppliers. While a review of the voluntary action in 2018 has shown that it has phased out a significant portion of microbeads, the New South Wales Plastic Reduction and Circular Economy Act 2021 bans the supply of rinse-off personal care products containing microbeads. New South Wales remains the only state to do so.[56]

Light-weight Plastic Bag Bans and Single Use Plastic Bans
All states in Australia have now phased out by legislation single use plastic bags, following the lead of South Australia in 2009. This was followed by the ACT and NT in 2011, Tasmania in 2013, Queensland 2018, WA 2018, Victoria 2019, and New South Wales in 2022. In 2022, WA banned ALL plastic bags from July. The opportunity to ban in 2008 nationally was lost as governments couldn't agree. The slowness of policy implementation and time lost, and confusion for industry having to do different things in each state, is a salient lesson to inform future actions. Of note is the apparent reluctance (so far) to ban single use wet wipes containing plastic. Such a ban would improve wastewater treatment, reduce clogging of sewerage systems and infrastructure maintenance costs.

The first state to introduce single use plastic bans was South Australia, legislated in 2021 and coming into effect 2022. Queensland quickly followed, with most other states. See below

[53] https://www.theguardian.com/australia-news/2023/apr/20/australia-recycles-just-18-of-plastic-packaging-and-will-not-reach-2025-target-review-finds
[54] https://www.dcceew.gov.au/sites/default/files/documents/national-waste-report-2022.pdf
[55] https://www.dcceew.gov.au/environment/protection/waste/publications/assessment-voluntary-phase-out-microbeads
[56] https://www.epa.nsw.gov.au/your-environment/waste/reducing-your-household-waste/what-are-microbeads#:~:text=While%20voluntary%20action%20has%20phased,microbeads%20from%201%20November%202022.

a chart from the Australian Marine Conservation Society and WWF that summarises progress to May 2023.

The Soft Plastics Task Force

Following the downfall of the REDcycle soft plastics in-store collections nation-wide (with 270 brand partners) in mid to late 2022, caused by reduced offtakes for soft plastics for manufacturers and the growth in soft plastics collections during Covid pandemic, a number of supermarket chains received interim ACCC approval to meet to find solutions. Those chains were Aldi, Woolworths and Coles, supported by the Commonwealth Government.

Their report[57] published 7 March 2023, identifies the pathway back for in-store collections to begin in some areas in late 2023. Australia's soft plastics recycling and reprocessing capability was below what REDcycle was collecting (about 7,500 tonnes in FY 2022), being of mixed polymer types. Most higher value offtakes need single polymer types such as

[57] https://www.aldiunpacked.com.au/storage/2023/03/Soft-Plastics-Taskforce-Roadmap-20230307.pdf

LDPE, which is also of a higher value in the market than a mixed stream. Investment by industry and Government will improve the situation over the next two to three years. That capacity is expected to be about 15,000tpy, and a broader collection of soft plastics through council kerbside collections is likely (already successfully piloted in several areas).

Stockpiles of REDcycle soft plastics are still to be processed (approximately 12,000 tonnes). Next steps will need to include funding models to enable collection, transport and recycling of this and new material, governance structures for oversight and management, contracting and product /supply chain development. In addition, it may be prudent to analyse and limit types of soft plastics used for packaging to enable the best recycling outcomes, or new sorting technologies to separate polymer types post-consumption. The latter is probably more likely, (but more expensive) as it must be remembered that a lot of soft plastics product is imported, is used in wrapping products purchased on-line, and this is not in the control of Australian supermarkets or retailers such as those comprising the Task Force.

Investment in sorting and reprocessing

The Commonwealth's Recycling Modernisation Fund was initiated in 2020 and has had plastics as a focus of the fund, and is co-funded by states along with industry (roughly one third each for projects). A number of large investments have already been agreed, and are being built, however it remains short of the capacity needed, but hopefully will improve to match that required. This will take significantly more investment in new technologies. $250m is earmarked with $60.4m to boost Australia's plastics recycling capabilities.

These technologies include plastics to oil through various chemical processes and pyrolysis, none of which are at commercial scale as yet. Research in this area is continuing in many research institutions, and the CSIRO is also taking a pro-active role.

A study undertaken in 2021 surveyed plastics recyclers and producers to find out if existing and planned reprocessing capacity would meet feedstock demand for 2024-25.[58] The table below is a summary of that work from the report and shows a gap of 2.4m tonnes. There's a serious risk this gap material will end up in landfill or be sent overseas.

[58] https://www.dcceew.gov.au/environment/protection/waste/publications/australian-plastic-flows-and-fates-report-2020-21

Polymer type	Current + Planned	EoL generation	Reprocessing gap	
	(tonnes)	(tonnes)	(tonnes)	(%)
PET (1)	148,200	353,300	205,100	58%
PE-HD (2)	162,300	526,900	364,600	69%
PVC (3)	8,600	249,200	240,600	97%
PE-LD/LLD (4)	124,400	428,500	304,100	71%
PP (5)	123,300	558,000	434,700	78%
PS (6)	16,300	66,500	50,200	75%
PS-E (6)	13,700	42,200	28,500	68%
ABS/SAN/ASA (7)	2,200	54,700	52,500	96%
PUR/PIR (7)	3,800	66,300	62,500	94%
PA (7)	6,700	100,500	93,800	93%
Other (7)	8,000	221,400	213,400	96%
Unknown polymer	62,700	424,600	361,900	N/A[1]
Total	**680,200**	**3,092,100**	**2,411,900**	**78%**

1. For 'Unknown polymers' the 'Current + Planned' and 'EoL generation' quantities are not the same polymer type and so are not directly comparable, and a reprocessing gap % cannot be calculated.

ANZPAC (Australia, New Zealand and Pacific Island Plastics Pact)
There has been much activity in Australia, by various proponents, to increase the mechanical recycling of plastics, for recovery back into food grade and non-food grade packaging.

The dominant player in building and operating this new reprocessing capacity is Pact Group, with a primary focus on PET and HPDE rigid packaging, but also with significant new capacity targeting PP rigid packaging, and LDPE packaging films.

From 2021 - 2025 Pact is constructing and operate 5 new mechanical recycling facilities in Australia and one in New Zealand, doubling the number of plastic reprocessing facilities operated by Pact from 6 to 12, and increasing Pact's annual reprocessing capacity from around 30 kt/yr to more than 120 kt/yr. Pact's plan is to return as much of the recovered plastics back into its own local plastic packaging manufacturing as possible, giving these new reprocessing facilities effectively guaranteed end-markets. This would give Pact's customers (i.e. brand-owners) a large increase in available material to contribute recycled content to plastic packaging in Australia.

Australian Micro-plastic Assessment Project (AUSMAP)
AUSMAP is a citizen science project surveying Australia's shorelines collecting reliable data and mapping micro-plastics hotspots.[59] It has developed a 'hotspot' map, which shows where most of Australia's micro-plastics have been found around its coastline. This is a valuable source of information for policy makers, but also enables communities to take part in first hand identifying the problems and informing them of possible solutions. Its work has also highlighted tyre wear particles in hotspots around coastlines near major cities.

[59] https://www.ausmap.org

Tyre wear emissions and particles have been and continue to be researched comprehensively by **Tyre Stewardship Australia**[60] and in its October 2022 literature research and report on the topic, found that there are 'minor risks' associated with particles emanating from tyres, artificial turf, playgrounds and crumb rubber modified asphalt. As stated earlier, research into this field is ongoing and global in nature.

South Australia

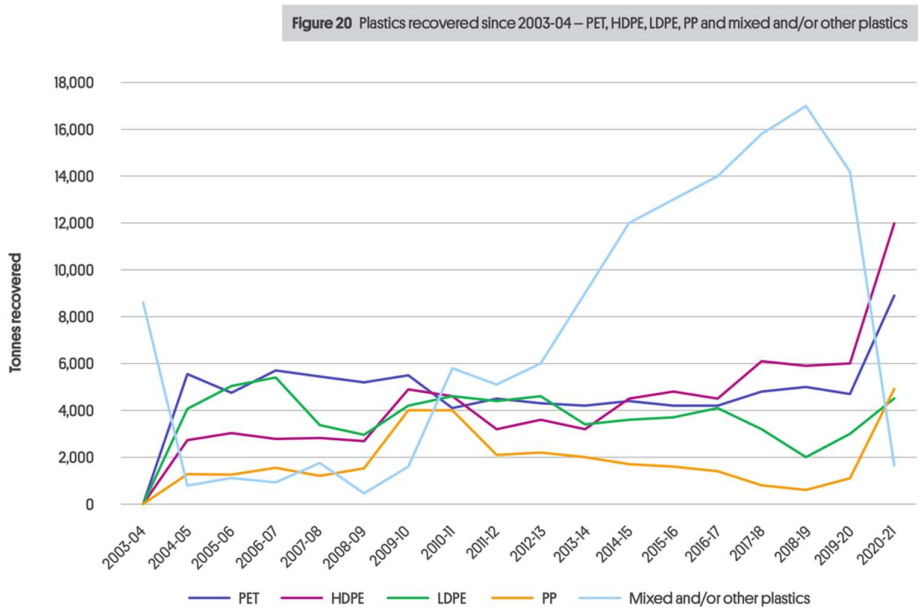
According to Green Industries SA[61] South Australia recovered 32,000 tonnes of plastics in 2020-21. There was a sharp decrease in mixed and/or other plastics recovered coupled with sharp increases in individual plastic polymer types. Most recovered plastics in 2020-21 were high-grade polymers such as HDPE (37%) and PET (27%). The rise in certain separated plastic polymers is attributed to the Commonwealth Government's ban on the export of mixed plastics and also to increased capacity from one of SA's major plastics reprocessors.

About two thirds of recovered plastics came from the MSW stream, with the remaining third from C&I sources. Over half (54%) is reprocessed in SA and 28% is sent overseas.

Material type	Recovery ('000 t)	Emissions saved kt CO_2 e	Energy saved TJ LHV	Water saved ML
Polyethylene terephthalate	8.9	11	490	610
High density polyethylene	12	10	600	270
Polyvinyl chloride	0.02	0.01	0.6	0.5
Low density polyethylene	4.5	3.7	230	100
Polypropylene	4.9	1.5	150	130
Polystyrene	0.4	0.1	10	10
Mixed and/or other plastics	1.7	0.5	50	40
Total	32	26.8	1,531	1,161

[60] https://www.tyrestewardship.org.au/wp-content/uploads/2022/11/TSA-Tyre-Particle-Safety-Report.pdf

[61] https://www.greenindustries.sa.gov.au/documents/circular-economy-resource-recovery-report-2020-21-summary.pdf



The above figure shows the huge growth from 2008-09 then drop from 2018-19 in mixed plastics recycling. This was due to export bans and more investment in local sorting infrastructure.

Keep South Australia Beautiful (KESAB) has the longest contiguous set of litter data in Australia, spanning nearly 30 years. It tells us that plastics have grown in prominence and remain prominent in the litter stream.[62] If one were to include cigarette butts as a form of plastic (which they are), then plastics become the overwhelming constituent of litter. Wrappers, bottles, coffee cups, takeaway containers, packaging tape all make up the plastic litter stream.

South Australia's plastic recycling rate of 28% and many of its regulatory and funding interventions have placed it as a leader nationally, and in some aspects internationally. South Australia has been home to a few notable industry leaders in the recycling of plastics and they have been innovative in their businesses to both sort and clean plastics and produce new products. This leadership has been assisted with funding for plastics recycling from Green Industries SA and the Commonwealth.

South Australia has also banned oxo-degradable plastics and promoted compostable plastics (PLA) to replace produce bags in supermarkets, with customers using these to dispose of food waste at home in local council kerbside organics recycling bins. This material goes to large well-managed EPA licensed composting operations.

The Government however is limited by what regulatory measures can be invoked due to the Australian Constitution (such as taxation measures), but it has brought in container deposit provisions (1977), and expanded those in 2002, doubled the deposit in 2008, funded plastics recycling infrastructure including materials recycling facilities, as well as banning various single use plastics (2022). These successful interventions have formed the basis for other Australian states and jurisdictions overseas to adopt, adapt and then improve upon. In July 2022 it also enabled citizens to bring their own containers for re-filling without public liability problems through changes to the Civil Liability Act.[63]

[62] KESAB litter report http://www.kesab.asn.au/wp-content/uploads/litter-research/KESAB-LitterStats-Wave83-May2022.pdf.
[63] https://www.premier.sa.gov.au/media-releases/news-items/bringing-your-own-container-no-longer-risky-busines

South Australia's container deposit system has been under review for several years, with the aim to modernise it and make it compatible with new schemes interstate. More than 600 million beverage containers (more than 40,000 tonnes) are returned by South Australians for refund and recycling each year resulting in one of the most effective CDS systems in the world, with beverage containers accounting for less than 3% of litter items in SA.[64]

Reverse vending machines are commonplace in other states. Brisbane Airport.

However not all is great in South Australia. The state still suffers from a lack of recycling infrastructure for plastics, as there is really only one high impact and large throughput facility in Kilburn. There are also hot spots for marine micro-plastics problems, as detected by AUSMAP and there appears to be leakage from recyclers and manufacturers upstream which needs urgent rectification. A recent study in Adelaide (2022)[65] showed the presence of microplastics in Adelaide's freshwater streams and rivers, suggesting micro-plastics from these are contributing to ocean pollution. The study shows quite high amounts compared to studies from other urban streams internationally and may be cause for some concern, but this variability may result from methodologies and/or environmental differences such as stream flows.

The way forward

Why are we failing to make a difference?
An over-arching problem is that the costs of production, use and disposal of most products including plastics do not incorporate the indirect costs or benefits to society (such as

[64] https://www.epa.sa.gov.au/environmental_info/waste_recycling/container_deposit/review-of-container-deposit-scheme
[65] https://doi.org/10.1016/j.scitotenv.2022.158672.

additional health costs or benefits) or to the environment (such as microplastics pollution or ingestion of plastics by mammals). These are considered as 'externalities' by economists and occur in all phases of production, sale and use. Externalities pose fundamental economic policy problems when firms do not internalize these indirect costs or the benefits from their economic transactions[66]. It is likely that in the case of plastics, the negative externalities would increase costs of production and use, sending a clear market signal to purchase and use less. Examples include where petrochemical plants emit plastic particles and other air pollutants and where waste plastics are sent from Europe to developing countries where emission standards for recycling are not as high[67]. Because negative externalities are not included, we have a risk of over production. Governments have been struggling to ensure these externalities are accounted for through various regulatory actions as discussed earlier, through bans, taxation, and product stewardship schemes etc.

Corporations have been largely doing business as usual and haven't taken responsibility for downstream (or upstream) impacts that result from plastic. A recent article[68] found that the food and beverage sector's transition to sustainability is slow and inconsistent. South Australia along with other jurisdictions internationally has had container deposit legislation since 1977, which was and has been opposed by large corporations, with the result that the last state to introduce it in Australia was Victoria in 2023. The volume of beverage container waste that might have been saved and recycled during the intervening 46 years if this had not occurred, is undoubtedly very significant.

Governments have also been quite reluctant to regulate, and when they have its been inefficient and patchy, city by city or state by state. That mindset is changing, it would seem, but again appears to be too slow.

This lag also affects investment, with investors unsure what to invest in, as they are unable to estimate risks. Will the rules change? Will there be a disruptive technology? With governments often being slow to regulate, there's no certainty to invest in innovation.

According to Professor Ed Kosior, an acknowledged global expert on plastics, there's a gap between what brand owners and packaging manufacturers are placing in the market and what's required for recycling.[69] He goes on to explain that these problems aren't limited to just additives, and describes what he calls 'Re-looping', design solutions that could really aid more effective recycling. These include, but are not limited to:

- Additives being limited to what is approved for food packaging;
- Use 'mono materials', in other words, the same polymer for closures as for the package;
- Label adhesives made to be easily removed in the recycling processes;
- Direct printing using inks onto plastic surfaces to be avoided unless this is easily removed;
- Use of natural colours to aid sorting, rather than branding, would simplify sorting e.g. use white or clear packaging for food items. Items that contained toxic materials could be black, making sure they're easily detected.

66 Helbling, Thomas (2022) Prices do not capture all Costs- International Monetary Fund; https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Externalities
67 https://www.foodpackagingforum.org/news/wrestling-with-the-externalities-of-the-plastics-supply-chain
68 Phelan, A. A., Meissner, K., Humphrey, J., & Ross, H. (2022). Plastic pollution and packaging: Corporate commitments and actions from the food and beverage sector. Journal of Cleaner Production, 331, 129827.
69 https://www.plasticstoday.com/packaging/why-re-looping-plastics-recycling-20

The above list includes some of the design elements that are required to enable a circular economy for plastic packaging. Recyclers cannot do this, for it must begin at the design stage and be adopted in manufacturing, then purchased by the fillers and retailers, then consumers. This sounds like a long supply chain, and it may take years for the chain to all adopt such design practices. But these changes will need to be fast tracked to reduce the environmental load represented by projected increases in plastics production and waste.

The problem with the approach we have been using

Broadly, from the foregoing, nationally and internationally, it could be said that efforts have been multifaceted but largely uncoordinated, often lacking focus and simply not getting results fast enough or at a scale to make a sufficient difference. There's a lack of government direction and regulation, leaving industry to flounder with un-even playing fields and difficult collaborations. There's as yet no single platform/place where solutions, knowledge sharing and experiences can be shared with respect to plastics, and there clearly needs to be. Investors are unsure, the public are confused, as the environment continues to be degraded. The new Plastics Treaty holds great hope, however this will also take time, and business as usual won't achieve the outcomes required in the time frames needed.

A Proposed Framework

Often in complex matters, its difficult to see 'the wood for the trees', as narrow focussed thinking leads to certain solutions, but these in turn may have other unintended consequences. From the foregoing its plain to see that plastics issues are complex and at large scale. We will require large scale thinking and solutions.

A small international group[70] has been working on identifying the key principles to help us move beyond being stuck in analysis or await a perfect solution. These have been described as follows:

Capability: Expanding the capability of communities to attain social, environmental and economic aspirations, as identified in the SDG targets. In the plastics realm many communities currently have no choice, they're importers of products but must find local solutions. Solutions need to be found for the varying polymers, and enable material to be re-made into food grade plastics.

Resilience: Building resilience in communities to better manage risks, and plan for and respond to natural and manmade crises, including progressing climate change. Risks relating to plastics extend to local waste management and litter, accumulation and storage for non-existent recycling, and a lack of technologies or systems to deal with plastic wastes. In many cases communities do not have the financial ability to fund solutions. Climate change and associated impacts only add to the problem.

Systems-Thinking: Creating system-wide, design-led approaches to innovation, where possible aligning technologies to increase positive, and reduce negative, impacts. Plastics technologists should be developing and using materials and systems that enable easier and faster recovery, using fewer polymers, not more. In legislative interventions, all too often plastics bans can lead to alternative single use products simply substituting plastic in the supply chain. This includes paper bags, wooden utensils etc. Interventions should take into account systems thinking in order to minimise these outcomes, as it in turn places greater

[70] Philip Vafiadis, Hans-Peter Plag, Vaughan Levitzke, Monica Oliphant, Robert Crocker 2023. A Roadmap for Investments. Team for Plenteous Futures, https://www.place4us.net/RM2F/Library/index.php?file=LibItem&group=LibItem&ID=kjvukugvvgt.

pressure on other finite resources such as forests and forest products. Ironically, this is the reason why plastics were substituted for paper in packaging so many years ago.

Transparency: Make transparent the origins and impacts of products, materials and supply chains, including the water and energy required. Labelling of plastics, including the identification of polymer types, and what is their impact from a lifecycle perspective, are all important for consumers and government to know. Supply chains, and where products are manufactured, are also important to understanding where material can be recycled, and who is the originator of the material. We will need block chain technology, radio frequency identification (RFID) technology, plastics markers etc to enable this, with a wider adoption of the Australasian Recycling Label (ARL).

Regeneration: Designing for regeneration in productive systems to recover biodiversity, improve resource management, and eco-system health. Ensuring that there's limited or no escape of plastics into the environment, and especially the marine environment is a difficult task, and requires behavioural as well as technological changes, barriers to entering ocean, and harvesting plastics from the land and ocean.

Circularity: Design for a high level of circularity to increase the long-term value of materials and products in use, to reduce material and energy flows, and resource use. Plastics are all too often designed for a single use/ trip to the consumer, without thought given to resources used, collection systems or post-consumer technologies to enable the material to re-enter the supply chain.

Decoupling: Decoupling of material flows, resource and energy use from economic activity in all domains of production and consumption.[71] The following actions are analysed for addressing the Decoupling and Circularity aspects of the plastics problem, based on the waste hierarchy as a starting point, i.e. Elimination, Refusal, Reduce, Reuse, Repair, Recycle, Energy Recovery, Landfill.

- **Elimination/ Avoidance**
  Little is done to eliminate plastics in the production of goods. They are fundamentally cheap, and very often have properties not easily replicated with other materials. These very properties also underscore why they persist in the environment. Plastics are first preferred items in packaging, bins, skins for vehicles, thermal insulation, electrical insulation, hand-held items, switches and cables, etc. The list is endless, and it is naive to believe they will all be eliminated. However, we can and should determine **best use** of various plastics and design out unnecessary plastics, and reduce their consumption, particularly single use plastics.

  A new tool that identifies best uses of polymers is urgently needed to inform designers, product developers and consumers about the health and environmental impacts associated with various forms of plastic. There's also a need to research and more clearly understand the multiple properties of various plastics, find better pre-sorting/collection, sorting and recycling technologies.

  We can also ban plastics from some uses (many single use applications), especially problematic packaging e.g. expanded polystyrene or oxo-degradables which cause difficulties in Material Recovery Facilities and in the environment, and for which no real secondary market is established. These can be replaced by other common plastics, reducing the need for sorting and disposal. Software tools such as PREP design tool can assist in designing better packaging, closures etc, (and potentially other plastic product forms), and with the ARL labelling system this can inform consumers about correct disposal.

[71] https://www.materialflows.net/decoupling-material-use-and-economic-performance/

- **Refusal:**
  To refuse, the consumer must be educated with respect to what they should refuse. Knowledge of plastics is almost non-existent in our communities, and the varieties of plastic and species are almost indistinguishable to the untrained eye. Why should the community be expected to refuse these, if the government can eliminate them, based on science and knowledge of impacts, etc?

  This then becomes mainly a regulatory opportunity to remove unnecessary plastics, removing the burden from consumers. PVC in packaging might be a classic case - it has no remarkable property above any other plastic and is in small amounts, so it becomes uneconomic to recycle and contaminates other plastics recycling. When burned it releases chlorine species which have other environmental impacts (see earlier discussion).

- **Reduction:**
  Reducing use goes back to design, and through better design, lessening the plastic material intensity of products. This needs to be front and centre in all product design, and particularly plastics packaging.

  How is this made to happen? Only manufacturers can monitor this in their own production lines and facilities. Therefore, plastics importers and manufacturers should be made to report on what they've done to minimise plastic publicly and be heavily taxed if they haven't reduced it, or fined if they have not reported it.

- **Reuse and Refill:**
  Many plastics can be re-used, however they need to be robust, washed or decontaminated from organic or other chemical contamination to make them safe for refilling, other rigid plastics designed for disassembly (e.g. vehicle parts), or re-moulding (panel repair). Common plastic items such as buckets, silos, sacks and some packaging can be feasibly reused and refilled many times over, significantly extending the life of the material in use.

- **Repair:**
  Plastics are relatively easy to repair, and a multitude of options are potentially available depending on the application, but usually various glues for cracks or heat treatment for distortions are used most commonly. This option extends the life of the product and is usually quite a lot better than recycling.

- **Recycling:**
  Recycling usually requires sophisticated polymer detection, sorting, washing and pelletising ready for use in new products. The material is sold on the open recycled polymer market, and that market is increasing. New investment into more sophisticated processing facilities is happening. The technology is improving and getting better at detection and processing.

- **Energy Recovery:**
  Recovery is usually by taking the plastic and recovering energy via oxidation in large waste to energy plants or cement kilns. Both should have emissions reduction technologies and monitoring. This is often seen as the final destination as plastics have a high calorific value compared to most other waste streams. However by using this material (originally derived from fossil fuels) we are also simply adding more CO_2 to the atmosphere, along with other contaminants such as dioxins, among other problematic chemicals (especially from PVC). Recovery may also include plastics to

oil where plastics are heated in a low oxygen environment to crack the molecular structure and recombine and condense to make an oil which is then further refined. Problems of product oil quality, energy costs for the pyrolysis, virgin oil costs out-competing the plastic-derived oil, and residual tar have made the process to date non-competitive, however there is investment happening and has promising results. A large increase to oil prices may also make the technology more viable.

A ban on PVC from packaging and such items as children's toys, etc, might be a good place to begin reducing the risk from these plastics, along with bans on many single-use plastics (straws, cutlery, plates, bags, cups, etc).

- **Landfill:**
  Landfilling of plastics might be considered a temporary mid-term storage until suitable processes are invented to deal with contaminated mixed plastic materials. Plastics will not degrade in landfill (low oxygen, stable temperature, encapsulated), so is not necessarily a bad final destination if well managed. Landfill can be used to store this material for hundreds of years (although not a preferred option).

Longer-term issues facing plastics
Oil, gas and associated fossil fuel extraction must reduce in the short to medium term in order to alleviate greenhouse gas emissions and climate impacts. This will have an enormous effect on plastics production from those fossil fuels. The plastics industry will need to pivot to bioplastics in the same period. We already see those bioplastics entering the product and waste stream now, and this will only increase. Whilst they're not made from extracted fossil fuels, and as such have lower GHG impacts, the products are in the main, essentially the same, with all the same properties and down-stream impacts. The question then is whether we can effectively produce enough biomass in an environmentally sound manner to match the apparent and growing plastic polymer demand.

With climate change leading to sea level rises and increased flooding events, there is an increasing and major risk of more of these materials entering the marine environment, as it will become harder to prevent, unless we collectively and globally arrest global warming, and reduce unnecessary plastics use. Landfills located near costal environments will become particularly problematic, as well as urban environments subjected to sea level rise.

So, what we should be doing?
According to UNEP, a shift to a circular economy can reduce[72] the volume of plastics entering oceans by over 80 per cent by 2040, reduce virgin plastic production by 55 per cent, save governments US$70 billion by 2040, reduce greenhouse gas emissions by 25 per cent, and create 700,000 additional jobs – mainly in the global south.[73] That includes us!

Earlier a 2020 report entitled 'Breaking the Plastics Wave'[74] referred to assessed global plastics solutions and pathways. The report recommends the following:

- Reduce plastics growth and eliminate avoidable plastic use and expand re-use and refill systems;
- Substitute plastics with alternatives; i.e. for certain products and packaging plastics can be substituted with alternatives such as paper and compostable materials;

[72] UNEP - https://www.resourcepanel.org/reports/policy-options-eliminate-additional-marine-plastic-litter
[73] UN- https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop.
[74] https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings

- Design recycling friendly products. For plastic that cannot yet be recycled we should design these products so that they can be efficiently recycled;
- Improve waste collection - scaling up collection rates in middle- and low-income countries should be a priority;
- Increase mechanical recycling - increasing global mechanical recycling capacity will be crucial to ensuring that collected plastic can be recycled;
- Develop plastic to plastic conversion - advances in plastic-to-plastic chemical conversion could enable us to recycle plastic that cannot be recycled mechanically but greenhouse gas emissions must first be addressed;
- Build better disposal facilities – as a transitional measure, facilities to dispose of residual waste are likely to be needed;
- Reduce plastic waste exports – countries should take responsibility for the waste they produce and end global exports of plastic waste.

The OECD states that Policies to reduce the environmental impacts of plastics and encourage a more circular use of them should include[75]:

- Taxes on plastics, including on plastic packaging
- Incentives to reuse and repair plastic items
- Targets for recycled content in new plastic products
- Extended producer responsibility (EPR) schemes
- Improved waste management infrastructure
- Increased litter collection rates

These are some very important recommendations which we can adopt, and build upon, nationally and at a state level. As can be seen from the foregoing, the interventions need to be multi-dimensional and across many areas. They are further unpacked below.

Investment opportunities for Australian Governments and the Private Sector

Research and Development/ Innovation

1. Fund research into health and environmental impacts with regard to plastics and their additives.
2. Quantify the economic externalities associated with plastics production, use and disposal.
3. Investigate the opportunity for compostable plastics in a variety of applications (mostly food packaging) which, together with food residues, can be home composted or commercially composted.
4. Identify best use of plant-based plastics.
5. Transition away from fossil fuel-based plastics.
6. Develop bio-based film plastics which can be commercially collected, sorted and recycled.
7. Identify the most suitable plastics for various applications, reducing the number of variants and complexity for designers so it becomes easier to comply with recycling and downstream demands from consumers and government (and environment).
8. Fund research into plastic coatings and the extent to which these have become problematic in the environment. Which ones are safest? Which are most problematic?
9. Research enzyme and pyrolysis reduction of plastics to establish capability and commercial viability.

[75] OECD Global Plastics Outlook Policy Scenarios to 2060. https://www.oecd.org/environment/global-plastic-waste-set-to-almost-triple-by-2060.htm

10. Standardise the methodologies used, routine monitoring approaches and reporting on the detection of micro-plastics, to ensure comparable tracking of changes, and the identification of sources, to inform mitigation strategies.

Infrastructure

1. Public bins and collection services in high visitation areas to enable collection of organic waste with compostable plastics.
2. Fast identifying and sorting of species of plastic at MRF, (such as IR, fluorescent markers, X-Ray, digital signatures, watermarks, etc) making sure different polymers are separated, and clean. Identification of compostable plastics is a priority, so these don't end up in landfills.
3. Implement storm water traps to intercept nurdles from plastics recyclers and manufacturers.
4. New infrastructure for container deposits returns (advanced reverse vending, aggregation points, digital scanning, sorting and accounting).
5. Technology for washing and refilling containers - in supermarkets and at public events.

Regulation and Policy

1. Identify and quantify economic externalities associated with plastics production use and disposal, with the aim of building these into the cost structure for products that use plastics.
2. Support the international treaty on plastics pollution and implement the same.
3. Develop and adopt International Standards and guidelines for labelling and markers to enable plastics to be easily identified at home and also at Materials Recovery Facilities (MRFs).
4. Product stewardship - extended producer responsibility. Require recycled content targets in various plastic applications, including packaging, textiles, clothing and tyres. The percentage of recycled content can rise over time as technology improves, but it must also carry over to food grade applications, as this is where most plastics are being, and will be used.
5. Imported recycled plastics should be accredited and certified and not to replace locally manufactured recycled resins.
6. Investigate deposits on other fast moving consumer goods in plastic containers e.g. coffee cups, in addition to current deposit bearing beverage containers. Review deposits on containers regularly to ensure return rates are high.
7. Demand better data and reporting from plastics importers and producers.
8. Ban non-essential single use plastics (numerous examples are available). However, simply replacing with another single use product is not necessarily a solution.
9. Promote green chemistry and its application to plastics in particular.
10. Ban problematic EPS in packaging as it is so easily broken and escapes windblown into the environment.
11. Ban wet wipes containing plastics.
12. Preferentially procure recycled content products.
13. Micro-plastic filters on washing machines to be made mandatory.
14. Ban micro-beads (follow the NSW lead).
15. Ban plastics additives which are toxic, or prevent or make recycling difficult to achieve e.g. PFAS.
16. Stop the import of packaging which cannot be recycled, repaired or reused.
17. Require all landfills to be properly managed and strictly enforce compliance.
18. Require recyclers and plastics processors to be licensed to take account of and prevent discharge of plastic pellets or other pollutants from their premises into the environment.

19. Enforce littering fines and educate public on their role in addressing improper plastic disposal.
20. Tighten sea dumping regulations and enforcement; nets, for example, should be labelled (e.g. RFID) and attributed to a fishing vessel, in this way an attribution to the source of the dumped material is achieved.
21. Levy tourists to ensure funds are available to ship back plastic containers and other wastes that cannot be recycled locally, to their place of origin (and keep destinations 'pristine').
22. Use taxation as a disincentive for using virgin plastics in packaging (in part to cover costs of regulation (user pays) and also to make recycled material more attractive) - known as eco-modulation.
23. Regulate the design of packaging to reduce complexity of plastics, number of components, and number of materials (i.e. no more than 1 material or a maximum number to enable 90% recycling).
24. Require the public reporting and testing of new plastic products BEFORE they come to market, to ensure this meets all of the requirements around environmental impacts, reduced carbon intensity, and has a pathway from collection to recycling, etc.
25. Ensure government agencies are working cohesively and systemically across and between governments.

What could South Australia do differently/ better to make a difference?

Many of the above interventions are needed to be developed and coordinated at a national level, however some can be applied locally, such as tourist levies, or at the state level, such as banning single use plastics.

However, this doesn't mean all states should await the Commonwealth Government to act. Instead, they should be each leading on different aspects of plastics regulation and management, feeding into a national strategy, so that multiple interventions can be explored simultaneously and coordinated and adopted nationally.

South Australia has led on the following interventions regarding plastics historically:

- Container deposit legislation and its expansion to new products in different product types, including plastics, and also increasing the deposit value (1977; 2002; 2008).
- Single use plastic bag ban 2009.
- A Landfill Ban for separately collected plastics placed for recycling in 2010.
- Single Use Plastics bans 2022.
- Investment in plastics sorting and reprocessing infrastructure.
- Market development for downstream applications of recycled content products.

There's no reason why this strong history cannot be built upon and expanded:

1. Examine whether deposit systems would benefit plastics recovery in markets other than beverage containers, e.g., laundry, detergent, sauces, and re-useable containers (crates) etc.
2. Join NSW to ban products with micro-beads.
3. Examine the extension of bans to other single use plastic items and plastics in use beyond the current list especially as a potential source of micro-plastics (e.g. artificial turf).
4. Ban wet wipes containing plastics as part of the Single Use Plastics bans.
5. Identifying opportunities for developing refillable containers and systems, to enable consumers to easily do so, and offer grants for new ventures in re-use. These could include laundry products, cleaning products, food applications, etc.

6. Require recyclers and plastics processors as part of environmental licensing to take account of and prevent discharge of plastics pellets or other chemicals from their premises into the environment.
7. Begin behaviour change education to enable consumers to reduce plastic consumption i.e. buy wiser, recycle better and make decisions to help the environment.
8. Co-invest with businesses in new technologies to help improve separating, sorting, recycling, treatment and reprocessing to enable food to food grade applications.
9. Invest in MRF upgrades that enable better identification of plastic types.
10. Increasingly prefer, procure and demand products/materials with recycled content and have a plan to bring on different products over time.
11. Use recycled content in infrastructure projects, including plastics for sound barriers, asphalt, etc. where safe and makes sense to do so.
12. Encourage design of new items, products and services which have fewer polymer types in their manufacture, use less hazardous or problematic chemicals and enable design for easier disassembly, re-use and repair, awarding industry prizes for accomplishing positive changes.
13. Support citizen science and engagement through funding and education, to enable citizens to monitor outcomes, change behaviours and be part of the solution.

Bali. Plastic litter is ubiquitous, and it is important to note that no nation is untouched. We need global solutions.

'Our beloved plastic is, after just 70 years, now dominant in the environment, and has come back to haunt us in ways we had never imagined'.
The author

GLOSSARY

6PPD	N(1,3-dimethyl-butyl)-N'-phenyl-p-phenylenediamine, an additive to tyres as an antioxidant.
ABS/SAN/ASA	Different types of Acrylonitrile Butadiene Styrene, copolymers of Styrene and Acrylonitrile and Acrylonitrile Styrene Acrylate used in various applications, including automotive parts and consumer goods.
ANZPAC	Australia, New Zealand, and Pacific Island Plastics Pact. A pact involving Australia, New Zealand, and Pacific Island countries to increase the recycling of plastics.
APCO	Australian Packaging Covenant Organisation, a not-for-profit organization working to improve packaging practices in Australia.
ARL	Australian Recycling Label, a labelling system to guide consumers on the recyclability of packaging.
ARL	Australasian Recycling Label. A label used in Australia and New Zealand that provides information about how to correctly recycle a product or package.
AUSMAP	Australian Micro-plastic Assessment Project. A citizen science project surveying Australia's shorelines to collect data and map micro-plastics hotspots.
Bioplastics	Plastics made from renewable biomass sources like corn starch or sugarcane, designed to be more environmentally friendly than traditional fossil-fuel-based plastics.
Biocides	Chemicals added to plastics to inhibit the growth of microorganisms.
BPA	Bisphenol A. A chemical used in the production of certain plastics and resins, known for its potential as an endocrine disruptor.
Brand owners	Companies that own and market specific brands of products.
C&I sources	Commercial and Industrial sources, referring to waste generated by businesses and industries.
CDS	Beverage container deposit system. A system where consumers are encouraged to recycle and reduce litter by receiving a refund for returning used beverage containers for recycling.
Circular Economy	An economic system designed to minimize waste and make the most of resources, keeping products and materials in use for as long as possible through recycling, reusing, and remanufacturing.
Circular Economy Action Plan	An EU plan for achieving a circular economy, including targets for reducing consumption and increasing recycled content.
Compostable Plastics	Plastics that can be broken down into organic matter under certain conditions, typically in industrial composting facilities.
Container Deposit Legislation	A policy that requires a refundable deposit on beverage containers.
Decoupling	Reducing the link between economic growth and resource consumption or environmental impact.

ECHA	European Chemicals Agency, responsible for proposing restrictions on the use of certain chemicals, including microplastics.
Eco-Modulation	A policy approach that penalizes less environmentally friendly materials and rewards the use of more sustainable ones.
Endocrine Disruptors	Chemical substances that interfere with the endocrine system and can affect hormonal functions in humans and wildlife.
Energy Recovery	The conversion of waste plastics into energy through processes like incineration or pyrolysis.
EPR	Extended Producer Responsibility. A policy approach that holds producers responsible for the entire lifecycle of their products, including recycling and disposal.
EPS	Expanded Polystyrene, a type of plastic used in packaging and foam products and disposable food containers.
EU Commission	The executive branch of the European Union responsible for proposing and implementing policies.
EU Plastics Strategy	A policy framework developed by the European Union to address plastic waste and pollution.
Export bans	Regulations restricting the export of certain materials, such as plastic waste, to prevent environmental harm in receiving countries.
Export bans	Restrictions on the export of plastic waste.
Flame Retardants	Chemicals added to plastics to reduce their flammability.
Flexible and Multilayer Plastics	Plastics used in packaging that are prone to leakage and contribute to ocean pollution.
GHG	Greenhouse Gas Emissions. Gases that trap heat in the Earth's atmosphere, contributing to global warming.
Green Industries SA	An organization responsible for promoting recycling and waste reduction in South Australia.
Greenwashing	The practice of falsely presenting a product or company as environmentally friendly to deceive consumers.
HDPE	High-Density Polyethylene. A type of plastic comprising 12.5% of plastics production, commonly used in packaging.
Hot spots for marine micro-plastics	Areas with a high concentration of micro-plastics in marine environments.
Industrial Compostable	Plastics that can be broken down through an industrial composting process, often based on renewable materials.
Keep South Australia Beautiful (KESAB)	An organization in South Australia dedicated to reducing litter and promoting environmental sustainability.
Landfill	A site for the disposal of waste materials by burying them in the ground.
LDPE	Low-Density Polyethylene, a type of plastic used in packaging and film products, comprising 14.4% of plastics production, used in various applications.
Mechanical Recycling	The process of physically converting plastics waste into new materials through sorting, cleaning, and reprocessing.
Micro-plastics	Small plastic particles measuring less than 5mm in size.
Microbeads	Tiny plastic particles used in personal care products, such as scrubs and cleansers.
Mono materials	Packaging materials made from a single type of polymer to facilitate recycling.

Nano-plastics	Extremely small plastic particles measuring less than 0.1mm in size.
National Plastics Plan	A plan in Australia to phase out certain types of plastic packaging and promote recycling.
Natural colours	Colours that are naturally occurring or resemble natural elements.
NEPM	National Environment Protection Measure, an instrument to address environmental issues in Australia.
Nurdles	Small plastic pellets used in the manufacturing of plastics, which can escape into the environment and accumulate pollutants.
PA	Polyamide. A type of plastic used in products like nylon fabric and automotive parts.
Packaging and Packaging Waste Directive	EU legislation aimed at managing and reducing the impact of packaging waste.
PE	Polyethylene
PET	Polyethylene Terephthalate, a type of plastic commonly used in food and beverage packaging comprising 6.2% of plastics production HDPE
Phthalates	Chemicals used in plastics, which can migrate into water, particularly in the presence of fats or oils and at higher temperatures.
Plasticisers	Chemicals added to increase the flexibility and durability of plastics.
Plastics Pacts	Initiatives in various countries aiming to address plastic pollution through collaboration and action.
Polymerisation	The process of chemically combining monomers to form polymers, a key step in plastic production.
Polymers	Large molecules composed of repeating subunits known as monomers, made from hydrocarbon-based compounds forming the basis of plastics.
POPs	Persistent Organic Pollutants .Toxic chemicals that are resistant to environmental degradation and can accumulate in food chains.
PP	Polypropylene, a versatile plastic used in various applications, including packaging and textiles, comprising 19.3% of plastics production, commonly used in packaging.
PPT	Plastic Packaging Tax, a tax on plastic packaging introduced in the UK to encourage the use of recycled plastic.
PREP	Packaging Recycling Evaluation Portal, a design tool to improve packaging recyclability.
Product Stewardship	A concept where producers take responsibility for the entire life cycle of their products, including recycling and disposal.
PS	Polystyrene. A type of plastic comprising 5.3% of plastics production, used in disposable cutlery, packaging, and insulation.
PUR/PIR	Polyurethane plastics used in foams, coatings, and adhesives
PVDC	Polyvinylidene chloride. A coating for films that blocks water, oxygen, and other gases (aromas), used in food and medical. A contaminant to recycling streams.

PVC	Polyvinyl chloride. A type of plastic used in products such as pipes, bottles, and plastic wrap. A contaminant to recycling streams.
Pyrolysis	A process that chemically decomposes plastics into smaller molecules using heat.
Re-looping	A term used to describe design solutions that aid more effective recycling of plastic products.
REACH	Regulation on the Registration, Evaluation, Authorization, and Restriction of Chemicals, an EU regulation for controlling chemical substances.
Recycled Content	The proportion of recycled material used in a product or packaging.
Recycled Plastics	Plastics that have undergone a recycling process to be reused in new products.
Recyclers	Companies or facilities that process and convert used plastics and other materials into new products or raw materials.
REDcycle	A soft plastics in-store collection program that operated nationwide but ceased in 2022.
Regeneration	Designing systems to restore and enhance ecological health, biodiversity, and ecosystem services.
Resilience	The ability of communities and ecosystems to withstand and recover from shocks and stresses, such as natural disasters or environmental changes.
Reverse Logistics	The process of managing the return of used products or materials to be recycled or repurposed.
Reverse Vending	A recycling system where consumers return used containers to automated machines in exchange for a deposit refund.
Single-use plastic bags	Lightweight plastic bags intended for one-time use, typically provided by retailers for carrying purchased items.
Single-use plastics	Plastic items intended for one-time use such as straws, cutlery, bags, and packaging and then discarded.
Soft Plastics Task Force	A group formed by supermarket chains and supported by the Commonwealth Government in response to the downfall of the REDcycle soft plastics in-store collections.
Stabilizers	Chemicals added to prevent degradation of plastics due to heat or UV exposure.
Styrene	A chemical found in polystyrene (PS) cups that can migrate into water.
Supply Chain	The network of organizations involved in the production, distribution, and sale of a product, from raw materials to the final consumer.
Sustainable Development Goals (SDGs)	A collection of 17 global goals set by the United Nations to address poverty, inequality, climate change, environmental degradation, peace, and justice.
Systems-Thinking	An approach to problem-solving that considers the interconnections and interdependencies among various components of a complex system.
Transparency	The practice of openly sharing information about products, materials, supply chains, and their environmental and social impacts.
Waste Framework Directive	EU legislation defining waste, recycling, and recovery, and establishing waste management principles.

Waste Hierarchy	A prioritized ranking of waste management options, with prevention and recycling as higher priorities than landfilling or incineration.
Waste to Energy	A process of converting waste materials into usable energy, often involving the incineration of plastics.

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